# UNIT 9 ATOMIC STRUCTURE, PERIODIC CLASSIFICATION AND CHEMICAL BONDING

## Structure



## 9.1 INTRODUCTION

Chemistry deals mainly with varieties of matter. Air, water, rocks, minerals, plants, animals including man, the earth on which we live, and other planets and galaxies, are some examples of matter. Even in our day to day life, we come across many things such as milk, food, paper, chalk, etc., which are examples of matter. Thus, matter exists in innumerable shapes, size, colours, odours and possesses different properties.

As you know, Sodium is kept in kerosene and not in water, whereas phosphorus is preserved in water. Inspite of all these diversities in appearance and properties, there is some basic unity in all these substances. These substances are all made up of particles called atoms and molecules which are the smallest units of matter. The behaviour of a substance depends on the properties of these particles.

We are aware that the glow produced in neon lamps and fluorescent tubes are different in colour. Have you ever thought why this is so? Atoms of one element combine with atoms of other elements in a number of ways and give a large variety of simple and complex substances. Atoms of different elements behave in different ways. In order to explore the answers to these queries raised regarding the behaviour of atoms of different elements, a detailed structure of atom becomes essential.

## 9.2 OBJECTIVES

At the end of this unit you, the teacher will be able to :

- list fundamental particles present in an atom;
- differentiate between these fundamental particles;
- describe various models of an atom;
- draw the schematic diagram representing the arrangement of electrons around the nucleus.

## 9.3 STRUCTURE OF ATOM

**Main Teaching Points**

- Matter is electrical in nature.
- Atoms are made up of three fundamental particles – protons, electroms and neutrons.
- Protons and neutrons are present in a small nucleus at the centre of the atom. Almost the entire mass of the atom is concentrated in the nucleus.
- Electrons which have negligible mass are present around the nucleus.
- The arrangement of electrons, protons and neutrons in an atom is explained by a number of models.
- The electrons in an atom revolve around the nucleus in definite energy levels or shells.
- Atom contains equal number of electrons and protons and is electrically neutral.

**Teaching Learning Process**

### 9.3.1 Electrical Nature of Matter

Take a balloon and fill it with air blown through your mouth. Now rub the balloon with a woolen, silk or terylene material. Bring it near the wall. What do you observe? It is attracted by the wall.

Now fill air in two balloons through your mouth. Suspend these balloons with the help of a thread. Bring them nearer to each other. What do you notice? You will see that the balloons come close to each other. Can you tell why is it so? Now, rub these balloons with your coat, silk or terylene shirt. Suspend them with thread and again bring them closer to each other. What do you observe now? The balloons move apart. Can you cite a few more examples of this kind of phenomena from your daily life experiences? Consider a few examples given below and try to explain them.

- While taking off your terylene or silk shirt from your body, the hair of your arm gets erect.
- Also while combing dry hair it gets erect.
- A plastic comb rubbed with dry hair can pick up small pieces of paper.

Take a burette and fill it with water. Open the stop cock. You see that water stream falls straight in a glass tumbler. Now bring a dry comb rubbed with dry hair or a glass rod rubbed with polythene paper near the stream of water. What do you observe? You will see that water stream becomes deviated from the straight line towards the comb or glass rod. Why ?

This phenomenon of attraction and repulsion occurs on account of electrical charges present in matter. Coat, silken shirt, terylene shirt, wall, balloons, comb, water and hair are different kinds of matter. These observations lead us to believe that matter is electrical in nature.

### 9.3.2 Atomic Particles

You know that matter is electrical in nature. After the discovery of electricity in the nineteenth century, scientists studied the passage of electricity through matter. They found that metals conduct electricity while many other substances (known as non-metals) were non-conductors (insulators). Passage of electricity through gases at low pressure was another interesting observation of the scientists at the end of nineteenth century.

If an electric charge is passed between two electrodes sealed in a glass tube containing air at a very low pressure (1mm Hg), a glow is seen in between the electrodes (Figure 9.1). If air in the tube is replaced by any other gas, the glow still persists, but the colour of the glow changes with the nature of the gas.

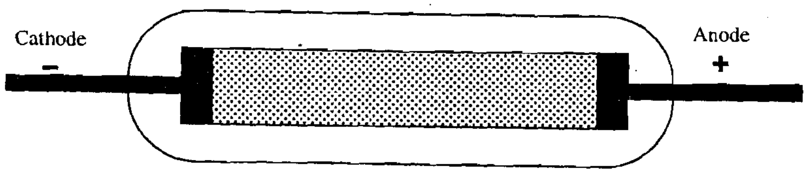


**Fig. 9.1 : Electric discharge through gases at a very low pressure.**

If similar experiments are performed at even lower pressures (0.001mm Hg), it is observed that the glow in the tube disappears and instead the glass tube at the end opposite to the cathode starts glowing and emits a greenish light.

It is now known that some invisible rays are formed at the cathode. When these rays strike the glass (discharge) tube, they emit a greenish light. As these rays seem to come out from the cathode, (negative electrode), scientists called these rays as **cathode rays.**

Let us study the properties of cathode rays.

1. Cathode rays travel in straight lines :

   When an opaque object like a metal cross is placed in the path of the cathode rays (between the electrodes) in a discharge tube (Fig.9.1), we find that a shadow of the metal cross is formed on the end wall of the tube opposite to the cathode (Fig.9.2).

   The fact that the cathode rays cast shadows of the object placed in their path shows that they travel in straight lines from the cathode towards the anode, (Fig.9.2).

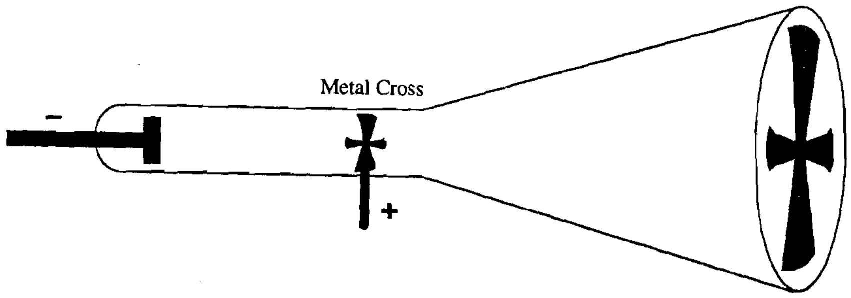


**Fig. 9.2 : Cathode rays cost a shadow.**

2. Cathode rays can produce mechanical effects :

   If cathode rays are allowed to strike the blades of a light paddle wheel placed in the path of the rays, the paddle wheel rotates. The paddle wheel can be rotated only if the cathode rays consist of material particles having mass and kinetic energy.

This implies that cathode rays carry mass and have kinetic energy (Fig. 9.3).

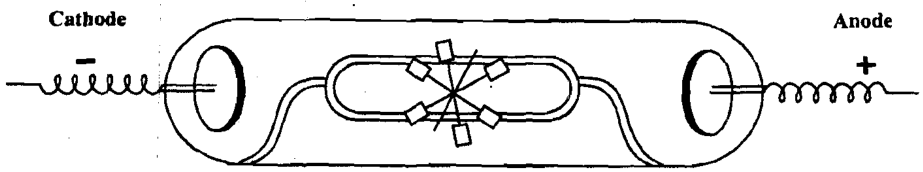


Fig. 9.3 : Cathode rays possess kinetic energy.

3. Cathode rays are negatively charged:

   When an electric field is applied in the path of cathode rays, they are deflected towards the positive electrode. This leads us to conclude that the rays are composed of negatively charged particles.

   The cathode rays are also deflected by a strong magnetic field.

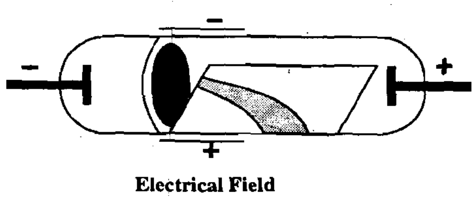


Fig. 9.4 (a) : Effect of an electric field on cathode rays

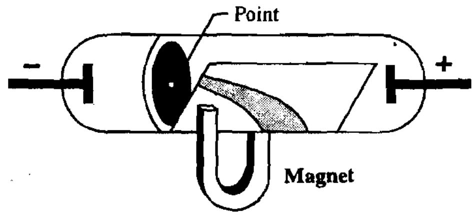


Fig. 9.4 (b) : Effect of a magnetic field on cathode rays

Further, investigations by scientists have proved that for each such particles, the ratio of its negative charge (e) to its mass (m) is a constant, whatever be the gas used in the discharge tube.

$$\frac{e}{m} = \text{Constant}$$

This indicates that such negative particles form a common constituent of all gases. This has been found to be true in the case of other forms of matter also. This fundamental negative particle is named ELECTRON.

This gas taken in the discharge tube consists of molecules and molecules are made of atoms. All the atoms contain electrons. When we apply high electrical voltage, the electrical energy pushes out some of the electrons from the atoms of the gas. These electrons form cathode rays. So the formation of cathode rays shows that one of the particles present in all the atoms is the negatively charged electron.

**Characteristics of electrons**

Scientists have established that :

- the mass of an electron is negligible and is about the 1/1840 that of hydrogen atom.
- the electron has a negative charge of $1.6 \times 10^{-19}$ coulumbs. This quantity is considered as a unit negative charge because this is the smallest negative charge that a particle can carry.

### Discovery of Proton

By now we have established that electrons, negatively charged particles, are present in matter. We also know that matter is electrically neutral as whole. This implies that matter should also contain positively charged particles as well to neutralize the (–)ve charge. In addition to electrons, matter contains positively charged particles, namely protons. This namely can be proved by repeating the discharge tube experiment using a perforated cathode (having holes). A faint glow is observed behind the cathode indicating the formation of some kind of rays. These rays are formed at the anode, so they are known as Anode rays or Positive rays.

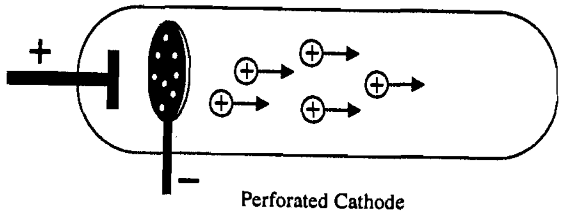


**Fig. 9.5: Production of positive rays in a discharge tube**

By performing experiments similar to those performed on cathode rays, it can be established that these rays are made up of positively charged particles called PROTONS.

It is observed that like cathode rays, anode rays also travel in straight lines, can produce mechanical effects. Also, the nature of these rays depends on the gas taken in the discharge tube.

The experiments were performed with several gases. The positive rays obtained from hydrogen gas showed the highest charge to mass ratio and consisted of single type of particles. This particle is named as PROTON.

### Characteristics of a Proton

It has been established that :

- charge to mass ratio (e/m) is not constant for positive particles obtained from different gases.
- positive rays obtained from hydrogen gas have the highest charge to mass ratio.
- the mass of a proton is about 1840 times that of an electron, i.e. it has mass equal to that of hydrogen atom.
- the charge carried by a proton is equal to that carried by an electron but is of opposite sign. This represents the unit positive charge.

### NEUTRON

After the discovery of protons and electrons, it was noticed that all the mass of an atom is not accounted for on the basis of only protons and electrons present in it. The mass of an electron is negligible (as compared to the mass of an atom as a whole ). So the mass of an atom should mainly depend upon the number of protons present in it. The average atomic mass of Carbon is 12. The number of protons present in a carbon atom is 6, which accounts for 6 mass units only. Similarly, Sodium atom has the average atomic mass 23, but sodium contains 11 protons only which will account only for 11 mass units. This problem was solved by the discovery of another fundamental particle by Chadwick in 1932. This particle was named Neutron. It has been established that this particle is electrically neutral and has a mass nearly equal to that of a proton.

**Check Your Progress**

**Notes** : a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.

1. What is the nature of charge on cathode rays?

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2. State one property of cathode rays.

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3. Explain why the e/m ratio for the positive particle in the case of different gases are found to be different?

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4. What is the relationship that exists between the number of negative and positive particles in an atom?

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5. What is a proton? State its relative mass and charge.

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6. How does a neutron differ from a proton?

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### 9.3.3 Model of an Atom

You are already familiar that atom is electrically neutral, i.e. the number of positively charged particles is equal to the number of negatively charged particles in an atom. In order to represent an arrangement of electrons and protons in an atom, following models may be proposed. One could, of course, suppose that they are uniformly distributed, and the entire atom looks like a water melon (Tarbooz) or a custard apple (sharifa).

At this stage, the students may be informed about the Rutherford experiment.

Rutherford took a thin gold foil and made alpha ($\alpha$) particles fall on it. The positively charged particles needed for this purpose were obtained from the radioactive element, radium enclosed in a cavity made on a lead block. Particles were made to fall on the window of a chamber of thin metal foil.

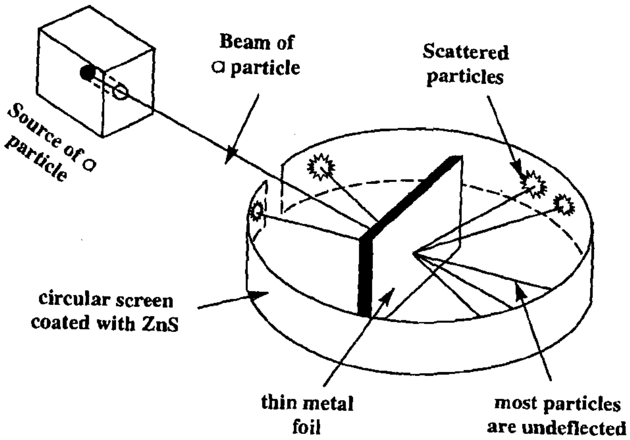



**Fig. 9.6 : Rutherford experiment on $\alpha$ particles scattering**

The particles passed through the window and were collected in the chamber. At the end of the experiment, Rutherford was able to show that the chamber contained helium gas, even though, it had no helium gas to start with. Rutherford established that the positive $\alpha$– particles were actually positively charged helium atoms.

The idea of an indivisible atom given by Dalton is now abandoned based on the fact that many minerals emitted radiations which could pass through material like paper. These radiations must have come from the atom. So it has been established that atom is divisible.

**Rutherford Experiment**

Rutherford bombarded positively charged $\alpha$– particles on a thin gold foil. To detect the particles coming out of the gold foil, he used a zinc sulphide screen. The observations of the experiment are as follows, Fig. 9.7.

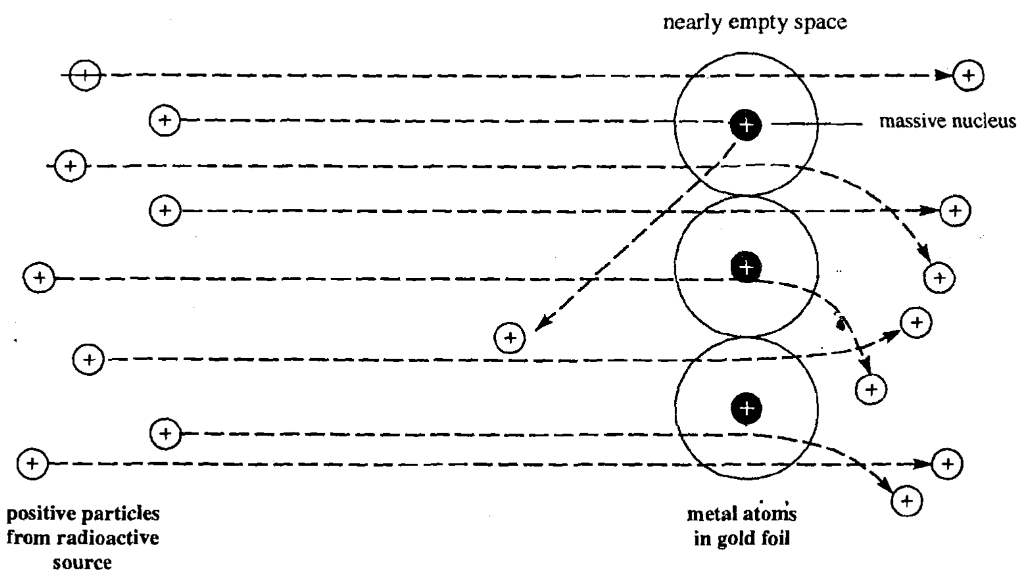
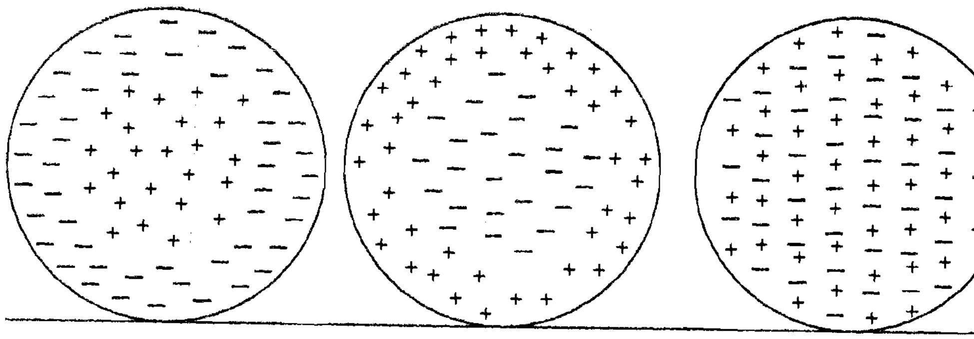



**Fig. 9.7 : Results of Rutherford's experiment**

- Most of the particles pass through the thin gold foil unreflected.
- Some particles are deflected at fairly large angles.
- Very few particles are rebounded back along their path at 180°.

In the light of the Rutherford observations we may now discuss various models mentioned. Model (3) which is infact, the **Thomson model** depicts the analogy of a water melon where seeds may be regarded as negative charged electron, distributed randomly and



(a) Model 1 : Positive charge concentrated at the centre

(b) Model 2 : Negative charge concentrated at the centre

(c) Model 3 : Uniform distribution of positive and negative charge

**Fig. 9.8 : Various models for the atom**

uniformly, in the reddish material which may be regarded as positive charge. If this model were true then what do you think should be our observations when particles bombard a gold foil ? In such case most of the particles will have very small but uniform deflection. Now the question is :Will it be an acceptable model ?

The answer of the pupils will be in negative because it is against the experimental observations.

Now ask pupils:

Can Model (2) explain the experimental observations of Rutherford ?

The answer of the students may be that if it were the model of the atom, then no $\alpha$– particles would have a deflection back along its path at 180°. So this model is also against the experimental observations of Rutherford.

Now, we can ask the students the validity of Model (1). On the basis of logical arguments, pupils will accept the Model (1) is in agreement with the experimental observations.

With the help of experimental observations of Rutherford and through discussion, each observation will lead to an independent conclusion as given below:

1. Most of the $\alpha$– radiations pass through the metal foil unreflected in straight lines. This shows that there is a lot of empty space within an atom.

2. Some of the $\alpha$– radiations are slightly deflected and a very small number (about 1 in 1,00,000) is deflected through a large angle almost 180° . This large deflection reveals three things:

i) the ∝– particle which is deflected largely is meeting a centre of very high mass within the atom.

ii) the centre of high mass is also positively charged and hence repels the positively charged ∝– particles.

iii) the centre must occupy only a very small space within the atom.

From Rutherford's experiment it becomes clear that the entire mass of an atom is concentrated in a small region. Hence all the protons and neutrons which account for the mass of an atom, must be present in this region. Consequently this region is positively charged. This portion of the atom is known as the nucleus. The number of protons in the nucleus tells the number of positive charges on the nucleus. This number is called Atomic number of the element. As the mass of an atom is concentrated in the nucleus, the total number of an atom is concentrated in the nucleus, the total number of protons (P) and neutrons (N) present in the nucleus is called the mass number of the element. The mass number thus, can be calculated as = N + P.

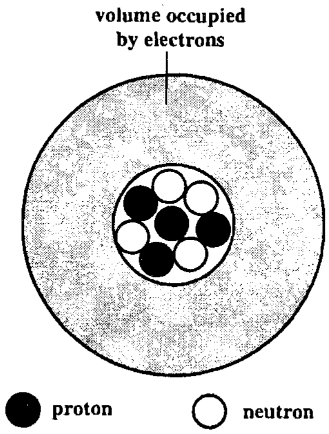



Fig. 9.9 : The 'modern' atom (relative size of the nucleus is much exaggerated)

You know that an atom as a whole is electrically neutral, so obviously, it is necessary that the number of electrons present in an atom must be equal to the number of protons present in its nucleus.

Rutherford used a gold foil of about 0.4 micro meter (0.0004 mm) thick. It means that the particle will have to pass through 1000 layers of gold atoms. He repeated this experiment using a gold foil of double thickness and found that the number of particles which bounced back were doubled. He then used the simple rule of three. If the film is 1000 layers thick, one particle in 100,000 (or $10^5$) is bounded back. With just a single layer, only one in $10^8$ would be bounced back. As an approximation, it can be said that area represented by the nucleus must be $10^8$ times smaller than the total area represented by an atom. In other words we can say that nucleus must be very small, compared to the size of the atom.

You can ask your student to visualize a scale model of the atom according to following specifications :

The diameter of the nucleus is $10^{-15}$ cm and that of an atom is $10^{-8}$ cm. Consider $10^{-5}$ cm as 1 cm. The nucleus would be an average size of a green pea of 1 cm diameter. The size of the atom would then be $10^5$ cm or 1 km. Where would the electrons be in this particular atom? The electrons would be at a distance of $10^5$ cm or 1 km from the nucleus.

Now you see how hollow an atom is ? If you try to shoot at this atom using small balls or bullets, the balls would mostly pass through. Only, occasionally one is $10^5$ scores a direct hit and is bounded back.

As the nucleus is positively charged, the electrons must be situated outside the nucleus. According to the experimental observations, the electrons occupy the bulk of the space in an atom. The number of electrons is equal to the number of protons (i.e. atomic number).

Based on experimental observations, Rutherford postulated that the atom consists of positively charged nucleus which contains practically all the mass. The electrons are revolving around the nucleus. The number of the electrons is equal to the number of protons present in the nucleus.

Such a model bears an analogy to our solar system where the earth (planets) are revolving around the Sun. But in this analogy there is one difficulty. An electron is a charged particle. A charged particle moving in a circular orbit (circular path) must emit radiation. So if the electron moving in a circular path continuously emits radiations/energy, ultimately it will fall into the nucleus. Such situation would mean that the atom is unstable. It is against the experimental observations which confirm atom as a stable unit.

But can you imagine what would have happened if the electrons were stationary?

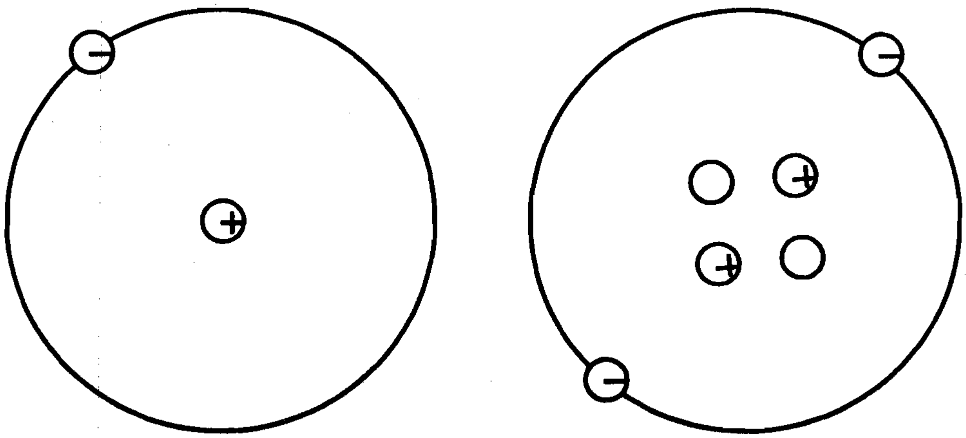


**Fig. 9.10(a): The atom of hydrogen contains one proton and one electron**

**Fig. 9.10(b): The atom of helium contains two protons, and one electron**

The second important experimental finding was that of **time-spectrum** of the elements. This finding could not be explained by the Rutherford model.

### Bohr Model of an Atom

To overcome the objections to the Rutherford model and also to explain the spectral lines of hydrogen, Bohr provided the connection between line spectrum of hydrogen and quantum ideas. He postulated that if an electron revolves around the nucleus in a certain fixed energy level, it does not radiate any energy. An electron does not emit energy continuously but it does so only when it jumps from a higher energy level to a lower energy level. This energy loss is in terms of discrete units of energy called quantum. So these energy levels were also named as the **principal quantum numbers** later on.

Let us visualize how electrons are arranged around the nucleus in an atom. The electrons from a cloud of negatively charged particles outside the nucleus. In this cloud, the electrons are arranged according to their energy (i.e. energy levels). These energy levels are described by numbers 1, 2, 3, 4.... (Principal Quantum Number) or by letters K, L, M, N, etc. referred to as shells. Smaller values of the **principal quantum number** indicates that the electrons are in a low energy level. The $n = 1$ energy level is lowest energy level. This corresponds to K-shell.

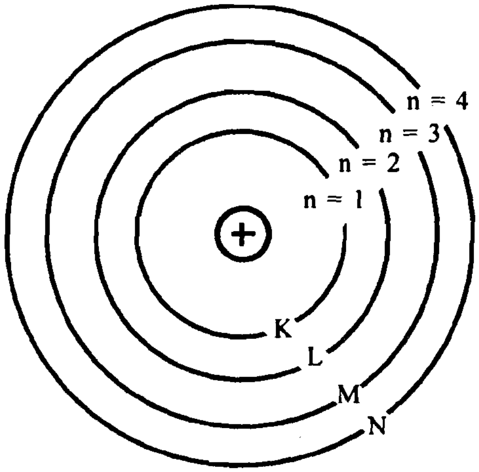



**Fig. 9.11: Different energy levels in an atom**

Similarly, the successive higher energy levels n = 2, n = 3 and so on correspond to L, M shell, etc.

- The first or the inner most shell (n = 1) can take only two electrons.
- The second shell (n = 2) can take upto 8 electrons.
- The next shell (n = 3) can take maximum 18 electrons, but if it is the outermost, then it can take 8 electrons only.
- Beyond this, shells become rather big and have several smaller shells within called sub-shells.
- Normally, electrons are not accommodated in particular shells unless earlier shells are filled. That is. a stepwise filling of shells is followed. These rules are used to write the following table. The number arrangement of electrons in an atom (electronic configuration) of the first 19 elements are given in the Table 9.1.

**Table 9.1**

| Element | H | He | Li | Be | B | C | N | O | F | Ne |
|---|---|---|---|---|---|---|---|---|---|---|
| Atomic No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Electronic Configuration | 1 | 2 | 2,1 | 2,2 | 2,3 | 2,4 | 2,5 | 2,6 | 2,7 | 2,8 |
| Element | Na | Mg | Al | Si | F | S | Se | Ar | K | |
| Atomic No. | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | |
| 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 | 2,8,8,1 | |

*Source* : **NCERT XI class Science Text.**

Model of atoms of some simple elements can be made as follows:

Take a long nail or a piece of long hard wire. Fix it vertically on a sturdy wooden block (Fig.9.12). Make circles of different diameters from pieces of hard wire and fix them onto a vertically fixed nail. Take plastecene of different colours and from them make spherical balls of different sizes. In place of plastecene, balls of clay can be used. Fix these balls on to the circles of wire and at the centre, make the nucleus of some simple atoms. The electrons, protons and neutrons can be shown using different colours.

This model can be used to constr... atoms of different elements.

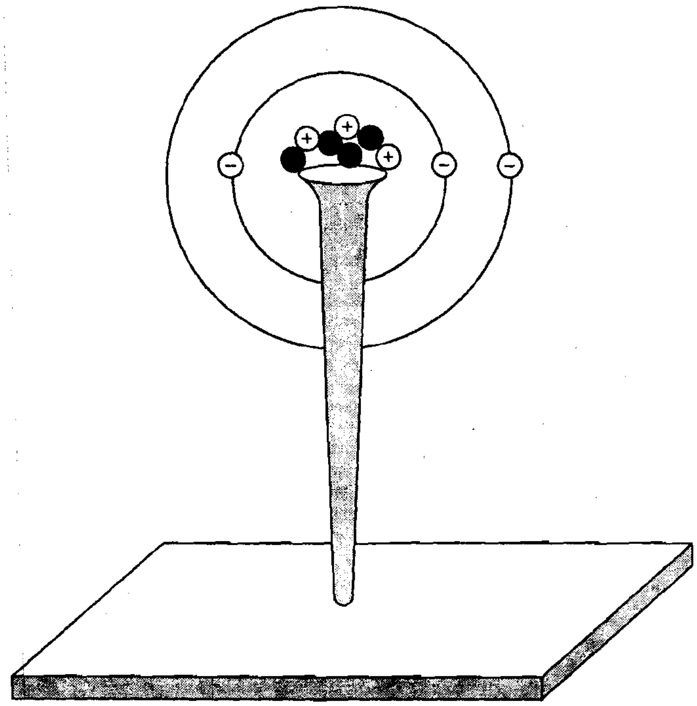


Fig. 9.12 : Model of lithium atom

Teaching aid in the form of a chart or model prepared by using the pieces of hard wire to make circles of different diameters can be used to represent the different energy levels in an atom.

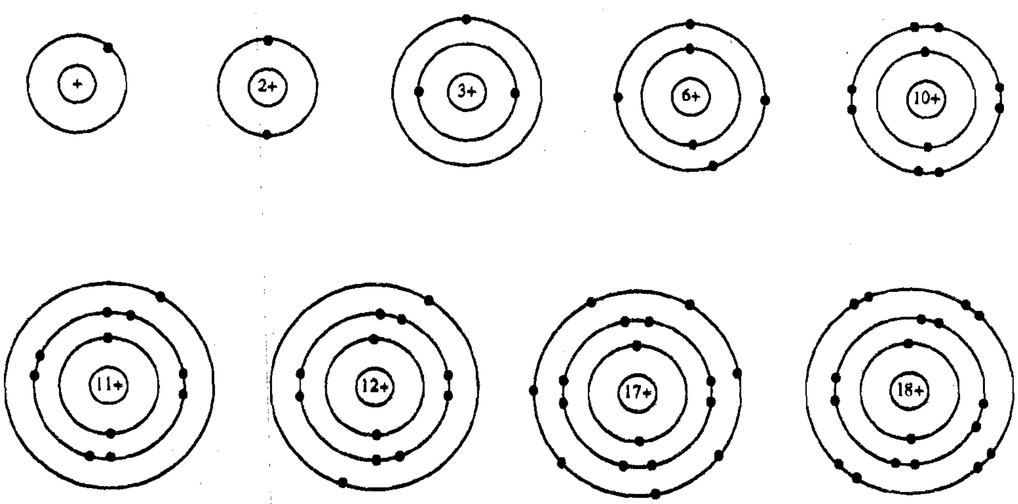



Fig. 9.13 : Distribution of electrons in various energy levels of some atoms.

**Distribution of electrons in different energy levels**

On the basis of experimental observations, Bohr and Busy suggested that:

- the maximum number of electrons that can be accommodated in an energy level is $2n^2$ where n is the number of that energy level.

K-shell (n = 1), $2 \times 1^2 = 2$ electrons

L-shell (n = 2), $2 \times 2^2 = 8$ electrons

M-shell (n = 3), $2 \times 3^2 = 18$ electrons

N-shell (n = 4), $2 \times 4^2 = 32$ electrons

- the outermost shell of an atom cannot have more than 8 electrons and next to the outermost-shell cannot have more than 18 electrons.

Ask the students to prepare the models of different atoms showing various energy levels.

Ask the students to prepare a table showing atomic number, mass number, no. of protons, no. of neutrons and distribution of electrons in different energy levels .

The atomic number and mass number of atoms can be represented as :

$^{1}_{1}H$, $^{7}_{3}Li$, $^{12}_{6}C$, $^{16}_{8}O$, $^{24}_{12}Mg$, $^{35}_{17}Cl$ and so on.

**Methodology used :** The activity mentioned in the development of concept-I has been taken as an example to teach in the class. Each student has performed this activity . The instructions are distributed to the students in the cyclostyled sheets alongwith the requisite material. Students work in groups .

The students are asked to record their observations in the notebook. The following questions based on student's observations are discussed :

- why does the balloon get stuck to the wall when it is rubbed with silk or terylene cloth ?
- when the experiment is tried with two balloons, why do they repel each other ?

Thereafter the students recall Coulomb's law and the phenomenon of electromagnetic induction. On the basis of these, they generalize that matter is electrical in nature. This activity is also correlated with daily experiences .This method is known as **activity method.**

The method used for developing other concepts is the **lecture-method.** While adopting lecture method, the use of teaching aids, models, charts, etc. were made at the appropriate place. A suitable sequencing of content was followed and students were encouraged to ask questions. All important conclusions emerged out of this discussion only.

**Check Your Progress**

**Notes** : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

7. Give experimental evidence to show that :

i) practically the whole mass of an atom is centered at its nucleus.

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ii) the nucleus of an atom is positively charged.

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8. The mass number of an element is 23 and the atomic number is 11, the number of neutrons present in the nucleus is:

   a) 11, b) 23, c) 12, d) 34

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9. The mass number of an element is 18. It contains 7 electrons. What is the number of protons and neutrons in it ? The atomic number of the elements is:

   a) 18, b) 7, c) 11, d) 25

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10. An element has atomic number 19 and atomic mass 39,

    i) How many electrons are present in the atom?

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    ii) How are these electrons arranged in the atom ?

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11. K and L shells of an atom are completely filled, what is the total number of electrons present in the atom?

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## 9.4 CLASSIFICATION OF ELEMENTS

In order to acquire systematic and informative knowledge, there is always an inherent desire of man to classify the mass of information. As knowledge regarding the behaviour of elements and their compounds grew, there was an inevitable need for classifying and systematizing the available information about them. From our daily life experiences, we know that every classification needs a definite set of criteria. It has been established that the physical and chemical properties of elements depend on the number of electrons and their arrangement around the nucleus. Therefore, the classification of elements is based on the electronic configuration. Here you will study how properties of the elements are related to electronic configuration of atomic structure.

### Objectives

- To illustrate the needs of criteria for any kind of classification.
- To explain the basis on which the modern periodic table has been developed.
- To develop the concept of periodicity and gradation in the properties of elements.

**Main Teaching Points**

- Elements are arranged in order of increasing **atomic mass** and atomic number, they exhibit periodicity in properties.
- Periodicity in properties of elements is explained on the basis of arrangement of electrons outside the nucleus.
- Gradation in properties of elements is exhibited in groups and periods.

**Teaching-Learning Process**

### 9.4.1 Mendeleev's Classification

First of all, the students were told by the teacher about the historical overview of classification the elements.

Early attempts at classification of elements were made by several scientists. Newlands (1864) arranged the then known elements in order of increasing atomic masses and found that every eighth element showed similarity in behaviour to the first element (law of octaves). He classified the elements as following:

**Table : 9.2**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Li<br>(7)<br>Na<br>(23)<br>K<br>(39) | Be<br>(9)<br>Mg<br>(24)<br>Ca<br>(40) | B<br>(11)<br>AI<br>(27) | C<br>(12)<br>Si<br>(28) | N<br>(14)<br>P<br>(31) | O<br>(16)<br>S<br>(32) | F<br>(19)<br>CI<br>(35.5) |

According to the Table 9.2, sodium resembled Li, and chlorine resembled F. This classification could not go further then in the table. However, it emphasized that some systematic relationship existed between the order of atomic masses and the properties of the elements.

This idea was further developed to a large extent by Dmitri Ivanovitch Mendeleev (1869). He developed a table of elements and propounded the generalization that the **properties of the elements were periodic functions of their atomic masses**. It was named as Periodic Law. The table prepared by him was given the name, Periodic Table. Mendeleev stressed more on similarities in properties of elements rather than following rigidly the increasing order of their atomic masses. Thus, in some cases he deviated from periodic law and left some gaps in his table for elements not known at that time (those elements were discovered later on). He even predicted the properties of these unknown elements for which gaps were left in the periodic table. Later, when these elements were discovered, then it was actually observed that there was a remarkable similarity in the properties with the ones predicted by Mendeleev.

During the same period working independently, Lothar Meyer pointed out periodicity in the physical properties of elements, especially the atomic volume, as a function of atomic masses. These results were quite interesting but he could not receive due credit because Mendeleev's work was published first.

In spite of the great advance in the study of chemical elements made possible by Mendeleev's classification, there were still certain irregularities in the periodic table which could not be explained there.

The students may be asked about the anomalies/irregularities observed in the Mendeleev's periodic table and let them give their own explanation.

During the time of Mendeleev, the concept of atomic number was not known. Later on it was found that atomic number of an element is a more fundamental property than its atomic mass in deciding the behaviour of the element.

Accordingly, the periodic law given by Mendeleev was also modified as properties of the elements are periodic functions of their **atomic numbers**.

## 9.4.2 Modern Periodic Table

The students should now be told that the basis of modern periodic table (long form of periodic table) is electronic configuration.

**Table 9.3: Periodic classification of elements.**

LONG FORM PERIODIC TABLE

| Groups / PERIODS | IA (Representative Elements) | IIA | IIIB | IVB | VB | VIB | VIIB | VIII | VIII | VIII | IB | IIB | IIIA | IVA | VA | VIA | VIIA | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | H 1 | | | | | | | | | | | | | | | | | He 2 |
| 2 | Li 3 | Be 4 | | | | | | | | | | | B 5 | C 6 | N 7 | O 8 | F 9 | Ne 10 |
| 3 | Na 11 | Mg 12 | | | | | | | | | | | Al 13 | Si 14 | P 15 | S 16 | Cl 17 | Ar 18 |
| 4 | K 19 | Ca 20 | Sc 21 | Ti 22 | V 23 | Cr 24 | Mn 25 | Fe 26 | Co 27 | Ni 28 | Cu 29 | Zn 30 | Ga 31 | Ge 32 | As 33 | Se 34 | Br 35 | Kr 36 |
| 5 | Rb 37 | Sr 38 | Y 39 | Zr 40 | Nb 41 | Mo 42 | Tc 43 | Ru 44 | Rh 45 | Pd 46 | Ag 47 | Cd 48 | In 49 | Sn 50 | Sb 51 | Te 52 | I 53 | Xe 54 |
| 6 | Cs 55 | Ba 56 | La 57 | Hf 72 | Ta 73 | W 74 | Re 75 | Os 76 | Ir 77 | Pt 78 | Au 79 | Hg 80 | Tl 81 | Pb 82 | Bi 83 | Po 84 | At 85 | Rn 86 |
| 7 | Fr 87 | Ra 88 | Ac 89 | Ku 104 | Ha 105 | | | | | | | | | | | | | |

TRANSITION ELEMENTS: IIIB ... IIB; Representative Elements: IIIA ... 0

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 Lanthanide Series → | Ce 58 | Pr 59 | Nd 60 | Pm 61 | Sm 62 | Eu 63 | Gd 64 | Tb 65 | Dy 66 | Ho 67 | Er 68 | Tm 69 | Yb 70 | Lu 71 |
| 7 Actinide Series → | Th 90 | Pa 91 | U 92 | Np 93 | Pu 94 | Am 95 | Cm 96 | Bk 97 | Cf 98 | Es 99 | Fm 100 | Md 101 | No 102 | Lr 103 |

Further the students should be asked by you, the teacher, to observe the long form of the periodic table carefully and find how the irregularities found in Medeleev's periodic table were removed.

Now the students know that in the long form of periodic table, the elements have been classified on the basis of electronic configuration which is, in turn based on atomic number. It is found that elements are arranged in order of increasing atomic number horizontally in such a way that elements having similar properties get placed in the same vertical columns. For example, sodium and potassium, having similar properties fall in the same group of the periodic table. This is so because of the similarity in the electronic arrangement in the outermost shells of their atoms. The long form of periodic table is found to consist of the seven horizontal rows which are called periods. Each period starts with a new principal quantum number (n). The number of the period is the number of outermost shell of the atom in which the electron is gradually being filled as the atomic number increases.

The students are asked to complete the following chart

| S.No. | Period | No. of Elements in the period | No. of principal quantum number | Name of elements from | to |
|---|---|---|---|---|---|
| 1. | I Period | - | | H | He |
| 2. | II Period (Short Period) | - | 1 | Li | Ne |
| 3. | III Period (Short Period) | - | - | - | - |
| 4. | IV Period (Long Period) | - | - | - | - |
| 5. | V Period (Long Period) | - | - | - | - |
| 6. | VI Period (Very Long Period) | - | - | - | - |
| 7. | VII Period (Very Long Period) | - | - | - | - |

It can be seen in the periodic table that there is a noble gas present at the end of each period.

It is also found that the seventh period is not completed. Some elements of this period are yet to be discovered.

You have seen that the properties of elements depend on the number of valence electrons (number of electrons in the outermost shell) in their atoms. When elements are arranged according to their increasing atomic numbers, then the elements having the same number of valence electrons occur at regular intervals. Since the number of valence electrons in the elements show periodicity (regular repetition), the chemical properties also show periodicity.

Ask the students to take an example to understand the repetition (or periodicity) of properties of elements more clearly.

**Table 9.4 : Periodic classification of elements.**

| Element | Li | Be | B | C | N | O | F | Ne |
|---|---|---|---|---|---|---|---|---|
| Atomic No. | 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 |
| Element | Na | Mg | Al | Si | F | S | Se | Ar |
| Atomic No. | 11 | 12 | 13 | 14 | 15 | 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 |

From the table, it is concluded that periodicity in the properties of elements relates to the periodicity in their electronic configuration.

**Prediction of some properties of an atom**

You know that the position of an element in the periodic table defines its electronic configuration. The electronic configuration tells the number of valence electrons i.e. the number of electrons in the outermost shell. This number defines many properties of the atoms such as valency, metallic character, the size of the atom, etc. Thus if you know the position of an element in the periodic table, you can predict its properties.

At this stage, you can ask the students to predict the properties-metallic character, activity, valency, formulae of its various compounds — e.g. its chloride, atomic size, ionization energy, electron affinity electro-negativity, etc.

Students should be asked to perform the following activity.

**Activity**

Collect commonly available elements such as sodium, potassium, aluminium, silicon, carbon (Graphite), calcium, magnesium, phosphorus, sulphur, chlorine. Note their state, appearance, hardness/softness, action with chilled and hot water and with acids. Prepare their oxides by burning them. Dissolve the oxides in water and test the resulting solution with blue and red litmus papers. Tabulate your results as in Table 9.5.

On the basis of resemblance in the properties, make groups of the elements. You know their atomic number.

Arrange the elements in such a way that elements with the same number of electrons in their outermost shell fall below each other. What relation do you find between the properties and their arrangement according to their increasing atomic number?

**Table 9.5**

| Name of the Element | State Appearance | Hardness/ Softness | Action with Water | Action with Acids | Behaviour of Oxides |
|---|---|---|---|---|---|
| Sodium | | | | | |
| Potassium | | | | | |
| Magnesium | | | | | |
| Aluminium | | | | | |
| Silicon | | | | | |
| Carbon | | | | | |
| Calcium | | | | | |
| Phosphorus | | | | | |
| Sulphur | | | | | |
| Chlorine | | | | | |

Ask the students to write the electronic configuration of elements with atomic number 1 to 20 on separate cards and arrange these cards according to their increasing atomic number.

Ask the students what relationship they find between the properties of elements and their electronic configuration. Ask the students to explain the periodicity on the basis of electronic configuration. The students can also be asked the relationship between no. of valence electrons and chemical properties of an element.

**Methodology used :** This unit is based on the basic ideas of scientific process of classification. Classification of elements is based on their properties. It may not be possible to cover all the properties which were used as one of the criteria to classify the elements. Therefore, only a few properties of some common metals could be identified.

This can be done by writing all the properties, on cards and arranging these cards in an increasing order of atomic number. Repetition of properties will give an idea of periodicity.

In most cases, individual pupil activity may not be possible, therefore, in such cases demonstration activity can be done. A question-answer discussion should also be arranged.

This section was taught by using inductive approach as it encourages inquiry and search for new ideas in students. Students generalised on the basis of the activities and data provided to them.

**Check Your Progress**

**Notes** : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

12. Which of the following characteristics is responsible for the common chemical behaviour of elements in any group of the periodic table?

    i) Atomic mass

    ii) Atomic size

    iii) Atomic volume

    iv) Electronic configuration

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13. As we move from left to right horizontally in a period, what happens to :

    i) the metallic character of the elements ?

    ..........................................................................................................................

    ii) atomic size ?

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14. What do you mean by a group in the periodic table? In what part of a group would you expect the elements to have :

    a) the greatest metallic character

    b) the largest atomic size

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15. An element x belongs to a third period and group I of the periodic table. Find out

    i) the number of electrons in the outermost shell

    ii) metal or non-metal, and

    iii) name of the element.

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16. The electronic configuration of an element A is K 2 L 8 M 7 :

    i) What is the group number of element 'A' in the periodic table?

    ii) What is the period of the element 'A' ?

    iii) What is the number of valence electrons in an atom of element 'A' ?

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## 9.5 CHEMICAL BONDING

You have already studied that all matter is made of atoms. But atoms rarely exist free in nature. They combine to form molecules of elements and compounds. A large variety of compounds have been prepared by the chemists. Now the question that arises is why these atoms combine to form molecules and what are various modes of their combination ? If atoms of the same element combine, we get a molecule of that element, e.g. a molecule of hydrogen. When atoms of two or more different elements combine, a molecule of the compound is formed; e.g. a molecule of hydrogen chloride, ammonia etc. The resultant molecule is always more stable than the combining atoms. This stability is normally judged in terms of energy changes. In such combination the potential energy of the system decreases with the formation of molecules. A system with lower energy always attains higher stability.

How the atoms combine can be understood with the knowledge of electronic structure of the atom. We have already studied electronic configuration of the elements and we are now in a position to explain the nature of the chemical bonds between atoms in a better way.

In the present chapter we will come across various concepts of **chemical bonding** and will learn how to develop them logically.

**Objectives**

- To explain the formation of a chemical bond using the octet rule.
- To explain formation of covalent and electrovalent bonds and differentiate them.
- To explain how energy decreases when a chemical bond is formed between two atoms.
- To define various terms related to chemical bonding e.g. bond length, bond energy, bonding capacity and valence electrons.
- To predict the bonding capacity of atoms from their electronic configurations.
- To predict the type of bonds between various combining elements based on their electronegativity.

**Main Teaching Points**

- The Octet rule explains the correlation between the electronic configurations of atoms with their tendencies to form chemical bonds.
- There is a lowering of the energy present in the concerned atoms in the formation of a chemical bond.
- Lowering of energy in the bond formation occurs due to simultaneous attraction of the electrons by the nuclei of combining atoms.
- The difference in electro negativities of the combining atoms decides the nature of chemical bonds.
- The properties of electrovalent and covalent compounds are different.

**Teaching Learning Process**

### 9.5.1 Formation of Chemical Bonds

You have studied the electronic configuration of atoms of various elements. Now let us develop a correlation between the electronic configuration of atoms with their tendencies to form chemical bonds.

This can be done by showing a chart containing the electronic configuration of the atoms of some alkali metals, halogens, noble gases and some other common elements. Recall that all the elements other than noble gases (present in the zero group of the periodic table) are reactive. If we carefully study the electronic configuration of noble gases, we find that all noble gases (except He) have 8 electrons in their outermost shells.

This special configuration provides them stability and normally does not allow them to undergo any chemical combination.

Now let us discuss the electronic configuration of other elements such as alkali metals and halogens with the help of the chart.

The outermost shell of the atoms of these elements is not complete (i.e. in other words they do not have 8 electrons in the outermost shell). So these elements do not posses the stable configuration that the noble gases have. It is perhaps because of this fact that these elements exhibit reactivity and try to attain Octet. The chemical combination between the atoms of these elements must result in a stable configuration. That is, each element tries to posses the electronic configuration of noble gases while forming a chemical bond. This is explained by showing the chart having the electronic configuration of several pairs of elements which undergo chemical combinations e.g. sodium-chlorine, and hydrogen-oxygen, magnesium-chlorine, etc.

**Table 9.6**

| **Pairs of elements undergoing chemical reaction** | | **Noble gases whose configuration they are reaching after reaction** | |
|---|---|---|---|
| 1. Na<br>2,8,1 | Cl<br>2,8,7 | Na $\rightarrow$[Ne]<br>2,8 2,8 | Cl $\rightarrow$ [Ar]<br>2,8,8 2,8,8 |
| 2. H+H<br>1 1 | O<br>2,6 | H $\rightarrow$[He]<br>2 | O $\rightarrow$ [Ne]<br>2,8 2,8 |
| 3. Mg<br>2,8,2 | Cl and Cl<br>2,8,7 and 2,8,7 | Mg $\rightarrow$[Ne]<br>2,8 2,8 | Cl $\rightarrow$ [Ar]<br>2,8,8 2,8,8 |

**Methodology used :** This concept is developed by the discussion method taking the known properties of some elements and their electronic configuration. The students are encouraged to relate the electronic configurations to reactivity of elements and generalise the Octet theory.

The reactivity of the elements is due to their tendency to attain the stable electronic configuration (Octet) of the nearest noble gas. This can be achieved either by **transfer** or sharing of electrons between combining atoms.

**Example :** Look at the electronic configuration of

Fluorine, Sodium and Neon

F (2,7) ; Na (2,8,1) and Ne (2,8)

Ne has totally closed shell (complete shell) configuration. It means that Ne is the most unreactive and inert out of these three atoms.

Fluorine would become stable and inert by accepting one electron and completing the outermost shell configuration. Sodium would become stable if it could lose one electron and attain the configuration of Ne (2,8). Thus it can be generalised that every atom has a tendency to acquire the electronic configuration of the nearest noble gas and become stable.

**The process of bond formation**

Lowering of energy results during bond formation. Let us consider this bond formation in a simple molecule of hydrogen. What makes a hydrogen molecule more stable than two hydrogen atoms? Consider a single hydrogen atom. The hydrogen atom has one electron in its first shell outside the nucleus. The distribution is spherically symmetrical meaning that it is the same in every direction. Imagine a second hydrogen atom having the same electronic distribution outside the nucleus (First shell). Initially both are at a distance far apart from each other. There is virtually no interaction between the two atoms at such a long distance and the total energy is just the sum of the energies of the individual atoms. Because energy is not lowered, no stability results. Molecule formation is thus not expected at large distances.

Now if you bring the tw**repulsion**o atoms gradually closer and closer what would happen?

The electron of one atom begins to experience the attractive force of the nucleus of the other atom. As the atoms are brought further closer (Fig.9.14), the electron of one atom will be strongly attracted by the nucleus of the other atom. As you know, in an isolated hydrogen atom the electron is attracted by only a single nucleus, but when two hydrogen atoms are close, each of the two electrons experiences the attractive pull of two nuclei. In this favourable situation we expect the energy to be lowered.

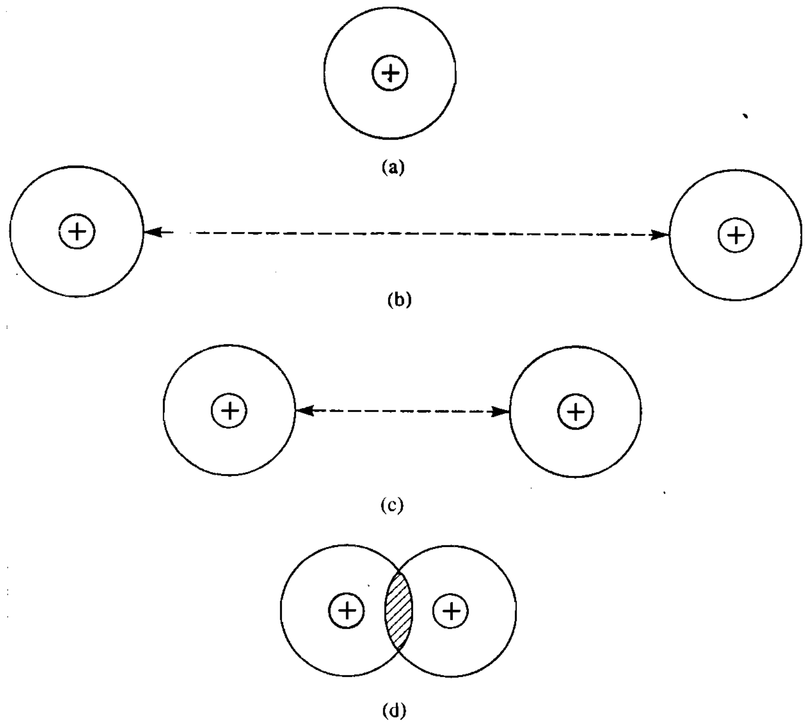


**Fig. 9.14 : Formation of a hydrogen molecule.**
**a) Simple hydrogen atom**
**b) Two hydrogen atoms at large distance and therefore no interaction**
**c) Two hydrogen atoms are at moderate separation, interaction stands**
**d) Two hydrogen atoms in a $H_2$ molecule**

Now what about the repulsive forces between the two electrons and between the two nuclei?

Certainly, these increase as the two atoms approach each other. It can be shown that there exists a critical distance where the attractive and repulsive forces balance each other. At distances larger than this, the attractive forces are stronger while at distances smaller than this, the repulsive forces are more powerful. Maximum lowering of energy takes place at this critical distance called the bond length.

Let us make a table showing the forces of attraction and repulsion existing when the atoms A and B are brought very close to each other at a critical distance.

| Forces of attraction | Forces of repulsion |
|---|---|
| i) Electrons of one atom attracting nucleus of the other. | i) Nucli of the two atoms repelling one another. |
| ii) Nucleus of one atom attracting the nucleus of that atom. | ii) Electrons of the two atoms repelling one another. |

The repulsive and attractive forces between the two hydrogen atoms forming a hydrogen molecule are shown with the help of a chart.

As you know there is a natural tendency of all systems to reach a state of least energy possible. Therefore, you know now why two hydrogen atoms combine with each other.

Lowering in the energy in the formation of $H_2$ molecule is shown with help of a plot between energy and internuclear distance. The diagram will be explained to the student by the teacher.

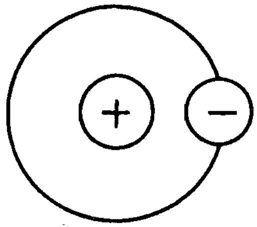

**Fig. 9.15 : A diagrammatic representation of hydrogen atom**

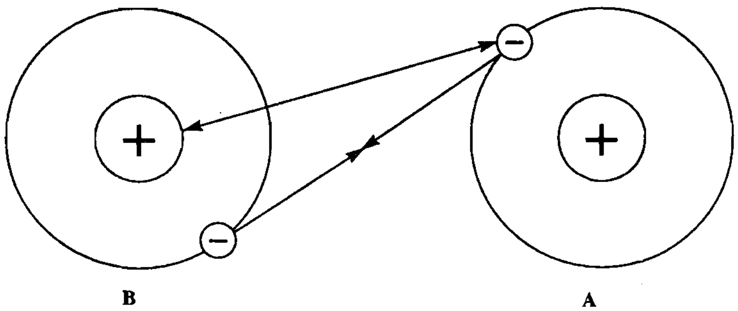


**Fig. 9.16 : Influence of particles in hydrogen atom B over the electron in hydrogen atom A**

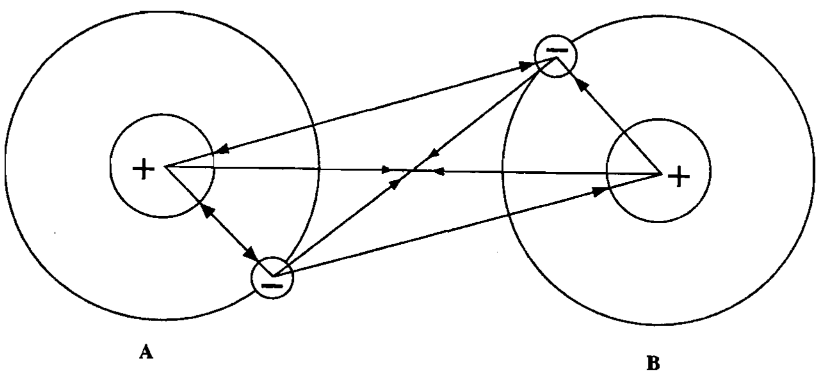


**Fig. 9.17 : Interaction between particles contained in atoms A and B.**

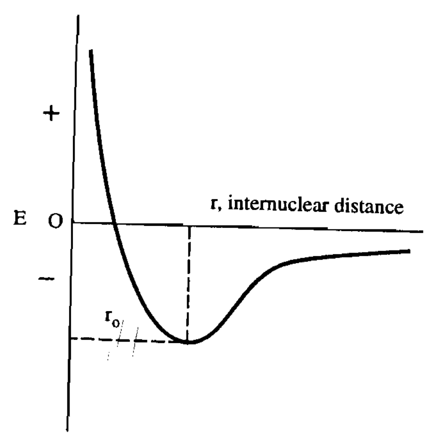


**Fig. 9.18 : Potential energy diagram**

Now let us discuss why $He_2$ molecule cannot be formed.

### 9.5.2 Electrovalent and Covalent Compounds

You have studied how chemical bonding takes place between two atoms of the same element or different elements. Now let us discuss how electrovalent (ionic) and covalent compounds are formed.

A chemical bond is formed either by transfer of valence electron from one atom to another or by sharing the electrons between two atoms of combining elements. This can be discussed by showing a chart on which the electronic configuration of atoms of different elements, e.g. Na, Mg, Cl, F, O are represented in the dot form.

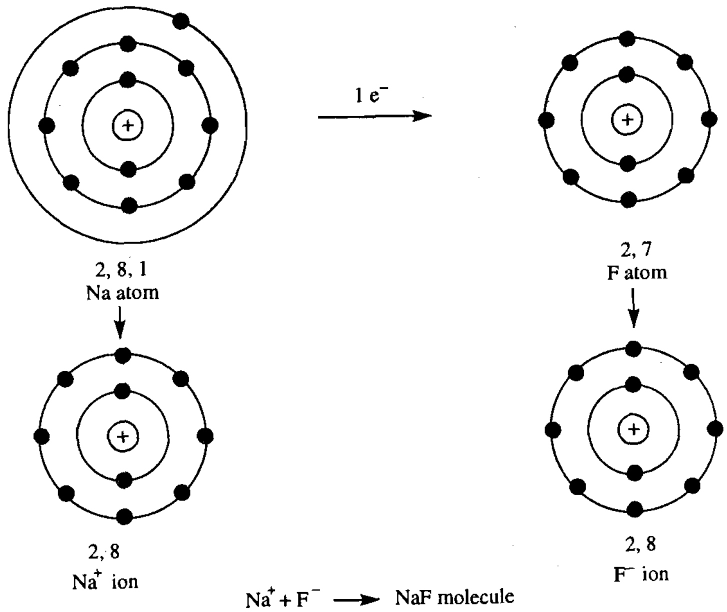


**Fig. 9.19 : Formation of ionic bond in sodium flouride**

The process begins with the transfer of one electron from the sodium atom [which is a highly electropositive element] to Fluorine atom (which is a highly electronegative element). This makes Na as $Na^+$ ion and F as $F^-$ ion. Both, $Na^+$ and $F^-$ ions having opposite charges form an ionic bond (electrovalent bond) between them.

Some more examples for the formation of ionic bond and hence ionic (electrovalent) compounds are discussed. Students are asked to show the diagrammatic representation of some common electrovalent compounds other than the ones taken up while teaching.

Similarly, a covalent bond is formed by sharing of valence electron of the combining atoms. Let us take up formation of a chlorine molecule as an example.

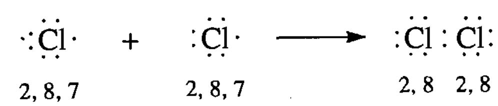


**Fig. 9.20 : Formation of covalent bond in chlorine molecule**

A sharing of one electron by each Cl-atom makes an octet in the outermost shell of the chlorine atom making an electronic configuration of Ar (2,8,8) atom. Covalent bond is formed between the atoms of the same element and also between the atoms of different elements, for example, $CCl_4$, $CH_4$ etc.

**Properties**

As you are aware, electrovalent compounds are generally formed by reactions between metals (e.g. sodium, potassium, magnesium, calcium, etc.) and non-metals (e.g.) chlorine, bromine, iodine, sulphur, etc.). Let us discuss some common properties of electrovalent compounds. These compounds are generally solid substances having high melting and boiling points. The ions of these compounds are held together by strong electrostatic forces of attraction. Crystals of ionic compounds are hard and brittle. They are generally soluble in water. They conduct electricity when in a molten state or when dissolved in water.

Covalent compounds which are formed by sharing of electrons of two combining atoms are generally sparingly soluble in water but readily soluble in organic solvents like carbon tetra chloride, acetone, carbon disulphide etc. Covalent compounds generally have low melting and low boiling points. Covalent compounds are bad conductors of electricity. (Graphite, which is good conductor of electricity is an exception).

An activity is carried out to identify whether a given compound is electrovalent or covalent.

**Activity**

Take three 100 ml beakers, containing the solutions of sodium chloride, potassium bromide and magnesium chloride, respectively. Now arrange the apparatus as shown in Fig. 9.21. It is observed that on passing the electric current through the aqueous solution of sodium chloride, the bulb starts glowing. Similar observations are made with other two solutions of potassium bromide and magnesium chloride.

It is evident from this experiment that aqueous solutions of ionic compounds conduct electricity. Ionic substances ionize in aqueous solutions. These ions conduct electric current.

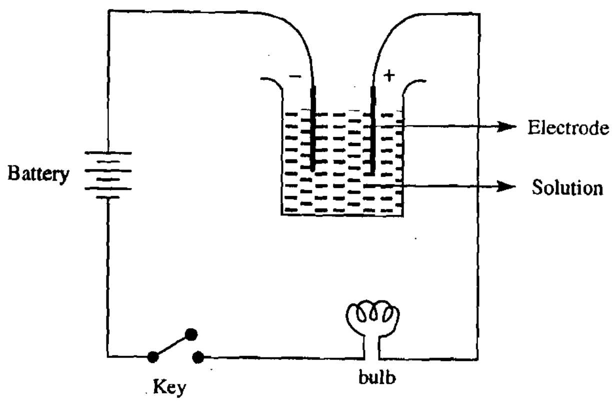


**Fig. 9.21 : Experimental set-up to demonstrate electrical conductivity**

**Covalent compounds do not conduct electricity**

**Activity**

Take acetone, carbon tetra chloride, sugar solution respectively in three different 100 ml beakers. Now set up the apparatus as shown in Fig. 9.21. Complete the circuit by connecting the terminals in the cell. It is observed that the bulb does not glow in any of these cases.

It can therefore, be concluded that covalent compounds do not furnish ions in solutions.

Covalent compounds are generally made up of discrete molecules whereas electrovalent compounds show lattice formation. List the names of the ionic substances and show their ionization. Also list the names of covalent compounds.

**Methodology used :** Chemical bonding can be taught very effectively by demonstrating the models of molecules of common ionic, and covalent compounds e.g. $CH_4$, $CCl_4$ etc.

Demonstrations of ideas are not always easily possible and development of concepts is based only on logical discussion taking suitable examples of known elements and compounds. For example, the idea of generalizing the octet theory comes from the study of known noble gas elements which have eight electrons in their outermost shell (valence shell). So by writing the electronic configuration of a few common known elements and compounds, it could be possible to generalize the octet rule.

For showing chemical bonding between the two elements, their electronic configuration can be written. By making the use of chalks of different colours, electrons on different atoms can be shown with **different colour.**

**Check Your Progress**

**Notes :** a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.

17. Consider the following elements

H, C, Na, Mg

i) Write the formula of the chloride of each of these elements.

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ii) Indicate the nature of bonding whether electrovalent or covalent in each case.

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18. An element, burns in oxygen to form an electrovalent compound MO. Write the formula of the compounds when the element M is made to combine with chloride and sulphur, respectively.

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19. Predict the type of bonds (ionic or covalent) likely to be formed when pairs of elements having following atomic numbers combine :

a) 11 and 17
b) 6 and 17
c) 11 and 7
d) 12 and 16

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20. How many covalent bonds does an ammonia molecule have?

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21. Describe the bond that holds 2 hydrogen atoms together in a hydrogen molecule $H_2$.

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22. How many electrons does sulphur need to achieve the electronic configuration of Argon atom?.

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## 9.6 LET US SUM UP

An atom consists of three fundamental particles – electrons, protons and neutrons. Electrons are negatively charged while protons are positively charged and neutrons do not carry any charge. Electrons revolve around the nucleus whereas protons and neutrons are concentrated in the nucleus. The mass of an atom is due to the mass of protons and neutrons. The atom is electrically neutral showing that the number of electrons and protons are the same. Hence the atomic number of an atom is equal to the number of protons in the nucleus and the mass number is equal to the sum of the number of protons and neutrons.

According to Rutherford's model of an atom, all the mass of an atom is concentrated at the centre of an atom covering a small space in the atom. The electrons move around the nucleus covering a large space in different energy levels. These energy levels are described by number n = 1,2,3 (Principal quantum number and by letters K,L,M,..............known as shells. The smaller values of the principal quantum number indicate that the electrons are in a low energy level. For example, n = 1 is the lowest energy level corresponding to K-shell. The maximum of electrons in K,L,M.............shells is 2,8,18 respectively. The number of electrons distributed in various successive shells are according to some definite rules i.e. ($2n^2$) where n is the number of the shell.

Today more than 105 elements are known. Classification of elements was done for the first time, by Mendeleev who arranged the known elements at that time according to their increasing atomic weight. He left the space in the periodic table for the unknown elements to be discovered later on A periodicity in the properties was observed in the elements when they were arranged according to their increasing atomic weights. Some discrepancies were found which were later on removed when the elements were arranged in order of increasing atomic numbers. This arrangement was known as long form of Periodic Table. The elements were arranged in periods (horizontal rows) and groups (vertical columns).

The properties of the elements depend on the number of valence electrons (number of electrons in the outermost shell) in their atoms. The elements having the same number of valence electrons occur at regular intervals. Since the number of valence electrons show periodicity the chemical properties also show periodicity.

The atoms of the elements having their outermost shell complete (noble gases) are stable and normally do not undergo any chemical combination. The elements which do not possess the stable configuration undergo chemical combination and always tend to complete their octet either by transferring the electrons from one atom to another or by sharing an electron pair between the atoms of same element, e.g. ($H_2$, $Cl_2$, $Br_2$, etc.) or HCl, $CCl_4$ etc.

The compounds formed by the transfer of electrons from the atom of one element (electropositive element) to the atom of another element (electro negative element) are called electrovalent compounds and the bond formed between the atoms is called as ionic bond.

The compounds formed by the sharing of electrons between the atoms of similar elements ($H_2$,$Cl_2$,$Br_2$) and between the atoms of different elements (HCl,$CCl_4$,$CO_2$ ) are called covalent compounds and the bond is known as covalent bond.

Electrovalent compounds are generally formed between the metal and non-metals. They are solid substances having high melting and boiling points. Crystals of ionic compounds are hard and brittle and are generally soluble in water. They conduct electricity when in a molten state or when dissolved in water.

Covalent compounds are generally sparingly soluble in water but readily soluble in solvents like $CCl_4$, acetone, benzene etc. Covalent compounds generally have low melting and boiling points and they do not conduct electricity.

## 9.7 UNIT-END EXERCISES

1. Compare the characteristics of electrons, protons and neutrons in respect of their mass and charge.
2. Draw a neat labelled diagram to show the formation of positive rays in a discharge tube.
3. Write the atomic number and mass number of the following elements:
   i) Hydrogen ii) Carbon
   iii) Sodium iv) Oxygen v) Chlorine
4. Show the electronic arrangement in the atoms of the following elements:
   i) Lithium ii) Aluminium
   iii) Magnesium iv) Potassium
5. The atomic numbers of magnesium and chlorine are 12 and 17 respectively. How many electrons are present in Mg and Cl, respectively.
6. What are the characteristics of a period and a group in the periodic table. Illustrate by giving suitable examples.
7. Locate the following groups in the periodic table:
   i) Alkali metals
   ii) The halogens
   iii) The alkaline earth metals
   iv) Noble gases
8. An element A has the atomic number 12 and another element B has the atomic number 17. What type of linkage will be formed when A and B, combine to form a compound? Give the molecular formula of the compound.
9. An element A has four electrons in the outermost shell of its atom. It combines with chlorine which has seven electrons in the outermost shell. The compound formed does not conduct electricity. It also does not give any precipate with $AgNO_3$ solution. What is the nature of the bond in the compound?

## 9.8 ANSWERS TO CHECK YOUR PROGRESS

1. Negative
2. Cathode rays being negatively charged are deflected by an electric field and also by a strong magnetic field.
3. As the mass of the positive particles in the case of different gases is different, hence the e/m ratio for the positive particle is different in different gases.
4. In an atom, the number of negative particles (electrons) are the same as the number of positive particles (protons).
5. Proton is a positively charged hydrogen atom which is present in the nucleus of an atom. The mass of a proton is equal to that of a hydrogen atom and is about 1840 times that of an electron. It possesses unit positive charge.
6. Neutron is neutrally charged particle whose mass is equal to that of proton. Proton has unit positive charge while neutron has no charge on it.
7. i) According to the observations recorded by Rutherford, while he bombarded the $\propto$-particles on the thin gold foil, a deflection of a very few $\propto$- particles by 180° indicate that there was a total positive charge situated in the centre of the atom.
   ii) As only the positively charged particles (protons) posses the mass, the total mass of an atom is concentrated at the centre of an atom (nucleus).
8. c) 12

9. Mass number (M) = No. of protons and No. of neutrons

   No. of electrons = 7 = No. of protons = atomic number

   The atomic number of an element is 7 (b)

   14 = 7P + 7N

   No. of protons = 7

   No. of neutrons = 7

10. Atomic number =19, Mass number = 39

    i) No. of electrons = 19

    ii) 2,8,8,1 K = 2

    L = 8

    M = 8

    N = 1

11. K = 2

    L = 8

    Total No. of electrons = 2 + 8 = 10

    The element is Neon.

12. iv) Electronic Configuration.

13. i) metallic character decreases.

    ii) atomic size decreases.

14. A vertical column in the periodic table is called a group.

    a) at the bottom of the group

    b) at the bottom of the group

15. i) One

    ii) Metal

    iii) Potassium (K)

16. K = 2

    L = 8

    M = 7

    Atomic Number = 17

    2,8,7

    i) Group Number = 7

    ii) Third period

    iii) Seven

17. i) HCl

    $CCl_4$

    NaCl

    $MgCl_2$

    ii) HCl - Covalent

    $CCl_4$ - Covalent

    NaCl - Electrovalent

    $MgCl_2$ - Electrovalent

18.

| Metal | Element | Compound | Valency |
|---|---|---|---|
| M | O | MO | 2 |
| M | Cl | $MCl_2$ | |
| M | S | MS | |

19. a) 11, 17 Nacl — Electrovalent
    b) 6, 17 $CCl_4$ — Covalent
    c) 11, 9 NaF — Electrovalent
    d) 12, 16 $CO_2$ — Covalent
20. $NH_3$ — 3 Covalent bonds.
21. Covalent bond between two hydrogen atoms

    H — H
22. Two electrons.

## 9.9 SUGGESTED READINGS

*Teaching of Science,* NCERT Publication.

*Teaching of Chemistry*, Newburry.

*Teaching of Chemistry*, Waddington.