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CHAPTER 1

PERIODIC CLASSIFICATION OF ELEMENTS

In 1661, Robert Boyle proposed the definition of an element as "any substance that cannot be decomposed into a simpler substance by a chemical reaction". At that time, only 13 elements were known. Towards the end of the 18th century, another 11 elements have been discovered. When only a few elements were known, it was easy to study and remember their properties. But gradually with the development of science, several new elements were discovered. At present about 114 elements are known to us. Each of these elements show different properties due to different kind of atoms constituting them and they form millions of compounds. A study of the properties of these elements and their compounds individually appear to be a difficult task. So attempts were made, from time to time, to find regularities or trends in the properties of these elements such that they could be classified into a handful of groups having similar properties. The study of the properties of a typical element of a particular group enables scientist to roughly predict the properties of other elements of that group.

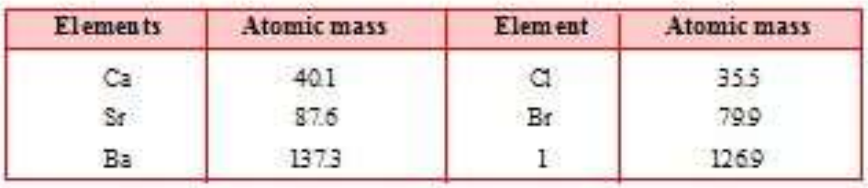
1.1. EARLY ATTEMPTS AT THE CLASSIFICATION OF ELEMENTS

Some elements like copper, silver and gold have characteristic lustre, malleability and ductility. Other elements like graphite (carbon), sulphur and phosphorus do not have lustre, are non-melleable and non-ductile. These important differences led Lavoisier to classify elements into two groups, **metals** and **non-metals**. However, such a grouping was too broad and unbalanced as there are only a few non-metals (about 10%) in one group and a large number of metals (90%) in the other group. Also there was no place for elements with properties resembling those of metals as well as non-metals.

1.1.1. Dobereiner’s Triads

In 1803, John Dalton published a table of relative atomic weights (now called atomic masses) of elements. Attempts were then made to find a relationship between the physical and chemical properties of elements and their atomic masses. In 1829, the German Chemist Dobereiner arranged elements having similar chemical properties into **groups of three**. These groups were called **triads.** *Doberiener found that when elements are arranged in a triad in the order of increasing atomic masses, the atomic mass of the middle element was approximately equal to the arithmetic mean of the atomic masses of the other two elements.* This is known as **Dobereiner’s law of triads**. For example, the elements calcium, strontium and barium resemble one another in most of their properties. The atomic mass of strontium is almost equal to the average of the atomic masses of calcium and barium. Again, in the case of another three elements, chlorine, bromine and iodine, the atomic mass of bromine is about the average of the atomic masses of chlorine and iodine (Table 1.1)

Table 1.1 Dobereiner’s triads



Elements	Atomic mass	Element	Atomic mass
Ca	40.1	Cl	35.5
Sr	87.6	Br	79.9
Ba	137.3	I	126.9

Dobereirner could identify four triads from the elements known at that time. Hence, this system of classification could not become successful because all elements could not be put into triads.

Find out which of the groups in the following table (table 1.2) form Dobereiner’s triads?

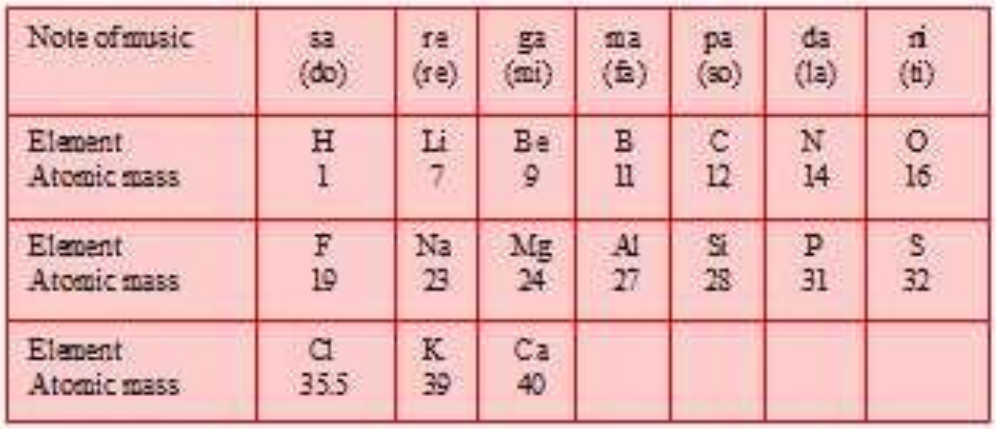
Table 1.2

Group A elements	Atomic mass	Group B	Atomic mass elements
N	14.0	Li	6.9
P	31.0	Na	23.0
As	74.9	K	39.0

1.1.2. Newlands' Octaves

In 1866, John Newlands, an English scientist observed an interesting regularity. He arranged the elements in the increasing order of their atomic masses as follows (Table 1.3).

Table 1.3. Newlands' Octaves



Note of music	sa (do)	re (re)	ga (mi)	ma (fa)	pa (so)	da (la)	ni (ti)
Element Atomic mass	H 1	Li 7	Be 9	B 11	C 12	N 14	O 16
Element Atomic mass	F 19	Na 23	Mg 24	Al 27	Si 28	P 31	S 32
Element Atomic mass	Cl 35.5	K 39	Ca 40				

The properties of the eighth element were found to resemble very closely the properties of the first, wherever one starts in such a grouping. He compared this to the octaves found in musical notes. He suggested a **Law of Octaves** for the classification of elements. For example, starting from hydrogen (H) the eigth element came out to be fluorine (F). The eigth element starting from fluorine was chlorine (Cl). The properties of F and Cl were found similar. Similarly, the properties of Li, Na and K were also found similar.

At the time of Newlands only 62 elements were known. It was found that the law of octaves worked well for lighter elements only upto calcium. But it could not be applied to elements of higher atomic masses, as after calcium every eigth element did not posses properties similar to that of the first.

Let us answer these.

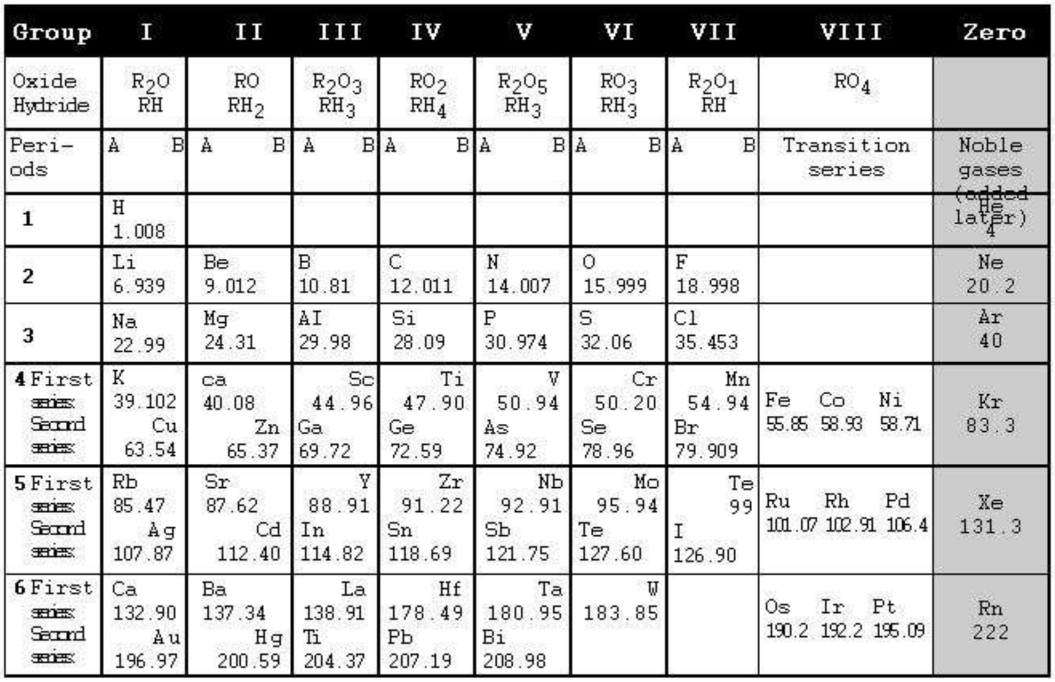
1. What is Dobereiner's law of triads ? Give one example.
2. A, B and C are the elements in Dobereiner's triad. If the atomic mass of A is 40 and that of C is 137, what would be the atomic mass of B ?
3. What is Newlands' Laws of octaves ? Explain with an example.
4. What were the limitations of Newlands' Law of octaves ?

1.1.3. Mendeleev's Periodic Classification

The most notable contribution towards a systematic classification of elements was made by Mendeleev, a Russian chemist in 1869. He studied the physical and chemical properties of the then known 63 elements and their compounds. Among chemical properties, Mendeleev concentrated on the compounds formed by elements with oxygen and hydrogen which are very reactive and formed compounds with most elements.The formula of the oxides and hydrides formed by an element were treated as one of the basic properties of an element for its classification into groups.

He arranged such elements in the increasing order of their atomic masses. He found that elements with similar properties appeared at regular intervals. This discovery led him to formulate a Periodic Law, which states that **"the properties of elements are the periodic functions of their atomic masses"**. This means, when the elements are arranged in order of increasing atomic masses then those with similar properties are repeated at regular intervals. The Mendeleev's periodic table is given in Table 1.4

Table. 1.4. Modified Mendeleev's Periodic Table



Group	I	II	III	IV	V	VI	VII	VIII	Zero
Oxide Hydride	R_2O RH	RO RH_2	R_2O_3 RH_3	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_3	R_2O_1 RH	RO_4	
Peri-ods	A B	A B	A B	A B	A B	A B	A B	Transition series	Noble gases (added later)
1	H 1.008								He 4
2	Li 6.939	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998		Ne 20.2
3	Na 22.99	Mg 24.31	AI 29.98	Si 28.09	P 30.974	S 32.06	Cl 35.453		Ar 40
4 First series Second series	K 39.102 Cu 63.54	ca 40.08 Zn 65.37	Sc 44.96 Ga 69.72	Ti 47.90 Ge 72.59	V 50.94 As 74.92	Cr 50.20 Se 78.96	Mn 54.94 Br 79.909	Fe Co Ni 55.85 58.93 58.71	Kr 83.3
5 First series Second series	Rb 85.47 Ag 107.87	Sr 87.62 Cd 112.40	Y 88.91 In 114.82	Zr 91.22 Sn 118.69	Nb 92.91 Sb 121.75	Mo 95.94 Te 127.60	Te 99 I 126.90	Ru Rh Pd 101.07 102.91 106.4	Xe 131.3
6 First series Second series	Ca 132.90 Au 196.97	Ba 137.34 Hg 200.59	La 138.91 Ti 204.37	Hf 178.49 Pb 207.19	Ta 180.95 Bi 208.98	W 183.85		Os Ir Pt 190.2 192.2 195.09	Rn 222

Mendeleev's Periodic Table was published in a German journal in 1872. In the formula for oxides and hydrides at the top of the columns, the letter 'R' is used to represent any of the elements in the group. For example, the hydride of carbon, CH_4*, is written as* RH_4 *and oxide of carbon,* CO_2*, as* RO_2*.*

The periodic table consists of eight vertical columns called **'groups'** and six horizontal rows called **'periods'**. The eight groups are designated as I, II, III, IV, V, VI, VII and VIII. Except group VIII, each group is divided into two sub-groups as A and B. The elements which lie on left hand side of each group constitute sub-group A. These are called **normal or representative elements.** The elements which lie on right hand side of each group constitute sub-group B. These are called **transition elements**. The properties of elements within a sub-group resemble more markedly but they differ from those of the elements of the other subgroup. For example, lithium (Li) , sodium (Na), potassium (K), etc of sub-group I A have close resemblance in properties but they have hardly any resemblance with those of coinage metals (Cu, Ag, and Au) of sub-group I B.

The horizontal rows or periods are numbered 1,2,3, etc.

In arranging the elements in the periodic table, Mendeleev was careful enough to group together elements with similarity in their physical and chemical properties. In doing this he had, in some cases, even to change the order of arranging the elements strictly according to their increasing atomic masses. There was provision for *including unknown elements* as well.

Why is Mendeleev's Classification Appreciated ?

By classifying elements on the basis of their atomic masses, Mendeleev brought some order in the properties exhibited by the elements and their compunds. It made the study of the elements easier. Knowing the properties of one element in a group, the properties of other elements in the group can be easily guessed.

The periodic table could predict errors in the atomic masses of some elements based on their positions in the table. For example, when the table was published the experimental value of the atomic mass of beryllium (Be) was supposed to be 13.65 and its valency, 3. So, the position of Be should have been somewhere else. But Mendeleev placed it at its appropriate position on the basis of its properties and its atomic mass corrected from 13.65 to 9.1 and valency, 2.

While arranging the elements in order of their atomic masses, however, the order had to be ignored at some places to make sure that the elements with similar properties fell in the same group. In doing so, Mendeleev left some vacant places in the table and boldly predicted the existence and properties of some undiscovered elements. For example, **scandium**, **gallium** and **germanium**, discovered later, have properties similar to **eka-boron**, **eka-aluminium** and **eka-silicon** respectively predicted by Mendeleev.

Noble gases like helium (He), neon (Ne) and argon (Ar), were not discovered at the time of Mendeleev. Therefore, there was no group of noble gases in Mendeleev's original periodic table. One of the achievements of Mendeleev's periodic table was that when these gases were discovered they could be placed in a new group called the **zero group** without disturbing the existing order.

Limitations of Mendeleev's Periodic Table

With the discovery of isotopes, the accommodation of the isotopic forms of the same element upset Mendeleev's periodic table. We have learnt that isotopes are the atoms of an element having similar chemical properties (same atomic number), but different atomic masses. If the elements are arranged according to atomic masses, the isotopes have to be placed in different groups of the periodic table. Another problem was that the atomic masses do not increase in a regular manner in going from one element to the next. So it was not possible to predict how many elements could be discovered between two elements especially when we consider the heavier elements.

Let us answer these.

- What was Mendeleev's principle for the classification of elements ?
- Using Mendeleev's Periodic Table, predict the formula for the oxides of the following elements :
  K, C, Al, Si, Ba.
- Besides gallium, which other elements have since been discovered that were left by Mendeleev in his Periodic Table ? (any two).
- Give your reason why the noble gases are placed in a separate group

1.2. Modern Periodic Table

In 1913, Henry Mosely found that the atomic number is a more fundamental property of an element than its atomic mass. This is quite convincing because the atomic number gives us the number of protons in the nucleus and also the number of electrons in an atom. This number increases by one in going from one element to the next higher element. The chemical properties of element depends on the number of electrons in its atom which in turn depends on the atomic number. So, atomic number was adopted as the basis for the classification of elements in the Modern Periodic Table. Thus the modern periodic law states that **" the properties of elements are the periodic functions of their atomic numbers"**. When elements are arranged in order of increasing atomic number, similar elements occur in regular intervals and this leads us to the classification known as the Modern Periodic Table (Table 1.5).

The modern periodic table has 7 horizontal rows called **'periods'** and 18 vertical columns called **'groups'** or **families**.

Periods:

Look at the periodic table (Table 1.4). We find that the elements in the periods are as follows:

1st period contains 2 elements, H(1) and He (2). It is called very short period.

2nd period contains 8 elements, Li(3) to Ne (10). It is called short period.

3rd period contains 8 elements, Na(11) to Ar(18). It is also a short period.

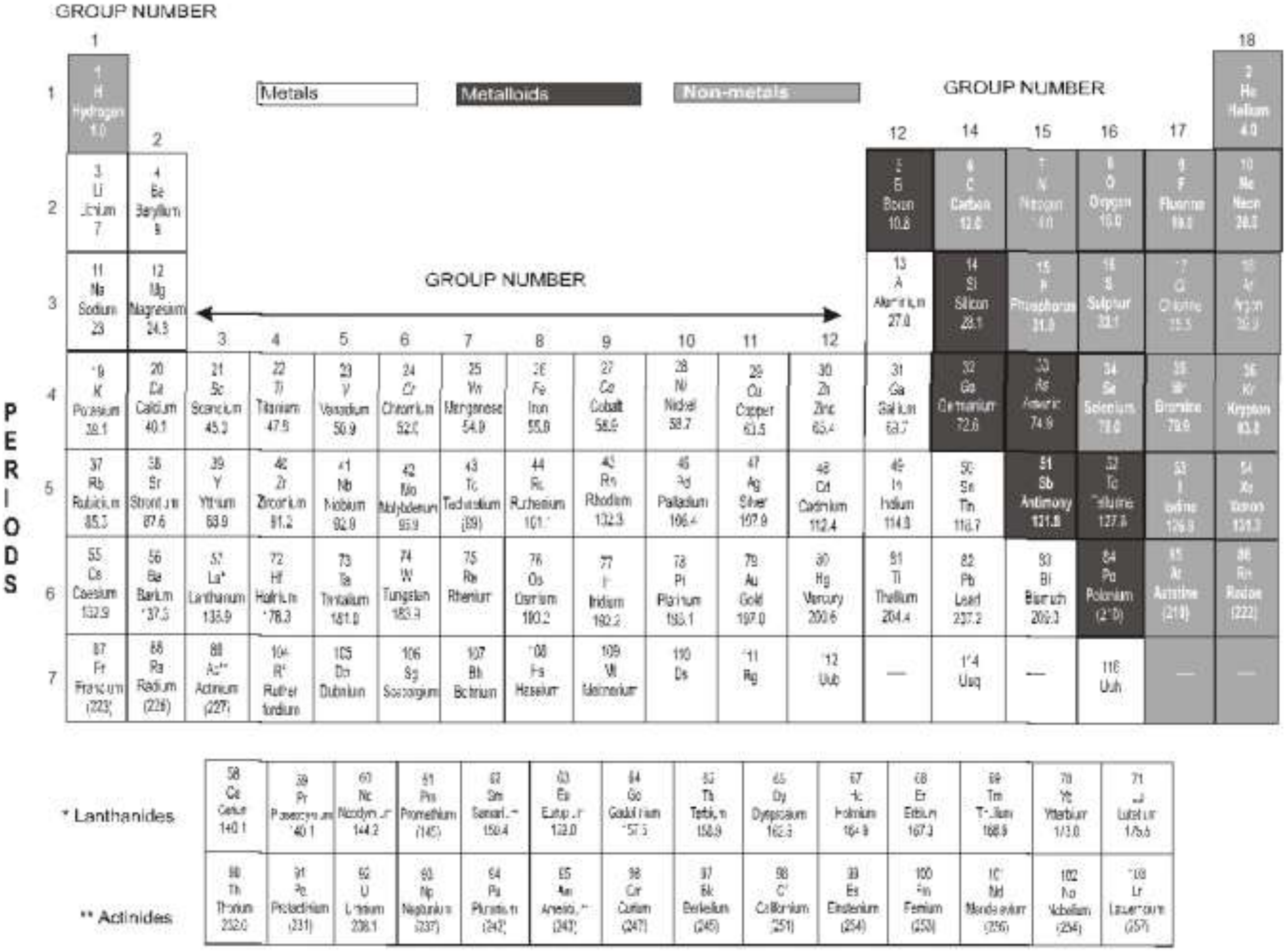
4th period contains 18 elements, K(19) to Kr (36). It is called long period.

5th period contains 18 elements, Rb(37) to Xe(54). It is also a long period.

6th period contains 32 elements, Cs (55) to Ru(86). It is called very long period.

7th period now contains 25 elements, starting from Fr(87) out of a possiblity of 32 elements. This period is still incomplete.

Two series of elements, 14 each, are placed at the bottom of the main periodic table. These are called **inner-transition elements**. The first series of 14 elements from atomic numbers 58 to 71 (Ce to Lu) is called **Lanthanide series**. The second series of 14 elements from atomic numbers 90 to 103 (Th to Lr) is called **Actinide Series**. They are placed separately at the bottom of the periodic table to avoid undue side-wise expansion of the table and to keep elements with similar properties in a single column.



GROUP NUMBER

Metals | Metalloids | Non-metals

PERIODS

	1	2	3	4	5	6	7	8	9	10	11	12	12	14	15	16	17	18
1	1 H Hydrogen 1.0																	2 He Helium 4.0
2	3 Li Lithium 7	4 Be Beryllium 9											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
3	11 Na Sodium 23	12 Mg Magnesium 24.3											13 Al Aluminium 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulphur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
4	19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
5	37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (99)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
6	55 Cs Caesium 132.9	56 Ba Barium 137.3	57 La* Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 181.0	74 W Tungsten 183.9	75 Re Rhenium	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (210)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac** Actinium (227)	104 Rf* Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds	111 Rg	112 Uub	—	114 Uuq	—	116 Uuh	—	—

* Lanthanides	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
** Actinides	90 Th Thorium 232.0	91 Pa Protactinium (231)	92 U Uranium 238.1	93 Np Neptunium (237)	94 Pu Plutonium (242)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (245)	98 Cf Californium (251)	99 Es Einsteinium (254)	100 Fm Fermium (253)	101 Md Mendelevium (256)	102 No Nobelium (254)	103 Lr Lawrencium (257)

Groups : The 18 vertical columns (groups or families) are numbered from 1 to 18. Group 18 is also known as **zero group** which consists of noble gases. Elements of the groups 1,2 and 13 to 18 are called **normal** or **representative elements** while those of groups 3 to 12 are called **transition** elements. At present we shall study only the first twenty elements of the eight groups (groups 1, 2 and 13 to 18) of the normal or representative elements.

Activity 1.1.

☞ Look at the periodic table. Find out the elements present in Group 1 of the table.
☞ Write down electronic configuration of the first four elements of the group.
☞ What similarity do you find in their electronic configurations ?
☞ How many valence electrons are present in these elements ?
☞ Repeat the above activities with those elements of group 2 and 17 elements.
☞ Compare your results with Table 1.6

Table 1.6. Electronic configuration of some elements of group 1,2 and 17

Group-1 elements	Atomic no.	Electronic configuration K, L, M, N,	Group-2 elements	Atomic no.	Electronic configuration K, L, M, N,	Group-17 elements	Atomic no.	Electronic configuration K, L, M, N
H	1	1						
Li	3	2, 1	Be	4	2, 2	F	9	2, 7
Na	11	2, 8, 1	Mg	12	2, 8, 2	Cl	17	2, 8, 7
K	19	2, 8, 8, 1	Ca	20	2, 8, 8, 2			

We find that the elements of group 1 have the same number of valence electrons i.e. 1, and those of group 2 and 17 have 2 and 7 valence electrons respectively.

Similarly, you will find that elements present in any one group have the same number of valence electrons. Hence, we can say that groups in the periodic table signify identical outer shell electronic configuration. On the other hand, the number of shells increases as we go down the group.

The electronic configuration of the first twenty elements in the Periodic Table are shown in Table 1.7.

Table 1.7. Electronic configuration of first twenty elements in the Periodic Table

Period	**Group1**	**--------------GROUP NUMBER-------------------**						**Group 18**
1st period	H 1	2	13	14	15	16	17	2 He 2
2nd period	3 Li 2,1	4 Be 2,2	5 B 2,3	6 C 2,4	7 N 2,5	8 O 2,6	9 F 2,7	10 Ne 2,8
3rd period	11 Na 2,8,1	12 Mg 2,8,2	13 Al 2,8,3	14 Si 2,8,4	15 P 2,8,5	16 S 2,8,6	17 Cl 2,8,7	18 Ar 2,8,8
4th period	19 K 2,8,8,1	20 Ca 2,8,8,2						
Valence Electrons	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**

The chart shows the arrangement of first twenty elements in the periodic table on the basis of their electronic configuration. The numbers given above the symbols of the elements are atomic numbers while the numbers given below the symbols are electronic configurations.

The atomic number of Hydrogen and Helium are 1 and 2 respectively. They have 1 and 2 electrons respectively in the K-shell. The atomic number of Lithium is 3, its electronic configuration is 2, 1. Thus Lithium has 1 electron in its outermost shell. With the increase in atomic number, the number of electrons in the outermost shell increases from 1(in Li) to 8 (in Ne). When the atomic number is 11 (in sodium), the electronic configuration is 2, 8, 1. Thus Li and Na have the same number of electrons in the outermost shell (they belong to group 1). They also have similar properties. Thus with the repetition of electronic configuration, the properties of elements are also repeated. In the same way, the group 17 elements having 7 electrons in their outermost shell show similar chemical properties.

Activity 1.2

☞ Find out the elements present in the 2nd and 3rd period of the periodic table.
☞ Write down their electronic configuration.

- ☞ Do these elements contain the same number of valence electrons ?
- ☞ Do they contain the same number of shells ?

We have observed that the elements in a period do not have the same number of valence electrons as we move from left to right, though they contain the same number of shells. Or we can say that atoms of different elements with the same number of occupied shells are placed in the same period. H and He belong to the first period, since the electrons in the atoms are filled in K shell. Na, Mg, Al, Si, P, S, Cl and Ar belong to the third period as the electrons of these elements are filled in K, L and M shells.

The progression of 2, 8, 8, 18, 18, 32, 32 elements in the seven periods are in accordance with the electronic configuration of elements. We have already learnt in class IX that the maximum number of electrons that can be accommodated in any shell is given by the formula, $2n^2$ where 'n' is the number of the given shell. For example,

K – shell : $2\times(1)^2 = 2$, hence first period has two elements, i.e. , H and He.

L – shell : $2\times(2)^2 = 8$, hence second period has eight elements, from Li to Ne.

M – shell : $2\times(3)^2 = 18$, but the outermost shell cannot have more than 8 electrons. Therefore, third period also has eight elements from Na to Ar.

The maximum number of elements which can be accommodated in 4th, 5th, 6th and 7th period are 18, 18, 32 and 32 respectively. You will learn about these in higher classes.

The position of an element in the periodic table tells us about its chemical reactivity. As you have learnt, the valence electrons determine the chemical characteristic of the element. Differences in electronic arrangement results in variation of the properties of the elements. In other words, elements having similar electronic configuration of the valence shell have similar chemical properties. On arranging the elements in the increasing order of their atomic numbers, the elements with the same valence electrons appear at regular intervals. Hence, the chemical properties of elements show similarities.

1.3. TRENDS ON THE BASIS OF MODERN PERIODIC TABLE

From the study of the modern periodic table, we find that there is a regular periodic repetition of the electronic configuration of elements as the atomic number increases. Consequently, in some properties of elements there is a periodic trend or the rythmic behaviour of the atoms as a function of the atomic number.

1.3.1. Valency

We have learnt that the combining capacity or the valency of an element is determined by the number of valence electrons present in the outermost shell of its atom.

Activity 1.3.

- ☞ Write down the electronic configuration of sodium (atomic number 11), magnesium (at. no. 12) and oxygen (at. no. 8). What are their valence electrons? What are their valencies?
- ☞ Similarly, find out the valencies of the first twenty elements.
- ☞ Find out how does the valency vary in a period on going from left to right ?
- ☞ How does the valency vary in a group?

We find that on moving from left to right in a period, the number of valence electrons in elements increases from 1 to 8 (Table 1.8). In the first period, the increase is from 1 to 2.

Table 1.8 Valency of the Elements of 2nd and 3rd period

Elements of 2nd Period

Elements	Li	Be	B	C	N	O	F	Ne
Atomic number	3	4	5	6	7	8	9	10
Electronic configuration.	2,1	2,2	2,3	2,4	2,5	2,6	2,7	2,8
Valence electrons	1	2	3	4	5	6	7	8
Valency	1	2	3	4	3	2	1	0

Elements of 3rd Period

Elements	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	16	16	17	18
Electronic Configuration	2,8,1	2,8,2	2,8,3	2,8,4	2,8,5	2,8,6	2,8,7	2,8,8
Valence electrons	1	2	3	4	5	6	7	8
Valency	1	2	3	4	3	2	1	0

Let us recall what we have learnt in class IX, that atoms of elements having a comletely filled outermost shell i.e. 8 electrons show little chemical activty. An outermost shell , which has eight electrons was said to possess an octet in the outermost shell. In other words, the valency of the atoms having octet in their valence shells are zero. These elements are known as inert or noble ***gas elements.*** *They are all gases and belong to group 18 of the periodic table. Of these inert elements, helium atom has two electrons in its outermost shell i.e. K-shell for which it represents full or stable structure.*

The combining capacity (valency) of the atoms of an element is the tendency to react or form molecules with other atoms of the same or different elements. It was thus explained as the tendency to attain a fully filled outermost shell or stable structure, i.e. octet of electrons in the outermost shell (except Helium structure which has two electrons in its outermost shell i.e. K-shell).

The number of electrons gained, lost or shared, so as to make the octet of electrons in the outermost shell, gives us directly the valency of the element. In other words, in a period, the valency of an element is either equal to the number of electrons in the valence shell or eight minus the number of electrons in the valence shell.

Thus, we find that on moving left to right in each of the short periods, the valency of elements increases from 1 to 4 and then decreases to 0 (zero).

The elements in a given group of the periodic table have the same valence electron (s). Hence, in a group, the elements have the same valency (Table 1.9)

Table 1. 9 . Valency of elements

Group I Elements				Group 17 Elements			
Symbol	At.no.	Electronic configuration	Valency	Symbol	At.no.	Electronic configuration	Valency
Li	3	2,1	1	F	9	2,7	1
Na	11	2,8,1	1	Cl	17	2,8,7	1
K	19	2, 8, 8, 1	1	Br	35	2,8, 18, 7	1

1.3.2. Atomic Size

The term atomic size refers to the radius of an atom. It may be visualised as the distance between the centre of the nucleus and the outermost shell of an isolated atom. The atomic radius is generally expressed in ‘picometre’ units whose symbol is ‘pm’.

1 picometre = m.
or 1 pm = 10^{-12} m.

The atomic radii of hydrogen and helium are 37 pm and 93 pm respectively.

The following table (Table1.10) gives the atomic radii of the second and third period elements.

Table 1.10. Atomic radii of 2nd and 3rd period elements in picometres (pm)

Elements								
2nd period	Li	Be	B	C	N	O	F	Ne
Atomic radius(pm)	123	90	80	77	75	74	72	112
3rd period	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic radius (pm)	186	160	143	118	110	104	99	154

It is observed that the *atomic radius decreases in moving from left to right along a period for normal elements.* The elements of the groups 1, 2, and 13 to 18 are called normal or representative elements. In a period, the atomic number increases from left to right. This means that the number of protons (positive charges of nucleus) and electrons in the atoms increases. The electrons are added to the same shell while the charge on the nucleus increases steadily. The increase in nuclear charge tends to pull the electrons closer to the nucleus and reduces the size of the atom. The atomic radii of noble gases (group 18 elements) have comparatively larger atomic radii than their preceding groups. This is due to the increase of electronic repulsions between completely filled outer shells.

How does atomic radius vary as we go down a group ? Table 1.11gives the atomic radii of group 1 and group 17 elments.

Table 1.11 Increase in atomic radii in a group

Group 1 Elements	**Atomic radius (pm)**	**Group 17 Elements**	**Atomic radius (pm)**
Li	123	F	72
Na	186	Cl	99
K	231	Br	114
Rb	244	I	133
Cs	262		

We can see that the atomic size increases down the group. This is because electrons are added to new shells as we go down the group. This increases the distance between the outermost electrons and the nucleus so that the atomic radius increases in spite of the increase in nuclear charge.

1.3.3. Metallic and non-metallic character

Activity 1.4

- ☞ Examine the elements of the second and the third period. Which of them are metals and which are non-metals ?
- ☞ On which side of the periodic table do you find the metals ?
- ☞ On which side of the periodic table do you find the non-metals ?

We can see that metals like lithium, sodium, magnesium etc. are found towards the left-hand side of the periodic table while the non metals like oxygen, sulphur, chlorine etc. are found on the right hand side. Towards the middle, we find boron and silicon, which are classified as semi-metals or metalloids because they exhibit some properties of both metals and non - metals.

Thus, we find that **on moving from left to right in a period, the metallic character of elements decreases i.e, it changes from metallic nature to metalloid, then to non-metallic and finally the last element in a period is inert in nature (Table 1.12).**

Table 1. 12. Metallic and non-metallic character of elements in 2nd & 3rd period

Elements of 2nd Period	Li	Be	B	C	N	O	F	Ne
Metallic/non-metallic character	metal	metal	meta-lloid	non metal	non metal	non metal	non metal	Noble gas
Elements of 3rd period	Na	Mg	Al	Si	P	S	Cl	Ar
Character	metal	metal	metal	meta-lloid	non metal	non metal	non metal	Noble gas

→ ***Metallic or Electropositive character decreases*** →

In the modern periodic table, a zig-zag line separate metals from non-metals. The borderline elements - boron, silicon, germanium, arsenic, antimony, tellurium and polonium are intermediate in properties and are called **semi-metals** or **metalloids**. We shall learn in the next chapter that metals lose electrons and form positive ions, so metals are electro positive in nature. The tendency of an element to lose electrons and form positive ions (cations) is called **Electropositive character.** Since metal have such a tendency the electropositive character is also known as **metallic character**.

Thus, metals like Na, K and Mg are electropositive, because they have high tendency to lose electrons.

$$\underset{\substack{2,\,8,\,1\\(\text{atom})}}{\text{Na}} \longrightarrow \underset{\substack{2,\,8\\(\text{sodium ion})}}{\text{Na}^{+}} + \underset{(\text{electron})}{e^{-}}$$

$$\underset{\substack{2,\,8,\,8,\,1\\(\text{atom})}}{\text{K}} \longrightarrow \underset{\substack{2,\,8,\,8\\(\text{potassium ion})}}{\text{K}^{+}} + \underset{(\text{electron})}{e^{-}}$$

$$\underset{\substack{2,\,8,\,2\\(\text{atom})}}{\text{Mg}} \longrightarrow \underset{\substack{2,\,8\\(\text{magnesium ion})}}{\text{Mg}^{2+}} + \underset{(\text{electron})}{2e^{-}}$$

The valency of Na and K is 1 and that of Mg is 2.

On the other hand, non-metals accept electrons and form negative ions, so non-metals are called electronegative elements. The tendency of an element to accept electrons to form an anion is called **electronegative character** or **non-metallic character.** For example, the elements fluorine (F), Chlorine (Cl) and Oxygen (O) are electronegative in nature, because they have high tendency to gain electrons.

$$\begin{array}{ccccc} \mathrm{F} & + & e^{-} & \longrightarrow & \mathrm{F}^{-} \\ 2,\,7 & & \text{(electron)} & & 2,\,8 \\ \text{(atom)} & & & & \text{(fluoride ion)} \end{array}$$

$$\begin{array}{ccccc} \mathrm{Cl} & + & e^{-} & \longrightarrow & \mathrm{Cl}^{-} \\ 2,\,8,\,7 & & & & 2,\,8,\,8 \\ & & & & \text{(chloride ion)} \end{array}$$

$$\begin{array}{ccccc} \mathrm{O} & + & 2\,e^{-} & \longrightarrow & \mathrm{O}^{2-} \\ 2,\,6 & & & & 2,\,8 \\ & & & & \text{(oxide ion)} \end{array}$$

As we move from left to right in a period, the effective nuclear charge (positive charge on nucleus) increases due to gradual increase in the number of protons. Due to this, the valence electrons are pulled in more strongly by the nucleus and the tendency to lose electrons will decrease. Down the group, the effective nuclear charge experienced by valence electrons is decreasing because the outermost electrons are farther away from the nucleus due to the addition of new shells. Therefore, these can be lost easily. Hence **metallic character (or electropositive nature) decreases across a period and increases down a group**. *The reverse will be the trend in electronegative character of the elements.*

1.3.4. Nature of Oxides of the elements

We know that oxides of metals are basic and that of non-metals are acidic in general. With the knowledge of the trends in metallic and non-metallic properties of elements in the periodic table, can you predict the nature of the oxides formed by the elements ?

As one moves from left to right in a period, the basic nature of the oxides gradually decreases and acidic nature of the oxides gradually increases. For example, in the third period of the periodic table, sodium oxide is highly basic and magnesium oxide is comparatively less basic. The aluminium and silicon oxides are amphoteric while phosphorous oxides are acidic. Sulphur oxides are more acidic whereas chlorine oxides are highly acidic in nature (Table 1.12).

Table 1.12. Nature of oxides of third period Elements

Elements of 3rd period	Na	Mg	Al	Si	P	S	Cl	Ar
Oxides	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_2SO_3	Cl_2O_7	
Nature	Strongly basic	Basic	Amphoteric	Amphoteric	Acidic	Acidic	Highly Acidic	

Can you predict what will be the basic character down a group? As the electropositive character increases down a group , so also is the basic character. For example, calcium oxide is more basic than magnesium oxide and strontium oxide is more basic than calcium oxide.

The modern periodic table is a very satisfactory attempt to the classification of elements. It summarises the vast knowledge of the chemical elements and helps us to see the relationship between their physical and chemical properties and their electronic configuration to a very large measure. However it is still not free from certain defects, the details of which you will learn in higher classes. Chemists are still trying to evolve a still better periodic table.

Let us answer these.

1. What name has been given to the horizontal arrangement of elements in the periodic table ? Is there any gradation in the properties of elements across these rows? Give two examples to illustrate.
2. How do the properties of group 1 elements differ from those of group 17 elements? Illustrate the differences in at least two properties ?
3. From the standpoint of electronic configuration, determine which element will be the first and which will be the last in a period of the periodic table ?

4. Accommodation of isotopic form of the same element was an upset in Mendeleev’s periodic table. How could the Modern Periodic table remove the anomaly ?

5. Name two elements you would expect to show chemical reactions similar to lithium. What is the basis of your choice ?

6. **Name**

(i) three elements having one electron in their shells,

(ii) two elements having four electrons in their outermost outer most shells,

(iii) three elements with completely filled shells.

7. Fluorine, chlorine and bromine belong to group 17 of the periodic table.What similarity is there in the atoms of these elements ?

8. By considering their position in the periodic table, which one of the following elements is expected to have maximum metallic character ?

In, Sn, Sb, Te, I.

9. How would be the tendency to gain electrons change as we go from left to right across a period ?

10. How would be the tendency to gain electrons change as we go down a group ?

11. Why is non-metals are found on the right-hand side of the periodic table towards the top?

SUMMARY

- Elements are classified on the basis of similarities in their properties.
- The earliest attempt to classify the elements resulted in grouping the then known elements into two groups, metals and non-metals.
- Dobereiner classified elements having similar properties into triads and stated that when elements are arranged in the order of increasing atomic masses in a triad, the atomic mass of the middle element was approximately equal to the arithmetic mean of the atomic masses of the other two elements.

- Newlands found that when elements are arranged in the order of increasing atomic masses, the properties of the eight element were found to resemble the properties of the starting element.
- Mendeleev arranged the elements in increasing order of their atomic masses and according to their chemical properties. He stated that the properties of elements are periodic functions of their atomic masses.
- Mendeleev's periodic table could predict the properties of several elements on the basis of their positions in the periodic table. He even predicted the existence of some yet to be discovered elements on the basis of gaps in the periodic table.
- In the modern periodic table, the basis for the classification of elements is the atomic number which is a more fundamental property of an element. It could remove the anomalies in the arrangement of elements based on increasing atomic mass.
- Elements in the modern periodic table are arranged in seven horizontal rows called periods and 18 vertical columns called groups.
- Elements thus arranged show periodicity in their properties.
- Trends like atomic size, valency, metallic and non-metallic character of elements could be predicted from their position in the periodic table.

EXERCISES

1. Why is there a need to classify the elements ? What difficulties are likely to arise if the classification is not made ?
2. Name the period and group to which the element with atomic number 15 belongs.
3. State one reason for keeping boron and aluminium in the same group of the periodic table.
4. Write the electronic configurations of the elements Na, Al, Ca, O and Si and justify their positions in the periodic table.
5. Why is atomic number more important than atomic mass to know the properties of the elements ?

6. State how atomic size varies from left to right in a period and from top to bottom in a group.

7. **The atomic radii of the elements of second period are given below:**

2nd period elements :	B	Be	O	N	Li	C
Atomic radii (pm):	80	90	74	75	123	77

(a) Arrange the elements in the decreasing order of their atomic radii, keeping the element with the largest atomic radius first.

(b) Find out whether the arragement is in the pattern of a period or not?

(c) From this data, infer how the atomic size of the elements changed as one goes from left to right in a period.

8. By considering their position in the periodic table, which one of the following elements would you expect to have the maximum metallic character ?

Ga, Ge, As, Se, Br.

9. **The position of three elements A, B and C in the periodic table are shown below.**

Group16	**Group 17**
—	—
—	A
—	—
B	C

(a) State whether A is a metal or non-metal ?

(b) State whether C will be more reactive or less reactive than A

(c) Will C be larger or smaller in size than B ?

(d) What type of ion (cation or anion) will be formed by A ?

10. Element X forms a chloride with the formula XCl_2. With which of the following elements, X would most likely be in the same group of the periodic table ?

Na, Mg, Al, C.

11. Name two elements you would expect to show chemical properties similar to Li. What is the basis of your choice ?

12. What properties do all elements in the same group of boron in the periodic table have in common ?

13. **An atom has electronic configuration 2, 8, 6.**

(a) What is the atomic number of this element ?

(b) Which of the following elements would it be similar in chemical properties?

N(7), F(9), P(15), O(8), Ar(18)

14. Nitrogen (at.no. 7) and Phosphorous (at. no. 15) belong to group 15 of the periodic table. Which of them will be more electronegative and why?

15. In the modern Periodic table, calcium (at. no. 20) is surrounded by elements with atomic numbers 12, 19, 21 and 38. Which of them have physical and chemical properties resembling calcium ?

★★★★★★

CHAPTER 2

CHEMICAL BONDING

We have learnt in previous classes that the smallest particle of an element or compound that is capable of an independent existence and shows all the properties of that substance is called a **molecule**. Molecules are made up of atoms. Molecule of an element is composed of atoms of the same kind. For example, a molecule of hydrogen consists of two atoms of hydrogen, two atoms of oxygen unite to form a molecule of oxygen etc. Atoms of different elements combine together in definite proportions to form molecules of compounds. For example, hydrogen chloride is a compound whose molecules are made up of one atom of hydrogen and one atom of chlorine. Similarly, a molecule of water contains two atoms of hydrogen and one atom of oxygen. When atoms of elements combine to form molecules, a force of attraction is developed between the combining atoms which holds them together. This force is called **chemical bond**. Thus, a **chemical bond is one which holds the atoms together in a molecule.**

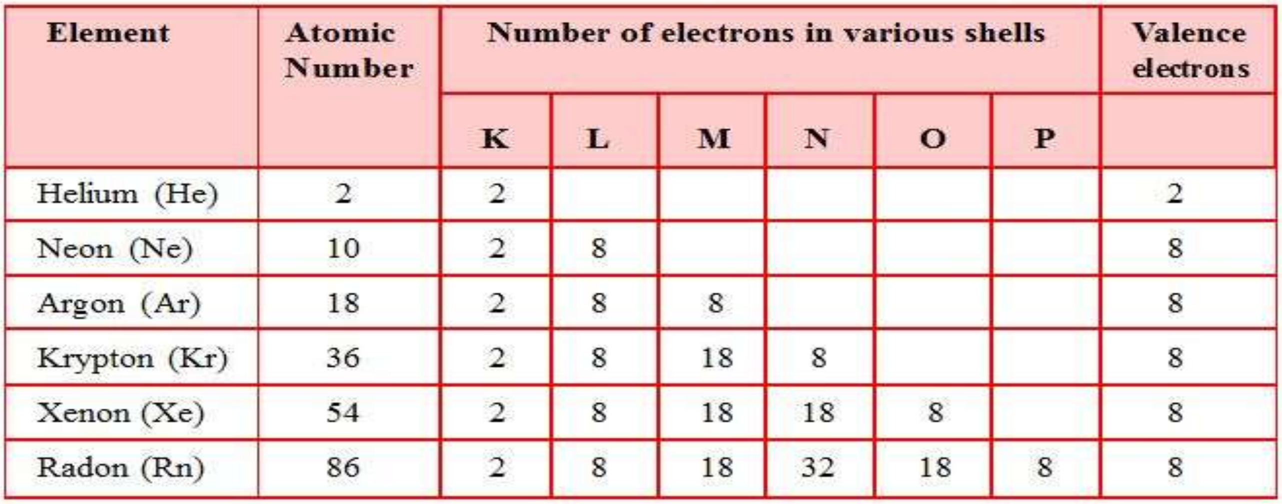
2.1. ATTAINMENT OF A STABLE ELECTRONIC CONFIGURATION

How do atoms combine together to form molecules and why do atoms form bonds ? The molecule formed must be more stable than the individual atoms or molecules would not be formed. It means that the process must be energetically favourable and lead to a minimum energy.

In the previous class, we have studied the structure of atom. We have also learnt that the chemical properties of elements depend upon the number of electrons present in the outermost shell of the atom or **valence electrons.** It is a well known fact that atoms of the noble gases do not normally react with any other atoms and their molecules are mono-atomic, that is, they contain only one atom. The lack of reactivity indicates that these atoms are extremely stable and their energy is so favourable that it cannot be further minimised by compound formation. They must be having a complete outer shell of electrons, so that we conclude that this is a very stable electronic arrangement or configuration.

The electronic configuration of these elements are given below (Table 2.1).

Table 2.1. Electronic configuration of noble gas atoms



Element	Atomic Number	Number of electrons in various shells						Valence electrons
		K	L	M	N	O	P	
Helium (He)	2	2						2
Neon (Ne)	10	2	8					8
Argon (Ar)	18	2	8	8				8
Krypton (Kr)	36	2	8	18	8			8
Xenon (Xe)	54	2	8	18	18	8		8
Radon (Rn)	86	2	8	18	32	18	8	8

We can see from the above table that all the atoms of noble gases (with the exception of helium) have eight electrons in the valence shell. Helium, on the other hand, has two electrons in its first and the only energy level (K-shell) which cannot hold more than two electrons. *Two electrons in the first (K-shell) and the only shell of helium (He) and eight electrons in the outermost shells of other noble gases give a stable configuration of electrons.* We can therefore, conclude that atoms having eight electrons in their outermost shells (two in case there is K-shell) are very stable and unreactive. Eight electrons in the outermost shell of an atom is called **octet** of electrons. Two electrons in the outermost shell of helium is called **duplet** of electrons. Thus, eight electrons in the outermost shell of an atom makes the atom stable. When there is only K-shell, in an atom, two electrons in this shell make the atom stable.

All atoms other than noble gases have less than eight electrons in their outermost shells. In other words, the outermost shells of the atoms of these elements do not have stable configurations.

Thererefore, **atoms combine with each other or with other atoms to acquire stable nearest noble gas electronic configurations. The principle of attaining eight electrons in the valence shell of atoms is called octet rule**.

However, it may be noted that for hydrogen and lithium atoms, the stable configuration means two (duplet) electrons which corresponds to the nearest noble gas helium. This is called **duplet rule**.

In the light of octet rule, Kossel and Lewis, in 1916 developed an important theory of chemical combination between atoms known as **Electronic Theory of Valency**. According to this theory, atoms combine to acquire the nearest noble gas electronic configuration by losing, gaining or sharing electrons. This leads to the formation of chemical bonds between the combining atoms.

There are three common types of bonds. These are

- **(i)** Electrovalent or ionic bond
- **(ii)** Covalent bond
- **(iii)** Co-ordinate bond.

2.1.1. Electrovalent or Ionic Bond

In the previous chapter, we have seen that elements can be divided into (a) metals or electropositive elements, whose atoms give up one or more electrons fairly readily, and (b) non-metals or electronegative elements which take up electrons.

An ionic or electrovalent bond is formed when an electropositive element combines with an electronegative element. Let us consider the sodium atom (atomic number 11), which has the electronic configuration 2, 8, 1. The first and second shells of electrons are full, but the third shell contains only one electron. When this atom reacts, it will do so in such a way that a stable electron configuration is attained. The nearest noble gas neon has the configuration 2,8. If the sodium atom can lose one electron from its outer shell, it will attain this configuration except that sodium atom becomes sodium ion with a net charge of +1. This is because there are eleven positive charges on the nucleus and only ten electrons. When supplied with energy sodium atoms tend to do this, so sodium is an electropositive element.

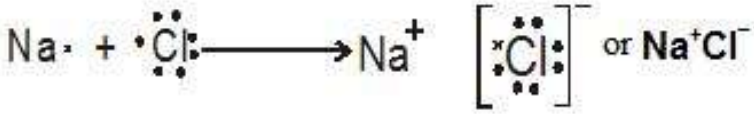
$$\text{Na} \longrightarrow \text{Na}_{+} \quad + \quad \text{electron}$$

2,8,1 2,8
Sodium Sodium
atom ion

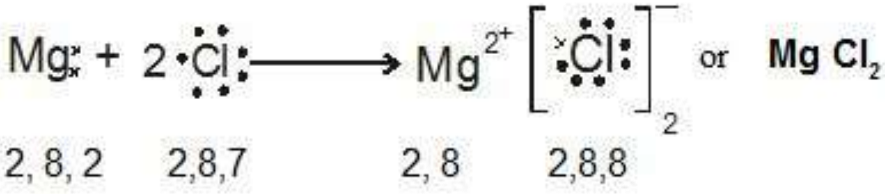
Chlorine atom has the electronic configuration 2, 8, 7. It is only one electron short of the stable inert gas configuration of argon, 2, 8, 8. Chlorine atoms tend to react and gain electrons that is they are electronegative. By gaining one electron, the electrically neutral chlorine atom becomes a chloride ion with a net charge of 1–.

atom

When sodium and chlorine react together, the outer electron of the sodium atom is transferred to the chlorine atom to produce sodium ion Na^+ and chloride ion Cl^-. The two ions (Na^+ and Cl^-), being oppositely charged, are now held together by the electrostatic force of attraction. Since both sorts of atoms attain a very stable inert gas configuration, the process is energetically favourable and sodium chloride, Na^+Cl^- is formed readily. This may be illustrated diagrammatically using dots and crosses to represent the valence electrons only as follows:

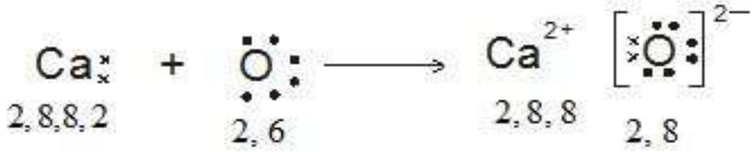


In a similar way, an atom of magnesium (Mg) can combine with two atoms of chlorine (Cl) to form magnesium chloride $MgCl_2$. The electronic configuration of Mg (atomic number 12) is 2, 8, 2. It has 2 electrons in its outermost shell. Thus the Mg atom transfers its two valence electrons to two Cl atoms and changes into a stable magnesium ion (Mg^{2+}), with a stable octet of electrons in its outer shell. The positively charged magnesium ion (Mg^{2+}) and negatively charged chloride ions (Cl^-) are now held together by the electrostatic force of attraction.



It should be noted that two chlorine atoms are needed to take up the two electrons coming from a single magnesium atom.

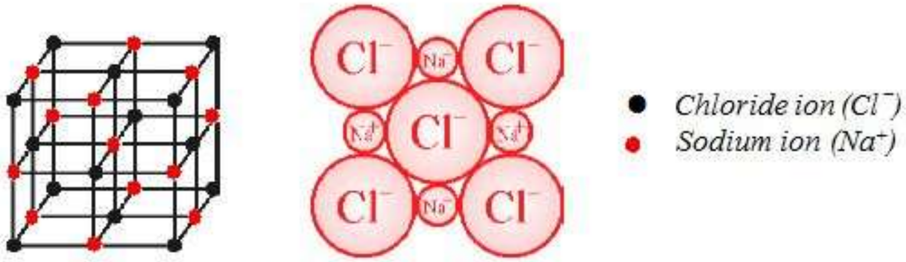
Combination of calcium (Ca) and oxygen (O) atoms to form calcium oxide (CaO) can be explained in a similar way. The atomic numbers of Ca and O are 20 and 8 respectively. So, their electronic configurations are 2, 8, 8, 2 and 2, 6, respectively, so that , Ca atom has two valence electrons, whereas the O atom has 6. When the two atoms combine, the two valence electrons of Ca are transferred to the valence shell of oxygen. In doing so, calcium, as well as oxygen atom, achieve a stable octet of electrons and thus attain stable noble gas configuration. Ca atom acquires two positive charges and becomes calcium ion (Ca^{2+}) and oxygen atom, two negative charges and becomes oxide (O^{2-}) ion. The two oppositely charged ions (Ca^{2+} and O^{2-}) are now held together by electrostatic force of attraction forming calcium oxide $Ca^{2+}O^{2-}$ or CaO.



In the above examples, we find that the stable structure like that of the noble gases is attained by combining atoms by the transfer of one or more electrons from one atom to another. **The type of combination between atoms which depend upon the transfer of electrons and in which oppositely charged ions are held together by electrostatic force of attraction, is called electrovalent or ionic bond**. *The number of electrons lost or gained by an atom to attain the stable electronic configuration is known as the electrovalency of the atom.* The compounds formed by electrovalent or ionic bonds are called electrovalent or ionic compounds.

Characteristics of Ionic or Electrovalent Compounds

(a) **Ionic compounds are generally crystalline in nature**. X-rays studies of these compounds have shown that they do not exist as single molecules but as ions which are arranged in a well defined geometric pattern. This is because of the fact that the forces of attraction are not restricted to a single unit, such as one Na^+ and one Cl^-, but due to uniform electric field around an ion, each ion is attracted to a large number of other ions. The ionic bond is **non-directional**. This results into a three dimensional aggregate of the oppositely charged ions arranged in a regular manner. For example, the arrangement of ions in sodium chloride is such that each Na^+ ions is surrounded by six Cl^- ions and each Cl^- ion is surrounded by six Na^+ ions.



The arrangement of ions in sodium chloride crystal.
The right hand side diagram shows the relative size of ion.
The left hand side diagram shows only the arrangement of ion, but not their relative sizes.

Fig. 2.1. Formation of aggregates in ionic crystals.

(b) **Ionic compounds have high melting and boiling points**. This is due to the strong electrostatic force of attraction between the oppositely charged ions. As a result of this, large amount of energy is needed to break the bond and hence melting and boiling points are high.

(c) **They conduct electricity in molten state and in their aqueous solution.** Solid ionic compounds do not conduct electricity as the ions are fixed at particular positions and are not free to move. However, when these are melted or dissolved in water, the ions become free and, therefore, conduct electricity.

(d) **Ionic compounds are usually soluble in water and other polar solvents** but insoluble in organic solvents such as benzene, ether, carbon tetrachloride, kerosene etc.

Let us answer these.

1. Which electronic configuration favour inert or noble behaviour of elements ?
2. Why do most of the elements form ions ?
3. What kind of elements form cation ? Support your answer by two examples?
4. What kind of elements form anions ? Support you answer by two examples.
5. Sodium atom reacts vigorously with water, but sodium ion does not. Why ?
6. What is an ionic bond ? State at least three conditions for its formation.
7. A metal A (atomic number 19) burns in chlorine to produce a white solid chloride ACl. By means of diagrams, show the arrangement of electrons in A before and after the reaction.
8. Give reasons of the following : (a) Ionic compounds have high melting and boiling points. (b) Ionic compounds are good conductors of electricity in fused state or aqueous solution.

2.1.2. Covalent Bond

The formation of ionic bond cannot explain the chemical combination between identical atoms or atoms of similar chemical nature to form molecules. Thus it cannot account for the formation of molecules like H_2, O_2, Cl_2, CO_2; and also for the organic molecules like methane (CH_4), carbon tetrachloride (CCl_4) etc. In such cases, the combining atoms attain the stable noble gas configuration by sharing electrons. The sharing always occurs in pairs and in each pair of shared electrons, one electron is contributed by each atom. **The bond formed by mutual sharing of electrons between the combining atoms is called covalent bond**. Sharing of one pair of electrons form a **single bond**, two pairs a **double bond** and three pairs a **triple bond**.

Let us consider the formation of hydrogen molecule (H_2) from two atoms of hydrogen. The nucleus of hydrogen has one proton and the only one electron revolves in the K-shell which is also the valence shell. In the formation of hydrogen molecule, H_2, when the two hydrogen atoms approach each other, the single electron of both the atoms form a shared pair. This electron pair revolve around the two nuclei of H-atoms i.e., the two H-nuclei are bound together by the electron pair. It is contained in the electron shells of both the atoms and each hydrogen atom attain the electronic configuration of the nearest inert gas helium. In the conventional system of writing the structural formula of molecules, a single covalent bond is represented by a dash (–) between the combining atoms. This may be represented as follows.

$$\underset{\substack{1\\ \text{atom}}}{H\cdot} \quad + \underset{\substack{1\\ \text{atom}}}{\cdot H} \longrightarrow H\!:\!H \text{ or } H-H \text{ or } H_2$$

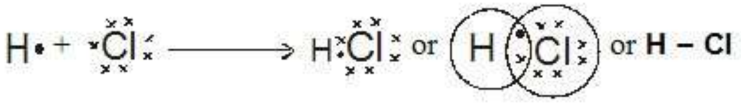
Pictorially hydrogen molecule may be represented as . Once the bond is formed, both the atoms have a stable configuration of the noble gas helium.

Formation of Chlorine molecule (Cl_2)

The atomic number of chlorine is 17. The electronic configuration of the Cl atom is 2, 8, 7. Thus, a Cl atom needs one electron to complete its octet. The two combining atoms of chlorine gives one of its electrons to be shared between them and constitute a shared pair of electrons. The two shared electrons are counted for both the atoms. Thus, each Cl atom in a chlorine molecule (Cl_2) acquires a stable configuration. Showing the outer (valence) electrons only, this may be represented as follows:

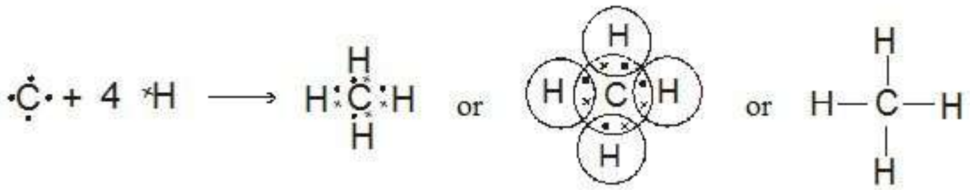
Formation of hydrogen chloride (HCl) molecule

Hydrogen atom has only one electron and chlorine atom has seven electrons in its valence shell. Hence, by mutual sharing of electron pair between them, both the atoms acquire nearest noble gas configurations. Hydrogen atoms acquire stable electronic configuration (duplet) of helium whereas chlorine atoms acquire stable electronic configuration (octet) of argon.



Formation of methane (CH_4) molecule

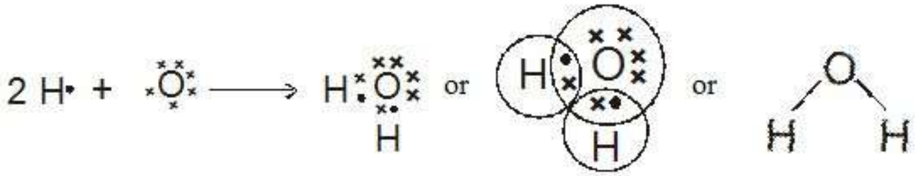
A carbon atom has four electrons in its valence shell. It shares its valence electrons with those of four H atoms. Thus, an atom of carbon forms four single covalent bonds with four H atoms.



In a molecule of methane, the carbon atom and each of the four H atoms acquire the stable electronic configurations of neon and helium respectively. In methane, we have four carbon-hydrogen (C–H) single bonds. Thus, a methane molecule has four pairs of shared electrons.

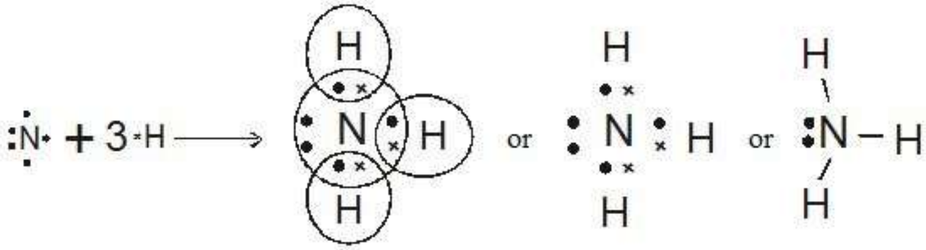
Formation of water (H_2O) molecule

A molecule of water is made up of one oxygen atom and two hydrogen atoms. An oxygen atom is two electrons short and hydrogen atoms are one electron short of a noble gas structure. Thus one atom of oxygen shares two of its electrons with two hydrogen atoms, thus attaining a stable configuration.



Formation of ammonia (NH_3) molecule

A molecule of ammonia is formed by the combination of one atom of nitrogen with three atoms of hydrogen. There are five electrons in the valence shell of nitrogen atom. So, it has three electrons short of to complete its octet and to be stable. When it shares three of its electrons with three H atoms, the stable electronic configuration of neon is achieved. The three H atoms acquire the stable helium configuration.



Multiple Covalent Bonding

We have seen that electron pair shared between two atoms is responsible for the formation of a covalent bond. This shared pair is also called **bonding pair of electrons**. The pair of electrons which do not take part in bonding are called **lone pairs**. The bonding atoms may share more than one pair of electrons also depending upon their requirement to complete the stable elctronic configuration or octet.

If the two atoms share one electrons pair, the bond is known as **single covalent bond** and is represented by one dash (–).

If the two atoms share two electron pairs, bond is known as **double covalent bond** and is represented by two dashes $(=)$.

If the two atoms share three electron pairs, bond is known as **triple covalent bond** and is represented by three dashes $(\equiv)$.

Formation of Double Bond

Two oxygen atoms combine to form an oxygen molecule(O_2) by sharing two electron pairs. We know that each oxygen atom has six electrons in the valence shell and requires two electrons to complete the octet. Therefore, in the formation of oxygen molecule, both the atoms contribute two electrons each for sharing resulting in two electron pairs. Hence there is double bond between the two oxygen atoms.

A molecule of carbon dioxide (CO_2) is formed when an atom of carbon combines with two atoms of oxygen. The C atom has four electrons in its valence shell and thus requires four more electrons to complete its octet while oxygen atom requires two electrons to complete its octet. This is achieved when the carbon atom shares its four electrons with two oxygen atoms to form a CO_2 molecule.

Formation of Triple Bond

In the formation of nitrogen molecule (N_2), each of the two nitrogen atoms having five valence electrons, provides three electrons to form three electron pairs for sharing. Thus a triple bond is formed between the two atoms.

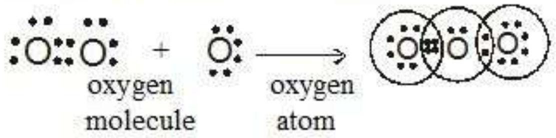
We have seen from the above examples that in the formation of covalent molecules, an atom shares electrons with other atoms as needed to acquire nearest noble gas configurations (octet or duplet).

The type of combination between atoms which results from the mutual sharing of pair of electrons between the combining atoms is called covalent bond and the molecules formed are called covalent molecules. The number of electrons contributed by an atom for sharing in the formation of a covalent molecule is known as **covalency**. Thus, the covalency of hydrogen, oxygen and nitrogen in the above examples is one, two and three respectively.

2.1.3. Co-ordinate or Dative Bond

A covalent bond results from the sharing of an electron pair, where each atom contributes one electron to the bond, as seen above. It is also possible to have an electron pair bond in which both the electrons of the shared pair came originally from one of the atoms. Such type of bond is formed between atoms, one of which is deficient in at least two electrons while the other has already acquired a stable configuration (or octet). The atom which contributes the electron pair is called the *donor* while the other which only shares the electron pair is known as *acceptor*. Such bonds are called **co-ordinate covalent or dative bonds**. The usual representation of co-ordinate bond is to point an arrow (→) from donor to the acceptor.

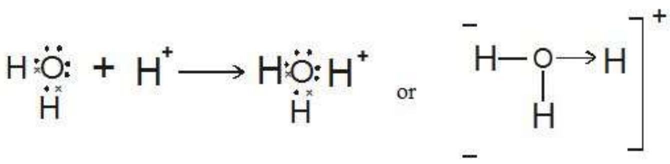
Let us consider the formation of ozone (O_3) molecule. A molecule of oxygen (O_2) contains two atoms of oxygen joined by covalent double bond so that each atom has stable octet configuration. In O_2 molecule, each oxygen atom has two pairs of unused valence electrons. Such pairs of electrons which are not involved in bond formation are called **lone pairs**. Now, if an atom of oxygen having six valence electrons comes close to O_2 molecule, the new atom may share a lone pair of electrons of one of the oxygen atoms of O_2 molecule. It gives rise to the formation of a co-ordinate covalent bond.



or O= O→O or O_3

Formation of hydronium ion (H_3O^+) and ammonium (NH_4^+) ion

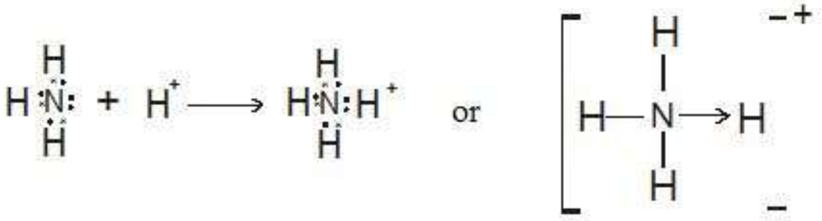
Water, H_2O has lone pair of electrons on oxygen atom while hydrogen ion (H^+) has empty K-shell thereby can accommodate two electrons. Thus, oxygen in H_2O can easily provide two electrons while H^+ ion can accept these



or H_3O^+

Hydronium ion

Similarly ammonium ion (NH_4^+) is formed by co-ordinate bond between ammonia (NH_3) molecule and hydrogen ion (H^+).



Ammonium ion

Characteristics of Covalent substances

Covalent substances show the following characteristic properties.

- **(a)** **Physical state :** The covalent compounds do not exist as ions but they exist as molecules. There are weak inter molecular forces between the molecules. Hence, generally they exist as liquids or gases at room temperature.
- **(b)** **Low melting and boiling points**: Since the forces between the molecules are weak, a comparatively small amount of heat energy is required to overcome these forces. Hence covalent compounds generally have low melting and boiling points.
- **(c)** **Solubility:** In general, they are sparingly soluble in polar solvents like water but soluble in non-polar solvents like benzene, carbon tetrachloride, kerosene, etc.
- **(d)** **Conductivity :** They do not conduct electricity. This is because they are made up of neutral molecules, not ions.

2.1.4. Do covalent bonds show partial ionic character ?

If we consider a covalent bond between similar atoms, the shared pair of electrons is equally attracted by the two atoms. As a result of this, it is situated exactly in between the two identical nuclei. The common examples are H_2, F_2, Cl_2 etc.

H_2

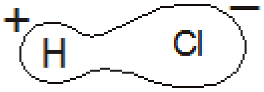
Cl_2

F_2

These are examples of pure covalent bonds.

However, if the atoms forming bonds are different, the electron attracting tendency of the two atoms may differ. *The relative tendency of an atom to attract shared electrons to itself when combined in a compound is termed as the electronegativity of the atom.* As a result of the difference in electronegativity, the shared electron pair will be displaced towards the atom with more electron attracting tendency or electronegativity. For example, the compound hydrogen chloride is formed by sharing a pair of electrons between the hydrogen and the chlorine atom.

Of the two nuclei, the attraction exerted on the shared pair of electrons by the chlorine nucleus is more than that by the hydrogen nucleus. In the hydrogen chloride molecule, therefore, the shared electron pair would be attracted more towards the chlorine end of the molecule. So the chlorine end of the molecule will be slightly negative and the hydrogen end slightly positive, these are represented as $\delta^+$and δ^- charges.

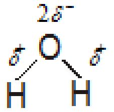


or $H^{\delta+} — Cl^{\delta-}$

In other words, the hydrogen chloride molecule develops a partial ionic character even though it is a covalent molecule. Such molecules are said to be **partially polar**. Almost all covalent bonds between unlike atoms are partially polar. They are thus **polar covalent compounds**.

Similarly, the molecules of HF and H_2O are polar covalent compounds.

$H^{\delta+} — F^{\delta-}$



Unlike the covalent bond in the HF and HCl molecule, the water (H_2O) molecule contains two covalent bonds between the oxygen and hydrogen atoms. These two bonds are not symmetrically arranged, and H_2O molecule is V-shaped. This results in the polar character of water. Hence water is a polar solvent.

Let us answer these.

1. Using dots (•) and crosses (×) to represent valence electrons, show the formation of covalent bonds in CO_2 and CCl_4.
2. Why does carbon tetrachloride not conduct electricity ?
3. How does a co-ordinate bond differ from a normal covalent bond ?
4. Why does H_2 molecule exist while He_2 does not exist ?
5. Why is HF is polar while H_2 and F_2 are not polar.

2.3. BONDING IN METALS

We know that metals are generally hard solids and they are made up of atoms. It has been established that the atoms in metals are closely packed together.

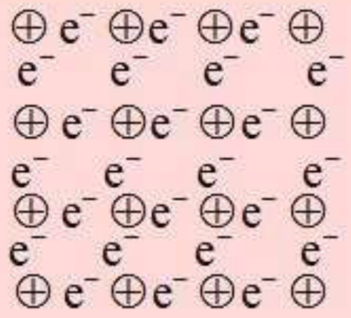


Fig. 2.1. Electron sea model of metal.

What force holds the atoms in metals closely together ? What type of bonding exist between the atoms of metals ? We have learnt that metal atoms can easily lose electrons to form positively charged ions and they are good conductors of electricity. This implies that the valence electrons of metal atoms are loosely held by the nucleus and can move freely.

To account for the bonding in metals, Lorentz has proposed a model known as *electron sea model*. According to this model, a metal lattice consists of positively charged **kernels** arranged in a regular way surrounded by loosely held valence electrons. Kernels are metal nuclei and other electrons except valence electrons. Alternatively, it can be assumed that there is a sea of valence electrons in which positively charged **kernels** are immersed. It is for this reason that it is called **electron sea model**. *The simultaneous force of attraction between the positively charged kernel and the mobile electrons which binds the metal atoms together is called metallic bond.*

Let us consider lithium metal. The electronic configuration of lithium is 2, 1; it has one valence electron. Without the valence electron, the kernel is Li^+. The arrangement of kernel of lithium atom, ⊕ and valence electrons (e^-) in its metal lattice is shown in Fig.2.1.

SUMMARY

The interaction between two or more atoms or groups of atoms holding the atoms together is called chemical bond.

- Noble gas atoms have stable electronic configurations.
- The type of combination which depends upon the transfer of electrons and in which oppositely charged ions are held together by electrostatic force of attraction is called electrovalent or ionic bond.
- Atoms which can lose electrons and form positive ions (cations) are said to be electropositive and the elements are called electropositive elements. Metals are generally electropositive.
- Atoms which can gain electrons and form negative ions (anions) are said to be electronegative and the elements are called electronegative elements. Non-metals are generally electronegative.
- The number of electrons gained or lost by an atom in the formation of ionic bonds is equal to its electrovalency.
- Covalent bonds are formed by mutual sharing of electrons between the combining atoms.
- Compounds formed by covalent bonds are called covalent compounds.
- The number of electrons contributed by an atom for sharing in the formation of covalent bonds to attain stable configuration is known as its covalency.
- A co-ordinate covalent bond is formed by sharing of electrons between two atoms where both the electrons of the shared pair come originally from one atom and none from the other .
- The force that holds the atoms closely together by simultaneous force of attraction by between the positively charged kernel and the mobile valence electrons in a metal is known as the metallic bond.

EXERCISES

1. Define the terms ‘valence shell’ and ‘valence electrons’.
2. Why do elements combine chemically ?
3. What is an electrovalent bond and how is it formed ?
4. What is a covalent bond and how is it formed ?
5. How does an ionic bond differ from a covalent bond ? Illustrate your

Answer with two examples of each type of bond.

6. What is a polar molecule ? Give example.

7. Give electron dot representation for the following molecules.
F_2, HF and H_2O.

8. State four properties each of electrovalent and covalent compounds.

9. The elements *w*, *x*, *y* and *z* have atomic numbers 7, 9, 10 and 11 respectively. Write the formula of the molecules that would be formed between the following pairs of elements and indicate the type of the bonding present using dots (**.**) and crosses (×) to represent valence electrons.

(a) *w* and *x* **(b)** *x* and *x* **(c)** *w* and *z* **(d)** *y* and *y*.

★★★★★★

CHAPTER

3

ACIDS, BASES AND SALT

You know the tastes of various fruits and vegetables. Some fruits and vegetables such as lemon, tamarind, green mango, oxalis, Indian goose berry (amla), unripe grapes, curd are sour to taste. Do you know the taste of sodium bicarbonate ? It is bitter in taste. Add some sodium bicarbonate on a half-cut lemon. What do you see ? There will be gas bubbles escaping from the lemon surface.

Those substances which have sour taste are said to contain acids. Different types of acids are present in different kinds of food materials. Acids present in food materials are generally called **organic acids**. Oxalic acid, lactic acid, tartaric acid, citric acid are some common organic acids found in food materials. Other types of acids are hydrochloric acid, sulphuric acid, nitric acid, phosphoric acid etc. which are called **mineral acids**. They are generally prepared from minerals. The liquid present in lead storage battery is dilute sulphuric acid. It is sour to taste.

Substances like potassium hydroxide, sodium hydroxide, calcium hydroxide etc. which are bitter to taste, are called **bases**. Sodium carbonate and sodium bicarbonate also shows basic character in their solutions. Bases react with acids to form compounds called **salts**. You know the salty taste of common salt.

Acids change the blue colour of litmus to red. Bases turn the colour of red litmus to blue. The colour of litmus generally remains unaffected in salt solutions. You must have seen the change of curry stain (turmeric stain) in soap solution. Turmeric and litmus are examples of natural indicators. They are called so because they differentiate acidic and basic solutions by changing their colours. Here we will discuss the reaction of acids and bases. We will also study how acids and bases interact with each other in reactions known as **neutralisation reactions.**

Litmus solution is a water soluble purple dye extracted from Lichen. Lichen is a plant belonging to Thallophyta family. Acid turns the purple color of litmus red while base turns it into blue. There are many natural substances like turmeric, red cabbage leaves, colour petals of Petunia, Geranium, Hydrangea etc. which can indicate the presence of acid or base in a solution. They are generally called acid-base indicators or simply indicators .

The teacher can ask the students to identify the solutions by using red and blue litmus papers.

3.1. Chemical Properties of Acids and Bases

3.1.1. Acids and Bases in the Laboratory

Activity 3.1

- Find the following solution samples from your laboratory : sulphuric acid (H_2SO_4) hydrochloric acid (HCl), acetic acid (CH_3COOH), oxalic acid ($H_2C_2O_4$), sodium hydroxide ($NaOH$), sodium carbonate (Na_2CO_3), ammonium hydroxide (NH_4OH).
- With the help of a dropper or glass tube, take out a few drops of each sample solution on a watch glass or a small test tube. Add a drop of the following indicators as given in the Table 3.1.
- Observe the change in the colour of each solution taken and note them in the Table 3.1.

Table 3.1

Sample Solution	Phenolphthalein	Blue litmus	Red litmus	Methyl orange
Hydrochloric acid				
Sulphuric acid				
Acetic acid				
Oxalic acid				
Sodium hydroxide				
Sodium carbonate				
Ammonium hydroxide				

Activity 3.2

- Prepare an aqueous solution of turmeric powder and filter. Collect the filtrate.
- Collect samples of lime juice, passion fruit juice, unripe tomato juice, soap solution, detergent solution and common salt solution. Filter, if necessary.
- Take 10 drops or about 1mL of each solution in separate test tubes and add 1 or 2 drops of the indicators and mix thoroughly as shown in the Table 3.2.
- Observe the change in colour of each solution taken and note them in the table.

Table 3.2

Sample solution	Turmeric solution	Phenolphthalein
Lime juice		
Passion fruit juice		
Unripe Tomato juice		
Soap solution (Toilet Soap)		
Detergent (washing powder) solution		
Common salt (NaCl) solution		

Let us answer these

1. From the observed facts draw your conclusion comparing with the results of the activity 3.1.
2. Suggest the usefulness of turmeric powder as an indicator.
3. Is sodium chloride solution acidic or basic ?

Indicators tell us the nature of a solution – acidic or basic by a change in their colour in different solutions.

3.1.2. Reaction of acids and bases with metals

Activity 3.3

Under the guidance of your teacher perform this activity

- Set up the apparatus as shown in Fig. 3.1
- Take 2-3 pieces of zinc granules in a double necked Woulf’s bottle, fitted with a thistle funnel and a delivery tube.

- Add some dilute sulphuric acid through the funnel to cover the zinc granules. See that the end of the Thistle funnel is under the acid.
- Observe the surface of zinc granules. Do you see the bubbles formed on it?
- Allow the gas formed to pass through the soap solution.

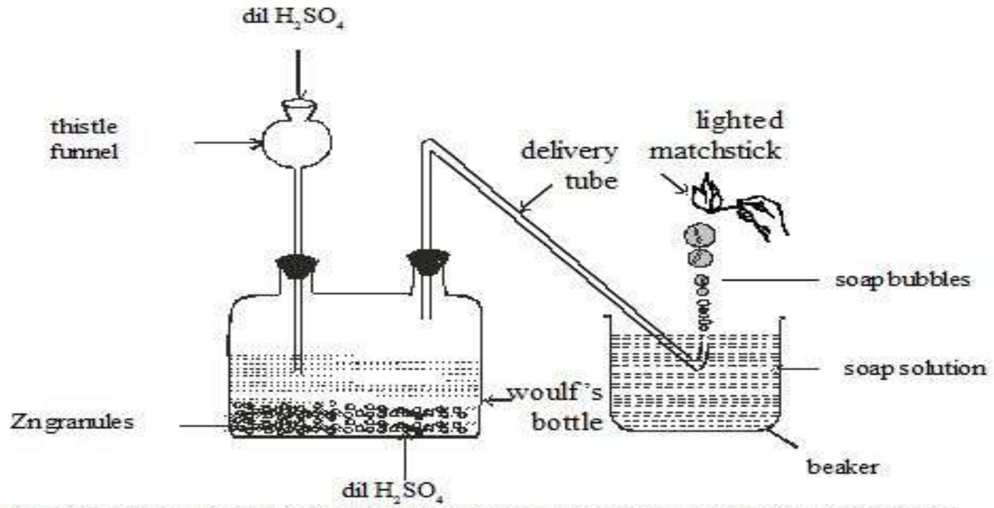


Fig 3.1. Zinc granules react with dilute sulphuric acid to give hydrogen gas. Hydrogen burns in air with a pop sound.

Let us answer these observations:

- Why are soap bubbles formed?
- Why do the bubbles go up in the air ?
  Compare with the hydrogen balloons you have seen in the market place.
  Did the ballons go up in the air when released ? Why ?
- Take a lighted match stick near the rising soap bubbles.
  What do you observe ?
- Repeat this activity using acetic acid solution in place of dilute suphuric acid solution.
- Are there any differences in your observations ?

Note carefully the composition of acids–sulphuric acid (H_2SO_4), hydrochloric acid (HCl), nitric acid (HNO_3), phosphoric acid (H_3PO_4), acetic acid (CH_3COOH) etc. All of them contain hydrogen and another part e.g., Cl^- and SO_4^{2-} in HCl and H_2SO_4 respectively.

In the above activity, the hydrogen (H) of the acid is replaced by the metal releasing hydrogen gas (H_2). Then the metal combines with the other part of the acid to form a compound which is called salt. In short, we can write

Acid + Metal   Salt + Hydrogen gas

For example,

Sulphuric acid + Zinc   Zinc sulphate + Hydrogen gas

H_2SO_4 + Zn   Zn SO_4 + H_2

Can you write the equation for the reaction between zinc and acetic acid ?

Activity 3.4.

Repeat the activity 3.3 using pieces of copper metal instead of zinc granules

☞ Do you see any gas formed on the metal surface ?

☞ Can you draw a conclusion from this observation ?

☞ Does this verify the general statement that
Acid + Metal   Salt + Hydrogen gas ?

☞ Are there exceptions to the above statement ?

Activity 3.5.

Repeat the activity 3.3 using dil sodium hydroxide (NaOH) in place of dilute sulphuric acid.

☞ You can repeat the activity using fine pieces of aluminium metal with dilute sodium hydroxide.

☞ Can you draw a conclusion from these observations ?

☞ Repeat all the steps in activity 3.3 and record all your observations.

Here, the metal zinc reacts with the alkali sodium hydroxide to release hydrogen gas and forms a salt. The reaction can be written as

Sodium hydroxide + Zinc   Sodium zincate (salt) + Hydrogen gas
2 NaOH + Zn Na_2ZnO_2 + H_2

Aluminium can also release hydrogen in a similar way. Thus,

Sodium hydroxide + Aluminium +Water Sodium meta aluminate + Hydrogen gas

$$2NaOH + 2Al + 2H_2O \quad 2NaAlO_2 + 3H_2$$

Alluminium powder and NaOH solution is used to prepare hydrogen for gas balloon sold in the market. Here, you find that hydrogen gas is formed in the reaction. However, such reactions do not occur with all metals. Besides zinc and aluminium, other elements which react with sodium hydroxide to liberate hydrogen are tin and silicon.

Lime and lime water are also bases. A suspension of lime (CaO) in water is called milk of lime but the clear supernatent liquid is called lime water. Chemically, it is calcium hydroxide $Ca(OH)_2$. Lime water readily absorbs carbon dioxide forming calcium carbonate which is insoluble in water.

Lime is used in the treatment of acidic soil. The acids in soil are released by the decay of organic matter. Lime neutralises these acids. Nitrifying bacteria (those bacteria which can increase the nitrogen content of the soil) which cannot function in acid soils become active again when the soil is treated with lime.

3.1.3. Reactions of acids with metal carbonates and metal hydrogen carbonates.

Activity 3.6

- Take about 0.5g of a metal carbonate like zinc carbonate, magnesium carbonate, sodium carbonate etc. in a test tube as shown in the Fig 3.2.
- Add about 3ml of dilute hydrochloric acid into the test tube.
- Note the evolution of a colourless gas.
- Pass the gas into a test tube containing clear lime water as in the figure.
- Record the changes you have seen.

Now repeat the above steps, taking sodium bicarbonate or baking soda in place of metal carbonate and record your observations.

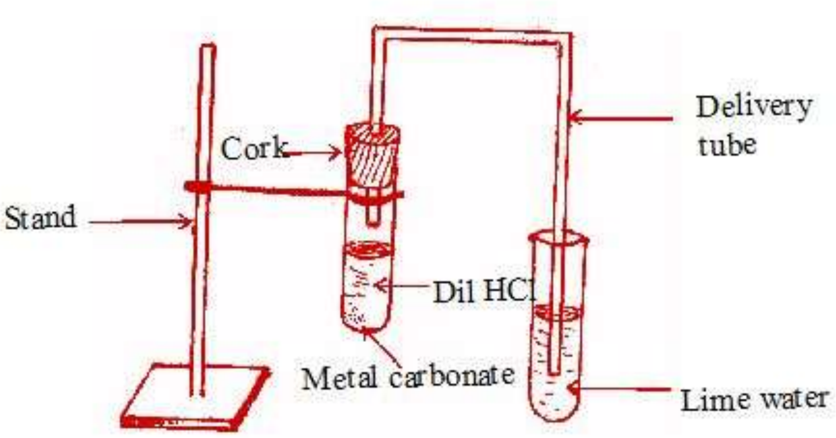


Fig. 3.2. Action of acids on metal carbonates and bicarbonates.

The reaction taking place in the above can be written as

Metal carbonate + Hydrochloric acid Metal chloride + Water + Carbon
(salt) dioxide

e.g., $ZnCO_3$ (s) + 2 HCl(aq) $ZnCl_2$ (aq) + H_2O (l) + CO_2 (g)

zinc carbonate zinc chloride

Na_2CO_3 (s) + 2 HCl (aq) NaCl(aq) + H_2O(l) + CO_2(g)

sodium carbonate sodium chloride

With sodium bicarbonate (sodium hydrogen carbonate) the reaction is

$NaHCO_3$ (s) + HCl (aq) NaCl(aq) + H_2O(l) + CO_2(g)

Sodium hydrogen carbonate

When the evolved carbon dioxide is passed into lime water, the clear solution becomes milky due to the formation of insoluble calcium carbonate. The reaction is

$Ca(OH)_2$(aq) + CO_2(g) $CaCO_3$(s) + H_2O (l)
Lime water Calcium carbonate
(insoluble)

When carbon dioxide is passed into lime water for a longer period, the milkyness of the solution will start disappearing. The solution will again become clear. This is due to the conversion of insoluble calcium carbonate into soluble calcium hydrogen carbonate. The reaction is

$$\underset{\text{(insoluble)}}{CaCO_3 \text{ (s)} + H_2O\text{(l)} + CO_2\text{(g)}} \longrightarrow \underset{\text{(soluble)}}{Ca(HCO_3)_2 \text{ (aq)}}$$

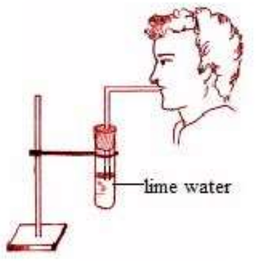


Fig. 3.3. Passing breath into lime water

Activity 3.7.

- Take about 5ml of lime water in a clean test tube.
- Exhale your breath into it as shown in Fig 3.3.
- Observe the change in lime water solution.
- What inference can you derive from the observation you made ?

3.1.4. Neutralisation Reactions

How do Acids and Bases React with each other ?

Different acids and different bases have different strengths. Generally dilute solutions of these substances are prepared by dissolving them in water. Such solutions generally have similar strengths. They are usually available in the laboratory. If different strengths are required for a specific purpose, they are further diluted with fixed amounts of water.

In acid-base reactions, solutions with similar strengths are usually taken. For example, samples of dilute HCl and dil NaOH solutions in the laboratory have nearly the same strength.

Activity 3.8

- Take about 5ml of dilute NaOH solution in a test tube and add two drops of phenolphthalein indicator.

  (Note that volume of a test tube is about 20 mL).
- Note the colour of the solution
- Add dilute HCl into the above solution drop by drop and mix well.
- Do you see any change in the colour of the mixture ?

- ☞ Continue to add dil HCl in the above manner till the solution becomes almost colourless.
- ☞ Now add a few drops of dilute NaOH to the above colourless solution.
- ☞ What is the colour of this solution ?
- ☞ Why is this happened ?

The effect of a base can be annulled by an acid. Similarly, we can find out that the effect of an acid can also be annulled by a base. (For this, repeat the steps of **activity 3.8** taking 5 mL of dilute HCl in the test tube first and adding dilute NaOH dropwise to it after adding two drops of phenolphthalein).

The reaction between the acid and the base is

Acid + Base   Salt + Water

e.g. $HCl\ (aq) + NaOH\ (aq)$ $NaCl\ (aq) + H_2O\ (l)$

Such a reaction between an acid and a base producing salt and water is known as **neutralisation reaction**.

The neutralisation reaction between dilute sulphuric acid and sodium carbonate solution can be studied using methyl orange indicator also. For this follow the similar steps in activity 3.8.

Consider again the reaction between dilute HCl and dilute NaOH solutions to form sodium chloride solution and water.

$HCl\ (aq) + Na\ OH\ (aq)$ $NaCl\ (aq) + H_2O\ (l)$

Here, 1 mole of HCl react with 1 mole of NaOH to form 1 mole of NaCl and 1 mole of water.

Molecular mass of HCl = 1 + 35.5 = 36.5
Molecular mass of NaOH = 23 + 16 + 1= 40
Molecular mass of NaCl= 23 +35.5 = 58.5
Molecular mass H_2O = 1 ×2 + 16 = 18

Therefore ,

$HCl\ (aq) + NaOH\ (aq)$ $NaCl\ (aq) + H_2O(l)$
36.5 g   40 g   58.5 g   18 g

36.5 g of HCl reacts with 40 g of NaOH to produce 58.5 g of NaCl and 18 g of H_2O.

Let us answer these.

1. Dissolve a small amount of $NaHCO_3$ in water. Add 1 drop of methyl orange into it. What is the colour of the mixture ?

   Add lime juice in the above solution till the evolution of the gas stops. What is the colour of the mixture now ?
2. How many grams of sulphuric acid (H_2SO_4) will be needed to react completely with a solution containing 10.6g of sodium carbonate (Na_2CO_3)?

3.1.4. Reaction of Acids with metal Oxides

Activity 3.9

- Collect samples of zinc oxide, magnesium oxide, copper oxide, mangnese dioxide, ferric oxide etc. and note their colours.
- Take a small amount of an oxide in a test tube.
- Add dilute hydrochloric acid into it and warm on a spirit lamp.
- What happens to the oxide ?
- Note the colour of the solution

.

In the case of colourless oxides, like that of zinc and magnesium , you will get a colourless solution when hydrochloric acid dissolve the oxides. The reaction in case of zinc oxide is

$$ZnO(s) \quad + \quad 2HCl\ (aq) \longrightarrow ZnCl_2\ (aq) \quad + \quad H_2O\ (l)$$

Zinc oxide (white) **Zinc (II) chloride(colourless)**

If you take the black copper oxide you will get a bluish green solution. The reaction is

$$CuO(s) + 2HCl\ (aq) \longrightarrow CuCl_2\ (aq) + H_2O\ (l)$$

Copper (II) oxide **Copper (II) chloride**

(Black) (Bluish green)

Thus the general reaction between a metal oxide and an acid can be written as

Metal oxide + Acid ⟶ Salt + Water

Let us answer these.

1. What is the nature of metal oxides – acidic or basic ?
2. Two metallic compounds A and B react separately with acid to form salt and water. The compound A also produces an effervescence. What could be A and B ?
3. When milk becomes curd lactic acid is produced as one of the products. Give reason why is it not advisable to keep curd in copper and brass vessels?
4. Carbon dioxide reacts with lime water, $Ca(OH)_2$ to form salt, $CaCO_3$ and water as

   $Ca\ (OH)_2\ +\ CO_2\ \ CaCO_3\ \ \ \ +\ \ \ H_2O$

   base salt water

   Indicate the nature of CO_2 . What will be the general nature of non-metallic oxides?
5. Write the reaction between sodium hydroxide and sulphur dioxide (SO_2).
6. What will happen when CO_2 gas is passed into water ? Write the chemical equation.
7. Write the reaction that takes place between water and sulphur dioxide.
8. Give definition of base.
9. Define acids.
10. Give definition of acidic oxides.

3.2. What Is Common In All Acids ?

You have seen that most metals react with acids to liberate hydrogen gas (Activity 3.3). You have also come across that metals replace all or some of the hydrogen (H) atoms present in acids and these replaced hydrogens came out as hydrogen (H_2) gas. Let us see the chemical formulas of some common acids :

Hydrochloric acid	HCl
Sulphuric acid	H_2SO_4
Sulphurous acid	H_2SO_3
Nitric acid	HNO_3
Nitrous acid	HNO_2
Phosphoric acid	H_3PO_4

Boric acid	H_3BO_3
Hydrofluoric acid	HF
Hydrobromic acid	HBr

All these acids known as **inorganic acids** (mineral acids), contain at least one or more hydrogen atoms which can be replaced by metals.

Let us see some of the acids found naturally in plants, fruits and insects which have acidic properties.

Plants and animal sources	**Name of the acid present**	**Chemical formula**
Lemon and oranges etc (citrus fruits)	Citric acid	$C_3H_4(OH)(COOH)_3$
Apple, Peach etc	Malic acid	$C_2H_3(OH)_2(COOH)_2$
Tamarind and grapes	Tartaric acid	$C_2H_2(OH)_2(COOH)_2$
Oxalis	Oxalic acid	$(COOH)_2$
Sour Milk (Curd)	Lactic acid	$C_2H_4(OH)COOH$
Vinegar	Acetic acid	CH_3COOH
Ants, Bees, Wasp	Formic acid	HCOOH
Cabbage, green leafy vegetables etc	Ascorbic acid (vitamin C)	$C_5H_5(OH)_4COOH$

If you observe the chemical formulas of these natural acids carefully it can be easily noted that all them are made up of carbon, hydrogen and oxygen elements. Some of the hydrogens are present as –OH, –COOH and some of the hydrogens are attached to carbon. In other words, there are different hydrogens in these acids. These acids are known as **organic acids**. Those hydrogen atoms (H) present only in the form –COOH can be replaced. For example, acetic acid reacts with sodium metal to form sodium acetate liberating hydrogen gas. The reaction is

$$\underset{\text{acetic acid}}{2\,CH_3COOH\,(aq)} + \underset{\text{sodium}}{2\,Na\,(s)} \longrightarrow \underset{\text{sodium acetate (salt)}}{2\,CH_3COONa\,(aq)} + H_2\,(g)$$

Organic acids contain hydrogen atoms which are not acidic i.e., which are not replaceable by metals. In the case of CH_3COOH, the three hydrogen atoms attached to carbon as $–CH_3$ are not replaced by metals i.e., these three hydrogens are not acidic.

3.2.1. What Constitute Bases ?

From the activities 3.5, 3.6 and 3.8 you have learnt that bases may be metal hydroxide, metal oxides. Metal carbonates and metal hydrogen carbonates also show basic character. All of them combine with acid forming a salt and water. For example, sodium hydroxide, NaOH, sodium oxide, Na_2O and calcium hydroxide, $Ca(OH)_2$, are bases. Sodium carbonate, Na_2CO_3 and Sodium hydrogen Carbonate , Na HCO_3 also have basic properties.

Water soluble hydroxide and metal oxide, which dissolve in water to form metal hydroxides are known as alkalis. However, the alkali NH_4OH is not a metal hydroxide.

Thus, sodium hydroxide is an alkali,

$$Na_2O \; + \; H_2O \qquad 2Na\,OH$$

sodium oxide sodium hydroxide

There are metal hydroxides (bases) like aluminium hydroxide $Al(OH)_3$, ferric hydroxide $Fe(OH)_3$, etc. which are not soluble in water. Such hydroxides are not alkalis.

3.2.2. What happens to an acid when dissolved in water ? Will dry HCl show the acidic reactions ?

Activity 3.10

- Take a clean dry hard test tube and set up the apparatus as shown in the Fig. 3.4.
- Add about 1g of NaCl into it.
- Add about 5 mL of conc. H_2SO_4 into the test tube.
- Quickly cover the test tube with the cork fitted with delivery tube protected by a calcium chloride guard tube.
- Test the issuing gas with a dry blue litmus paper.
- Is there any change in the colour of litmus paper ?
- Now dip the blue litmus paper in water and test the gas with it as before ?
- Do you see any change in the colour of litmus paper ?

Dry litmus paper is unaffected by the dry HCl.

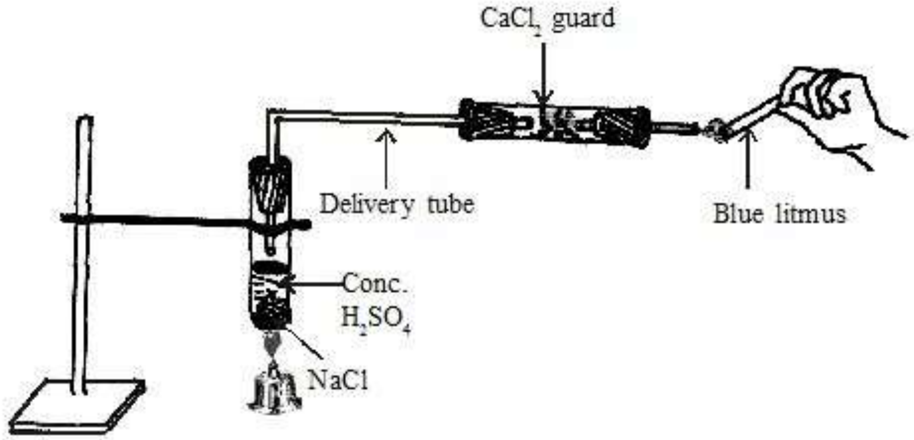


Fig. 3.4. Reaction between conc. H_2SO_4 and NaCl to form HCl

$$\text{Conc } H_2SO_4\,(l) + 2NaCl\,(s) \longrightarrow 2HCl\,(g) + Na_2SO_4\,(aq)$$

However colour of the blue litmus paper becomes red when it is moistened with water. Because dry HCl reacts with water to form hydrogen ions (H^+) as

$$HCl\,(g) + H_2O \longrightarrow \underset{\text{Hydronium ion}}{H_3O^+} + Cl^-$$

Hydrogen ions (H^+) do not exist independently but it readily combine with H_2O to form hydronium ion, (H_3O^+).

$$\underset{\text{Hydrogen ion}}{H^+} + \underset{\text{water}}{H_2O} \longrightarrow \underset{\text{Hydronium ion}}{H_3O^+}$$

When dissolved in water HCl forms ions as

$$HCl\,(g) + H_2O\,(l) \longrightarrow H_3O^+\,(aq) + Cl^-(aq).$$

Similarly, H_2SO_4 in aqueous solution gives

$$H_2SO_4\,(l) + 2H_2O\,(l) \longrightarrow 2H_3O^+\,(aq) + SO_4^{2-}\,(aq)$$

Acetic acid also dissolves in water as

$$\underset{\text{acetic acid}}{CH_3COOH\,(l)} + H_2O\,(l) \longrightarrow H_3O^+\,(aq) + \underset{\text{acetate ion}}{CH_3COO^-(aq)}$$

As you know, the acidic reaction of acids are due to the presence of ionisable or replaceable hydrogens in them. Actually, it is the reactions of hydronium ions (H_3O^+) in solution.

3.2.3 What happens when a base is in aqueous solution ?

When solid sodium hydroxide is dissolved in water, it is ionised to form ions ;

$$\text{Na OH (s)} + \text{Water} \longrightarrow \text{Na}^{+}\text{ (aq)} + \text{OH}^{-}\text{ (aq)}$$

Similarly all soluble hydroxides of metals ionise to give hydroxide ion OH^- and the metal ion.

$$\text{Ca(OH)}_2\text{(s)} \xrightarrow{\text{water}} \text{Ca}^{2+}\text{ (aq)} + 2\text{OH}^{-}\text{(aq)}$$

$$\text{KOH (s)} \xrightarrow{\text{water}} \text{K}^{+}\text{(aq)} + \text{OH}^{-}\text{ (aq)}$$

Aqueous solution of alkalis are soapy to touch, bitter to taste and corrosive. You should not directly touch them as it causes burn on your skin. NaOH and KOH are highly corrosive and they are also known as **caustic soda** and **caustic potash** respectively.

You have seen above that soluble metal oxides also produce hydroxides in their aqueous solution .

Does the disolution of acids and alkalis in water involve heat change ?

Activity 3.11

- Take about 10 mL of water in a test tube
- Add about 10 drops of concentrated sulphuric acid to it slowly.
- Hold the test tube in your palm
- What do you feel – hot or cold ?
  Draw your conclusion from the observations you made.
- Now take about 3–4 pellets or flakes of NaOH in a test tube.
- Add about 5 ml of water into it and shake slowly to dissolve.
- Hold the test tube in your palm.
- What do you feel again– hot or cold ?

\

Now let us answer the following.

1. Is the dilution of acid with water exothermic or endothermic ?
2. 'NaOH dissolves in water with the absorption of heat'.

   Is it correct or not ? If not, give the corect statement.
3. Why does an aqueous solution of an acid conduct electricity ?
4. How is dilution affect on the concenctration of H_3O^+ ion of an acid ?
5. What will happen to the concentration of H_3O^+ in a given volume of an acid if it is mixed with a same amount of NaOH solution ?

3.3. Do all acids have the same strength ? Do all bases have the same strength ?

We have seen that all acids produce hydronium ion H_3O^+ in their aqueous solutions. The strength of an acid depends upon the amount of H_3O^+ ion it can produce in equimolar solutions. However, all acids do not produce the same amount of H_3O^+ ions. Therefore, all acids do not have the same strength.

The strength of a base (alkali) depends upon the number of OH^- ions it can produce in equimolar solution. All alkalis do not give the same amount of OH^- ion in solution. Thus, all alkalis are not of the same strength.

It is important to ascertain the strength of a given acid or base. This can be done with the help of a **universal indicator** which is a mixture of indicators. Strips of paper dipped in the universal indicator and dried are available in the market. With the help of this paper the strength of a given acid or alkali solution can be determined.

The strength of acid or base is expressed in a sacle called **pH scale**. The scale of pH values ranges from 0 to 14. Acidic solutions have pH value less than 7 and that of basic solutions above 7. You will learn more about pH in higher classes.

Acid solution that contains higher concentration of hydronium ions H_3O^+ is said to be stronger acid. Higher H_3O^+ ion concentration means the lesser pH value, i.e., solutions with lower pH values are stronger acids.

Solution with higher OH^- ion concentrations is more alkaline and therefore, such solution will have higher pH values. The scale of pH and the nature of the solution is given below:

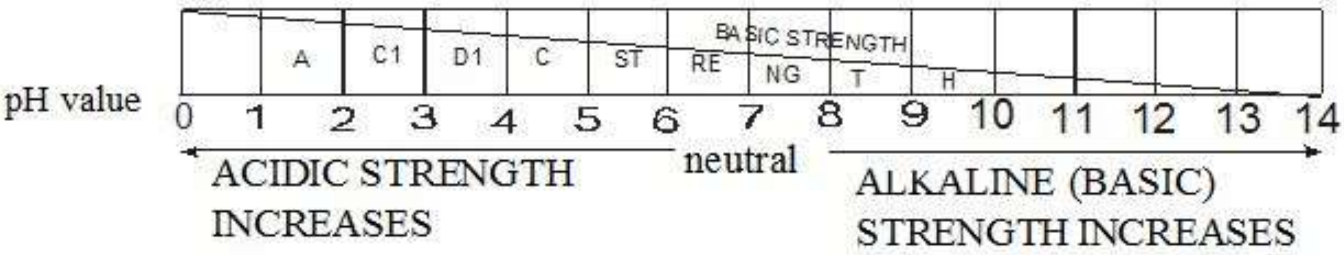


Fig. 3.5 pH scale.

Activity 3.12

- Collect the solutions listed in the Table 3.3. Fruit juices should be collected fresh and filter if necessary.
- Test the solutions with universal indicator paper.
- Match the colour of the test papers with the chart colour given along with the paper.
- Note the pH values of the solutions in the table

Table. 3.3.

Sl. No.	Sample solutions	Colour of P^H paper	P^H value	Nature of the substance
1	Tap water			
2	Mineral water			
3	Black tea			
4	Orange juice			
5	Sodium bicarbonate solution			
6	Sugarcane juice			

3.4. Different Kinds of Salts

We have come across that salts are the products obtained when an acid reacts with a base. We have also seen that all acids do not have the same strength. Similarly all bases do not have the same strength. Thus, the neutralisation of an acid by a base and vice versa may have different products. Let us discuss further.

Activity 3.12.

- Take about 10 mL or $\frac{1}{2}$ test tube of dilute HCl in a conical flask.
- Add two drops of phenophthalein indicator. (Note the colour, if any)
- Then add dil NaOH solution drop by drop, with constant swirling of the conical flask, till the colour of the mixture becomes light pink
- Why does the colour of the solution become pink ?

Here, HCl is neutralised by NaOH to form NaCl and water. The changes can be writen as,

$$HCl(aq) + H_2O \longrightarrow H_3O^+ (aq) + Cl^- (aq)$$

$$NaOH\ (aq) + H_2O \longrightarrow Na^+ (aq) + OH^- (aq)$$

H_3O^+ ions from the acid solution combine with OH^- ions from the base solution to form unionised water.

$$H_3O^+ + OH^- \longrightarrow 2H_2O$$

All the above changes can be written, in short, as

$$NaOH\ (aq) + HCl\ (aq) \longrightarrow NaCl\ (aq) + H_2O\ (l)$$

NaCl (aq) will ionise in the solution

$$NaCl\ (aq) \longrightarrow Na^+ (aq) + Cl^- (aq)$$

Here we get a salt sodium chloride by the complete neutralisation of HCl with NaOH. Such salts are called **normal salts**.

NaCl, Na_2SO_4, $MgCl_2$, KNO_3, $CuSO_4$ etc. are examples of normal salts.

3.4.1. Reaction between NaOH and H_2SO_4

The reaction between dilute NaOH and dilute H_2SO_4 may take place in the following steps:

$$H_2SO_4\ (aq) + NaOH\ (aq) \longrightarrow \underset{\text{sodium hydrogen sulphate}}{NaHSO_4\ (aq)} + H_2O\ (l)$$

$$NaHSO_4\ (aq) + NaOH\ (aq) \longrightarrow \underset{\text{sodium sulphate}}{Na_2SO_4 (aq)} + H_2O\ (l)$$

Even though sodium hydrogen sulphate, $NaHSO_4$, is a salt, it can further react with more NaOH to form the normal salt, sodium sulphate, Na_2SO_4. $NaHSO_4$ has got some acidic property and it can therefore, react with the base, NaOH. Salts like $NaHSO_4$ are called **acid salts**. They are obtained by the incomplete neutralisation of the acid by a base. Some other examples of acid salts are

Sodium bicarbonate (sodium hydrogen carbonate)	$NaHCO_3$
Sodium dihydrogen phosphate	NaH_2PO_4
Disodium hydrogen phosphate	Na_2HPO_4
Calcium bicarbonte	$Ca(HCO_3)_2$

3.4.2. Reaction between magnesium hydroxide Mg $(OH)_2$ and HCl

The reaction between $Mg(OH)_2$ and HCl can be written as

$$Mg\,(OH)_2 + HCl \longrightarrow \underset{\text{Magnesium hydroxychloride}}{Mg\,(OH)\,Cl + H_2O}$$

$$Mg\,(OH)\,Cl + HCl \longrightarrow \underset{\text{Magnesium chloride}}{Mg\,Cl_2 + H_2O}$$

Salts like Mg(OH) Cl are called **basic salts**. Such salts can further react with acids to form normal salts.

There are also some other types of salts about which you will learn in higher classes.

Hydrolysis of salts in water

When a salt is dissolved in water, the solution obtained may be neutral, acidic or alkaline which depends upon the nature of the salt taken.

Soluble normal salts derived from strong acids and strong bases give neutral solution. Thus NaCl solution or K_2SO_4 solution is neutral to litmus.

However, the normal salts derived from weak acid and a strong base such as Na_2CO_3 and normal salts derived from strong acid and a weak base such as $AlCl_3$ on hydrolysis give an alkaline (basic) or an acidic solution respectively.

$$Na_2CO_3 + 2H_2O \rightleftharpoons \underset{\text{(strong base)}}{2NaOH} + \underset{\text{(weak acid)}}{H_2CO_3}$$

$$AlCl_3 + 3H_2O \rightleftharpoons \underset{\text{(weak base)}}{Al(OH)_3} + \underset{\text{(strong acid)}}{3HCl}$$

Soluble acid salts usually give solutions acidic to litmus. Thus, NaHSO4 solution turns blue litmus red. But $NaHCO_3$ solution is slightly alkaline due to the formation of strong base NaOH. It turns red litmus blue.

$$NaHCO_3 + H_2O \rightleftharpoons NaOH + H_2CO_3$$

Basic salts are usually insoluble in water

SUMMARY

- Acids are sour to taste. Sour fruits and vegetables contain organic acids.
- Bases are bitter to taste (Do not taste bases directly).
- Acids neutralise bases to form salt and water.
- Indicator litmus is water soluble purple dye extracted from Lichen.
- Indicators change their colour in acidic and alkaline solutions.
- Most metals react with acids to liberate hydrogen gas.
- Hydrogen is lighter than air.
- Metals like Zn, Al and Sn react with sodium hydroxide to liberate hydrogen gas.
- Acids liberate carbon dioxide from metal carbonates.
- Metal oxides dissolve in water to form alkaline solutions.
- CO_2 turns lime water milky.
- Lime water reacts with carbon dioxide to form insoluble calcium carbonate.
- Excess CO_2 dissolves $CaCO_3$ to produce soluble $Ca(HCO_3)_2$.
- Acids neutralise bases to form salt and water.
- All acids have replaceble or ionisable hydrogen.
- Acids have different strengths.
- Organic acids are made of C, H and O.
- Organic acids are found plenty in vegetables & fruits .
- Bases are corrosive.
- In aqueous solutions, acids produce H_3O^+ ions while alkalis produce OH^- ions.

- Dry HCl cannot produce hydrogen ions H^+.
- pH scale is used to measure the strength of acids and alkalis. pH scale ranges from 0 to 14.
- Salts may be normal, acidic and basic salts.
- Normal salts are the products of complete neutralisation of an acid with a base.
- Acid salts can further react with more bases to form normal salts.
- Basic salts can react with more acids to form normal salts.
- Aqueous solutions of the normal salts of strong bases and strong acids are neutral.
- Aqueous solution of a normal salts of a strong bases and a weak acids is basic (alkaline).
- Aqueous solution of a normal salt of weak base and strong acid is acidic.

EXERCISES

1. Write the products obtained when Na_2SO_4 is hydrolysed. i.e., reacts with water ?

2. Write the formula of the acid and the base from which the salt Na_2CO_3 is obtained.

3. pH of samples of HCl and acetic acid are 2 and 3.5 respectively. Which one is a stronger acid?

4. $Fe(OH)_3$ is less soluble in water than $Ca(OH)_2$. Which one is a weaker base ?

5. Device an experimental set up to show that dilute hydrochloric acid is a good conductor of electricity.

★★★★★★

CHAPTER
4
TYPES OF CHEMICAL REACTION

In previous classes, we have learnt about physical and chemical changes. Changes which occur in physical properties such as states of matter, shape, size, colour, texture, electrical and magnetic condition etc, of matter without bringing any change in composition are called physical changes. Evaporation of water, melting of ice, dissolving sugar in water, breaking of wood into smaller pieces, magnetization of iron, glowing of electric bulb are examples of physical changes.

There are also many changes which results in the formation of new substances whose composition and properties are entirely different from those of the original substances. Let us consider the following changes occurring around us.

(i) Burning of paper producing ash, carbon dioxide and water vapour
(ii) Burning of candle wax and fuels like kerosene oil, petrol etc.
(iii) Rusting of iron rod, nail etc producing rust (hydrated iron oxide)
(iv) Souring of milk (formation of curd)
(v) Cooking of food
(vi) Digestion of food in our body
(vii) Taking of antacids when one gets stomach burn/ pain.

In all these changes, the original substances lose their nature and identity and form new substances. For example, when the paper is burnt, the products such as the ash, carbon dioxide, water vapour etc are entirely different from paper. Rust is a different substance from iron. These are examples of **chemical changes**. **Whenever such a chemical change occurs, we say that a chemical reaction has taken place**. In other words, a chemical change takes place as a result of chemical reaction. In a chemical reaction, the substances originally present and taking part in the reaction are called **reactants** and the new substances formed are called **products.** For example, in the burning of paper, the paper (cellulose) and air (oxygen) are the reactants and the ash, carbon dioxide and water vapour are the **products.**

Depending upon the nature of the reaction and the chemical change taking place, we can classify chemical reactions into various types.

4.1. TYPES OF CHEMICAL REACTIONS

We have learnt in class IX, that in a chemical reaction, atoms can neither be created nor destroyed as given by the Law of Conservation of Mass. During a chemical reaction atoms of one element do not change into those of another element. Nor do atoms disappear from the mixture or appear from elsewhere. We have also learnt in the previous chapter that atoms in molecules are held together by a force of attraction called **bond**. **In chemical reactions, the bonds present in the reactants are broken and new bonds are formed to produce new substances or products.** That is, there take place rearrangements or regroupings of atoms in various ways to give products.

4.1.1. Combination reactions

Activity 4.1.

[This activity is better demonstrated by the teacher. Students should not see directly to the white dazzling light produced on burning magnesium ribbon as it is harmful to the eye]

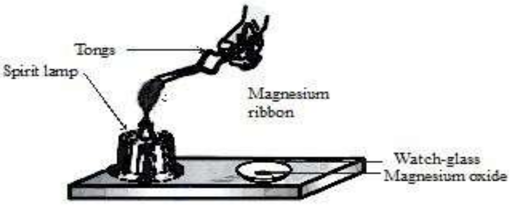


Fig.4.1. Burning of magnesium ribbon to produce magnesium oxide

- Take a strip of magnesium ribbon 2-3 cm long and clean it by rubbing with sand paper.
- Hold it with a pair of tongs in the flame of a spirit lamp or burner. (Do not observe directly the dazzling white light produced).
- Collect the ash formed in a watch glass. (Fig. 4.1.).
- What do you observe ?

It is observed that when heated strongly magnesium burns in air with dazzling white light. The white powder produced can be collected in a china dish. The white powder is magnesium oxide. It is formed due to the reaction between magnesium and oxygen present in the air.

The reaction can be represented by a chemical equation as follows :

$$\underbrace{\underset{\text{(Magnesium)}}{2\ \mathrm{Mg}} \quad + \quad \underset{\text{(Oxygen)}}{\mathrm{O_2}}}_{\text{Reactants}} \longrightarrow \underbrace{\underset{\text{(Magnesium oxide)}}{\mathrm{MgO}}}_{\text{Product}}$$

Showing the physical states of the reactants and products, we may write the equation as follows :

$$2\ \mathrm{Mg}\ (s) + \mathrm{O_2}\ (g) \longrightarrow 2\ \mathrm{MgO}\ (s)$$

The gases, liquid, aqueous and solid states of reactants and products are represented by the notations (g), (l), (aq) and (s) respectively.

A reaction in which a single product is formed from two or more reactants is known as a combination reaction.

The reaction of magnesium and oxygen to form magnesium oxide is an example of combination reaction between two elements.

Let us discuss some more examples of this type.

(i) Carbon or coke burns in air to produce carbon dioxide gas.

$$\mathrm{C}(s) + \mathrm{O_2}\ (g) \longrightarrow \mathrm{CO_2}\ (g)$$

(ii) Hydrogen burns in oxygen to form water.

$$2\ \mathrm{H_2}(g) + \mathrm{O_2}(g) \longrightarrow 2\ \mathrm{H_2O}\ (l)$$

(iii) Hydrogen combines with chlorine in the presence of light to form hydrogen chloride.

$$\mathrm{H_2}(g) + \mathrm{Cl_2}(g) \longrightarrow 2\ \mathrm{HCl}\ (g)$$

(iv) Iron and sulphur combine on heating to form iron sulphide.

$$\mathrm{Fe}\ (s) + \mathrm{S}(s) \longrightarrow \mathrm{FeS}(s)$$

(v) Nitrogen combines with hydrogen to form ammonia gas.

$$\mathrm{N_2}(g) + 3\ \mathrm{H_2}(g) \longrightarrow 2\ \mathrm{NH_3}\ (g)$$

Combination reactions also take place between two compounds to form a single product. Let us perform the following activity :

Activity 4.2.

Fig. 4.2. Formation of slaked lime by the reaction of calcium oxide with water

- Take a small lump of calcium oxide (quick lime) in a beaker.
- Add water slowly to the lump of calcium oxide.
- Observe what happens.
- Touch the side of the beaker as shown in Fig 4.2.
- What do you feel ? Hot or cold ?

When water is added to quick lime, they react vigorously to produce calcium hydroxide called slaked lime. A large amount of heat is evolved. The reaction can be represented by the following equation.

$$\underset{\text{quick lime}}{CaO(s) + H_2O\ (l)} \longrightarrow \underset{\text{slaked lime}}{Ca\ (OH)_2\ (aq)}$$

A few more examples are given below.

(i) Ammonia combines with hydrogen chloride to form ammonium chloride.

$$NH_3\ (g) + HCl\ (g) \longrightarrow NH_4Cl\ (s)$$

(ii) Calcium oxide reacts with sulphur trioxide to form calcium sulphate

$$CaO\ (s) + SO_3\ (g) \longrightarrow CaSO_4\ (s)$$

(iii) Sodium oxide reacts with water to form sodium hydroxide

$$Na_2O(s) + H_2O(l) \longrightarrow 2\ NaOH\ (aq)$$

Combination reaction also takes place between an element and a compound to form a new compound.

(i) Nitric oxide (a colourless gas) combines with oxygen of the air to form nitrogen dioxide which is a brown gas.

$$\underset{\text{(colourless)}}{2\ NO(g) + O_2(g)} \longrightarrow \underset{\text{(brown)}}{2\ NO_2(g)}$$

(ii) Sulphur dioxide reacts with oxygen (in the presence of catalyst) to form sulphur trioxide.

$$2\ SO_2\ (g) + O_2\ (g) \longrightarrow 2\ SO_3(g)$$

(iii) Carbon monoxide gas combines with oxygen of air to form carbon dioxide gas.

$$2\,CO\,(g) + O_2\,(g) \longrightarrow 2\,CO_2\,(g)$$

4.1.2. Decomposition Reactions

The reactions in which a compound is broken down into two or more simpler substances are known as **decomposition reactions**. Thus, these reactions are just opposite of combination reactions. Let us perform the following activity.

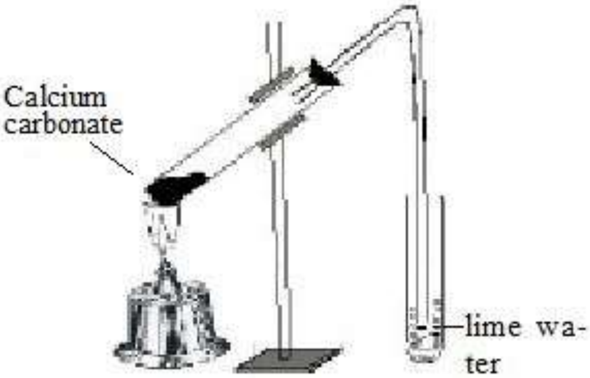


Fig.4.3. Heating of calcium carbonate and giving out carbon dioxide gas which turns lime water milky

Activity 4.3.

- Take about 4 g calcium carbonate in a hard glass test tube fitted with a delivery tube dipped in a test tube containing lime water as shown in Fig. 4.3.
- Heat the tube over the flame of a spirit lamp or burner.
- Observe the change in lime water

It is observed that lime water turns milky. When calcium carbonate is heated, it decomposes to carbon-dioxide gas.

The reaction that take place may be represented as follows.

$$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$$

Carbon dioxide which comes out turns lime water milk

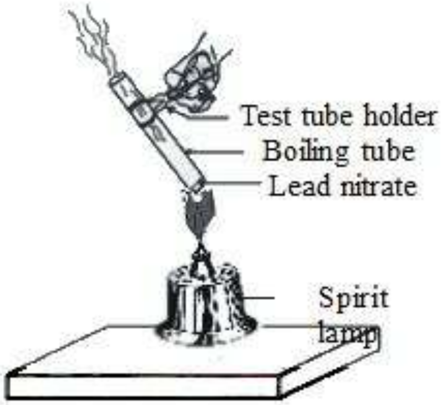


Fig.4.4. Decomposition of lead nitrate on heating

Activity 4.4.

- Take about 2 g of powdered lead nitrate in a test tube.
- Hold it in the test tube holder.
- Heat it over a flame, as shown in Fig. 4.4.
- Observe the brown fumes evolved.
- Note down the changes observed.

When lead nitrate is heated, it breaks down into lead monoxide, nitrogen dioxide and oxygen.

$$2\ Pb(NO_3)_2\ (s) \xrightarrow{\text{heat}} 2\ PbO(s) + \underset{\text{(brown fumes)}}{4\ NO_2\ (g)} + O_2\ (g)$$

The colourless lead nitrate becomes yellow due to the formation of lead monoxide (PbO). Brown fumes are observed due to the evolution of nitrogen dioxide (NO_2) gas.

Similarly, when we heat green coloured crystals of ferrous sulphate in a dry test tube, we observe that the green colour of ferous sulphate becomes reddish brown due to the formation of iron (III) oxide. Sulphur dioxide and sulphur trioxide gases are also produced.

$$\underset{\substack{\text{Ferrous sulphate}\\ \text{crystals}}}{FeSO_4.\ 7H_2O(s)} \xrightarrow{\text{heat}} \underset{\substack{\text{Ferrous sulphate}\\ \text{(anhydrous)}}}{FeSO_4(s)} + 7H_2O\ (g)$$

$$2\ Fe\ SO_4(s) \xrightarrow{\text{heat}} Fe_2O_3\ (s) + SO_2\ (g) + SO_3\ (g)$$

The reactions given above are examples of decomposition reactions caused by **heat**. They are called **thermal decomposition reactions**.
Decomposition reactions may also take place when electric current is passed through the compound in the molten state or in aqueous solution (decomposition by electricity). In certain cases, light also causes decomposition reactions. They are called *photochemical reactions*.

Decomposition by Electricity

Activity 4.5.

- Take a water voltameter with platinum electrodes.
- Pour sufficient water to the voltameter so that the platinum electrodes are well below the level of water.
- Fill two test tubes with water and close its mouth with your finger or thumb.
- Bring the test tubes with water upside down in the voltameter so that its mouth is under water. Then release your finger.
- Invert the test tubes with water over the two platinum electrodes so that the electrodes remain inside the tubes. (Fig 4.5).

- Now connect the electrodes to a 6 volt battery and see for bubbles of gas at both electrodes. If none appears, add a few mL of dilute sulphuric acid solution.
- Observe the formation of bubbles at both the electrodes. The gas in the bubbles displaces water in the test tubes.
- Compare the volume of the gases collected in both the test tubes.
- Test the gas over the anode with a glowing splinter.
- Try to light the gas collected over the cathode. Always bring out the gas collected over the cathode with mouth of the test tube downwards.
- What happens in each case ?
- Which gas is present in each test tube ?

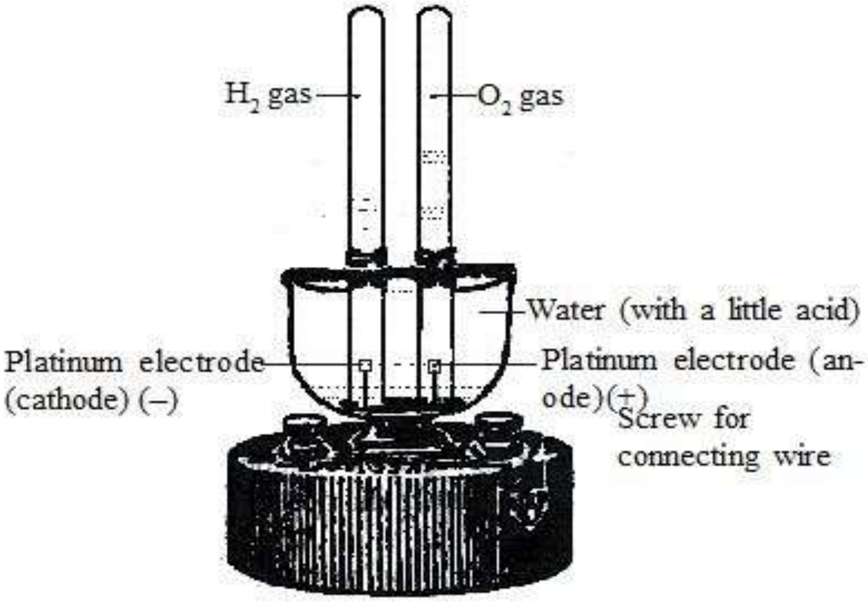


Fig. 4.5. Electrolysis of water

The following results are observed :

(i) Volume of gas collected over the cathode is double that of the gas collected over the anode.

(ii) The gas collected over the cathode burns with a 'pop' sound. It is hydrogen gas.

(iii) The glowing splinter introduced into the gas collected over the anode burst into flame. The gas is oxygen.

The above experiment shows that on passing electric current, water decomposes into hydrogen and oxygen according to the reaction :

$$2\,H_2O\,(l) \xrightarrow[\text{current}]{\text{electric}} 2\,H_2(g) + O_2\,(g)$$

Some more examples of decomposition reactions caused by passing electric current are given below.

(i) Electrolytic decomposition of molten sodium chloride

On passing electric current through molten sodium chloride, it decomposes to sodium and chlorine gas.

$$2\,NaCl\,(\text{fused}) \xrightarrow[\text{current}]{\text{electric}} 2\,Na(s) + Cl_2\,(g)$$

The reaction is used to obtain sodium metal on a large scale. Chlorine gas is obtained as a by-product.

(ii) Electrolytic decomposition of molten alumina (Al_2O_3)

When electric current is passed through molten alumina mixed with a little cryolite (it lowers melting point of alumina), alumina decomposes to give aluminium metal and oxygen gas.

$$2\,Al_2O_3\,(\text{fused}) \xrightarrow[\text{current}]{\text{electric}} 4\,Al + 3\,O_2$$

Decomposition by Light (Photochemical decomposition)

There are some reactions which take place in the presence of light. These are called **photochemical reactions**.

Activity 4.6

- Take a pinch of silver chloride or silver bromide on a watch glass.
- Observe its colour.
- Keep the watch glass and its contents in sunlight for some time.
- Observe the change in the colour of the silver chloride in the sunlight. (Fig. 4.6).

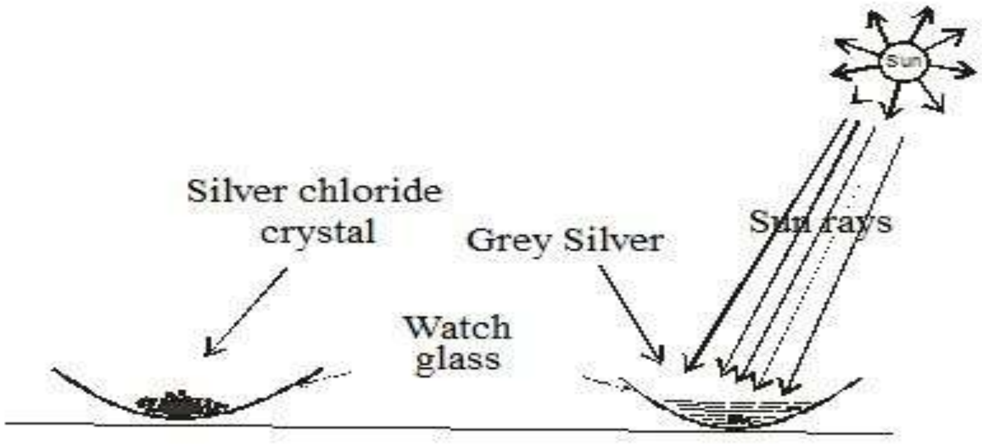


Fig. 4.6. Silver chloride turns grey in sunlight forming silver metal

It is observed that white silver chloride turns grey in sunlight. This is due to the decomposition of silver chloride into silver and chlorine by light.

$$2\ AgCl(s) \xrightarrow{sunlight} 2\ Ag(s) + Cl_2\ (g)$$

Silver bromide behaves similarly,

$$2\ Ag\,Br \longrightarrow 2\ Ag + Br_2$$

Black and white photography is based upon these reactions. The photographic film is coated with these salts.

Exothermic and Endothermic Reactions

Every chemical reaction involves a change in energy. Either the reaction takes place and energy is liberated to the adjacent surroundings, or the reaction takes place with the absorption of energy i.e. energy is absorbed from the adjacent surroundings. The first type of reaction is said to be **exothermic** (heat comes out), and the second type **endothermic** (heat goes in). All chemical reactions are in one of these two categories.

As the root form **thermic** indicates, the original definition of these two terms was based only on heat energy. Today, however, *exothermic reactions refer to reactions which take place with the evolution of energy in any form —— heat, light, electrical, mechanical, etc. Endothermic reactions refer to reactions which are accompanied by the absorption of any form of energy*.

In activity 4.2, we have observed that a large amount of heat is evolved in the reaction. This makes the reaction mixture warm. Hence, the reaction of calcium oxide with water to form calcium hydroxide or slaked lime is an example of exothermic reaction.

Other examples of exothermic reactions are :

(i) Burning of natural gas (methane) and, other fuels.

$$\underset{\text{methane}}{CH_4\ (g)} + 2\ O_2\ (g) \longrightarrow CO_2(g) + 2\ H_2O(g) + \text{energy}$$

$$\underset{\text{(octane)}}{2\ C_8H_{18}} + 25\ O_2 \longrightarrow 16\ CO_2\ (g) + 18\ H_2O\ (g) + \text{energy}$$

Respiration is an Exothermic Process

We get energy from the food we eat. The food that we eat mainly contains starch (carbohydrate) from rice, potato, bread etc and proteins from meat, egg, milk, pulses etc. During digestion, food materials are broken down into simpler substances. Starch decomposes into simple sugars such as glucose. Similarly, protiens decompose to form simpler molecules called amino acids. The glucose combines with oxygen in the cells of our body and provides energy. The process is called respiration.

The reaction can be represented as follows :

$$\underset{\text{glucose}}{C_6H_{12}O_6\ (aq)} + 6\ O_2\ (g) \longrightarrow 6\ CO_2\ (g) + H_2O\ (g) + \text{energy.}$$

Decomposition Reactions are Endothermic Reactions

It is observed that decomposition reactions require energy in the form of **heat, light** or **electricity** for breaking down the reactants. As already learnt, those reactions in which energy is absorbed are called **endothermic reactions.**

However, there are also certain combination reactions in which heat is absorbed. For example, combination of nitrogen and oxygen to form nitric oxide (NO) takes place with the absorption of heat.

$$N_2(g) + O_2(g) + \text{heat} \longrightarrow 2NO\ (g)$$

A mixture of hydrogen and chlorine when exposed to sunlight forms hydrogen chloride.

$$H_2\,(g) + Cl_2\,(g) \xrightarrow{\text{sunlight}} 2\,HCl\,(g)$$

Photosynthesis is also an endothermic reaction. Chlorophyll present in green plants absorbs light and helps in the conversion of carbon dioxide and water into glucose

$$6\,CO_2(g) + 6\,H_2O\,(l) \longrightarrow \underset{\text{glucose}}{C_6H_{12}O_6} + 6\,O_2$$

Let us answer these.

1. A solution of an oxide 'X' is used for white washing.
   (i) What could be 'X'? Write its formula.
   (ii) Write the reaction of substance 'X' named in (i) above with water.
2. Why is the amount of gas collected in one of the test tubes in activity 4.5 double of the amount collected in the other ? Name this gas.

4.1.3. Displacement Reactions

Activity 4.7.

- ☛ Take two iron nails and clean them by rubbing with sand paper.
- ☛ Take two clean test tubes and mark A and B.
- ☛ Take about 10 mL of copper sulphate solution in each of them.
- ☛ Tie a thread on one iron nail and suspend it in test tube A. (Fig 4.7)

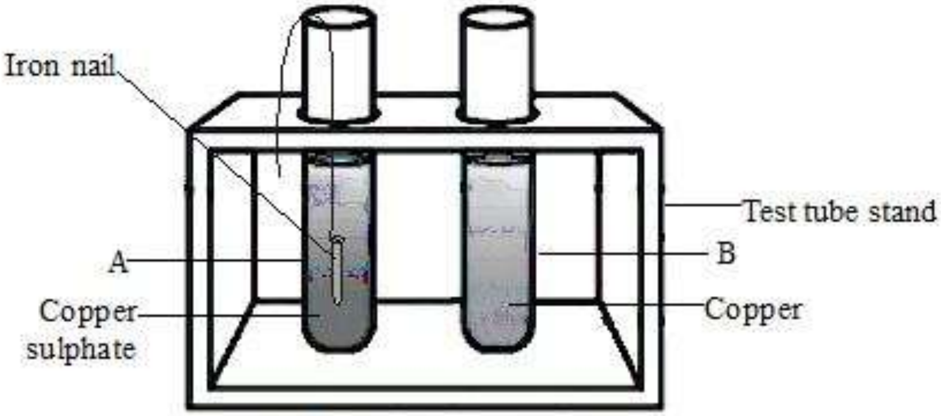


Fig. 4.7. Iron displaces copper from Copper sulphate solution

- Wait for about 30 minutes.
- Take out the nail from the solution.
- Observe the change in the colour of the solution in test tube A and compare it with solution in test tube B.
- Also, compare the colour of the iron nail that was suspended in the test tube with that of other nail.

It is observed that the blue colour of copper sulphate fades and iron nail becomes brownish in colour. These changes show that the following reaction takes place.

$CuSO_4$ (aq)	+	Fe(s) $\longrightarrow$	$FeSO_4$ (aq) +	Cu (s)
copper sulphate	iron	iron	sulphate	brownish deposit
(blue)			(light green)	on iron

Some more examples of displacement reactions are :

(i) When a piece of zinc is added to dilute sulphuric acid or dilute hydrochloric acid, hydrogen gas is evolved. The following reactions take place.

$$H_2SO_4 \text{ (dil)} + Zn \text{ (s)} \longrightarrow Zn\,SO_4 \text{ (aq)} + H_2 \text{ (g)}$$

$$2\,HCl \text{ (dil)} + Zn \text{ (s)} \longrightarrow ZnCl_2 \text{ (aq)} + H_2\text{(g)}$$

(ii) Zinc and magnesium displace copper from copper sulphate solution.

$$CuSO_4 \text{ (aq)} + Zn \text{ (s)} \longrightarrow Zn\,SO_4 \text{ (aq)} + Cu \text{ (s)}$$

$$CuSO_4 \text{ (aq)} + Mg \text{ (s)} \longrightarrow MgSO_4 \text{ (aq)} + Cu\text{(s)}$$

(iii) Copper displaces silver from silver nitrate solution

$$2\,Ag\,NO_3\text{(aq)} + Cu \text{ (s)} \longrightarrow Cu\,(NO_3)_2 \text{ (aq)} + 2\,Ag \text{ (s)}$$

(iv) When chlorine water is added to potassium iodide solution, iodine is liberated.

$$2\,KI\text{(aq)} + Cl_2 \text{ (aq)} \longrightarrow 2\,KCl \text{ (aq)} + I_2\text{(aq)}$$

Reactivity Series Of Metals Or Activity Series Of Metals

We have learnt that iron can displace copper from its solution as follows.

$Fe(s) + Cu\ SO_4 \longrightarrow Cu(s) + FeSO_4(aq)$

However, it may be noted that copper cannot displace iron from its solution. This means that the following reaction does not take place.

$Cu\ (s) + FeSO_4(aq) \longrightarrow$ No reaction

This raises an important question, **"which metal can displace another metal from its salt solution"?**

We know that some metals are highly reactive while some others are less reactive. Based on the study of their reactions, metals can be arranged in order of their reactivities. **The arrangement of metals in the decreasing order of their reactivity is called reactivity series or activity series of metals. (Table 4.1).**

The metal which is higher in the reactivity series is more reactive than metals below it. Hence, in general, a more reactive metal (placed higher in the activity series) can displace the less reactive metal from its solution. Thus, iron displaces copper (less reactive) from its solution as

$CuSO_4\ (aq) + Fe\ (s) \longrightarrow FeSO_4\ (aq) + Cu\ (s)$

But copper cannot displace iron from $FeSO_4$ solution.

$FeSO_4(aq) + Cu\ (s) \longrightarrow$ No reaction

However, copper can displace silver (less reactive) from its solution.

$2\ Ag\ NO_3\ (aq) + Cu(s) \longrightarrow 2\ Ag\ (s) + Cu\ (NO_3)_2\ (aq)$

Table 4.1 Activity series of metals

Element	Symbol		
Potassium	K		(Most reactive)
Barium	Ba	↑	
Calcium	Ca		
Sodium	Na		
Magnesium	Mg		Metals more
Aluminium	Al	↑	reactive than
			hydrogen
Zinc	Zn		
Iron	Fe		
Cobalt	Co		
Nickel	Ni		
Tin	Sn		
Lead	Pb		
Hydrogen	H		
Copper	Cu		
Mercury	Hg		Metals less
Silver	Ag	↓	reactive than
Gold	Au		hydrogen
Platinum	Pt		(Least reactive)

4.1.4. Double Displacement Reactions

Activity 4.8.

- Take about 3 mL of barium chloride solution in a test tube.
- In another test tube, take about 3 mL of dilute sulphuric acid.
- Mix the two solutions.
- Observe what happens.

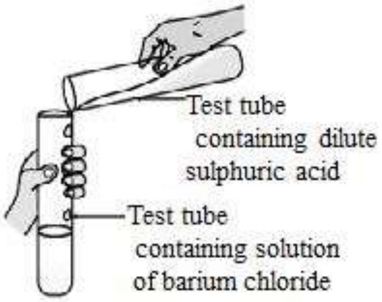


Fig 4.8. Formation of white

We observe that a white substance which is insoluble in water is formed. This insoluble substance is known as a **precipitate.** The white precipitate is barium sulphate which is formed due to the following reaction :

$BaCl_2(aq) + H_2SO_4\ (aq) \longrightarrow BaSO_4\ (s) + 2\ HCl\ (aq)$

The reactions which produce precipitates are also called **precipitation reactions.** What causes this ? The white precipitate of $BaSO_4$ is formed by the combination of SO_4^{2-} ion with Ba^{2+} ion. The other product formed is hydrogen chloride which is in solution.

Some more examples of double displacement reactions are given below.

(i) When silver nitrate solution is mixed with sodium chloride solution, a white precipitate of silver chloride is formed.

$Ag\ NO_3(aq) + NaCl(aq) \longrightarrow AgCl\ (s) + NaNO_3(aq)$

(ii) When dilute sulphuric acid is added to iron (ferrous) sulphide, a double displacement reaction takes place with the evolution of hydrogen sulphide gas ; ferrous sulphate formed remains in solution.

$Fe\ S(s) + H_2SO_4\ (aq) \longrightarrow FeSO_4\ (aq) + H_2S\ (g)$

(iii) When hydrogen sulphide gas is passed through a blue solution of copper sulphate, a black precipitate of copper sulphide is formed. Sulphuric acid formed remains in solution.

$Cu\ SO_4\ (aq) + H_2S\ (g) \longrightarrow CuS\ (s) + H_2\ SO_4\ (aq)$

Neutralisation Reactions

A double displacement reaction also takes place when an acid reacts with a base to form salt and water

Acid + Base $\longrightarrow$ Salt + Water

These reactions are called neutralisation reactions.

A few examples are given below:

(i) $NaOH + HCl \longrightarrow NaCl + H_2O$

(ii) $2\ NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2\ H_2O$

(iii) $KOH + HCl \longrightarrow KCl + H_2O$

Oxidation and Reduction Reactions (Redox reactions)

Activity 4.9.

☛ Heat about 1g of copper powder in a China dish (Fig 4.9)

☛ Observe what happens.

Fig 4.9. Oxidation of copper to copper oxide

It is observed that reddish brown copper powder becomes coated with a black substance. How is this black substance formed ?

This is because when copper is heated, it combines with oxygen and black copper oxide is formed.

$$2Cu + O_2 \xrightarrow{neat} 2CuO$$

We say that copper has been oxidized to copper (II) oxide.

If hydrogen gas is passed over this heated material of copper (II) oxide, the black coating on the surface turns brown. The reverse reaction takes place and copper is obtained.

$$CuO + H_2 \xrightarrow{neat} Cu + H_2O$$

We say that copper oxide has been reduced to copper.

If a substance gains oxygen during a reaction, it is said to be oxidised. If a substance loses oxygen during a reaction, it is said to be reduced.

During the above reaction, the copper (II) oxide is losing oxygen and is being reduced. The hydrogen is gaining oxygen and is being oxidised. In other words, one reactant gets oxidised while the other gets reduced during the reaction. Thus oxidation and reduction occur simultaneously. Such reactions in which oxidation and reduction occur simultaneously are called **oxidation - reduction reactions** or **redox** reactions.

Let us consider the following reaction.

$$MnO_2 + 4\ HCl \longrightarrow Mn\ Cl_2 + 2\ H_2O + Cl_2$$

In this reaction, HCl is oxidised to Cl_2 whereas MnO_2 is reduced to

$MnCl_2$. From this example, we can say that **if a substance gains oxygen or loses hydrogen during a reaction, it is said to be oxidised. If a substance loses oxygen or gains hydrogen during a reaction, it is said to be reduced.** The substance which oxidises other substances but itself undergoes reduction is called **oxidising agent.** The substance which reduces other substances but itself undergoes oxidation is called the **reducing agent**. In the above example, MnO_2 undergoes reduction and oxidises HCl. Hence MnO_2 is the oxidising agent, while HCl is the reducing agent.

Some more examples of redox reactions are given below.

(i) $ZnO + C \longrightarrow Zn\ (s) + CO$

(ii) $H_2S + Cl_2 \longrightarrow 2\ HCl + S$

According to electronic concept, **oxidation is a process which involves loss of one or more electrons. Reduction is a process which involve gain of electrons.** You will learn about these in higher classes.

Oxidation-Reduction Reactions in Everyday Life

There are a number of redox reactions taking place around us which affect our everyday life. We have observed that iron articles are bright and shining when new. But they get coated with a brown flaky substance when left exposed to moist air for a long time. This process is commonly known as rusting of iron. Rust is mainly hydrated ferric oxide (Fe_2O_3. xH_2O). It is formed due to the action of oxygen, water vapour or moisture and other gases present in the air on the surface of iron. The reaction may be represented by the following equation :

$$\underset{\text{iron}}{4\,Fe(s)} + \underset{\text{(from air)}}{3\,O_2\,(g)} + \underset{\text{moisture}}{2x\,H_2O\,(l)} \longrightarrow \underset{\text{hydrated ferric oxide (rust)}}{2Fe_2O_3 \cdot xH_2O\,(s)}$$

Rusting is an oxidation process. It causes damage to car bodies, bridges, iron railings, automobile parts and many other articles made of iron. The reason is that, the reddish brown crust of rust does not stick to the surface. It peels off exposing fresh surface for rusting. Thus, corrosion of iron is a continuous process which ultimately eats up the whole iron object.

Some other metals also lose their luster and shine after some time. The surface of articles made of copper and brass acquires a green coating of basic carbonate, $CuCO_3$. $Cu(OH)_2$ when exposed to moist air. This is due to the action of O_2, CO_2 and water vapour present in the air on the surface of copper.

$$\underset{\text{copper}}{2\,Cu\,(s)} + \underbrace{CO_2(g) + O_2(g) + H_2O\,(l)}_{\text{from moist air}} \longrightarrow \underset{\substack{\text{basic copper carbonate}\\ \text{(green)}}}{CuCO_3 .\ Cu(OH)_2}$$

Likewise, the surface of silver metal gets tarnished on exposure to air. This is due to the formation of coating of black silver sulphide (Ag_2S) on the surface by the action of hydrogen sulphide gas present in the air.

$$4\,Ag(s) + 2H_2S(g) + O_2\,(air) \longrightarrow \underset{\substack{\text{silver sulphide}\\ \text{(black)}}}{2Ag_2S\,(s)} + 2H_2O$$

When a metal is reacted with substances around it such as oxygen, moisture, acids etc, it is said to corrode and the process is called corrosion. Rusting of iron, the formation of black coating on silver and the green coating on copper are examples of corrosion.

We have seen that iron objects such as window grills, iron gates, steel furnitures, bodies of cars, buses etc are painted with colours and the painted iron does not rust. Why is it so ?

Corrosion of iron (rusting) can be prevented if iron objects are not allowed to come in contact with damp air. Painting not only makes the iron objects beautiful but also prevents from corrosion by forming a barrier between the iron surface and the damp air.

Iron articles such as mechanical tools, machine parts etc can be prevented from corrosion by **greasing** and **oiling**.

Rusting of iron can be effectively prevented by coating iron with zinc. The process is called **galvanization**

Rancidity

Have you ever tasted or smelt the food materials containing fat or oil left for a longer time ?

When fats and oils in foods are oxidised, they become rancid and their smell and taste change. **The oxidation of fats or oils in foods resulting into bad smell and taste is called rancidity.** A common example is the rancidity of butter on keeping for a longer time.

To prevent rancidity, usually substances which prevent oxidation are added to foods containing fats and oils. These substances are called **anti-oxidants**. Keeping food in air tight containers also helps to slow down oxidation. We have noticed that bags of chips are flushed with gas such as nitrogen to prevent them from oxidation. In a number of cases, while packing the foods, the container is evacuated before sealing so that no air or oxygen is available inside for the oxidation of food. This is called **vacuum packing**.

4.3. SLOW AND FAST REACTIONS

We have observed that a piece of iron rusts in the course of time. We have also observed that the colour of many clothes fades slowly even if they are not washed. If we thrust our hand into a heap of rotting grass or straw, we find it very hot inside. These are all due to chemical reactions and are evidently very slow.

Food is digested in the stomach and intestines very slowly and takes hours for the digestion to complete. Setting of cement and fermentation of sugar to form alcohol are also examples of slow reactions.

When ethyl alcohol and acetic acid is heated in the presence of a little concentrated sulphuric acid, the reaction takes place after a few minutes and an ester called ethyl acetate is formed.

$$CH_3COOH\,(aq) + C_2H_5OH\,(l) \longrightarrow CH_3COOC_2H_5\,(aq) + H_2O\,(l)$$

Acetic acid Ethyl alcohol
Ethyl acetate
(sweet smelling ester)

It is a slow reaction. Generally reactions between covalent compounds are slow.

Fast reactions

Recall activity 4.6 where a white substance, barium sulphate is formed when a solution of barium chloride is mixed with dilute sulphuric acid solution. The precipitation is formed at once. So the reaction is very fast or instantaneous.

The reaction between silver nitrate solution and sodium chloride solution is also very fast. The white precipitate of silver chloride is formed at once. **Generally the reactions between ionic compounds in solution are fast.**

Burning of magnesium in air (oxygen) to form magnesium oxide and combination of nitric oxide (NO) with oxygen (O_2) to form nitrogen dioxide (NO_2) are also fast reactions.

Moderately Fast Reactions

In between very fast and very slow reactions, there are certain reactions which occur at moderate speed. These reactions may be called **moderately fast reactions**. The examples of such reactions are :

(i) Decomposition of hydrogen peroxide into water and oxygen

$$2\,H_2O_2\,(l) \longrightarrow 2\,H_2O\,(l) + O_2\,(g)$$

Hydrogen peroxide

(ii) Hydrolysis of sugar into glucose and fructose in presence of a little acid

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{acid} C_6H_{12}O_6(aq) + C_6H_{12}O_6(aq)$$

Sugar Glucose Fructose

Catalysts

The progress of a reaction can be altered (increases or decreases) by the use of specific substances called catalysts. *A catalyst is a substance which increases the rate of a chemical reaction without itself being consumed and the phenomenon is called catalysis. On the other hand, if a catalyst decreases (retards) the rate of a reaction, it is called a negative catalyst and the phenomenon is called negative catalysis.*

Activity 4.7.

- Take two beakers labelled A and B. In each of them take 10 mL of oxalic acid solution, 5 mL of dilute sulphuric acid solution and 10 mL of dilute potasium permanganate solution.
- Observe the colour of the solution in the two beakers.
- Now, in beaker A add one or two crystals of manganese (II) sulphate ($MnSO_4$) and observe carefully.
- Why is the colour of the solution in beaker A fades up faster and finally disappeared?
- Why is there slow change in the colour of the solution in the beaker B ?

What is the role of $MnSO_4$ in the above reaction ? It has speeded up the reaction between oxalic acid and potassium permanganate.

Catalysts are used in the preparation of a large number of industrially important compounds. For example, in the manufacture of ammonia from nitrogen and hydrogen, finely divided iron is used as a catalyst.

$$N_2\,(g) + 3\,H_2\,(g) \xrightarrow{Fe\ (catalyst)} 2\,NH_3\,(g)$$

Similarly, vanadium pentoxide (V_2O_5) is used a as a catalyst in the manufacture of sulphur trioxide.

$$2\,SO_2\,(g) + O_2(g) \xrightarrow[\text{catalyst}]{V_2O_5} 2\,SO_3\,(g)$$

A large number of reactions of industrial and biological importance takes place in the presence of catalyst, which would otherwise never occur in their absence. Most of the chemical reactions taking place in plants, animals and micro-organisms require their own specific catalyst called enzymes. Thus, enzymes are biocatalysts present in the living cells which catalyse reactions in living plants and animals. Enzymes are highly specific in their action. Each enzyme catalyses a particular reaction. For example, an enzyme called **invertase** can convert sucrose into glucose and fructose, but fails to in the case of very similar sugar maltose

$$\underset{\substack{\text{sucrose}\\\text{(cane sugar)}}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{invertase (catalyst)}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

Maltose requires another enzyme called **maltase** for this purpose.

$$\underset{\text{maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{maltase}} \underset{\text{glucose}}{2\,C_6H_{12}O_6}$$

In most of the cases, catalysts use to accelerate the reactions. In a few cases, however, catalysts are used to slow down the rate of reactions. Such catalysts are known as **negative catalysts.**

For example, glycerine is sometimes added to hydrogen peroxide as negative catalyst to slow down its rate of decomposition into hydrogen and oxygen.

Let us answer these.

1. Why does the colour of copper sulphate solution change when an iron nail is dipped in it ?
2. Give an example of a double displacement reaction other than the one given in activity 4.8.
3. Identify the substances that are oxidised and the substaces that are reduced in the following reaction.

(i) $4\,Na(s) + O_2(g) \longrightarrow 2\,Na_2O(s)$

(ii) $CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$

SUMMARY

- A chemical reaction is a process in which one or more substances called reactants are changed to one or more new substances called products.
- Combination reactions are those reactions in which two or more substances combine to form a new single substance (compound).
- Decomposition reactions are those reactions in which a single substance splits into two or more substances.
- Reactions in which energy is given out along with the products are called exothermic reactions.
- Reactions in which energy is absorbed are called endothermic reactions
- A displacement reaction occurs when an element displaces another element from its compound.
- Two different atoms or group of atoms or ions are mutually exchanged in double displacement reactions.
- In a double displacement reaction, if one of the products is a precipitate, it is called precipitation reaction.
- When an acid reacts with a base to form salt and water, it is called neutralization reaction.
- Reactions may also involve the gain or loss of oxygen or hydrogen by substances. Oxidation is the process which involves gain of oxygen or loss of hydrogen. Reduction is loss of oxygen or gain of hydrogen.
- Depending upon the rate at which a chemical reaction proceeds, all chemical reactions may be classified into slow reactions, fast reactions and moderately fast reactions.
- The process of slowly eating away of the metal due to the action of the atmospheric gases on the surface of the metals resulting in the formation of compounds is called corrosion. Corrosion of iron is called rusting.
- Corrosion of metals can be prevented by providing protective layers with substances like grease, paint or metal coatings so that the metals do not come in contact with damp air.

- The oxidation of fatty foods forming products which have bad taste and bad smell is called rancidity.

EXERCISES

1. **Which of the statements about the reaction given below are NOT correct ?**

$2\,PbO\,(s) + C(s) \longrightarrow 2\,Pb(s) + CO_2\,(g)$

(a) Lead is reduced.

(b) Carbon dioxide is oxidised.

(c) Carbon is oxidised

(d) Lead oxide is reduced.

(i) (a) and (b)
(ii) (a) and (c)
(iii) (a), (b) and (c)
(iv) all

2. $Fe_2O_3 + 2\,Al \longrightarrow Al_2\,O_3 + 2\,Fe$

The above reaction is an example of a

(a) combination reaction

(b) double displacement reaction.

(c) decomposition reaction.

(d) displacement reaction.

3. What are combination reactions ? Give one example.

4. What are decomposition reactions ? Give one experiment to demonstrate a decomposition reaction.

5. Why are decomposition reactions called the opposites of combination reactions ?

6. Write one equation each for decomposition reactions where energy is supplied in the form of heat, light and electricity

7. What is the difference between displacement and double displacement reactions. Write equations for these reactions.

8. What is a displacement reaction ? Give one example.

9. In the refining of silver, silver can be recovered from silver nitrate solution by adding zinc metal. Write down the reaction invlolved.

10. What is a precipitation reaction ? Explain it by giving one example.

11. What are exothermic and endothermic reactions ? Give two examples each.

12. Why is respiration considered an exothermic reaction ?

13. Explain the terms **(a)** oxidation and **(b)** reduction with two examples each.

14. Why does painted iron not rust ?

15. Fat and oil containing food items flushed with nitrogen, why ?

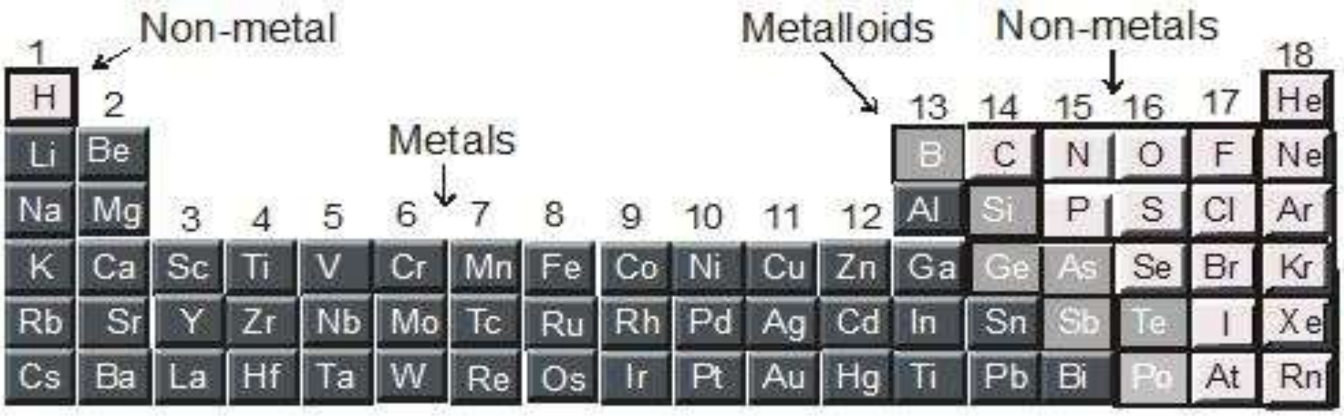
★★★★★★

CHAPTER

5

METALS AND NON-METALS

In unit 1, we have learnt that the earliest classification of elements on the basis of their common features was the grouping of the elements into two broad categories– **metals** and **non-metals**. In the periodic table, the metals are placed on the left hand side and in the centre of the periodic table. On the other hand, the non-metals are placed on the right hand side of the table (Table 5.1)



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Ti	Pb	Bi	Po	At	Rn

Table 5.1. Position of metals and non-metals in the Periodic Table

The metals and nonmetals are separated from each other in the periodic table by a zig-zag line. The elements close to zig-zag line show some properties of metals and some properties of non-metals. They are **metalloids**. The common examples of metalloids are germanium (Ge), arsenic (As), antimony (Sb), tellurium (Te) and polonium (Po). Although metals show a great diversity of properties, there are a few unifying characteristics, which set them apart from the non-metallic elements.

5.1. PHYSICAL PROPERTIES OF METALS AND NON-METALS

Some of the examples of metals are Iron, Aluminium, Copper, Silver, Gold, Tin, Lead, Mercury, Zinc, Sodium, Potassium, Calcium and Magnesium. All the metals are solids, except Mercury which is a liquid at room temperature.

Some of the examples of non-metals are Carbon, Sulphur, Phosphorus, Silicon, Hydrogen, Oxygen, Nitrogen, Chlorine, Bromine, Iodine, Helium, Neon and Argon.

Carbon occurs as diamond and graphite. Out of the non-metals, five are solids, one (bromine) is a liquid whereas remainings are gases.

Activity 5.1.

- Take samples of metals iron, copper, lead, silver, zinc and aluminium.
- Take samples of non-metals sulphur and graphite (carbon).
- Clean the surface of each sample of the metals by rubbing them with sand paper.
- Note their appearences.
- Carry out the same activities with the samples of non-metals.

Metals, in their pure state, have a shining surface. This propery is called **metallic lustre**. **Non-metals, in general, do not have such property.**

Activity 5.2.

- Take pieces of iron, aluminium, copper and zinc.
- Try to cut these metals with a sharp knife.
- Note your observations.
- Hold a piece of sodium metal with a pair of tongs. Dry it by pressing between the folds of a filter paper.
- Put it on a watch-glass or filter paper and try to cut it with a knife.
- Note your observations.
- Repeat the activity with non-metals, sulphur and graphite.
- Note the differences.

We find that **metals are generally hard.** Only a few metals like sodium are soft i.e.the hardness varies from metal to metal. **Non-metals are generally soft.**

Activity 5.3.

- Take pieces of iron, zinc, lead, aluminium and copper.
- Place any one metal on a block of iron and strike it four or five times with a hammer. What do you observe?
- Repeat with other metals.
- Record the change in the shape of these metals.
- Repeat the activities with the samples of non-metals-sulphur and graphite
- Note the differences.

We find that **metals can be beaten into thin sheets**. This property is called **malleability**. Gold and silver are the most highly malleable metals.

Non-metals are not malleable.

Activity 5.4.

- Take wires of copper, iron and aluminium. How can these wires be formed?
- Can we draw out wires of sulphur and graphite ?

Metals can be drawn into thin wires. This property is called **ductility**. Gold is the most ductile metal. One gram of gold can be drawn into very thin wires.

Activity 5.5.

- Take a thick copper or aluminium wire. Clamp it horizontally as shown in Fig. 5.1
- Fix a pin with the help of wax (this can be done by keeping the pin over the wire and putting molten wax over it and allowing to cool).
- Heat the wire with a spirit lamp, candle or a burner near the place where it is clamped.
- What do you observe after some time?
- Does the metal wire melt ?

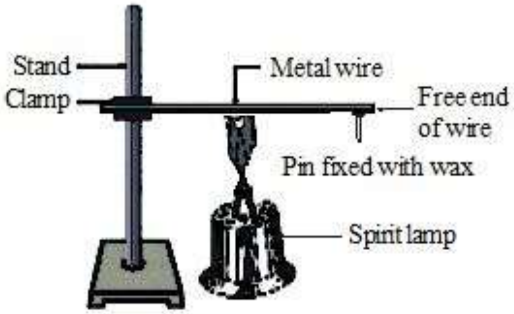


Fig. 5.1. Metals are good conductors of heat

It will be observed that the wax melts and the pin falls. This shows that heat flows through the metal wire. Further, the wire does not melt even after long heating. The above activity shows that **metals are good conductors of heat and have high melting points**. Silver and copper are very good conductors of heat while lead and mercury are comparatively poor conductors. Non -metals do not have this property. *They are poor conductors of heat.*

You must have observed that if we connect a bulb to a battery through a metal wire, the bulb glows. We use copper or aluminium wires to carry electric current in our homes. This shows that **metals allow electric current to pass through them. Thus, metals are good conductors of electricity.** We have seen that wires which carry current in our homes have a Plastic coating of polyvinylchloride (PVC). This coating protects us from the current when we use the metal wires.

Most of the metals produce sound when they strike a hard surface or hard object. The **metals that produce a sound on striking a hard surface is said to be sonorous**. Strike a hard surface with a graphite rod. Can you get a ringing sound ?

Can you say why school bells are made up of metals ?

Non-metals are not sonorous.

Some exceptions to general trends

A comparison of the general physical properties of metals and non-metals shows that there are many exceptions in the general properties. For example –

(i) **Physical state**: We have studied that metals are solids. But mercury is an exception as it is a liquid at room temperature.

(ii) **Melting and Boiling Points**: In activity 5.5, we have observed that metals have high melting points. But sodium, potasium, gallium and cesium have low melting points. Gallium has such a low melting point (30·15°C) that it melts even when kept on our palm. We have also studied that non-metals have low melting and boiling points. But diamond which is a non-metal carbon has very high melting point.[Carbon, a non-metal, can exist in different forms. Each form is called an allotrope. Diamond and graphite are allotropes of carbon].

(iii) **Lustre**: We have learnt that non-metals do not have a shining appearance or lustre. However, iodine is a non-metal but it is lustrous.

(iv) **Hardness**: In activity 5.2, we have learnt that metals are generally hard, and hardness varies from metal to metal. We have found that sodium is a soft metal which can be easily cut with a knife. Similarly, lithium and potassium are soft. We have also studied that solid non-metals are soft. But carbon in the form of diamond is extremely hard.

(v) **Electrical conductivity :** We have studied that non-metals are poor conductors of electricity. But graphite is a conductor of electricity .

From the above discussions, it is obvious that we cannot classify the elements as metals or non-metals on the basis of their physical properties alone because there are many exceptions. We have to see if elements can be more clearly classified as metals and non-metals on the basis of chemical properties.

5.2. CHEMICAL PROPERTIES OF METALS & NON-METALS

5.2.1. Formation of Oxides

Activity 5.6.

Fig. 5.2. Burning of sulphur powder

- Take a magnesium ribbon and some sulphur powder.
- Recall activity 4.1. Burn the magnesium ribbon. Collect the ashes formed and dissolve them in water.
- Test the resultant solution with both blue and red litmus paper.
- Is the product formed on burning magnesium acidic or basic ?
- Take a little sulphur in a deflagrating spoon. Hold it over the flame of a spirit lamp till the sulphur melts and start burning.
- Now introduce the spoon into a jar containing some water at its bottom (Fig. 5.2)

- After the sulphur has burnt, take the deflagrating spoon out of the jar.
- Test the solution in the jar by dipping into it blue and red litmus paper.
- Is the product formed on burning sulphur acidic or basic ?
- Can we write the equations for these reactions ?

We can see that magnesium burns brilliantly with a dazzling white light. Magnesium combines with oxygen forming magnesium oxide.

$$Mg + O_2 \longrightarrow 2\ MgO$$

Magnesium oxide reacts with water to form an alkali called magnesium hydroxide. It turns red litmus blue.

$$MgO + H_2O \longrightarrow Mg\ (OH)_2$$

Almost all metals combine with oxygen to form metal oxides.

$$\text{Metal} + \text{Oxygen} \longrightarrow \text{Metal Oxide.}$$

For example,

$$2\ Ca + O_2 \longrightarrow 2\ CaO$$

$$4\ Al + 3O_2 \longrightarrow 2\ Al_2O_3$$

$$4\ K + O_2 \longrightarrow 2\ K_2O$$

Many metal oxides are insoluble in water but some of these dissolve in water to form alkalis. Sodium oxide and potassium oxide dissolve in water to produce alkalis as follows :

$$Na_2O(s) + H_2O\ (l) \longrightarrow 2\ NaOH\ (aq)$$

$$K_2O(s) + H_2O\ (l) \longrightarrow 2\ KOH\ (aq)$$

Metal oxides react with acids to form salt and water.Thus metal oxides are basic in nature . For example,

$$CuO + 2\ HCl \longrightarrow Cu\ Cl_2 + H_2O$$

$$MgO + H_2SO_4 \longrightarrow MgSO_4 + H_2O$$

But some metal oxides, such as aluminium oxide, zinc oxide, etc, show both acidic as well as basic behaviour. Such **metal oxides which react with both acids as well as bases to produce salts and water are known as amphoteric oxides**. Aluminium oxide reacts with acids and bases in the following manner.

$$Al_2O_3 + 6\,HCl \longrightarrow 2\,AlCl_3 + 3\,H_2O$$

$$Al_2O_3 + 2\,NaOH \longrightarrow \underset{\text{(Sodium meta aluminate)}}{2NaAlO_2} + H_2O$$

Non-metals react with oxygen to form acidic or neutral oxides:

When sulphur burns in air, it combines with the oxygen of air to form an acidic oxide called sulphur dioxide

$$S(s) + O_2(g) \longrightarrow SO_2(g)$$

Sulphur dioxide dissolves in water to form an acid called sulphurous acid.

$$SO_2(g) + H_2O(l) \longrightarrow \underset{\text{sulphurous acid}}{H_2SO_3\,(aq)}$$

Similar behaviour is shown by carbon.

$$C(s) + O_2(g) \longrightarrow CO_2(g)$$

$$CO_2(g) + H_2O\,(l) \longrightarrow \underset{\text{(carbonic acid)}}{H_2CO_3(aq)}$$

However, some oxides of non-metals are **neutral**. For example, carbon monoxide, nitric oxide (NO) and water are neutral oxides.

5.2.2 . Reaction with Water

Activity 5.7.

- Dry a piece of sodium metal by using a filter paper and cut a small piece of it.
- Place the piece of sodium metal in water taken in a trough.
- Observe what happens.
- Repeat the test with other samples of metals such as copper, iron, zinc etc, and also with non-metals, sulphur and graphite (carbon).
- Do they react with water in the same way as sodium ?

When sodium is placed in water, we find that the piece of sodium floats on water, starts moving on water making a hissing sound and then sodium catches fire with a little explosion. Sodium metal reacts vigorously with cold water forming sodium hydroxide and hydrogen gas. A lot of heat is also produced in the reaction. The heat burns hydrogen gas as well as the sodium metal. The reaction is highly exothermic.

$$2\,Na + 2\,H_2O \longrightarrow 2\,NaOH + H_2 + Heat$$

Potassium also reacts with cold water more vigorously.

$$2\,K + 2\,H_2O \longrightarrow 2\,KOH + H_2 + Heat$$

Calcium reacts with cold water to form calcium hydroxide and hydrogen gas. The reaction is less violent.

$$Ca + 2\,H_2O \longrightarrow Ca\,(OH)_2 + H_2 + Heat$$

Magnesium does not react with cold water. It reacts slowly with hot water to form magnesium hydroxide and hydrogen but reacts very rapidly with steam to form magnesium oxide and hydrogen gas.

$$Mg(s) + \underset{\text{(hot)}}{2\,H_2O\,(l)} \longrightarrow Mg\,(OH)_2\,(aq) + H_2$$

$$Mg(s) + \underset{\text{steam}}{H_2O\,(g)} \longrightarrow MgO(s) + H_2\,(g)$$

Aluminium, zinc and red hot iron also react with steam to form their respective oxides and hydrogen.

$$Zn(s) + \underset{\text{(steam)}}{H_2O\,(g)} \longrightarrow Zn\,O(s) + H_2\,(g)$$

$$2\,Al + \underset{\text{(steam)}}{3\,H_2O} \longrightarrow Al_2\,O_3 + 3\,H_2$$

$$Fe + \underset{\text{(steam)}}{4H_2O} \longrightarrow \underset{\text{Iron (II, III) oxide}}{FeO.\,Fe_2O_3} + 4\,H_2$$

Non- metals do not react with water or steam to evolve hydrogen gas.

5.2.3. Reaction with Dilute Acids

Activity 5.8.

- Take small pieces of metals such as magnesium, zinc, iron, aluminium, copper etc except sodium and potasium. [sodium and potasium need not be taken as they react vigorously even with cold water]
- Put the samples separately in test tubes containing dilute hydrochloric acid.
- Observe the rate of formation of hydrogen gas bubbles carefully.
- Which metals react vigorously with dilute hydrochloric acid ?

Metals react with dilute acids to give salt and hydrogen gas

$$\text{Metal} + \text{Dilute acid} \longrightarrow \text{Salt} + \text{Hydrogen}$$

$$Mg\,(s) + 2\,HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g)$$

$$Zn + 2\,HCl \longrightarrow ZnCl_2 + H_2$$

$$Fe + 2\,HCl \longrightarrow Fe\,Cl_2 + H_2$$

Similarly, $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4\,(aq) + H_2(g)$

The rate of formation of bubbles was very fast in the case of magnesium. The reactivity decreases in the order Mg > Al > Zn > Fe.

In the case of copper, no bubble is seen. This shows that copper does not react with dilute HCl. Silver and gold metals also do not react with dilute acids.

We also find that non-metals do not react with dilute acids.

Hydrogen gas is not evolved when a metal reacts with nitric acid. It is because HNO_3 is a strong oxidising agent. It oxidises the H_2 produced to water and itself gets reduced to one of the nitrogen oxides (nitrous oxide N_2O, nitric oxide, NO, nitrogen dioxide NO_2). But magnesium reacts with very dilute HNO_3 to evolve H_2 gas.

Let us answer these.

1. Name five metals and five non-metals
2. Name one metal and one non-metal which exist in liquid state at room temperature.
3. Give an example of a metal which
   - **(i)** can be easily cut with a knife,
   - **(ii)** is the best conductor of heat,
   - **(iii)** is a poor conductor of heat.
4. What is meant by saying that metals are malleable and ductile ?
5. Which property of copper and aluminium make them suitable for making electric wires.
6. Name a non-metal which conducts electric current.

7. Write equations for the reactions of

(a) potasium with water

(b) red-hot iron with steam

(c) zinc with dilute sulphuric acid.

8. How do metals differ from non-metals in their reaction with oxygen and the product is dissolved in water ?

5.3. OCCURRENCE OF METALS

The major source of metals is the earth's crust. Sea water also contains some soluble salts of metals like sodium chloride, magnesium chloride, etc. The most abundant metal in the earth's crust is aluminium. The second most abundant metal is iron and third one is calcium.

Metals occur in nature in free (native state) or in combined state, i.e. in the form of their compounds. We have already studied the reactivity series of metals in Unit 4. The metals at the bottom of the activity series are the least reactive. They are often found in a free state. For example, gold, silver, platinum and copper are found in the free state. Copper and silver are also found in nature as their sulphides or oxides. The metals at the top of the activity series (K, Na, Ca, Mg and Al) are so reactive that they are never found in nature as free elements. They are found in the combined state as oxides, suphides, halides or carbonates. The metals in the middle of the activity series i.e., Zn, Fe, Pb etc are moderately reactive. They are also found in the earth's crust mainly as oxides, or carbonates. It is found that many metals occur as oxides. This is because oxygen is a very reactive element and is very abundant on the earth. Thus we find that the occurrence of metals are closely related to their reactivity (Fig. 5.3).

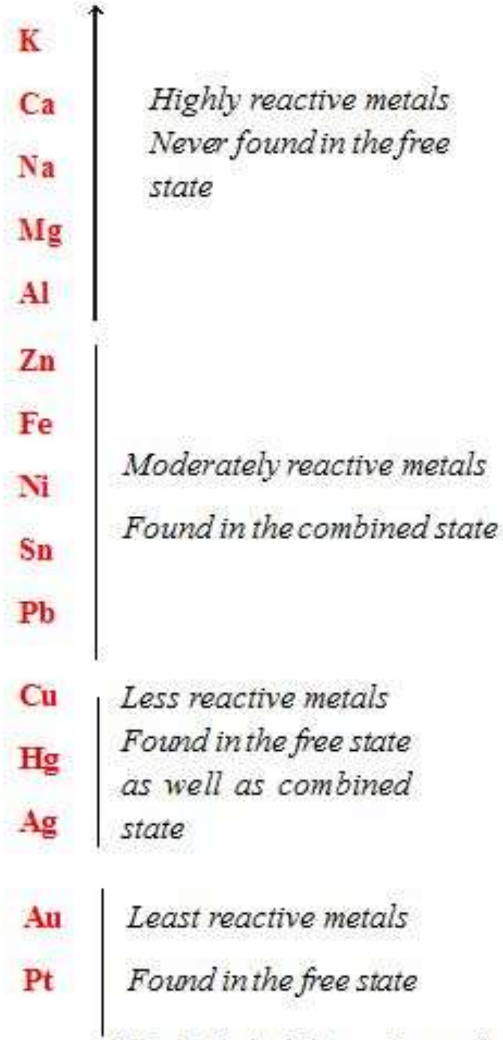


Fig. 5.3. Activity series and occurences of metals.

The natural materials in which the metals or their compounds are found in earth are called minerals. Some minerals may contain a large percentage of metal whereas others may contain a small percentage of the metal. Thus, all the minerals cannot be used to extract metals. Those minerals from which metals can be extracted profitably are called **ores**. For example, aluminium occurs in the earth's crust in the form of two minerals, bauxite (Al_2O_3. $2H_2O$) and clay (Al_2O_3. $2SiO_2$. $2H_2O$). Out of these two, aluminium can be profitably extracted from bauxite but not from clay. Therefore, the ore of aluminium is bauxite. Thus, all ores are minerals but all minerals are not ores.

The ores of some common metals are given below :

Metal	**Name of the ore**	**Name of compound present in the ore**	**Formula of the ore**
1. Sodium (Na)	Rock salt	Sodium chloride	Na Cl
2. Aluminium (Al)	Bauxite	Aluminium oxide	$Al_2O_3 . 2H_2O$
3. Copper (Cu)	(i) Cuprite	Copper (I) Oxide	Cu_2O
	(ii) Copper glance	Copper (I) sulphide	Cu_2S
	(iii) Copper pyrite	Copper iron sulphide	$CuFeS_2$
4. Iron (Fe)	Haematite	Iron (III) oxide	Fe_2O_3
5. Zinc (Zn)	(i) Zinc blende (ii) Calamine	Zinc sulphide Zinc carbonate	ZnS $ZnCO_3$
6. Mercury (Hg)	Cinnabar	Mercurry (II) sulphide	HgS
7. Lead (Pb)	Galena	Lead sulphide	PbS

5.4. EXTRACTION OF METALS (METALLURGY)

As we have learnt above, metals are obtained from their ores. An ore may contain the metal in the elementary state or in the form of its compounds along with earthy and sandy impurities. **The unwanted impurities such as the earthy, sandy and rocky materials associated with the ores are called gangue or matrix.** So, after mining of the ore from the ground, it is converted into pure metal. Several steps are involved in this process. **The various steps involved in the extraction of the metal from its ores followed by refining of the metal is called metallurgy.** The steps involved in the metallurgy varies from metal to metal. The actual process of metallurgy employed for a particular metal depend upon the nature of the ore, nature of the metal and the types of impurities present. However, metallurgy of most of the metals involves the following steps

(i) Concentration or enrichment of the ore.

(ii) Extraction of the metal from the concentrated ore.

(iii) Refining or purification of the impure metal.

Step 1. Concentration or Enrichment of the ore

The first step in metallurgy is to remove the unwanted impurities or gangue from the ore. As the mined ore is in the form of big lumps, it is first broken into small pieces in mechanical crushers and then pulverised to a fine powder in special mills. The processes used for removing the gangue from the ore are based on the differences between the physical or chemical properties of the gangue and the ore. Different separation techniques are employed.

(a) Gravity Separation or Hydraulic Washing

The crushed and powdered ore is taken in large wooden tanks or spread on special types of tables having grooves on the top. It is then washed with a stream of water. The lighter gangue particles are washed away while the heavier ore particles are left behind. The method is used for the concentration of oxide ores of heavy metals like lead, tin and iron.

(b) Froth Floatation Process

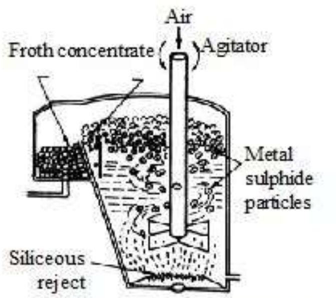


Fig. 5.4. Apparatus for froth floatation concentration

A convenient method widely used in the concentration of sulphide ores is the **froth floatation process**. Sulphides are more readily wetted by oil than by water, while those of gangue are preferentially wetted by water. The crushed and powdered ore is wetted with oil and then agitated in a tank of soapy water. Air is bubbled through the mixture (Fig. 5.4), bubbles stick to oil coated particles, and they float on the surface as **froth**. The gangue being wetted by water settles down to the bottom of the tank. The froth on the top of the tank is allowed to flow off, and the concentrated ore is recovered. Sulphide ores such as copper pyrites ($CuFeS_2$), galena (PbS), zinc blende (ZnS) etc are concentrated by this method.

(c) Electromagnetic Separation

This method is used for the concentration of the ore when either the ore or the impurities (gangue) is magnetic in nature.

The arrangement consists of two rollers over which a leather belt moves. One of the rollers is an electromagnet. The powdered ore is dropped over the belt on the side of non-magnetic roller. As the ore particles move attracted by the magnetic roller and fall into a heap on the inner side. The non magnetic particles simply falls down from the edge of the magnetic roller (Fig 5.5). Some ores like tinstone, magnetite etc. are separated by this method.

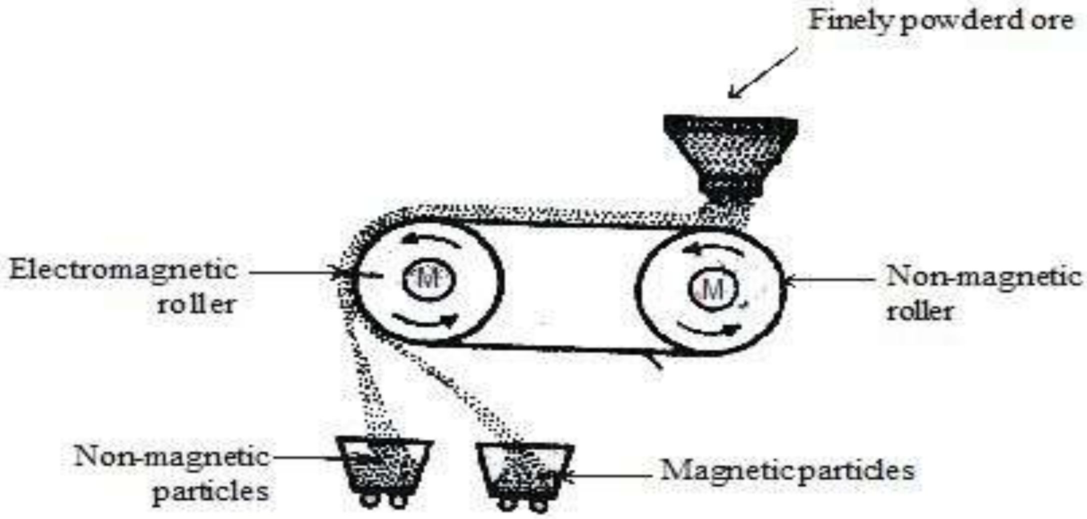


Fig. 5.5. Electromagnetic methods of concentration

(d) Leaching

This is a chemical method for the concentration of the ore. In this process, a particular mineral in the ore is dissolved selectively by employing certain acids, bases or other reagents , separating it from the gangue.

For example, bauxite, (Al_2O_3) an aluminium ore is concentrated by leaching with hot sodium hydroxide solution. The aluminium oxide dissolves in the excess base forming soluble sodium meta-aluminate

$$Al_2O_3 + 2\,NaOH \longrightarrow \underset{\text{sodium meta aluminate}}{2\,NaAlO_2} + H_2O$$

The solution is filtered to remove insoluble gangue particles. The filtrate when diluted with water and agitated gives precipitate of aluminium hydroxide.

$$NaAlO_2 + 2\,H_2O \longrightarrow Al(OH)_3\downarrow + NaOH$$

The precipitate is dried and then heated strongly to get pure aluminium oxide (alumina).

$$2\,Al(OH)_3 \xrightarrow{\text{heat}} Al_2O_3 + 3\,H_2O$$

(pure
alumina)

Step II Extraction of the Metal from the Concentrated Ore (Reduction)

On the basis of reactivity, we have classified the metals into three categories. They are (i) highly reactive metals (ii) moderately reactive metals and (iii) metals of low reactivity (Fig.5.3) Different techniques are used for obtaining the metals in each category. You are familliar with the process of oxidation and reduction explained in previous chapter. Obtaining metals from their compounds is also reduction process.

(a) Extraction of Metals which are low in the Activity series

Metals in this group are unreactive. The sulphides and oxides of these metals can be reduced to metals by heating alone. For example, cinnabar (HgS) is an ore of mercury. When it is heated in air, it is first converted into mercuric oxide (HgO). Mercuric oxide is then reduced to mercury on further heating.

$$2\,HgS\,(s) + 3\,O_2\,(g) \xrightarrow{\text{heat}} 2\,HgO(s) + 2\,SO_2(g)$$

$$2\,HgO \xrightarrow{\text{heat}} 2\,Hg\,(l) + O_2\,(g)$$

Similarly, when copper glance (Cu_2S), an ore of copper, is heated strongly in air, it gives copper according to the following reactions :

$$2\,Cu_2S + 3\,O_2 \longrightarrow 2\,Cu_2O + 2\,SO_2\uparrow$$

$$2\,Cu_2O + Cu_2S \longrightarrow 6\,Cu + SO_2\uparrow$$

(b) Extraction of Metals in the Middle of the Activity Series. (Fe, Zn, Pb, etc.)

These metals are found in nature in the form of their oxide, sulphide or carbonate ores. Further, it is easier to obtain the metal from its oxide than sulphides or carbonates. Therefore, prior to reduction, the sulphide and carbonate ores are first converted into the corresponding metal oxides. This is done by either of the following two methods.

(i) Calcination (for carbonate ores)

The carbonate ores are changed into oxides by heating strongly in limited air. The process is known as calcination. For example, calamine, a carbonate ore of zinc can be converted to zinc oxide by calcination.

$$ZnCO_3\,(s) \xrightarrow{\text{heat}} ZnO(s) + CO_2\,(g)$$

(ii) Roasting (for sulphide ores)

It is the process of heating the ores strongly in the presence of excess air. As a result, the sulphide ores are converted into oxides

For example,

$$\underset{\text{(zinc blende)}}{2\,ZnS\,(s)} + 3\,O_2\,(g) \xrightarrow{\text{heat}} 2\,ZnO(s) + 2\,SO_2\,(g)$$

$$\underset{\text{(galena)}}{2\,PbS\,(s)} + 3\,O_2\,(g) \xrightarrow{\text{heat}} 2\,PbO(s) + 2\,SO_2(g)$$

Reduction to the Metal

To reduce the metal oxide to the metal, the roasted or calcined ore is mixed with suitable quantity of coke (carbon), or another element which has greater affinity for oxygen. They act as reducing agents. Oxides of zinc, iron and lead are reduced to their respective metals by heating with coke.

$$ZnO\,(s) + C(s) \xrightarrow{\text{heat}} Zn\,(s) + CO(g)$$

$$Fe_2O_3(s) + 3\,C(s) \xrightarrow{\text{heat}} 2\,Fe(s) + 3\,CO(g)$$

Carbon monoxide formed also acts as reducing agent. It further reduces the metal oxide to metal.

$$Fe_2O_3\,(s) + 3\,CO(g) \longrightarrow 2\,Fe\,(s) + 3CO_2(g)$$

$$ZnO(s) + CO\,(g) \longrightarrow Zn\,(s) + CO_2\,(g)$$

The process by which the metal oxides in the fused state are reduced by carbon to the free metal involving melting is also called **smelting**.

Certain metallic oxides cannot be reduced by carbon because the affinity of oxygen for the metal is greater than its affinity for carbon. Such metallic oxides can be reduced with the help of highly reactive metals such as sodium, magnesium, aluminium, etc. Such metals can act as reducing agents. For example, oxides of manganese and chromium are reduced to their corresponding metals by heating with aluminium powder.

$$3\,MnO_2\,(s) + 4\,Al\,(s) \xrightarrow{heat} 3\,Mn\,(l) + 2\,Al_2O_3\,(s) + Heat$$

$$Cr_2O_3\,(s) + 2\,Al\,(s) \longrightarrow 2\,Cr\,(l) + Al_2O_3\,(s) + Heat$$

The reaction is **highly exothermic**. The heat evolved is so high that the metal is obtained in the molten state. As the reaction using aluminium libertate a large amount of heat, the process is known as **aluminothermic process**.

Similarly, when iron (iii) oxide (Fe_2O_3) is heated with aluminium powder, the heat evolved is so high that iron obtained melts.

$$Fe_2O_3\,(s) + 2\,Al\,(s) \xrightarrow{heat} 2\,Fe\,(l) + Al_2O_3\,(s)$$

The reaction is , therefore, used for welding the broken parts of iron machinery, join railway tracks or cracked machine parts.

(c) Extraction of Metals of High Reactivity (K, Na, Ca, Mg, Al)

These highly reactive metals cannot be obtained by reduction of their oxides by heating with carbon or aluminium. This is because these highly reactive metals have greater affinity for oxygen than for carbon or aluminium. These metals are obtained by the electrolysis of their fused salts. The method is called **electrolytic reduction.** As an example, we may consider the manufacture of sodium metal by the electrolysis of fused sodium chloride (NaCl). Various reactions taking place during electrolysis may be represented as given below.

When sodium chloride melts, it splits into sodium ion (Na^+) and chloride ion (Cl^-).

$$NaCl\,(s) \xrightarrow{fusion} Na^+\,(l) + Cl^-(l)$$

When electricity is passed through the melt, Na^+ ions go to the negatively charged electrode (cathode) and reduced to sodium atoms. Chloride (Cl^-) ions move towards the positively charged electrode (anode) and are oxidised to chlorine gas.

$$\text{At cathode, } Na^+ + e^- \longrightarrow Na \quad [\text{ reduction }]$$

$$\text{At anode, } 2\,Cl^- \longrightarrow Cl_2 + 2\,e^- \quad [\text{ oxidation }]$$

Similarly, calcium and magnesium are also obtained by the electrolysis of their fused chlorides. Aluminium is obtained by the electrolytic reduction of the molten alumina (Al_2O_3).

Step III . Refining of Impure Metals

The metals obtained by various reduction processes are not very pure. They are called crude metals. They contain impurities, which must be removed to obtain pure metals. The method used for refining depends upon the nature of the metals and the nature of the impurities present.

The most widely used method for refining impure metals is **electrolytic refining**. The procedure generally followed in this method is as follows .

(i) The impure metal, taken in the form of a thick block is made the anode in the electrolytic cell.
(ii) A thin sheet of pure metal is made the cathode.
(iii) A solution of the salt of the metal is taken as the electrolyte (electrolytic bath).

When an electric current is passed through the solution, the pure metal from the anode passes into the solution in the form of metal ions. An equivalent amount of metal ions from the solution is deposited as pure metal on the cathode. Thus, as the electrolysis proceeds the size of anode keeps on decreasing while that of the cathode keeps on growing. The soluble impurities go into the solution, whereas, the insoluble impurities settle down below the anode as **anode mud**.

As an example, we may consider the electrolytic **refining of copper** (Fig. 5.6)

The block of impure copper is made the anode. A thin sheet of pure copper is made the cathode . The electrolyte is a solution of copper sulphate acidified with dilute sulphuric acid. On passing electric current, pure copper from the anode passes into solution as copper (II), Cu^{2+} ions. Equivalent amounts of Cu^{2+} ions from the solution are deposited on the cathode as pure copper.

At Anode, $Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
At Cathode, $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

Thus, as the electrolysis proceeds, anode becomes thinner whereas cathode becomes thicker. The impurities present in the crude copper either go into the solution or fall down below the anode. The less reactive metals like

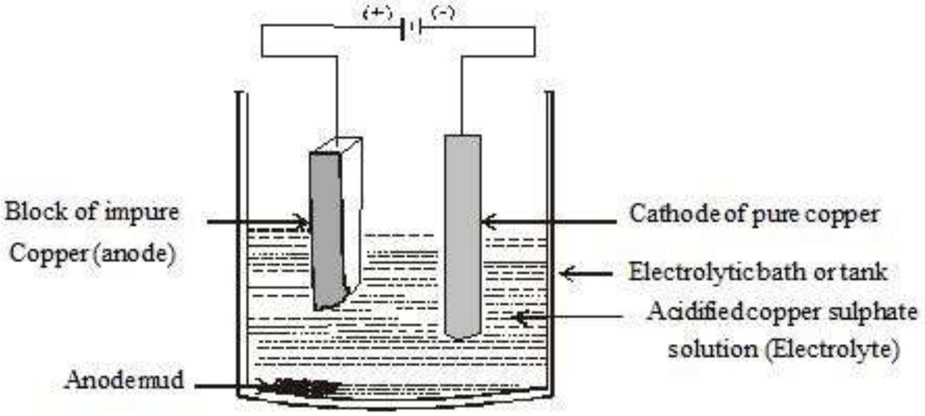
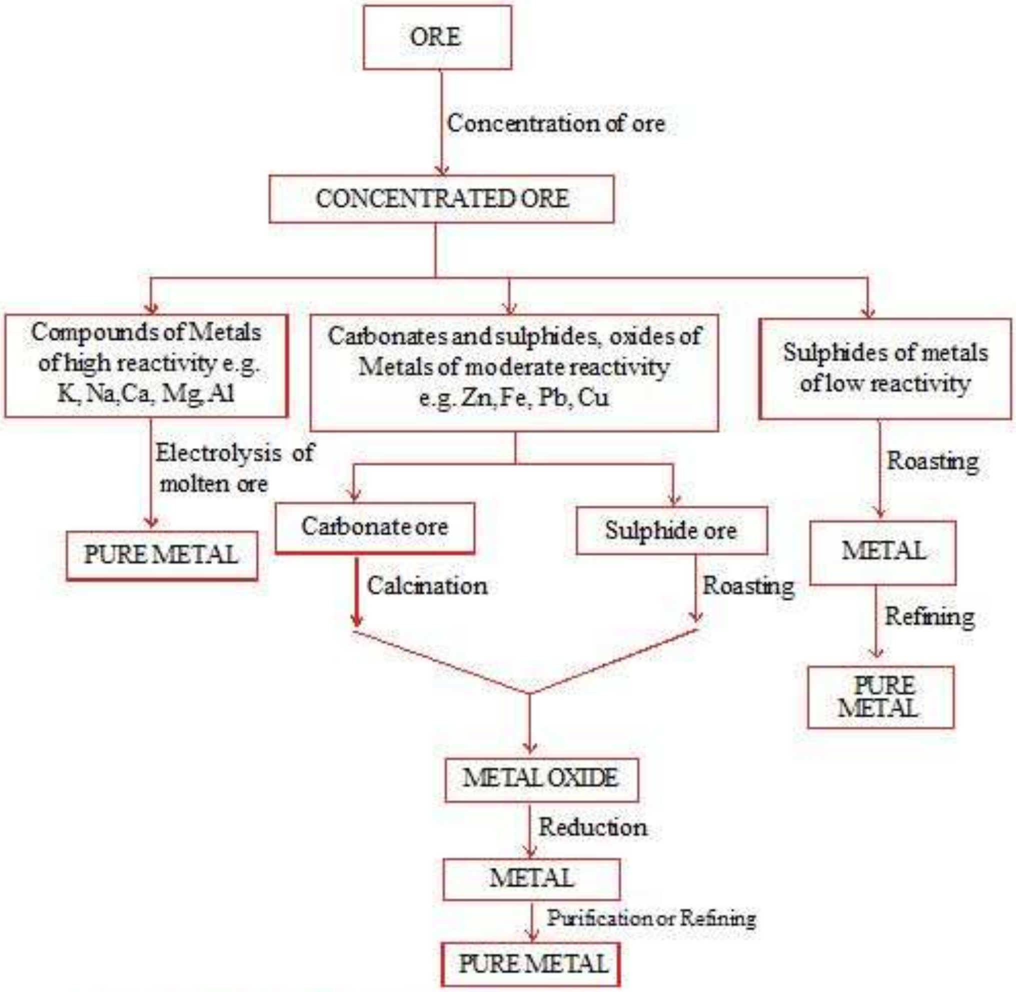


Fig.5.6. Electrolytic refining of Copper

gold, silver etc present in the impure coppers falls below the anode as such in the form of **"anode mud"**.

Many metals, such as zinc, tin, nickel, silver, gold, etc. are refined electrolytically in this manner.

The different steps involved in the extraction of pure metal from ores may be summarised as follows.



5.5. ALLOYS AND AMALGAM

We are familiar with many household implements like knife, dagger, spades, springs, saws etc. made of steel. We are also familiar with various kitchen utensils like dishes, bowls, spoons, nuts, screws etc. made of stainless steel or brass. Statues are made of bronze. They are made of materials called **alloys**.

A homogenous mixture of two or more metals or metal and non-metal is called an alloy. An alloy containing mercury as one of the constituent metals is known as **amalgam**. For example, sodium amalgam, zinc amalgam etc. Although there are only about 75 naturally occuring metal elements, there are thousands of different combinations of them, each of which has its own special properties. This shows that metals have the ability to mix with and combine with one another to form practically a large number of alloys. In general, an alloy is the solid which result when two or more metals, or metal and non-metal are melted together to form a homogenous mixture and then allowed to cool.

Alloys have properties of their own that often differ markedly from those of the elements of which they are made. For example, solder is a low melting alloy of tin and lead. Its melting point is lower than that of any of its constituents. There are also alloys which have higher melting points than any of their constituents.

Alloys are usually harder than the parent metals. Pure iron is quite soft and ductile in comparison with steel alloys which are composed mainly of iron and small percentage of carbon. The tensile strength of duralumin (an alloy of Al with Cu, Mg & Mn) is five times that of pure aluminium. Gold is too soft even for jewelery. It must be hardened by alloying with copper or some other metal.

One of the chief differences between pure metals and alloys is corrosion resistance. Alloys are usually more resistant to corrosion, hence they are more useful for materials that are exposed to the action of corrosive agents. However, alloys are generally poorer conductors of heat and electricity than pure metals. Very pure copper is needed for electrical wires, because even traces of certain impurities decrease the conductivity a great deal.

In spite of the important differences between the elemental metals and alloys, there are some important similarities. Alloys usually, have to some degree the metallic properties of heat and electrical conductivity, ductility and malleability, and they show metallic lustre.

Table 5.4. gives some of the commonly used alloys, their composition and uses.

Table 5.4. Some common alloys

Name	Composition	Properties	Uses
1. Steel	Iron (98.4 –99.2%) Carbon (0.2– 1.6%)	Hard, tough and strong	Fabrication, cutting blades, saws, springs, ships,bridges, vehicles etc
2. Stainless Steel	Iron (74%) Chromium (18%) Nickel (8%)	Corrosion-resistant, hard	Kitchenware, stainless cutlery, ornamental pieces, surgical instruments
3. Brass	Copper (60–80%) Zinc (20– 40%)	Malleable, strong. corrosion resistant, can be easily cast	Utensils, hardware, radiator cores, screws, nuts, bolts, musical instruments
4. Bronze	Copper (75–90%) Tin (10-25%)	Light, strong, highly resistant to corrosion	Statues, coins, medals, cooking utensils, valves, rods
5. Duralumin	Aluminium (95%) Copper (4%) Mangnese (0.5%) Magnesium (0.5%)	Light, strong, corrosion resistant, great tensile strength	Aeroplanes, automobile parts, pressure cookers
6. Solder	Lead (40 – 60 %) Tin (40– 60%)	Lower melting point than either Pb or Sn	Soldering, joining electrical wires.

A great deal of scientific research is going on at present to the study of alloys for use in high-temperature jet and rocket engines and nuclear energy power plants. When the methods for the production of rarer metals are perfected, these researches will undoubtedly lead to the formation of more valuable alloys than we have today.

Let us Answer these.

1. Name two metals which are found in nature in the free state.

2. Define the following terms.

(i) Mineral (ii) Ore (iii) Gangue

3. Differentiate between roasting and calcination used in metallurgy.

4. Name two sulphide and two oxide ores.

5. Name the systematic steps involved in metallurgy.

6. Write the chemical process used for obtaining a metal from its oxide.
7. Give an example of a sulphide ore which is reduced to metal by heating alone. Give the relevant equations involved.
8. Why aluminium cannot be obtained by reduction of its oxide with coke ?
9. Explain how the following metals can be obtained from their compounds by reduction process.

   (a) Metal "X" which is low in activity series

   (b) Metal "Y" which is moderately reactive

   (c) Metal "Z" which is high up in the reactivity series

   Give one example of each type.
10. An alloy "solder" is used in electronic industry to join different electronic components. What are the constituents of this alloy ?
11. Which alloy is used for making bodies of aircrafts ? What is its approximate composition?

SUMMARY

- Elements can be classified as metals and non-metals.
- Metals have metallic lustre, malleability ductililty and are good conductors of heat and electricity. They are solids at room temperature except mercury which is a liquid.
- Non-metals have properties different from those of metals. They are neither malleable nor ductile. They are bad conductors of heat and electricity, except graphite which conducts electric current.
- Metals combine with oxygen to form basic oxides. Aluminium oxide and zinc oxide show the properties of both basic and acidic oxides. These oxides are known as amphoteric oxides.
- Non-metals combine with oxygen to form acidic or neutral oxides.
- Different metals have different reactivities with water and dilute acids.
- Metals occur in nature as free elements or in the form of their compounds.
- The extraction of metals from their ores and then refining them for use is known as metallargy.
- Several steps are involved in the extraction of pure metal from ores. Different techniques are to be used for obtaining the metals from their ores.

- Metallurgy of most of the metals involve three steps–
  (i) Concentration or enrichment of the ore (ii) Extraction of the metal from the concentrated ore and (iii) Refining or purification of the impure metal.
- A homogenous mixture of two or more metals, or metal and non-metal is called an alloy.

EXERCISES

1. Give five points to distinguish metals from non-metals.

2. You are given a hammer, a battery, a bulb, wires and a switch.

- **(a)** How would you use them to distinguish between samples of metals and non-metals.
- **(b)** Assess the usefulness of these tests.

3. Frying pans and boilers are generally made from aluminium but not from steel. Why? Give two reasons.

4. Distinguish between metals and non-metals on the basis of their chemical properties. (Give three points).

5. What are amphoteric oxides ? Give examples of two amphoteric oxides.

6. Name two metals which will displace hydrogen from dilute acids, and two metals which will not.

7. Differentiate between :

- **(i)** Mineral and ore
- **(ii)** Alloy and amalgam
- **(iii)** Calcination and roasting.

8. What are the common methods of ore concentration ?

9. Name the process that is used to concentrate sulphide ores. Describe the stages that are involved in the conversion of concentrated sulphide ore into the corresponding metal.

10. How is impure metal refined electrolytically ?

11. What is an alloy ? Write the compostion and two uses of brass and bronze.

★★★★★★

CHAPTER

6

CARBON AND ITS COMPOUNDS

Coal, charcoal and graphite are black substances. Graphite is used for making pencils and dry cells. These substances are made up of carbon. Diamond is a bright, beautiful, hard and colourless substance which is used in jewellery. It is very rare and costly. Diamond is pure carbon. Carbon can exist in distinctly different forms which have quite different properties.

Many substances around us are made up of carbon. Clothes, foods, medicines, paper, plastic, cooking gas, electric cables and even transport vehicles and aeroplanes have components made up of carbon compounds. All living things have structures mainly based on carbon compounds.

The amount of carbon present in the earth's crust and in the atmosphere is quite low. Only about 0.02 % of carbon is present in the earth's crust as minerals in the form of carbonates, bicarbonates, coal and petroleum and about 0.03 % of the atmosphere is carbon dioxide. The importance of carbon is quite large inspite of its meagre abundance in the earth. In this chapter, we will discuss the uniqueness of carbon and its properties. This will illustrate the usefulness of carbon and its compounds.

6.1. Allotropes of Carbon

As seen above carbon occurs in nature, in physically distinct forms. However chemically they are the same. When heated strongly in air diamond and graphite leaves no residue but all are converted into carbon dioxide. Graphite is soft, slippery and greyish black in colour. It is a good conductor of electricity. However, diamond is transparent, very hard and is a non-conductor of electricity.

The difference between them lies in the manner in which the carbon atoms are bonded to one another. In diamond each carbon atom lies at the centre of a regular tetrahedron and is covalently bonded with four carbon atoms located at its four corners (Fig 6.1a). All the bonding electrons of the carbon atoms are thus used leaving no free electrons. This makes diamond an extremely poor conductor of electricity.

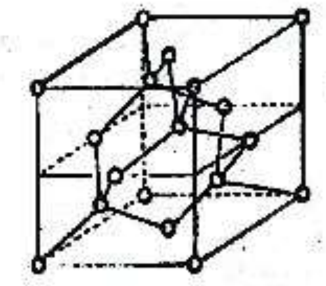


Fig. 6.1 (a) Structure of Diamond

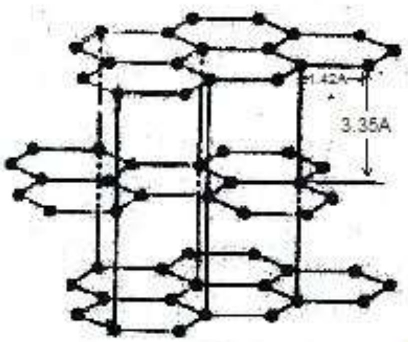


Fig. 6.1 (b) Structure of Graphite

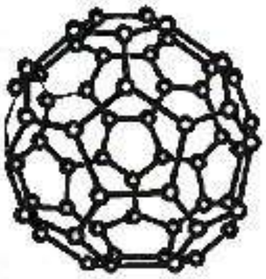


Fig. 6.1 (c) Structure of Fullerene

The tightly bonded three dimensional tetrahedral arrangement of carbon atoms produce a rigid network and makes diamond the hardest substance known. The melting point of diamond is 3500^{o}C which is very high.

Each carbon in graphite is covalently bonded to only three neighbouring carbon atoms forming layers of hexagonal networks (Fig 6.1b), separated by a comparatively larger distance. Because of this distance between two successive layers, the possibility of a covalent bond being formed between carbon atoms lying in opposite layers is ruled out. The fourth valence electron thus remains almost free. This enable the easy flow of electrons through graphite and makes it a good conductor of electricity. These layers slide over one another. This makes graphite soft to feel, greasy to touch and thus graphite has lubricating properties. Thus powdered graphite is used as lubricants in machines where high temperature makes other lubricants unsuitable.

Graphite and diamond are the allotropes of carbon. Allotropism is the phenomenon of existence of an element in two or more physically different forms but with similar chemical properties and those forms are called **allotropes**.

Carbon also has another allotropic form known as fullerene (Fig 6.1c). It is a form in which sixty carbon atoms are arranged in the shape of a football. Since this looks like the geodisic dome designed by the US architect Buckminster Fuller, the molecule is named as **fullerene**.

Since carbon has four valence electrons, it is capable of bonding with four other carbon atoms or atoms of some other monovalent element. Such bonds are single bonds. Carbon forms compounds with hydrogen, oxygen, nitrogen, sulphur, phosphorus, chlorine, bromine and many other elements giving rise to a large number of compounds. These compounds have specific properties which are characteristics of the elements rather than carbon present in the molecule.

6.2. Catenation – Unique propety of Carbon

The number of carbon compounds whose formulas are known to us is about three million. The number of compounds formed by all the other elements put together is less than one lakh.

What makes the number of carbon compounds so large ?

Carbon has the unique property to form bonds with other carbon atoms to form long chains. This property of carbon is called **catenation**. The carbon chains may be straight, branched or even rings. The carbon atoms may be linked by double or triple bond in addition to single bonds. The carbon-carbon bond is very strong and hence stable.

The bonds that carbon forms with most other elements are very strong and therefore, these compounds are exceptionally stable. One reason for the formation of strong bonds by carbon is its small size. This enables the nucleus to hold on to the shared electron pairs strongly. Generally, the covalent bonds formed by elements having larger sizes are much weaker.

6.2.1. Hydrocarbons Saturated hydrocarbons

Compounds of carbon and hydrogen only are called hydrocarbons. Methane, CH_4 is the simplest possible hydrocarbon. Carbon is tetravalent while hydrogen is monovalent. Each of the four valence electrons of carbon shares with one electron of hydrogen to acquire the noble gas configuration. Thus, methane is formed as shown in Fig. 6.2

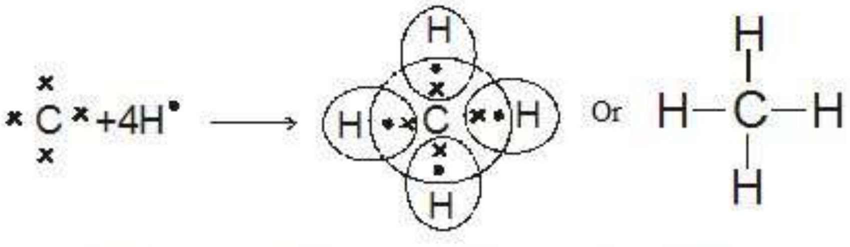


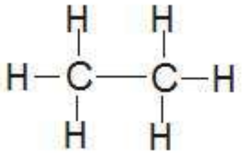
Fig. 6.2. Electron dot and cross structure of methane

Methane occurs in the nature in the form of gas. It is formed by the decay of plants and animals i.e., organic matters and is also known as marsh gas. Natural gas found in earth's crust is always associated with petroleum. Methane is widely used as fuel and is a major component of bio-gas and Compressed Natural Gas (CNG).

The next hydrocarbon after methane is ethane with the molecular formula C_2H_6. To arrive at the structure first write the two carbon atoms linked by a single bond,

$$C — C$$

Then, in the second step, use the hydrogen atoms to satisfy the remaining three valencies of each carbon,



The electron dot structure of ethane is shown in the Fig 6.3

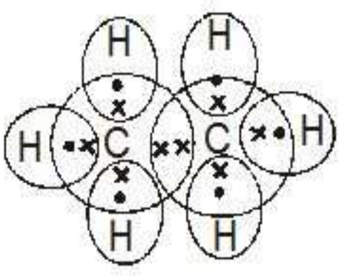


Fig 6.3. Electron dot structure of ethane molecule.

Now give answers for the following

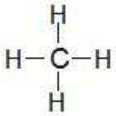
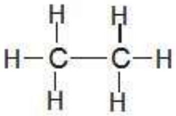
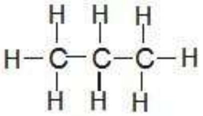
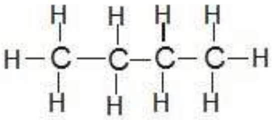
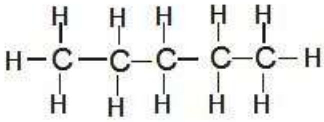
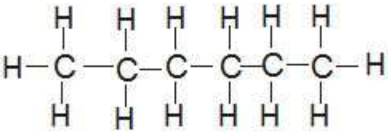
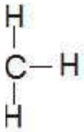
1. Draw the structure of propane with the molecular formula C_3H_8.

2. Draw the electron dot structure of chloromethane with the molecular formula CH_3Cl.

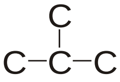
The hydrocarbons ethane C_2H_6, propane C_3H_8 etc. contains carbon -carbon single bonds only. Such hydrocarbons along with methane CH_4 are known as **saturated hydrocarbons** or simply **alkanes**. They are **open chain** compounds.

Alkanes are represented by the general formula C_n H_{2n+2} when n = 1,2,3 .....etc. Alkanes when arranged in order of increasing molecular mass constitute a series in which any two consecutive alkanes differ by $–CH_2–$. Such a series is called **homologous series**. The names and structures of a few alkanes are given in Table 6.1.

Table 6.1. Names and Structures of some Alkanes

Name	Formula	Straight chain formula	ula
Methane	CH_4		
Ethane	C_2H_6		
Propane	C_3H_6		
Butane	C_4H_{10}		H
Pentane	C_5H_{12}		–H
Hexane	C_6H_{14}		

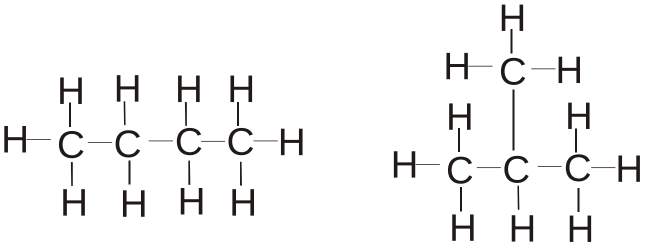
Will it be possible to write structures of butane C_4H_{10} other than the straight chain structure given above ? We can write two different carbon skeletons of C_4H_{10} using the principle of carbon-carbon single bonds only. They are (Fig 6.4)

C–C–C–C and 

$$\begin{matrix} & \mathrm{C} & \\ & | & \\ \mathrm{C}- & \mathrm{C} & -\mathrm{C} \end{matrix}$$

Fig 6.4 Two possible carbon skeletons of **some C_4H_{10}**

Satisfying the remaining valencies of carbon with hydrogen atoms we have the complete structures of the molecules of C_4H_{10} (Fig. 6.5).



(a) (b)

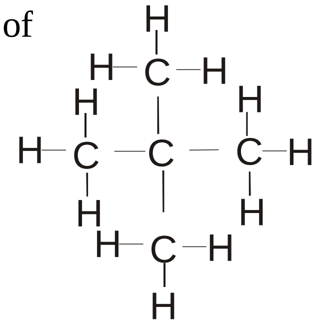
Fig. 6.5 Complete structure of **C_4H_{10}**

The structure (a) has all the four carbon atoms in a single line or chain. Its name is n-butane (read as normal butane). The structure (b) has three carbon atoms in a single chain and one carbon atom is branched. It is called iso-butane. If the carbon atoms in the longest chain are numbered as

then the structure (b) is also called as 2-Methyl propane. Why is it so?

Let us answer these.

1. Give the name of



2. **(a)** Write the possible carbon skeletons of C_5H_{12}.

   (b) Then write the possible structures of C_5H_{12}.

   The two structures of C_4H_{10}, although they have the same molecular formula, are different from each other. Such compounds with the same molecular formula but different structure are called **structural isomers**. They can be writen in short as

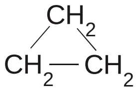
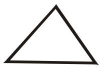
$CH_3CH_2CH_2CH_3$ and

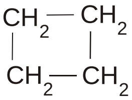
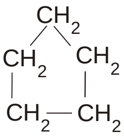
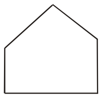
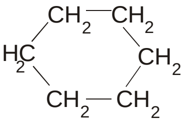
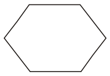
What is the relationship between the two structures ?

In addition to straight and branched chains, the same hydrocarbon may have carbon atoms in the form of a ring. Such hydrocarbons are called **cycloalkanes**. They have the general formula C_nH_{2n} i.e., they have two hydrogen atoms less than the corresponding saturated hydrocarbons.

Why is it so? Examples of some cycloalkanes are given in Table 6.2

Table 6.2.

NAME	**FORMULA**	**STRUCTURE**		
Cyclopropane	C_3H_6		or	

Cyclobutane	C_4H_8		or	
Cyclopentane			or	
Cyclohexane			or	

Unsaturated Hydrocarbons

In section 6.2 we have seen that carbon-carbon bonds may also be double or triple. Such open chain hydrocarbons containing double or triple bonds are called **unsaturated hydrocarbons**. They are so called as they have fewer number of hydrogen atoms when compared to the saturated hydrocarbons.

Alkenes are those unsaturated hydrocarbons which contain double bond. Such compounds have the general formula C_nH_{2n} (same as cycloalkanes). The first member of this group is ethene (or ethylene) which have the formula C_2H_4. Let us write the electron dot structure of ethene, C_2H_4. It is shown in Fig 6.6.

Fig. 6.6 (a) Electron dot structure of ethene (b) Structural formula

Table 6.3 Shows the homologues of ethene, name and the structural formulas.

Table 6.3

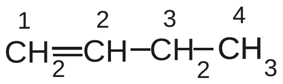
Molecular Formula	Structure	Name
C_2H_4	$CH_2 = CH_2$	**Ethene**
C_3H_6	$CH_3—CH = CH_2$	**Propene**
C_4H_8	(i) $CH_2 = CH—CH_2 — CH_3$	**But–1– ene**
	(ii) $CH_3 — CH = CH — CH_3$	**But – 2 – ene**

Let us answer these.

1. Why is the first member of alkene C_2H_4?
2. Why does butene have two names ?

Isomerism in alkene

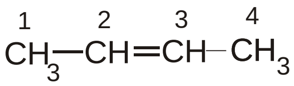
The two structures of butene C_4H_8 have the same carbon chain but differ in the position of carbon-carbon double bond. The carbon atoms in the chain are numbered starting from the end which is nearer to the double bond. Thus



$$\overset{1}{CH_2}=\overset{2}{CH}-\overset{3}{CH_2}-\overset{4}{CH_3}$$

But - 1-ene (1– Butene)

Fig 6.7 (a)



$$\overset{1}{CH_3}-\overset{2}{CH}=\overset{3}{CH}-\overset{4}{CH_3}$$

But - 2- ene (2-Butene)

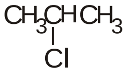
Fig 6.7 (b)

In Fig 6.7 (a) the double bond lies between the C_1 and C_2 and therefore it is called **But–1–ene.** This indicates that the position of double bond is between C_1 and C_2. In Fig 6.7 (b) the double bond lies between C_2 and C_3 and therefore it is called **But-2-ene.** This indicates that double bond lies between C_2 and C_3

Such compounds having the same carbon chain but differ in the position of double bond (which is a characteristic property) are called **postion isomers**. Let us answer the following.

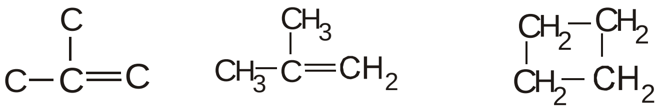
1. Write the position isomers of pentene C_5H_{10}.

2. Identify the relationship between

(i) $CH_3CH_2CH_2Cl$ and  $CH_3\underset{\underset{Cl}{|}}{C}HCH_3$

(ii) CH_3CHCl_2 and CH_2ClCH_2Cl

Examine the structures given in Fig 6.8 (a) and 6.8 (b)



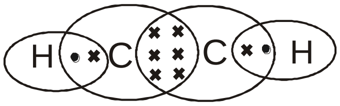
Skeleton (a) Isobutene (2-Methyl propene) (b) Cyclobutane

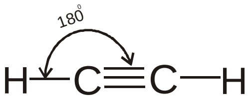
Fig 6.8 Different structures of $\mathbf{C_4H_8}$

They have the same molecular formula C_4H_8 as butenes shown in Figs 6.7. But the structure of carbon chains are all different. Thus the relationship between But-1-ene or But-2-ene with isobutene (2-Methyl propene) or cyclobutane is structural isomerism. Thus butene can show both **structural** and **position isomerisms.**

Alkynes:

Hydrocarbons with carbon-carbon triple bond are called alkynes. They have the general formula $C_nH_{2n-2.}$ The first member of the series is ethyne (or acetylene) with the formula C_2H_2. Let us draw the structure of this molecule.





Some of the compounds of the family are

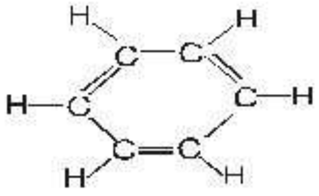
Formula	Structure	Name
C_2H_2	$H-C\equiv C-H$	Ethyne
C_3H_4	$CH_3-C\equiv C-H$	Propyne
C_4H_6	(i) $H-C\equiv C-CH_2-CH_3$	But-1-yne
	(ii) $CH_3-C\equiv C-CH_3$	But-2-yne

Question : **(i)** Why does Butyne has two isomers ?

(ii) Is there any other structural isomer of Butyne ?

Alkenes and alkynes are highly reactive organic compounds. They are used for making many useful chemicals and other substances like plastic, rubbers etc.

Yet there is another type of hydrocarbons which are known as **arenes** or **benzene** and its **derivatives**. They are cyclic and contain at least one benzene ring. Benzene itself is C_6H_6. The simplest representation of benzene is



Arenes are known as aromatic hydrocarbons. They are very stable hydrocarbons inspite of their general formula C_nH_{2n-6}.

We are familiar with cooking gas, motor spirit, petrol, diesel, kerosene, lubricating oil. They are all hydrocarbons and their source is petroleum which is a black liquid found in the crust of the earth.

6.3. Petroleum (Mineral Oil)

Petroleum is a dark coloured viscous liquid found deep in the earth's crust. Chemically it is a mixture of various types of hydrocarbons along with some oxygen, sulphur and nitrogen containing compounds.

Petroleum is believed to be formed by the decay and decomposition of marine animals as well as that of plant materials of the prehistoric forests. In other words, petroleum is of animal and plant origin. It is thought that due to some upheavals like earthquake, volcanic eruptions etc, these prehistoric forests, and sea animals get buried under the earth's crust. Due to prolonged action of high pressure and high temperature in the interior of the earth for ages, the organic matter decomposed into petroleum.

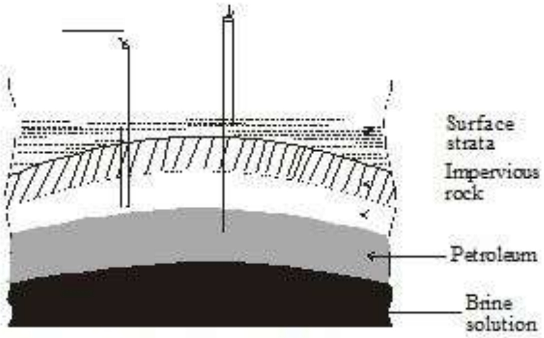


Fig. 6.9. Mining of Petroleum

A diagrametic representation of the occurrence and mining of petroleum is given in Fig 6.9. Petroleum is pumped out through the deep wells bored into the crust.

The process of separating crude petroleum into useful fractions by fractional distillation is known as refining. Fractions condensing at different boiling points are collected separately and are called products of petroleum. They are– gas, gasoline or petrol, kerosene, gas oil, diesel oil, lubricating oil, vaseline, paraffin, wax and asphalt.

Uses

Gas is used as a fuel, gasoline as a motor fuel, kerosene as household fuel and lighting purpose, gas oil and diesel oil as furnace fuel and for diesel engines, lubricating oil and grease for lubrication, vaseline for softening skin, paraffin wax for making candles, and asphalt for road surfacing. LPG (liquefied petroleum gas) is widely used for cooking.

6.4. Some compounds of carbon other than hydrocarbons

Carbon can form covalent bonds with many other elements like oxygen, sulphur, halogens– fluorine, chlorine, bromine, iodine etc. In a hydrocarbon one or more hydrogens can be replaced by these elements to form stable compounds.These hetero atoms may also be present as a group combined with other atoms.

Functional Groups

The heteroatoms and the group attached to the hydrocarbon part forming a stable molecule characterise the specific properties of the compound irrespective of the nature and length of the carbon chain. Hence these heteroatoms and groups are called **functional groups**. Example of some of these functional groups are given in Tables 6.4.

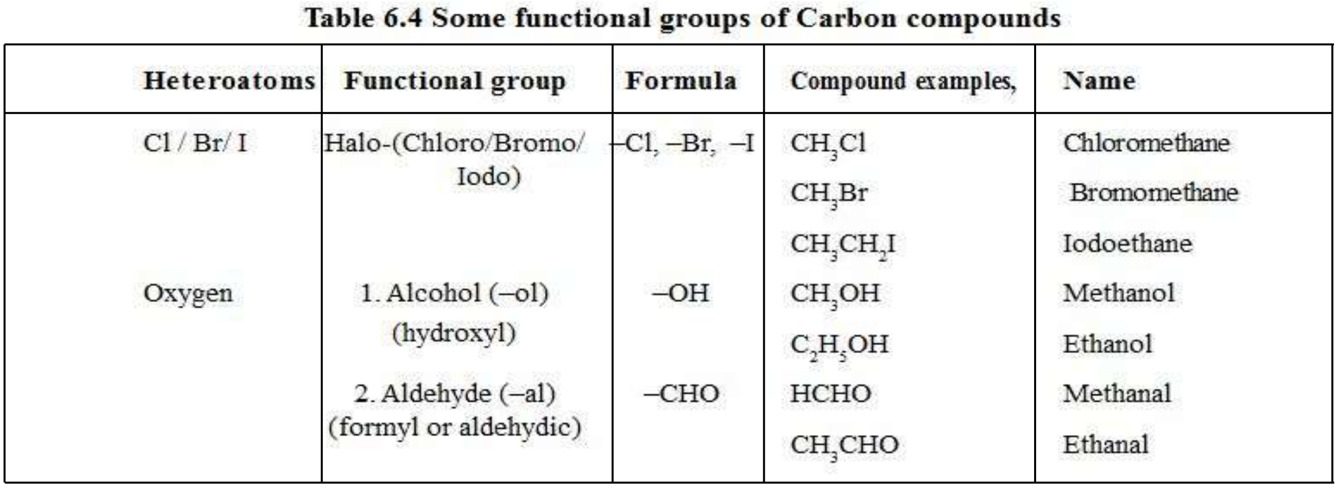


Table 6.4 Some functional groups of Carbon compounds

Heteroatoms	Functional group	Formula	Compound examples,	Name
Cl / Br/ I	Halo-(Chloro/Bromo/ Iodo)	–Cl, –Br, –I	CH_3Cl	Chloromethane
			CH_3Br	Bromomethane
			CH_3CH_2I	Iodoethane
Oxygen	1. Alcohol (–ol) (hydroxyl)	–OH	CH_3OH	Methanol
			C_2H_5OH	Ethanol
	2. Aldehyde (–al) (formyl or aldehydic)	–CHO	HCHO	Methanal
			CH_3CHO	Ethanal

3. Ketone (–one)	–CO–	CH_3–CO–CH_3	Propanone
4. Carboxylic acid (–oic acid)	–COOH	HCOOH CH_3COOH	Methanoic acid Ethanoic acid (Acetic acid)

Alcohols are a family of carbon compounds which contain the functional group –OH attached to a saturated carbon as C OH. These compounds have similar chemical properties inspite of the differences in the number of carbon chain. They are represented by the general formula $C_nH_{2n+1}OH$.

Let us answer the following.

1. Write the homologous series of alcohols upto four carbon atoms.
2. Write any two isomers of C_4H_9OH.

6.5. Nomenclature of Carbon Compounds

The name of an organic compound essentially consists of the following three parts.

1. Word root 2. Suffix and 3. Prefix.

Word root : It is the basic unit of the name. It denotes the number of carbon atoms present in the **main chain** (the longest possible continuous chain of carbon atoms including the functional group and carbon-corbon multiple bonds) of the molecules. For molecules upto four carbon atoms special word root are used but for chains of five or more carbon atoms Greek roots are used as given below :

Chain length	Word Root
C_1	Meth –
C_2	Eth –
C_3	Prop –
C_4	But –
C_5	Pent –
C_6	Hex –
C_7	Hept–
C_8	Oct–
C_9	Non–
C_{10}	Dec–

The general name of the word root for any carbon chain is **alk–**.

Suffix : There are two types of suffixes.

(a) Primary suffix

A primary suffix is added to the the word root to indicate whether the carbon chain is of single bonds only (saturated) or contains carbon - carbon multiple bonds (unsaturated). The three basic primary suffixes are:

Nature of carbon chain	Primary suffix	General Name
i) Saturated	– ane	Alkane
ii) Unsaturated with a double bond	– ene	Alkene
iii) Unsaturated with a a triple bond	– yne	Alkyne

It is illustrated as in the following example.

Oraganic compound	Word Root	Primary Suffix	Name
$CH_3CH_2CH_3$	Prop	– ane	Propane
$CH_3CH{=}CH_2$	Prop	– ene	Propene
$CH_3{-}C{\equiv}CH$	Prop	– yne	Propyne

b) Secondary Suffix

A secondary suffix is added to the primary suffix to indicate the nature of the functional group present in the molecule. Some secondary suffixes are given below:

Family of compound	Functional group	Secondary suffix
Alcohols	– OH	– ol
Aldehydes	– CHO	– al
Ketones	– CO –	–one
Carboxylic acids	– COOH	– oic acid

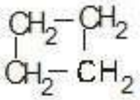
The examples given below illustrate the use of word root, primary suffix and secondary suffix while naming an organic compound.

Compound	**Word Root**	**Primary Suffix**	**Secondary Suffix**	**Name**
CH_3OH	Meth	an (e)*	ol	Methanol
CH_3CH_2OH	Eth	an (e)*	ol	Ethanol
$CH_3CH_2CH_2OH$	Prop	an (e)*	ol	Propanol (Propan-1-ol)
CH_3COOH	Eth	an (e)*	oic acid	Ethanoic acid

* The terminal 'e' from the primary suffix has been dropped because the secondary suffix begins with a vowel.

Prefix: There are two types of prefixes. They are

a) Primary prifix: It is used to distinguish open chain compounds from ring compounds (closed chain compounds). For example, in the case of cyclic (ring) compounds, a primary prefix, **Cyclo** is used immediately before the word root. Thus the name of the compound is

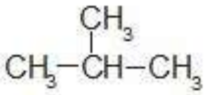


is Cyclo + but + ane = Cyclobutane

(Primary prefix) (Word root) Primary suffix (Name)

If the prefix 'Cyclo' is not used, it simply indicates open chain (acyclic) compound.

b) Secondary prefix: Certain groups are not considered as functional groups but are treated as substituents. These are called secondary prefixes. These prefixes are added immediately before the word root or primary prefix in **alphabetical order**. Some important secondary prefixes are given below

Group	**Secondary prefix**	**Example**	**Name**
$-F$	Fluoro	CH_3F	Fluoromethane
$-Cl$	Chloro	CH_3CH_2Cl	Chloromethane
$-CH_3$	Methyl	 $CH_3-\overset{CH_3}{\overset{\vert}{C}H}-CH_3$	2–Methyl propane

Note : *Fluromethane, chloroethane are single word name.*

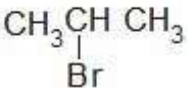
Thus, the complete name of an organic compound in the IUPAC system (International Union of Pure and Applied Chemistry) consists of the following parts :

Secondary prefix + primary prefix + word root + primary suffix + secondary suffix .

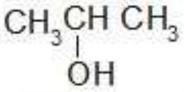
Questions

1. **Let us name the following compounds :**

(a) $CH_3CH_2CH_2Br$

b) 
$CH_3\underset{\displaystyle Br}{CH}CH_3$

(c) $CH_3CH_2CH_2OH$

d) 
$CH_3\underset{\displaystyle OH}{CH}CH_3$

(e) CH_3CHO f) CH_3CH_2COOH

2. **Draw the structures of**

a) 1-Bromobutane b) 2-bromobutane c) Ethanoic acid

d) Propanone f) Butanal

6.6. Chemical Properties Of Carbon Compounds

Let us try to understand some of the properties of carbon compounds. Carbon and its compounds are combustible substances.

6.6.1. Combustion

All the allotropic forms of carbon burn in oxygen to form carbon dioxide producing large amounts of heat and light (energy).

$$C + O_2 \longrightarrow CO_2 + \text{Energy}$$

Some fuels like coal, charcoal and wood burn leaving some residue. But fuels like LPG, kerosene, alcohol etc. burn without leaving any residue. Some of the carbon compounds burn with sooty flame while some others burn with clean flames. All compounds of carbon burn to form carbon dioxide and water. Thus

$$\underset{\text{methane}}{CH_4} + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O + \text{Energy}$$

$$\underset{\text{ethanol}}{CH_3CH_2OH} + 3O_2 \longrightarrow 2CO_2 + 3\,H_2O + \text{Energy}$$

Activity 6.1

- Hold a metal scale or plate over the flame of a burning candle and observe. Is there any deposit of soot ?
- Repeat the above step using a spirit lamp.
- Repeat again using a diesel oil lamp
- Record your observation and draw a conclusion.

Saturated hydrocarbons usually burn with a clear flame whereas unsaturated hydrocarbons burn with coloured (yellow to orange) flame with a lot of soots. Can you explain why is it so ?

When the supply of air (oxygen) is limited even the saturated hydrocarbons burn with a sooty flame. Why ? The gas and kerosene stoves used at home have air inlets to mix with the fuel to burn them completely. If the bottoms of the cooking vessels become black , it means that air holes are blocked and the fuel is wasted (incomplete burn). Fuel such as coal, petrol and diesel contain some compounds of sulphur and nitrogen. Their combustion produces oxides of sulphur and nitrogen. These oxides are the major pollutants of air. Besides fine particles of carbon often missed combustion and are released in the air as particulates. These particulates cause pollution.

6.6.2. Oxidation

Combustion is also an oxidation process. The final product of oxidation of an organic compound is carbon dioxide and water. Many organic compounds may form intermediate products when reacted with oxygen or any other oxidising agent. Oxidation, in its simplest sense, may be defined as the additon of oxygen or removal of hydrogen from a carbon compound.

Activity 6.2.

- Take about 3 mL of ethanol in a test tube and warm it gently on a water bath as in Fig 6.10.
- Add drop by drop a solution of 1% alkaline $KMnO_4$ (potassium permagnanate).
- Note the change in the colour of $KMnO_4$ solution.
- Why does not the colour of potassium permaganate disappear when added in excess?

Note

The above activity may be performed by using acidic potassium dichromate solution ($K_2Cr_2O_7$ + Conc H_2SO_4). However, precaution must be taken not to touch this solution by hand.

Alkaline $KMnO_4$ or acidified $K_2Cr_2O_7$ are oxidising agents i.e. they can supply oxygen atoms which can be added to organic compounds.

The reaction between ethanol and alkaline $KMnO_4$ produces an aldehyde which in turn is oxidised further to acid. The reaction occurs in the two steps

$$\text{i) } \underset{\text{ethanol}}{CH_3CH_2OH} + \underset{\text{(from } KMnO_4\text{)}}{[O]} \xrightarrow{\text{alk. } KMnO_4} \underset{\text{(ethanal)}}{CH_3CHO} + H_2O$$

$$\text{ii) } CH_3\ CHO + [O] \xrightarrow{\text{alk. } KMnO_4} \underset{\text{(ethanoic acid)}}{CH_3COOH}$$

Nascent oxygens (oxygen atoms) are released within the reaction medium (*in situ*). The first step is oxidation of ethanol by the removal of two hydrogens, and the second step is the oxidation by adding oxygen atom to the intermediate product ethanal. Intermediate product is readily converted to ethanoic acid.

6.6.3. Addition Reactions

(i) **Hydrogenation (addition of hydrogen):** Unsaturated hydrocarbons add hydrogen in presence of catalyst like palladium, platinum, nickel etc. to form saturated hydrocarbons. Thus, ethene adds a molecule of hydrogen to form ethane.

$$CH_2{=}CH_2 + H_2 \xrightarrow{\text{Ni cat.}} CH_3 - CH_3$$

ethene ethane

This reaction is commonly used in the hydrogenation of vegetable oils which contain unsaturated carbon chains. On hydrogenation vegetable oils give vegetable ghee.

(ii) **Bromination (Halogenation) :** On treatment with bromine water, ethene adds a molecule of bromine to form dibromoethane. (Orange colour of bromine water is discharged during the reaction).

$$CH_2{=}CH_2 + Br_2\ (\text{water}) \longrightarrow CH_2Br - CH_2Br$$

ethene 1, 2 - dibromoethane

This reaction is used as a test for the unsaturated organic compounds (pressence of double or triple bonds)

(iii) **Addition of Hydrobromic acid :** Ethene readily reacts with hydrobromic acid HBr to produce bromoethane

$$CH_2{=}CH_2 + HBr\ (aq) \longrightarrow CH_3\ CH_2Br$$

ethene bromoethane

6.6.4. Substitution Reaction: Saturated hydrocarbons are very stable and unreactive towards most reagents. But, in the presence of diffused sunlight (indirect light), chlorine can react with methane to produce various products. One or all the hydrogens of CH_4 can be replaced by chlorine atoms. Such a reaction is known as s**ubstitution reaction.**

$$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$$

Methane Chloromethane

$$CH_3Cl + Cl_2 \longrightarrow CH_2\ Cl_2 + HCl$$

Dichloromethane

$$CH_2Cl_2 + Cl_2 \longrightarrow CHCl_3 + HCl$$

Trichloromethane
(Chloroform)

$$CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl$$

Tetrachloromethane
(Carbon tetrachloride)

However, the reaction is very complex and very fast.

6.7. Properties of ethanol CH_3CH_2OH

Ethanol (ethyl alcohol) is one of the important compounds of carbon. Let us see some of its properties.

Ethyl alcohol is a colourless volatile liquid with a boiling point of 78°C. It has a typical pleasant smell. It is inflammable and burns with a blue flame. It is miscible with water in all proportions. It is also miscible with many organic solvents. Ethanol mixed with petrol, is used as a fuel for internal combustion engines. It is also used as the solvent for lacquers.

Ethyl acohol is the active ingredient of all alcoholic drinks. Depending upon the type of drinks the alcohol content ranges from 3 – 50%. When consumed, the alcohol is oxidised and supplies energy which in turn stimulates the human system. However alcohol affects Central Nervous System (CNS) as it is neurodepressant. When taken in small amounts, apparent excitation and euphoria are experienced. Hesitation, caution, self-respect and restraint are lost first. Mood and feelings are altered. When taken in larger amounts it causes disorganization of thought, impairment of memory and other faculties and drowsiness.

Alcohol has been believed to produce CNS depression by a generalized membrane action by altering the state of membrane lipids. A person , therefore, loses control over his body after drinking alcohol.

Some simple reaction of ethanol

(i) Reaction with sodium metal

Ethanol reacts with sodium metal to produce sodium ethoxide and hydrogen gas.

$$\underset{\text{Ethanol}}{2CH_3CH_2OH} + 2Na \longrightarrow \underset{\text{Sodium ethoxide}}{2CH_3CH_2ONa} + H_2$$

(ii) Dehydration of ethanol

Ethanol on heating with concentrated sulphuric acid, H_2SO_4 at 170°C, loses a water molecule giving ethene.

$$\underset{\text{ethanol}}{CH_3CH_2OH} \xrightarrow[\text{170°C}]{\text{Conc. } H_2SO_4} \underset{\text{ethene}}{CH_2 = CH_2} + H_2O$$

(iii) **Oxidation of ethanol :** Oxidation of ethanol with alkaline $KMnO_4$ gives ethanoic acid which is called acetic acid (Refer to 6.10)

Oxidation of fermented liquors which contain about 12–15% ethyl alcohol, with air under the influence of bacteria *Mycoderma aceti* gives dilute acetic acid solution (containing about 4–7% acetic acid) called vinegar. Vinegar is widely used as a preservative of pickles and as table food.

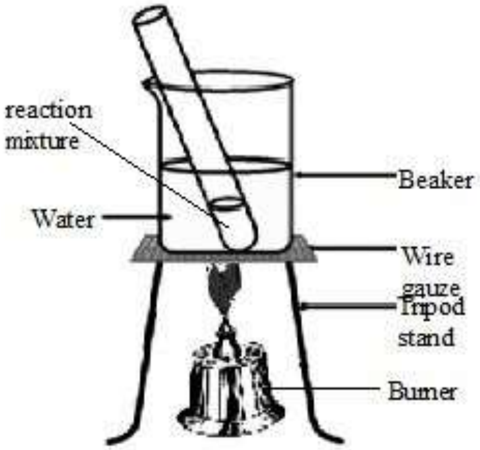


Fig. 6.11 Formation of ester

6.8. Properties of Ethanoic acid

Ethanoic acd is commonly called acetic acid. Acetic acid is a colourless, corrosive liquid with a sharp vinegar odour and sour taste. Its freezing point is 16.6 °C and boiling point is 118°C. Its vapours are suffocating and cause damage to lungs. Below its melting point acetic acid is converted into ice like solid hence it is called glacial acetic acid. It is miscible with water, ether and ethanol.

Activity 6.3

- Take about 2ml of ethanol and equal volume of glacial acetic acid in a test tube,.Add 2–3 drops of concetrated sulphuric acid.
- Heat the test tube on a water bath as shown in the Fig. 6.11. for about 5 minutes
- Pour the contents of the tube in about 20 ml cold water taken in a beaker and smell the mixture.

  What is your observation ?

Some of the reactions of acetic acid are

i) Reaction with metals, alkalis etc. Acetic acid reacts with metal, metal oxides, alkalis, carbonates and bicarbonates to form corresponding salts.

$$2CH_3COOH + 2Na \longrightarrow 2CH_3COONa + H_2$$

Acetic acid → Sodium acetate

$$2CH_3COOH + Zn \longrightarrow (CH_3COO)_2Zn + H_2$$

Zinc acetate

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$$

$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + H_2O + CO_2$$

$$CH_3COOH + Na\,HCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

(ii) Reaction with alcohol (Esterification reaction)

Acetic acid reacts with ethyl alcohol in presence of an acid catalyst to form ester, ethyl acetate,

$$CH_3COOH + CH_3CH_2OH \xrightarrow{H^+} CH_3\ COOC_2H_5 + H_2O$$

Acetic acid Ethyl alcohol — Ethyl acetate
(Ethanoic acid) (Ethanol) — (Ethyl ethanoate)

Ethyl acetate (ester) is a sweet-smelling liquid. It is used in making perfumes and as flavouring agents.

SUMMARY

- Graphite, Diamond and Fullerene are the allotropes of carbon.
- Carbon forms largest number of compounds.
- Graphite is a good conductor of electricity whereas diamond is a non-conductor.
- Carbon can bond with other carbon atoms. This property carbon is called catenation.
- Compounds of carbon and hydrogen are called hydrocarbons.
- Hydrocarbons with C–C single bonds only are called saturated hydrocarbons.
- Unsaturated hydrocarbons contain C–C multiple bonds.
- Isomers are compounds with the same molecular formula but having different structures.
- Any two successive members of a homologous series differ by a $-CH_2-$ unit.
- Hydrocarbons may be of straight chain or ring structures.
- Cycloalkanes have the same general formula C_nH_{2n} as alkenes.
- Butene shows position isomerism.
- Petroleum is the major source of hydrocarbons.
- Asphalt is used for road surfacing.

- Complete burning of organic compounds produce carbon dioxide as the end product.

- Saturated hydrocarbons burn with a clean flame.
- Unsaturated hydrocarbons usually burn with a sooty flame.
- Oxidation of ethyl alcohol with alkaline $KMnO_4$ or acidic $K_2Cr_2O_7$ produces acetic acid.
- Hydrogenation of vegetable oils give, vegetable ghee.
- Saturated hydrocarbons undergo substitution reaction with chlorine in presence of indirect sunlight.
- Ethanol produces depression of Central Nervous System.
- Ethanol on dehydration with conc H_2SO_4 produces ethene.
- Vinegar is dilute aqueous solution of acetic acid.
- Vapours of acetic acid cause damage to lungs.
- Acetic acid reacts with ethanol to give sweet smelling ester ethyl acetate.

EXERCISES

1. Why does graphite conduct electricity ?
2. Why is diamond so hard ?
3. What is CNG ? Give an use of it.
4. Draw the electron dot structure of ethane and count the number of covalent bond in a molecule of it.
5. Draw the structure of propane and find out the number of hydrogens which have similar properties.
6. Draw the structure of 2–methyl propane. How many types of carbon and hydrogens are there ?
7. What is the general formula of cycloalkanes ?
8. Can you write But–3–ene? If not why ?
9. Draw the structure of benzene molecule.
10. What are important fractions obtained from petroleum ? Mention their important uses.
11. Define functional groups. Write the functional groups of alcohol , aldehyde and carboxylic acids.
12. What is a word root ?

13. What are primary and secondary prefixes?

14. What are primary and secondary suffixes ?

15. How is oxidation different from combustion ?

16. Write equation for esterification reaction.

17. What is the formula of chloroform ?
Mention one use of chloroform.

★★★★★★

CHAPTER

7

MATERIALS OF COMMON USE

Can we live without common salt ? Common salt (or table salt) is chemically sodium chloride, NaCl. We have seen that it is the product obtained by the neutralisation of HCl with sodium hydroxide NaOH. We use common salt in our food. Can you say some more uses of common salt ?

7.1. Sources of common salt, NaCl

Sodium chloride or common salt, NaCl occurs abundantly in nature as rock salt. Rock salt forms cubic crystals which are colourless when pure, but often have yellow tinge due to the presence of impurities.

Sodium chloride also occurs in solution as brine containing upto about 25% NaCl. Brine also contains chlorides and sulphates of calcium and magnesium. There are brine wells at Ningel, Chandrakhong and Waikhong villages of Thoubal district in Manipur. However, the amount of sodium chloride in these brine solutions is quite low. A small quantity only of *Meitei Thum* is produced now. Sea water also contains about 2.5 % of common salt.

In India, common salt is generally obtained from the sea by evaporation of sea water in open fields or shallow iron pans utilising the heat of sun. Such salts are not of pure quality. Pure sodium chloride is prepared by passing hydrochloric acid gas into a saturated solution of impure salt. The pure salt is precipitated and obtained on filtration. It is then dried. Table salt sold in the market is now iodised to prevent iodine deficiency diseases.

Activity 7.1

- Take two cups of crushed ice.
- Insert a thermometer and note the temperature.
- Mix the ice thoroughly with a cup of common salt.
- Note the temperature again with the thermometer.
- What change do you observe ?
- What can be inferred from the observation ?

Ice and common salt mixture is often used as a freezing mixture and the temperature can even go down upto about – 20°C. Why do we use freezing mixture ?

Common salt gives a characteristic flavour to food. It is also used for preserving fish, meat and other foods like pickles etc. Sodium chloride is also used for salting out soap, regenerating water softeners and in the "Salt-glazing" of earthenwares.

7.1.1. Common salt – a raw material for various chemicals

Common salt, a basic component of food for us is also a key raw material for various materials (chemicals) of our use such as sodium hydroxide, sodium carbonate (washing soda), sodium, chlorine, bleaching powder, sodium bicarbonate, sodium sulphate, sodium hypochlorite and sodium chlorate. Let us see how some of these useful materials are obtained from sodium chloride.

Sodium hydroxide, NaOH

On passing electricity through brine (aqueous solution of sodium chloride) in specially designed electrolytic cell, sodium chloride is decomposed to produce sodium hydroxide, hydrogen and chlorine. All these products have industrial applications

$$2\ NaCl\ (aq) + 2\ H_2O\ (l) \xrightarrow{\text{Electricity}} 2\ NaOH\ (aq) + Cl_2\ (g) + H_2(g)$$

Hydrogen gas (H_2) is given off at the cathode and sodium hydroxide (NaOH) is formed arround the cathode while chlorine gas (Cl_2) is given off at the anode.

Hydrogen gas so obtained can be used as fuel and for the manufacture of ammonia for further use in the manufacture of fertilisers. Chlorine gas is used for sterilizing water (water treatment), in swimming pools; manufacture of PVC (poly vinylchloride) plastics, pesticides and CFC (Chlorofluro Carbon). CFC is used in refrigerators. However, its use as refrigerent is not encouraged as it causes depletion of ozone layer.

Can you think of any other use of hydrogen and chlorine ?

Hydrogen and chlorine can be made to combine to form hydrogen chloride (HCl).

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl\ (g)$$

Sodium hydroxide is used for making soaps and detergents, paper and artificial fibre etc.

Sodium hydroxide can also combine with chlorine to produce sodium hypochlorite which is a bleaching agent for paper and fabrics.

$$2\,NaOH(aq) + Cl_2\,(g) \longrightarrow NaCl\,(aq) + \underset{\text{sodium hypochlorite solution.}}{NaOCl\,(aq)} + H_2l\,(O)$$

Sodium hypochlorite is the basic ingredient of all commercial bleaching solutions sold in the market. It is used to remove ink stains and for bleaching clothes etc. Such bleaching agents have a strong smell of chlorine.

The bleaching action of such a solution is due to the chlorine liberated in solution. Chlorine can also kill germs present in water. These properties are due to the fact that chlorine acts as an oxidising agent.

What is the white powdery substance used to disinfect drains in hospitals ? It is also used to kill germs in drinking water.

7.1.2. Bleaching powder (chloride of lime), Ca (OCl) Cl

The white substance which have a peculiar smell, used as a disinfectant in public places like hospitals, drains, market places etc. is bleaching powder . The chlorine gas produced by the electrolysis of sodium chloride can be used for the manufacture of bleaching powder. Chemically, it is calcium chloro-hypochlorite,and is obtained commercially by passing chlorine gas over slaked lime at about 35–45°C.

$$\underset{\text{slaked lime}}{Ca(OH)_2 + Cl_2} \longrightarrow \underset{\text{Bleaching powder}}{Ca\,(OCl)\,Cl + H_2O}$$

Formula of bleaching powder is usually written as above or simply $CaOCl_2$ as it explains all its reactions and agrees with available chlorine content. However, it is a mixture of calcium hypochlorite and basic calcium chlorides, $Ca(OCl)_2 \cdot 4H_2O$ and $CaCl_2 \cdot Ca(OH)_2 \cdot H_2O$

Bleaching powder has strong smell of chlorine. It absorbs moisture from the air. It does not dissolve completely in water but, always leaves a white residue of lime. The aqueous suspension, however, contains calcium hypochlorite $Ca\,(OCl)_2$ in the solution.

Carbon dioxide and moisture of the atmosphere decompose bleaching powder liberating chlorine.

$$Ca(OCl)Cl + CO_2 \longrightarrow Ca\,CO_3 + Cl_2$$
$$Ca(OCl)\,Cl + H_2O \longrightarrow Ca(OH)_2+Cl_2$$

Let us answer the following.

1. Why does bleaching powder act as a disinfectant ?
2. Why does bleaching powder act as a bleaching agent ?

Uses: Bleaching powder is used

- **(i)** as a disinfectant,
- **(ii)** for sterilising water to make water free from disease causing germs and bacteria,
- **(iii)** for bleaching pulp in paper industry, linen and cotton in textile industry,
- **(iv)** as an oxidising agent in chemical industries.

Commercial samples of bleaching powder contains 35–37 % available chlorine. Available chlorine is the amount of chlorine set free by the sample of bleaching powder when decomposed. This free chlorine is responsible for the oxidising and bleaching properties of bleaching powder.

7.1.3. Baking Soda (sodium hydrogen carbonate), $NaHCO_3$

Baking soda is usually kept in all kitchens. It is used in making *Pakoras* and special Manipuri dish *Uti*. Chemically it is sodium hydrogen carbonate $NaHCO_3$. It is also known as *Soda bicarb*

When an excess of carbon dioxide is bubbled through a nearly saturated solution of common salt containing ammonia, ammonium hydrogen carbonate is formed. This will react with more of sodium chloride to form sparingly soluble sodium hydrogen carbonate and ammonium chloride.

$$NaCl + H_2O + CO_2 + NH_3 \longrightarrow \underset{\text{Sodium hydrogen carbonate}}{NaHCO_3} + NH_4Cl$$

Sodium hydrogen carbonate is separated by filtration. It is then washed with cold water and dried in air.

Sodium hydrogen carbonate is a white solid. It is sparingly soluble in water. The aqueous solution of sodium hydrogen carbonate is slightly hydrolysed and the solution is alkaline in reaction.

$NaHCO_3 + H_2O$ □ $NaOH + H_2CO_3$

Uses

(i) Sodium hydrogen carbonate is used in medicine to reduce acidity in the stomach.

(ii) A mixture of $NaHCO_3$ and mild edible acid like tartaric acid is known as baking powder. When heated or mixed with water the following reaction takes place

$$2NaHCO_3 \xrightarrow{\text{heat}} Na_2CO_3 + H_2O + CO_2$$

$$NaHCO_3 + H^+ \text{ (from tartaric acid) } \xrightarrow{\text{water}} \text{Na-tartarate (salt)} + H_2O + CO_2$$

Carbon dioxide so produced during the reaction causes bread or cake to swell making them soft and fluffy.

(iii) sodium hydrogen carbonate is used in soda -acid fire extinguishers.

7.1.4. Washing Soda (Sodium carbonate) $Na_2CO_3 . 10H_2O$)

Washing soda is another very important chemical obtained from sodium chloride. Sodium carbonate is also found naturally in lakes of Magadi in East Africa, and in lakes of lower Egypt. The Magadi deposits, containing about 200 million tons of native soda, is an important source of soda.

Formerly sodiun carbonate was obtained from the ash of plants growing on the sea-shore. This method is no longer used nowadays.

A French chemist Nicholas Leblanc prepared washing soda directly from sodium chloride in the following steps:

(i) Sodium chloride is treated with concentrated sulphuric acid to form sodium sulphate which is called **salt-cake**.

$$2NaCl + H_2SO_4 == \underset{\text{salt-cake}}{Na_2SO_4} + 2HCl$$

The HCl gas liberated is absorbed in water giving commercial hydrochloric acid.

(ii) The salt-cake is grounded, and mixed with its own weight of limestone and half its weight of coal and strongly heated to 800–1000°C . The salt cake is reduced by coke to sodium sulphide, which then reacts with calcium carbonate to form sodium carbonate :

$Na_2SO_4 + 4C == Na_2S + 4CO$
$Na_2S + CaCO_3 == Na_2CO_3 + CaS$

The product called black-ash, contains about 45% sodium carbonate. The Leblanc process is no longer used nowadays but salt-cake is prepared for using in glass industry.

The ammonia soda or Solvay Process

Sodium carbonate is prepared by this process. In the section 7.1.3, you have seen that $NaHCO_3$ is prepared from brine solution by bubbling CO_2 into it after being saturated with ammonia (NH_3). From the solution sparingly soluble $NaHCO_3$ is separated by filtration and dried. $NaHCO_3$ is then calcined (heated at high temperature) to produce Na_2CO_3:

$$2\ NaHCO_3 == Na_2CO_3 + H_2O + CO_2$$

Carbon dioxide so liberated is used for further reaction with brine.

Washing soda has the formula $Na_2CO_3\ .10\ H_2O$. It is prepared by crystallising the solution below 32°C. It is commercially known as **washing soda.**

Anhydrous Na_2CO_3 is called soda ash and it is an amorphous powder. It absorbs moisture form air, forming sodium carbonate monohydrate, $Na_2CO_3\ .H_2O$ which is known **as crystal carbonate.**

Uses of washing soda

(i) Sodium carbonate is used as cleansing agent for domestic purposes and that is why it is called washing soda.
(ii) It is used in the manufacture of glass, soap, paper and borax.
(iii) It is used for making hard water soft.

You have seen amorphous sodium carbonate and crystalline sodium carbonate. Why is Na_2CO_3 amorphous while $Na_2CO_3\ .H_2O$ and $Na_2CO_3.10\ H_2O$ are crystalline ?
Let us find out the reason.

7.1.5. Water of Crystallisation

Na_2CO_3 is an amorphous white solid while $Na_2CO_3 \cdot H_2O$ and $Na_2CO_3 \cdot 10\ H_2O$ are crystalline solids. It is evident that H_2O molecules play an important role in the crystal structures of solids. Let us see this fact.

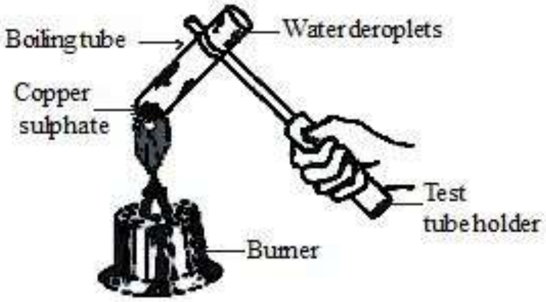


Fig. 7.1. To show that water of crystallisation can be lost on heating.

Activity 7.2

- Take a dry boiling tube and place in it some crystals of copper sulphate.
- Heat the copper sulphate crystals in the tube over a spirit lamp.
- What is the colour of copper sulphate now ?
- What do you observe near the mouth of the boiling tube ? (Droplets of water are collected near the mouth of the tube)
- Can you explain the collection of water drops?
- Cool the tube, then add 1–2 drops of water. What happened to the colour of the crystal?

  Blue colour is restored again.

Crystalline copper sulphate is blue and is called blue vitriol. It has the formula $CuSO_4.5\ H_2O$. These five molecules of water present in copper sulphate is called its **water of crystallisation.** When the blue crystals are heated, these water molecules are lost and the blue clour becomes colourless. When it is treated with water the lost water of crystallisation is regained and it is again blue in colour. Many a crystal contain water of crystallisation.

Examples are : Green vitriol $FeSO_4 \cdot 7H_2O$, (Ferrous sulphate), Zinc sulphate $ZnSO_4 \cdot 7\ H_2O$ (white vitriol), Gypsum $CaSO_4 \cdot 2\ H_2O$.

All crystals need not have water of crystallisation. For example NaCl, NH_4Cl, KCl, KI, sugar etc.

Gypsum is naturally occuring calcium sulphate, $CaSO_4 \cdot 2\ H_2O$. Do you know the white powder used for making casts and used in surgical bandages?

7.1.6. Plaster of Paris, $2CaSO_4 \cdot H_2O$.

When gypsum ($CaSO_4 \cdot 2\,H_2O$) is heated to about 120°–130°C it loses water molecule to form calcium sulphate hemihydrate $CaSO_4 \cdot \frac{1}{2} H_2O$. It can also be written as $(CaSO)_2 \cdot H_2O$ i.e. two calcium sulphate molecules share one water molecule. This substance is called Plaster of Paris.

$$\underset{\text{gypsum}}{2CaSO_4 .\, 2H_2O} \xrightarrow{\text{heat}} \underset{\text{plaster of paris}}{(CaSO_4)_2 \cdot H_2O} + 3H_2O$$

Uses : Plaster of paris is a white powder. It can be converted back to gypsum when treated with water. The newly formed product, on rehydration, sets into a hard solid. Plaster of paris is, therefore, used for making casts in moulds, and as a plaster for supporting fractured bones in the right position. It is also used for wall plaster.

7.2. Soaps and Detergents

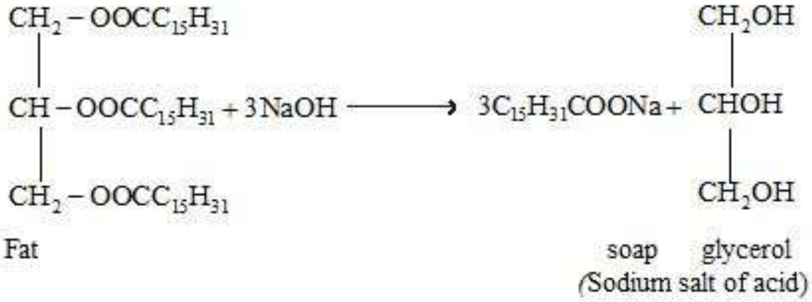
Soap has been used as a cleansing agent for more than two thousand years. It is used for washing clothes. We use toilet soaps in the form of solid cakes or in the solution form. Can you think of any other material which can be used for washing clothes ?

Activity 7.3

- Collect some ash obtained by burning straw or dried plantain leaves or dried stems of pea, cowpea etc, in a beaker.
- Add sufficient water to leach it and stir. Allow it to settle for some time.
- Filter the mixture.
- Soak your dirty handkerchief in the filtrate for some time and wash it.
- Does the hadkerchief become clean ?

The ash is rich in carbonates of potassium and sodium. The solution is actually alkaline and therefore, it can remove oil and grease from dirty clothes and linens.

Soap is made from oil or fat which are esters of higher fatty acids and glycerol. When fats and oils are heated with a solution of sodium hydroxide, they are decomposed (hydrolysed) to form sodium salt of the fatty acid and glycerol. An example is given below:



$$\begin{array}{l} CH_2-OOCC_{15}H_{31} \\ | \\ CH-OOCC_{15}H_{31} + 3NaOH \longrightarrow 3C_{15}H_{31}COONa + \begin{array}{c} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array} \\ | \\ CH_2-OOCC_{15}H_{31} \end{array}$$

Or $(C_5H_3\ COO)_3\ C_3H_5 + 3Na\ OH \longrightarrow 3C_{15}H_{31}COONa + C_3H_5(OH)_3$

The soap is precipitation by the addition common salt. It is called salting out of soap. The soap is separated from the mixture by filtration and the filtrate is used for the recovery of glycerol. The soap is then mixed with colours, perfumes etc. and cast into various shapes for use.

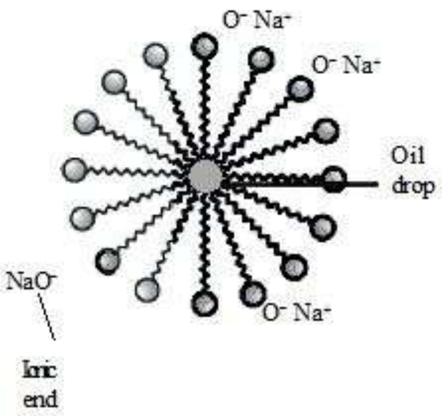


Fig. 7.2. Formation of Micelles

Activity 7.4.

- Take two test tubes and label them A and B.
- In each of them, put 10mL of water and two drops of cooking oil
- To the tube A add a few drops of soap or detergent solution.
- Shake both the test tubes vigourouslx y closing the month of the tube with your thumb. After some time leave the tubes undisturbed.
- In which test tube the oil layer appears again? Why ?

This activity demonstrates the cleansing action of soap or detergent. Dirts are oily in nature and oil is not soluble in water. The molecules of soap which are sodium salt of long chain fatty acid have two ends. One end which is water soluble is ionic and the other end is non-ionic hydrocarbon part which is fat or oil soluble. The soap molecules, thus form structures called micelles (Fig. 7.2) where the hydrocarbon end lies inside the oil drop and the ionic-end lies in the aqueous region. When the dirty cloth is soaked in soap solution and then beaten, the oily drop is converted into innumerable pieces on being pulled out by the soap melecules. Thus the dirt (oil) is passed into water and the cloth is washed clean.

Now a days detergents have replaced soap for washing cloths. Detergents are of many types. They are generally ammonium or sodium sulphonate salts of long chain hydrocarbons which are generally obtained from petroleum. A typical example is $C_{17}H_{35}–OSO_3Na$. The cleansing action of detergents is similar to that of soaps. One advantage of detergent is that it can form copious lather even with hard water and therefore, washes clothes more effectively. Soap forms insoluble scum with hard water which contains calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. This is due to the formation of calcium and magnesium salts of fatty acids. However, one disadvantage of synthetic detergents is that , they are not biodegrable. Therefore, they may pollute soily river, take and other water bodies. Soaps are biodegradable.

Let us answer these

1. Why are beating, scrubbing or agitation required while washing clothes ?
2. Device a simple method for detection of hard or soft water.
3. Can detergent be used to detect hard water ?

SUMMARY

- We use common salt for the preparation of food daily.
- Rock salt is natural common salt.
- Brine wells are available in Manipur.
- A mixture of crushed ice and common salt is called freezing mixture.
- NaCl is a starting material for the manufacture of NaOH, Na_2CO_3, $NaHCO_3$, and Na_2SO_4.
- Cl_2, H_2 and NaOH are the products obtained from the electrolysis of NaCl.
- Bleaching powder is prepared by passing chlorine over slaked lime.
- Bleaching powder is a strong antiseptic and bleaching agent.
- The bleaching and antiseptic properties of bleaching powder are due to Cl_2 liberated on hydrolysis

- Baking powder is $NaHCO_3$ mixed with some edible organic acid.
- Washing soda is prepared from NaCl solution.
- Washing powder contains 10 molecules of water of crystallisation.
- Water of crystallisation may be removed by heat
- Anhydrous salts may regain colour by absorbing water.
- Plaster of Paris is prepared from gypsum.
- Soaps and detergents are used for cleansing.
- Soap is sodium or potasium salt of long chain fatty acids.
- Detergents are ammonium or sodium sulphonates of long chain hydrocarbons.

EXERCISES

1. How is pure sodium chloride obtained from the impure salt ?
2. What is the product obtained by reacting NaOH with HCl ?
3. How is freezing mixture made ?
4. Give important uses of sodium chloride.
5. Name the products obtained when aqueous sodium chloride is electrolysed.
6. What are the main uses of chlorine ?
7. What is the use of sodium hypochlorite ?
8. How is bleaching powder prepared ?
9. How does bleaching powder decompose in moist air ?
10. Give the important use of bleaching powder
11. Give a method for obtaining sodium hydrogen carbonate.
12. What happens when $NaHCO_3$ reacts with dil HCl ?
13. What is salt cake ?
14. Describe Solvay process.
15. What is the colour of anhydrous copper sulphate ?
16. What are green vitriol and blue vitriol ?
17. How is plaster of Paris made ?
18. What is the difference between soap and detergents ?

★★★★★★

CHAPTER 8

ELECTRICITY

Electricity is the most important, convenient and controllable form of energy in the modern times. It can be easily converted to light, heat and mechanical energies for using in our homes for-lighting ; operating fans, washing machine etc. It is also used in schools, hospitals, industries and so on. In this chapter we shall study to answer some basic questions viz. what is the basis of electricity ? How does electric current flow in electrical circuits ? What are the factors that affect the flow or regulate the current in electrical circuits ? We shall also discuss the application of heating effect of electric current in household electric appliances. In fact, it is now difficult to imagine a world without electricity.

8.1 Electric Charge; Current and Circuit

The word electricity means the energy associated with electric charges such as electrons either stationary or in motion. We also know that in air current and water current in rivers – air particles and water particles are flowing respectively. Likewise electric current is said to flow in a wire of conductor, if the electric charges flow continously through it. Let us take up an example. In a torch, you have seen that there are cells(or a battery when placed in proper order) to provide the flow of electric charges i.e. to constitute an electric current through the bulb. Such a current makes the bulb to glow. We have also observed that the bulb glows giving out light only when the switch of the torch is on. What is the function of the switch? Now, you know that a switch provides a conducting link for the electric current between the cell and the bulb. **Such a continuous and closed path of an electric current is called an electric circuit**. When the switch of the torch is turned off the bulb does not glow because the circuit is broken.

The electric current is expressed by the quantity of charge flowing through a particular area in unit time i.e. it is the rate of flow of electric charges through the conductor. Thus, larger the rate of flow of charge the greater is the current.

8.1.1 Direction of Electric Current

When electricity was invented, a long time back, two types of charges : positive and negative charges were known. But electron was not discovered at that time. So, electric current was considered to be the flow of positive charges and this direction was taken to be the direction of electric current. **Thus the conventional direction of electric current is from positive terminal of a cell or battery to the negative terminal through the outer circuit.** So in circuit diagrams you will see an arrowhead on the connecting wire pointing from the positive terminal of the cell or battery towards the negative terminal. In circuits using metallic wires, electrons constitute the flow of charges and actual direction of electron flow is from negative terminal to the positive terminal of the cell or battery which is opposite to the direction of conventional current.

8.1.2 Expression of Electric Current

Amount of charge flowing through a given cross-section of a conductor per unit time constitutes electric current. If a net charge 'Q' flows across any cross-section of a conductor, perpendicular to the direction of current flow, in time 't' then the current 'I' through the cross-section is $I = \frac{Q}{t}$ . . . 8.1

The SI unit of electric charge is coulomb (C) while that for electric current is ampere(A), named after the French scientist, Andre-Marie Ampere (1775–1836). Thus one ampere of electric current is constituted by the flow of one coulomb of charge per second, that is given by $1\,\text{A} = \frac{1\,\text{C}}{1\,\text{s}}$

(Since an electron possesses negative charge of 1.6×10^{-19} C, 1C of charge is equivalent to the charge contained in nearly 6×10^{18} electrons)

The electric current in a circuit is measured by an instrument called **ammeter**. It is always connected in series in a circuit. Figure 8.1 shows the schematic diagram of typical electric circuit comprising a cell, a torch light bulb, an ammeter and a switch in the form of a plug key. It may be noted that the electric current flows in the circuit from the positive terminal of the cell through the bulb and ammeter.

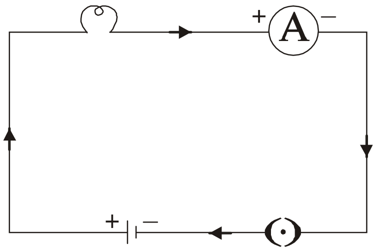


Figure 8.1 A schematic diagram of an electric circuit

Smaller quantities of current are expressed in milliampere ($1mA=10^{-3}$ A) or in microampere ($1A=10^{-6}$ A), or in nanoampere($1nA=10^{-9}$ A).

Example 8.1 **A current of 0.4 A is made to pass through an electric circuit for 15 minutes. Find the amount of electric charge that flows through the circuit.**

Solution We are given, I = 0.4 A; t = 15 min = 15 × 60s.

From Eq (8.1), we have

$$
\begin{aligned}
Q &= I\,t \\
&= 0.4\text{ A} \times (15 \times 60)\text{s} \\
&= 4 \times 15 \times 6 \text{ As} = 360 \text{ C.}
\end{aligned}
$$

Try to Answer

1. **What do you mean by an electric circuit ?**
2. **Define one ampere of current.**
3. **Calculate the number of electrons in 4.8 C of electric charge.**

8.2 Electric Potential and Potential Difference

The charges do not flow in a metallic wire by themselves just as water in a perfectly horizontal pipe or tube does not flow by itself. Then we can put a question – What makes the electric charges to flow ? In order to answer let us consider the analogy of flow of water in a pipe. When one end of the pipe is connected to a tank of water which is kept at a higher level than the other end of the pipe then water flows out. This flow is due to the pressure difference between the two ends of the tube, caused by gravity. For flow of charges in a conducting wire, say copper wire, gravity has no role to play but the electrons move only if there exists a difference of electric pressure along the conductor or conducting wire. This difference of electric pressure is called the **potential difference**. This difference of potential is generated by a battery, consisting of one or more cells. The chemical action within such cells generates the electric potential difference between its terminals, even when no current is drawn from it i.e. when no electric circuit is connected to the cell. When the cell is connected to an electric circuit, the potential difference sets the charges (electrons) in motion within the conductor and produces an electric current. In order to maintain the current in a given circuit, the cell has to expend its stored chemical energy.

Note that in metals each atom allows some of its outermost electrons to detach from it and to move quite freely in the whole of the metal. When an electron is detached from the atom, the atom becomes positively charged. Such a charged atom is called a **positive ion**. So the metal can be visualised as collection of positive ions fixed in their respective positions and a large number of free electrons moving here and there. These free electrons are not bound to any specific atom or location but wander throughout the body of the metal with random speeds and directions, as shown in figure 8.2.

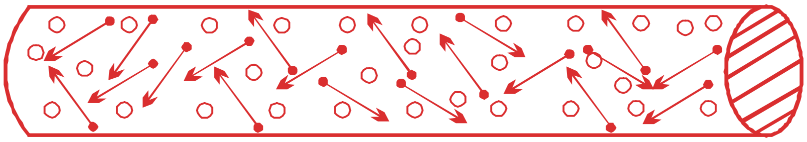


Figure 8.2

A schematic diagram of random motion of electrons

o ⟶ positive ion
• ⟶ electron.

When a potential difference is maintained across the metal, the electrons move in a more systematic way and in a specific direction towards the positive terminal of the cell or battery in the circuit. The schematic diagram is shown in figure 8.3.

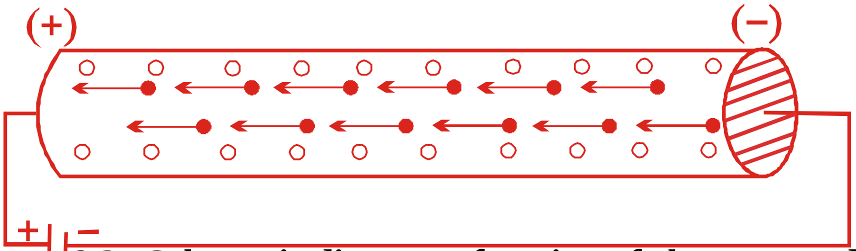


Figure 8.3 Schematic diagram of motion of electrons under applied potential difference.

o ⟶ positive ion
• ⟶ electron.

The electric potential difference between two points in an electric circuit carrying current is defined as the amount of work done to move a unit charge from one point to the other.

Thus, potential difference (V) between two points = $\frac{\text{Work done (W)}}{\text{Charge (Q)}}$

$\frac{W}{Q}$ $\frac{W}{I t}$

$V = \quad =$ 8.2

The SI unit of potential difference is one volt (V), named after Alessandro Volta (1745–1827), an Italian physicist. One volt is the potential difference between two points in a current carrying conductor when one joule of work is to be done in order to move a charge of one coulomb from one point to the other.

Thus, $1\text{volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$

OR, $1\text{V} = \frac{1\text{ J}}{1\text{ C}} = 1\text{ J/C} = 1\text{ JC}^{-1}$ 8.3

The potential difference is measured by means of an instrument called **voltmeter**. This instrument is always connected in parallel across the points whose potential difference is to be measured.

Example 8.2 **How much work will be done in moving a charge of 2.5C across two points having a potential difference of 6V ?**

Solution Amount of charge Q flowing between the two points = 2.5 C

Potential difference between the points, V = 6 volt.

Thus, the amount of work done in moving the charge is

$$\begin{aligned} W &= VQ \\ &= 6\text{ volt} \times 2.5\text{ C} \\ &= 15.0\text{ J} \end{aligned}$$

Example 8.3 **Calculate the amount of work done by a battery in a circuit where a current of 2 A flows for 1 min between two points of potential difference 2V.**

Solution Quantity of charge flowing in 1 min is $Q = 2\text{A} \times (1 \times 60)\text{s}$

$= 120\text{C}$

Potential difference = 2V

Thus, the amount of work done,

$$W = VQ = 2\text{V} \times 120\text{C} = 240\text{ J}.$$

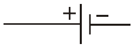
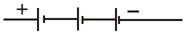
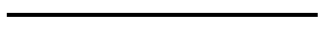
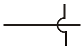
Try to Answer

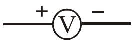
1. What is the device that can maintain a potential difference across a conductor?
2. What is meant by saying that the potential difference between two points is 1 volt ?
3. How much energy is given to 2 coulomb of charge passing through a cell of 1.5 volt?

8.3 Electrical Symbols

It is convenient to draw a schematic diagram for electrical circuits in which different components used in the circuit are represented by symbols. Conventional symbols for commonly used electrical components are given in Table 8.1.

Table 8.1 *Symbols of some commonly used components in electrical circuit diagrams*

Sl. No	**Components**	**Symbol**
1.	An electric cell	
2	A battery (a combination of cells)	
3.	Connecting wire	
4.	An open switch	
5.	An open plug key	
6.	A closed switch	
7.	A closed plug key	
8.	A wire joint	
9.	Wires crossing without contact	
10.	Electric bulb	

11.	A resistor of fixed resistance	
12.	Variable resistance or rheostat	 or 
13.	Ammeter	
14.	Voltmeter	
15.	Galvanometer	
16.	Electric fuse	

8.4 Ohm's Law

So far, we have studied potential difference as the cause of current flow along a conductor. Let us explore the relationship between potential difference across a conductor and current flowing through it, with the help of an Activity.

Activity 8.1

Take a nichrome wire of suitable length say 0.5 m, an ammeter, a votlmeter, a plug key and four torch cells of 1.5 volt each. Set up a circuit as shown in figure 8.4

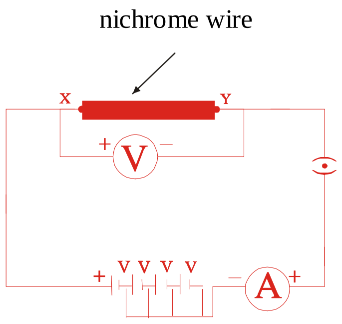


Figure 8.4 Electric circuit for the Activity 8.1

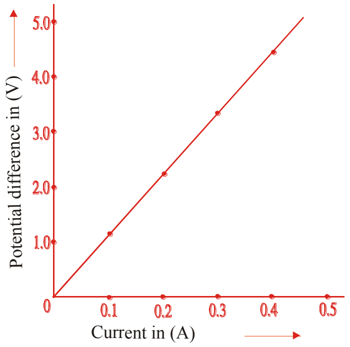


Figure 8.5 V–I Graph for a wire of metal

First use one cell only as the source in the circuit. Note the reading in the ammeter for the current I and the reading in the voltmeter for the potential difference V across the nichrome wire in the circuit.

Enter or tabulate the readings in the Table 8.2 given below.

In the next step, connect two cells in the circuit and note the respective readings of the ammeter and votmeter and enter the readings in the Table 8.2.

Repeat the above steps using three cells and then four cells in the circuit in turn. Calculate the ratio of voltage (V) across the nichrome wire to current (I) flowing through the wire for each step of observation.

Table 8.2

Step No.	Number of cells in the circuit	Current through the nichrome, I in ampere	Potential difference across the nichrome wire, V in volt	$\frac{\text{V volt}}{\text{I ampere}}$
1	1			
2	2			
3	3			
4	4			

In this Activity you will see that the ratio of V to I almost remains the same for each step of observation. Now plot a graph of the potential difference (V) against current (I) . The graph will be a straight line passing through the origin as shown in Fig. 8.5 Thus the value of is a constant ratio. This is Ohm's law.

Since the unit of potential difference is one volt (V) and that of the current is ampere (A), the ratio is in .

In 1827, a German physicist George Simon Ohm (1787 – 1854) found out the relationship between the current flowing through a metallic conductor (wire) and the potential difference across its ends. **He stated that at a constant temperature the current flowing through a conductor is directly proportional to the potential difference across its ends. The above statement is called Ohm's law.**

If 'I' is the current flowing through a conductor and 'V' is the potential difference (or voltage) across its ends then according to the above law :

$$V \propto I$$

OR $\frac{V}{I}$ = a constant (R) 8.4

OR V = I R 8.5

In equation (8.4), R is a constant called 'resistance' of the conductor. The value of this constant depends on the nature of the material of the conductor, length, area of cross-section and temperature of the conductor. It is the property of a conductor to resist the flow of charges through it. In other words, every conductor (metal) offers some resistance to the flow of current and to increase the amount of current through it proportionally, more energy per coulomb of charge is required. The SI unit for resistance of a conductor is ohm, represented by the Greek letter . The above equation can also be written as :

$R = \frac{V}{I}$ 8.6

If potential difference across the ends of a conductor is 1 volt and the current through it is 1 ampere, then its resistance R, at that temperature is 1 ohm.

Thus, $1\,\Omega = \frac{1V}{1A}$

From equation 8.5, we get, $I = \frac{V}{R}$ 8.7

From equation 8.7, it is obvious that the current through a conductor is inversely proportional to its resistance. If the resistance is doubled the current gets halved and vice-versa. In practice it is necessary to vary the current in an electric circuit. A component or a device is generally used to regulate the quantity of current in the circuit without changing the voltage of the source. This device is called **rheostat**. Thus a rheostat is used to change the resistance in the circuit.

8.4.1 Resistance of conductors

Activity 8.2

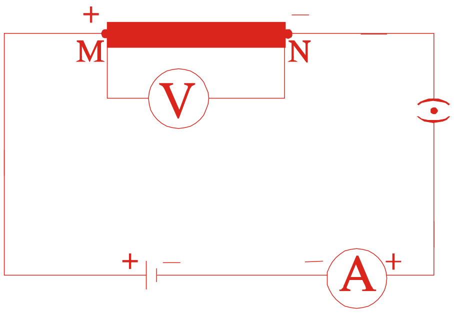


Figure 8.6

Make the connection as shown in Fig. 8.6. Then place wires each of 50cm in length and having the same area of cross-sections but of different metals e.g. iron, copper, nichrome, silver, aluminium etc. in turn across MN. Bulbs of differents wattages may also be used in the gap MN.

Complete the circuit by connecting the iron wire in gap MN. Plug the key and note down the readings of ammeter and voltmeter. Take out the key from the plug as soon as the readings are noted.

Replace the iron wire by copper wire in the gap MN and note the readings of the ammeter and voltmeter as in the above step.

Now, repeat the above step with torch bulb in the gap MN of the circuit.

Are the ammeter and voltmeter readings differ for different wires and for different bulbs connected in the gap MN ?

What do the above observations indicate ?

Repeat this Activity by keeping any other wires in the gap and note down the readings of the ammeter in each case. Analyse the observations.

In the above Activity you will notice that the current is different for different components. This indicates that the conductors having identical dimensions and temperature but of different materials offer resistance to the flow of current to different degrees. This means that certain components offer easy path for the flow of current while the others resist the flow. In other words, certain material components offer more resistance to the flow of electric current than others. This property of a material component due to which it opposes the flow of electric current through it is called electrical resistance or simply **resistance** of the conductor.

In the above we have learnt that the motion of electrons in the body of the conductor in an electric circuit constitutes an electric current. However, the motion of electrons in a conductor are not completely free. Their motions are restrained as they collide with other electrons and with the atoms and ions present in the body of the conductor.

Thus, the motion of electrons through a conductor is retarded by its resistance and plays an important role in electric circuits. Any component of a given size in the circuit which offers low or negligible resistance is a good conductor. Sometimes, components of a circuit are designed to offer high or appreciable resistance to the flow of current. They are called the **resistors**. A component of identical size that offers a higher resistance is a poor conductor. An insulator of the same size offers even higher or infinite resistance to the flow of current.

8.5 Factors on which the Resistance of a Conductor Depends

There are a number of factors on which the resistance of a conductor at a constant temperature depends. To study those factors, let us take up the following Activity.

Activity 8.3

Connect a cell, an ammeter, a nichrome wire of fixed length, a plug key as shown in a circuit given in Fig. 8.7. Let the nichrome wire be of length '*l*' cm and marked 'X'.

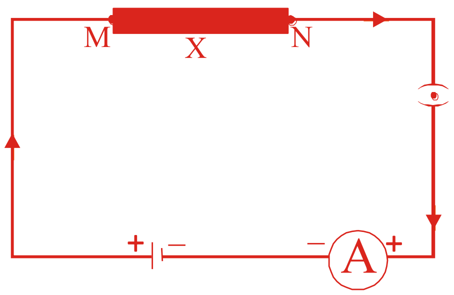


Figure. 8.7(a) Electric circuit to study the factors affecting resistance of conducting wire.

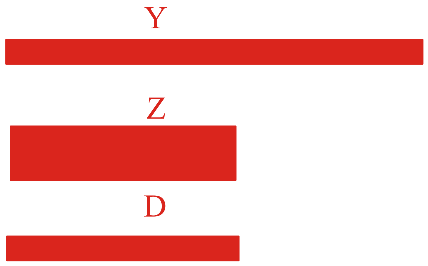


Figure 8.7(b) Different wires

Connecting the gap MN by the sample wire 'X', plug the key and note the current, I_1 A (say) indicated by the ammeter reading.

Replace the nichrome wire 'X' by another wire of nichrome of same thickness but twice the length i.e. 2*l* cm which is marked as 'Y' shown in Fig. 8.7 (b). Record the current I_2 A (say) from the ammeter reading.

Now, replace the wire 'Y' by a thicker nichrome wire marked 'Z' having the same length '*l*' cm as that of the sample marked 'X'. A thicker wire has a larger cross-sectional area. Again record the current I_3 A (say) from the ammeter reading.

In the next step, connect a copper wire marked ‘D’ in Fig. 8.7 (b) in the gap MN of the circuit. The wire ‘D’ has the same length and same cross-sectional area as that of the first nichrome wire marked ‘X’. Record the current I_4 A (say) from the ammeter reading.

After examining the currents in each of the steps, you will notice the difference in the current. This result shows that the current depends on (i) the length of the wire (conductor) (ii) the area of cross-section of the wire (iii) the nature of the material of the respective wires though they have the identical geometrical dimensions.

It is observd that the ammeter reading i.e. the quantity of current decreases to one-half when the length of the nichrome wire is doubled though they have the same cross-sectional areas. The ammeter reading is increased when a thicker wire of the same meterial and of the same length is used in the circuit. A change in the ammeter reading is observed when a wire of different material but of the same length and of the same area of cross-section is used in the circuit.

Using Ohm’s law given in (Eqs. 8.5 to 8.7), we can understand that the resistance of a metallic conductor of a given material at constant temperature is directly proportional to its length (l) and inversely proportional to its area of cross-section (A). That is

$$R \propto l \qquad \ldots\ldots\ldots\ldots \quad 8.8$$

and $$R \propto \frac{1}{A} \qquad \ldots\ldots\ldots\ldots \quad 8.9$$

Combining Eqs. 8.8 and 8.9 we have,

$$R \propto \frac{1}{A}$$

OR, $$R = \frac{\rho l}{A} \qquad \ldots\ldots\ldots\ldots \quad 8.10$$

Thus, $$\rho = \frac{RA}{l} \qquad \ldots\ldots\ldots\ldots \quad 8.11$$

Here (rho) is a constant of proportionality and is called the electrical resistivity of the material of the conductor. The SI unit of ‘’ is m (ohm-metre) and it is characteristic property of the material. In general, the metals and their alloys have low resistivity in the range of 10^{-8} m to 10^{-6}m. They are treated as good conductors of electricity. The substances like rubber and glass which are well known insulators have resistivity of the order of 10^{12} to 10^{17} m. Both the resistance and resistivity of a material vary with temperature.

Note : Ohm’s law does not hold for the flow of currents through electrolytic cells, vacuum tubes, semi-conductor devices and electric discharge tubes. They are called non-ohmic substances.

The electrical resistivity of some substances at 20^0 C are given in Table 8.3 (Need not to memorise but values can be used for solving problems whenever required.)

Table 8.3 : *Electrical resistivity of some materials at 20^0 C.*

Substance	Material	Resistivity (m)
Metals	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.00×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of copper and nickel)	49×10^{-6}
	Manganin (alloy of copper, manganese, nickel)	44×10^{-6}
	Nichrome (alloy of nickel, chromium, manganese and iron)	100×10^{-6}

Insulators	Glass Hard rubber Ebonite Diamond Paper (dry)	$10^{10} - 10^{14}$ $10^{13} - 10^{16}$ $10^{15} - 10^{17}$ $10^{12} - 10^{13}$ 10^{12}

Example 8.4 **A 4.5 V battery is connected to a bulb of resistance 9. Calculate the current through the bulb.**

Solution We have given V = 4.5 V ; R = 9 Ω

From the Eq. 8.7, we get the current through the bulb,

$$I = \frac{4.5V}{9\Omega} = 0.5A$$

Example 8.5 **When a heater draws a current 4A from a battery, the terminal potential difference across it is 24V. What current will the heater draw when it is connected across a battery of 60 V ?**

Solution We are given the potential difference, V = 24V ; current, I = 4A

From Ohm's law, the resistance of the heater, $R = \frac{V}{I} = \frac{24}{4} 6 \quad \Omega$

When the potential difference applied is 60V, the current I' passing through the heater will be

$$I' = \frac{V}{R} = \frac{60V}{6\Omega} = 10\ A$$

Thus, the current through the heater becomes 10 A.

Example 8.6 **The resistance of a wire is 50 at 20^0 C. If the length and diameter of the wire are 1m and 5×10^{-4} m respectively, calculate the resistivity of the material of the wire.**

Solution We are given the resistance R of the wire = 50 Ω ; the diameter 'd' = 5×10^{-4} m and the length '*l*' = 1m.

Thus, from Eq. 8.11, the resistvity of the material of the wire is

$$\rho = \frac{RA}{l} = \frac{R.\pi d^2}{4l} [\ \because \text{the area of cross-section ,} \quad A = \frac{\pi d^2}{4}$$

Substituting the values in the above, we get

$$\rho = \frac{50\times 22\times\left(5\times 10^{-4}\right)^{2}}{7\times 4\times 1} = 9.82\times 10^{-6}\,\Omega\text{m}$$

Thus, the resistivity of the metal at 20^{0}C is 9.82×10^{-6} m.

Eample 8.7 **A wire of certain length has a resistance of 4Ω .The wire is elongated or stretched to double its length. Calculate the new resistance of the wire.**

Solution We are given, R = 4Ω

When the wire is stretched to double its length, the area of cross-section would be half. Thus a wire of length '*l*' and area of cross-section 'A' becomes of length 2*l* and area of cross-section $\frac{A}{2}$ respectively.

Thus, from Eqn. 8.11, we get

$$R = \frac{\rho l}{A}$$

And $R_1 = \dfrac{\rho \times 2l}{\frac{A}{2}}$ Where R_1 is the new resistance.

$$\therefore \quad \frac{R_1}{R} = \frac{4\rho l}{A}\times\frac{A}{\rho l} = 4$$

Hence, $R_1 = 4R = 4 \times 4 = 16\,\Omega$

The new resistance of the wire is 16.Ω

Try to Answer

1. Name the factors on which the resistance of a conductor depends.
2. Through which of the wires – a thick one and a thin one of the same material will current flow easily, when connected to the same battery or cell ? Why ?
3. Suppose the potential difference across an electrical component of fix resistance decreases to half of its former value. What change will occur in the current passing through it ?

8.6 Combination of Resistances (or Resistors)

In the preceding sections, we have learnt about potential difference, current and resistances in simple electric circuits. We have also noticed how the current through a conductor depends upon its resistance and potential difference applied across its ends. In electrical circuits of radio, television and electrical gadgets, we often use resistors in various combinations in order to get the required current in the circuit. There are two methods of joining two or more resistors in a circuit. The methods are (i) series combination and (ii) parallel combination. Figure 8.8 shows an electric circuit in which three resistors of resistances R_1, R_2, R_3 are joined end to end.

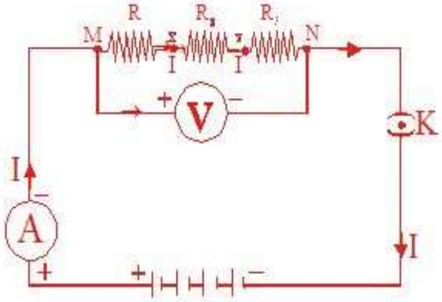


Figure 8.8 Resistors in series

The resistors are connected end to end between the points M and N. Here, the resistors are said to be in series.

Figures 8.9 shows another combination of resistors in which the resistors R_1, R_2, R_3 are connected together between the points M and N of the circuit. Here, the resistors are said to be combined in parallel.

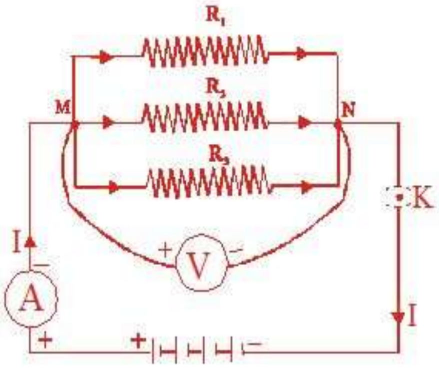


Figure 8.9 Resistors in parallel

8.6.1 Resistors in Series

In order to know the value of the current flowing through the circuit when a number of resistors are connected in series and value of equivalent resistance, let us perform the following Activity.

Activity 8.4

Take three resistors having values like $2\,\Omega$, $4\,\Omega$, $6\,\Omega$ and a battery 12V for performing this activity. Connect them as shown in Fig. 8.8.

Plug the key and note the ammeter reading.

Change the position of ammeter to anywhere in between the resistors. Record the ammeter reading for each of the positions of it.

Try to observe for any change in the value of current through the ammeter.

You will observe that the value of current in the ammeter will remain the same independent of its position in the circuit. This result shows that in a series combination of resistors the current is the same through each of the resistors irrespective of resistance and is equal to the total current of the circuit. Now, note down the reading V volt (say) of the voltmeter.

In the next step, take out the plug key and disconnect the voltmeter. Now insert the same voltmeter across the ends M and X of the resistor R_1 as shown in figure 8.10.

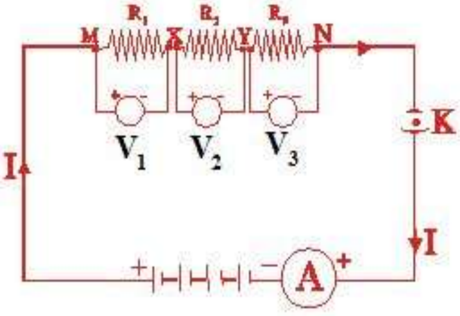


Figure 8.10

Now, plug the key and record the potential difference V_1 across the resistor R_1.

In the same manner, measure the potential difference V_2, V_3 across the resistors R_2, R_3 respectively. Try to observe the relation between V_1, V_2, V_3 and V.

From the record, you will find that the potential difference V is equal to the sum of potential differences V_1, V_2 and V_3. This shows that the total potential difference across a combination of resistors in series is always equal to the sum of potential differences across the indivitual resistors.

Thus, $V = V_1 + V_2 + V_3$ 8.12

Referring to the circuit in Fig. 8.10, let I be the current through the circuit. The current through each of the resistors is also I (from the above Activity). It is now possible to replace the three resistors joined in series by an equivalent single resistor having a resistance R_S such that the potential difference across it is 'V' when the current 'I' through the circuit remains the same.

Applying Ohm's law to the entire circuit, we get

$V = I R_S$ 8.13

Again, applying Ohm's law to the individual resistors, we have,

$$V_1 = I\,R_1 \qquad \ldots\ldots\ldots\ldots \quad 8.14$$

$$V_2 = I\,R_2 \qquad \ldots\ldots\ldots\ldots \quad 8.15$$

$$V_3 = I\,R_3 \qquad \ldots\ldots\ldots\ldots \quad 8.16$$

From Eq. 8.12, $I\,R_S = I\,R_1 + I\,R_2 + I\,R_3$

$$\text{OR} \qquad R_S = R_1 + R_2 + R_3 \qquad \ldots\ldots\ldots\ldots \quad 8.17$$

Hence, we can conclude that when two or more resistors are combined in series, the equivalent or resultant resistance R_S equals to the sum of their individual resistances and R_S is greater than the greatest of the individuals.

8.6.2 Resistors in Parallel

Referring to the circuit given in figure 8.9, let us try to understand the current flowing through each of the resistors and potential difference across each with the help of the following Activity.

Activity 8.5

Make a parallel combination MN of three resistors R_1, R_2, R_3 and complete the circuit connections as shown in the Figure 8.9.

Plug the key and note the ammeter reading as well as the voltmeter reading. The ammeter reading 'I' ampere (say) and voltmeter reading 'V' volt (say) give the total current in the circuit and total potential difference across the parallel conbination MN respectively.

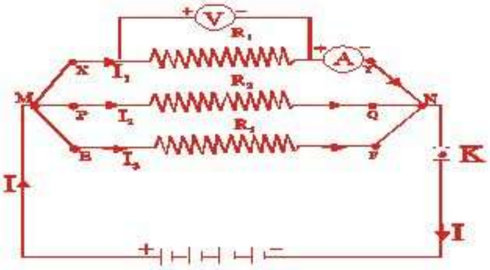


Figure 8.11

Remove the plug from the key, ammeter and voltmeter from the circuit. Then complete the circuit connection as shown in the figure 8.11. Here, voltmeter is connected across R_1 while the ammeter is connected in series to R_1.

Insert the plug in the key and note the ammeter reading, say, I_1 and voltmeter reading V_1, and then remove the plug. Now connect voltmeter across R_2 and ammeter in series to it. Insert the plug and note the reading I_2 of the ammeter and voltmeter reading V_2. Then remove the plug. Repeat the observation for the branch EF and let I_3 and V_3 be the ammeter reading and voltmeter reading respectively. Analyse the relationship between (a) I_1, I_2, I_3 and I (b) V_1, V_2, V_3 and V.

From the Activity, it is observed that the total current I is equal to the sum of the separate currents flowing through each branch of combination.

Thus, $I = I_1 + I_2 + I_3$ 8.18

and $V = V_1 = V_2 = V_3$

It is now possible to replace the three resistors joined in parallel by an equivalent resistor having a resistance R_P (say) such that the total current 'I', from Ohm's law, is given by

$$I = \frac{V}{R_P} \qquad \text{. . . . . 8.19}$$

Again, applying Ohm's law to each branch resistor, we have,

$$I_1 = \frac{V}{R_1}\ ;\ I_2 = \frac{V}{R_2}\ ;\ I_3 = \frac{V}{R_3} \qquad \text{. . . . . 8.20}$$

Combining the Eqs. 8.18, 8.19 and 8.20, we have,

$$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\text{OR} \quad \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \text{. . . . . 8.21}$$

Thus, we may conclude that the reciprocal of the equivalent resistance of a group of two or more resistors connected in parallel is always equal to the sum of the reciprocals of the individual resistances. This means that R_P is less than the least of the resistances in the grouping.

8.6.3 Laws of Combination of Resistances

(i) Series combination :–

(a) The combined resistance of any number of resistors connected in series is equal to the sum of individual resistances.

(b) The same current flows through all resistors irrespective of the value of resistance.

(c) The potential difference across each individual resistor is directly proportional to the resistance.

(ii) Parallel combination :–

(a) The reciprocal of the combined resistance of any number of resistors connected in parallel is equal to the sum of the reciprocal of all the resistances.

(b) The potential difference across each individual resistor remains same, irrespective of the values of the resistance.

(c) The current flowing through each of the resistors is inversely proportional to the value of resistance.

8.6.4 How are the Household Electric Appliances/Components connected to the Mains Supply ?

You have seen different electrical components used in a house. For example, electric bulb, fan, toaster, heater, iron, television, radio receivers etc. They need electric currents of widely different values to operate properly. Thus it becomes obviously impracticable to connect those different components in series, since each of them needs different current to operate properly. Moreover, the total resistance will increase with the increasing number of components and the smaller will be the current flowing through the series arrangement. Thus none of the components may operate, if the arrangement were in series. This is the disadvantage of series combination. Another major disadvantage of series combination is that when one of the components gets fused, the circuit is broken and none of the components will work. Series connection is generally used in 'fairy light' to decorate buildings, temples on festivals and marriage celebrations etc. If the system does not work, it is very difficult and time consuming task for the electricians to locate and replace the dead bulb.

On the other hand, if the above cited components were combined in parallel, the circuit divides the total current to the components acordingly. Since, the total resistance in a parallel circuit is decreased with the increasing number of resistors or components (Eq. 8.21), more and more current will be drawn from the source i.e. mains supply. This is helpful particulary when each component has different resistance and requires different current to operate properly. Another major advantage for parallel connection of electric components is that when one of the components gets fused or fails, the other components are not affected. That is why in the household, the electric wiring is done in parallel circuits.

Example 8.7 **A resistor of 10 Ω is connected in series to an electric bulb of 20 Ω. The combination is connected to a battery of 6V comprising four cells, (Fig 8.12). Calculate (i) total resistance of the circuit (ii) total currrent in the circuit (iii) potential difference across the bulb and the resistor.**

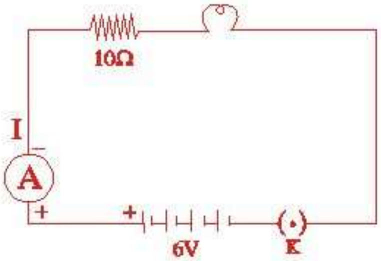


Figure 8.12 An electric bulb and a resistor connected in series to a battery

Solution The resistance R_1 of the bulb = 20 Ω and that of the conductor, $R_2 = 10\,\Omega$

Then the total resistance of the circuit,

$R_s = R_1 + R_2 = 20+10 = 30\ \Omega$

The total potential difference, V = 6V

Applying Ohm's law, the current flowing through the circuit,

$$I = \frac{V}{R_s} = \frac{6V}{30\Omega} = 0.2\text{ A}$$

Again, potential difference across the bulb,

$V_1 = I \times R_1 = 0.2 \times 20 = 4\text{ V}$

And, potential difference across the resistor,

$V_2 = I \times R_2 = 0.2 \times 10 = 2\text{V}$

Here, $V_1 + V_2 = 4V + 2V = 6V$ = the total potential difference across the battey terminal.

Example 8.8 **Consider the circuit shown in (Fig. 8.13). Calculate the potential difference across each resistor.**

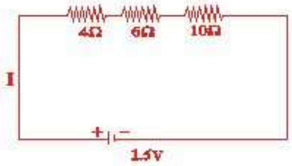


Figure 8.13

Solution The three resistors are in series and the equivalent resistance,

$R_s = 4\,\Omega + 6\,\Omega + 10\,\Omega = 20\,\Omega$

Current through the circuit, $I = \frac{1.5V}{20\Omega} = 0.075A$

The same current of 0.075 A passes through all the resistors.

Applying Ohm's law, the potential difference across the 4 Ω resistor = 0.075 ×4 = 0.3V

across the 10 Ω resistor = 0.075 ×10 = 0.75V

across the 6 Ω resistor = 0.075 × 6 = 0.45V

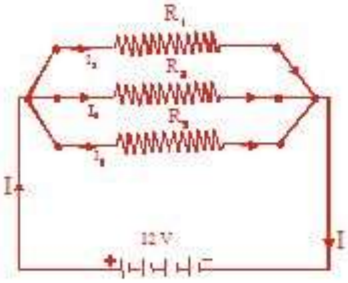


Figure 8.14

Example 8.9 Three resistors $R_1 = 4\,\Omega$; $R_2 = 10\,\Omega$; $R_3 = 20\,\Omega$ are arranged in parallel across a 12V battery as shown in Figure 8.14. Calculate the (i) total circuit resistance (ii) current in the circuit (iii) current through each resistor.

Solution Total circuit resistance, R_p is given by [Eq. 8.21],

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{4} + \frac{1}{10} + \frac{1}{20}$$

$$\text{OR} \quad \frac{1}{R_p} = \frac{5+2+1}{20} = \frac{8}{20} = \frac{2}{5}$$

$$\therefore \quad R_p = \frac{5}{2} = 2.5\,\Omega$$

Current through the circuit, $I = \frac{V}{R_p} = \frac{12}{2.5} = 4.8\text{ A}$

Applying Ohm's law, the current

$$\text{through } R_1,\ I_1 = \frac{V}{R_1} = \frac{12}{4} = 3.0\text{ A}$$

$$\text{through } R_2,\ I_2 = \frac{V}{R_2} = \frac{12}{10} = 1.2\text{ A}$$

$$\text{through } R_3,\ I_3 = \frac{V}{R_3} = \frac{12}{20} = 0.6\text{ A}$$

Since the resistors are in parallel, the total current is $I_1 + I_2 + I_3$

$= (3.0 + 1.2 + 0.6) = 4.8\text{ A}$

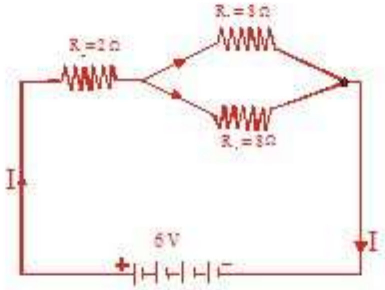


Figure 8.15

Example 8.10 Find the current supplied by the battery in the circuit shown in Fig. 8.15 .

Solution Suppose we replace the parallel combination of R_2 and R_3 by R_p, which is the equivalent resistance.

Then from Eq. 8.21 we have,

$$\frac{1}{R_p} = \frac{1}{8} + \frac{1}{8} = \frac{2}{8} = \frac{1}{4}$$

$\therefore R_p = 4\,\Omega$

Thus, the total resistance,

$$R = R_1 + R_p = 2\,\Omega + 4\,\Omega = 6\,\Omega$$

To calculate total current supplied by the battery, we use Ohm's law and get

$$I = \frac{V}{R} = \frac{6}{6} = 1A$$

8.7 Heating Effect of Electric Current

In section 8.2 we have learnt that the potential difference between the terminals of the cell is generated with the help of chemical reaction in it. This potential difference sets the electrons in motion along a definite direction. As a result, current flows through conductor and resistor or a system of resistors connected to the battery. At the same time the cell which is the source of electrical energy has to keep expending its stored energy. Where does the energy go ? Out of the total energy expended, a part may be consumed in maintaining the current for useful work such as in rotating the blades of an electic fan while the remaining part may be expended in the form of heat energy resulting to raise of temperature of electric gadgets viz. television, fan etc. As an example, you must have observed the rise in temperature of table fan or television when used continuously for longer time. On the other hand , if the electric circuit comprises purely resistive components i.e. resistors only, the source energy of the battery gets dissipated in the form of heat energy. This is called the heating effect of current. Because of this effect, when an electric current is passed through nichrome wire which have high resistance, it becomes very hot and produces heat. In other words, the heating effect of current is obtained by the transformation of electrical energy into heat energy. This effect is utilised in devices like electric heater, electric kettle and cooker, electric iron etc.

Imagine a resistor R connected across the terminals of a battery. Let I be the current flowing through it when the potential difference across it is V, shown in the Fig. 8.16. The amount of electrical work done in moving the charge Q through a potential difference V is VQ. If 't' is the time during which the amount of charge Q flows through, as explained above, the source must supply an energy equal to VQ.

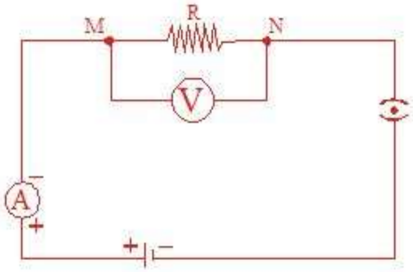


Fig. 8.16.

Hence the energy input to the circuit by the source (i.e. battery) per unit time is

$$\frac{VQ}{t} = VI \qquad \ldots\ldots\ldots\ldots \quad 8.22$$

Here, $I = \frac{Q}{t}$

In other words the energy supplied to the resistive circuit by the battery in time *t* is VI t. Thus, the energy supplied gets dissipated as heat in the resistor. That is, the amount of heat 'H' produced in time 't' is

$$H = VIt$$

$$= I^2Rt \qquad \ldots\ldots\ldots\ldots \quad 8.23$$

[From Ohm's law, (Eq 8.5), V = IR]

When V is in volt, I is in ampere, t is in second and H is in joule.

The above relation is known as Joule's law of heating.

The law states that heat produced in a resistor is directly proportional to

(i) the square of the current for a given resistance

i.e. $H \propto I^2$ when R is constant.

(ii) the resistance for a given current

i.e. $H \propto R$ when I is constant.

(iii) the time for which the steady current flows through the given resistance i.e. $H \propto t$ when R and I remain constant.

For using the Eq. 8.23, the current through the resistor is calculated from the relation $I = \frac{V}{R}$

8.7.1 Applications of Heating Effect of Electric Current

Since electrical conductors have resistance, whether large or small, the generation of heat in a conductor is an inevitable consequence. In electrical circuits, the inevitable heating can increase the overall or ambient temperature of the components and may lead to alter their properties. In most of the circuits, radiating devices are used to reduce the excessive heating.

On the other hand heating effect of electric current has many useful household applications. The appliances such as electric toaster, electric iron, electric oven, electric cooker, electric kettle, electric immersion heater are some of the familiar devices based on Joule's heating.

The heating effect of electric current is utilised in electric bulbs for producing light. When electric current passes through a thin, high resistance tungsten wire called the filament of the bulb, the filament becomes white hot since it retains as much of the heat generated as is possible and emits light. Since the melting point of tungsten is about 3380^0 C, it does not melt inside the bulb. The filament is also thermally isolated by using insulating supports. The bulbs are usually filled with chemically inactive nitrogen and argon gases at low pressure. This prolongs the life of the filament. A larger part of the power consumed by the filament appears as heat while a smaller part of it is in the form of light radiated. It must be noted that the same amount of electric current flowing through the filament of tungsten produces enormous heat but negligible heat is produced in the connecting copper wires. This is because of the fact that tungsten filament has very high resistance whereas connecting copper wires have very low resistance.

Another important and common application of heating effect of electric current is **electric fuse** in electric circuits. When the current in electric circuits and appliances rises too much, the fuse wire gets heated to such an extent that it melts and breaks the circuit. Thus, a fuse wire protects the circuit components. The fuse wire is placed in series with the device. The fuse wire is made of a metal or alloy of **low melting point** and of **high resistivity**. A cheaper varity of fuse wire is made of an alloy of tin and copper. The thickness and length of fuse wire depends on the maximum current permissible through the circuit. The fuse wire is generally encashed in a cartridge of procelain or similar material with metal ends and with a marking of rated current as 0.3A, 0.5 A, 1A, 2A, 3A, 5A, etc. As an example, if an electric appliance is of maximum current 4.5A then a 5 A fuse must be used.

8.8 Electric Power

In class IX, you have studied that the rate of doing work is power. In one sense, it is also the rate of consumption of energy. Equation (8.22) gives the rate at which electrical energy is dissipated or consumed in an electric circuit. Thus the electric power P is given by

$$P = VI$$

$$\text{OR,} \quad P = IR \times I = I^2 R = \frac{V^2}{R} \quad \ldots\ldots\ldots\ldots \quad 8.24$$

The SI unit of power is watt (W). 1 watt is the power consumed by a device that carries 1A of current when operated at a potential difference of 1V.

$$\begin{aligned} \text{Thus, } 1\,\text{watt(W)} &= 1\text{ volt (V)} \times 1\text{ ampere (A)} \\ &= 1\text{VA} \end{aligned}$$

The unit 'watt' is very small. In actual practice a much larger unit called kilowatt (kW) is used. 1 kW = 1000W. Since the electrical energy is the product of power and time, the unit of electrical energy is watt hour (Wh) which is the energy consumed when 1W of power is used for 1 hour. The commercial unit of electrical energy is 'kilowatt hour' (kWh) and is commonly known as one unit of energy.

$$\begin{aligned} 1\text{ kWh} &= 1000\text{ watt} \times (60 \times 60)\text{ second} \\ &= 3.6 \times 10^6\text{ watt second} \\ &= 3.6 \times 10^6\text{ joule (J)} = 3.6\text{ MJ} \end{aligned}$$

Note : We pay the electricity department for providing electrical energy to move electrons through the houshold electric gadgets like bulb, fan, motor for water pump, television etc. In fact electrons are not consumed in an electric circuit. We pay for energy that we use.

Try to Answer

1. Why does the connecting wires i.e. the cord of an electric iron or an electric heater not glow while the heating element glows ?

Example 8.11 **A potential difference of 250 V is applied across a resistance of 500 Ω in an electric iron. Calculate (i) the current through the resistor (heating element) (ii) power of the electric iron (iii) heat energy produced in joule in 30 seconds.**

Solution (i) The current through the resistor can be calculated by using Ohm's law :

$$\text{Thus, the current } I = \frac{V}{R} = \frac{250V}{500\Omega} = 0.5A$$

(ii) The power P $= VI$

$= 250 \times 0.5$ VA or J/s or Watt

$= 125$W

(iii) The heat energy produced can be calculated by using the formula

$$H = I^2 \times R \times t$$
$$= (0.5)^2 \times 500 \times 30$$
$$= 0.25 \times 500 \times 30$$
$$= 25 \times 5 \times 30$$
$$= 3750 \text{ J}$$

Example 8.12 **An electric motor marked (or rated) 750 W operates 8 hours/day in a workshop. What will be the cost of energy to operate it for one month (i.e. 30 days) at Rs 3.00 per unit of energy ?**

Solution Total energy consumed in 30 days would be

750 W × 8 hours/day × 30 days

$= 750 \times 8 \times 30$ Wh

$= 180000$ Wh

$= 180$ kWh

Thus, the cost of energy for 30 days is 180 kWh × Rs 3.00/kWh = Rs 540.00

POINTS TO REMEMBER

i. The motion of electrons through a conductor constitutes the (flow of) electric current.

ii. The direction of current is taken opposite to the direction of flow of electrons.

iii. The SI unit of charge is coulomb (C).

iv. The SI unit of current is ampere (A).

v. To set the electrons in motion through an electric circuit, a cell or a battery is required. A cell or a battery generates a potential difference across its terminals.

vi. The SI unit of potential difference is volt (V).

vii. The resistance is an inherent property that resists the flow of electrons in a conductor. Resistance controls the magnitude of current.

viii. The SI unit of resistance is Ohm (Ω).

ix. Ohm's law – The potential difference across the ends of a metallic wire is directly proportional to the current flowing through it, provided its temperature remains constant.

x. The resistance of a conductor is directly proportional to its length ;inversely proportional to its area of cross- section and depends on the nature of the material of the conductor.

xi. The resistivity of a conductor or an alloy of metals is independent of the geometrical dimensions but depends on the nature of material and temperature of it.

xii. When two or more resistors are combined in series, the equivalent resistance is equal to the sum of their individual resistances. The equivalent resistance, R_s is greater than the greatest of the individuals.

xiii. When two or more resistors are combined in parallel, the equivalent resistance, R_p is given by $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ ...... and R_p is less than the least among the individuals.

xiv. The electrical energy dissipated in a resistor is given by

$$W = V \times I \times t = I^2 Rt = \frac{V^2}{R}.t = \text{power} \times \text{time of current flow.}$$

xv. The SI unit of power is watt (W).

xvi. The commercial unit of electrical energy is kilowatt hour (kWh) ; $1\text{kWh} = 3.6 \times 10^6$ J.

EXERCISES

1. 3×10^{17} electrons cross in 30 seconds through an area. What is the electric current? (1.6×10^{-3} A)

2. The potential at a point is 20V. Calculate the amount of work done to bring a charge of 0.5 C from infinity to this point. (10 J)

3. A potential difference of 20V appears across the ends of a resistor when 2.5 A of current is passed through it. What is the resistance of the resistor? ($8\,\Omega$)

4. How much charge flows through a wire carrying 2.5 A of current in 20 minutes? (3×10^3 C)

5. A nichrome wire has diameter 1.0mm and resistivity of 1.0×10^{-4} Ω m. Calculate the required length of this wire to make a resistance of $14\,\Omega$. (11cm)

6. A copper wire of certain length has a resistance of $10\,\Omega$. What will be its resistance after stretching to double its length? ($40\,\Omega$)

7. Two resistors of resistances $10\,\Omega$ and $20\,\Omega$ are connected in parallel. A battery supplies a current of 6A to the combination shown in the circuit in Fig. 8.17. Calculate the current in each resistor.

($i_1 = 4$A ; $i_2 = 2$A)

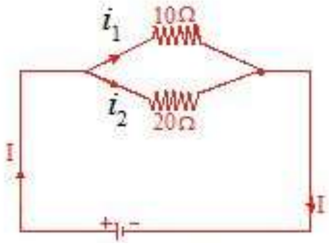


Fig. 8.17

8. You are given three resistors of resistance 1,2,3 ohms. Show by diagrams, how with the help of these resistors you can get resistance of

(i) $6\,\Omega$ (ii) $1.5\,\Omega$ (iii) $2.2\,\Omega$ (iv) $\frac{6}{11}\,\Omega$ (v) $\frac{11}{3}\,\Omega$

9. A resistor of $10\,\Omega$ is combined in parallel with another resistor of 'X' Ω. The resultant resistance of the combination is found to be $3.75\,\Omega$. What is the value of 'X'? ($6\,\Omega$)

10. How many resistors of $200\,\Omega$ each are required in parallel combination, so as to carry 5A on a 200V line supply? (5)

11. Suppose there are a number of bulbs rated at 220V – 100W each. How many bulbs can be connected in parallel across a 220V supply line, if the maximum permisible current is 5A only ? (11)

12. Calulate the anergy transferred in kWh by a 5A current flowing through a resistance of 2 Ω for 40 minutes. (0.033)

13. An electric bulb is rated at 220V – 200W. What is the resistance of the filament ? (242 Ω)

14. Two resistors of 10 Ω and 20 Ω are connected in series acorss a 12V battery. Calculate the power consumed by each of them respectively. (1.6W; 3.2W)

15. If the potential difference between the ends of a fixed resistor is doubled, to how much does the electric power change ? (4 times)

16. Which one will consume more energy – (i) a 300W Television set in 1 hr. (ii) 1000W electric heater in 10 minutes ? (Television set)

17. State whether an electric heater will consume more or less electrical energy per second when the length of its heating element is reduced. Give an explanation for your answer. (More electrical energy)

18. Is it possible to have a particle with charge 2.0×10^{-19} C . (No)

19. A bulb is rated as 250V ; 0.4A. Find its (i) resistance (ii) power - (625 Ω ; 100W)

20. An electric kettle rated at 220V, 2.2 kW, works for 3 hours. Find the energy consumed and current drawn. (6.6 kWh ; 10A)

21. **A piece of nichrome wire of resistance R is cut into four equals parts. These parts are then combined in parallel. If R' is the equivalent resistance of the parallel combination then the ratio $\frac{R}{R'}$ will be**

(A) 16 **(B)** 4 **(C)** $\frac{1}{4}$ **(D)** $\frac{1}{16}$ (A)

22. **The term that does not represent the electrical power of a circuit is**

(A) I^2R **(B)** IR^2 **(C)** $\frac{V^2}{R}$ **(D)** VI (B)

23. **An electric bulb is rated 220V – 100W.The same is operated at 110V due to load shedding. The actual power consumed will be**

(A) 100 W **(B)** 75 W **(C)** 50 W **(D)** 25 W (D)

24. **Two identical heating coils are first connected in series and then in parallel across the same potential difference. The ratio of heat generated in series to that of parallel would be**

(A) 1:1 **(B)** 1:2 **(C)** 1:4 **(D)** 4:1 (C)

25. **A positive charge free to move is released from rest. It will move towards the regions of**

(A) lower potential **(B)** higher potential

(C) equal potential **(D)** any of the above (A)

26. **Joule/coulomb is the same as**

(A) watt. **(B)** volt. **(C)** ohm. **(D)** ampere. (B)

27. **An ammeter is always connected in .... and a voltmeter in .... The proper words for the empty places are respectively.**

(A) series ; series **(B)** parallel ;parallel

(C) series ; parallel **(D)** parallel ; series (C)

28. **Three equal resistances, when combined in series have equivalent resistance of 90. Their equivalent resistance when combined in parallel will be**

(A) 60Ω **(B)** 30 Ω **(C)** 20 Ω **(D)** 10 Ω (D)

29. Why is the series arrangement of components not used for domestic circuits ? Explain.

30. Why are copper and alluminium wires usually used for transmission of electricity ? Explain.

★★★★★★

CHAPTER

9

MAGNETISM

We are familiar with bar magnet and magnetic compass. Any magnet has two poles at its ends. They are north pole and south pole, irrespective of shape. A magnetic compass needle is a very light needle-shaped magnet being pivoted at its centre and free to rotate about the pivot in a horizontal plane. The needle is enclosed in a small case with a fixed glass cover. When no magnet is around the magnetic needle it sets parallel to the south-north direction of the earth. When two magnets are kept close to each other they exert forces on each other, due to the magnetic field created around. Such magnetic field can also be produced by a current carrying conductor. In this chapter you shall study about the fields due to bar magnet and current carrying conductor along with the principle of an electric motor.

9.1 Magnetic Field and Lines of Force

When there is no magnet or magnetic material in the vicinity of a magnetic compass needle, the needle stays parallel to the south-north direction of the earth. If a magnet is brought close to the needle, it deflects in general. This is because the magnet produces a magnetic field and this field exerts a deflecting force on the needle. The direction of the needle from its south pole to the north pole gives the direction of the magnetic field produced by the magnet.

In order to study the above phenomenon you can take up the following Activity.

Activity 9.1

Take a bar magnet, a magnetic compass needle, a white sheet of paper, a wooden board and some drawing pins. Place the magnetic compass on the sheet of paper fixed on the board with the help of drawing pins. Remove any magnet or magnetic material far away from the board. Now, note the position of the magnetic needle as shown in Figure 9.1. Again, suspend the bar magnet from an unspun cotton thread to its middle. The other end of the thread is tied to a stand as shown in Figure 9.2.

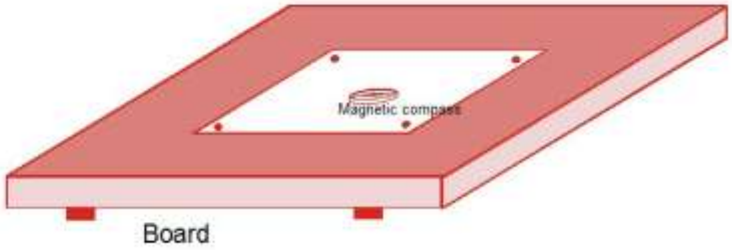


Figure 9.1 A compass needle on the board

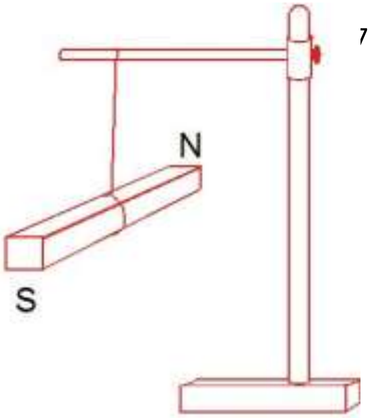


Figure 9.2 A suspended bar magnet

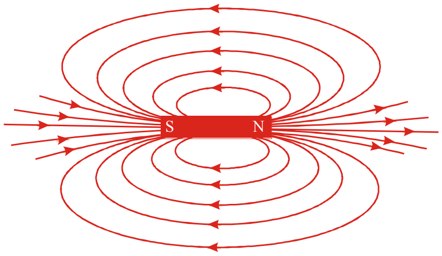
Mark the direction in which it comes to rest. Turn the magnet gently by your hand to point it in another direction and leave it. Notice, the direction in which it finally settles. The tip of the bar magnet which points towards the north is its north pole while the tip that points towards south is its south pole.

1. A freely suspended magnet always points in the south-north direction, (directive property).
2. A magnet always attracts substances like iron, steel, cobalt, nickel, (attractive property).
3. Like magnetic poles repel each other but unlike magnetic poles attract each other.
4. Magnetic poles always exist in pairs (magnetic monopole does not exist).
5. The region surrounding a magnet in which the magnetic force can be detected is called its magnetic field.

Activity 9.2

Place a compass needle close to the north pole. Mark the position of the north pole of the needle. Shift the compass needle so that its south pole falls at the same point where its north-pole was situated in the previous positions, a shown in Figure 9.3 Again, mark the position of the north pole of the needle.

Repeat the procedure till the needle reaches near the south pole of the bar magnet. You will see that the deflection of the needle increases as the needle is nearer to the poles.

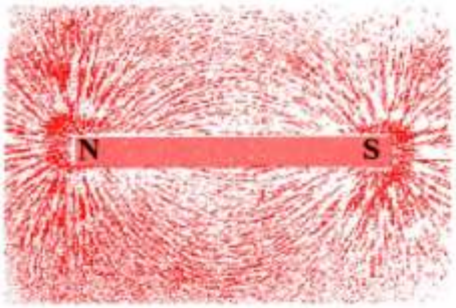


Now connect the marked points using a pencil. A close curve is obtained [It represents a magnetic line of force]. A member of lines of force due to the bar magnet which is shown in Figure 9.4. No two field-lines are found to cross each other. If they cross, the compass needle would point towards two directions at the point of crossing each other – which is not possible.

Figure 9.4

A magnetic line of force is used to indicate the direction of the magnetic field. The field at any point is along the tangent to the line of force at that point.

The magnetic lines of force can also be obtained without using a compass needle. Take a glass plate with a bar magnet as shown in Figure 9.5



Sprinkle iron filings on the glass plate and then gently tap the plate with your finger. You will observe the iron filings arranging themselves in a regular pattern, as shown in the same figure. This regular pattern shows the magnetic lines of force due to the magnet. The relative strength of the magnetic field is shown by the degree of closeness of the field lines, being closer in the stronger regions near the poles.

Figure 9.5

9.2 Magnetic Field produced by Current Carrying Wire

Does an electric current carrying wire behave like a magnet or produce a magnetic field ? Let us perform the following Activity to answer the above questions.

Activity 9.3

Take a straight copper wire XY in an electric circuit as shown in Figure 9.6. The position of the wire XY is set parallel to the needle of the magnetic compass.

Now, pass the electric current through the circuit by inserting key into the plug key. Observe the change in the position of the needle of the magnetic compass. Also observe the position of the needle in the compass after removing the key from the plug.

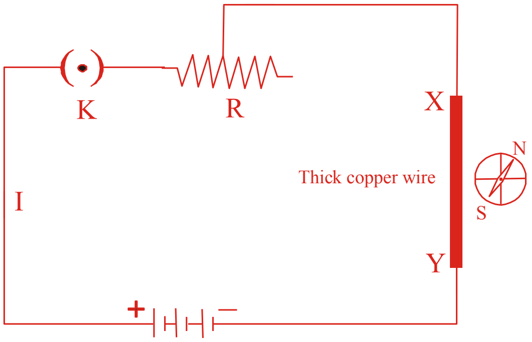


Figure* 9.6 *Compass needle is deflected on passing current

We see that the needle is deflected when the current is made to pass through the circuit and it returns to the earlier position when the current is cut off. What does it mean ? It means that the electric current through the copper wire produces a magnetic field. In other words a current carrying conductor behaves as a magnet. This is called magnetic effect of electric current or electromagnetism. Here we shall study about electromagnetism and electric motors which involves the magnetic effect of electric current.

Hans Christian Oersted, Danish Physicist, in 1820 accidentally discovered that a compass needle placed in parallel and close to a metallic wire carrying electric current got deflected. Through this observation Oersted showed that electricity and magnetism are related phenomena. His research work later created technologies such as electric motor, radio, television etc. The unit of magnetic field strength is named ***oersted*** *in honour of him.*

Repeat the Activity 9.3, by varying the amount of electric current with the help of rheostat 'R'. You will observe that the amount of deflection of needle also changes; being larger with the increase of current through the circuit and vice-versa.

9.3 Magnetic Field due to a Straight Conductor Carrying Current

In order to find the direction of the magnetic field produced by a straight conductor carrying current, let us take up the following Activity.

Activity 9.4

Take a long copper wire, a battery of two or three cells of 1.5 V each and a plug key. Connect accordingly as shown in the Figure 9.7(a).

Adjust the position of the copper wire parallel to and above the needle of the magnetic compass.

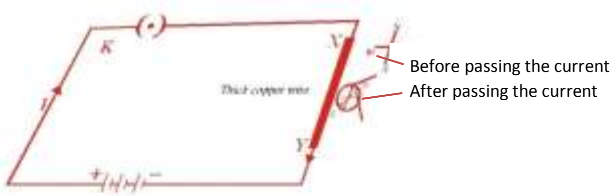


Figure 9.7(a) An electric circuit to observe magnetic effect of current

Insert the key in the plug key and observe the direction of deflection of the north pole of the needle. If the current flows from north to south, the north pole of the compass needle would move towards the east as shown in Figure 9.7(a).

Reverse the cell connection in the circuit as shown in the next Figure 9.7(b). You will observe the change in the direction of deflection of the needle because the direction of current flow is from south to north. That is the needle moves towards west. It means that the direction of magnetic field produced by the current is also reversed.

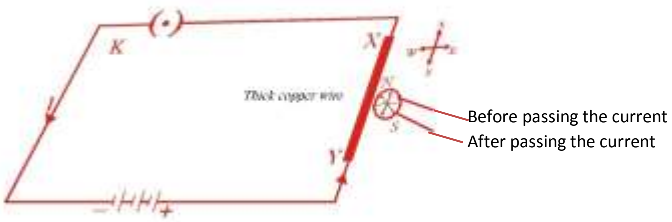


Figure 9.7(b) The deflection of the needle becomes opposite when the direction of current is reversed

9.2.1 Magnetic Field due to a Straight Conductor Carrying Current

From the above section you have learnt that the direction of the magnetic field generated depends on the direction of current flow. You must have an eagerness to know further dependence such as – “Does the pattern depend on the shape or configuration of conductor carrying current”?

To understand that we shall first consider the pattern of the magnetic field around a straight conductor carrying current through the following Activity.

Activity 9.5

Use a battery of 12 V, a variable resistance, an ammeter, a plug key and a long straight thick copper wire of length about 30cm and a rectangular cardboard with a circular hole at the centre.

Insert the copper wire XY through the hole in the card board so that it is normal to the plane of the board. Care must be taken so that the card board does not slide up and down freely.

Then connect the copper wire vertically between X and Y as shown in Figure 9.8,. Sprinkle some iron filings uniformly on the cardboard.

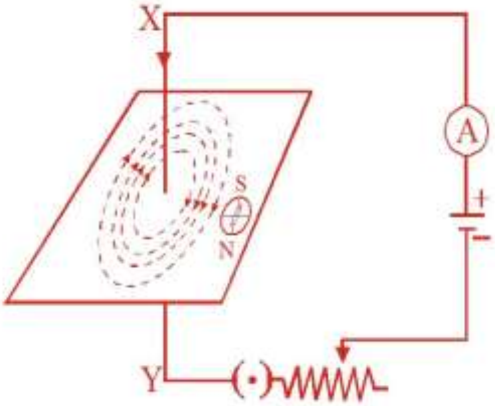


Figure 9.8

Close the key and note the current in the ammeter. The value of the current can be fixed to a desired value by adjusting the position of the variable of the rheostat at a fixed position.

Now, gently tap the cardboard a few times with the finger. In doing so, ensure that the copper wire remains vertical and cardboard is exactly normal to the wire. You will see, finally, that the iron filings align themselves forming a pattern of concentric circles with the copper wire (i.e.hole) as centre.

What do these concentric circles indicate ? They represent the magnetic field lines produced by the current carrying straight conductor.

What about the direction of the magnetic field ? To ascertain the direction, place a magnetic compass at a point over a circle as shown in the same figure. Notice the direction of deflection of needle. The direction of north pole of the needle would give the direction of the magnetic field lines. Mark the direction using an arrow.

Check whether the direction of the magnetic field lines get reversed or not with the change in the direction of current flow along the copper wire. You will observe that the direction of the field lines gets reversed. The strength of such magnetic field decreases as the distance from the wire increases.

9.2.2 Right-Hand Thumb Rule

The direction of magnetic field generated by a straight conductor carrying current can be conveniently found out. Imagine that you are holding a straight conductor carrying current in your right hand such that the thumb points towards the direction of the current, as shown in Figure 9.9. The other fingures will wrap around the conductor which gives the direction of field lines of the magnetic field associated with the straight current.

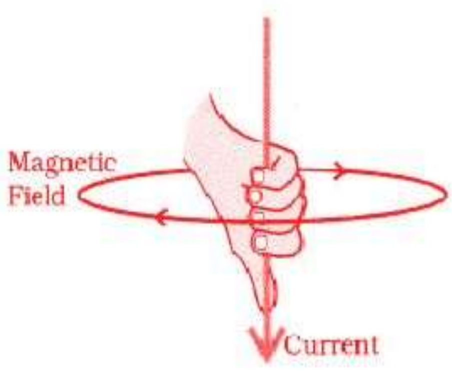


Figure 9.9 Right hand thumb rule

This is known as **right-hand thumb** rule. The above result is also given by Maxwell's corkscrew rule. If we consider ourselves driving a corkscrew using a screw driver, in the direction of advancing current, then the direction of rotation of corkscrew gives the direction of the magnetic field.

Example 9.1 **Suppose a current flows along a horizontal conductor in south to north direction. What will be the direction of the magnetic field at points (i)directly below (ii) directly above it?**

Solution The current is in south to north direction. Applying right-hand thumb rule, the direction of the magnetic field, at a point below the wire, will be from east to west. While the direction of the magnetic field above the wire will be from west to east.

9.2.3 Magnetic Field due to a Current through a Circular Loop or Coil (of wire)

You are familiar with the direction of magnetic field lines produced around a straight conductor carrying current. Imagine that the same conductor is bent in the form of circular loop and then a current is passed through it. How would the magnetic field lines look like ? Let us try to visualise.

We have learnt that the magnetic field associated with a straight conductor carrying current decreases in magnitude with increasing distance from the conductor. As a result, at every point of a current carrying circular loop, the concentric circles representing the magnetic field around it, would become larger and larger as one moves away from the common centre i.e. the conductor.

By the time when we reach the centre of the circular loop, the arcs of these big circles would appear as straight lines, as shown in Figure 9.10. Thus, every point on the wire carrying current would give rise to the magnetic field appearing as straight lines at the centre of the loop. It is easy to check that every section of the wire contribute to the magnetic field lines in the same direction within the loop.

Now, you have already learnt that magnetic field produced by a current carrying wire at a given point depends directly on the magnitude of the current passing through it. Therefore, if there is a circular coil consisting of ‘n’– number of turns, the field produced by this will be n–times as large as that produced by a loop of single turn carrying the same current as that of the coil. The above is supported by the fact that the current in each circular turn has the same direction and strength and hence the field due to each turn just adds up.

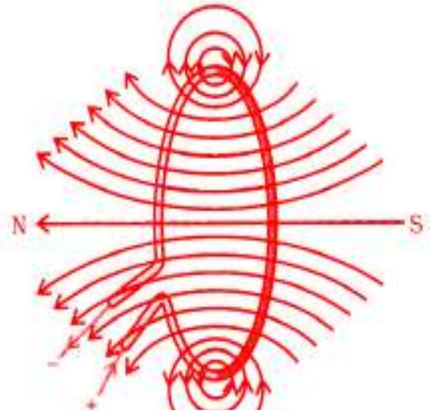


Figure 9.10 Magnetic field lines of the field produced by current carrying circular loop.

To understand magnetic field pattern due to circular coil of large number of turns carrying current, let us perform the following Activity.

Activity 9.6

Prepare a rectangular cardboard with two holes. Then wind a circular coil of fine insulated copper wire through the holes as shown in Figure 9.11 so that winding is normal to the plane of the cardboard.

Connect the ends of the coil with a battery through a plug key as shown in Figure 9.11. Sprinkle some iron filings uniformly on the cardboard. Thereafter, plug the key. Finally, tap the cardboard gently a few times with finger. Note the pattern of the arrangement of the iron filings. The pattern would appear as shown in Figure 9.11. The lines of force are circular near the wire but they become straight and parallel at the middle point M of the coil. In fact, each small segment of the coil is surrounded by such magnetic lines of force. At the centre of the coil, all the lines of force add each other due to which the strength of magnetic field increases.

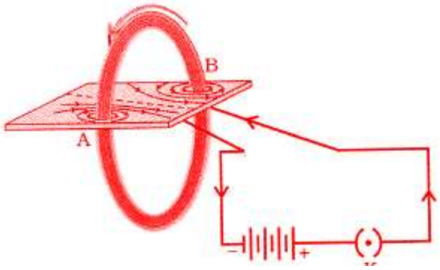


Figure 9.11 Magnetic lines of force due to circular coil or a wire, carrying current.

Thus, the strength of the magnetic field produced by a current carrying circular coil can be increased : (i) by increasing the number of turns of wire in the coil (ii) by increasing the current through the coil (iii) by decreasing the radius of the coil.

Moreover, a circular coil carrying current behaves as thin disc shaped magnet, whose one face is north pole and the other face is south pole.

9.2.4 Magnetic Field due to a Current in a Solenoid

A solenoid is a long coil of many circular turns of insulated copper wire, wrapped closely in the shape of cylinder whose radius is very small in comparison with the length of the winding. (When a long wire is coiled over a non-conducting hollow cylinder in the shape of a spring so that the turns are closely spaced and insulated from each other, it is called a solenoid). The structure of a solenoid is shown in Figure 9.12. In certain solenoid, an iron rod of proper size is inserted inside the hollow tube. Thin rod is called core.

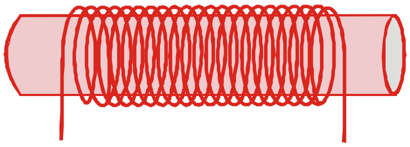


Figure 9.12 A solenoid

The free ends of the solenoid wire are connected to a battery through a key. When a current is passed through the winding, a magnetic field is established. The magnetic field inside the solenoid is almost constant in magnitude and direction. The pattern of the magnetic field is shown in Figure 9.13. Compare the pattern of the field with the magnetic field around a bar magnet (Fig 9.4). Do they look similar ? Yes, they are similar. This shows that one end of solenoid behaves as a magnetic north-pole, while the other behaves as the south-pole, due to the passage of current.

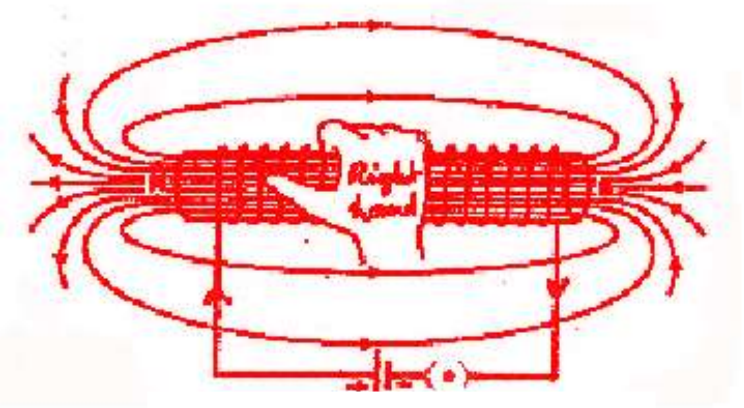


Figure 9.13 Magnetic field lines around a current carrying solenoid.

Again imagine that you are holding the solenoid in your right hand with the fingers curled along the direction of current through the winding. The direction of the thumb points always towards the end where the north pole appears. The field lines inside the solenoid are in the form of parallel straight lines.

This pattern shows that the strength of field is the same at all points inside the solenoid i.e., the field is uniform inside the solenoid.

The strength of the magnetic field depends on (i) the current : the larger the current the stronger is the magnetic field. (ii) the number of turns per unit length: the larger the number, the stronger is the magnetic field.

The north pole and south pole of a current carrying solenoid may be interchanged by reversing the current direction in it.

The magnet formed by passing an electric current in a solenoid is temporary i.e. magnetism exists so long current flows and it is no more when the current is off.

The strong magnetic field produced inside a current carrying solenoid can be used to magnetize a piece of magnetic material, such as soft iron rod, when placed inside the solenoid as shown in Figure 9.14. The magnet so formed is called an electromagnet. We can easily change the strength of a given electromagnet by changing the value of current flow. The strength of an electromagnet depends on (i) the number of turns per unit length in the coil – the strength increases with the increasing number of turns (ii) the current flowing in the coil – if the current in the coil is increased the strength increases.

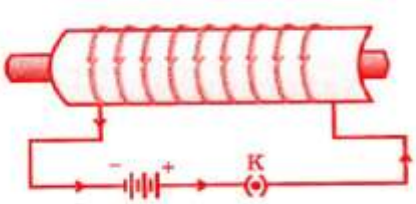


Figure 9.14 An electromagnet

Try to Answer

1. Why don’t two magnetic lines of force belonging to the same field intersect each other ?
2. Draw magnetic field lines or magnetic lines of force around a bar magnet.
3. Write the properties of magnetic lines of force.
4. Applying right hand thumb rule, find out the direction of the magnetic field inside and outside a loop of wire carrying current in the clockwise direction and lying on the plane of the table or the page.

9.3 Force on a Current-Carrying Conductor in a Magnetic Field

We have already learnt that an electric current flowing through a conductor produces a magnetic field or in short, a conductor carrying current is associated with a magnetic field. The field so produced can exert a force on a magnet (magnetic needle of a compass) when placed in the vicinity of the conductor. French scientist – Andre Marie Ampere (1775–1836) suggested that the magnet must also exert an equal and opposite force on the current carrying conductor. The nature and direction of the force due to a magnetic field acting on a current-carrying conductor can be studied through the following Activity.

Activity 9.7

Take an aluminium rod XY of about 2mm in diameter and about 5cm in length. Using two plastic rings suspend it from a fixed support through two light strings connected to these rings.

Bring a horse-shoe magnet near the aluminium rod so that the north pole lies on one side of the aluminium rod while the south pole lies on the other side. Here, the line joining the poles of the magnet is vertical and perpendicular to the suspended aluminium rod.

Connect the rod in series to the battery through the plug key K. Now pass a current through the rod from the end X to Y as shown in Figure. 9.15

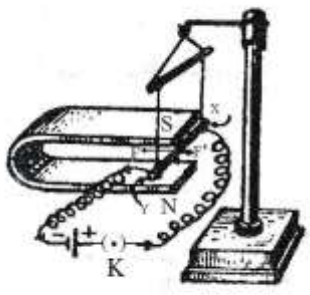


Figure 9.15

What do you observe ? You will observe that the rod is pulled towards 'F'. If you remove the magnet the rod will regain its original position. On the other hand, if the current is off by opening the key the rod will also regain its original position. Thus you can understand that only when the rod of aluminium carries a current, the magnetic field exerts a force on it

Repeat the experiment by reversing magnetic field direction i.e., with the south pole taking the position of the north pole and vice-versa. What will happen to the rod ? The rod will be pushed in opposite direction, F'. The same result will be seen if you reverse the direction of current, without changing the position of the poles of horse shoe magnet.

We conclude that

1. When a current carrying wire is placed in a magnetic field, a force acts on the wire.
2. The direction of force depends on the direction of the magnetic field as well as direction of the current.

Experiments have shown that the displacement of the rod is largest or the magnitude of the force is largest, when the direction of current is at right angles to the direction of magnetic field in which the conductor is placed.

In Activity 9.7, the direction of the current and that of the magnetic field are perpendicular to each other and found that the force is perpendicular to both of them. Thus, all are perpendicular to one another.

9.3.2 Fleming's Left -Hand Rule

The direction of the force on a current carrying conductor (or wire) placed in a magnetic field may be easily obtained by a simple rule known as Fleming's Left-Hand rule, which was suggested by Professor J.A Fleming of England.

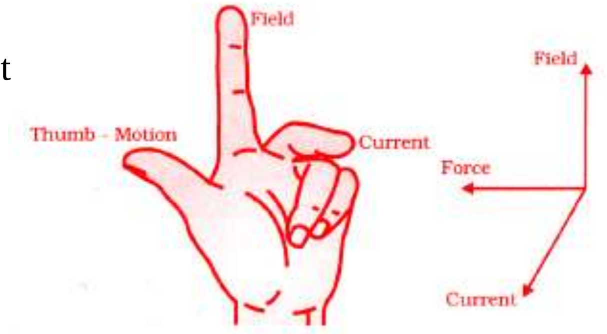


Figure 9.16 Fleming's Left-Hand rule

According to this rule, stretch the thumb, forefinger and middle finger of your left hand such that they are mutually perpendicular (Fig. 9.16). If the forefinger points in the direction of magnetic field and middle finger points in the direction of current then the thumb will point in the direction of motion or the force acting on the conductor.

9.4 Electric Motor

An electric motor is a rotating device that converts electrical energy to mechanical energy of a rotating system known as the **shaft** . Anything connected to the shaft rotates with it. In short an electric motor converts electrical energy into mechanical (Kinetic) energy. It is an important component in electric fans, refrigerators, washing machines, grinders, mixers, computers etc. Let us try to know how an electric motor works.

An electric motor consists of a coil of insulated copper wire. The copper wire is tightly wound over a soft-iron core to form a coil of a large number of turns, as shown in Fig. 9.17. The core with the coil is called the **armature**. The armature is fixed on the shaft of the motor.

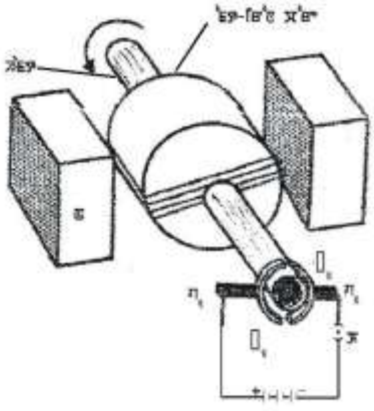


Figure 9.17 A simple electric motor

Strong and permanent magnetic north and south poles are fixed facing each other. The coil is kept between them, so that the coil lies in a magnetic field directed from the north pole to the south pole. The two free ends of the coil are connected to the two halves C_1 and C_2 of a split ring. The inner sides of C_1 and C_2 are insulated electrically and fixed on the shaft. The external conducting edges of C_1 and C_2 touch two conducting stationary brushes B_1 and B_2 respectively. The brushes are 180^0 apart from each other, as shown in the Figure 9.17. The brushes are connected to the terminals of a battery. At any instant of time, one brush touches only one split ring, when the shaft rotates i.e. when the motor works.

9.4.1 Working of the Motor

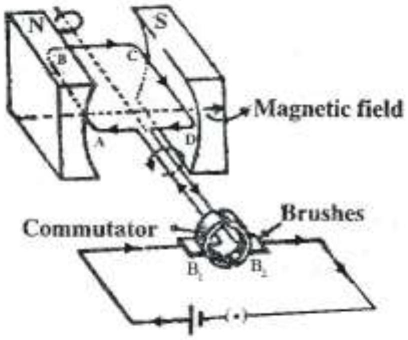


Figure 9.18(a)

When the battery is connected to the motor, the current in the coil ABCD enters through the conducting brush B_1 and flows back to the battery through the brush B_2. In the portion shown in Fig. 9.18(a). The current in the left arm is a long AB while that in right arm is along CD. As these currents are flowing in a magnetic field, forces are exerted on them. As given by Fleming's Left-Hand rule . AB is pushed down while the arm CD is pushed up. As a result, the coil and the shaft together known as the armature mounted free to turn about an axis, rotate anti-clockwise. At half rotation C_2 is in contact with the brush B_1 while C_1 is in contact with the brush B_2. Therefore, the current in the arms AB and CD gets reversed as shown in Fig. 9.18(b) and flows along DCBA. Here, the change of direction of the current flow through the circuit is carried out by the split rings and the two taken together is called **commutator**.

Thus, the current in the coil is from D to C to B to A. On applying Fleming's Left-Hand rule the arm AB of the coil that was earlier pushed down is now pushed up while the arm CD previously pushed up is now pushed down and anti-clockwise rotation of the armature continues.

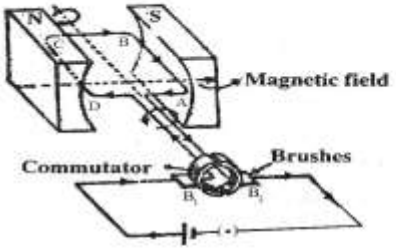


Figure 9.18(b)

Therefore, the coil and the shaft together rotates half a turn more in the same direction. The reversing of direction of current flow is repeated at each half rotation and it gives rise to a continuous rotation of the armature, so long as the battery supplies current i.e. key remains close.

The commercial motors use (i) an electromagnet in place of permanent magnet (ii) large number of turns of insulated copper wire in the coil (iii) a soft iron core on which the coil is wound. By doing so, the power of the motor can be increased.

Try to answer

1. **State Fleming's Left-Hand rule.**
2. **What is the principle of an electric motor ?**
3. **What is the role of commutator ?**

POINTS TO REMEMBER

- **i.** A compass needle is a small magnet pivoted at its centre so as to enable it to rotate freely in a horizontal plane.
- **ii.** The end which points towards north is its north pole and the other end is called south pole
- **iii.** A field line is the path along which a hypothetical free north pole would tend to move. These field lines around a magnet are used to represent a magnetic field. The resultant direction of the magnetic field at a point is given by the direction of motion of the north pole which is free to move.

iv. The field lines are closer in the region of stronger magnetic field.

v. A metallic conductor carrying an electric current has associated with a magnetic field due to the current, the magnetic field lines are a series of concentric circles with the wire as common centre. The direction of the field is given by the right hand (thumb) rule.

vi. The magnetic field due to a current carrying solenoid is similar to that of a bar magnet except that the direction of field can be reversed with the change in the direction of current through it.

vii. An electromagnet consists of a core of soft iron wrapped around with a coil of insulated copper wire.

viii. A current carrying conductor when placed in a magnetic field experiences a force. The force acting on the conductor is perpendicular to both the direction of magnetic field and the current which are also perpendicular to each other and is governed by the Fleming's Left-Hand Rule. This is the basis of an electric motor.

ix. Electric motor is a device which can convert electric energy into mechanical energy.

EXERCISES

1. Draw a sketch to show the magnetic lines of force due to a current carrying straight conductor.
2. Draw the magnetic lines of force due to a circular wire carrying current.
3. State the effect of inserting an iron core into a current carrying solenoid.
4. Describe how you will locate a current carrying wire embedded in a wall.
5. State right-hand thumb rule.
6. What is a solenoid ? Draw a sketch to show the magnetic lines of force produced by a current carrying solenoid.
7. What is an electric motor ? With the help of a diagram, describe the working of an electric motor.
8. What is the function of commutator in an electric motor ?
9. **A magnetic line of force is used to show the direction of**

(A) south-north **(B)** a bar magnet

(C) a compass needle **(D)** magnetic field. (D)

10. The magnetic lines of force inside a solenoid due to an electric current in it are nearly

(A) straight lines **(B)** circular lines

(C) parabolic lines **(D)** elliptic lines (A)

11. If the number of turns in a solenoid is increased, the strength of the electromagnet so formed will

(A) decrease **(B)** increase

(C) remain constant **(D)** become zero. (B)

★★★★★★

CHAPTER

10

ELECTROMAGNETIC INDUCTION

We have seen that an electric current can be produced using an electric battery. Can we have an electric current without any battery ? We are using electricity at our home. From where do we get the electric current in our home ? The electric current that we use in our home is generated at power plants also known as power stations. In this chapter we shall study the principle, working and uses of electric generator.

10.1 Electromagnetic induction

We have studied that a conductor carrying electric current perpendicular to the magnetic field experiences a force. This force causes the conductor to move. Can the reverse process be possible ? Can electric current be generated in the conductor when it moves perpendicular to the magnetic field ? This was first studied by English Physicist Michael Faraday. In 1831 he discovered that relative motion between a magnet and a coil can generate electric current in the coil. The phenomenon is known as electromagnetic induction.

To understand the discovery let us perform the following activity.

Activity 10.1

Take a coil of a large number of turns, a sensitive galvanometer and a strong magnet.

Connect the terminals of the coil to the galvanometer Figure 10.1. Push a pole, say N-pole of the magnet towards the end of the coil very quickly. Do you find any change in the galvanometer needle ? There is a momentary deflection

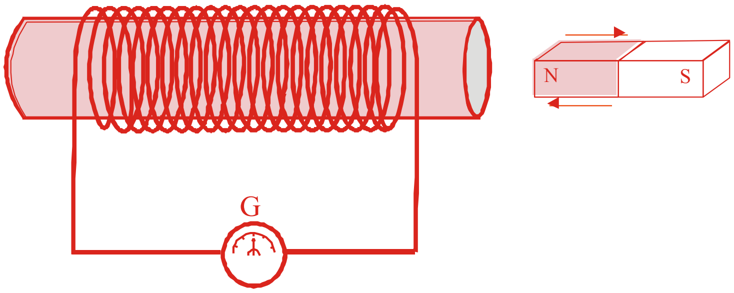


Figure 10.1

in the needle of the galvanometer. This indicates the presence of a current in the coil. The deflection becomes zero at the moment when the motion of the magnet stops.

Withdraw the N-pole of the magnet way from the coil very quickly. Do you find any deflection of the needle of the galvanometer ? There is a momentary deflection of the needle in the direction opposite to the first.

Repeat the experiment using the other end of the magnet i.e. S-pole of the magnet. Record the finding.

Keeping the magnet stationary move the coil towards and away from the magnet. Observe the deflection of the needle of the galvanometer. Observe the amount of deflection of the needle varying the speed of movement of the magnet or coil.

Whenever there is relative motion between the coil and the magnet electric current is developed in the coil. The phenomenon is known as electromagnetic induction. The current in the coil is called induced current and the potential difference developed between the ends of the coil is called induced voltage or induced e m f.

The result of Faraday's Experiment on electromagnetic induction may be summarised as follows

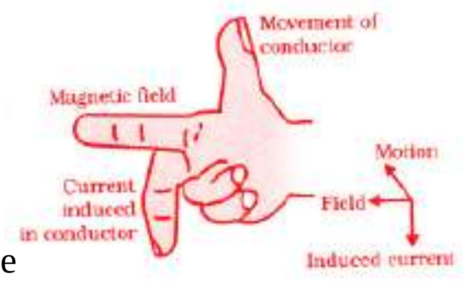
(i) Whenever there is a relative motion between a coil and a magnet an induced current flows in the coil. In another words, whenever there is a change in the number of magnetic lines of force linking with a coil an induced e m f is set up in the coil.

(ii) Induced current in the coil lasts only as long as there is change in number of magnetic lines of force linking with the coil.

(iii) The strength of induced e m f is directly proportional to the rate of change of magnetic lines of force linked with the coil.

In practice we can induce electric current in the coil either by rotating the coil in a magnetic field or by rotating a magnet (about a perpendicular axis) around the coil. It is convenient to rotate the coil in the magnetic field. The direction of the induced current depends upon the direction of the magnetic field and direction of motion of the coil. The induced current is found to be the highest when the direction of motion of the coil is at right angle to the magnetic field. In this situation, we can use a simple rule known as Fleming's right hand rule to know the direction of the induced current.

Fleming's right hand rule



Stretch the thumb, forefinger and middle finger of right hand so that they are perpendicular to each other as shown in the figure 10.2 . If the thumb shows the direction of motion of the conductor and the forefinger indicates the direction of the magnetic field, then the middle finger will show the direction of induced current in the conductor.

The principle of electromagnetic induction is used in the construction of generator, microphone, electric guitar, etc.

Figure 10.2

10.2 Electric Generator Principle

Electric generator works on the principle of electromagnetic induction. In electric generator mechanical energy is used to rotate a coil in a magnetic field to produce electricity. Hence, generator is a device to convert mechanical energy into electrical energy. When the coil is rotated in the magnetic field the direction of the induced current changes alternately. A commutator may be used to produce the current in the same direction. Generators are of two types – A C Generator (alternating current Generator) and D C Generator (direct current Generator)

Construction

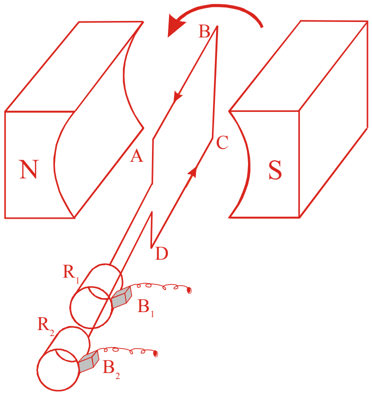


Figure 10.3

Figure 10.3 shows a schematic diagram of an A C Generator. An A C Generator consists of

(i) Two pole pieces N–S of a permanent magnet.

(ii) An armature consisting of a number of turns of rectangular coils. There is an arrangement to rotate the coil about an axle perpendicular to the magnetic field with a high speed. (It is represented in the diagram with a single turn coil ABCD)

(iii) Two metal slip rings R_1 and R_2 connected to the two terminals of the coil.

(iv) Two stationary conducting brushes B_1 and B_2, kept pressed separately on the rings R_1 and R_2. The brushes are connected to two separate leading wires of an external load.

Working

At start let us assume that the plane of the coil is vertical with the side AB being uppermost and CD being lowermost. When the coil rotates the side AB moves downwards and CD moves upwards cutting across the magnetic field. Electric current is developed in the coil due to electromagnetic induction. Applying Fleming's right hand rule the direction of induced current will be along BA and DC. Now the current will complete its flow along DCBA then through R_1 to the external circuit or load and returning through R_2.

After the completion of half rotation the side AB will occupy the lowermost and CD the uppermost position. When the armature continues its rotation the side AB moves upwards and CD moves downwards cutting across the magnetic field. In this second half of rotation the current will flow along AB and CD completing its circuit along ABCD then through R_2 to the external load and returning through R_1. Thus the polarity of R_1 and R_2 changes alternately. After the completion of one rotation the armature will resume the starting position. Then the same cycle continues as the armature goes on rotating continuously. Thus the direction of current in the external circuit changes for every half rotation. Such current is known as alternating current (A C) and the generator is known as A C Generator.

If there are larger number of turns in the coil the current generated in each turn adds up to give a large current through the coil.

How frequently does the direction of the current change ? In a second the number of times the current flows in a given direction is known as frequency of the A C source. Frequency is the number of complete cycle in one second. Most of the A C generators are designed to have frequency 50 cycles per second (hertz- Hz). In such generators direction of current alters 100 times in a second.

D C Generator

To get a direct current (D C) which does not change the direction of current with time a split ring (a single ring splitted into two halves) is used as commutator. With this arrangement one brush is at all time in contact with the arm of the coil moving downwards in the field. While the other brush is in contact with the arm moving upwards. Such generator which sends current in a direction only is known as D C generator.

Figure 10.4 shows the schematic diagram of a D C Generator.

Difference between AC Generator and DC Generator

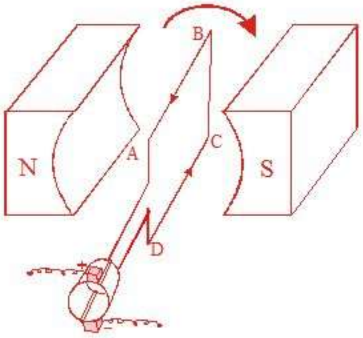


Figure 10.4

(i) In A C generator the direction of electric current reverses periodically. But in D C generator the current flows in one direction only.

(ii) In A C generator there are two metal slip rings connected to the terminals of the coil separately. While in D C. generator there are two split half rings (splitted into two halves from a single ring) connected to the terminals of the coil.

(iii) In A C generator the two conducting brushes are in contact with the two rings separately. While in D C Generator the brushes are in contact with the two halves(split ring) alternately in the right time. A brush is always in contact with the half of the ring where electric current flows out and another brush is always in contact with the half ring where electric current returns. Thus a brush is always (+)ve terminal and the other is always (–)ve terminal.

The nature of variation of the generated e m f from an A C generator is shown in the figure 10.5. When the plane of the coil is perpendicular to the magnetic field any side of the coil does not move across the magnetic field. In the first quarter of its rotation the rate of cutting across the field rises. Hence the e m f generated increases from zero to maximum value. During the second quarter e.m.f decreases and becomes zero. However, in the second half of the rotation the e m f generated follows the same pattern as obtain in the first half with the reversal in the direction of e m f only.

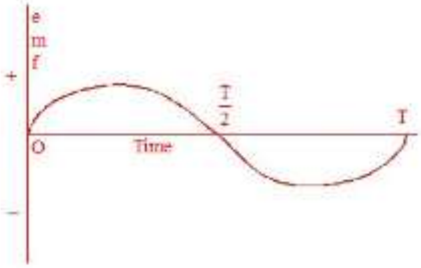


Figure 10.5

Advantage of AC over DC.

Voltage of A C can be stepped up or down easily with the help of a device called transformer. Energy loss in long distance transmission is large at low voltage and high current. It can be minimised by stepping up the voltage and reducing the current for long distance transmission. A C can be converted to D C more easily.

However, there are some devices where A C cannot be used directly.

10.3 Domestic electric circuits

We use different kinds of electrical appliances in our house. The electricity from a power station is transmitted through a long distance at high voltage. It is to minimise the loss of energy in the transmission line in the form of heat. The high voltage is reduced using a step down transformer at our locality. In our house we receive the electric power at 220 V. It is to suit with the domestic appliances commonly used.

The wiring inside the house is done according to our needs in different parts of the house.

The electric power lines enter our house through three wires consisting of live, neutral and earth. However, the live and the neutral wires are connected directly to the main supply through electricity meter.

The earth wire is connected to a large metal plate which is embedded deep in the earth in a moist region near the house. The earth wire carries no electricity. The neutral wire is maintained at the zero potential by connecting it to the earth at the power station. This provides the return path for the current. The live wire is at a high potential.

There is a colour convention for wiring. According to this convention

- live line has red insulation
- neutral has black insulation and
- earth has green insulation.

(in some countries black is used for live, white for neutral and green for earth).

In a house we use a number of appliances like electric bulbs marked 220V – 60W, 220 V – 100W, 220V – 200W, 220V–1000W, heater marked 220V – 1000W, electric iron marked 220V – 500W, electric fan marked 220V – 60W, etc. From this we must know that each of them requires 220V potential difference for proper functioning.

If a number of appliances are connected is series to the power supply the appliances cannot get the right potential difference and hence they cannot function properly. Another disadvantage of series connection is when the resistance of an appliance get fused or switched off the other appliances will not get the electric current and hence will not work. If the appliances are connected in parallel each appliance can get the proper voltage to function properly and separate switches can be put for each appliance. Another advantage of parallel connection is that even when one part is switched off or fused the other parts are not affected.

However, when connected in parallel each part will draw different current according to their rating. When they are used simultaneously the total current drawn from the main will be the sum total of the currents in each appliance. Hence, it may be very large.

Again a bulb marked 220V – 100W has a resistance of 484 ohms and will draw a current of about 0.45A. A heater of 220V – 2000W has a resistance of 24.2 ohms and will draw a current of about 9A. To carry a larger current we need thicker wires and better quality materials in switches and sockets.

The appliances used at our house may be categorised into two groups – (i) light power appliance – like electric bulb, fan, TV sets, radio, etc. which draw current less than 5 A and (ii) high power appliance – like heater, cooker, refrigerator, etc. which draws larger current above 5 A when a few of them are used simultaneously. So, it is convenient to provide two different main lines – 5A line and 15A power line through different boards for 5A and 15A sockets and switches. (They are available in the market with specification).

Some electrical appliances like bulbs, tubes, fans, need not be connected with earth. They have just two terminals to be connected to the live and neutral. A wire from the live line passes through a switch then to one terminal of the appliance. The neutral line is connected to the other terminal of the appliance. The switch is placed at a convenient height to enable us to operate it.

Some appliances have plugs instead of the permanently fixed terminals. An electric iron is an example. It has a plug at the end of the cord. The plug (may) contains three pins. The pins correspond to Earth, Neutral and Live generally marked with letters E N and L near the pins. For them we need socket. The socket is fitted permanently on a switch board and the three lines Earth, Neutral and Live are connected to the terminals at the back of the socket. Usually the live wire is passed through a switch before it is connected to the socket.

Role of fuse – a safety device

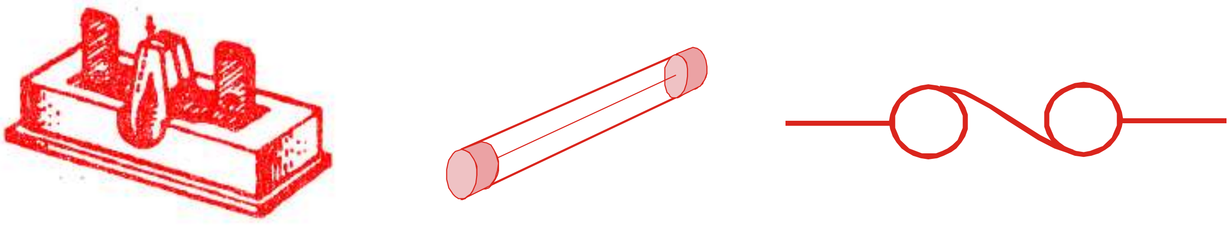
The wire used for wiring have limit for a certain maximum current to pass through them. If the current exceeds that limit, the wires may get over heated and cause fire. There are two main reasons for increasing current in the wires. They are – (i) Overloading (electrical power consumed by the appliance is greater than the maximum wattage) and (ii) short circuiting (direct connection of the live and neutral wires). Whenever there is short circuiting wires may be overloaded and at the same time at the point of short circuit sparking may occur and cause a fire.

Many precautions and safety measures are taken up to protect from the possible damages. All wires used in domestic electric circuits are coated with a layer of insulating material like rubber or plastic. So, the wires do not come in direct contact and short circuit does not occur. Besides there is division of circuits into different sections. This process not only facilitates repair of each section independently but also restricts the damage due to over loading or short circuiting.

The most important safety device used for protection of electrical circuits is the use of fuse. The fuse is a piece of wire made of material with a low melting point. Whenever a high current flows in the circuit due to overloading or short circuiting, the fuse gets heated then melts and disconnects the circuit from the main supply line. Fuse must be connected to the live wire.

Fuse wire is made of pure tin, but a cheaper variety is made of an alloy of tin and copper. The thickness and length of fuse wire depend on the maximum current permitted through the circuit.

Two types of electric fuse and circuit symbol of a fuse are shown in the figure 10.6.



(a) (b) (c)

Figure 10.6

Figure 10.7 shows a schematic diagram of a common domestic wiring.

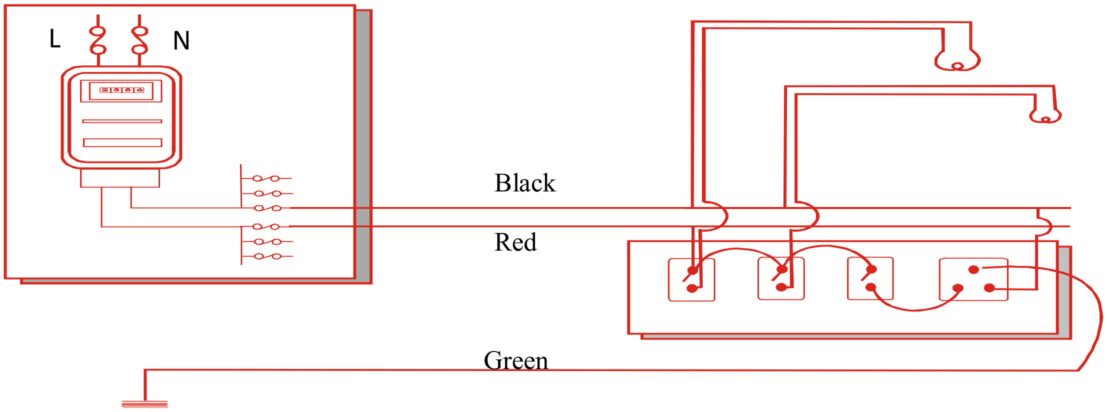


Figure 10.7

10.4 Hazards of electricity and precaution

Electricity is one of the most important and convenient sources of energy available to us. It can be used for different purposes. However, it is dangerous if certain precautions and safety measures are not taken up while use. You know that if you touch any point of the electric circuit you get shock (but don't try it). Sometimes the shocks are too severe to kill the person. The cracks or flaws in electric circuits (loose connection) defective switches, damaged wire, short circuit or overloading may cause sparking or overheating that may cause fire in the house. To avoid such hazards we require not only the safety devices of using fuse but also the following precautions in handling electric circuits.

(i) The metallic body of certain appliances like wattmeter, main switch, refrigerator, electric iron, computer, etc. must be connect to the earth wires. The reason for this is, if there is a slight leakage of current to the body of the appliance its potential remains the same as that of the earth and prevents from electric shocks.

(ii) All household wires must be of good quality and properly insulated (insulation thickness must be proper). Any exposed part must be insulated.

(iii) No direct handling must be done while repairing any part of a circuit. Use rubber hand gloves and wear rubber shoes or put off the main switch at the entry of main supply.

(iv) The tools like tester, pliers, screw drivers, pincers used in repairing should have proper insulation.

(v) One should not touch the metallic body of any electric appliance when they are switched on, if proper earthing is not given to them.

(vi) One should not touch any part of electric appliances and even the switches with wet skin and bare footed.

(vii) In case of fire, the main switch must be immediately switched off.

(viiii) Electric fuse should be used in each section. Proper fuse should be used. The practice of using ordinary copper wires instead of proper fuse wires can cause accident.

Despite of all precautions, it is possible that someone accidentally touches a live wire of the overhead domestic supply or inside the house. If this happen one should try to provide such a person with a support of some non-conducting materials like dry wood, plastic, rubber etc. One should try to pull away the person, who has contacted the live wire by not touching directly. The first and most appropriate step is to switch off the current at once.

Remember electricity is your friend so long as you take proper care. It can be fatal if you fail to observe the guidelines for using electricity.

10.5 Electric Power plants

From where do you get electricity at your home ? The electricity that we use is generated at power plants or station. In the power stations the armature of the generator is rotated by connecting its shafts to a prime mover. Power plants can be named according to the method used to rotate the armature. Some important ones are described below :

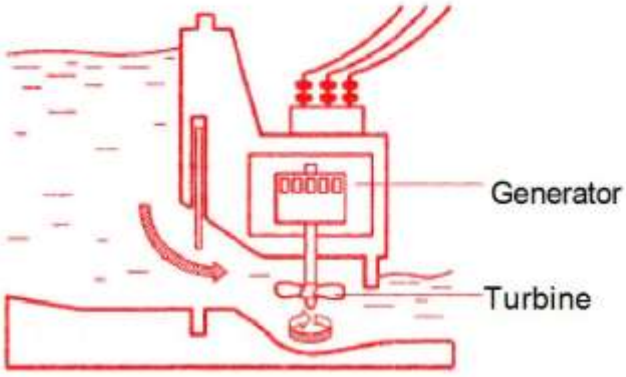


Figure 10.8 Hydel power plant

(a) Hydel (hydro electric) Power plants

In this type of power plant water at the higher level is allowed to fall on the blades of the turbine Figure 10.8. The pressure of water makes the blades of the turbine move making the armature (coil) of the generator rotate with a great speed. Then electricity is produced. Indira Gandhi Loktak Hydro electric project at Leimatak and Nungsangkhong Hydel power station at Ukhrul are examples of Hydel power plants.

(b) Thermal Power plant

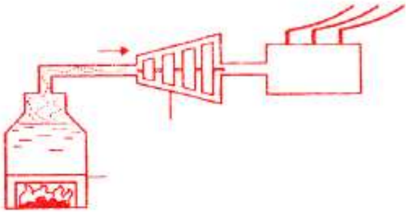


Figure 10.9 Thermal

In this type of power plant water is boiled using coal as fuel. Steam is produced at high pressure in the boiler. The steam is used to drive the turbine Figure 10.9. Then the armature coil of the generator is rotated. Thus electricity is produced.

(c) Nuclear Power plant

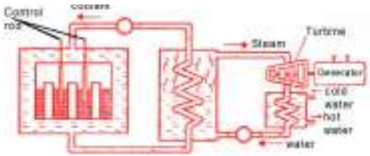


Figure 10.10 Nuclear Power

In nuclear power plant also known as Atomic Power plants the energy released through fission is used to produce steam by boiling water. The steam in turn, is used to rotate the turbine of electric generator Figure 10.10.

(d) Genset

Genset also known as Generator set is a small unit. In a Genset diesel, petrol or kerosene engine is used to rotate the armature coil of the generator. A genset can be small enough to meet the requirement of a single house or large enough to be used in a small industrial unit.

POINTS TO REMEMBER

i. When there is a change in the number of magnetic lines of force linked with a coil an induced e m f is developed in the coil. The phenomenon is known as electromagnetic induction.

ii. The strength of the induced e m f is proportional to the rate of change of the number of magnetic lines of force linked with the coil.

iii. The direction of the induced current in the coil is given by Flemings right hand rule.

iv. Electric generators work on the Principle of electromagnetic induction.

v. A generator converts mechanical energy into electrical energy.

vi. An A C has some advantages over D C.

vii. In domestic wiring earthing and use of proper fuse are very important.

viii. Power plants can be named according to the method used to rotate the armature.

EXERCISE

1. A coil of copper wire is connected to a galvanometer. What would happen if a bar magnet is (a) pushed into the coil very slowly ? (b) pushed into the coil very rapidly? (c) held at rest inside the coil ? (d) pulled out again rapidly ?

2. State the principle of the electric generator.

3. Explain with diagram the action of either A C generator or D C generator.

4. Distinguish between A C and D C.

5. What is the purpose of Fleming's right hand rule ?

6. A dynamo converts energy from one form to another. Name the two forms of energy in proper sequence.

7. A galvanometer is connected to the ends of a metal rod. The rod falls with its length horizontally extending East-West. What changes will you observe in the galvanometer? Explain the reason.

8. A galvanometer is connected to the ends of a metal rod. The rod falls with its length horizontally extending North-South. What changes will you observe in the galvanometer ?

9. Name two devices in which the principle of electromagnetic induction is used.

10. Many electrical appliances and circuits are earthed. What is the reason?

11. What is the usual colour code followed for connecting live, neutral and earth wire ?

12. What is meant by overloading in an electric supply ? How can it be prevented ?

13. What precautions should be taken to avoid overloading of domestic electric circuit ?

14. Why is material of low melting point chosen for fuse wire ?

15. What is short circuiting ? Mention the possible consequences of short circuiting.

16. Explain two safety measures commonly used in electric circuit and appliance.

17. What are the advantages of parallel connection of the domestic appliances in house hold wiring ?

18. For domestic wiring give reasons why sections are separated.

19. In a switchboard there are three switches no socket or any other element. How many wire will be going in the switch board ?

20. Is it possible to step up D C using a transformer ?

21. What is the use of a commutator in generator ?

22. Mention an important advantage of A C over D C.

23. Name three main types of power plants.

24. Which device is used to change the A C voltage ?

25. In a thermal power plant, how is the turbine rotated ?

26. How is the turbine rotated in a Hydel power plant.

27. What is the basic difference between thermal power plant and hydel power plant ?

28. How is the core of the coil of a Genset rotated to produce electricity ?

★★★★★★

CHAPTER

11

LIGHT

We see a number of objects around us. How do we see the objects ? We see the objects with the help of light emitted by them. Luminous objects like, the sun, lighted candles, etc. emit light of their own. We see the luminous objects with the help of light emitted by them. Then, how do we see non-luminous objects ? We see the non-luminous objects with the help of light falling on them. That is how we are reading this book.

Light travels rectilinearly in a transparent medium. The path of the light is turned back on falling on a polished surface. The phonomenon is known as reflection of light. What does happen when light passes through different media ? The path of light is mostly deviated when it passes through different media. The phenomenon is known as refraction of light. White light is splitted when it suffers refraction. Refraction occurs in human eye also. In this chapter we shall study the phenomena caused by reflection and refraction of light.

11.1 Reflection of light from plane surface

It is quite a common experience that when light from a torch light is directed towards a mirror the light beam is redirected back. This redirected light beam is known as reflected light and the phenomenon is called the reflection of light. If the direction of the incident beam be altered then the direction of the reflected beam will also change correspondingly. Thus the direction of reflected light depends on the direction of the incident light. Hence, reflection occurs under some laws. These laws are known as Laws of Reflection. Before discussing these laws let us acquaint with some terms and definitions first.

By using a proper slit, the beam of light comming out of a torch-light can be made narrower and narrower. Such a narrow beam can be taken as a ray of light though, in practice, it consists of a lot of light rays. In fact a ray of light is an imaginative assumption like that of a ‘straight line’ in geometry which has no breadth but only length. The point where incident light ray falls is called point of incidence. The vertical line perpendicular on the surface of reflection is known as the normal on the reflectives surface at the point of incidence. The angle between the incident ray and the normal is called the angle of incidence and the angle between the reflected ray and the normal is called the angle of reflection.

Laws of reflection

(i) The angle of incidence and the angle of reflection are always equal to each other.

(ii) The incident ray, the reflected ray and the normal at the point of incidence are always in the same plane known as plane of incidence.

These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces. If the reflecing surface is not perfectly polished the rays in a beam of light may be reflected irregularly. Then, diffused reflection occurs. The rays reflected from this book is an exmple of diffused reflection.

We dress up in front of a dressing mirror. What do you see through the mirror ? That is our image. The rays emitted from a point in front of the mirror after suffering regular reflection from the plane mirror appear to be emitted from an imaginary point behind the mirror. That imaginary point is the image of the point in front of the mirror. This is the virtual image formed by the plane mirror. If the reflection is not a regular reflection the rays will be reflected in different directions irregularly and they will not appear to be emitted from any single imaginary point. Hence, no image will be seen.That is why we cannot see our own image through this page. Here only diffused reflection occurs.

Activity 11.1

Use a plane mirror. Observe the image formed by it. What are the properties of the image formed by a plane mirror ?

The image is always virtual and erect. The size of the image is equal to that of the object. The image formed is as far behind the mirror as the object is in front of it. The image is laterally inverted.

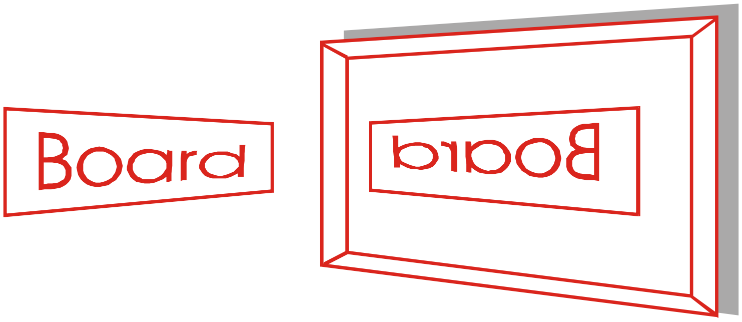


Figure 11.1

Try to answer

1. You see your image through a plane mirror at a distance of 2m from you. What is the distance of the mirror from you ?
2. A brick wall reflects the rays of light emitted from a candle lamp. But you do not see the image of the candle through the wall. What is the reason ?

11.2 Reflection from spherical mirror

Have you ever seen your own image through a curved surface like a shining spoon or side glasses of motor vehicles? How would be the image when the reflecting surface is a curved one ? To understand it let us perform the following activity.

Activity 11.2

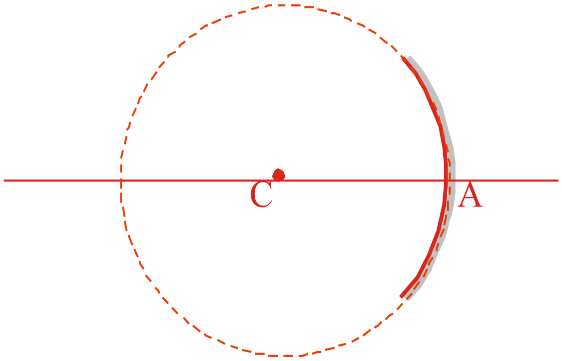


Figure 11.2

Take a large shining spoon. Try to see your own image through its curved side. Move the spoon away. Record the change of the image. Repeat the activity using the other side of the spoon. What can you conclude from this activity?

The most common type of curved mirror is the spherical mirror.

The spherical mirror is a part of a hollow sphere. Either the inner or outer side is a reflecting surface. If the inner side is reflecting surface the mirror is known as **concave mirror**. And, if the outer side is a reflecting surface the mirror is known as **convex mirror**. Before we discuss the formation of image by spherical mirrors let us first acquaint with the terms and definitions which we will be using in the study.

Centre of curvature – Centre of carvature is the centre of the sphere of which the spherical mirror is a part.

Radius of curvature – The radius of the sphere, of which the mirror is a part, is known as radius of curvature.

Pole – The central point of the mirror or the point on the mirror directly facing the object is known as pole.

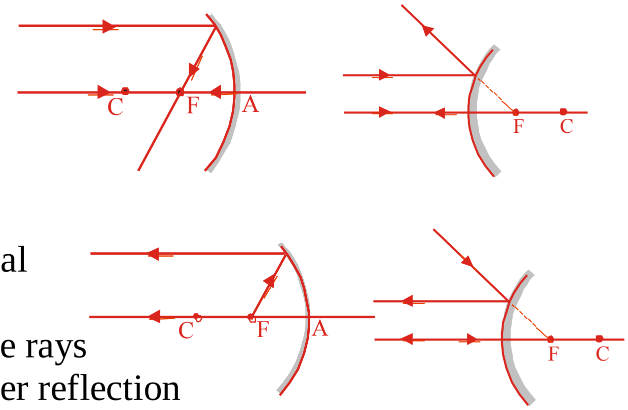


Figure 11.3

Principal axis – The straight line passing through the centre of curvature and pole of the mirror is called principal axis.

Principal section – It is the section of the mirror obtained with a plane passing through the principal axis. In a diagram a mirror is represented by its principal section with shade on the back side of the mirror.

Principal focus – It is a point on the principal axis. The rays incident on the mirror parallel to the principal axis, after reflection pass through (in the case of concave mirror) this point or appear to diverge (in the case of convex mirror) from this point.

The rays emitted from the principal focus in the case of concave mirror after reflection emerge parallel to the principal axis. In the case of convex mirror the rays converging towards principal focus are reflected parallel to the principal axis.

Focal length – Focal length is the distance between pole and principal focus. With the help of simple geometry you will be able to show that focal length is nearly equal to half of the radius of curvature.

Aperture – Aperture is the extent of the exposed portion of the mirror.

Two types of image

If the rays from a point object after reflection appear to diverge from or actually converge to a second point. The second point is known as image of the first point. If the rays appear to diverge from the second point this image is known as **virtual image**. Virtual images are always erect. If the rays actually converge to the second point the image is known as **real image**. Real images are always inverted. Real images can be focussed on a screen.

Using a concave mirror you can focus the rays from the sun at a point in front of the mirror. This is the real image of the sun. Assuming the sun is at infinity the rays from the sun are nearly parallel to each other. They focus at a point. The distance of the point from the mirror gives the measure of focal length of the concave mirror.

Image formed by spherical mirror

How would you locate the position of an image formed by a spherical mirror for an object, using ray diagram ? To locate the position of an extended object, placed on the principal axis you can follow the following steps.

Step I – Draw the principal section of the mirror showing distinctly the position of centre of curvature (C), and principal focus (F) on the principal axis (conveniently facing towards the left)

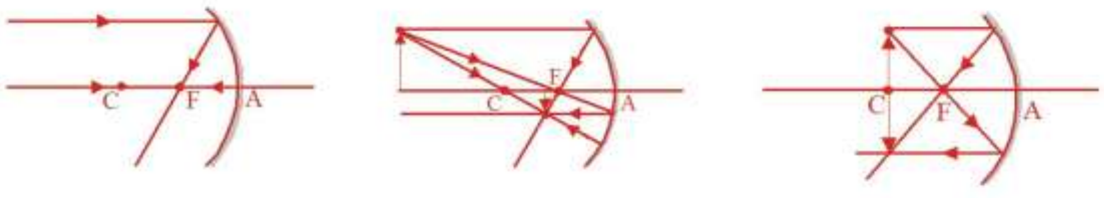
Step II– From the top of the extended object, on the principal axis trace the path of any two of the following rays

- **(a)** a ray, incident on the mirror parallel to the principal axis. After reflection it passes through principal focus (F) in the case of concave mirror and appears to emit from (F) in the case of convex mirror.
- **(b)** a ray, incident on the mirror passing through the principal focus (F) in the case of concave mirror or approachig towards the principal focus (F) in the case of convex mirror. It is reflected back parallel to the pricipal axis.
- **(c)** a ray, incident on the mirror passing through the centre of curvature (C) in the case of concave mirror or approaching towards the centre of curvature (C). It is reflected back normally. That is, it retraces back the path of the incident ray.

Step III– Find out the point where the two reflected rays intersect actually or intersect producing backwards.

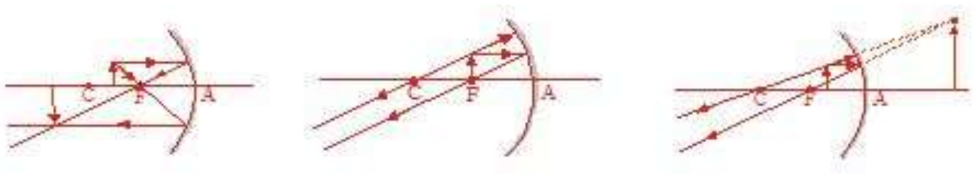
Step IV– Draw a perpendicular from the point of intersection on the principal axis. The perpendicular represents the image of the extended object. (While drawing ray diagram use arrow- head to show the direction of the ray)

The positions of images formed by a concave mirror when the object is placed at different positions are shown in the figure 11.4.



(a) Object at infinity *(b) Object beyond C.* *(c) Object at C.*

Figure 11.4(A)



(d) Object between C and F ***(e) Object at F.*** ***(f)Object between F and A.***

Figure 11.4(B)

The position, nature and size of the image formed when the object is placed at different distances are summarised in the following table.

Table 11.1 Image formed by a concave mirror

Position of object	Position of image	Nature of image	Size of the image
Object at infinty	image formed at focus F	real and inverted	(infinitely) small point size
Object between infinity and C	image formed between C and F	real and inverted	smaller than the object
Object at C	image formed at C	real and inverted	same size as the object
Object between	image formed between	real and inverted	enlarged
C & F	C and infinity		
Object at F	image formed at infinity	real and inverted	highly enlarged
Object between Pole and F	image formed behind the mirror	virtual and erect	enlarged

Study the change of the size of the image when the object is moved form C to F.

In the case of convex mirror the image formed is shown in the figure 11.5 When the object is placed in front of the convex mirror the image is formed behind the mirror, virtual, erect and diminished in size.

Study the size of the image when the object is brought very close the mirror. What will be the size of the image when the object is placed just at the pole ?

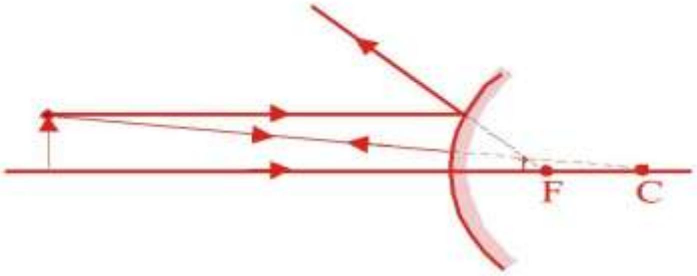


Figure 11.5

A plane mirror can be assumed as a spherical mirror having infinite radius of curvature.

Uses of spherical mirror

A concave mirror is used to produce parallel beam of light in the torch light, head light, search light etc. Dentists use it to see magnified image of small spots in the teeth. It is used as shaving mirror also. It is used to concentrate parallel beam of light.

In a reflecting type of telescope it is used as objective.

A convex mirror is used as rear viewer in vehicles. A convex mirror forms diminished virtual image, hence, its field of view is large. The image is also erect.

Mirror Equation

The object distance (u), image distance (v) and focal length (f) are related. Their relation is given by

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \qquad \text{Where } f=\frac{r}{2} \; [\, r - \textit{radius of curvature}]$$

While using the formula and to enable to indicate whether the point whose distance is measured is in front or behind the mirror certain sign conventions are used. There are some sets of sign convention. In this book we shall follow a set of sign convention called the New Cartesian Sign Convention.

New Cartesian Sign Convention

(i) All measurements of distance are made from the pole of the mirror.

(ii) If the measurement from pole be along the direction of the incident ray, a (+) sign is assigned to the value.

(iii) If the measurement from pole be against the direction of the incident ray then a (–) sign is assigned to the measurement.

Further, for convenience and for keeping similarity with that of Cartesian Co-ordinate System in assigning signs the pole of the mirror is made coincident with the origin of the perpendicular co-ordinate system and facing to the left side so that the direction of the incident ray may be from left to right.

In the above sign convention the focal length of a concave mirror is taken to be negative while that of a convex mirror is positive.

Magnification

The relative extent of the image with respect to the object size is the magnification produced by the spherical mirror. Thus, magnification of a spherical mirror is defined as the ratio of the image height to the object height. It is generally represented by (M).

$$\mathrm{M} = \frac{\text{height of the image}(h_i)}{\text{height of the object}(h_o)}$$

The magnefication (M) is also related to the image distance (v) and object distance (u). Following the sign convention mentioned above.

$$\mathrm{M} = \frac{(h_i)}{(h_o)} = -\frac{v}{u}$$

Using the equation above image-position corresponding to an object when placed at different positions can be solved. A few examples are given below.

Example 11.1 **An object 4cm high is placed at a distance of 20cm in front of a concave mirror of radius of curvature 60cm. Find the position, nature and size of the image.**

Solution From the question we have,

image distance, $v = ?$ height of the image, $h_i = ?$ height of the object, $h_o = 4\text{cm}$.

object distance, $u = -20\text{cm}$

radius of curvature $r = -60\text{cm}$

$\therefore$ focal length, $f = \dfrac{-60}{2} = -30\text{cm}$.

Using the relation $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f}$

We have,

$$\frac{1}{v} + \frac{1}{-20} = \frac{1}{-30}$$

$$\Rightarrow \frac{1}{v} = -\frac{1}{30} + \frac{1}{20} = \frac{-2+3}{60} = \frac{1}{60} \quad \therefore v = 60\text{cm}$$

(+) sign shows that the image is behind the mirror and it is virtual.

Again, magnification $m = \dfrac{h_i}{h_o} = \dfrac{-v}{u}$

$$\therefore\ \frac{h_i}{4} = \frac{-60}{-20} = 3$$

$$\therefore\ h_i = 3 \times 4 = 12\text{cm.}$$

The image is formed 60cm behind the mirror, it is virtual 12 cm high and erect.

Example 11.2 **An object 4cm high is placed at a distance of 40cm in fornt of a concave mirror of radius of curvature 60cm. Find the position, nature and size of the image.**

Solution From the question we have,

image distance, $v = ?$ height of the image, $h_i = ?$ height of the object, $h_o = 4\text{cm}$

object distance, $u = -40\text{cm}$

focal length, $f = \dfrac{-60}{2} = -30\text{cm.}$

Using the relation $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f}$

We have,

$$\frac{1}{v} + \frac{1}{-40} = \frac{1}{-30}$$

$$\Rightarrow\ \frac{1}{v} = -\frac{1}{30} + \frac{1}{40} = \frac{-4+3}{120} = \frac{-1}{120} \quad \therefore\ v = -120\text{cm}$$

The (−) sign shows that the image is in front of the mirror and real.

Again, magnification $m = \dfrac{h_i}{h_o} = \dfrac{-v}{u}$

$$\therefore\ \frac{h_i}{4} = \frac{-(-120)}{(-40)} = -3$$

$$\therefore\ h_i = -3 \times 4 = -12\text{cm.}$$

Thus the image is formed at a distance of 120 in front of the mirror. It is real, 12cm high and inverted.

Example 11.3 **It is intended to focus an image magnified 4 times on a screen using a concave mirror of focal length 20cm. Where should the object be placed?**

Solution From the question we have,

object distance, $u = ?$

magnification, $m = 4$

focal length, $f = -20$cm.

Let (x)cm be the object distance

$\therefore u = -x$

Since, $m = \dfrac{v}{u}$ (numerically) where v – image distance, u – object distance

We have, $v = 4x$. Since the image is focussed on the screen the image is real and formed in front of the mirror. So (v) is $(-)$ve.

$\therefore v = -4x$.

Using the equation $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f}$

We have,

$$\frac{1}{-4x} + \frac{1}{-x} = \frac{1}{-20}$$

$$\Rightarrow \frac{-5}{4x} = \frac{1}{-20} \Rightarrow \frac{4x}{5} = 20$$

$$\therefore x = \frac{20 \times 5}{4} = 25$$

Hence, object is to be placed at a distance of 25cm in front of the mirror.

Example 11.4 **Find the object distance to form an image magnified 4 times by a concave mirror of focal length 20cm.**

Solution Let (x)cm be the object distance

$\therefore$ Object distance, $u = -x$ cm

focal length, $f = -20$cm

magnification, $m = 4$

$\because m = \dfrac{v}{u}$ [numerically]

We have, $v = 4x$ [numerically]

When the image is real, $v = -4x$

Using the equation $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

We have,

$$\frac{1}{-4x}+\frac{1}{-x}=\frac{1}{-20}$$

$$\Rightarrow \quad \frac{-1-4}{4x}=\frac{-1}{20}$$

$$\Rightarrow \quad \frac{-5}{4x}=\frac{-1}{20}$$

$$\Rightarrow \quad \frac{4x}{5}=20$$

$$\therefore\ x=\frac{20\times 5}{4}=25\text{cm}$$

To form real image the object is to be placed at 25cm in front of the mirror.

When the image is virtual (v) is (+)ve.

$$\therefore\ v=+4x$$

Using the equation $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

We have,

$$\frac{1}{+4x}+\frac{1}{-x}=\frac{1}{-20}$$

$$\Rightarrow \quad \frac{1-4}{4x}=-\frac{1}{20}$$

$$\Rightarrow \quad \frac{-3}{4x}=\frac{-1}{20}$$

$$\Rightarrow \quad \frac{4x}{3}=20$$

$$\therefore\ x=\frac{20\times 3}{4}=15$$

$\therefore$ To form virtual image the object is to be placed at 15cm in front of the mirror.

Example 11.5 **A dentist uses a concave mirror of focal length 10cm to see a small spot on a patient's teeth. Find the magnification produced if a virtual image is formed at 25cm behind the mirror.**

Solution From the quesion we have,

focal length, $f = -\ 10\text{cm}$

image distance, $v = \ +25\text{cm}$

object distance $u = ?$

Using the equation $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

We have,

$$\frac{1}{25}+\frac{1}{u}=\frac{1}{(-10)}$$

$$\Rightarrow \frac{1}{u}=-\frac{1}{10}-\frac{1}{25}=\frac{-5-2}{50}=\frac{-7}{50}$$

$$\therefore \quad u=-\frac{50}{7}$$

$$\therefore \ magnification,\ m=\frac{-v}{u}=\frac{-25\times 7}{-50}=3.5$$

Example 11.6 **A convex mirror of radius of curvature 4m is used for rear view in an automobile. A person appears to be at 1m behind. What is the actual distance of the person?**

Solution From the question we have

object distacne, $u = ?$

focal length, $f = +\frac{4}{2} = 2\text{m}$ [(+) ve since the mirror is convex]

image distance, $v = 1\text{m}$.

Using the equation $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

We have,

$$\frac{1}{1}+\frac{1}{u}=\frac{1}{2}$$

$$\Rightarrow \frac{1}{u}=\frac{1}{2}-\frac{1}{1}=\frac{1-2}{2}=-\frac{1}{2}$$

$$\therefore \quad u=-2$$

Hence, the actual distance of the object (person) is 2m.

Try to answer

1. A concentrated image of the Sun can be focussed at 50cm away from a mirror. What is the focal length of the mirror ? [Ans. 50 cm]
2. A concave mirror forms a real image having the same size as the object at a distance of 40cm in front of the mirror. What is the focal length of the mirror? (Ans. 20 cm)
3. An object is placed at a distcance of 50cm in front of a concave mirror of focal length 25cm. Find the image distance. If the object is 10cm high what will be the nature and size of the image ?
[Ans. 50 cm, real inverted, 10 cm high]
4. An object is placed at a distance of 50 cm in front of a convex mirror of focal length 25 cm. Find the image distance. What will be its nature ?
[Ans. 16.67 cm, virtual and erect]
5. An object is placed at a distance of 15 cm in front of a concave mirror of focal length 30 cm. Find the nature and position of the image ?
[Ans. Virtual erect ; 30 cm behind the mirror]
6. An objects is placed at a distance of 15 cm in front of a convex mirror of focal length 30 cm. Find the nature and position of the image.
[Ans. Virtual, erect, 10 cm behind]

11.3 Refraction through plane interface

The bottom of a vessel containing clear water appears to be raised up. When a thick glass slab is placed over some printed matter, the letters appear raised up when viewed through the glass slab. A straight pole inserted slantly in clear water appears to be bent at the surface of water. How can you account for such experiences ?

Light travels in straight line in a uniform transparent medium. When light passes from one medium into another obliquely on the interface its path gets deviated at the interface of the two media. This in known as refraction of light.

Why does light suffer refraction ? The speed of light is different in different media. In vaccum and air (approximately) under normal condition light travels at 3,00,000km per second. In water the speed of light is about 2,25,000 km per second. The medium in which the speed of light is smaller is known as optically denser medium. Thus, water is optically denser than air.When light enters from one medium to another obliquely on the interface, to enable to negotiate the change of speed, the path of the light is bent starting from the interface. Thus refraction takes place.

The ratio of the speed of light in vacuum to the speed of light in a medium i.e. the reciprocal of relative speed of light in a medium to the speed in vacuum is called refractive index of the medium. The ratio of the speed of light in two different media gives the relative refractive index of the second medium with respect to the first medium.

If v_o – represents speed of light in vacuum
v_a – represents speed of light in medium (A)
v_b – represents speed of light in medium (B)

$$\frac{v_o}{v_a} = \frac{1}{\left(\dfrac{v_a}{v_o}\right)} = \text{refractive index of (A)} = (\eta_{\mathrm{A}})$$

$$\frac{v_o}{v_b} = \frac{1}{\left(\dfrac{v_b}{v_o}\right)} = \text{refractive index of (B)} = (\eta_{\mathrm{B}})$$

$$\frac{v_a}{v_b} = \frac{1}{\left(\dfrac{v_b}{v_a}\right)} = \text{refractive index of (B) with repect to (A)} = \left[{}_{\mathrm{A}}\eta_{\mathrm{B}}\right]$$

We have,

$$\frac{v_a}{v_b} = \frac{v_a v_o}{v_o v_b} = \frac{\dfrac{v_o}{v_b}}{\dfrac{v_o}{v_a}} = \frac{\text{refractive index of (B)}}{\text{refractive index of (A)}}$$

$$\therefore \left[{}_{\mathrm{A}}\eta_{\mathrm{B}}\right] = \frac{\eta_{\mathrm{B}}}{\eta_{\mathrm{A}}}$$

When a ray of light passes from one medium to another the amount of deviation and the sense of deviation of its path are determined by the ratio of the refractive indices of the two media . When a ray of light enters a denser medium the path of the ray is deviated towards the normal on the interface at the point of incidence. When the ray of light is refracted to a rarer medium the path is deviated away from the normal on the interface at the point of incidence.

To understand the phenomenon further let us perform the following activity.

Activity 11.3

Fix a sheet of paper on a drawing board. As shown in the figure 11.6 draw the boundary of a glass slab (ABCD). Remove the glass slab and draw a normal NOM on the side AB at O.

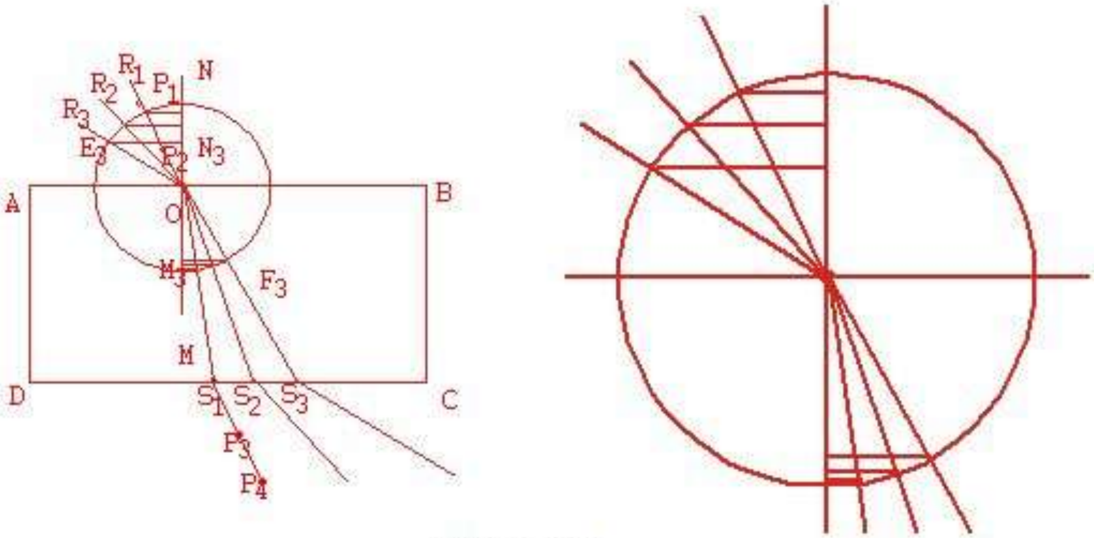


Figure 11.6

Draw a line R_1O making an angle i_1 to the normal ON. Fix two pins P_1 and P_2 upright on the line R_1O. Place the glass slab in the former position.

Look the two pins P_1 and P_2 through the glass slab and fix two pins P_3 and P_4 so that these two pins and the images of the former pins P_1 and P_2 lie on a straight line.

Draw a straight line passing through the two pins P_3 and P_4 meeting the side CD at S_1.

Join OS_1. Now OS_1 is the path of the refracted ray inside the glass slab corresponding to the incident ray R_1O. Thus angle MOS_1 is the angle of refraction r_1.

Observe the path OS_1 is not in the same line as R_1O. It is deviated closer to the normal.

Repeat the same activity using R_2O and R_3O as two more incident rays making angle of incidence i_2 and i_3 to the normal ON. OS_2 and OS_3 are the refracted rays making angle of refraction r_2 and r_3 to the normal respectively.

The incident rays, refracted rays and normal on the refracting surface at the point of incidence lie in the same plane.

Draw a circle of suitable radius with centre O cutting the incident rays at E_1, E_2 and E_3 and refracted rays at F_1, F_2 and F_3.

Draw perpendiculars E_1N_1, E_2N_2 and E_3N_3 from these points on the normal ON also F_1M_1, F_2M_2 and F_3M_3 on the normal OM.

Measure the length of the perpendiculars and find the ratio of $\frac{E_1N_1}{F_1M_1}; \frac{E_2N_2}{F_2M_2}; \frac{E_3N_3}{F_3M_3}$ and compare the results. The ratios are found the same.

What can you conclude from these observations

$$\text{Here, } \frac{E_1N_1}{F_1M_1} = \frac{E_2N_2}{F_2M_2} = \frac{E_3N_3}{F_3M_3} = \text{ a constant.}$$

$$\text{We have, } \frac{E_1N_1}{F_1M_1} = \frac{\frac{E_1N_1}{OE_1}}{\frac{F_1M_1}{OF_1}} = \frac{\text{Sin}\,i_1}{\text{Sin}\,r_1} \quad [\because OE_1 = OF_1 \text{ being radii of same circle}]$$

$$\frac{E_2N_2}{F_2M_2} = \frac{\frac{E_2N_2}{OE_2}}{\frac{F_2M_2}{OF_2}} = \frac{\text{Sin}\,i_2}{\text{Sin}\,r_2}$$

$$\frac{E_3N_3}{F_3M_3} = \frac{\frac{E_3N_3}{OE_3}}{\frac{F_3M_3}{OF_3}} = \frac{\text{Sin}\,i_3}{\text{Sin}\,r_3}$$

$$\text{Thus, we have} \qquad \frac{\text{Sin}\,i_1}{\text{Sin}\,r_1} = \frac{\text{Sin}\,i_2}{\text{Sin}\,r_2} = \frac{\text{Sin}\,i_3}{\text{Sin}\,r_3} = \text{ a constant.}$$

The activity gives two results known as the laws of refraction as stated below –

First law of refraction : The incident ray, refracted ray and normal on the refracting surface at the point of incidence lie in a plane.

Second law of refraction : The Sine of the angle of incidence bears a constant ratio to the sine of angle of refraction i.e. $\frac{\text{Sin}i}{\text{Sin}r}$ = a constant. The ratio is also known as refractive index of the second medium with respect to the first medium.

(The ratio is different for different colours (frequencies) of light. Light of different frequencies travel with the same speed in vaccum, however they travel with different speed in other media. In refraction different colours deviate through different angles corresponding to the same angle of incidence).

The ability of a medium to refract light depends upon the refractive index of the medium. It is also expressed in terms of optical density. A medium with larger refractive index is optically denser. Light travels with less speed in denser medium.

Successive Refraction

Let us study a ray of light PQRS passing through a glass slab ABCD with parallel refracting surfaces AB and DC and placed in air. Fig 11.7.

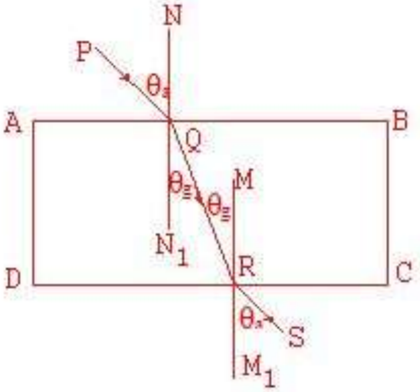


Figure 11.7

For the refraction at the first interface AB

θ_a – angle of incidence

θ_g – angle of refraction

$\therefore \frac{\text{Sin}\theta_a}{\text{Sin}\theta_g} = {}_a\eta_g$ (refractive index of glass with respect to air)

Since, AB and DC are parallel to each other the angle of incidence at the interface DC will be equal to the angle of refraction at AB. Thus the refraction at DC is just the reverse to that at AB.

For the refraction at the second interface DC.

$$\frac{\text{Sin}\theta_g}{\text{Sin}\theta_a} = {}_g\eta_a \text{ (refractive index of air with respect to glass)}$$

From these two refraction we can conclude that ${}_a\eta_g = \frac{1}{{}_g\eta_a}$

Thus, refractive index of a medium (A) with respect to another medium (B) is the reciprocal of the refrative index of (B) with respect to (A).

Apparent raising of the bottom of a vessel containing water

The bottom of a vessel containing water is apparently raised up. How is it ? Let us consider a point (P) at the bottom Fig. 11.8. A ray PA from the point meets the water surface normally.

It suffers no deviation and travels along AC. (As the angle of incidence is zero). Another ray PB meets the refracting surface at an angle of incidence θ_w. It is refracted away along BD making an angle of refraction θ_a. Here, $\theta_a > \theta_w$. The refracted rays BD and AC meet at Q producing backwards. Thus, the rays emitted from P appear to be emitted from Q, which is the virtual image of P. All the points at the level of P will appear to be at the level of Q. Thus the bottom appears raised up.

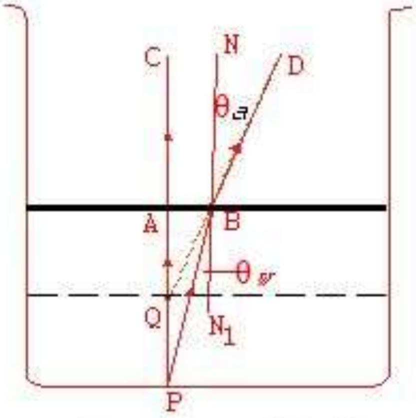


Figure 11.8

Now, PA is the real depth and QA is the apparent depth of the bottom.

With reference to the figure 11.8 the refractive index of water with respect to air, ${}_a\eta_w = \frac{\text{Sin}\theta_a}{\text{Sin}\theta_w}$

$$= \frac{\text{SinAQB}}{\text{SinAPB}} = \frac{\frac{AB}{QB}}{\frac{AB}{PB}} \quad \text{[Since } \angle AQB = \theta_a \text{ and } \angle APB = \theta_w \text{]}$$

$$= \frac{PB}{QB} = \frac{PA}{QA} \quad \text{[When B is close to A} \quad PB = PA \quad QB = QA.\text{]}$$

$$= \frac{\text{real depth}}{\text{apparent depth}}$$

Example 11.7 **A fish appears to be at a depth of 0.5m from the surface of water. Find the real position of the fish if refractive index of water is 1.33.**

Solution From the question we have, real depth = ?

Apparent depth = 0.5m

refractive index, $\eta = 1.33$

Using the relation,

$$\text{refractive index, } \eta = \frac{\text{real depth}}{\text{apparent depth}}$$

$$\text{We have, } 1.33 = \frac{\text{real depth}}{0.5}$$

$\therefore$ real depth = 1.33 × 0.5 = 0.665m.

Refraction from denser to rarer medium

When a ray of light enters a rarer medium from a denser one the path of the ray is deviated away from the normal. Hence angle of refraction is greater than the corresponding angle of incidence. When the angle of incidenc is increased the angle of refraction also increases correspondingly. For a particular angle of incidence the angle of refraction is 90^0. That is, the ray emerges at the grazing angle along the interface. The angle of incidence for which the angle of refraction is 90^0 is called **critical angle** (figure 11.9). What will happen when the angle of incidence is increased beyond critical angle ? The ray will not suffer refraction. The ray will be reflected back completely (totally) obeying the laws of reflection. The phenomenon of reflection of light approaching from a denser medium towards a rarer medium, at the interface of the two media is called total internal reflection.

Two conditions to obtain total internal reflection are :

(i) The ray must approach a rarer medium from a denser one.

(ii) The angle of incidence must be greater than the corresponding critical angle.

Refractive index of the denser medium is equal to the reciprocal of the sine of the critical angle.

$$\text{i.e. } \eta = \frac{1}{\text{Sin C}}$$

Assuming

Refractive index of glass = 1.52 the critical angle of glass with respect to air (vacuum) is given by

$$\text{Sin C} = \frac{1}{\eta} = \frac{1}{1.52} = 0.6579 = \text{Sin}\,(41.1)^0 \quad \therefore \; C = 41.1^0$$

When the angle of incidence is greater than 41.1^0 the ray will suffer internal reflection.

In the case of diamond the refractive index is very high. It is 2.42. For diamond critical angle with respect to air (vacuum) is given by

$$\text{Sin C} = \frac{1}{2.42} = 0.4132 = \text{Sin}\,(24.4)^0$$

Hence, $C = (24.4)^0$

When a ray of light enters diamond it suffers a number of internal reflections inside diamond. The angle of incidence inside easily exceeds the critical value 24.4^0 hence total internal reflection occurs successively inside diamond and it is found exceptionally bright.

Table 11.2 Absolute refractive index of some material media

Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Rock salt	1.54
Ice	1.31	Flint glass	1.65
Water	1.33	Ruby	1.71
Kerosene	1.44	Sapphire	1.77
Crown glass	1.52	Diamond	2.42

N.B. Optically denser medium may not always possess greater mass density.

Try to answer

1. In which medium will light travel faster water or kerosene ?
2. If the refractive index of glass is 1.5 what will be the apparent thickness of a glass plate of 1.5cm thick ?

11.4 Refraction Through Thin Lenses

Have you ever seen an object through a clean bottle of water ? The object appears distorted. Have you seen an object through a small water drop? The object appears bigger. Some spectacle lenses can concentrate the light from the sun at a point. The point gets heated, sometimes it catches fire. These experiences are related with lens.

What is a lens ? A lens is a transparent medium bounded with two spherical surfaces. [or, a plane surface and a spherical surface.]

There are two types of lenses. They are (i) Convex lens and (ii) Concave lens.

Convex lens – It is the type of lens in which the central portion is thicker than the peripheral portion. It always converge or tends to converge any beam of light passing through it. So, this type of lens is called as converging lens.

Concave lens – It is the type of the lens in which the central portion is thinner than the peripheral portion. When a beam of light passes through this type of lens, it always tends to diverge the beam of light. So, it is called as diverging lens.

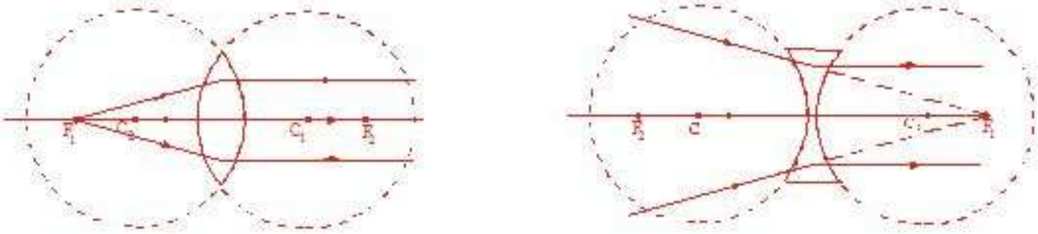
Terms associated with thin lenses

Principal axis – It is the straight line passing through the two centres of curvature of the two surfaces of the lens.

Principal section – It is a section of the lens obtained with a plane passing through the principal axis. In a diagram a lens is represented by its principal section.

Optical centre (O) – It is a point on the principal axis of the lens. Any ray passing through this point does not suffer deviation.

First principal focus (F_1) – It is a point on the principal axis. The rays diverging from this point in the case of convex lens or the rays converging towards this point in the case of concave lens, are refracted by the lens parallel to the principal axis.



(a) *(b)*

Figure 11.10

Second principal focus (F_2) – It is a point on the principal axis. The rays incident on the lens parallel to the principal axis after refraction actually converge to this point or appear to diverge from this point.

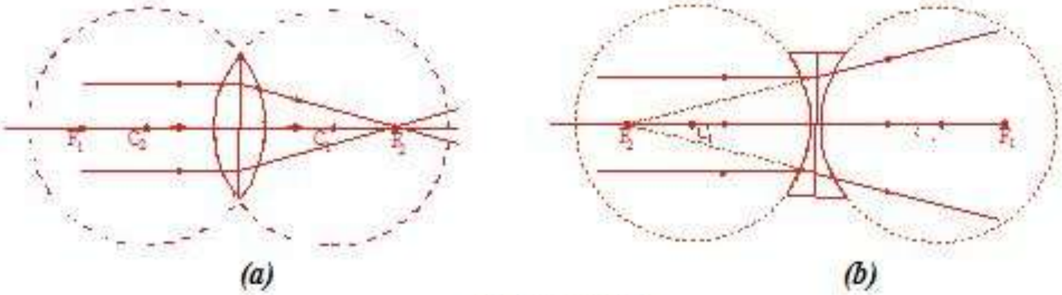


Figure 11.11

Focal length (*f*) – It is the distance of either first principal focus or second principal focus from the optical centre.

Image formed by lens

To locate the position of the image of an extended object, placed on the principal axis using ray diagram you can follow the following steps.

Step I Draw the principal section of the lens showing the position of optical centre (O), first principal focus (F_1) and second principal focus (F_2) on the principal axis. (distance of F_1 and F_2 from O will be equal).

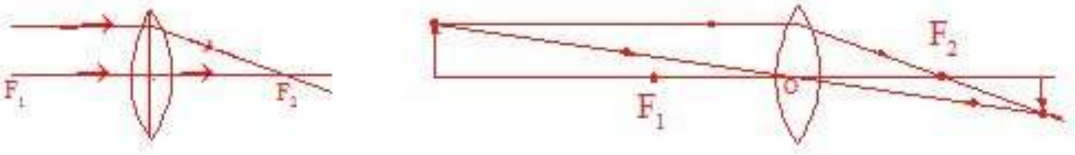
Step II From the top of the object placed on the principal axis conveniently on the left side of the lens trace the path of any two of the following rays.

- **(i)** The ray passing through the optical centre O. It does not suffer any deviation.
- **(ii)** The ray incident parallel to the principal axis. It is refracted through the second principal focus (F_2) in the case of convex lens. In the case of concave lens it is refracted as if it emerges from the second principal focus (F_2).
- **(iii)** The ray incident on the lens through first principal focus (F_1) in the case of convex lens or incident towards the first principal focus (F_1) in the case of concave lens. It is refracted parallel to the principal axis.

Step III Find out the point where the two refracted rays intersect actually or intersect producing backward. It is the image of the point on the top of the object.

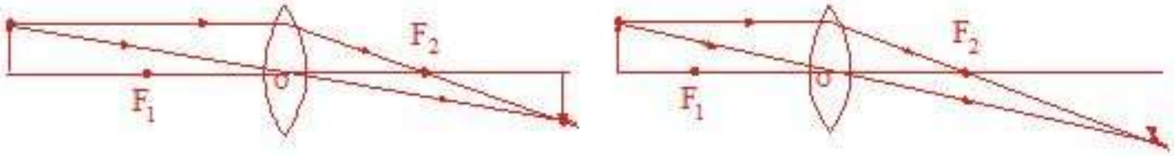
Step IV Draw a perpendicular from the point on the principal axis. The perpendicular represents the image of the extended object.

The following ray diagrams show the image formed by the convex lens when the object is placed at different distances. From the diagrams study the position, nature, and size of the image.



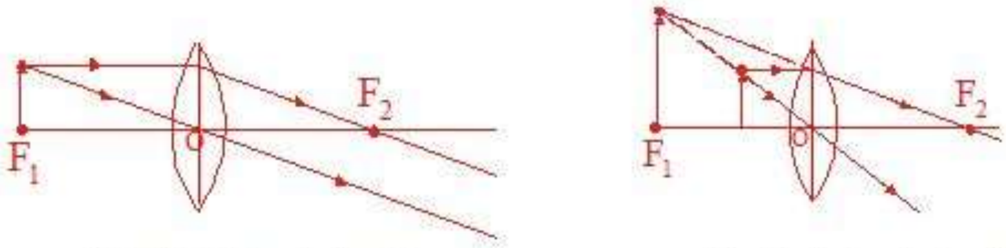
(a) object placed at infinity

(b) object placed at a distance greater than 2f



(c) object placed at a distance equal to 2f

(d) object placed at a distance less than2f and greater than f



(e) object placed at a distance equal to (f)

(f) object placed at a distance less than f

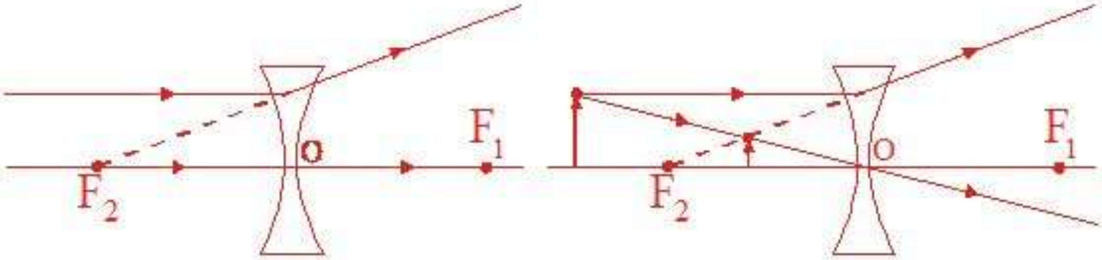
Figure 11.12

The position, nature and size of the image formed by a convex lens when the object is placed at different distances are summarised in the following table.

Table 11.3

Position of the object	Position of the image	Nature of image	Size of the image
At infinity	At the principal focus (F_2)	Real and inverted	highly diminished
At a distance $>2f$	At a distance greater than (f) and less than $2f$	Real and inverted	diminished
At a distance $= 2f$	At a distance equal to $2f$	Real and inverted	same size
At a distance $< 2f$ and greater than f	At a distance greater than $2f$	Real and inverted	Magnified
At focus	At infinity	Real and inverted	Infinitely magnified
At a distance $<f$	On the same side as the object.	Virtual and erect	Magnified

Ray diagrams of the image formed by concave lens :



(a) Object placed at infinity ***(b) Object placed between infinity and O***

Figure 11.13

From these diagrams we can conclude that concave lens always forms virtual, erect and diminished image for real object.

Lens formula

The image distance(v) formed by a lens depends upon the object distance (u) and focal length (f). Their relation is given by the formula

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

While using the formula we shall follow a sign convention similar to the one used for spherical mirror. In the case of lens all measurements are taken from the optical centre of the lens. According to this convention focal length of a convex lens is positive and that of a concave lens is negative.

Magnification – The ratio of the size of the image to the size of the object is called magnification(m). It is also related to the image distance (v) and the object distance (u). The relation is given by

$$\text{Magnification } (m) = \frac{\text{height of the image } (h_i)}{\text{height of the object } (h_o)} = \frac{\text{image distance}(v)}{\text{object distance}(u)}$$

$$\text{i.e } m = \frac{h_i}{h_o} = \frac{v}{u}$$

Power of lens

The converging or diverging ability of a lens is called power of the lens. This ability depends upon the value of focal length. Larger the focal length, power of the lens is less. Power of a lens is measured by the reciprocal of the focal length.

$$\text{Power, } P = \frac{1}{f}$$

When the focal length is expressed in metre the power is expressed in dioptre(D). One dioptre is the power of a lens whose focal length is 1 metre. Thus, $1\text{D} = 1\text{m}^{-1}$.

Example 11.8 **An object 3cm high is placed at a distance of 20cm from a convex lens of focal length 12cm. Find the position, nature and size of the image.**

Solution From the question we have

object distance, $u = (-)\ 20\text{cm}$

focal length, $f = (+)\ 12\text{cm}$.

Image distance, $v = ?$

By the formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

We have

$$\frac{1}{v} - \frac{1}{(-20)} = \frac{1}{12}$$

$$\Rightarrow \frac{1}{v}+\frac{1}{20}=\frac{1}{12}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{12}-\frac{1}{20}=\frac{5-3}{60}=\frac{2}{60}=\frac{1}{30}$$

$$\therefore\ v=30\text{cm}$$

magnification, $m=\frac{v}{u}=\frac{30}{-20}=-1.5$

$$\frac{h_i}{h_o}=-1.5\ \therefore\ h_i=-1.5\times 3=-4.5\text{cm}$$

Therefore, the image is formed at a distance of 30cm on the positive side i.e. on the other side of the lens. The image will be inverted and real. The size of the image is 4.5cm.

Example 11.9 **An object is placed at a distance of 10cm from a convex lens of focal length 15cm. Find the position, nature and magnification of the image.**

Solution From the questions we have

object distance, $u=(-)\ 10\text{cm}$

focal length, $f=(+)\ 15\text{cm}$.

Image distance, $v=?$

By the formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

We have,

$$\frac{1}{v}-\frac{1}{-10}=\frac{1}{15}$$

$$\Rightarrow \frac{1}{v}+\frac{1}{10}=\frac{1}{15}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{15}-\frac{1}{10}=\frac{2-3}{30}=\frac{-1}{30}$$

$$\therefore\ v=-30\text{cm}$$

magnification, $m=\frac{v}{u}=\frac{-30}{-10}=+3$

The image is formed at a distance of 30cm on the (–)ve side i.e. on the same side as the object. The magnification is +3. The image is erect and virtual.

Example 11.10 Find the image position of an object kept at a distance of 4cm from a concave lens of focal length 12cm. What is the magnification as well ?

Solution From the question we have

object distance, $u = (-)\,4\text{cm}$

focal lenth, $f = (-)\,12\text{cm}$.

image distance, $v = ?$

By the formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

We have,

$$\frac{1}{v} - \frac{1}{-4} = \frac{1}{-12}$$

$$\Rightarrow \quad \frac{1}{v} + \frac{1}{4} = \frac{-1}{12}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{-1}{12} - \frac{1}{4} = \frac{-1-3}{12} = \frac{-4}{12} = \frac{-1}{3}$$

$$\therefore \quad v = -3\text{cm}$$

magnification, $m = \frac{v}{u} = \frac{-3}{-4} = 0.75$

The image is formed at a distance of 3cm on the (–)ve side that is on the same side as the object. The magnification is (+)ve 0.75. The image is erect and virtual.

Try to answer

1. A lens can focus an image having the same size as the object on a screen 1m away from the lens. What is the focal length of the lens ?
2. An object is seen magnified through a lens. What is the type of the lens convex or concave ?
3. An object is seen diminished through a lens. What is the type of lens – convex or concave ?

(Numerical problems)

4. An object is placed at a distcance of 50cm in front of a convex lens of focal length 25cm. Find the image distance. If the object is 10cm high what will be the nature and size of the image ? [Ans. 50 cm, real inverted, 10 cm high]

5. An object is placed at a distance of 50 cm in front of a concave lens of focal length 25 cm. Find the image distance. What will be its nature ?

   [Ans. 16.67 cm, virtual and erect]

6. An object is placed at a distance of 15 cm in front of a convex lens of focal length 30 cm. Find the nature and position of the image ?

   [Ans. Virtual erect ; 30 cm on the same side as the object]

7. An objects is placed at a distance of 15 cm in front of a concave lens of focal length 30 cm. Find the nature and position of the image.

   [Ans. Virtual, erect, 10 cm on the same side as the object]

11.5 Human Eye and Defects of Vision

The human eye consists of a crystalline convex lens. The lens forms the image of the object (in front of the eye) on the retina. Retina contains a number of light sensitive nerves. The nerves carry the information of the image, formed on it to the brain. Then sensation of sight occurs. Only when the image is formed on the retina distinctly the object is seen clearly.

Can you see an object when it is placed at different distance ? Yes, we can see the object, placed within a wide range of distance. How is it possible ? A lens having fixed focal length can form the image of an object only at a fixed position. If the lens in the human eye has a fixed focal length, it will be able to focus the image on the retina for the object placed at a fixed position only. The eye lens can change its focal length. With the help of ciliary muscles the curvature of the eye lens can be changed. When the eye lens becomes thicker its focal length is reduced. To enable to focus the image on the retina focal length of the eye lens is adjusted. The ability of the eye lens to adjust its focal length is called **power of accommodation**. If the object is brought much closer, the eye lens may not be able to adjust its focal length any more to enable to focus the image on the retina. The nearest point upto which the eye can see is known as least distance of distinct vision (or near point). For normal eye the least distance of distinct vision is 25cm. When the eye lens is in the thinnest condition (normal condition) its principal focus lies on the retina (in the case of normal eye). The image of the object at infinity can be focussed on the retina. Thus, the far point of normal eye is infinity.

Try to read a printed page by holding it closer and closer. At what distance is it most comfortable ? Can you read upto what distance ? If you bring the printed page still closer what sensation do you feel ? Certainly you will feel a strain sensation in your eye.

Defect of vision

Can you read what is written on the blackboard of your class room from the back bench ? If not check your eye sight. When you read the book do you read with strained eye ? Perhaps you have seen some old persons reading books or newspaper keeping at arms length. Sometimes, the eye may gradually lose its power of accommodation. In such conditions, the vision becomes blurred due to refractive defect of the eye.

For a normal eye the range of vision is from 25cm to infinity. When an eye cannot see distinctly and comfortably the objects within the normal range (that is, between 25cm and infinity) the eye is said to have refractive defect of vision.

There are four common refractive defects of vision. They are (i) myopia or nearsightedness, (ii) hypermetropia or farsightedness, (iii) presbyopia or loss of accommodaton, and (iv) astigmatism or loss of horizon.

(i) Myopia or Nearsightedness

The eye suffering from this defect cannot see clearly the far off objects but can see distinctly the objects nearby. The far point of the defective eye is less than infinity and near point also is less than 25cm. The defect is due to either (i) the eye ball is elongated or (ii) the eye lens becomes thicker making its normal focal length too short. In such a situation the image of the distant object is formed in front of the retina Figure 11.14(a). This type of eye defect is corrected by using a concave lens of proper focal length Figure 11.14(c).

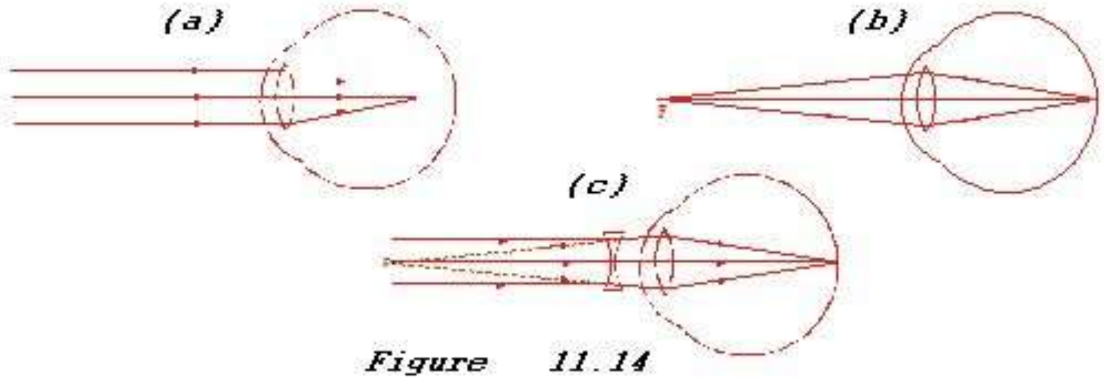


Figure 11.14

[The focal length of the concave lens is equal to the distance of the far point (F) of the defective eye Figure 11.14(b)]

(ii) Hypermetropia or Farsightedness

The eye suffering from this defect can see distant objects clearly but cannot see nearby objects distinctly. The near point of such defective eye is farther away from the normal near point i.e. 25cm. This defect may arise due to (i) shortening of eye ball length or (ii) normal focal length of the eye lens is too long. In such situation, the image of the distant object would be formed behind the retina Fig.11.15(a) if the eye lens is not adjusted by accomodation. To see the distant object the eye lens is adjusted by accommodation Figure 11.15(b). When the object is brought nearer, the eye lens is adjusted accordingly. But the ability to adjust the focal length by accommodation is exhausted when the object reaches a near point (N) which is greater than 25cm, the near point of normal eye Figure 11.15 (c). Hence the hypermetropic eye cannot see clearly objects nearer than N, which is beyond 25cm.

This defect can be rectified by using a converging or convex lens of suitable focal length Figure 11.15 (e).

(iii) Presbyopia or Loss of accommodation

Usually with ageing the flexibility of the eye lens diminishes and hence power of accommodation of the eye decreases.

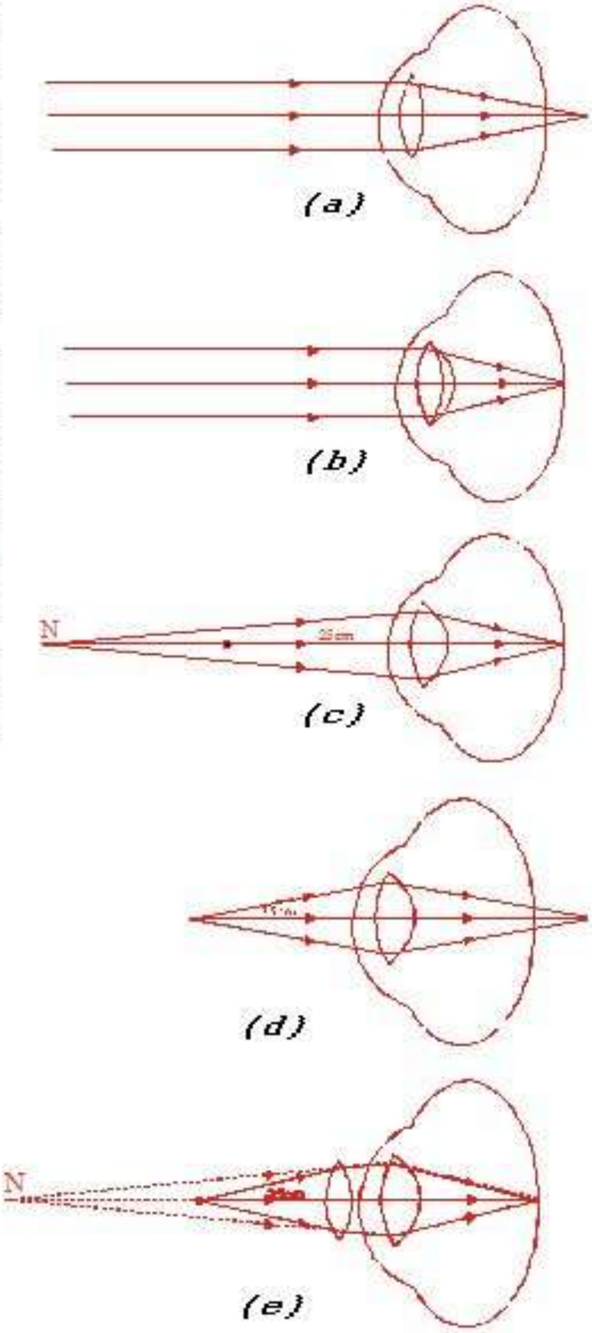
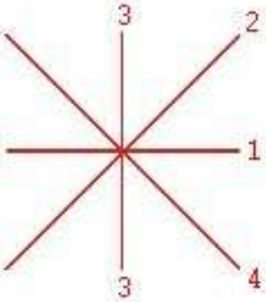


Figure 11.15

Sometimes, the eye may suffer from both myopia and hypermetropia. Such defect is known as presbyopia. The eye has a short range of vision. The near point recedes away and far point becomes close. Such defect can be rectified using bi-focal lens. A common type of bi-focal lens consists of both concave and convex lenses. The upper portion consists of a concave lens, it is used for distant vision. The lower portion is of a convex lens. It is used for near vision.

(iv) Astigmatism or Loss of horizon

An eye suffering from this defect cannot see all the directions– horizontal or vertical equally well simultaneously. The defect is due to the irregular curvature of the eye lens. The vertical and horizontal curvature of the eye lens are different. Such a defect can be removed using suitable cylindrical lens. To test astigmatism yourself do the following activity.



Figure

Activity 11.4

Draw four lines 1 – 1, 2 – 2, 3 – 3, 4 – 4 as shown in the diagram Figure 11.16 passing through a point with equal intensity.

Look the lines with the eye (left or right) which you are going to test. If all the lines appear equally intense the eye is not astigmatic.

If a particular line is most intense and its perpendicular line is least intense the eye is most likely astigmatic.

Rotate the diagram through 90^0. Does the most intense and least intense lines interchange ? If yes further testing with expert may be required.

Try to answer

1. An eye feels comfortable in reading the book keeping at a distance of 15cm. What is the defect ? What type of lens will be used to rectify the defect ?
2. A defective eye cannot see distinctly the object beyond 1m clearly. What is the defect ? What is the power of the lens required to rectify the defect ?

11.6 Dispersion of Light

We have seen the spectacular colours in a rainbow. How is a rainbow formed ? How could the white light of the sun gives us various colours of a rainbow ?

Light consisting of a number of components with different frequencies or wavelengths is called polychromatic or composite light. Light consisting of a single wavelength is called monochromatic light.

Solar light is a polychromatic or composite light. Splitting of a composite light into its constituent colours is known as dispersion of light.

A glass prism can split white light into its constituent colours. A prism is a transparent medium having two refracting faces inclining at certain angle. When a ray of light is passed through a prism, the ray always suffers deviation. To understand how white light is splitted by a prism let us perform the following activity.

Activity 11.5

- Prepare a narrow slit in a sheet of card board.
- With the help of a plane-mirror a beam of solar light is passed through the slit.
- Take a glass prism and allow the light to pass through the prism.
- Turn the prism slowly until the light that comes out of it falls on a nearby screen.
- What do you observe ? You will find a beautiful band of colours. Observe the sequence of the colour.

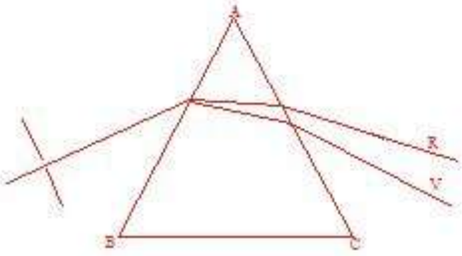


Figure 11.17

You will find that violet colour is deviated the most and red the least. If you see minutely you will find the sequence of the colours as – Violet, Indigo, Blue, Green, Yellow, Orange and Red. The acronym VIBGYOR will help you to remember the sequence of colours. The colour-band is called the spectrum.

When refraction takes place through the first refracting surface of a prism violet colour is deviated most and red colour is deviated least. Other colours are deviated in between the two extreme range. In the refraction through the second refracting surface also deviation takes place in the same sense and hence different colours are deviated further producing the colour spectrum more distinct. But in the case of glass slab the opposite refracting surfaces are parallel to each other. In this case, the composite light is splitted into its constituent colours when refraction takes place through the first surface. When the rays are refracted through the second surface the rays emerge without any deviation from the direction of the incident ray. Splitted rays of different colours corresponding to adjacent incident rays combine to form composite emergent rays. Only the extreme sides of the beam appear coloured. Thus a glass slab cannot cause dispersion of light.

When do you see a rainbow ? It is a natural spectrum appearing in the sky. It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere. To see a rainbow the sun will be at your backside. A rainbow is always formed in a direction opposite to that of sun. The water droplets act like small prisms. They refract the sunlight, disperse, then internally reflected. Finally the reflected rays emerge out of the raindrop (actually suffering refraction). Due to the dispersion of light and internal reflection, different colours reach the observer's eye Figure 11.18.

Can you create a rainbow on a sunny day for your friend ?

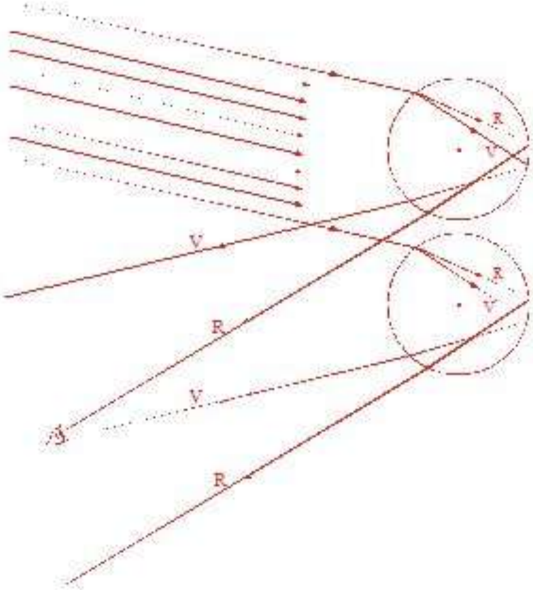


Figure 11.18

Try to answer

1. In the morning in which direction may you observe a rainbow ?

11.7 Phenomena caused by refraction in atmosphere

Some phenomena caused by refraction in atmosphere are accounted below :

(A) Advance Sunrise and delayed Sunset

Do you know the Sun is visible to us about 2 minutes before the actual sunrise? The sunset is also delayed by about 2 minutes. The day gets elongated by about 4 minutes. The rays of the solar light coming from space undergo refraction as they penetrate the atmosphere of the earth. Further, the density of the atmosphere decreases with altitude. Thus, as the ray travels from top of the atmosphere to the surface of the earth the density of the air medium gradually increases. As a result the path of the ray is slightly, curved and the rising sun which is actually lying below the horizon appears to be a little raised and becomes visible Figure 11.19. Because of this the sun is visible slightly before it actually rises and slightly after it sets. Also the setting sun appears slightly oval in shape rather than being circular. This is due to unequal refraction of light coming from the upper and lower portion of the sun's disc.

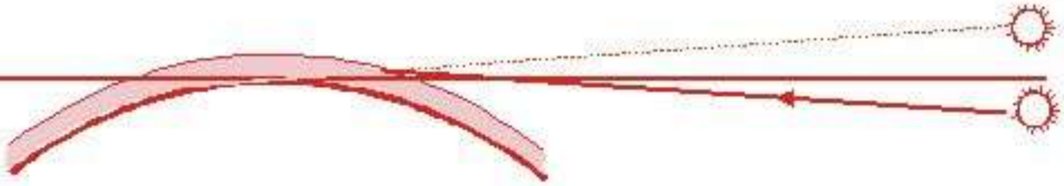


Figure 11.19

(B) Twinkling of Stars

The twinkling of star is also due to the refraction caused by the atmosphere. There are always irregular currents of hot air in the atmosphere. This causes the refractive index of the atmospher vary continually. As a result the position of the star appears to fluctuate to an observer on earth. Further, when a sudden current of hot air crosses the line of vision, the light from the star suddenly gets deflected away and the star is temporarily lost from view. Thus the stars twinkle.

The planets and the moon do not twinkle because they are much nearer to the earth and so do not behave like a point source. Further, they appear bright. Because of the reasons they do not twinkle.

(C) Scattering of light

Atmosphere contains not only air particles, but also some more minute particles like – smoke particles, tiny water droplets, dust particles, The interaction of light wave with these tiny particles gives rise to several spectacular phenomena in nature. Blue colour of sky, reddening of the sun at sunrise and sunset are some interesting phenomena. The path of a beam of light passing through a true solution is not visible. However, its path become visible through a colloidal solutions where the size of the particles is relatively larger. When a beam of light strikes such fine particles the path of the beam is visible as diffusely reflected rays reach our eye. The phenomenon of diffused reflection is called scattering of light.

Tiny particles can diffuse the light of shorter wavelength more effectively and light ray of longer wavelength are transmitted undisturbed. Blue light has shorter wavelength than red light. The molecules of air and other fine particles have the size more effective in scattering light of shorter wave lengths at the blue. The red light has a wavelength of about 1.8 times greater than that of blue light. Thus, when sunlight passes through the atmosphere the fine particles in air scatter the blue colour (shorter wavelengths) more strongly than red. The scattered blue light enters our eye. Thus we see the sky blue.

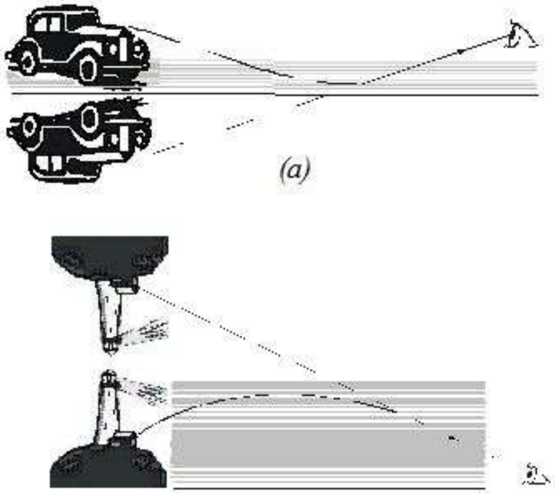
If the earth had not atmosphere, there would not have any scattering, then the sky would have looked dark.

Red light is not scattered or least scattered by the air and suspended particles in the atmosphere. It can penetrate through the air easily with least disturbance. So, red light is used in danger signal.

During sunrise and sunset the light rays from the sun passes through thicker layers of air and larger distance in the earth's atmosphere before reaching our eye. Almost violet and blue part of the solar light are scattered away on the way leaving only the red portion undisturbed. Therefore, the light that reaches our eye is of longer wavelengths. This gives rise to the reddish appearance of the sun.

At noon the sun is at overhead. Light from the sun would travel relatively shorter distance, so only a little portion of the blue and violet colours are scattered and the sun still appears white.

(D) Mirages


(a)

(b)

Figure 11.20

When different layers of the atmosphere are at different temperatures the layers will have different optical density. Many strange phenomena may occur – an object on the street may appear inverted as if reflection occurs on a water surface on the street Figure 11.20(a). A Ship or light house may appear floating in the sky in cold polar region. Such strange phenomena are known as mirages.

On a hot sunny day the layer of the atmosphere just above the road may become very hot and may have least optical density. Overlying layers of air are relatively cold. As we go up higher and higher the layer are optically denser and denser.

The rays from the top of an object on the street suffer refraction consecutively increasing angle of incidence layer after layer. At certain lower layer the angle of incidence may surpass the critical angle. Then the rays will be reflected back internally. To the observer an inverted image of the object will be seen.

In the cold polar region the optical density of the different layers of air decreases as we go higher and higher. Hence rays from the object on the surface of the sea after consecutive refraction are internally reflected back from a layer above. Hence the object is seen hanging in the sky Figure 11.20(b).

POINTS TO REMEMBER

i. Light travels rectilinearly.
ii. Regular reflection can cause the formation of image.
iii. Irregular reflection cannot cause the formation of image.
iv. The image formed by a plane mirror is laterally inverted.
v. Concave spherical mirror can form both real and virtual images depending upon the position of object.
vi. Convex spherical mirror can form only virtual diminished image.
vii. Speed of light is different in different media. Hence when light travels from one medium to another its path is deviated.
viii. The amount and sense of deviation depend upon the relative optical density of the media.
ix. Optical denser medium may not always possess greater mass density.
x. Apparent raising of the bottom of a vessel containing water is due to refraction.
xi. Lens is a transparent medium bounded with two spherical surfaces.
xii. Convex lenses have converging ability while concave lenses have diverging ability.
xiii. The converging or diverging capacity is known as power of a lens.
xiv. Human eye consists of a convex lens, whose focal length can be adjusted.
xv. Refractive defects of vision can be rectified using lens of suitable nature and focal length.
xvi. The range of vision of normal eye is from 25cm to infinity.

xvii. Splitting of composite light into its constituent colours is known as dispersion of light.

xviii. Dispersed pattern of a composite light is spectrum.

xix. Rainbow is formed by dispersion, internal reflection and refraction of solar light.

EXERCISE

1. What are the properties of the principal focus of a concave mirror ?
2. The image formed by a concave mirror is observed to be real, inverted and larger than the object. Where should be the position of the object ?
3. You are given three mirrors– convex, concave and plane appearing identical. How can you identify them without touching ?
4. Name a mirror that can give an erect and enlarged image of an object.
5. Name a mirror that can give an erect and diminished image of an object.
6. Can a convex mirror form a real image of a real object ?
7. Which spherical mirror is used for shaving ?
8. Why do we prefer a convex mirror as a rear-view mirror in vehicles ?
9. The radius of curvature of a spherical mirror is 40cm. What is its focal length ?
10. A concave mirror produce three times magnified real image of an object placed at 20cm in from of it. Where is the image formed ?
11. You are given a concave mirror, a scale and a screen. How will you determine the height of a tree ?
12. A ray of light travelling in air enters obliquely into water. Does the light ray bend towards the normal or away from the normal ? Why ?
13. Light enters from air to glass having refractive index 1.5. What is the speed of light in the glass ? The speed of light in vaccum is 3×10^8 ms^{-1}.
14. What is refraction of light ? Illustrate with example.
15. What is refractive index of a medium ?
16. Refractive indices of Kerosene and crown glass are 1.44 and 1.52 respectively. In which medium will light propagate faster and how much faster ?
17. Which one is optically denser water of refractive index 1.33 or Kerosene of refractive index 1.44 ?
18. What is total internal reflection ?

19. What is critical angle ? How is it related to the refractive index ?

20. A convex lens forms a real and inverted image of a needle at a distance of 40cm from it. Where is the needle placed in front of the convex lens if the size of the image is equal to that of the object ? Also, find the power of the lens.

21. Define 1 dioptre.

22. Find the power of a concave lens of focal length 50cm.

23. What is meant by power of accomodation of the eye ?

24. When an object is placed before a lens the lens forms a virtual image for any position of the object. Is the lens convex or concave ?

25. Name four common defects of vision. Give the causes and remedial measure.

26. A person has to use concave lens in his spectacle. Which defect of vision is he suffering from ?

27. What type of lens is used to correct (a) myopia and (b) hypermetropia ?

28. Distinguish between real image and virtual image.

29. Convex mirrors are used as side mirror in motorcycles. Explain how they are useful.

30. Why is a convex lens called converging lens ?

31. Why can you not see an object clearly if it is placed very close to your eye ?

32. A person with a myopic eye cannot see objects beyond 2m distinctly. What should be the type of corrective lens used to restore proper vision?

33. A student has difficulty of reading the black board while sitting in the last bench. What could be the defect ? How can it be corrected ?

34. What are the far point and near point of the human eye with normal vision ?

35. What is dispersion of light ?

36. Explain the reason of twinkling the star.

37. Why does the Sun appear reddish during sunset in the month of February and March particularly?

38. To an astronaut outside the atmosphere how would the sky appear ?

39. Why do we see distant object very small ?

40. Explain the reason of advance sunrise and delayed sunset.

★★★★★★

CHAPTER

12

SOURCES OF ENERGY

We have learnt in the previous class that the total energy during a physical or a chemical process is conserved. Why, then, do we talk so much about the energy crisis ? The question can be answered if we recall what else we learnt about energy. We have also learnt that energy exists in different forms and one form of it can be converted to another. Let us consider some examples. If we drop a metallic plate from a height, the loss in potential energy is converted mostly into sound energy, when it hits the ground. If we light a candle, the chemical energy of the wax is converted to heat and light energies on burning. Besides, some other products are also obtained on burning. Since, the total energy during a chemical or physical change remains the same – can we put together the heat and light generated along with the products of the reaction during the burning of candle to get back the chemical energy in the form of wax ?

In another example, suppose 400ml of water at 75^0 C is kept in a room whose temperature is 25^0 C (say). The temperature of water will come to 25^0 C by losing its heat content. Is there any way of collecting the heat lost to the surrounding and making the water hot once it was cooled down ?

In the above examples we will see that energy in the usable form is dissipated to the surroundings in less usable form. That is why, we are not able to perform endless activities without thinking about the energy resources, for any process.

Hence, to do work, we use source of energy. The energy so consumed cannot be used again.

12.1 What are the various Sources of Energy ?

In our day-to-day life we use energy from various sources for doing different works. We use petrol to run cars, scooter and motor cycles etc. We also use diesel to run buses, trucks, water pump, electric generators etc. We use electricity for lighting our houses and streets. We also use energy in our muscles to perform physical works such as household works, running, cycling etc. Try to recognise the different forms of energy with which we are using in day-to-day life, as an activity.

Activity 12.1

1. List four forms of energy that you use from morning, when you wake up, till you reach school.
2. From where do we get these forms of energy ?
3. Can we call them as sources of energy ?

The muscular energy required for carrying out physical work, the electrical energy needed for using electric appliances and the chemical energy required for cooking food, for running different vehicles are obtained from different sources. Sometimes, we need to know how to select the suitable source for obtaining the required energy in its suitable form. To understand the above facts, let us try to perform the following activity.

Activity 12.2

1. Examine the various options that we should have when we choose a fuel for cooking our food.
2. What are the criteria for categorising a good fuel.
3. Would your choice be different if you live
   (A) in a forest ? (B) in a remote village on a mountain or island ? (C) in town or city? (D) five hundred years ago ?
4. How are the factors different in each of the cases ?

After studying the above two activities, one can see that the particular fuel or source of energy we select for performing some work depends on a number of factors. For example, while selecting a fuel for any purpose we should ask ourselves the following relevant questions. The questions are –

(i) How much heat does the fuel release on burning ?

(ii) Does it produce a lot of smoke on burning ?

(iii) Does it produce poisonous material on burning ?

(iv) Is it readily and abundantly available ?

12.2 Selection of Fuel

The selection of fuel depends on the need of the consumers. Local conditions and personnel liking also influence the consumer in the selection of the fuel. Besides, selection of fuel depends on the work to be done. Would we choose one fuel for cooking and another for heating the room in winter or cold season ?

Thus a good source of energy would be one

- **(i)** Which would do a large amount of work by burning unit volume or unit mass of it,
- **(ii)** be easily accessible or available in plenty,
- **(iii)** be easy to transport and handle,
- **(iv)** be easy to store i.e. it should need less space for storage, and
- **(v)** be economical

Try to answer

1. What is a good source of energy ?
2. What are the characteristics of a good fuel ?

12.3 Conventional Sources of Energy

The simplest, earliest and the most common use of energy by man has been in the form of the energy stored in muscles of his body. The next use of energy by man was in the form of fire. In ancient times wood was the most common source of heat energy. Man next learnt to harness the energy of moving water and wind (i.e. the moving air). The energy so obtained was used for limited activities. Try to find out some of these uses. Next, the exploitation of coal as a source of heat and other forms of energy made the industrial revolution possible. Increasing industrialization has resulted to a better quality of human life all over the world. As a result, the global demand for energy is at a tremendous rate. The growing demand for energy was met on a larger scale by the fossil fuels – coal and petroleum. For India coal is the backbone of national economy and is a source of energy in key industries like railways, steel and thermal power plants. Our technologies were also developed for using coal and petroleum.

But the fossil fuels (coal and petroleum) were formed over millions of years ago on the earth and there are only limited resources because of the finite size of the earth.

Fossil fuels are preserved in the earth's crust as remains of animals and plants. The main fossil fuels are (i) coal (ii) petroleum and (iii) natural gas. Thus, the fossil fuels are non-renewable sources of energy. So we need to conserve them. Experts are of the opinion that if we were to continue consuming these sources of energy at the present alarming rates, we would soon run out of these sources of energy. In order to avoid this, alternate sources of energy were explored by scientists. However, we still continue to be largely dependent on fossil fuels for most of our energy requirements. The situation can be understood from the pie-chart given in figure 12.1.

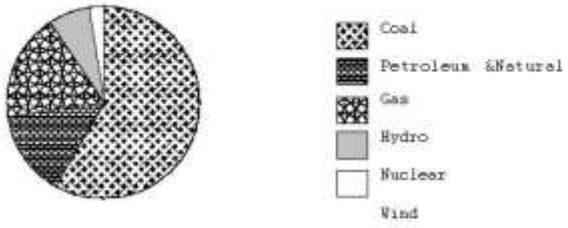


Figure 12.1

The burning of fossil fuels has many disadvantages since the end products of combustion enter into the air. We learnt in class IX, about the air pollution caused by burning of coal or petroleum products. These are mainly oxides of carbon, hydrogen, nitrogen and sulphur, which are acidic oxides. These oxides introduced in the atmosphere are the cause of acid rain which affects our water and soil resources. The unburnt particles of carbon and hydro carbons also enter into the atmosphere. These substances deteriorate the quality of air and the air is said to be polluted. Breathing in such air is harmful. In addition to the problem of air pollution, recall the green house effect, caused by excessive release of carbon dioxide.

Now-a-days, the pollution caused by burning of fossil fuels can be somewhat reduced by increasing the efficiency of the combustion process. This is done by using various techniques to reduce the escape of harmful gases and ashes into the surroundings. Fossil fuels are used directly in gas stoves and vehicles. Moreover, the major fuels used for generating electricity are fossil fuels, inspite of pollutions caused by burning them.

Let us think over for a while – how would our lives change if we could no longer get electricity ? The amount of electricity consumed by each individual in a country is one of the parameters to measure the growth of the country.

Potential energy of a water body stored at a height is another traditional source of energy. Hydel power plants convert the potential energy into electricity. The natural water reservoir or water falls which could be used for this plant is very few. So, hydro-power plants are associated with dams. High rise dams are constructed on the river to collect water in larger reservoirs. The water from the higher level is allowed to run down through a pipe. The potential energy in the stored water is changed into kinetic energy. This kinetic energy is used to move the turbine of the generator. Thus electricity is produced.

The reservoir would be refilled when there is rain. It is a natural process of water cycle. Thus hydro-power plant is a renewable source of energy.

Construction of big dams have certain problems. Large areas of agricultural land and human habitation are to be sacrificed as they get submerged. Large eco-systems are destroyed when submerged under the water. When the vegetation are submerged they rot under anaerobic condition and give rise to large amount of methane which is also a green house gas.

12.4 Improvements in the Technology for using Conventional Sources of Energy

About 80% of the energy consumed by the rural mass in India is based on biomass. The material contained in the bodies of plants and animals is called biomass. When plants die, their biomass can be used as fuel for domestic purposes. In our homes, we burn wood in the traditional Chullas which have poor efficiency of about 8 percent only. At the same time it leads to health hazards from the smoke coming out due to incomplete combustion. The above problems are overcome in smokeless Chullas which allow better combustion and have better efficiency. The smoke, at the same time is removed through chimney attached to it. Charcoal is also used as fuel for domestic and industrial purposes. Charcoal is made by burning wood in a pit where the supply of air is insufficient. In doing so, volatile matters in the wood are drawn off leaving behind a residue black in colour. This black residue is charcoal. Charcoal is mainly carbon.

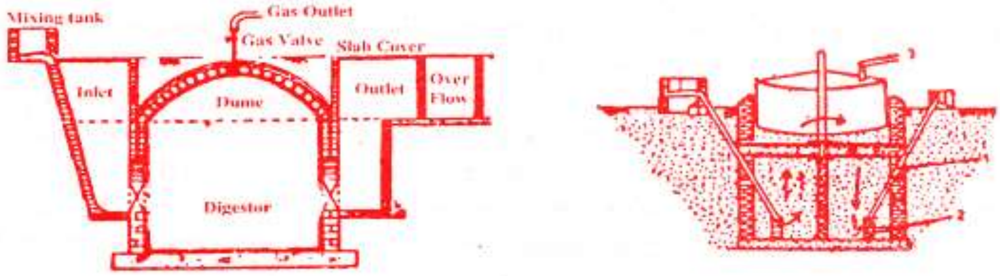
Dried animal dung cakes are also used as domestic fuels in rural areas. When they burn with insufficient supply of air a lot of smoke is produced. This leads to air pollution. At the same time animal dung contains a lot of nutrients vital to soil. It is, therefore, unwise to burn animal dung cakes directly. In order to save the vital nutrients from the animal dung for use in agriculture and to reduce the air pollution to some extent, bio-gas plants have now been designed and are used in rural and some sub-urban house-holds.

The wastes from animals and plants, what we called as biomass can be degraded easily by anaerobic organisms in absence of air but with water. In this process, organic manure which is better than the dry cattle dung and mixture of gases such as methane, carbon dioxide, hydrogen, hydrogen sulphide are produced. The gas mixture is called the biogas. Biogas mainly contains methane about 65 to 75 percent. It is an excellent fuel. It burns without smoke, leaving no residue like ash in wood, charcoal and coal burning. Its heating capacity is high. Bio-gas is also used for lighting. By converting biomass into biogas heating efficiency is increased by about 20 percent.

The slurry left in the plant after the gas is withdrawn is rich in phosphorous and nitrogen compounds and is a good quality manure.

Taking due considerations of the above advantages, Khadi and village industries Corporation and other government agencies actively promote the construction of biogas plants. In a country like India having largest cattle population, there is tremendous scope for community size biogas plants which can meet a large percentage of domestic energy needs in the rural areas. This would reduce pressure on chemical fertilizers, stress on forest and other fossil fuels.

There are two types of biogas plants. They are fixed dome type and floating gas holder type.



Fixed dome *Floating gas holder*

Figure 12.2

In both the types, thin semiliquid mixture of animal dung and water is put into the plant. Human excreta can also be added in the mixture. The biogas so produced is drawn off through pipes for use at specific points. For continuous supply of it, the plant needs regular supply of biomass. In big cities where underground sewage facilities exist, sewage gas – a mixture of methane and carbon dioxide may be collected. Out of this mixture methane gas may be separated out for using as fuel.

12.5 Alternative or Non-Conventional Sources of Energy

Our life -style is changing. We are using machines to do more and more work for us. Our demand for energy increases day by day. Our basic requirements are also increased. So, we need to look for more and more sources of energy. To develop the technology for using the available or known source of energy more efficiently and to look to new sources of energy are two main areas to pay our attention. Any new source of energy we seek to exploit would need specific devices developed with that source in mind. We shall now look at some source of energy that we seek to tap and the technology designed to capture and store energy from that source.

Solar Energy

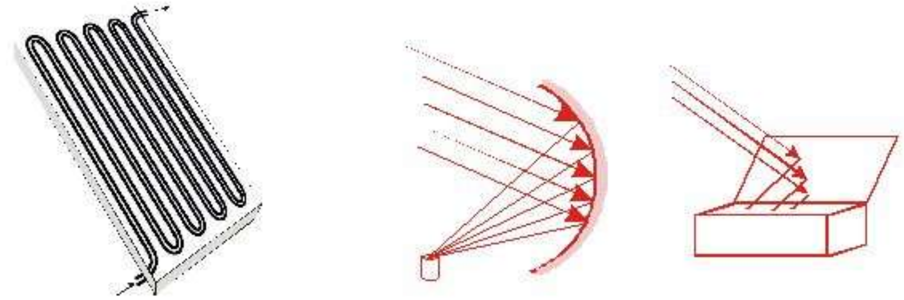
We are receiving the energy from the sun in the form of light energy and heat energy. The quantity of solar energy reaching the earth's upper atmosphere has been estimated at about 1.39 kJ/m^2/s. The total solar energy of all wavelengths received per unit time by a surface of unit area oriented normally to the Sun's rays at the top of the earth's atmosphere is called **Solar constant**. Thus, the solar constant is 1.39 kJ/m^2/s. It has been calculated that energy received over the total surface of the earth amounts to 3. 57 × 10^{14} kJ/s, roughly 20,000 times larger than the current global energy consumption. The energy is absorbed by numerous atmospheric particles. The total incoming radiation may be divided into direct radiation and diffused or indirect radiation resulting from scattering in the atmosphere and earth's surface. The maximum influx on the average is about 4 to 7 kWh/m^2. The heat that we feel in sunlight is mainly due to the presence of infra-red wavelength in sunlight and it heats up the land and water on the surface of earth. How can you tap this huge amount of energy ? To understand it a little more let us perform the following activity.

Activity 12.3

1. Take two bottles of the same capacity.
2. Paint one white and the other black (or wrap one with white paper and the other with black paper)
3. Fill both the bottles with the same quantity of water.
4. Place the bottles in direct sunlight for an hour.
5. Touch the bottles. Which one is hotter ?

Can you think of ways in which this finding could be used in your daily life .

A black surface absorbs more heat as compared to a white surface. Solar cookers and solar water heaters are designed using this principle. A solar cooker may have solar heat collector. Solar collectors may be divided into two types – (i) Concentrating or focussing type and (ii) flat or non-focussing type.



(a) Solar water heater *(b) Solar collector (concentrating type)* *(c) Solar collector (flat reflector type)*

Figure 12.3

The reflector is made of foils of aluminium or almuminised plastics or strips of mirror and the pot used of cooking may be of aluminium or stainless steel. The outer surface of the cooker is coated with lamp black or nickel black. Solar cookers are covered with glass plate to trap the heat more by green house effect also.

These devices are useful only at certain times during the day, when there is sunshine.

Solar energy can be used to generate electricity

Heat produced by the sun’s rays can be used to generate electricity indirectly. In this process, solar energy is used to heat a liquid of low boiling point. The resulting vapour is made to turn turbines which are connected to generators. One such example is Abhimanyu solar pump developed at the National Physical Laboratory, New Delhi, which can generate 1 kW of electricity. At present the use of these engines is rather limited.

In another way, sunlight can be used to generate electricity with the help of light sensitive cells known as solar cells or solar batteries. Such devices are also called photo voltaic devices. These cells are used most often in space vehicles and artificial satellites to power their electrical devices and electronic instruments.

Solar batteries were developed for the first time by the scientists of the Bell Telephone Laboratories, America. Now-a-days, Central Electronics Limited (CEL), India has developed solar batteries. It is made up of a number of cells. Each cell consists of a wafer of pure silicon, to which certain impurities have been doped. In other words, they are solid state semi-conductor devices which convert solar energy directly into D C (direct current) electrical energy. Because of limitations on the maximum voltage and current of a single solar cell a number of solar cells are connected in series and then arranged in parallel resulting to a mixed grouping of cells. Such a combination is known as panel. The panel is finally covered with glass in order to protect the cells from the atmosphere and dust. To use the electricity during the night time and on cloudy days when there is no direct sunshine, the electrical energy is stored in accumulators or secondary batteries. The stored electrical energy is used again in the night or in cloudy periods. This system is very much useful in remote unelectrified villages.

Wind Energy

Wind is nothing but the air in motion. The movement of air is also due to the convection current set up in the atmosphere on account of non-uniform heating of the earth's surface by the sun. There are both horizontal and vertical motions of air. What we call wind is mainly the horizontal movement of the air near the earth's surface. We are primarily interested in it.

Earlier wind power was used for propulsion of ships or directly converted into mechanical energy to lift water, to grind corn and for agricultural uses. For the use of wind power to generate electricity, the kinetic energy of the wind is to be converted into some convenient form of mechanical motion which in turn will drive the shaft of an electric generator. For the purpose there is a wind turbine mounted upon a tower Figure 12.5. The kinetic energy of the wind is used to provide rotatory motion of the wind turbine which can be used to do work. The other equipments like gear boxes, speed control devices, safety devices and electrical generators may be mounted on the tower. The diameter of the turbine and height of the tower are designed to suit the wind velocity in the region of installation and the power requirement. It is known that at higher points above the earth's surface, the wind is steady and has greater velocity.

Figure 12.5

The power available from the wind depends on :

(i) the area of the blade circle, **(ii)** density of the air, and **(iii)** cube of the wind velocity.

The output of a single wind mill is quite small and cannot be used for commercial purpose. Therefore, a number of wind mills are erected over a large area, which is known as wind energy farm. The energy output is coupled together to get electricity on a commercial scale.

The merits of using wind energy are :

(i) It is an environment friendly effort.

(ii) No recurring expenses for energy production required.

The limitations in harnessing wind energy are :

(i) Wind energy farms can be established only at selected places where wind blows for the greater parts of a year with a speed higher than 15km/h to maintain the required speed of the turbine.

(ii) Establishment of wind energy farm requires large area of land.

(iii) There should be enough back up facilities like storage cells.

(iv) Initial cost of establishment of the farm is quite high.

(v) Since the equipments are exposed outside, they need proper maintenance.

It is estimated that nearly 45,000 MW of electrical power can be generated if India’s wind potential is fully exploited. The largest wind energy farm in India is located at Kanyakumari in Tamil Nadu. It generates 380 MW of electricity. In the case of Denmark wind energy, from a vast network of wind mills, claims more than 25% of the total electricity used in the country.

Energy from the Sea

Tide is a natural phenomenon occurring periodically on the sea. It creates the difference of water level on the sea. Thus Tidal energy is developed. Can you think how to tap the energy there ? Sea water is never at rest. Sea water has a huge amount of kinetic energy. Would it be possible to tap the energy associated with sea wave?

The water at the surface of sea or ocean is heated by the sun while water in the deeper section is relatively cold. This difference in temperature is exploited to obtain energy in ocean thermal energy conversion plants. The difference of temperature is about 20^0 C at the depth of 2km. The heat in the surface water is used to boil a volatile liquid like ammonia. The vapour of the liquid are then used to run the turbine of generator. Cold water from the depth is used to condense the vapour again to liquid.

The potent energy of the sea is quite large, but efficient commercial exploitation is yet to be worked out.

Geothermal Energy

Have you heard about hot springs ? Sometimes the molten rocks in the deeper regions of earth's crust are pushed up and trapped in certain regions as hot spots. When underground water comes in contact with the hot spot steam is generated. Some of the hot water and steam may find outlets at the surface. They are found in the form of hot spring. Still a large amount of steam remains trapped in the rocks. When the steam is rooted through a pipe to a turbine of a generator, electricity can be produced. The site where such energy can be exploited on the commercially viable project is very limited. There are a number of power plants based on geothermal energy operational in New Zealand and United States of America.

Nuclear Energy

What is nuclear energy ? The energy released during nuclear reaction is called nuclear energy. There are two types of nuclear reactions. They are (i) nuclear fission and (ii) nuclear fusion. In nuclear fission the nucleus of a heavy atom (such as uranium, plutonium or thorium) is splitted into two lighter nuclei with the help of slow moving neutron. In this process a huge amount of energy is released. The sum of the masses of the product nuclei is less than the mass of the original nucleus. The mass lost is converted into energy. In nuclear reactors the amount of energy released is controlled and used to run the turbine of electric generator.

In nuclear fusion two energetic light nuclei fuse together to make a heavy nucleus with the release of huge amount of energy. In this process also the lost of mass of the interacting nuclei is responsible for the production of the huge amount of energy. Nuclear fusion is responsible for the energy in the sun and the star. To control the fusion reaction for the production of electricity for our use is yet to achieve. Still, nuclear energy cannot be used in large scale on the following grounds (problems). Storage and disposal of spent or used fuel is a major problem. Harmful radiation from the nuclear waste cause damage to the human body and environment. Improper nuclear-waste storage and disposal result in environmental contamination. Further, there is a risk of accidental leakage of nuclear radiation. The high cost of installation is also an additional problem.

We have studied various sources of energy either conventional or non-conventional. Exploiting any source of energy disturbs the environment in some way or the other. We always choose the source depending upon the following factors –

(a) the ease of extracting energy from the source.
(b) the economics of extracting energy from the source.
(c) efficiency of the technology available.
(d) the environmental damage that would be caused by using the source.

POINTS TO REMEMBER

i. Muscular energy, electrical energy, chemical energy etc. are obtained from different sources.

ii. Energy from wood, fossil fuel, hydel power plants are conventional sources of energy.

iii. Improvement in the technology of using conventional sources of energy is highly needed.

iv. Use of solar energy, wind energy, tidal energy, geothermal energy etc. are non-conventional sources of energy.

v. While selecting a fuel we have to consider the easiness of extracting energy from the source, cost of extraction, efficiency of technology available and impact on environment.

EXERCISE

1. What is a good source of energy ?

2. What is a good fuel ?

3. If you could use any source of energy for heating your food, which one would you use and why ?

4. What kind of mirror – concave, convex or plain would be best suited for use in a solar cooker? Why ?

5. What is geothermal energy ?

6. Can any source of energy be pollution free ? Give reason in support of your answer.

7. Name two energy source that you would consider to be renewable. Give reasons for your choice.

8. Give the name of two energy sources that you would consider to be exhaustible. Give reasons for your choice.

9. What are the qualities of an ideal source of energy ?

10. What are the advantages of using a solar cooker ? Are there places where solar cookers would have limited utility ?

★★★★★★

CHAPTER

13

LIFE PROCESSES

We have learnt that many of the objects around us are said to be alive while many others are not alive. Then, what are the differences between these living and non living objects ? If we see a grazing cow, a running cat, a man doing work, we know that these are alive. Even while they are sleeping we know that they are alive. Why ? Because they are respiring. So, all that are alive respire while those which are not alive do not respire. We also see that a calf grows up in size with the sucking of the mother’s milk. A young plant also grows in size with time. Thus, all the living things grow in size with the consumption of food. We also see a cow giving birth to a calf, a hen laying eggs which later hatch to chicken. So the living organisms reproduce their own kind to continue their race.

In earlier classes, we have learnt that the living organisms possess well organised structures. They have organs, organs have tissues, tissues have cells, cells have smaller components in them and so on.

13.1. Processes required for living

The maintenance of the functions of the body go on continuously in living organisms. Even when they are not doing any work or even when they are asleep, these function go on continuously. The processes concerned with maintenance of life are **life processes**.

The life processes of the living body need energy. This energy normally comes from outside the body of the organism in the form of food. This energy from the food from outside the body of the organism is released inside the body by a process called **nutrition.**

Food, the outside sources of energy, may occur in varied forms. These food materials need to be broken down in the body and finally converted to a uniform source of energy that can be used for the various cellular functions necessary for maintaining life. A series of chemical reactions are necessary for this. Most common chemical reactions for breaking down molecules are oxidation-reduction reactions. For this, many organisms take in oxygen from outside the body. This taking in of oxygen and breaking down of food materials inside the body for cellular need is known as **respiration**.

In most unicellular organisms, generally no specific organs or organ systems occur for taking in food, exchange of gases or removal of wastes, as the entire body surface is in contact with the environment. But, in case of multicellular organisms, most of the cells are not in direct contact with the surrounding environment. For them, various body parts have become specialised for performing these functions. These specialised structures or tissues also do the function of uptake of food and oxygen. But these are done only in the specialised parts of the body while every cell of the body needs these food and oxygen. Thus there arises a need for distribution of the food and oxygen to every cell by developing a transporting system.

When chemical reactions take place for the release of energy by using food materials and oxygen, by-products are released. Accumulation of these by-products beyond a permitted level is harmful to the body. So these are to be continuously removed from the body and discarded outside. This process is known as **excretion**. In multicellular organisms, a specialised system for excretion is present.

Now, let us discuss the various life processes, more in detail.

Let us answer these.

1. How can we know that something is alive ?
2. In which form the living organisms get energy from outside the body ?
3. What are life processes ?
4. No specific organ for gaseous exchange is needed in an unicellular organism. Why is it so ?

13.2. Nutrition

When we do some work or ride a bicycle, we are using up energy. Even when we are not doing any work or sleeping, we need energy to maintain a state of order in our body. We also need materials from outside the body in order to grow, to repair worn out tissues and also to synthesize protein and other substances needed in the body. The sources of energy and materials required come form the food we eat.

13.2.1. How do living things get their food ?

The requirement for energy and materials is common to all living organisms. But, it is fulfilled in different ways. Some organisms synthesize their food from simple inorganic components like carbon dioxide and water. These organisms, known as **autotrophs** , include green plants and some bacteria. Other organism, known as **heterotrophs,** utilise the food materials synthesized by the autotrophs. Thus, the heterotrophs depend directly or indirectly on autotrophs for their food. Heterotrophic organisms include animals, fungi and protists.

13.2.2. Autotrophic nutrition

Autotrophs take in simple substances from the outside and convert them into more complex forms of energy through a process called as **photosynthesis.** In this process, carbon dioxide (CO_2) and water (H_2O) are converted into carbohydrates with the help of the light energy absorbed by the chlorophyll pigment of the green plants. Carbohydrates are utilized for providing energy to the plant and excess carbohydrates are stored in the form of starch.

During this process, oxygen (O_2) is evolved as a byproduct, as shown below

$$\underset{\text{Carbon dioxide}}{6\,CO_2} + \underset{\text{Water}}{12\,H_2O} \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \underset{\text{Carbohydrate}}{C_6H_{12}O_6} + \underset{\text{Water}}{6H_2O} + \underset{\text{Oxygen}}{6O_2} \uparrow$$

The following events occur during photosynthesis:

(i) Chlorophyll of the plant traps the light energy.

(ii) Conversion of light energy to chemical energy and splitting of water molecules into hydrogen and evolution of oxygen.

(iii) Reduction of carbon dioxide to carbohydrates.

Activity 13.1.

- ☞ Take a potted plant with variegated leaves e.g. *Coleus* or *Croton*.
- ☞ Keep the plant in a dark room for three days. Pluck a leaf from the plant and keep the leaf in a dark place.
- ☞ Now keep the plant in sunlight for about 6 hours.
- ☞ Again pluck another leaf from it.

- Dip both the leaves in a beaker containing alcohol. Carefully place the above beaker in a water bath and heat till the alcohol began boil.
- Transfer the leaves in a beaker containing dilute solution of iodine for starch test.
- Take out the leaves and rinse with clean water.
- Observe the colour of the leaves.

What can you conclude from the above experiment ?

Why the first leaf does not change its colour after starch test ?

Why the second leaf shows colouration only in various places ?

13.2.3. Let us see how CO_2 and chlorophyll are necessary for photosynthesis

A transverse section of a green leaf under the microscope (Fig. 13.1.) shows the presence of many cells containing green dot like cell organelles. These dot like organelles are the chloroplast which contain chlorophyll.

How do the plants obtain carbon dioxide ?

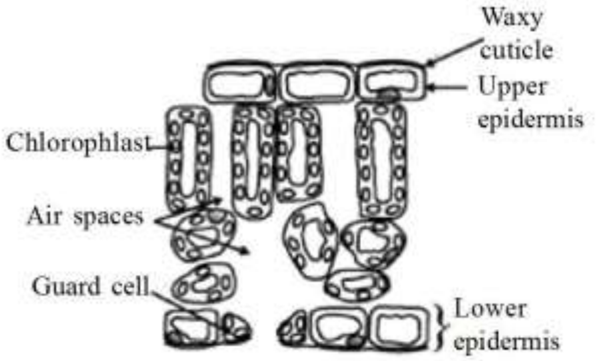


Fig. 13.1. Cross section of a leaf

The stomata are the minute openings present on the epidermis of green leaves through which gases move in or out during photosynthesis. Water is also lost in the form of water vapour through these pores. Each stoma is surrounded by two specialised, kidney shaped **guard cells**. A few cells adjacent to guard cells are modified into **subsidiary cells**.

These pores close when the plant does not need carbon dioxide for photosynthesis. The opening and closing of the stomata is brought about by the change in shape of the guard cells. The stomatal pore remains open when the guard cells swell due to the absorption of water and closed when the guard cells shrink (Fig. 13.2).

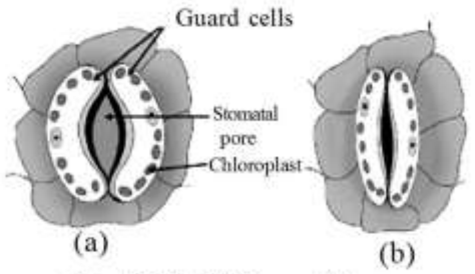


Fig. 13.2. (a) Opened stoma
(b) Closed stoma

The water used during photosynthesis is absorbed from the soil by the roots of land plants . Other nutrients like nitrogen, phosphorus, magnesium and iron etc. are also absorbed from the soil. Nitrogen is absorbed from the soil in the form of inorganic nitrates or nitrites or as organic compounds prepared by bacteria.

13.2.4. Heterotrophic Nutrition

Animals are heterotrophic organisms requiring readymade organic and inorganic compounds as food. These food substances are broken down, absorbed and used as a source of materials and energy.

Types of heterotrophic nutrition

- **(i)** Holozoic animals take in whole material and break it down inside their bodies. Protists like *Amoeba* and higher animals are important examples.
- **(ii)** Saprozoites like roundworms and flatworms feed on soluble organic matter in solution.
- **(iii)** Saprophytic fungi and bacteria break down the food materials outside the body and then absorb it.
- **(iv)** Parasitic organisms obtain their food from the body of other living organisms called the host. Examples are *Cuscuta*, Ticks, Leeches, etc.

13.2.5. Nutrition in Animals

In different animals, the food and the way it is obtained are different. So the digestive system is also different in different animals. In single celled organisms, the food may be taken in by the entire body surface. But, with the increase of complexity of the organism, different parts become specialised to perfom different functions. In *Amoeba*, food is taken in by using pseudopodia which are temporary finger-like extensions of the cell surface and form a temporary food vacuole. Inside the food vacuole, complex substances are broken down into simple forms that are absorbed by the cytoplasm. The undigested material is thrown out of the body by moving to the surface.

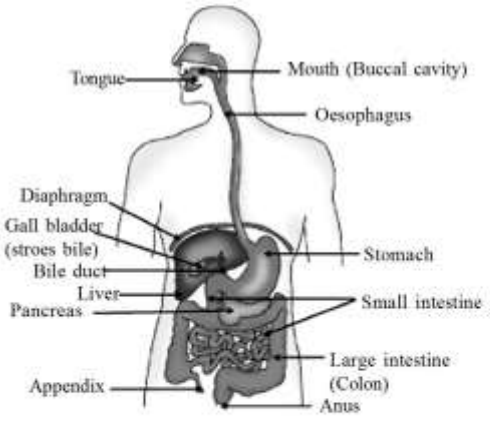


Fig.13.3. Human alimentary canal

material is thrown out of the body by moving to the surface. In *Paramoecium* which is also an unicellular organism, the cell body has a definite shape and food is taken in at a specific spot. Food is driven to this spot by the action of the moving cilia which cover the entire surface of the body.In higher animals, for example, in human beings, the alimentary canal is basically a long tube extending from the mouth to the anus. The tube has different regions specialised to perform different functions. The different types of food we eat are crushed into small fragments in the mouth with the help of teeth. During crushing, the food is also mixed with saliva secreted by the salivary glands in the mouth. This makes the crushed food particles soft and facilitate swallowing . The saliva also contains an enzyme, ptyalin (salivary amylase) which initiates the digestion of starch to make simple sugars. The lining of the alimentary canal has muscles that contract involuntarily and rhythmically to push the food down the alimentary tract. This rhythmic movement is known as **peristalsis** and occurs all along the gut.

The food from the mouth comes to the stomach passing through the oesophagus. The stomach is a large bag like organ which expands when food enters into it. The muscular walls of the stomach which also performs peristaltic movement, help in mixing the food thoroughly with digestive juices secreted by the gastric glands of the stomach. The gastric glands secrete hydrochloric acid (HCl), pepsin (a protein digesting) enzyme and mucus. The HCl creates an acidic medium which facilitates the action of the enzyme pepsin. It also kills some of the micro-organisms entering the stomach along with the food materials. The mucus in the stomach protects the inner lining of the stomach from the action of HCl.

The stomach is followed by the small intestine. The passage of food from the stomach to the small intestine is regulated by a sphincter muscle. The small intestine is the longest part of the alimentary canal which is fitted into a compact space because of extensive coiling.

The length of the small intestine varies in different animals depending on the type of food they eat. The small intestine is very long in herbivores. This facilitates digestion of the cellulose of the plants by passing the food through a long distance . The small intestine is shorter in carnivores because it is easier to digest the animal tissues.

The digestion of carbohydrates, proteins and fats are completed in the small intestine. It receives the secretion of the liver, the bile and the secretion of the pancreas, the pancreatic juice. The food coming from the stomach is acidic as it is mixed with HCl. This acidic food has to be made alkaline since the pancreatic enzymes act in an alkaline medium. This change from acidic to alkaline medium is achieved with the help of bile . Bile salts also act on large fat globules and break them down to smaller globules thus helping in the digestion of fat. It is known as emulsification of fat.

The pancreatic juice contains enzymes such as trypsin for digesting proteins, lipase for digesting emulsified fats. It also contains the enzyme amylase for the digestion of carbohydrates. The walls of the small intestine also contain glands which secrete protein, carbohydrate and fat digesting enzymes. These enzymes finally convert the proteins to amino acids, complex carbohydrates into glucose and fats to fatty acids and glycerol.

The digested food is absorbed by the wall of the small intestine. The inner lining of the small intestine is provided with numerous, small, finger like projections called **villi** which increase the surface area of absorption.

The villi are richly supplied with blood vessels. The absorbed food is transported by blood to each and every cell of the body, where it is used for obtaining energy, building up new tissues and repair of damaged tissues.

The undigested and unabsorbed food is sent to the next part of the alimentary canal, the large intestine. Here most of the water is absorbed in the blood. After this the undigested portion of the food is removed from the body through the anus. The exit of undigested waste material is regulated by a sphincter muscle of the anus.

Let us answer these.

1. What are the differences between autotrophic and heterotrophic nutritions?
2. From where plants get the raw materials required for photosynthesis?
3. What are the different types of heterotrophic nutrition ?

4. Write the role of HCl in our stomach.
5. What are the functions of digestive enzymes ?
6. How does the small intestine designed to absorb digested food ?

13.3. Respiration

Activity 13.2.

- Take a clean test tube and fill about half of it with freshly prepared lime water.
- Blow air into this lime water by using a glass tube.
- Note how long it takes for the lime water to turn milky.
- Take another test tube and fill about half of it with freshly prepared lime water as before.
- Allow air to pass through the lime water using a syringe.
- Note in this case also how long it takes for this lime water to turn milky.

What does this tell us about the amount of CO_2 in the exhaled air ?

We know that during the process of nutrition food material is taken in the body of the organism. This food material is used in cells to provide energy for various life processes. Diverse forms of organisms do this in different ways. Some use oxygen to break down glucose completely into CO_2 and water, some use other pathways that do not use oxygen. The first step of the reaction for the liberation of energy in all cases is the break down of glucose, a six carbon molecule, into a three carbon molecule called **pyruvate** (Fig. 13.4.). This process takes place in the cytoplasm. Pyruvate may further be converted into ethanol and carbon dioxide. This takes place in yeast during fermentation. Since this process takes place in the absence of oxygen, it is called **anaerobic respiration**. Pyruvate may also be broken down by using oxygen in the mitochondria. In this process, the three carbon pyruvate is broken down to give three CO_2 molecules and water. Since this process takes place in the presence of oxygen, it is called **aerobic respiration**. The release of energy in the aerobic process is greater than in anaerobic process. There is another pathway for breakdown of pyruvate. This takes place when there is lack of oxygen in the muscle cells. In this pathway the pyruvate is converted to lactic acid which is also a three carbon molecule. The accumulation of lactic acid in our muscles during sudden activity causes **cramps**.

The energy released during cellular respiration is immediately used up to synthesize a molecule called ATP. All the energy required for different life processes are supplied in the form of ATP. During the process, ATP is broken down giving rise to a fixed amount of energy. This energy can drive the endothermic reactions taking place in the cell.

Being a living organism, plants also need energy. The energy is supplied by the process of respiration. The process of aerobic respiration is similar in both plants and animals. The exchange of gases in plant takes place through the stomata and the large intercellular spaces ensure that all cells are in contact with air. The exchange of oxygen and carbon dioxide between the cells and atmosphere occurs by **diffusion**. The direction of diffusion depends upon the environmental conditions and the requirements of the plant. The CO_2 released by respiration during daytime is used up by photosynthesis, hence there is no CO_2 released but O_2 is released. At night, there is no photosynthesis, so CO_2 is eliminated as a byproduct. The unique feature in plant respiration is anaerobic respiration. This process does not occur in animals.

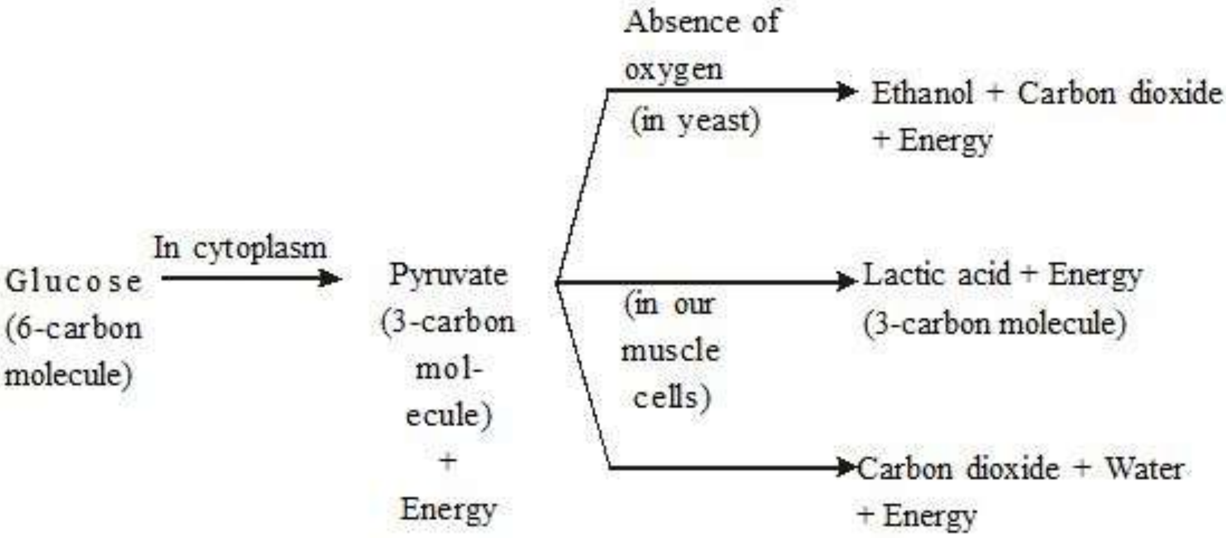


Fig. 13.4. Break down of glucose by various pathways

Various animals have developed different organs for taking in oxygen and giving out CO_2. The terresterial animals use atmospheric oxygen for breathing but the aquatic animals used oxygen dissolved in the water.

The amount of oxygen dissolved in water is very low when compared to the amount of oxygen present in the atmospheric air. So the rate of breathing in aquatic organisms is much faster than that in terrestrial animals. For breathing, fishes take in water through their mouths and force it to pass the gills where the dissolved oxygen is taken up by blood through diffusion.

Activity 13.3

- Observe some fishes in an aquarium. They open and close their mouths and gill slits or the operculum covering the gill slits also open and close. Are the timings of the opening and closing of the mouth and gill slits co-ordinated in some manner ?
- Count the number of times the fish opens and closes the mouth in a minute.
- Compare this to the number of times you breathe in and out in a minute.

Different terrestrial animals have different organs to absorb atmospheric oxygen. All these organs have a structure that increases the surface area which is in contact with the oxygen rich air. Since the exchange of oxygen and carbon dioxide has to take place across this surface, it is very fine and delicate. Moreover, in order to protect the surface, it is lodged inside the body and so there have to be a passage that will take air to this area. A mechanism to move the air in and out of this area where the oxygen is absorbed is also developed.

Human beings take in the air into the body through the nostrils. The passage is provided with fine hairs and mucus to filter the air. From the nostrils the air comes to the lungs passing through the throat. The throat is provided with rings of cartilages. These ensure that the air passage does not collapse.

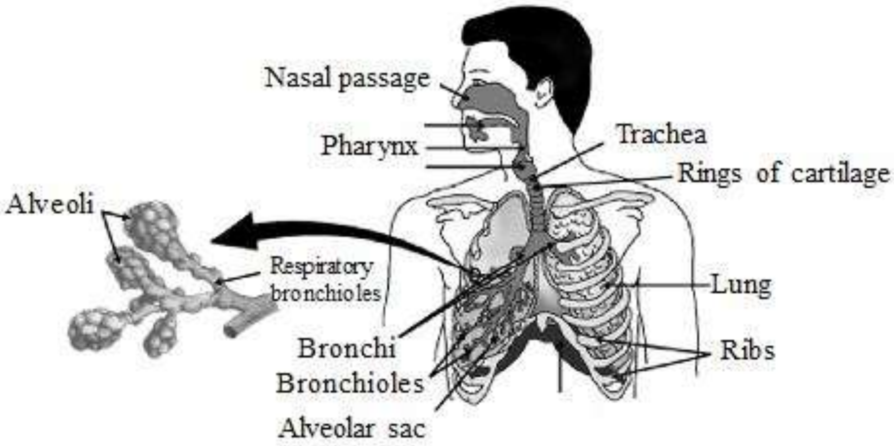


Fig.13.5. Human respiratory System

The wind pipe or air passage known as **trachea** divides into two **bronchi** leading each to each lung. In the lungs the bronchi divide into smaller branches called **bronchioles**. These bronchioles end in alveolar sac where the gaseous exchange takes place. The walls of the alveoli contain an extensive network of blood-vessels. When we breath in the ribs are lifted and the diaphragm is flattened . As a result the chest cavity becomes larger. By doing so, the air is sucked into the lungs and fills the expanded alveoli. The blood in the alveolar blood vessels absorb the oxygen from the alveolar air and the carbon dioxide in the alveolar blood vessels diffuse out in the alveolar sac. The oxygen absorbed in the alveolar blood vessels is transported to all the cells of the body. During the breathing cycle, when air is taken in and let out, the lungs always contain a residual volume of air so that there is sufficient time for oxygen to be absorbed and for the carbon dioxide to be released.

When the body size of the animal is large, the diffusion pressure alone is not sufficient for supply of oxygen to all parts of the body. In addition there are respiratory pigments in the blood which take up oxygen from the air in the lungs. In human beings, haemoglobin is the respiratory pigment. It has very high affinity for oxygen. This pigment is present in the red blood corpuscles (RBC). Carbon dioxide is more soluble in water than oxygen. So, it is mostly transported in the dissolved form in our blood.

Do you know ?

- ***If the alveolar surface were spread out it would cover about 80m^2. What is the approximate surface area of your body ? Consider how efficient exchange of gases carried out because of the large surface area available.***
- ***If diffusion were to move oxygen in our body, it is estimated that it would take about 3 years for a molecule of oxygen to get to our toes from our lungs. This does not happen due to the presence of haemoglobin.***

Let us answer these.

1. What advantage does a terrestrial animal get with regard to obtain oxygen during respiration over an aquatic animal ?

2. How is oxygen and carbon dioxide transported in human beings ?

3. “The human lungs are designed to have maximum surface area for exchange of gases”.

Explain.

13.4. TRANSPORTATION

Transportation in Human beings

13.4 Activity

- ☞ Visit your local health centre and find out what is the normal range of haemoglobin content in human beings.
- ☞ Is it same for children and adults ?
- ☞ Is there any difference in the haemoglobin levels for men and women ?

In previous sections, we have seen that the blood transports digested food, oxygen, carbon dioxide, waste materials, etc. in our bodies. In previous classes also we have learnt that the blood is a fluid connective tissue. Blood consists of a fluid called plasma and cells suspended in it. Plasma transports digested food materials, carbon dioxide and nitrogenous wastes in dissolved forms. Oxygen is transported by red blood corpuscles. Many other substances like salts, hormones are also transported by the blood. Thus, for transporting various substances from one part of the body to another part, there is the necessity of a pumping organ to ensure a continuous flow of blood and a network of blood vessels to reach all the tissues.

13.4.1. Heart

The heart is the pumping organ which send blood to every part of the body. The human heart is a muscular organ which is as big as our fist. Since both oxygenated and deoxygenated bloods are to be transported by the heart, it has four separate chambers to check the mixing of the two types of blood. The oxygen rich blood from the lungs comes to the left upper chamber of the heart known as the left atrium. It is a thin walled chamber. The left atrium relaxes when the blood enters into it. Then it contracts and the blood from this enters the thick walled left ventricle. When the left ventricle contracts the blood is

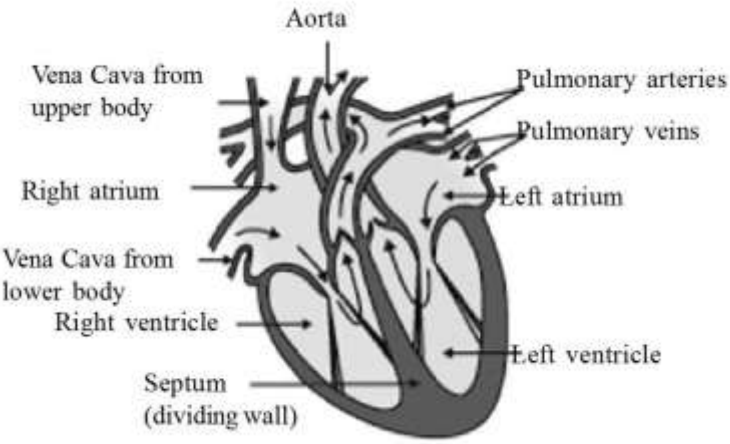


Fig.13.6. Sectional view of the human heart.

pumped out to the different parts of the body. Deoxygenated blood returning from different parts of the body enters the right atrium when it expands. As the right atrium contracts, the blood from here enters the right ventricle. When the right ventricle contracts in turn the deoxygenated blood from here is pumped to the lungs for oxygenation. The ventricles pump the blood to various organs, they have thick muscular wall while the atria have comparatively thinner walls. The back flow of the blood when the atria or ventricles contract is checked by the presence of valves.

The separation of the flow of blood in the right and left sides of the heart is useful in preventing the mixing of oxygenated and deoxygeneted blood. This complete separation of the two types of blood gives a sufficient supply of oxygenated blood in the animals that have high energy needs. Such type of heart is present in birds and mammals which constantly use energy to maintain their body temperature. Animals like amphibians and many of the reptiles have only three chambered heart in which there is mixing of oxygenated and deoxygenated blood. In these animals the body temperature depends on the temperature of the environment. In fishes also the body temperature depends on the temperature of the surrounding environment . In these animals the heart is only two chambered. The deoxygenated blood collected in the heart is pumped to the gills for oxygenation. From the gills after oxygenations the blood is supplied to different parts of the body. So the heart in fishes contains only deoxygenated blood. Thus, in these animals the blood passes only once through the heart during one cycle of flow through the body. In other higher vertebrates, the blood goes through the heart twice during each cycle. Such condition is known as double circulation.

13.4.2. Blood vessels

The blood vessels which carry blood from the heart to various organs of the body are the **arteries**. These are thick walled because they are to carry the blood emerging under high pressure from the heart. The blood vessels which collect blood from various organs and return it to the heart are the **veins**. These are thin walled because the blood passing through them are not under high pressure. They posseses valves which check the backflow of blood.

The artery divides into smaller and smaller vessels in the organs or tissues and the smallest vessels are known as **capillaries**. The capillary wall is of one-cell thickness and arranged in such a way that each and every cell is in contact with blood. Exchange of materials between the blood and surrounding cells takes place across this thin wall. After supplying blood to the cell the capillaries join together to form veins and carry the blood from the organs or tissues and back to the heart.

13.4.3. Platelets

When there is an injury, bleeding starts. The leakage in the blood vessels would lead to a loss of pressure which would reduce the efficiency of the pumping system. To prevent it, there are platelets in the circulating blood which bring about the clotting of blood. Clotting prevents the loss of blood from the sides of injury.

13.4.4. Transportation in Plants

Plant transport systems involve the movement of raw materials from roots to the leaves for photosynthesis and synthesized food from leaves to the different parts of the plant. Movement of water and minerals is through the xylem and transport of photosynthetic products is through the phloem.

In lower plants, transport of water and other organic materials is done by different processes like simple diffusion, osmosis and active transport. Transportation of substances in algae and fungi take place across the cell membrane and within the cell cytoplasm by the above processes.

How the transportation takes place in vascular plant ? What types of forces are essential for transportation in higher plants.

In higher plants, the leaves can directly absorb carbon dioxide through diffusion for the process of photosynthesis. Other kinds of raw materials needed by the plant are taken in the form of solution through its root system. If the distance between the root system and chlorophyll containing parts are short, energy and raw materials can be easily diffused to all parts of the plant body. In trees the distance become long and simple diffusion processes is not sufficient. So a proper system of transportation is essential in such situation.

A single rye plant in four months of growth have 350 km of roots. There are approximately 13 million root tips possessing an estimate total of 14 billion root hairs.

13.4.5. Transport of water in vascular plant

The water conducting system of higher plant includes xylem tissues, like vessels and tracheids of the roots, stems and leaves are interconnected to form a continuous system reaching all parts of the plant. The capacity of root cells to take up ions from the soil creates a difference in the concentration of these ions between the root and the soil. So, water moves from the soil into the root to stabilize this difference. Such a steady movement creates a pressure that can push the water upward. The root pressure is not enough to lift the water upto the height that we commonly see in a plant. Plants thus, have to use other strategies to overcome it.

13.5. Activity.

- ☞ Cut a leafy twig of Balsam plant (it has semitransparent stem) under water to avoid entry of airbubble through the cut end.
- ☞ Place the cut end in a beaker containing water coloured with eosin (a red dye) dissolved in it.
- ☞ After some time red lines will be seen moving upward through the stem.
- ☞ If a section of the stem is observed under microscope, only the xylem elements will be seen filled with coloured water.

In which tissues transport of water takes place ?

Can uplift of water takes place without root ?

What are the processes responsible for the uplift of water through stem ?

Water is lost in the form of water vapour from the aerial portion of the plant through the stomata of leaf. This loss of water is replaced by water from the xylem vessels in the leaf and also creates a suction which pulls water from the xylem cells of roots.

Thus the loss of water in the form of vapour from the aerial portions of the plant is called **transpiration.** It helps in the absorbtion and movement of water and minerals dissolved in it from the roots to the leaves. It also helps in temperature regulations. During night transportation of water is done by root pressure and by transpiration during daytime when the stomata are open. So transpirational pull is major driving force in the movement of water in the xylem.

13.4.6. Transport of food and other substances

The transport of soluble products of photosynthesis from the leaves and stem to the other parts of the plant through the phloem is called **translocation**. Phloem also transport amino acids and other substances. The upward and downward translocation of food and other substances takes place through the sieve tubes with the help of companion cells of phloem tissue.

Unlike water transport, the translocation in phloem is performed by utilising energy from ATP. The transfer of substances like sucrose into the phloem tissue results in increase of osmotic pressure causing water to move into it. This pressure moves the material in the phloem tissues which have less pressure. In this way the materials are translocated by the phloem to all the parts of a plant, which need it for various activities and storage. During spring stored materials in root or stem tissue would be transported to the bud which need energy to grow.

Let us answer these.

1. Name the components of the transport system in human being. Write the functions of the components.
2. What are the advantages of separation of oxygenated and deoxygenated blood in birds and mammals ?
3. What are the components of the transport system in highly organised plants ?
4. How are water and minerals transported in plants ?
5. How is food transported in plants ?

13.5. Excretion

The removal of harmful metabolic waste from the body is known as **excretion**. The metabolic activities in the body generate nitrogenous materials. These nitrogenous wastes are harmful if accumulated in the body so these are to be removed. Different organisms use different devices for the removal of waste materials. Many unicellular animals remove these waste products by diffusion through the body surface to the surrounding water. Other multicellular organisms use specialised organs for the removal of the nitrogenous wastes.

13.5.1. Excretion in Animals

Different groups of animal have different organs for the removal of nitrogenous waste products.

Certain animals like platyhelminthes use structures called **flame cells** to remove the waste products. The Insects remove the nitrogenous waste by the help of structures called **Malpighian tubules**. The vertebrates have **kidney** for excretion. In human beings the excretory system consists of a pair of kidneys, a pair of ureters, a urinary bladder and a urethra.

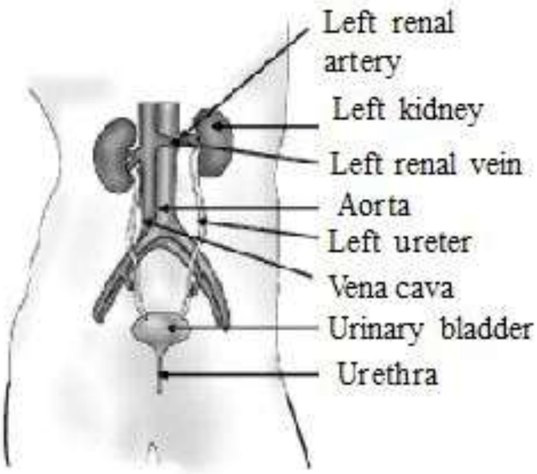


Fig. 13.7. Excretory system in human beings

Kidneys are located in the abdomen, one on either side of the backbone. Urine produced in the kidneys passes through the ureter and is stored in the urinary bladder. From the urinary bladder it is released through the urethra.

Nitrogenous waste products collected by the blood from different organs of the body are filtered in the kidney. Such compounds like urea or uric acid are removed from the blood. Like in the lungs, clusters of very thin walled blood capillaries are present in the kidney. Each capillary cluster in the kidneys is associated with the cup-shaped end of a tube that collects the filtered urine. Each kidney has large numbers of these filteration units called **nephron** packed closed together. Some substances

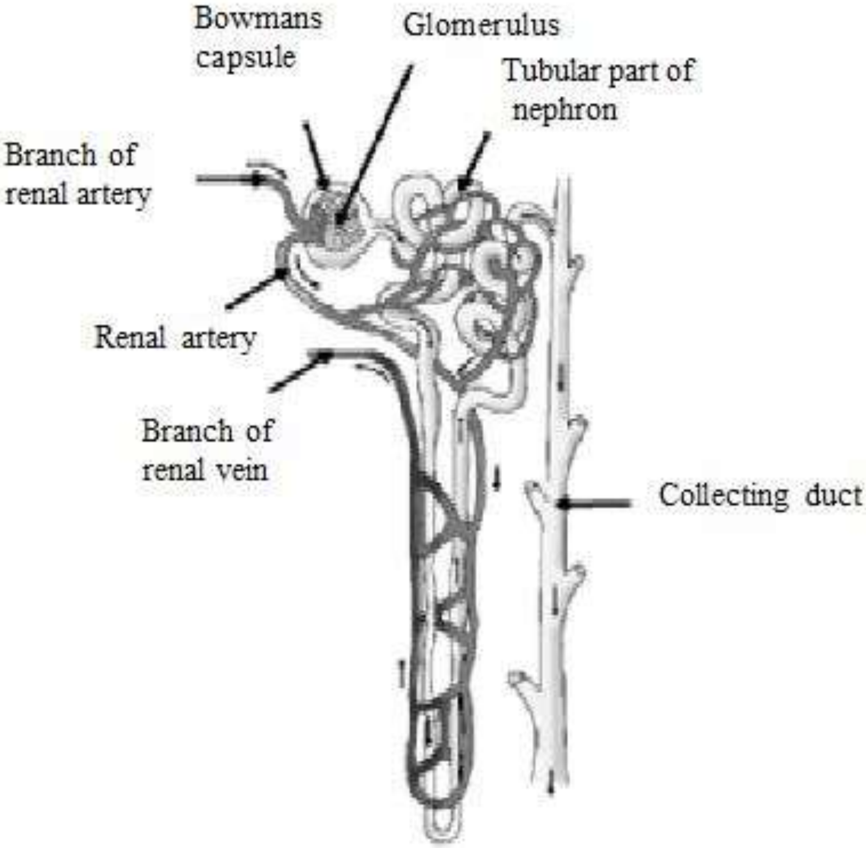


Fig. 13.8. Structure of a Nephron

like glucose, amino acids, salt and major amount of water are selectively re-absorbed as the urine flows along the tube. The urine forming in each kidney enters a long tube, the ureter, which connects the kindneys with the urinary bladder. From the urinary bladder the urine passes out of the body through the urethra.

13.5.2. Excretion in plants

Plants give out oxygen during photosynthesis and carbondioxide during respiration. Water in released as vapour during day time and in liquid form during night. Roots also exudate waste materials into the soil. All mineral salts absorbed in the form of ions are not essential in plants. The excess minerals are deposited in the leaves that fall off. Other waste products are stored as resins and gums specially in old xylem.

Let us answer these.

1. What are the methods used by plants to get rid of excretory products ?
2. Which organs are responsible for excretion in platyhelminthes and insects ?

POINTS TO REMEMBER

- All living organisms respire.
- The maintenance of life requires proceses like nutrition, respiration, transport of materials within the body and excretion of waste products.
- Autotrophic nutrition involves the manufacture of complex high energy organic material from simple inorganic materials by using solar energy.
- Heterotrophic nutrition involves the intake of complex material prepared by other organisms.
- In human beings the food eaten is broken down by various steps along the alimentary canal and the digested food is absorbed in the small intestine to be sent to all cells in the body.
- Respiration provides energy in the form of ATP by broken down complex organic compounds such as glucose. ATP is the source energy for other reactions in the cell.
- Respiration may be aerobic or anaerobic. Aerobic respiration produces more energy available to the organism.

- ⇨ In human being, the transport of materials such as oxygen, carbon dioxide, food and excretory products is the function of the circulatory system. The circulatory system consists of the heart, blood and blood vessels.
- ⇨ In highly differentiated plants, transport of water, minerals, food and other materials is a function of the vascular tissues which consist of xylem and phloem.

EXERCISES

1. What is the function of xylem ?
2. Which part of the alimentary canal absorbs the digested food ?
3. In which part of the cell the three carbon compound pyruvate is broken down to give CO_2, H_2O and energy.
4. What is the function of kidney ?
5. Describe the structure and function of nephrons.
6. Describe double circulation in human being.
7. How are the alveoli designed to maximise the exchange of gases ?
8. What is the role of saliva in the digestion of food ?
9. How does the small intestine designed to absorb digested food ?
10. What are the differences between the transport of materials in xylem and phloem?
11. What are the differences between aerobic and anarobic respiration ? Name some organisms that use the anaerobic mode of respiration.
12. What are the necessary conditions for autotrophic nutrition and what are its byproducts ?
13. What would be the consequences of a deficiency of haemoglobin in our bodies ?
14. Compare the alveoli in the lungs and nephrons in the kidneys with respect to their structure and function.
15. Draw and label the sectional view of the human heart.

★★★★★★

CHAPTER

14

CONTROL AND CO-ORDINATION IN LIVING BEINGS

14.1. Co-ordination in Animals

Irritability or sensitivity is one of the characteristic features of the living organisms. The living organisms have the ability to respond to a stimulus. They respond to changes in the environment. When the temperature around us is very low we feel cold and like to use warm cloth. When a teacher teaches a lesson in the class he speaks somewhat loudly so that every student can hear him. But when a student in the class wants to say something to his friend he whispers rather than shouting loudly. A cat, on seeing a rat, moves very silently and slowly at the begining so that the rat might not see him but when nearer the cat will jump suddenly to catch the rat. It is seen that in all organisms some degree of control and internal co-ordination is necessary in order to ensure that the events of the stimulus and response bear some mutual relationship. In multicellular organisms, specialised tissues are present to perform control and co-ordination activities.

14.1.1. Nervous System

In animals, control and co-ordination activities are performed by the nervous and muscular tissues. When we touch a hot object, we will feel the heat and respond to it. Then how do we know that we are touching a hot object ? Some of the nerve cells have specialised tips which detect all the information from our environment. These receptors are usually located in our sense organs, such as the skin, the tongue, the nose, the ear and the eye. Thus, the olfactory receptors of the nose will detect smell, the gustatory receptors of the tongue will detect taste and so on.

The information received at the end of the dendritic tip of a nerve cell (Fig.14.1.) sets off a chemical reaction that creates an electrical impulse. This impulse passes from the dendrite to the cell body, then it moves along the axon to its end. At the end of the axon, the electrical impulse sets off the release of some chemicals. The chemicals cross a gap known as **synapse** and start a similar electrical impulse in a dendrite of the next neuron. A similar synapse finally allows delivery of such impulses from neurons to other cells such as muscle cells or glands. Thus, the nervous tissue is made up of an organised network of nerve cells or neurons and is specialised for conducting information via electrical impulses from one part of the body to another.

The brain and spinal cord constitute the central nervous system.The brain is divided into three major regions, namely the fore-brain, mid-brain and hind-brain.

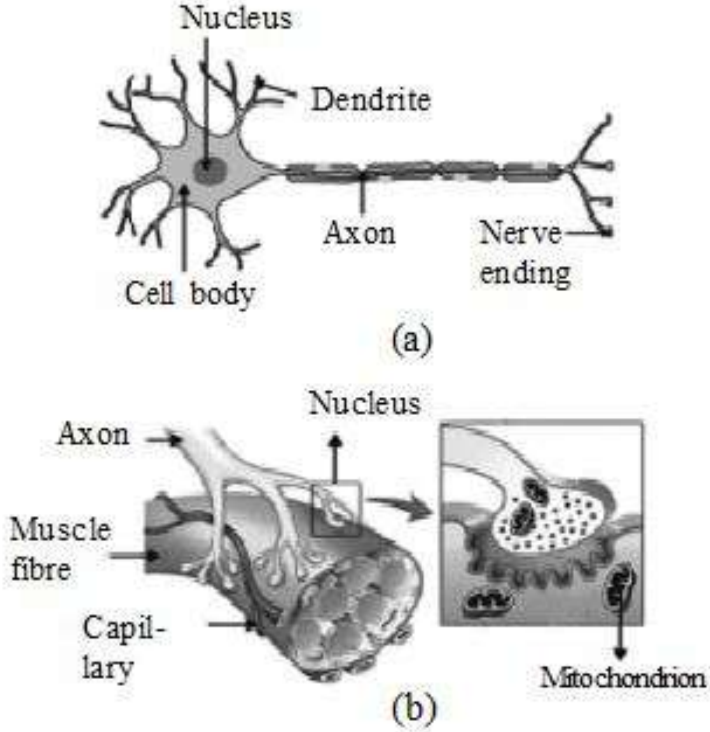


Fig. 14.1. (a) Structure of neuron (b) Neuromuscular junctions

We human beings think about our actions. Doing something like running , walking, talking, writing etc. are examples of voluntary actions which are based on deciding what to do next. For these the brain has to send messages to muscles. This is the second way in which the nervous system communicates with the muscles. There is another nervous system known as peripheral nervous system which constitutes the cranial nerves arising from the brain and spinal nerves arising from the spinal cord. The communication between the central nervous system and the other parts of the body is facilitated by the peripheral nervous system.

The main thinking part of the brain is the fore-brain. It has regions which receive sensory impulses from various receptors. The fore-brain has seperate areas specialised for smell, hearing, sight and so on.

There are seperate areas of association where the sensory information is interpreted by putting it together with information from other receptors as well as with information that is already stored in the brain. Then, a question arises on how response and the information are passed on to the motor areas which control the movement of voluntary muscles, for example the muscle of the hand or leg.

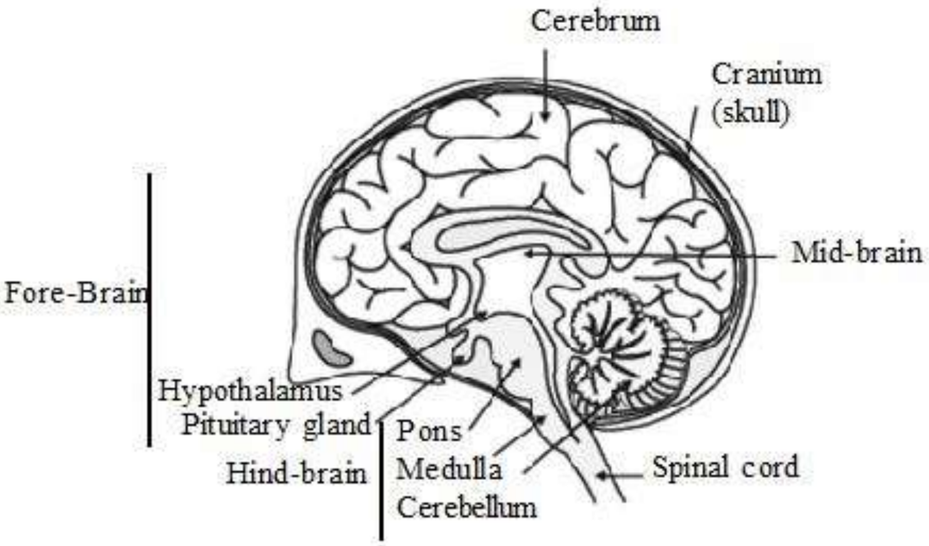


Fig. 14.2. Human brain

There are certain sensations which are different from seeing or hearing etc. for example, feeling of fullness of our stomach. The sensation of being full is because of a centre associated with hunger, which is a separate part of the fore -brain. Mid-brain is comperatively a small region. It controls the reflex movement. The change in eye pupil size and shape of the eye lens are controlled in this region of the brain.

On the other hand, there are other actions that we cannot control easily by thinking about them. For example, our mouth waters when we see food we like, our heart beat or we breathe without thinking about it. These involuntary actions are controlled by the medulla in the hind-brain.

The brain which is very important for a variety of activities, is a delicate organ and needs to be protected. It is protected by a bony box, the cranium. In between the bony covering and the brain there is a fluid filled space which provides further shock absorption. The spinal cord is lodged inside the vertebral column.

14.1.2. Reflex Action

When we walk accidentally on an inverted nail and pierces the foot we feel pain and suddenly remove our leg from it without thinking anything about it. Such an involuntary sudden action in response to something in the environment is the **reflex action**. In another example when our hand touches a hot object or a burning charcoal, we suddenly remove the hand automatically without thinking about it. The sudden response in these pain or heat is done in such a way that the nerves that detect pain or heat are connected to the nerves that move muscles in a simpler way, the process of detecting the signal or the input and responding to it by an output action might be completed quickly. Such a connection is commonly called a **reflex arc** (Fig .14.3.). Nerves from all over the body meet in a bundle in the spinal cord on their way to the brain. Such reflex arcs are formed in this spinal cord itself, although the information input also goes on to reach the brain.

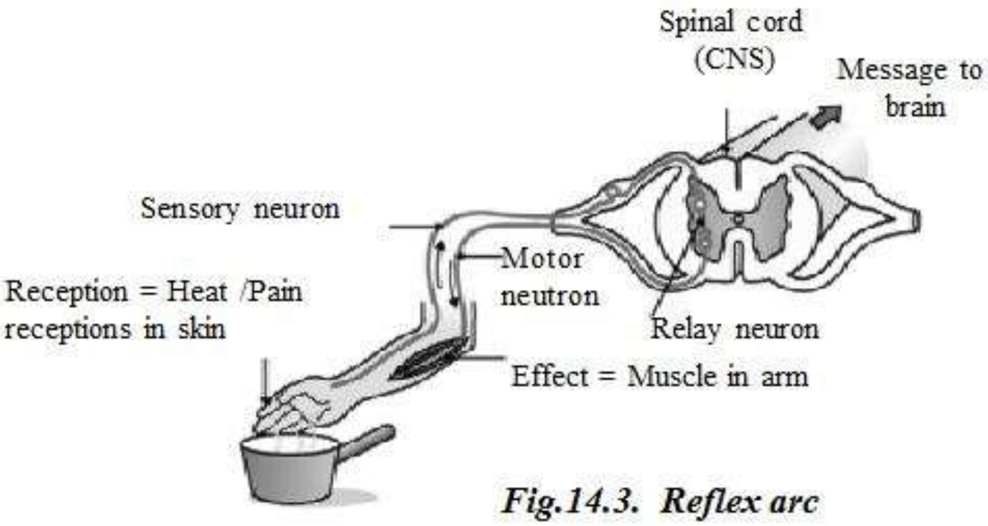


Fig.14.3. Reflex arc

14.1.3. Conditioned Reflexes

Conditioned reflexes are the acquired reflexes during the lifetime of an individual. These are not constant that they may disappear or reappear again. They depend on previous experience. They are not transmitted by heredity.

Ivan Pavlov, a Russian Physiologist, for the first time discovered the existance of conditioned reflexes.

14.1.4. Pavlov's Experiment on conditioned reflex

Pavlov conducted his experiment on a dog. He used to ring a bell every time just before the food was placed in front of the dog. The dog gradually learnt to associate the bell with food. Later when the bell was rung, the dog would salivate even though no food was placed (Fig.14.4).

14.1.5. Chemical Co-ordination – Animal hormones

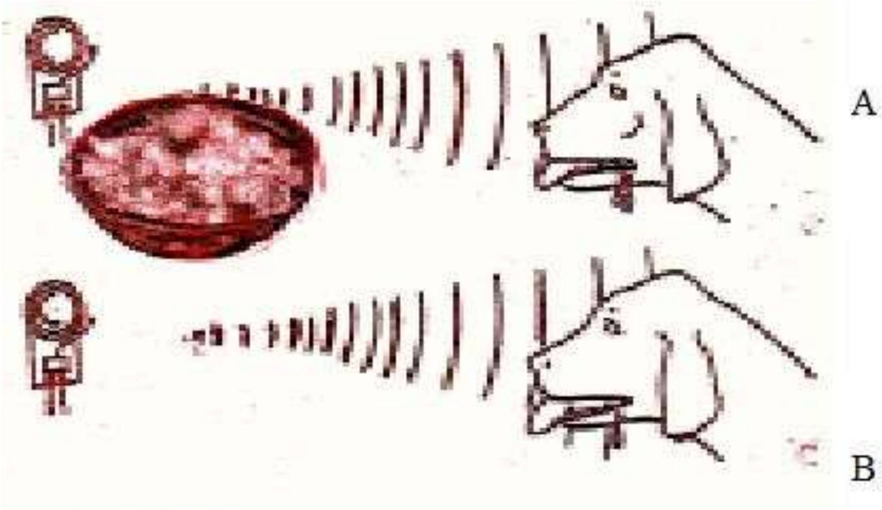


Fig.14.4. Pavlov's experiment on conditioned reflex.
A. The dog salivated at the sight of the food with a sound of a bell.
B. The dog salivated at the sound of the bell even though no food was placed.

In animals control and co-ordination is done not only by the nervous system but also by the hormones. The hormones are secreted by the endocrine glands (ductless glands) of the body (Fig. 14.5.). Different hormones perform different functions of co-ordination in the animal body. Among human beings there are very short (dwarf) individuals and sometimes extremely tall (gaint) individuals while majority are of normal size. These conditions are related with a pituitary hormone, known as growth hormone. If the secretion of this hormone is optimum during the childhood there will be normal growth of the individual. If the secretion of this hormone is less during childhood it will lead to dwarfism. If there is excessive secretion during growth period, it will result to extremely tall individual (gigantism).

Nowadays diabetes is very common among us. This is also caused due to inadequate production of a hormone known as insulin secreted by the pancreas. It maintains normal blood sugar level in the body. If there is insufficient secretion of insulin the sugar level in the blood becomes high and we suffer from diabetes.

Another example of chemical co-ordination is the role of the thyroid hormone, the thyroxin, in the growth of an individual. Nowadays we use iodised salts in our diet. Iodine is needed by the thyroid gland to make thyroixin hormone. Thyroxin regulates carbohydrates, protein and fat balance for growth. If there is deficiency of iodine in our diet there will be no synthesis of this thyroid hormone. In such a condition, one may suffer from goitre, the characteristic symptom being a swollen neck.

Adrenaline is a hormone secreted by the adrenal gland. The action of this hormone is widespread throughout the body. It prepares the animal for situations of 'fight or flight'. It facilitates the response to sudden demands imposed by stress such as pain, shock, cold, low blood sugar, low blood pressure, anger, passsion etc. Adrenaline, being a hormone, is secreted directly into the blood and carried to different parts of the body. The target organs on which it acts include the heart. As a result the heart beats faster resulting in supply of more oxygen to the muscles. The blood supply to the digestive system and skin is reduced due to contraction of muscles around small arteries in these organs and diverted to skeletal muscles. The breathing rate also increases. As a result of these responses, the animal body is ready to face with the hard situation. Thus, this hormone participates in the a chemical control and co-ordination in our body.

You might have experienced the changes in your general appearance as well as that of your friends as you reach 10–12 years of age. These changes are associated with puberty and these are resulted by the secretion of testosterone in males and oestrogen in females.

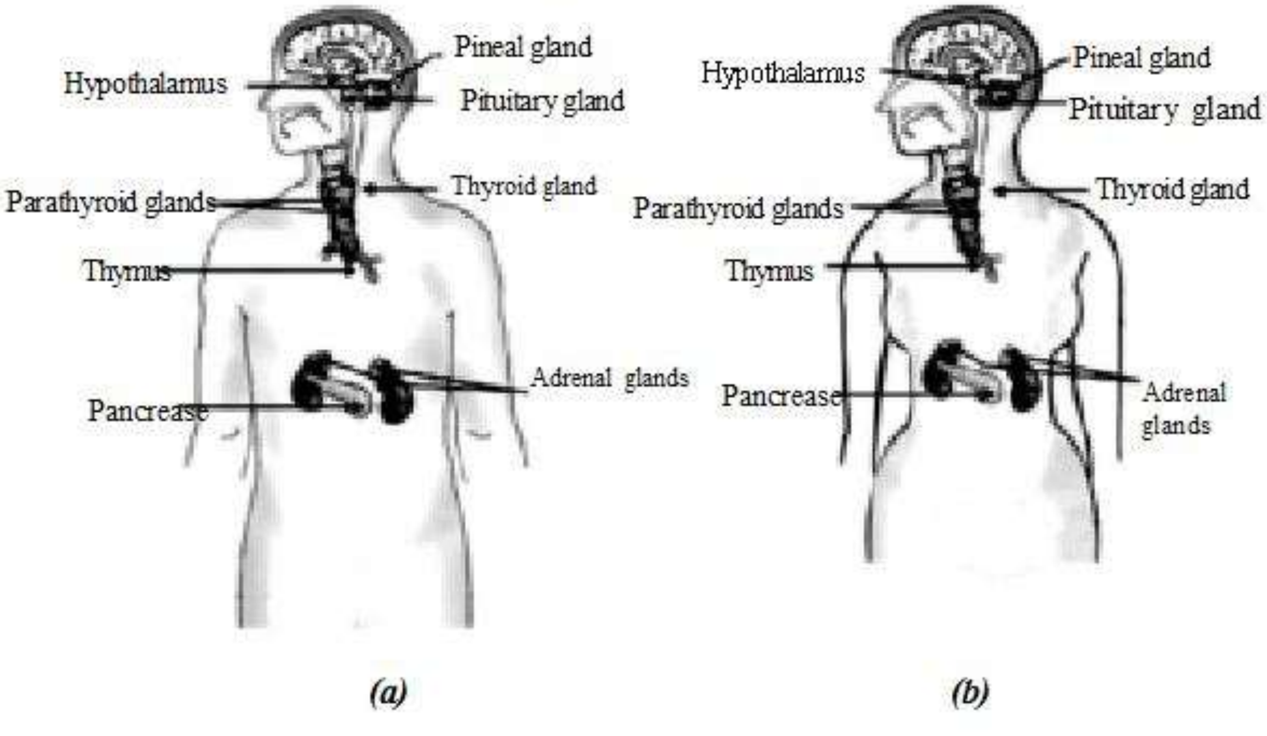


Fig .14.5. Endocrine glands in human beings (a) male, (b) female.

14.2. Co-odination in Plants

Let us answer these.

1. What is a reflex action ?
2. What happens at the synapse between two neurons ?
3. Why should we use iodised salt ?
4. Why are some patients of diabetes treated by giving injections of insulin ?

Nervous system is the controlling and co-ordinating unit of body activities in animals. But plants have no nervous system. Then, how do plants respond to stimuli ? When a sensitive plant (*Mimosa pudica*) leaflets are touched, they fold up and drop. In germinating seeds, the root goes down the soil and the stem comes up into the air. The response to touch is very quick in sensitive plants without involving any growth. But the directional movement of a seedling is caused by growth which shows a slow movement.

How many kinds of movements are recognized in plants ?

14.2.1. Immediate response to stimuli

The leaves in sensitive plants move in response to touch. This plant does not posses nervous tissue or muscle tissue. How does the plant feel the touch ? How do the leaves move in response?

Fig. 14.6. Sensitive Plants (Mimosa pudica)

If you touch the plant and examine the part of the plant actually moves. The movement happens to a point different from the point of touch. So, information that a touch has occured must be communicated. Unlike in animals, plants do not have specialised tissues for collection of information. Instead of specialised proteins found in animals, the plant cells change shape by changing the amount of water in them. The swelling and shrinking due to water pressure makes a change in the shape of plant.

14.2.2. Movement due to growth

A pea plant climb itself with the help of tendrils. When a tendril comes into contect with any support, the side of the tendril in contact with the object ceases to grow as rapidly as the side of the tendril away from the object. So the tendril can encircle an object and thus clings to it. Plants can respond to stimuli and grow slowly in a particular direction. This directional growth makes a plant appears as if it is moving. **Tropism** is the movement of curvature brought about by more growth on one side and less growth on opposite side of plant organ induced by some external stimuli. Depending upon the nature of stimuli the tropism can be phototropism (light induced), geotropism (induced by gravitational force), hydrotropism (water induced), thigmotropism (touch induced) and chemotropism (chemical induced).

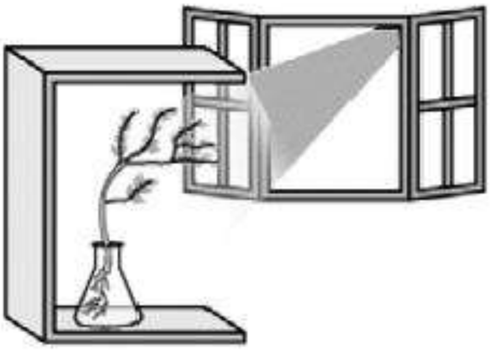


Fig.14.7. Stem is positively phototropic.

Activity 14.1.

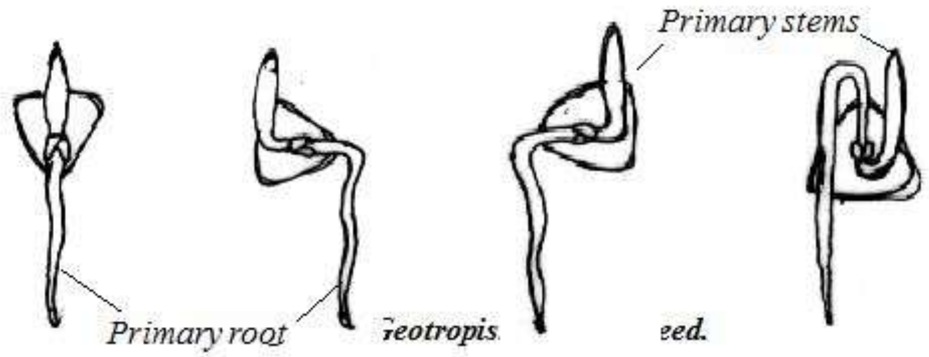
- Take a potted plant and keep the potted plant in a room near an open window.
- Observe after 2 or 3 days.
- The stem is seen bending towards the open window.

What conclusion you can draw from this activity ?

Environmental factors like light, gravity, water etc. are responsible for the directional movement in plants. In phototrophic movement shoots bend towards light while roots respond by bending away from light. So the directional or tropic movement can be either towards the stimulus or away from it.

14.2.3. Why do roots grow towards the soil ?

The tropic movements in response to gravity are called **geotropism**. In plants the primary roots grow down into the soil and are positively geotropic. On the other hand, the primary stems are negetively geotropic (Fig. 14.8.).



Geotropis *eed.*

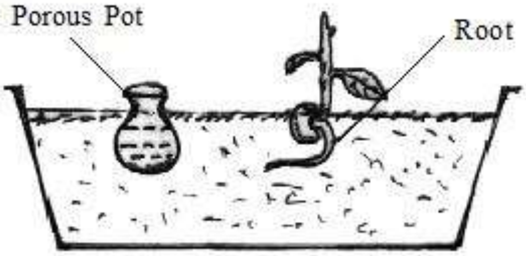


Fig. 14.9. Hydrotropism in germinating seed

Activity 14.2.

- Take a vessel nearly filled with sand.
- On one side immersed a porous pot filled with water.
- Place a germinating seed away from the porous pot in the vessel.
- Examine the germaniting seed after 4 to 5 days.

How the root elongates ?

It has been observed that roots grow vertically downwards due to gravitational pull. Then, the root bends towards the porous pot, showing a tendency to grow towards the source of moisture (Fig.14.9.). So, the root is said to be positively hydrotropic. Hydrotropism is stronger than geotropism.

One example of the chemotropism is the growth of pollen tube through stigma and style, towards ovule with the stimulus of chemical substances present in the carpel.

How the information is communicated in the body of multicellular plants? The movement in sensitive plant in response to touch is very quick, whereas growth related movements in plants are quite slow. If the response to stimuli is to be made quickly, information must be transferred very fast. It can be easily achieved by means of electrical impulses. But electrical impulses can reach only those cells that are connected by nervous tissues. Once an electrical impulse is generated in a cell and transmitted, it takes more time to reset its mechanism before it can generate and transmit a new impulse. Moreover, cell can not continuously create and transport electrical impulses.

In multicellular organisms, the control and co-ordination is done by the release of certain chemical compounds from the stimulated cells. These compounds are detected by other cells around it by using special molecules on their surface then, they would be able to recognise information and even transmit it. This is a slow system but regardless of nervous connection. The co-ordination in growth, development and respond to environment in plant is done with the help of different compounds or plant hormones. They are synthesised at places away from where they act and simply diffuse to the area of action.

14.2.4. Plant hormones

What are plant hormones ? How do they act on plants? The growth of the stem towards light in Fig.14.7., is the action of a hormone called **Auxin**. It is synthesized at the shoot tip. Auxin diffuses towards the shade side of the stem. The higher concentration of auxin stimulates the cells to grow longer on the side of the shoot which is away from light. So, the plant bend towards light. No growth can occur in plant without auxin.

Auxins in plants are to stimulate the elongation of cells in shoot. Similarly **Gibberellins** also help in the growth of stem by inducing elongation of internodes. **Cytokinins** stimulates cell division and also cause the enlargement of cells and promote seed germination.

All the above hormones are growth promoters. But plants also need signals to stop growing. **Abscisic acid** (ABA) is a powerful growth inhibitor and can induce bud dormancy in varieties of plants. There are significant evidence to support that ABA controls geotropic response of roots.

Ethylene also acts as a plant hormone and can prevent the longitudinal elongation of stem and roots but is associated with radial enlargement of tissues. It can hasten post harvest maturation of fruits.

14.2.5. Apical dominance

It is common observation in vascular plants, specially the taller ones, that if the apical bud is intact and growing, the lateral buds remain suppressed. Removal of apical bud causes fast growth of lateral buds.

Let us observe the three potted plants (Fig. 14.10.). The first pot is

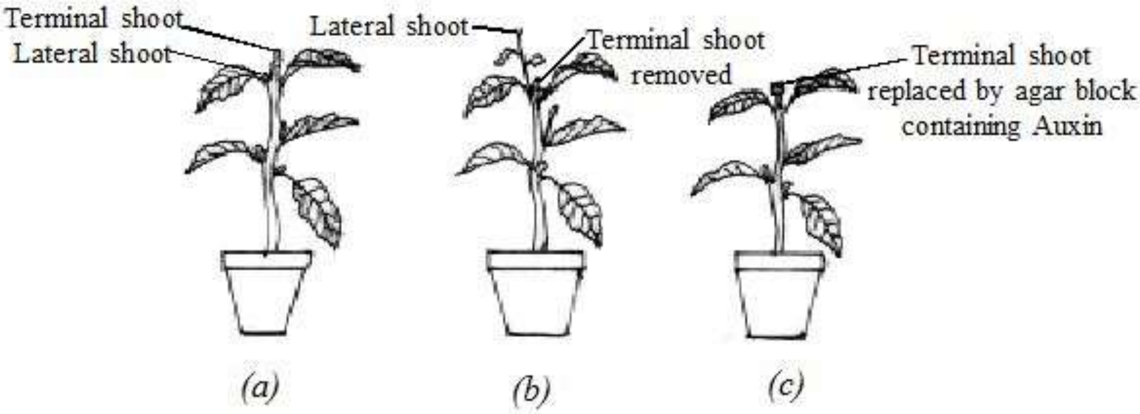


Fig.14.10. Apical dominance in Plants (a,b&c)

kept as control, so growth of lateral buds are suppress. The terminal shoot is removed from the second pot and the lateral buds commence to grow. What is the inhibitor which supresses the growth of lateral bud?

Apical dominance seems to result from the downward transport of auxin produced in the apical meristem.

In the third plotted plant terminal shoot is replaced by an agar block containing auxin showing the inhibition of lateral bud. A plain block of agar has no such effect. What inferance can you narrate from the above observations?

Let us answer these.

1. What is the factor responsible for the movement of leaves in the sensitive plants ?
2. What are plant hormones ?
3. How do auxins promote the growth of tendril around a support ?
4. Give an example of chemotropism.

POINTS TO REMEMBER

⇨ Control and co-ordination are the functions of the hormones and nervous system in our bodies.

⇨ The responses of the nervous system can be classified as reflex action, voluntary action or involuntary action.

⇨ The nervous system uses electrical impulse to transmit messages.

- The nervous system gets information from our sense organs and acts through our muscles.
- Plants do not have nervous system, but some plants can response to external stimuli.
- Stem moves upward towards light whereas root moves downward away from light.
- Chemical co-ordination is seen in both plants and animals.
- Hormones are organic sustances which are synthesized in minute quantities in one part of the plant body and transported to another part where they influence specific physiological processes.
- Auxin is responsible for apical dominance in plants.

EXERCISES

1. How does phototropism occur in plants?
2. Why do roots grow towards the soil ? Explain with three points.
3. Explain the function of two growth inhibitors in plants.
4. In what way auxin is involved in the process of apical dominance ?
5. What is the name of the gap between the two neurons ?
6. What is the function of receptors in our body ? What will be the conditions if the receptor are not properly working ?
7. How do the reflex actions differ from the involuntary actions ?
8. Explain the functions of any three hormones in human being.

★★★★★★

CHAPTER

15

REPRODUCTION

Unlike the essential life processes such as nutrition, respiration or excretion, reproduction is not necessary to maintain the life of an individual. When an organism reproduces, it creates more individuals and a lot of its energy is spent in the process. Then, why do organisms reproduce? The organisms reproduce to maintain the continuity of their own race.

15.1. Reproduction in Plants

The origin of life is estimated to have happened over 3000 million years ago and has produced all living organisms of today by different methods of reproduction. One of the most important aspects of living organisms is their ablity to produce copies of themselves.

Two distinct methods of producing offspring are found among living organisms.

Asexual reproduction is a rapid method of increasing the number of a species without involving an union of two cells (gametes). **Sexual reproduction** is a slower method in which the union of two cells take place for the production of a new individual . Do plants and animals have similar reproductive cycles ?

15.1.1. Asexual reproduction

In asexual reproduction, the nucleus divides by mitosis, producing two daughter cells, each having the same number of chromosomes in their nuclei as the parent. **Cloning** is a term used to describe the formation of a group of organisms of the same species by asexual methods involving mitosis and vegetative or artificial propagation. The clones have identical genetic composition. This method is widely used by microorganisms, plants and lower animals.

Activity 15.1.

☛ Prepare a 10% sugar solution (10 g in 100 ml of water).

☛ Transfer 20 ml of the solution to a test tube.

☛ Add a pinch of yeast granules in it.

☛ Close the mouth of the test tube with a cotton plug.

- Keep it undirsturbed for about 2 hours in a warm place.
- Take a drop of the yeast culture from the test tube on a slide and cover it with a cover slip.
- Observe the slide under a microscope.

Write down your observations.

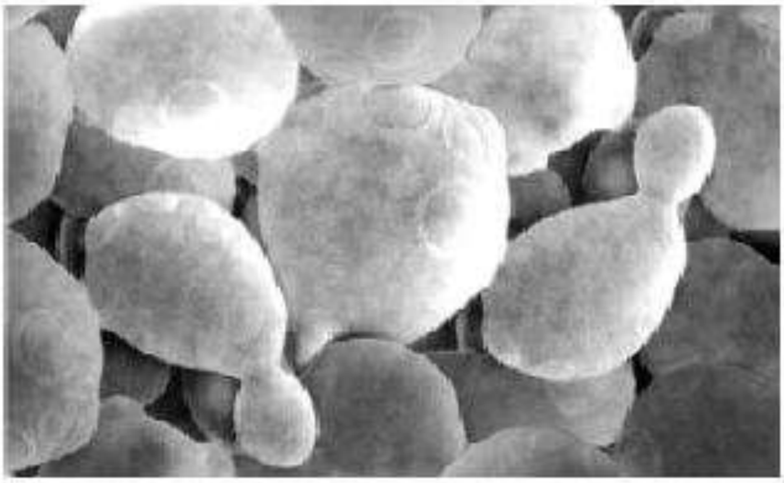


Fig . 15.1. Yeast budding

15.1.2. Budding

Yeast cell forms a small bud into which cytoplasm and a nucleus pass. The bud is much smaller than the parent cell and becomes detached (Fig. 15.1.). A multicellular organism like *Hydra* also reproduced by the formation of bud which later separates from the parent body.

15.1.3. Fragmentation

In multicellular filamentous algae like *Spirogyra*, a parent cell divides by forming a new cell wall or septum into daughter cells i.e. septation or fragmentation.

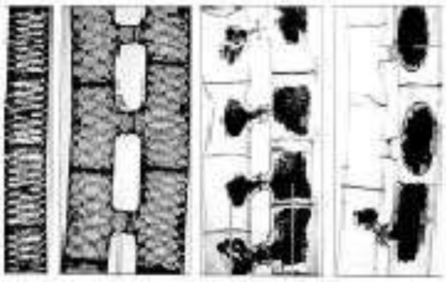


Fig. 15.2. Conjugation in Spirogyra

15.1.4. Sporulation (Spore formation)

Fungi, liverworts, mosses and ferns can produce enormous number of spores.

Spores are small bodies containing a nucleus and a small amount of cytoplasm. The spores of terrestrial organisms are usually very light and have a protective wall around them.

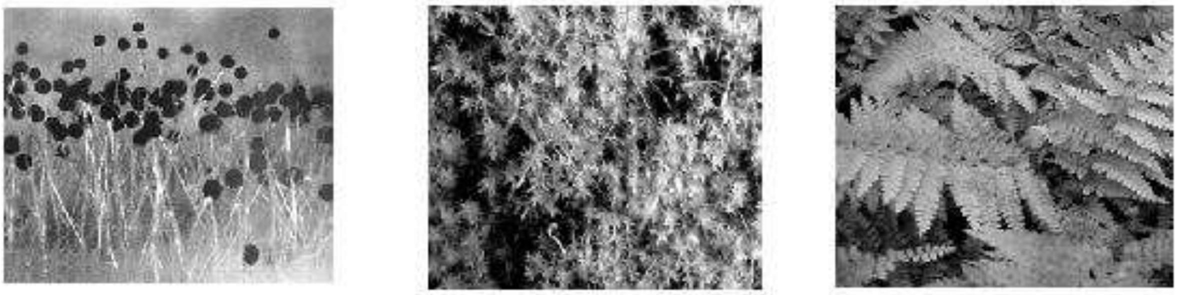
Many bacteria form a thick-walled spore inside the bacterial cell wall. This can not be considered as a reproductive mechanism for them but provides a means of survival during unfavourable conditions.

Some of the green algae and aquatic fungi form two to eight small zoospores, each with a nucleus, cytoplasm and two flagella. Swimming by means of their flagella, the spores disperse the species to new locations.

Activity 15.2.

- Keep a slice of moistened bread in a moist, warm and dark place.
- Observe the slice daily, for a week with a magnifying glass.
- Record your daily observations.

The thread like structures that developed on the bread in Activity 15.2. above are hyphae of either the bread mould (*Rhizopus*) or the pin mould (*Mucor*) from its body or mycelium. The erect hypha develops a swelling at its tip to form a sporangium. Inside the sporangium, a large number of spores are produced by mitosis and they are liberated.



(a) *(b)* *(c)*

Fig.15.3. (a) Rhizopus (b) Moss (c) Fern

The mosses, clubmosses and common ferns also produce enormous number of tiny windblown spores which serve to disperse the species to new locations.

15.1.5. Vegetative Reproduction

Vegetative reproduction is a method of asexual reproduction in which vegetative parts (root, stem, leaf and buds) can be detached from the parent plant body and developed into another complete daughter plant. This method of asexual reproduction is seen in many flowering plants like sweet potato, onion, potato, grasses, banana etc. Perennial plants which overwinter as bulbs, corms, tubers or rhizomes are vegetatively propagated plants.

This property of vegetative propagation is used artificially by the methods of layering, grafting, cutting and by artificial culture in different media. Artificial propagation is successfully performed in plants like rose, orange, grapes, sugarcane, banana, jasmine etc. Another advantage of vegetative reproduction is that the offsprings produced are genetically identical to the parent plants.

15.1.6. Micropropergation or Tissue Culture

It is a teachnique of propergation of plants from cells, tissues or organs by using the methods of tissue culture. Here the plant parts (roots, steam, leaf etc.) are cultured on a sterilized medium containing necessary nutrients. After some days a mass of undifferentiated cells known as callus is developed. By transferring the cells of callus to other media containing hormones the callus differentiated into plantlets. This method is successfully used in many economically important plants such as orchids, chrysanthemum, gladiolus etc.

The ability of a somatic cell to produce the complete organism is called cellular totipotency. It was first observed in carrot cells.

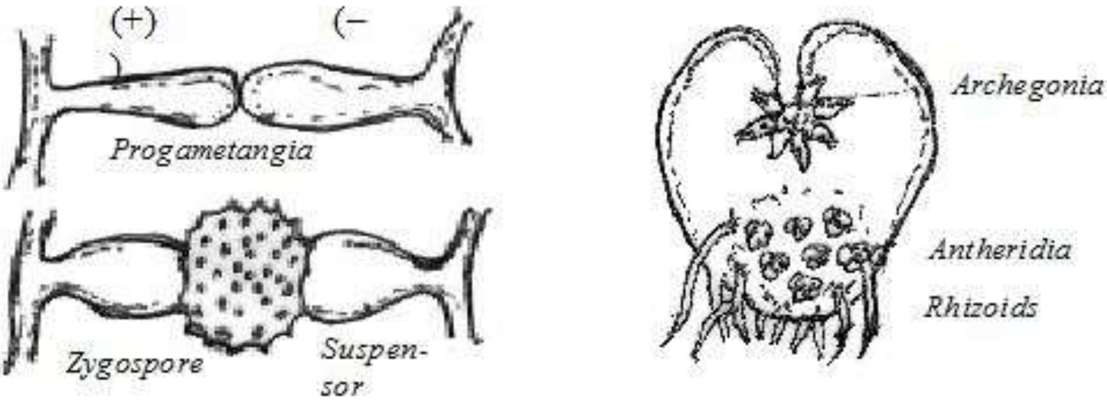
15.1.7. Parthenogenesis

Parthenogenesis is a type of asexual reproduction in which the organism is developed from unfertilized egg. This process may be natural as well as artificial. Natural parthenogenesis is found in many plants and animals.

Nonflowering plants like Spirogyra, Chara, Marsilea etc., and flowering plants like Thalictrum and certain species of Asteracae (Sunflower family) and Solanaceae (tomato family) can reproduce by parthenogenesis. In animals the process is found in Aphids or Greenfly, but they are normally reproduce by sexual reproduction.

15.1.8. Sexual reproduction in plants

Sexual reproduction occurs widely in lower plants like *Spirogyra* (through the process of conjugation , Fig.15.2.) and *Mucor* (by gametangial contact). In mosses and ferns, there is the formation of motile male gametes in the antheridium and non-motile female ova in the archegonium. It is followed by the union of male and female gametes to form zygotes and reduction division (meiosis) to form spores. What is the significance of this sexual reproduction in non-flowering plants ?



(a) Gamentangial contact ***(b) Prothallus***

Fig.15.4. Sexual reproduction in (a) Mucor (b) Fern

Let us answer these .

1. Why reproduction is essential in living organisms?
2. Name the two methods of reproduction.
3. How can you differentiate budding from fragmentation ?
4. How does an organism be benefited, if it reproduce through spores?
5. Why vegetative propagation is more suitable in some types of plants?
6. What is tissue culture?

7. How will you define a callus?
8. Name two plants which can reproduce by natural parthenogenesis.
9. Give the definition of cellular totipotency.?

15.2. Sexual reproduction in flowering plants

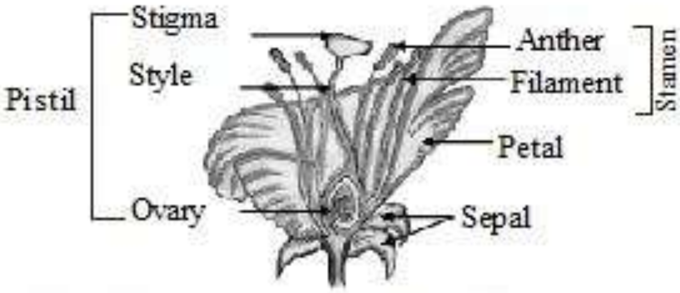


Fig. 15.5. Longitudinal section of a flower

A flower can be defined as a reproductive structure of a flowering plant. A complete flower will have four sets of floral parts. They are **Calyx** (composed of mainly green sepals), **Corolla** (composed of brighty coloured petals), **Androecium** (the male parts consisting of stamens , composed of filaments and anthers) and **Gynoecium** (the central fimal part consisting of a swollen bottom part called ovary, middle elongated part is the style and terminal part which may be sticky is the stigma).

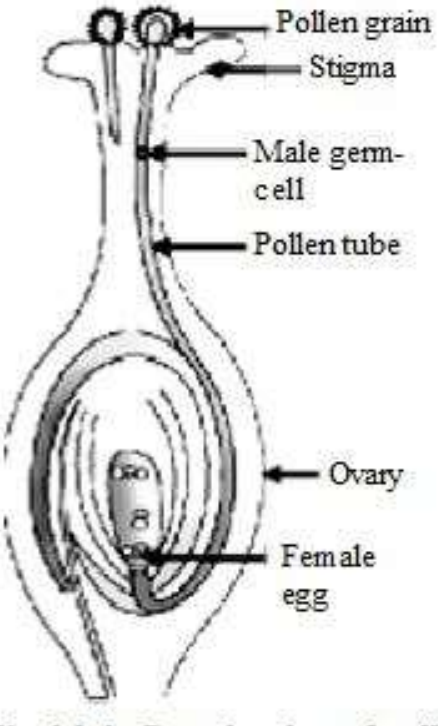


Fig.16.6. Germination of pollen on stigma

Flowers are generally bisexual in mustard, pea, china rose having both male and female floral parts. Many flowers are unisexual, (papaya, watermelon) when it contains either androecium or gynoecium. The male germ cell from the pollen, produces by the anther unites with the female gamete present in the ovule. The fusion of germ cells or fertilisation gives raise to zygote which is capable of growing into a new plant. What could be the possible functions of calyx and corolla ? Their function is mainly for protection of floral sex organs and also act as flag apparatus for insect pollination.

For the process of fertilisation the pollen grains from the anther has to be the same flower or different flowers of the same plant, it is refered to as **self pollination**. And if the transfer takes place between two different flowers of **different plants**, the process is called as **cross pollination**. Pollination is generally done in nature by wind, water, insects and animals. Artificial pollination (Pollination by human with some intention) is widely practiced in economic plants for the production of hybrids.

After the pollen lands on a suitable stigma, the male gamate from the pollen is brought by the pollen tube grows out of the pollen grain and travels through the style to reach the ovule. The zygote resulted from the union divides several times to form an embryo within the ovule. The ovule develops a tough coat and is gradually converted into a seed. The ovary grows rapidly and ripens to form a fruit. Other floral parts like sepals, petals, stamens and style fall off. The seed contains the future plant or embryo. What are the advantages of seed formation in a plant ?

Activity 15.3.

- Soak a few seeds of pea in water and keep them overnight.
- Transfer the seeds on a wet cloth and leave them for a day under cover.
- Open the wet seeds carefully and observe the different parts.
- Try to draw the parts you have seen and compare it with Fig. 15.7.

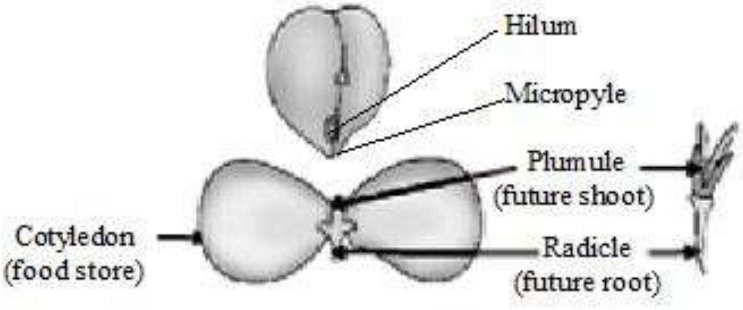
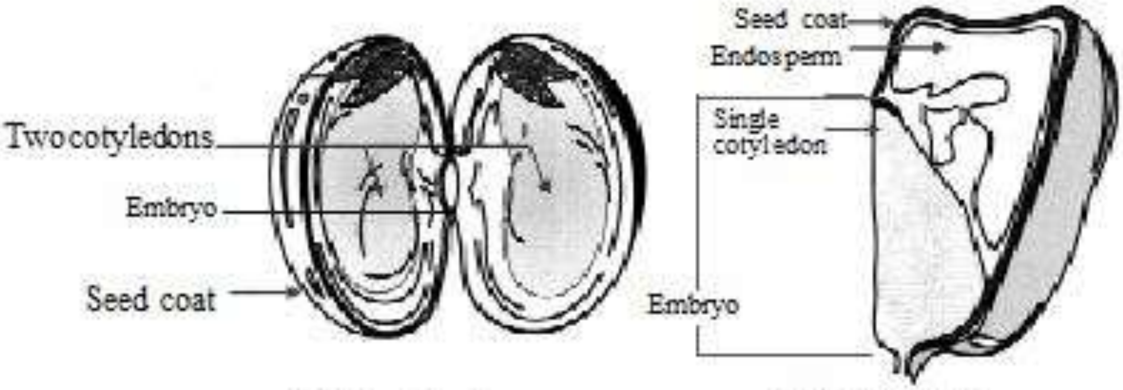


Fig.15.7. Dicotyledonous seed (gram)

15.2.1. Seed and Germination

Seed is a part of plant which contains a young plantlet in a dormant and resting condition. Can you get seeds in all the plants ? Seeds are formed within the cones of gymnosperms and inside the fruits of angiosperms, as a result of fertilization.

A seed is surrounded by a thick seed coat or testa providing protection



(a) Bean Seed *(b)* Maize Seed

Fig. 15.8. L.S. of seeds (a) dicot and (b) monocot seeds showing em-

against dehydration. A hilum is the scar of the seed stalk. The embryo inside the seed consists of a plumule (future shoot), radicle (future root) and seed leaves or cotyledons. Monocotyledonous plants like, grasses, rice, etc. have only one cotyledon. Dicotyledonous plants have two cotyledons, i.e. pea seeds, castor seeds, etc. Endosperm is a nutritive tissue which may surround the embryo of maize, rice, castor seed etc. or it may be absorbed into the cotyledons of non-endospermous seeds of pea, bean, etc.

Seed growth or germination commences by water entering the seed through the micropyle and the testa absorb water. The testa splits and radicle emerges.

Activity 15.4.

- Soak one healthy seed of pea and another healthy seed of castor overnight with water.
- Keep them in a petridisc containing humid sand.
- Observe the seeds for a period of 5 days.
- Record your daily observations.

Compare the mode of germination in the two seeds.

Hypogeal germination occurs in maize, gram, bean, etc. when the

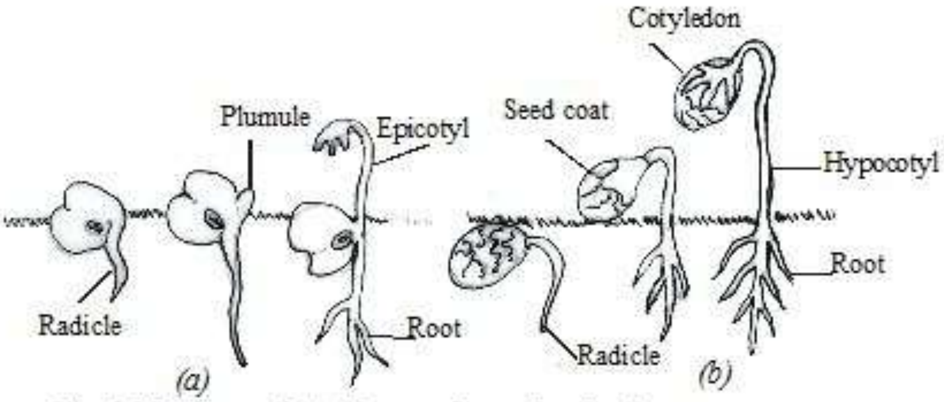


Fig.15.9. Stages of : (a) Hypogeal germination in gram
(b) Epigeal germination in castor

cotyledons remain below ground and the plumule emerges (by the elongation of epicotyl).

Epigeal germination occurs in castor, sunflower, etc. when the pulmule and cotyledons emerge above ground (by the elongation of hypocotyl). The cotyledons function as leaves (Fig.15.9.).

Let us answer these.

1. How is the process of pollination different from fertilisation ?
2. Describe the parts of a dicot seed.
3. How does a seed germinates ?
4. Name the different parts of a typical flower.

15.3. Reproduction in animals

Among animals there are two types of reproduction – Asexual and sexual.

15.3.1. Asexual Reproduction

Asexual type of reproduction may be binary fission, multiple fission, regeneration and budding. **Binary fission** is seen in unicellular animals like *Amoeba, Leishmania,* etc. In this the single - celled body is divided into two daughter individuals (Fig.15.10).

Fig.15.10. Binary fission in Amoeba

In multiple fission, the unicellular body is divided into a number of daughter

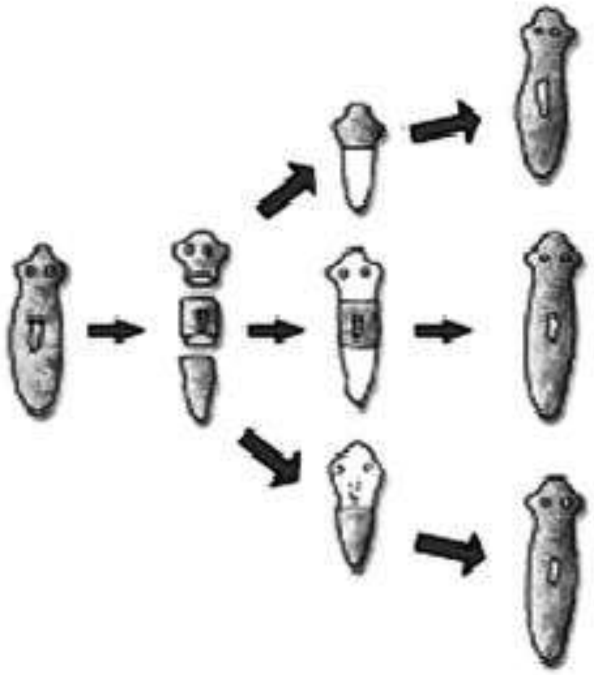


Fig.15.11. Regeneration in Planaria

cells. This type of reproductions is seen in *Plasmodium*, *Amoeba*, etc.. In some animals like *Hydra* and *Planaria*, if the body is cut or broken up into many pieces, many of the these pieces grow into separate individuals. This is known as **regeneration** (Fig. 15.11).

Regeneration is carried out by specialised cells. These cells divide and

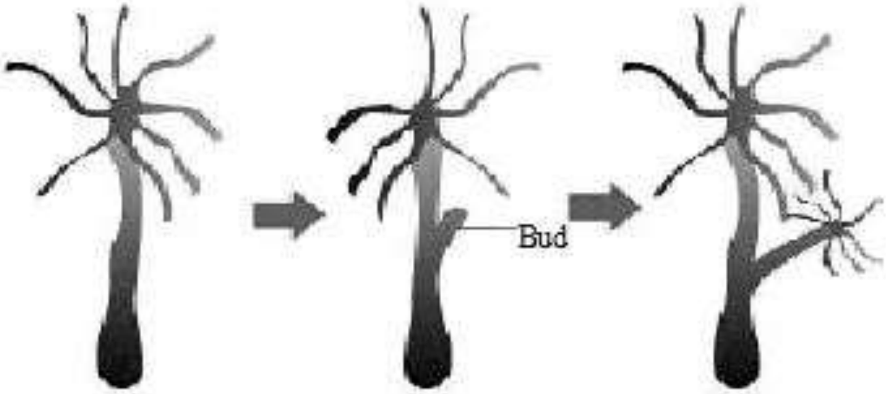


Fig.15.12. Budding in Hydra

make large number of cells, different cells give rise to various cell types and tissues. Finally they give rise to a complete individual. However regeneration is not a normal process of reproduction. Most organisms would not normally depend on being cut up to be able to reproduce.

In some animals like *Hydra* some regenerative cells are used for reproduction in the process of budding. In such cases, a bud develops as an outgrowth due to repeated cell division at a specific site. Later these buds give rise to small individuals and when fully mature, detach from the parent body and become new individuals independently.

15.3.2. Sexual reproduction

This involves two individuals, male and female, followed by the fusion of two gametes one from male parent and other from female parent. Majority of the animals reproduce by this method.

In the sexual mode of reproduction, the germ-cells from two individuals have to meet and fuse together. This can happen by the external release of germ-cells from the bodies of individuals, as happens in fishes and amphibians; or it can happen by joining their bodies together by two individuals for internal transfer of germ cells for fusion as happens in many animals.

15.3.3. Sexual reproduction in invertibrates

In Paramecium the two partners meet with their oral grooves opposite. There is exchange of cytoplasmic and nuclear materials by breaking the surface membrane. After separation each individual divides into two by binary fission.

Hydra, Earthworm and Tapeworm are hermaphrodite animals having gonads, ovary and testes. But these animals have different devices to perform sexual reproduction with their partners. In Hydra and Tapeworm the male and the female gonads mature at different time. In earthworm sperms are exchanged between two individuals by copulation. This prevent them from self fertilization.

Sexual reproduction in insect is by copulation between a male and female partner. The fertilized eggs undergo metamorphisis to become a complete young individual.

15.3.4. Sexual reproduction in vertebrate animals

The fertilization (union of gametes) is external in fishes and amphibians. The eggs are laid in great numbers into the surrounding water. These eggs are fertilized by the sperms released over the eggs from the male. In amphibians the fertilized eggs undergo metamorphosis.

Internal fertilization is the characteristic feature of birds and mammals. In birds the fertilized zygotes are converted into eggs and the eggs are laid down. Further development of embryo takes place inside the egg. Most mammal embryos develop within the mother's uterus and are protected and nourished by embryonic membranes and a placenta. Such placental mammals are called viviparous e.g. rat, rabbit, monkey and human beings.

Let us answer these.

1. Name an animal that reproduces by budding.
2. What is meant by binary fission?

POINTS TO REMEMBER

- Reproduction, unlike other life processes, is not essential to maintain the life of an individual organism.
- Various organisms use different modes of reproduction depending on their body design.
- Budding, fragmentation and sporulation are examples of asexual reproduction where new generations are created from a single individual.
- Roots, stems and leaves of some plants develop into new plants through vegetative propargation.
- Sexual reproduction involves two individuals for the creation of a new individual.
- Lower plants like algae, fungi, mosses and ferns etc. also can reproduce by sexual methods.
- Reproduction in flowering plants involves transfer of pollen grains from the anther to the stigma. This process is referred to as pollination. This is followed by fertilisation.
- Germination is the beginning of growth and developement of the dormant embryo within the seed.
- Hypogeal germination occurs in maize, pea and bean, whereas epigeal germination occurs in castor, sunflower, etc.
- Micropropergation is a technique of propagation of plants from cells tissues or organs by using the methods of tissue culture.

- ⇨ Parthenogenesis is the development of ovum without fertilization into a new individual.
- ⇨ Metamorphosis is the period of rapid transformation from larval to adult form.
- ⇨ Viviparous is the method of development of embryo within the maternal organism and derive nutrition by close contact with maternal tissues, frequently by a placenta, without interposition of any egg membranes.
- ⇨ Cellular totipotency is the genetic potential of a plant cell to produce the entire plant.

EXERCISES

1. What type of asexual reproduction takes place in yeast ?
2. Name the plant which reproduces by the process of conjugation.
3. What are the advantages of sexual reproduction over asexual reproduction ?
4. Draw a labelled diagram of the longitudinal section of a typical flower.
5. Describe the two types of germination with labelled diagram.
6. How does binary fission differ from budding in animals.
7. How sexual reproduction takes place in Paramecium?
8. Give one similarity between the sexual reproduction of Hydra and Tapeworm.
9. In what way earthworm prevent itself from self fertilization?
10. What is metamorphosis ? Give two examples which shows metamorphosis.
11. How will you define a viviparous animals ? Give two examples.
12. What are the advantages of tissue culture in plant?
13. Why parthenogenesis is considered as asexual reproduction?

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CHAPTER 16

HEREDITY AND EVOLUTION

Living organisms produce new individuals that are similar to themselves by the process of reproduction. Generally very low degree of differences are observed in the offsprings produced through asexual reproduction. On the other hand, in case of sexually reproducing organisms, their offsprings develop traits different from those of their parents. In plants like sugarcane and bamboo, which are generally reproduce asexually, we find very little variation amongst individual plants so long as they are grown under similar conditions. But in a number of animals including human beings, which reproduce sexually, quite distinct variations are visible among different individuals (except in identical twins).

DNA (deoxyribonucleic acid), the genetic material provides instructions for making structural and functional proteins that give members of the same species similar recognisable external and internal features which are called **characters** or **traits**. A segment of DNA molecule that provides information for one trait is called the **gene** for the traits.

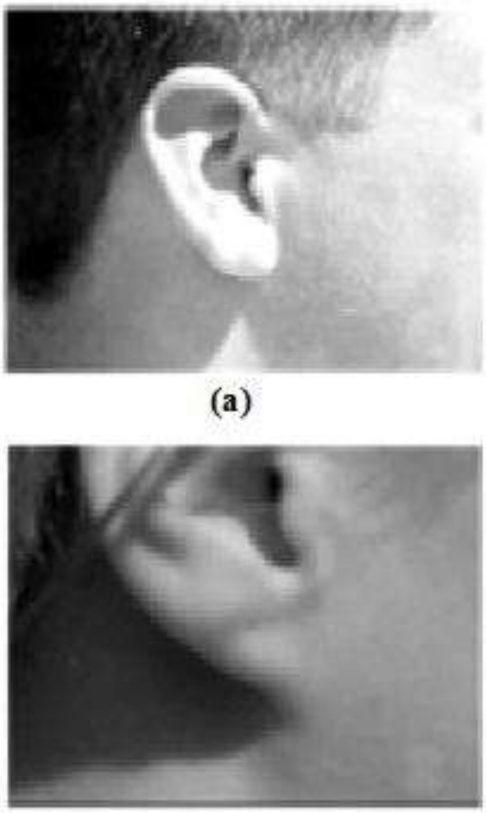
The genetic material sometimes changed or mutated due to certain internal or external factors. Such changes can cause the genetic material to give different instructions and lead to different kinds of traits being formed. Consequently, small differences or variations in structural and functional characters between members of the same species are observed.

All these variations in a species do not have equal chances of surviving in the environment in which they find themselves. Depending on the nature of variations, different individuals would have different kinds of advantages. Selection of variants by environmental factors forms the basis of evolutionary processes.

16.1. HEREDITY

Long before the discovery of genetic materials, biologists tried to discover rules which would explain why observable characteristics of offsprings are similar to those of their parents and even their grand parents.

Anormal child bears all the basic features of a human being. However, it shows variation from their parents. Thus every person possesses certain characters which distinguish himself from others. Can you imagine how much variations exist in human population ?


(a)

(b)

Fig.16.1. (a) Free and (b) attached earlobes. The lowest part of the ear, called the earlobe, is closely atttached to the side of the head in some of us and not in others. Free and attached earlobes are two variants found in human populations.

Activity 16.1.

- Let us observe the ears of all the students in the class. Prepare a list of students having either free or attached earlobes and calculate the parcentage of students having each type of earlobe (Fig.16.1).
- Find out the earlobe types of the parents of each student in the class. Compare the earlobe type of each student with that of their parents.
- Based on this evidence, suggest a possible rule for the inheritance of earlobe types.

16.1.1. Mendel's Contributions

Of the several theories that have been formulated to explain how traits are inherited, Mendel's theory has provided the foundation upon which all later works in genetics have been built.

Gregor Johann Mendel(1822-1884)

*Gregor Johann Mendel was an Austrian monk, educated in science & mathematics at the University of Vienna. From 1858 to 1865, Mendel worked in the garden of his monastery in the town of Brünn (now Brno), breeding garden pea (**Pisum sativum**) and explaining the characters of the offsprings. This helped him to arrive at the famous laws of inheritance.*

Mendel selected the common garden pea for his exprimental work. In garden pea, he found a number of contrasting visible characters, namely, round and wrinkled seeds, tall and dwarf plants, yellow and green seeds and so on.

In garden pea flower, the petals entirely enclose the reproductive structure i.e. male/stamens(which produce pollen) and pistil/female (which produce the egg). Although insects may occasionally penetrate in the flowers, self-fertilization is the rule. In his experiments, Mendel opened the buds and removed the stamens before they are ripened. Then, by dusting the pistil with pollen grains from another plant, he performed cross pollination between them.

In one series of experiments, he selected only one pair of contrasting characters viz. tallness and dwarfness. He crossed a dwarf male plant with a tall female plant and vice versa. The results he obtained in these experiments were the same in all the cases.

Rediscovery of Mendelian principles

Mendel read out his findings before the Brünn Natural History Society in 1865 and was published in the Annual proceedings of the Brünn Natural History Society in 1866. But his findings were not accepted by other scientists of those days. He died in the year 1884. Hugo de-Vries (Holland), Carl Correns (Germany) & E.Von Tschermak (Austria) rediscovered the Mendel's discovery in 1900. Mendel did not formulate any Laws of heredity. Carl Correns summerize Mendel's findings into two laws i.e. Law of segregation and Law of independent assortment.

16.1.2. Mendel's Laws of Inheritance

From the results of Mendel's experiments, Carl Correns formulated certain laws to explain the inheritance.

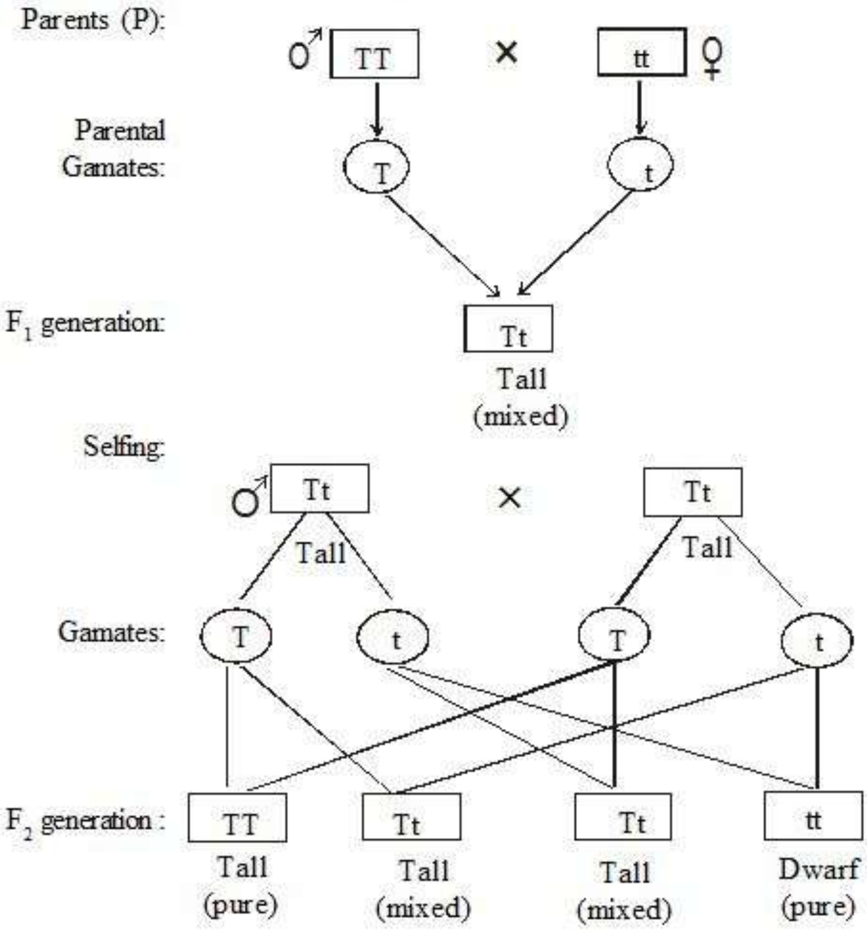
First Law / Law of segregation

Allelic genes in a hybrid do not blend or contaminate each other but segeregate & pass into different gametes. This law is derived from a Monohybrid cross.

Monohybrid Cross

In monohybrid cross only one pair of contrasting characters is taken into consideration at a time. Mendel brought about artificial crossing between a tall and a dwarf pea plant. The progeny that resulted from this cross were all tall. This means that only one of the parental traits appear in the progeny. He named this progeny as the first filial generation or F_1 generation.

Monohybrid Cross



The F_1 tall plants were left for reproduction by self pollination. The resulting seeds were collected and sown next year. They gave rise to a mixed generation of tall and dwarf plants, in the ratio of 3:1, i.e. three-fourth talls and one fourth dwarfs. This is known as the second filial generation or F_2 generation. All dwarfs of the F_2 generation bred true, producing dwarf only in third and subsequent generations. Seeds were collected separately from each F_2 tall plants and sown separately. It was seen that one-third of the tall plants bred true, while the other two third again split up in the same ratio of 3:1. The F_2 ratio is therefore 1:2:1. (one pure tall : two mixed tall : one pure dwarf). The ratio of F_2 generation (3:1) considers only its external structural forms is known as **phenotypic ratio**. Whereas the F_2 ratio of 1:2:1 is called as **genotypic ratio.**

In this experiment (Fig. 16.3), both **TT** and **Tt** are tall plants while only **tt** is a dwarf plant. In other words, a single copy of '**T**' is enough to make the plant tall while both copies have to be '**t**' for the plant to be dwarf. Traits which are transmitted unchanged in the F_1 generation, Mendel called it as **dominant**. Those which are hidden in F_1 but reappeared in F_2, he called it as **recessive**. Here tallness is dominant and dwarfness is recessive.

Second Law / Law of independent assortment

The segregation in one pair of allele is independent of the segregation in any other pair of allele. This law is derived from a dihybrid cross.

Dihybrid Cross

In dihybrid cross two pairs of contrasting characters are taken into consideration at a time. What do the progeny of a round and yellow seed with wrinkled, and green seed look like? They are all round and yellow seeds in F_1 progeny. Round and yellow seeds are thus dominent traits. But what happens when these F_1 progeny are used to generate F_2 progeny by self pollination ? From the knowledge of the previous monohybrid experiment, the expected F_2 progeny are round, yellow seeds and some wrinkled and green seeds. However, there would also be some F_2 progeny that showed new mixtures. All possible combinations took place in the following proportion i.e. 9 round, yellow; 3 round, green; 3 wrinkled, yellow and 1wrinkled, green. Thus the phenotypic ratio of F_2 generation in dihybrid cross is 9:3:3:1. What will be the genotypic ratio of F_2 generation in dihybrid cross ?

Dihybrid cross can be explained by the checkerboard method as shown below.

Parents (P) : RR YY × rr yy
(round , yellow) (wrinkled, green)

Parental gametes : RY ry

F_1 generation Rr Yy
(round, yellow)

F_1 gametes : RY Ry rY ry

F_2 generation :

Male gametes of F_1 generation

Female gametes of F_1 generation

♀ ♂	RY	Ry	rY	ry
RY	RRYY Round, yellow)	RR Yr Round, yellow	Rr YY Round, yellow	Rr Yy Round, yellow
Ry	RR Yy Round, yellow	RR yy Round, green	Rr Yy Round, yellow	Rr yy Round, green
rY	RrYY Round, yellow	Rr Yy Round, yellow	rr YY Wrinkled, yellow	rr Yy Wrinkled, yellow
ry	Rr Yy Round, yellow	Rr yy Round, green	rr Yy Wrinkled, yellow	rr yy Wrinkled, green

The genotypic ratio of F_2 generation in dihybrid cross is 1:2:2:4:1:2:1:2:1. i.e. 1(RRYY) :2 (RRYy) : 2(RrYY) : 4 (RrYy) : 1(RRyy) : 2(Rr yy) :1(rr YY) : 2(rr Yy) : 1(rr yy)

Thus the Round/Wrinkled traits and Yellow / Green seed traits are independently inherited.

Whether the genotypes of F_1 generation are homozygous or heterozygous can be determined by back cross or test cross.

Glossary of some genetical terms

Phenotype : Characters that we can see through naked eye, e.g. Tall & dwarf plants.

Genotype : Genetic constitution of an individual e.g. TT for tallness, and tt for dwarfness.

Allele/Allelomorph : Alternative form of the same factor/gene.

Homozygote : True breeds e.g., Tall is genotypically represented by TT.

Heterozygote: Hybrid ; Tall is represented by Tt.

Dominant : The character which appears in F_1 generation is called Dominant character.

Recessive : The other parental character which is not appear in the F_1 generation is called recessive character.

Back cross : It is a cross between F_1 offspring and one of its parents.

Test cross : A cross made between an F_1 offspring and its recessive parent.

Activity 16.2.

- ☞ Take two middle size cotton carry bags.
- ☞ Add 100 yellow pea seeds in one carry bag, representing mother's 50 sets of 'XX' chromosomes.
- ☞ Add 50 yellow and 50 green pea seed in the other bag, representing 50 sets of 'XY' chromosomes of a father.
- ☞ Take out one seed each, from each bag representing the two sex chromosomes.
- ☞ Repeat at least ten times to get ten pairs.
- ☞ Calculate the number of similar and dissimilar pairs of pea seeds.

The pair of yellow seeds will represent the number of female children and the pairs of yellow and green seeds will represent the number of male children. Write the numbers of male and female children.

Let us answer these.

1. What is a gene ?
2. Why did Mendel select garden pea for his experiments ?
3. What is the genotypic ratio of F_2 generation in a monohybrid cross ?
4. What are back cross and test cross ?
5. How many perfect pairs of chromosomes are found in the father of a girl ?

16.2. The origin of life

Darwin's theory of evolution tells us how life evolved from simple to more complex forms and Mendel's experiments give us the mechanism for the inheritance of traits from one generation to the next. But neither tells us anything about how life begin on earth in the first place.

Chemical evolution is one means of explaining the origin of life on Earth through the formation of complex organic compounds like the DNA molecule, capable of reproducing themselves. Alexander Ivanovich Oparin (1894), a biochemist, first produced an account for the chemical origin of life.

J.B.S. Haldane, a British scientist, suggested in 1929 that life might have developed from the simple inorganic molecules which were present on earth soon after it was formed. How did these organic molecules arise ?

An answer was suggested by the experiment conducted by Stanley L. Miller and Harold C.Urey in 1953. They performed a simple experiment by assembling a mixture of ammonia, methane and hydrogen sulphide all believed to be present in the atmosphere of the primitive earth, over water. This was maintained at a temperature just below $100^{\circ}C$ and electric sparks were passed through the mixture of gases to simulate lightening. At the end of the week, the mixture was analysed and was found to have acquired a mixture of amino acids, which are building blocks of protein molecules.

In the primitive condition of our planet these amino acids were converted to DNA and the nucleic acid is capable of replicating itself. Once a living organism has been formed from non- living organic compound, more living things would arise. All living organisms may have had a common ancestory in the soup of organic materials. The sea should have been the home of first life.

Let us answer these.

1. Who had first proposed the chemical origin of life ?
2. Name three gases that were present on the primitive atmosphere of the earth.

16.3. Evolution

Evolution is a process of gradual change from one form of life to another through a series of intermediate forms. In the course of this process, new forms were formed and get established along side or in the place of the original types. The evolution in living organisms is known as organic evolution.

As already stated, the first living organisms emerged over 3000 million years ago and today the earth is inhabited by more than two million different species. How these new species had evolved or how the present day plants and animals came into being ?

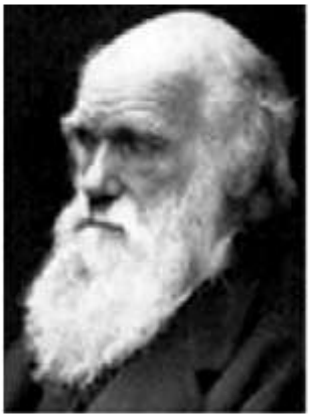
The process of changing the genetic material (DNA) has occured gradually and continuously since life started on earth. The inheritable variations had been the means of life survival when external conditions changed on earth, these variations become traits evident in different species alive on earth today.

There are three different theories to explain the course of organic evolution.

1. **Lamarckian Theory of Inheritance of Acquired Characters propounded by Jean Baptist Lamarck in 1809.**
2. **Theory of Natural Selection propounded by Charles Darwin and Affred Russel Wallace in 1858.**
3. **Mutation theory propounded by Hugo de-Vries in 1901.**

If we breed a group of mice, all these progeny will have tails. Now, if the tails of these mice are surgically removed in each generation, will these tailless mice produce a tailless progeny? Obviously not, because changes in the non-reproductive tissues can not be passed on to the DNA of the germ cells. So, the removal of the tails can not change the genes of the germ cells of the mice.

Charles Robert Darwin (1809-1882)



Charles Darwin was born on February 12, 1809 at ***Shrewsbury.*** *He was educated at Shrewsbury and later sent to Cambridge. During his three years' stay there he used to mix with the Cambridge naturalists. At the age of 22, he was entertained as a naturalist on board the Admiralty vessel, H.M.S. Beagle which sailed from the shores of England on a long five year voyage of survey (December, 27, 1831 to October 2, 1836,) in the South Atlantic and Pacific Oceans. The studies that he conducted during this five year voyage were to change forever the way we look at the variety of life on earth. But he did not know the mechanism whereby variation arose in the species. Darwin's work was published with R. Wallace's paper in the "Proceeding of the Linnean Society" in 1859, later on Darwin published his famous book "Origin of species". Darwin expired on 19 th April 1882 at the age of 73 years.*

One of the most accepted theories of organic evolution is the theory of Natural Selection proposed by Charles Darwin along the following lines.

16.3.1. Over production of offspring and a consequent struggle for existance

The multiplication of individual of a species occurs in a geometrical proportion. But a large majority of the individuals do not survive and consequently the numbers of individuals in a species remain more or less the same. The survivors in any population remain survive because of being better adapted to reach the limited resources, food etc. of the environment. These limited resources are the cause of struggle for existance.

16.3.2. Variations and their inheritance

The survivors in the struggle for existance have certain favourable variations. As a result of struggle for existance only those individuals showing variation in the right direction survive, and these variations are transmitted to the offspring. Others with unfavourable variations perish, resulting to the survival of the fittest.

16.3.3. Natural Selection

Nature or the environment selects those individuals best fitted for survival. The survival of fittest is a result of selection and prolification of only those organisms which are most suitably adapted to the environment and most successful in mating.

16.3.4. Formation of new species (Speciation)

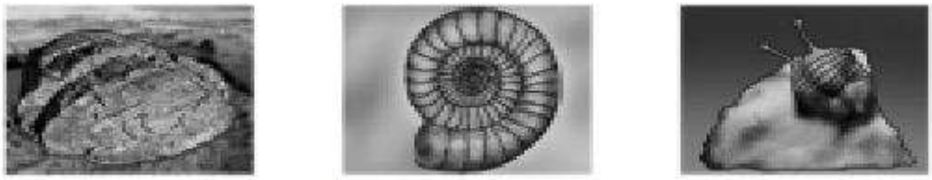
Speciation is the evolution of a new species from the pre-existing one. A species consists of a population of organisms which are able to breed amongst themselves in the natural conditions. Whenever segments of a population are isolated geographically over a period of a number of generations the two isolated segments of the population might gather enough genetic differences to result in a lack of genetic exchange even if the original barrier is removed. In this way new species are being generated.

How will you observe the occurance of evolution in nature ?

16.3.5. Fossils

When organisms die, their bodies will decompose and be lost. But, fossils are the material remains or traces of organisms preserved inside the earth's crust. Fossilization or formation of fossils involves the conversion of an organism or its parts into a hard structure or rock. While a body or some parts of it get caught in hot mud, they will not decomposed quickly and the mud will eventually hardern and retain the impression of the body or body parts. How do we know how old the fossils are ? It is reasonable to suppose that the fossils we find closer to the surface are more recent than the fossils we find in deeper layers. Fig.16.3., shows various forms of fossils.

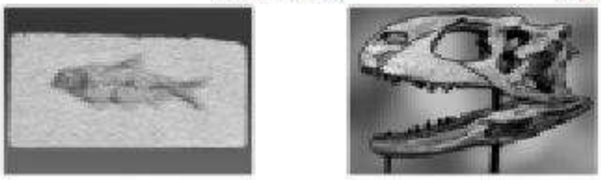
From the study of these fossils one can understand about the life forms of the past. It enables us to trace the origin and trend of evolution of several groups of plants and animals.



Fossil- tree trunk

Fossil- invertebrate (Ammonite)

Fossil- invertebrate (Trilobite)



Fossil- fish (Knightia)

Fossil- dinosaur skull (Rajasaurus)

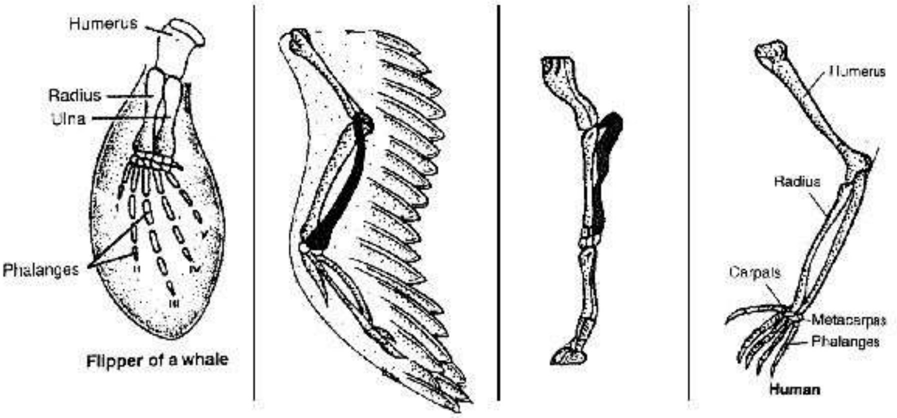
Fig.16.3. Various kind of fossils. Note the different appearances and degrees of detail and preservation.

The dinosaur skull fossil shown was found only a few years ago in the Narmada valley.

16.3.6. Homologous and Analogous Organs.

Homologous organs are those structures of organisms, which have the same embryonic origin, though they may or may not perform the same function. A front flippper of whale, a wing of bird, a forelimb of sheep, a human hand (Fig.16.4) perform different functions but they have a common origin. In plants a thorn (in *Bougainvillea*) and a tendril (in *Cucurbita*) are morphologically & functionally different, but they are homologous organs.

On the other hand wings of dragon fly, wings of eagle and wings of bat (Fig.16.5.) appear similar and perform same function but are different in their basic structure and developmental origin. So they are called analogous organs. Thorns (in *Duranta*), spines (in *Opuntia*) and prickles (in Rose) are sharped and pointed structures. Due to their difference in origin they are analogous structures.



Flipper of a whale Wing of bird Forelimb of sheep Human Hand

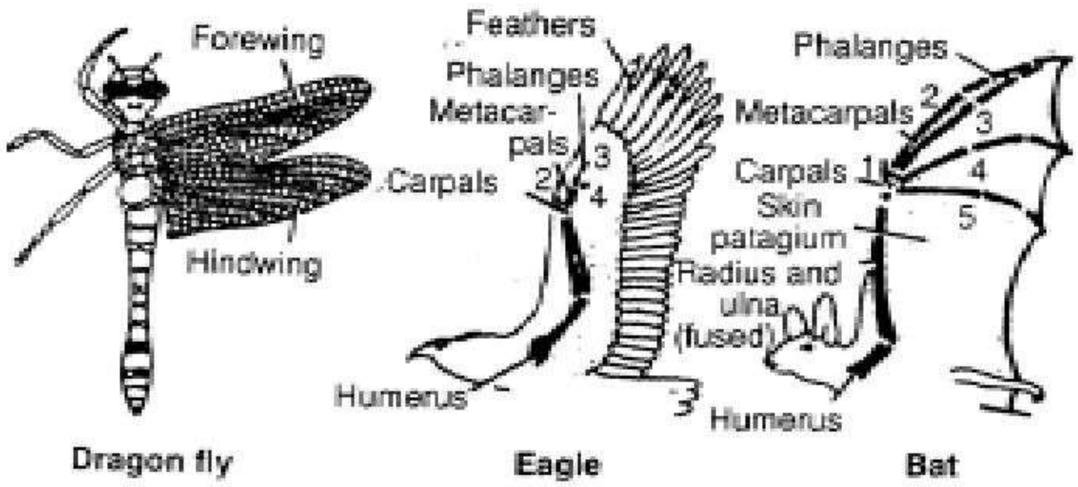


Fig.16.5. Analogous organs in animal

Homologous structures which is specialised to perfom a variety of different functions represent evolution of new forms in several directions from the common ancestral type. Whereas analogous structures does not bear close phylogenetic link but shows adaptation to perform the same function during the course of evolutionary history.

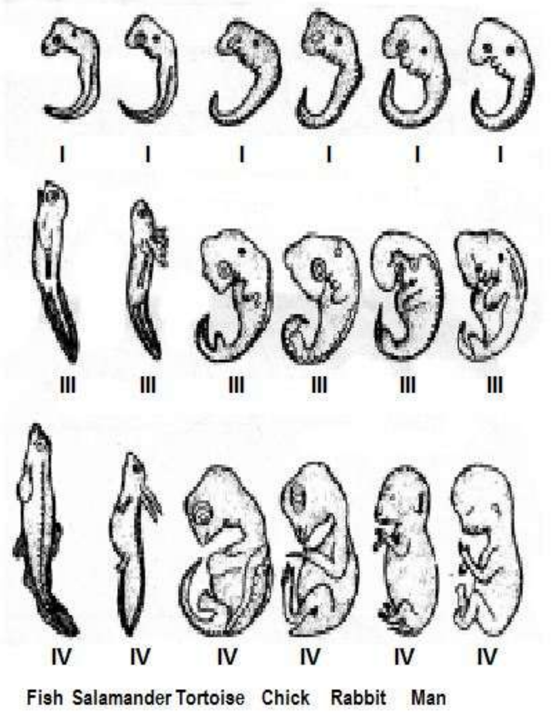


Fig.16.6. Depicting the remarkable similarlity in the early embryos of some vertebrates

16.3.7. Resemblance among vertebrate Embryos

There is a close relationship among the early embryonic stages of vertebrates. Fig.16.6. shows the embryonic development of some vertebrates.

It is difficult to differentiate a human embryo from the other vertebrate embryos of **Rabbit**, **Chick**, **Tortoise**, **Salamander** and **Fish** at their early stage of embryogenesis. There are similarities in having gill clipts, notochord, tail, rudimentary eyes and ears, limb buds, etc. The study of embryonic development among verterbrates can also give a clear idea about the evolution of different vertebrates.

Let us answer these.

1. Define organic evolution.
2. Who proposed the theory of natural selection ?
3. What are fossils ?
4. Mention two examples of analogous organs in plant.

16.4. Human evolution

More than a hundred years ago Charles Darwin suggested in his Descent of Man, a common ancestary for apes and humans based on their similarities in anatomy and behaviour. A great diversity of human form and features makes us a great confusion about the origin of human races. Human races have yellow, black and white or brown skin colour.

But all human individuals belong to a single species. It had been proved by using tools for tracing evolutionary relationship like excavating, time dating, studying fossils as well as determining DNA sequence.

The earliest member of human species, *Homo sapiens* has appeared about 300,000 years ago. Our genetic foot prints can be traced back to our African roots. From Africa they migrates slowly to West Asia, then to Central Asia, Eurasia, South Asia, East Asia, then to Indonasia and the Philippines to Australia.

There is no single line of migration. They went forwards and backwards.

In India, the earliest fossil remains of *Homo sapiens* in the form of skull and other bones was discovered in Bhimbetka near Bhopal. It is about 25 to 60 thousand years old. Like all other species in this planet, human being evolved as an accident of evolution and were trying to live their lives the best they could.

Let us answer these.

1. Trace the migratory root of human species.
2. From where the earliest fossil of human species, was discovered in India ?

POINTS TO REMEMBER

- Variations arising as a result of mutation can be inherited.
- All variations do not have equal chance of survival.
- Variations may lead to increase survival of an individual.
- Mendel selected garden pea (*Pisum sativum*) with many contrasting characters for his experiment on inheritance.
- Sexually reproducing organisms have two copies of genes for the same trait. If the copies are not identical, the trait that gets express is called the dominent trait and the other is called the recessive trait.
- Traits in one individual may be inherited separately, giving rise to new combinations of traits in the offsprings of sexually reproducing organisms.
- In dihybrid cross a trait of one pair can combine with another trait of the second pair.
- In human beings, the sex of the child depends on whether the paternal chromosome is **X** (for girls) or **Y** (for boys).
- Mendel formulated certain principles to explain the inheritance, viz. Principle of segregation and Principle of independent assortment.
- Life on earth had originated from inorganic molecules.
- Organic evolution is a process of gradual change of living organisms from simple forms to complex forms through a series of intermediate forms.
- The theory of organic evolution through natural selection was proposed by Darwin.
- Speciation may take place when variation is combined with geographical isolation.
- Evolution can be worked out by the study of not just living species, but also fossils.
- Evolution from a common ancestor can be achieved from the study of embryonic development.
- The earliest human species, *Homo sapiens* had appeared about 300,000 years ago in Africa.

EXERCISES

1. What is the Phenotypic ratio in F_2 generation of a dihybrid cross ?
2. What supportive evidence for evolution is provided by comparative embryology ?
3. What is heredity ? What are the laws of inheritance?
4. Explain the term adaptation and how it is related to evolution.
5. How does the creation of variations in a species promote survival ?
6. How do Mendel’s experiments show that traits may be dominant or recessive ?
7. How is the sex of a child determined in human being ?
8. What factors could lead to the formation of a new species ?
9. How does the study of fossils provide an evidence in favour of organic evolution?
10. Explain, the theory of organic evolution proposed by Charles Darwin.
11. Explain three evidences of organic evolution.
12. Give three points of difference between homologous and analogous organs with suitable examples.
13. How does the experiment of Miller and Urey provide some support to the hypothesis of Oparin.
14. How the human beings who look so different from each other in terms of size, colour and looks said to belong in the same species ?
15. Draw neat labelled diagrams of two homologous organs in animals.

★★★★★★

CHAPTER

17

OUR ENVIRONMENT

Environment literally means everything in our surroundings. How do you define our environment? Our environment includes the physical (nonliving or abiotic) and biotic (living) components which influence with each other including ourself. It also provide us all the materials required for our survival and comfort. The growth of human population increases in demand for food, water, shelter, electricity, roads, automobiles and numerous other commodities. These demands exert a tremendous pressure on our natural resources and brings about undesirable changes in physical, chemical and biological characteristic of our environment. The need of the hour is to check the degradation and depletion of our precious natural resources and undesirable change of our environment without halting the process of development.

In order to control environmental degradation, the Government of India had passed the Environment (Protection) Act, 1986 to protect and improve the quality to our environment (air, water and soil).

We shall now see how the various factors of the environment interact with each other and how human activities affect their cycles.

17.1. What happen if we bury different materials in the soil?

A lot of materials in the form of solid waste and sewage (liquid form of waste) are added to the environment due to our daily activities. It is beyond the capacity of nature to degrade many of these. These materials create a great problem in our natural environment if they are not properly managed.

What happens to the waste materials that we throw away in our surrounding ? Let us perform an activity to find out the answer to these questions.

Activity 17.1.

- ☞ Collect all the solid waste materials produced in a day at your home. They include kitchen waste (mostly organic), paper, plastic, glass, leather, old and torn cloths, metals etc.
- ☞ Bury them in a pit in your garden or in a bucket or flower pot and cover with at least 15 cm of soil.

☞ Observe the buried materials after an interval of 15 days and keep them moist.
☞ What are the materials which changes their form and structure over time?
☞ What are the materials that remain unchanged over long periods of time ?
☞ Which ones change the fastest ?

The food we eat is digested by various enzymes in our body. Verious enzymatic activities are also taking place in the degradation of these waste materials. Enzymes are specific in their action, i.e. specific enzymes are needed for the breakdown of a particular substance. Organic matters are easily broken down in nature whereas many man made materials like plastics are not easily acted upon by micro-organisms. They are slowly broken down by physical processes like heat and pressure.

Substances that can be broken down naturally into harmless products are called biodegradable substances. In the above activity, how many of the substances are biodegradable ?

Substances which can not easily broken down into harmless products through biological processes, are called non-biodegradable substances.

Activity 17.2.

☞ Collect more information about biodegradable and non-biodegradable substances by using library or internet.
☞ How long are various non-biodegradable substances expected to last in our environment.
☞ Find out more about such materials which do not harm the environment.

Let us study some of the various waste products and their mode of disposal in various parts of Manipur.

In Fig. 17.1, we can see various forms of solid waste collected from an area of Imphal, the capital city of Manipur. Make a list of the biodegradable and non-biodegradable substances present in it. Can you expect the same type of materials in all the other areas of this state?

Fig. 17.1. Solid waste at Imphal

for effective collection and disposal of waste are very much inadequate in all towns resulting to a large proportion of these remaining uncollected. There is no specific landfill site for disposal. As a result the waste is dumped at unspecified places in unscientified manners.

The average output of waste is around 120 tones per day in Imphal city area. Most of these wastes are dumped into the Naga and Nambul rivers, while some portion are disposed at Lamphel and other law laying areas. (Fig.17.2.).

a. Naga River *b. Nambul River* *c. Lamphel Area*

Fig. 17.2. Solid wastes disposal

Characterisation of solid Waste materials (Imphal)

Component	Percentage
Organic Waste :	60
Paper :	10
Plastic :	05
Glass :	02
Leather :	01
Textile :	05
Rubber :	01
Wood :	05
Porcelain/Stone/Clay :	03
Metals :	01
Fine Fractions (<10 mm) :	07

Source : State of Environment Report - Manipur, 2004.

Let us answer these.

1. Why are some substances biodegradable an some non-biodegradable ?
2. Explain how biodegradable substances would affect the environment ?
3. Explain how non-biodegradable substances would affect the environment ?

17.2. Ecosystem and its components

Organisms and environment are two nonseparable factors. Organisms interact with each other and also with the physical factors that are present in the environment.

The interacting organisms in an area together with the nonliving components of the environment form an ecological system or ecosystem.

The biotic components consists of micro-organisms, plants and animals, including human being. The abiotic components comprise physical factors like temperature, rainfall, wind, soil and minerals.

In a garden you will find different plants such as grasses, trees, rose, jasmine, banana trees, etc. and animals like frogs, lizards, insects, birds etc. All these living organisms interact with each other. Their growth, reproduction and other biological activities are also affected by the nonliving components of the ecosystem. Grasslands, forests, ponds and lakes are natural ecosystems while gardens and crop-fields are man made (artificial) ecosystems. The earth is also a big ecosystem.

17.2.1. Food chains

In an ecosystem, green plants, which are known as producers trap solar energy and convert it into chemical energy. The food or chemical energy manufactured by the green plants is utilized by themselves and also by plant eating organisms or **herbivores**. Herbivores fall prey to some carnivorous animals. Thus, the food energy passes from one population to the other population, in this way a chain is established. This is known as **food chain.** (Fig.17.3.). The various steps/ levels through which the food energy passes are called **trophic levels.** (Fig. 17.4.).

Producers represent the first trophic level. Herbivores and consumers of the first order constitute the second trophic level/primary consumers. Consumers of second order or primary carnivores form the third trophic level secondary consumers. The ultimate carnivores which are not eaten by others are called top carnivores tertiary consumers . They represent the fourth trophic level.

Let us answer these.

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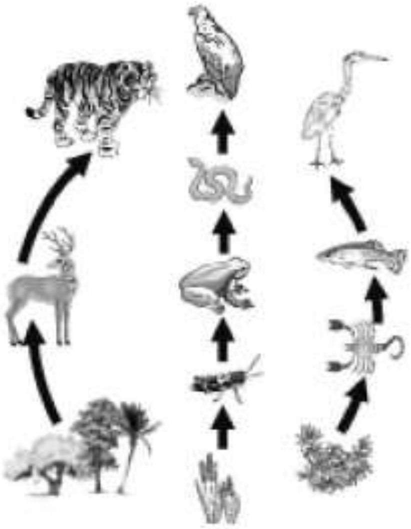

Fig. 17.3. Food chain in nature
(a) in forest
(b) in grassland and
(c) in a pond

Fig. 17.4. Trophic levels

There is another group of organisms which live on organic wastes, dead and decomposing animal bodies. Vultures, feed on dead animal body. They are called **scavengers**. Decomposers are also another category of scanvengers which live on the dead bodies of plants and animals. While scanvenging they break down the bodies and thus become agents of decay. The materials in the dead bodies are converted into organic and inorganic substances. Thus they make soil fertile and make these substances available for the producers. Men eat plant and animal parts as their food, and hence they are **omnivores**.

17.2.2. Food Webs

Food does not always pass from one population to another in a linear sequence as in a food chain. Instead several food chains are linked together in a web-like manner, thus consistituting a food web. Thus, a food web is the interlocking of different food chains by developing interconnections at various trophic levels so as to form a number of feeding interaction in a biotic community (Fig. 17.5.).

Human beings occupy the top level in any food chain. They can not be classify either as herbivores or carnivores. There are people who live on plant products only. Yet many others favour non-vegetarian food (live on animal products). What about other animals like insects, rabbits, goats, cows etc. who feed grasses. Frogs and toads live on insects. Many small birds feed on insects and plants. Snakes feed on frogs, birds, rabbits etc. Elephant is a plant eater. Tiger and Lion live on other animals as their prey. In which trophic level cats and dogs are included?

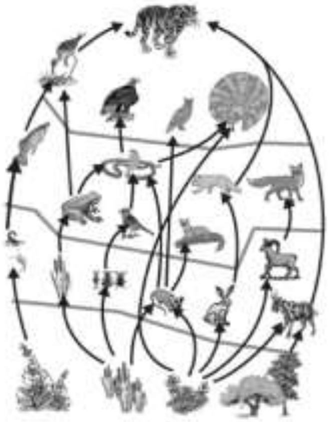

Fig.17.5. Food web

Activity 17.3.

☞ Write down the common names of any five producers (green plants) you had come across in class -IX.

☞ Which animals are consumers of first order ? Give the names of any five animals.

☞ Write the names of any five animals included in the second order of consumers.

☞ Find out the names of any three top carnivores.

In the above activity you classify the plants and animals as producers and consumers of different orders. Is there any plant in the consumer's level or any animal in the producer's level ? Can you identify more plants and animals in different trophic levels ?

17.2.3. What will happen if we kill all insects ?

Give the common names of any two insects which is harmful to man and to our crop plants. Mosquito & housefly suck human blood and can spread malaria and other killer diseases. Grasshopper and thrips cause great loss to our crop plants.

In food chain of ecosystem, insects are good prey for many other animals like spiders, toads and birds. Honeybee gives us honey. During the collection of nectar, they pollinate flowers. Insects are best pollinaters and also help in the dispersal of spores. Insect larvae are used as food by animals including man. Caterpillars have medicinal values.

Let us answer these.

1. Describe the various components of an ecosystem.
2. Give the names of any three natural ecosystem.
3. How does sun act as the source of energy for all the organisations on earth?
4. How does food chain differ from food web ?
5. Give two functions of insects in our ecosystem.

17.3. How do our activities affect the environment ?

We are an integral part of the environment. Changes in the environment affect us and our activities change the environment around us. Over and above the problem of waste disposal, let us look to other problems caused by our industrial development e.g. depletion of ozone layer.

17.3.1. Ozone depletion

Ozone is a deadly poisonous gas formed by three atoms of oxygen i.e.O_3. At the higher levels of the atmosphere, ozone performs an essential function.

Ozone filters away the ultraviolet radiation from the sun and protects the earth from its harmful effect. Thus, it acts as a protective sheild.

Ozone is an unstable gas and for both its formation and destruction , UV rays are essential which comes from the sun.

The following reactions are involved

$$O_2 \xrightarrow{UV} O + O$$
$$O + O_2 \xrightarrow{UV} O_3$$
$$O_3 \xrightarrow{UV} O + O_2$$

This is a continuous process. But the amount of ozone in the atmosphere began to drop sharply since 1980s.

17.3.2. Depletion of ozone layer allows harmful ultraviolet rays to reach the part of earth

Sunburn, ageing, wrinkling of skin, cataract of eye, destruction of protein, mutation of genes leading to skin cancer or melanoma etc. are some of the effects of UV radiation to human population.

Thinning of ozone shield is caused by a number of synthetic chemicals like chloroflurocarbons (CFCs), which are used as refrigerants and in fire extinguishers. In 1987, the United Nations Environment Programme (UNEP) succeded in organising a conferance to reduce the level of CFCs to 50 p.c. by 1999. All nations of the world has agreed to phase out their CFCs emissions in the year to come.

Activity 17.4.

- ☞ Collect more information about chemicals responsible for the depletion of the ozone layer through internet or newspaper report and library.
- ☞ Find out if the regulations put in place to control the emission of these chemicals have succeeded in reducing the damage of the ozone layer.
- ☞ Is there any improvement of ozone layer in recent years ?

Let us answer these.

1. What is ozone and how does it protect the organisms on earth ?
2. How can you help in improving the depleted ozone layer ?

POINTS TO REMEMBER

- ✹ Our environment is composed of biotic and abiotic components.
- ✹ The various components of an ecosystem are interdependent.
- ✹ The producers convert sunlight to energy to make it available for consumers.
- ✹ The energy is loss when passing from one trophic level to the next, this limits the number of trophic levels in a food chain.
- ✹ The solid waste we generate may be biodegradable or non-biodegradable.
- ✹ In Manipur the facilities for effective collection and disposal of waste are very much inadequate.
- ✹ Human activities create great impact on our environment.

- Chemicals like CFCs affect ozone layer. Ozone layer protects our environment from ‘UV’ radiation from the Sun. This could damage the environment and causes many diseases to human being.

EXERCISES

1. What are the impacts caused on the environment by the biodegradable and non-biodegradable wastes that we generate ?
2. How can you handle the problem of solid waste in Manipur ?
3. What are the causes and effects of O_3 layer depletion ?
4. Explain the role of decomposers in an ecosystem.
5. Can you imagine, what will happen if all the insects are eliminated from our environment ?
6. Draw and lavel a food chain system showing interrelationship among the producers, primary consumers and secondary consumers.

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CHAPTER

18

NATURAL RESOURCES

We human beings depend upon a number of things and services provided by the nature, which are known as Natural resources.Examples of the natural resources are water, air, soil, minerals, coal, petroleum, forests, crops, wild life etc.

18.1. Kinds of Natural Resourses

(i) Renewable natural resources and **(ii)** Non-renewable natural resources.

18.1.1. Renewable/Natural resources

These are inexhaustible resources and can be regenerated within a given span of time. Examples are forests, wildlife, wind energy, tidal energy, hydro power, solar energy etc.

18.1.2. Non-renewable/Natural resources

These are resources which cannot be regenerated. Examples are coal, petroleum, minerals etc. Once these reserves are exhausted, the same cannot be replenished.

Sometimes the renewable resources may become non-renewable resources when we exploit them to such extend that their rate of consumption exceeds their rate of regeneration. For example, a particular species, if it is expoited too much, its population declines to a great extent that it is not be able to sustain itself. So, it gradually becomes endengered and finally extinct.

The protection and conservation of our natural resources are very important. We should use them in a judicious manner so that it does not become exhausted. We should conserve them for use by our future generations.

18.1.3. Forest resources

Forest is one of the most important resources. About 1/3 of the earth's land surface is covered by forests. The forests not only provide us innumerable material resources but also serve to maintain several environmental conditions which are essential for life. But, it is becoming a matter of concern that everywhere the natural forest cover has declined over the years due to human activities.

Commercial uses of forests

We get a large number of commercial goods from the forests. These include timber, firewood, pulpwood, food items, resins, gums, non-edible oils, fibres, rubbber, lac, bamboo, medicines, etc.

Ecological significance on importance of forests

It is said that the environmental services provided by a typical tree is worth more than three times its commercial value.

The ecological services provided by the forests include the following :

(i) Production of oxygen– All the green plants of the forest produce oxygen through photosynthesis which is essential for respiration of all the living organisms.

(ii) Reducing global warming : CO_2 which is the main greenhouse gas is absorbed by the forests as a raw material for photosynthesis. Thus, the forests act as an absorbant for CO_2 thereby reducing the problem of global warming caused by CO_2.

(iii) Habitat for wild life : Forests are the homes of millions of wild animals and plants.

(iv) Regulation of hydrological cycle : The forest floor absorbs most of the rainwater by slowing down the surface runoff. Such water is released slowly for recharge of springs. About 50-80% of the water vapour in the air above tropical forests comes from transpirtion by plants and helps in bringing rains.

(v) Soil conservation : The trees of the forest bind the soil particles tightly in their roots thus preventing soil erosion. They also act as wind breakers.

(vi) Pollution moderator : Forests also act as pollution moderators by absorbing many toxic gases and thus help in keeping the air pure. The forests are also reported to abosrb noise. Thus reducing noise and air pollution.

18.1.4. Deforestation

Due to rapid increase in population growth, more lands for housing and agriculture are needed. To accomodate the increasing population more houses are to be constructed leading to the requirements of more construction materials like timber, bamboos etc. More and more forest products are consumed for fire wood, charcoal etc. leading to exploitation of forests. Many tribes still follow the practice of **shifting cultivation**. They burn down the forest in different areas for cultivation. With growing civilization more lands are required for establishment of industries. Use of wood for making boxes, furnitures, railway sleepers, plywood, pulp for paper industry etc. also exert tremendous pressure on forests. Construction of hydro-electric projects, roads, big dams and mining also result in deforestation.

18.1.5. Major consequences of deforestation

Deforestation leads to many far reaching consequences, as follows :

(i) The existence of many wild life species are threatened due to the destruction of their natural habitat.

(ii) Rainfall is affected due to changes in hydrological cycle.

(iii) Problems of soil erosion and loss of soil fertility increase.

(iv) In hilly areas deforestation leads to landslides.

18.1.6. Forest conservation

Since forest cover has become decreased very fast (about 14%) it needs conservation. The following situations are ways through which conservation of forest is done.

(i) Conservation of reserve forests

These include National Parks, Sanctuaries, Sacred Groves, Biosphere Reserves and all ecologically fragile areas. No exploitation of flora and fauna can be done for commercial purpose. Cutting of trees for fuel and consumption of fodder by cattles should be prevented. For this public support is needed to fulfil the real goal of eco-development. The Chipko Movement is a very good example of public support.

Chipko Movement – A case study

About 300 year ago, a ruler in Rajasthan started to fell the 'Khejarli' trees in his state. Local women led by a Bishnoi woman, Amrita Devi, clung to the trees to prevent the felling of the trees that were the valuable resources on which they were dependent. The women were mercilessly massacred. Later the ruler knew his mistake. The story was remembered and revived in December 1972 when the illiterate tribal women in Tehri-Garhwal district of Uttrakhand commenced the movement against the felling of trees by timber contractors. The movement gathered momentum in 1978 when the women faced police firing. This movement was known as Chipko (means to embrace) Movement in memory of the Bishnoi women who had clung to their trees and given up their lives. These women had realized that their firewood and fodder resources had receded fast in the areas around their settlements due to excessive commercial timber extraction. This led to serious floods and the loss of precious soil. The movement was supported by the persons like as Sunderlal Bahuguna and Chandi Prasad Bhat who led the people's movement to prevent deforestation by timber contractors.

Chipko activists made long padyatras across the Himalayas protesting against deforestation. The movement was successful and supported by empowering local women's groups who were the most seriously affected population. The movement had proved to the world that the forests in the hills were the life supporting systems of local communities and of immense value in ecological services such as soil conservation and maintanance of the natural water regime of the whole region.

(ii) Forest plantations

Extensive planting of trees through afforestation programmes is needed to save the diminishing forest cover. For this, production or commercial forestry has been widely adopted in different regions of the world. This aims to fulfil the commercial demand, without causing destruction of the natural forests, through intensive plantation in all available spaces.

(iii) Social forestry and Agroforestry

In social forestry, the trees and shrubs are planted in unused areas like unused farmland, community land, sides of road and rail tracks, etc. This provides firewood, fodder etc. thereby reducing pressure on existing forests.

Agroforestry is a combination of agriculture and forestry technologies for integrated, diverse and productive land use system. This combines the plantation of trees and other woody perennial plants in association with agricultural crops, pastures on the same unit of land either at the same time or in time sequence.

18.1.7. Forest Conservation through Law

According to the National Forest Policy, 1952, one third of the geographical area of the country should be under forests. But, due to continuous deforestation in the country for various reasons, it is estimated that 4.238 million hacters of forest land was officially diverted to non-forest purposes betweeen 1951-52 and 1979-80. Under such condition, Government of India could enact the Forest (Conservation) Act, 1980 with a view to conserve forests.

18.1.8. Forest (Conservation) Act, 1980

Forest (Conservation) Act, 1980 was enacted with a view to check indescriminate dereservation and diversion of forest land for non-forest purposes. Under this Act, prior permission should be taken from the Central Government before any reserved forest is declared as de-reserved, or any forest land is diverted to non-forest purposes. If there is permission for diversion, compensatory afforestation should be done. Where non-forest lands are available compensatory afforestation be raised over equivalent area of non-forest lands. If non-forest lands are not available, compensatory plantations be raised over degraded forests twice in extent to the area being diverted.

The Forest (Conservation) Act, 1980 was amended in 1988. This is to incorporate stricture penal provisions against violators. Important amendments are as follows :

(i) No state government or other authority may direct that any forest land may be assigned by way of lease or otherwise to any person, corporation, agency or organisation (not owned by the government) without prior approval of the Central Government.

(ii) No forest land or any portion thereof may be cleared of trees which have grown naturally in that land or portion, for the purpose of using it for reforestation without prior approval of Central Government.

(iii) Scope of existing “non-forest purposes” has been extended to other areas as cultivation of tea, coffee, spices, rubber, palms, medicinal plants, etc.

(iv) Admissible punishment to the offender of the provision of Section 2 of the Act.

Let us answer these

1. What are renewable and non-renewable resources ?
2. How does the forest act in reducing the global warming ?
3. What are the major consequences of deforestation ?

18.2. Wildlife

All kinds of non-cultivated plants and non-domesticated animals living freely in their natural habitats far from human interference, control and dominance are known as **wildlife**. In India, a wide variety of vegetation and animals are found. It is estimated that in India there are about 350 species of mammals, 2,100 species of birds, 500 species of amphibians and reptiles and 30,000 species of invertebrates. Many of the important wildlife fauna are becoming threatened to extinction. Some of them are Indian lion (*Panthera leo persica*), Royal Bengal tiger (*Panthera Tigris*), Sangai (*Cervus eldi-eldi*) etc.

18.2.1. Why should we conserve wildlife?

Some of the important reasons for conserving wild life are as follows :

1. Ecological balance

Every animal is a link in one food chain or the other. A loss or extinction of an animal may affect the food chain. In addition to this, every animal has a specific role in an ecosystem. If the role is that of a scavenger (animal eating dead body of other animal), then in its loss, our surrounding will be filled with rotting flesh of dead animals. If it is a rat eating snake, then in the absence of the snake, the number of rats will increase so much that they may consume all our grains which may lead to famine. So, the existance of the animals are required for ecological balance.

2. Utility to man

We can get many useful materials like meat, honey, wax, silk, lac, fur, hide ornamental materials (elephant tusks, horns, mollusk shells, pearls etc.), scent (from musk-deer), timber, medicines and many other things from the animals and plants. If the wild life is conserved and propogated, we can get these materials abundantly and can be used for commercial purpose. But, killing animals for these materials without propagating them will lead to the extinction of the animals. Their consevation and propagation is thus highly essential.

3. Helps to our survival

For the conservation of a particular animal, say tigers or lions, we are to protect or conserve the natural habitat of the animals. For their protection we should not disturb the vegetation of the area as well as the smaller animals like deer, wild boar etc. on which they eat. By doing so we will get oxygen from the plants through the process of photosynthesis and CO_2 gas also will be taken in. As a whole, the ecological balance is maintained in the area. The rainfall may not be disturbed, the climatic condition of the area will not be changed.

4. Science and Education

Animals such as frogs, rabbits, dogs, guineapigs , monkeys, etc. are used in teaching students and also by scientist to experiment in surgery and medicine.

5. Tourist attraction

Many people like to see the wild animals in their natural habitats and also at zoos. So animal lovers travel to far off countries to see the different animals. Such activity helps to increase income of the country.

6. Game value

Many people enjoy fishing and hunting (except those decleared protected) as their hobby. This is also a source of income for a country. For this the government opens their forest reserves for hunters who pay and hunt a specified number of animals and birds. At times, it is closed to allow the animals to increase their number. In this way a lot of revenue can be earned.

7. Aesthetic value

Many animals by their beauty and pattern (peacock, butterflies), majestic elegance (tiger and lions), sweet voice (cuckoo) and playful behaviour (dolphins and chimpanzees) appeal to the aesthetic sense of man and often become a subject of inspiration for painting, poetry, sculptures and writing.

18.2.2. Conservation of Wildlife

It is clear that the conservation of wild life is necessary not only for the benefit of the wildlife itself but also for our survival. The number of endangered species of flora and fauna is increasing continuously. For this, steps have been taken up to protect and manage the wildlife of the country. Non-governmental organizations (NGO) as well as government organizations at state and central levels have been set up to protect the wildlife. Recently the subject was given top priority and a separate Ministry of Environment and Forests under the central government is entrusted with the task to environmental protection. The Department of Environment, Forests and Wildlife was set up under this Ministry with a view to bring co-ordination between states and centre and speedy implementation of the steps to be taken up for the protection and conservation of Wildlife.

Wildlife conservation can be done by

(i) protection of natural habitats through controlled, limited exploitation of species.

(ii) establishing Biosphere Reserves for plant and animal species.

(iii) improving the existing protected areas as sanctuaries, national parks etc.

(iv) imposing restrictions on export of rare plant and animal species and their products.

(v) imposing protection through legislation.

(vi) educating public for environmental protection at all levels of education.

Some of the Wild Life Acts enacted by the State and Central Government for the conservation of Wildlife are:

1. Madras Wild Elephant Preservation Act, 1873
2. All India Elephant Preservation Act, 1879
3. The Wild Birds and Animals Protection Act, 1912
4. Bengal Rhinoceros Preservation Act, 1932
5. Assam Rhinoceros Preservation Act, 1952
6. Wild Life (Protection) Act, 1972

Some Government organizations for wildlife protection

1. Indian Board for Wildlife (IBWL) , 1952
2. Indian National Man and the Biosphere committee, 1972 for Biosphere Reserve.

Some principal Non-Government Organizations

1. Bombay Natural History Society, founded in 1883.
2. Wildlife Preservation Society of India, Dehradun, founded in 1958.
3. World Wide Fund for Nature India.

Let us answer these.

1. What is meant by wildlife ?
2. How the wildlife can be conserved ?

18.3. Conservation of Coal and Petroleum

Coal and petroleum are important conventional sources of energy.These are fossil fuels and non-renewable sources of energy.

Coal was formed 255-350 million years ago in the damp, hot regions of the earth. The ancient plants growing in swamps and river banks were burried into the soil after death. Due to heat and pressure they became gradually converted into peat and coal over millions of years. Coal is the world's most abundant fossil fuel. The coal reserves are likely to last for about 200 years at the present rate of usage. But if the usage increases by 2 % per year then it will last for another 65 years only.

Coal is a prime source of industrial energy. It provides about 60% of the industrial power requirement in our country. Many thermal and superthermal power stations are located near the coal fields where the coal is burned and converted to electric power which can be used for many purposes. Sixtytwo percent of the world's electric power is generated from the burning of coal. Being a non-renewable resorce, if extracted at the present rate, it will soon become totally exausted. So, it needs conservation for the future generations.

Petroleum is found in the sedimentary rocks, containing plants and animals remains about 100 to 200 million years old. Crude petroleum is a complex mixture of alkane hydrocarbons. It is purified and refined by the process of fractional distillation. During this process different constituents separate out at different temperatures and get a large variety of products namely petroleum gas, kerosene, petrol, diesel, fuel oil, lubricating oil, paraffin, wax, plastic, etc.

It is estimated that at the present rate of usage, the world's crude oil reserves will be exhausted in just 40 years.

Since many of the petroleum products and coal are utilized for the production of electricity, the conservation of electric energy also will lead to the conservation of coal and petroleum. The following practices can be followed for the conservation of coal and petroleum.

1. To turn off light, fans and other electric appliances when not in use.
2. To arrange for getting as much heat as possible from natural sources. If it is a sunny day, we can dry our clothes in sun instead of using a drier.
3. To use solar cooker for cooking our food on sunny days which will cut down the expenses of LPG .
4. Plantations of deciduous trees and climbers at proper places outside our house. This will cut off intense heat of summer and get a cool breeze and shade. This will lead to the reduction of electrcity charges on coolers and air conditioners. The deciduous trees shed their leaves in winter so it will not obstruct sunlight during winter.
5. To drive the vehicles less, make fewer trips and to use public transportations when ever possible. If some people are to go regularly to the same place, like office going then we can share by joining a car-pool.
6. To wear adequate woolen warm clothes in winter days inside the house instead of using the heat convector.
7. To ride bicycle or just to walk down small distances instead of using car and scooter.
8. To use as far as possible renewable energy sources like solar energy, wind energy, hydro power sources etc.

18.3.1. CNG (Compressed natural gas) use as an alternative fuel for vehicles

The use of petrol and diesel as fuels of the vehicles add more and more pollutants in the environment particularly in urban areas where large number of vehicles are running. CNG , is nowadays used in place of petrol and diesel as fuel in buses and autorickshaws in the cities like Delhi. CNG use has greatly reduced the vehicular pollution.

Let us answer these.

1. About how many years more are likely to last the coal reserves of the world at the present rate of usage ?
2. What are different constituents of the petroleum separated after fractional distillation ?
3. Which fuel can be used in place of petrol and diesel to reduce pollution ?

POINTS TO REMEMBER

- The natural resources like forests, wildlife, coal, petroleum etc. need to be used in a sustainable manner.
- The environmental services provided by the forest are more than its commercial value.
- There are many far reaching consequences of deforestation.
- The fossil fuels, coal and petroleum, will ultimately be exhausted. Because of this and because their combustion pollutes our environment, we need to use these resources judiciously.

EXERCISES

1. What is meant by natural resources ?
2. What are the two kinds of natural resources ?
3. What are the ecological services provided by the forests ?
4. How the forests can be conserved ?
5. Why should we conserve wildlife ?
6. What steps can be taken up for the conservation of coal and petroleum ?

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CHAPTER 19

THE REGIONAL ENVIRONMENT

The environment of a region changes considerably due to human activities. The construction of big dams, deforestation, urbanisation or industrialization of a locality are main factors for the changes in the regional environment of the area.

19.1. Human activities and regional environment

How does the construction of a big dam affect the life of the people and the regional environment ?

19.1.1. Advantages

Big dams constructed in the river valley projects are considered to play a key role in the development process due to their multiple uses. India is known for having largest number of river valley projects. These dams take a big role in the development of the nation. The inhabitants of the area are always having big hopes on these projects as they aim at providing employment and raising the standard and quality of life. The big dams have tremendous potential for economic upliftment and growth. They can generate electricity and reduce power shortage. They provide irrigation water to cultivated lands in lower areas. They supply drinking water in remote areas. The dams also can help in checking floods and famines. These also promote navigation, fishery etc.

19.1.2. Limitations – Environmental Problems:

The environmental impacts of big-dams are numerous. Due to this, the construction of big dams very often become a subject of controversy. The impacts can be at the upstream as well as downstream levels, as follows:

(A) The upstream problems include the following:

(i) The inhabitants of the nearby area are to be displaced as the water level raises due to construction of the dam.

(ii) There is loss of forests, plants and animals.

(iii) There are changes in fisheries and the breeding grounds of the fishes.

(iv) Siltation and sedimentation of reservoirs occurs.

(v) Lost of non-forest land occurs.

(vi) There may be stagnation and water logging near the reservoir.

(vii) There may be increase in vector-borne diseases due to breeding of vectors in the expanding waterlogged areas.

(viii) Possibility of earthquakes due to reservoir induced seismicity (RIS).

(ix) There will be microclimatic change.

(B) The dowstream problems may be of the following:

(i) Micro-climatic change.

(ii) In the river, water flow will be reduced and due to this there will be silt deposition in the river.

(iii) There may be intrusion of salt water at river mouth.

(iv) The fertility of the land along the river will be reduced as the sediments carrying nutrients get deposited in the reservoir.

(v) There may be outbreak of vector-borne diseases like malaria.

Although the construction of big dams are of multiple uses for the development of the society, besides there are many serious side effects. Therefore, nowadays, as an alternative, attentions have been given to the construction of small dams or mini-hydel projects.

19.1.3. Water harvesting

Water is the most essential thing of all living organisms. We can live without food for many days. But we cannot live even for few days without water. Water is needed in our body to help in the digestion of the food we eat, to remove the waste products and also to maintain the blood pressure. It is also necessary to grow all the plants.

19.1.4. From where we get this water ?

We get water from different sources in different localities, such as tanks, rivers, lakes, wells, streams, taps etc. But the ultimate source of all these waters is rain. Nowadays we are facing shortage of drinking water in almost all the places. Even in Cherrapunji where the annual rainfall is more than 1100 cm, there is shortage of drinking water. This is due to lack of proper harvesting and proper management of the rain water.

19.1.5. Rainwater harvesting

Rainwater harvesting is done by constructing special water storage tanks, ponds, dugwells, pits, lagoons, check dams etc. Rainwater, wherever it falls is collected and pollution of this water is prevented. Harvesting of rainwater is usefull not only for the poor and scanty rainfall regions but also for the rich ones.

The average annual rainfall in India is 120 cm. In most places it is concentrated over the rainy season, from June to September. So proper arrangement for the storage of water to use in the dry season also is needed. Due to lack of proper harvesting and management of rain water, people face scarcity of water even in the areas where there is the highest annual rainfall.

Rainwater harvesting is done with the following objectives :

1. to check the surface run off loss of water.
2. to meet the increasing demands of water.
3. to avoid flooding of roads.
4. to recharge the ground water for raising the water table.
5. to supplement the groundwater supplies during lean season.

Rainwater harvesting can be done by any one of the following methods:

1. By storing in special storage tanks or reservoirs constructed above or below ground.
2. By constructing pits, dug-wells, lagoons or check- dams on small streams.
3. By recharging the ground water.

In India as a traditional practice, in the high rainfall areas the rainwater is collected from roof-tops into storage tanks. In the foot hills, water flowing from the springs are collected in the embankment type water storage. In Rajasthan people use ‘tankas’ (underground tanks) and ‘khadins’ (embankments) for rainwater harvesting.

The harvested rainwater needs proper management so that it should not be contaminated and also for safe future use.

Let us answer these.

1. What are the advantages of the construction of big dams ?
2. What are the disadvantages of the construction of big dams ?

POINTS TO REMEMBER

- The construction of big dams take a big role in the development of the nation.
- Big dams can generate electricity and also supply drinking water.
- Construction of big dams on the other hand creates many environmental problems.
- Harvesting of rainwater should be done to meet the shortage of drinking water.
- Rainwater harvesting can be done by the construction of pits, dug-wells, check dams etc.

EXERCISE

1. The construction of big dams in the river valley projects are considered to play a key role in the development process. Explain.
2. Write the environmental problems faced to the construction of big dams.
3. What are the alternative practices to the construction of big dams to avoid serious side effects?
4. What are the objectives of rainwater harvesting?
5. Write the methods that can be taken up for harvesting rainwater.

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