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UNIT 10

MATTER AROUND US

Learning Objectives

After completing this lesson, students will be able to

- classify substances as elements, compounds and mixtures based on their chemical composition.
- group mixtures as homogeneous and heterogeneous.
- identify suitable method to separate components of a mixture.
- classify solutions based on the size of the solute particles and compare the true solutions, colloids and suspensions based on their properties.
- differentiate colloids based on the nature of dispersed phase and dispersion medium.
- compare o/w and w/o emulsions.
- discuss some important examples and uses of colloids.

Introduction

We use the term **matter** to cover all substances and materials from which the universe is composed. Matter is everything around us. The air we breathe, the food we eat, the pen we write, clouds, stones, plants, animals, a drop of water or a grain of sand everything is matter. Samples of any of these materials have two properties in common. They have mass and they occupy space.

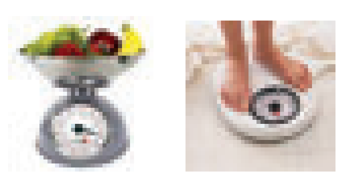


Figure10.1 Examples to show Matter has mass

Figure 10.2 Examples to show Matter occupies space

Thus, we say that **matter** is anything that has mass and occupies space.

10.1 Classification of Matter

In class VIII, You have studied the classification of matter on the basis of their physical states. Now let us see how we can classify matter on the basis of chemical composition.Broadly speaking, it has been classified into pure substances and mixtures. From the point of view of chemistry, pure substances are those which contain only one kind of particles whereas impure substances (mixtures) contain more than one kind of particles.

The flow chart given below will help us to understand the chemical classification of matter in detail.

DO YOU KNOW?

Not all things that we see or feel are matter. For example, sunlight, sound, force and energy neither occupy space nor have any mass. They are not matter.

- **Matter**
  - **Pure substances**
    - **Elements**: Cannot be broken into simpler substances *E.g.,* copper, oxygen, hydrogen.
    - **Compounds**: Can be broken down into elements by chemical reactions *E.g.,* water, sugar, salt, etc.
  - **Impure substances (Mixtures)**
    - **Homogeneous**: Uniform composition *E.g.,* sugar + H_2O, water + alcohol
    - **Heterogeneous**: Non-uniform composition *E.g.,* sand + sugar, water + oil

Activity 1

1. Is air a pure substance or Mixture? Justify
2. You must have seen brass statues in museums and places of worship. Brass is an alloy made up of approx. 30% zinc and 70% copper. Is Brass a pure substance or a mixture or compound?

10.1.1 Elements

Most of you may be interested in music, and some of you may know how it is composed. Music is the combination of a few basic musical notes i.e., Sa, Re, Ga,…Thus, the building blocks of music are the musical notes.

Sa, Re, Ga, Ma, Pa...	Building blocks of music

Likewise , all substances on earth are made up of certain simple substances called elements. Plants, cats, apples, rocks, cars and even our bodies contain elements. Thus, elements are the building block of all materials.

DO YOU KNOW?

In the modern periodic table there are 118 elements known to us, 92 of which are naturally occurring while the remaining 26 have been artificially created. But from these 118 elements, crores of compounds are formed- some naturally occurring and some artificial. Isn't that amazing?

H, He, Li……. 118 elements	Building block of all materials

Robert boyle used the name element for any substance that cannot be broken down further, into a simpler substance. This definition can be extended to include the fact that each element is made up of only one kind of atom. For example, aluminium is an element which is made up of only aluminium atoms. It is not possible to obtain a simpler substance chemically from the aluminium atoms. You can only make more complicated substances from it, such as aluminium oxide, aluminium nitrate and aluminum sulphate.

Atom: The smallest unit of an element which may or may not have an independent existence, but always takes part in a chemical reaction is called atom.

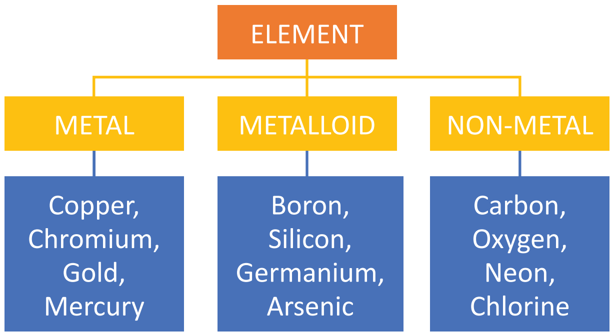
Molecules: The smallest unit of a pure substance, which always exists independently and can retain physical and chemical properties of that substance is called a molecule.

Examples:

Hydrogen molecule consists of two hydrogen atoms (H_2)

Water molecule consists of two hydrogen atoms (H_2) and one oxygen atom (O).

All elements can be classified according to various properties. A simple way to do this is to classify them as metals, non metals and metalloids.



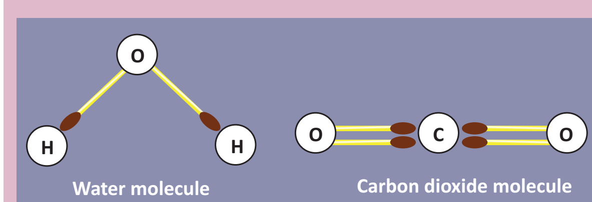
10.1.2 Compounds

When two or more elements combine chemically to form a new substance, the new substance is called a compound. For example, cane sugar is made up of three elements carbon, hydrogen and oxygen. The chemical forumula of cane sugar is $C_{12}H_{22}O_{11}$.

A compound has properties that are different from those of the elements from which it is made. Common salt, also known as sodium chloride, is a compound. It is added to give taste to our food. It is a compound made up of a metal, sodium and a non-metal, chlorine.

Activity 2

Make models of the molecules of compounds by using match sticks and clay balls as shown below,



DO YOU KNOW?

Compounds of phosphorous, nitrogen and potassium are used in fertilizers. Silicon compounds are of immense importance in the computer industry. Compounds of fluorine are used in our toothpastes as they strengthen our teeth.

Table 10.1 Difference between elements and compounds.

Element	Compound
Made up of only one kind of atom.	Made up of more than one kind of atom.
The smallest particle that retains all its properties is an atom.	The smallest particle that retains all its properties is the molecule.
Cannot be broken down into simpler substances.	Can be broken down into elements by chemical methods.

10.1.3 Mixtures

A mixture is an impure substance. It contains *two or more kinds of elements or compounds or both physically mixed together in any ratio.* For example, tap water is a mixture of water and some dissolved salts. Lemonade is a mixture of lemon juice, sugar and water. Air is a mixture of nitrogen, oxygen, carbon dioxide, water vapour and other gases. Soil is a mixture of clay, sand and various salts. Milk, ice cream, rock salt, tea, smoke, wood, sea water, blood, tooth paste and paint are some other examples of mixtures. Alloys are mixtures of metals.

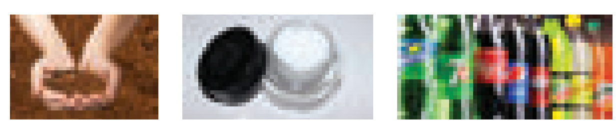


Figure 10.3 Mixtures

More to Know

LPG – Liquefied Petroleum Gas

It is highly inflammable hydrocarbon gas. It contains mixture of butane and propane gases. LPG, liquefied through pressurisation, is used for heating, cooking, auto fuel etc.

10.1.4 Differences Between Compound and Mixture

There are differences between compounds and mixtures. This can be shown by the following activity.

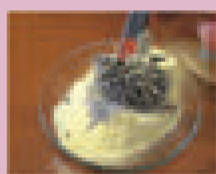
Activity 3

Take some powdered iron filings and mix it with sulphur.

i. Divide the mixture into two equal halves.

ii. Keep the first half of the mixture as it is, but heat the second half of the mixture.

iii. On heating you will get a black brittle compound.



Mixture of iron and Sulphur

Iron Sulphide compound

The black compound is Iron (II) sulphide.

$$\text{Iron + sulphur} \xrightarrow{\text{heat}} \text{Iron sulphide}$$

The Iron sulphide formed has totally different properties to the mixture of iron and sulphur as tabulated below:

Substance	Appearance	Effect of magnet
Iron (element)	Dark grey powder	Attracted to it
Sulphur (element)	Yellow powder	None
Iron + Sulphur (Mixture)	Dirty yellow powder	Iron powder attracted to it
Iron sulphide (compound)	Black solid	No effect

From the above experiment, we can summarise the major differences between mixtures and compounds:

DO YOU KNOW?

Blood is not a pure substance. It is a mixture of various components such as platelets, red and white blood corpuscles and plasma.

Table 10.2 Difference between mixtures and compounds.

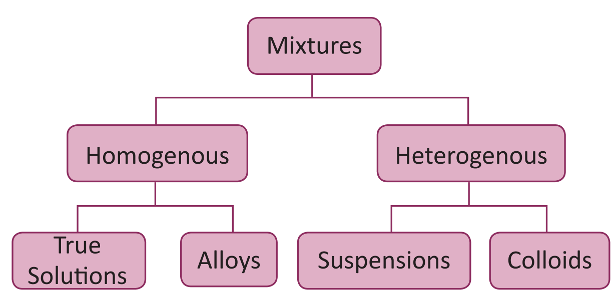
Mixture	Compound
It contains two or more substances	It is a single substance
The constituent may be present in any proportion.	The constituents are present in definite proportions.
They show the properties of their constituents.	They do not show the properties of the constituent elements.
The components may be separated easily by physical methods.	The constituents can only be separated by one or more chemical reactions.

Activity 4

Identify whether the given substance is mixture or compound and justify your answer. 1. Sand and water 2. Sand and iron filings 3. Concrete 4. Water and oil 5. Salad 6. Water 7. Carbon dioxide 8. Cement 9. Alcohol.

10.2 Types of Mixtures

Most of the substances that we use in our daily life are mixtures. In some we will be able to see the components with our naked eyes but in most others the different components are not visible. Based on this mixture can be classified as below:



10.2.1 Homogeneous and Heterogeneous mixture

A mixture in which the components cannot be seen separately is called a homogeneous mixture.

It has a uniform composition and every part of the mixture has the same properties. Tap water, milk, air, ice cream, sugar syrup, ink, steel, bronze and salt solution (Figure 10.4a) are homogeneous mixtures.

A mixture in which the components can be seen separately is called a heterogeneous mixture. It does not have a uniform composition and properties. Soil, a mixture of iodine and common salt, a mixture of sugar and sand, a mixture of oil and water, a mixture of sulphur and iron filings and a mixture of milk and cereals (Figure 10.4b) are heterogeneous mixture.

(a) (b)

Figure 10.4 (a) Homogeneous and (b)Heterogeneous mixture

10.3 Separation of mixtures

Many mixtures contain useful substances mixed with unwanted material. In order to obtain these useful substances, chemists often have to separate them from the impurities. The choice of a particular method to separate components of a mixture will depend on the properties of the components of the mixture as well as their physical states (as shown in Table 10.3).

10.3.1 Sublimation

Certain solid substances when heated change directly from solid to gaseous state without attaining liquid state. The vapours when cooled give back the solid substance. This process is known as sublimation. Examples: Iodine, camphor, ammonium chloride etc.,

Figure 10.5 Sublimation

The powdered mixture of Ammonium chloride and sand is taken in a china dish and covered with a perforated asbestos sheet. An inverted funnel is placed over the asbestos sheet as shown in Figure 10.5. The open end of the stem of the funnel is closed using cotton wool and the china dish is heated. The pure vapours of the volatile solid pass through the holes in the asbestos sheet and condense on the inner sides of the funnel. The non-volatile impurities remain in the china dish.

More to Know

The air freshners are used in toilets. The solid slowly sublimes and releases the pleasant smell in the toilet over a certain period of time. Moth balls, made of naphthalene are used to drive away moths and some other insects. These also sublime over time. Camphor, is a substance used in Indian household. It sublimes to give a pleasant smell and is sometimes used as a freshner.

Table 10.3 Methods of separating substances from mixtures

Type of mixtues	Mixtures	Methods of separation
Heterogeneous	Solid and solid	Handpicking, sieving, winnowing, magnetic separation, **sublimation**.
	Insoluble solid and liquid	Sedimentation and decantation, loading, filtration, **centrifugation**
	Two immiscible liquids	Decantation, **solvent extraction**
Homogeneous	Soluble solid and liquid	Evaporation, **distillation**, crystallisation
	Two miscible liquids	**Fractional distillation**
	Solution of two or more solids in a liquid	**Chromatography**

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10.3.2 Centrifugation

Centrifugation is the process by which fine insoluble solids from a solid- liquid mixture can be separated in a machine called a centrifuge. A centrifuge rotates at a very high speed. On being rotated by centrifugal force, the heavier solid particles move down and the lighter liquid remains at the top.

Figure 10.6 Centrifugation

In milk diaries, centrifugation is used to separate cream from milk. In washing machines, this principle is used to squeeze out water from wet clothes. Centrifugation is also used in pathological laboratories to separate blood cells from a blood sample.

10.3.3 Solvent extraction

Two immiscible liquids can be separated by solvent extraction method. This method works on the principle of difference in solubility of two immiscible liquids in a suitable solvent. For example, mixture of water and oil can be separated using a separating funnel. Solvent extraction method is used in pharmaceutical and petroleum industries.

Figure 10.7 Solvent extraction

DO YOU KNOW? Solvent extraction is an old practice done for years. It is the main process in perfume development and it is also used to obtain dyes from various sources.

10.3.4 Simple distillation

Distillation is a process of obtaining pure liquid from a solution. It is actually a combination of evaporation and condensation i.e

Distillation = Evaporation + Condensation

In this method, a solution is heated in order to vapourise the liquid. The vapours of the liquid on cooling, condense into pure liquid. For example, sea water in many countries is converted into drinking water by distillation. This method is also used to separate two liquids whose boiling points differ more than 25 K.

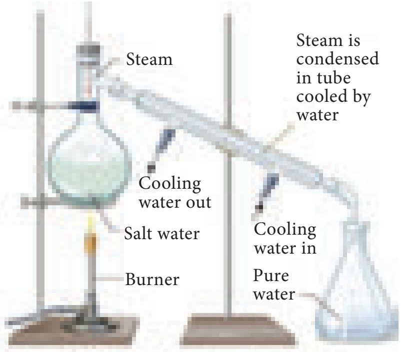


Figure 10.8 Solvent extraction

A distillation flask is fixed with a water condenser. A thermometer is introduced into the distillation flask through an one-holed stopper. The bulb of the thermometer should be slightly below the side tube.

The brackish water (sea water) to be distilled is taken in the distillation flask and heated for boiling. The pure water vapour passes through the inner tube of the condenser. The vapours on cooling condense into pure water (distillate) and are collected in a receiver. The salt are left behind in the flask as a residue.

10.3.5 Fractional distillation

To separate two or more miscible liquids which do not differ much in their boiling points (difference in boiling points is less than 25 K) fractional distillation is employed.

Fractional distillation is used in petrochemical industry to obtain different fractions of petroleum, to separate the different gases from air, to distill alcohols etc.

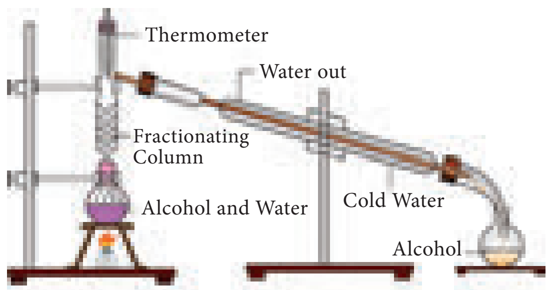


Figure 10.9 Fractional distillation

10.3.6 Chromatography

Before we discuss the technique we will take a look at the difference between the two important terms: **Absorption** and **Adsorption**

Adsorption is the process in which the particles of a substance is concentrated only at the surface of another substance.

Absorption is the process in which the substance is uniformly distributed throughout the bulk of another substance.

For example, when a chalk stick is dipped in ink, the surface retains the colour of the ink due to adsorption of coloured molecules while the solvent of the ink goes deeper into the stick due to absorption. Hence, on breaking the chalk stick, it is found to be white from inside.

Chromatography is also a separation technique. It is used to separate different components of a mixture based on their different solubilities in the same solvent. There are several types of chromatography

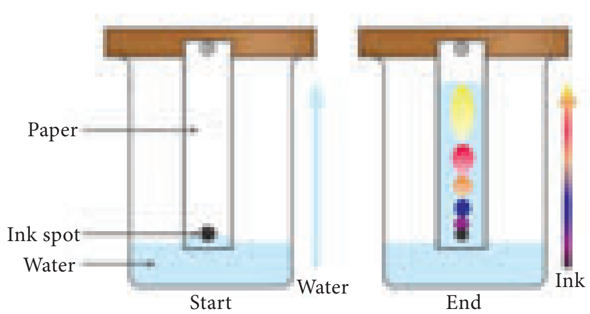


Figure 10.10 Paper chromatography

based on the above basic principles. The simplest type is paper chromatography.

Paper chromatography

This method is used to separate the different coloured dyes in a sample of ink. A spot of the ink (e.g. black ink) is put on to a piece of chromatography paper. This paper is then set in a suitable solvent as shown in figure 10.10. The black ink separates into its constituent dyes. As the solvent moves up the paper, the dyes are carried with it and begin to separate. They separate because they have different solubility in the solvent and are adsorbed to different extents by the chromatography paper. The chromatogram shows that the black ink contains three dyes.

10.4 Solutions

A solution is a homogeneous mixture of two or more substances. In a solution, the component present in lesser amount by weight is called solute and the component present in larger amount by weight is called solvent.

In short, a solution can be represented as follows: solute + solvent $\longrightarrow$ solution

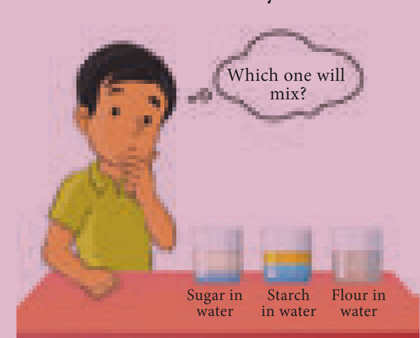
Example: salt + water $\longrightarrow$ salt solution

10.4.1 Types of solution

Based on the particle size of the solute, the solutions are divided into three types. Let us study them through an activity.

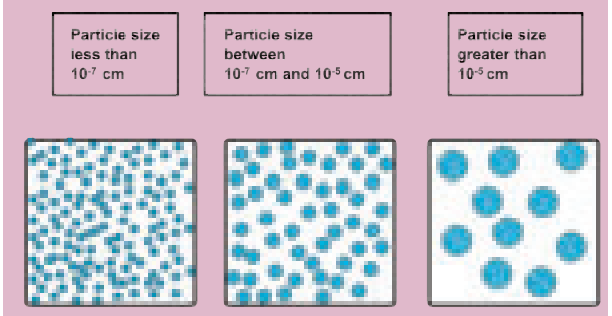
Activity 5

Take bottles containing sugar, starch and wheat flour. Add one tea spoon full of each one to a glass of water and stir well. Leave it aside for about ten minutes. What do you observe?



We can see that in the case of sugar we get a clear solution and the particles never settle down. This mixture is called as true solution. In the case of starch and water we get a cloudy mixture. This mixture is called as colloidial solution In the case of wheat flour mixed with water we get a very turbid mixture and fine particles slowly settle down at the bottom after some time. This mixture is called as suspension.

What are the differences among True solutions, colloids and suspensions?
The major difference is the particle size of the solute. In fact interconversions of these mixtures are possible by varying the particle sizes by certain chemical and physical methods.



10.4.2 Colloidal Solutions

A colloidal solution is a heterogeneous system consisting of the dispersed phase and the dispersion medium. Dispersed phase or the dispersion medium can be a solid, or liquid or gas. There are eight different combinations possible (Table 10.4). The combination of gas in gas is not possible because gas in gas always forms a true solution.

Brownian movement

When colloidal solution are viewed under powerful microscope, it can be seen that colloidal particles are moving constantly and rapidly in zig-zag directions. The Brownian movement of colloidal particles is due to the unbalanced bombardment of the particles by the molecules of dispersion medium.

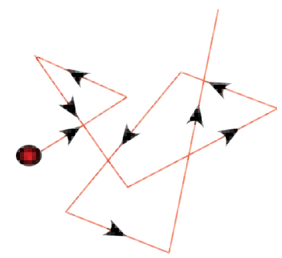


Figure 10.11 Brownian movement

Tyndall effect

Tyndall (1869) observed that when a strong beam of light is focused on a colloidal solution the path of the beam becomes visible. This phenomenon is known as **Tyndall effect** and the illuminated path is called **Tyndall cone.** This phenomenon is not observed in case of true solution.

More to Know

The beam of light coming from headlights of vehicles is due to Tyndall effect. Blue colour of sky is also due to Tyndall effect.

Table 10.4 Classification of colloids based on physical state of dispersed phase and dispersion medium

S.No	Dispersed Phase (Solute)	Dispersion Medium (Solvent)	Name	Examples
1	Solid	Solid	Solid sol	Alloys, gems, coloured glass
2	Solid	Liquid	Sol	Paints, inks, egg white
3	Solid	Gas	Aerosol	Smoke, dust
4	Liquid	Solid	Gel	Curd, Cheese, jelly
5	Liquid	Liquid	Emulsion	Milk, butter, oil in water
6	Liquid	Gas	Aerosol	Mist, fog, clouds
7	Gas	Solid	Solid foam	Cake, bread
8	Gas	Liquid	Foam	Soap lather, Aerated water

Differences between the types of solutions.

Property	Suspension	Colloidal sol.	Solution
Particle size	>100nm	1 to100nm	<1nm
Filtration separation	Possible	Impossible	Impossible
Settling of particles	Settle on their own	Settle on centrifugation	Do not settle
Appearance	Opaque	Translucent (or) Semi transparent	Transparent
Scatterting of light	Does not penerate	Scatteres	Does not Scatter
Diffusion of particles	Do not diffuse	Diffuse slowly	Diffuse rapidly
Brownian movement	May show	Shows	Does not show
Nature	Heterogeneous	Heterogeneous	Homogeneous

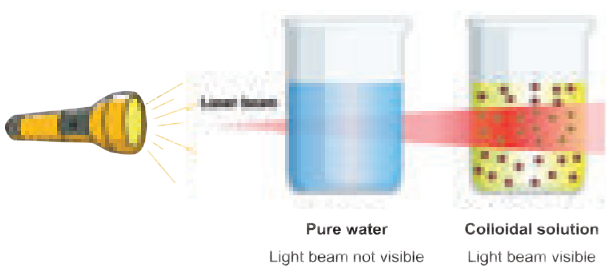


Figure 10.12 Tyndall effect

Test Yourself

1. Why whole milk is white?
2. Why ocean is blue?
3. Why sun looks yellow when it is really not?

10.4.3 Emulsions - a special kind of colloids

An emulsion is a colloid of two or more immiscible liquids where one liquid is dispersed in another liquid. This means one type of liquid particles get scattered in another liquid. In other words, an emulsion is a special type of mixture made by combining two liquids that normally don't mix. The word emulsion comes from the Latin word meaning "to milk" (milk is one example of an emulsion of fat and water). The process of turning a liquid mixture into an emulsion is called emulsification. Milk, butter, cream, egg yolk, paints, cough syrups, facial creams, pesticides etc. are some common examples of emulsions.

Types of emulsions

The two liquids mixed can form different types of emulsions. For example, oil and water can form an oil in water emulsion (O/W -e.g. cream), where the oil droplets are dispersed in water, or they can form a water in oil emulsion (W/O -e.g. butter), with water dispersed in oil.

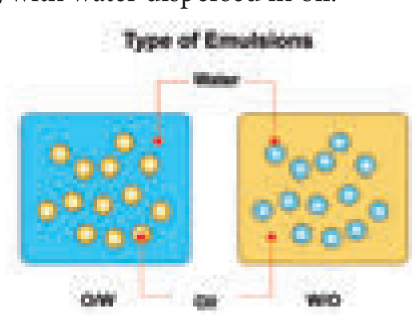


Figure 10.13 Emulsions

Emulsions find wide applications in food processing, pharmaceuticals, metallurgy and many other important industries.

More to Know

Have you seen colourful patches on a wet road? When oil drops in water on road, it floats over water and forms a colourful film. Find out why.

Points to Remember

- Depending upon the chemical composition, matter is classified into elements, compounds and mixtures
- Elements and compounds are considered to be pure substances as they contain only one kind of particles whereas mixtures contain more than one type of particles and they are considered as impure substances
- In a homogenous mixture (true solution) the components are uniformly mixed and it will have single phase
- A heterogeneous mixture are not mixed thoroughly or uniformly and it will have more than single phase
- Based on the size of the solute particles heterogeneous mixtures can be classified as colloidal solutions and suspensions

A-Z GLOSSARY

Elements A substance composed of atoms having an identical number of protons in each nucleus.

Compounds A pure, macroscopically homogeneous substance consisting of atoms or ions of two or more different elements in definite proportions.

Mixtures A composition of two or more substances that are not chemically combined with each other and are capable of being separated.

Solution Homogeneous mixture composed of two or more substances.

Colloid A system in which finely divided particles, which are approximately 1 to 100 nm in size, are dispersed within a continuous medium in a manner that prevents them from being filtered easily or settled rapidly.

Suspension A suspension is a heterogeneous mixture in which solute-like particles settle out of a solvent-like phase sometime after their introduction

Emulsion A colloid in which both phases are liquids: an oil-in-water emulsion.

Absorption Process by which atoms, molecules, or ions enter a bulk phase (liquid, gas, solid)

Adsorption Adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface

Centrifugation Sedimentation of particles under the influence of the centrifugal force and it is used for separation of superfine suspensions.

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TEXTBOOK EXERCISES

EVQDGD

I. Choose the correct answer.

1. The separation of denser particles from lighter particles done by rotation at high speed is called _____________
   a) Filtration b) sedimentation
   c) decantation d) centrifugation
2. Among the following ____________ is a mixture
   a) Common Salt b) Juice
   c) Carbon dioxide d) Pure Silver
3. When we mix a drop of ink in water we get a _________________
   a) Heterogeneous Mixture b) Compound
   c) Homogeneous Mixture d) Suspension
4. ________________ is essential to perform separation by solvent extraction method.
   a) Separating funnel b) filter paper
   b) centrifuge machine d) sieve
5. __________ has the same properties throughout the sample
   a) Pure substance b) Mixture
   c) Colloid d) Suspension

II. State whether true or false. If false, correct the statement.

1. Oil and water are immiscible with each other.
2. A compound cannot be broken into simpler substances chemically.
3. Liquid – liquid colloids are called gel.
4. Buttermilk is an example of heterogeneous mixture.
5. Aspirin is composed of 60% Carbon, 4.5% Hydrogen and 35.5% Oxygen by mass. Aspirin is a mixture.

III. Match the following.

Element	Settles down on standing
Compound	Impure substance
Colloid	Made up of molecules
Suspension	Pure substance
Mixture	Made up of atoms

IV. Fill in the blanks.

1. A _________________ mixture has no distinguishable boundary between its components.
2. An example of a substance that sublimes is _________________
3. Alcohol can be separated from water by _________________
4. In petroleum refining, the method of separation used is _______________
5. Chromatography is based on the principle of _______________

V. Answer very briefly.

1. Diffentiate between absorption and adsorption.
2. Define Sublimation.
3. A few drops of 'Dettol' when added to water the mixture turns turbid. Why?
4. Name the apparatus that you will use to separate the components of mixtures containing two, i. miscible liquids, ii. immiscible liquids.
5 Name the components in each of the following mixtures.
   i. Ice cream ii. Lemonade
   iii. Air iv. Soil

VI. Answer briefly.

1. Which of the following are pure substances? Ice, Milk, Iron, Hydrochloric acid, Mercury, Brick and Water.
2. Oxygen is very essential for us to live. It forms 21% of air by volume. Is it an element or compound?
3. You have just won a medal made of 22-carat gold. Have you just procured a pure substance or impure substance?
4. How will you separate a mixture containing saw dust, naphthalene and iron filings?
5. How are homogenous solutions different from heterogeneous solution? Explain with examples.

VII. Answer in detail.

1. Write the differences between elements and compounds and give an example for each.
2. Explain Tyndall effect and Brownian movement with suitable diagram.
3 How is a mixture of common salt, oil and water separated? You can use a combination of different methods.

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2. http://www.chemteam.info/ChemTeamIndex.html
3. http://www.chem4kids.com/files/matter_solution2.html
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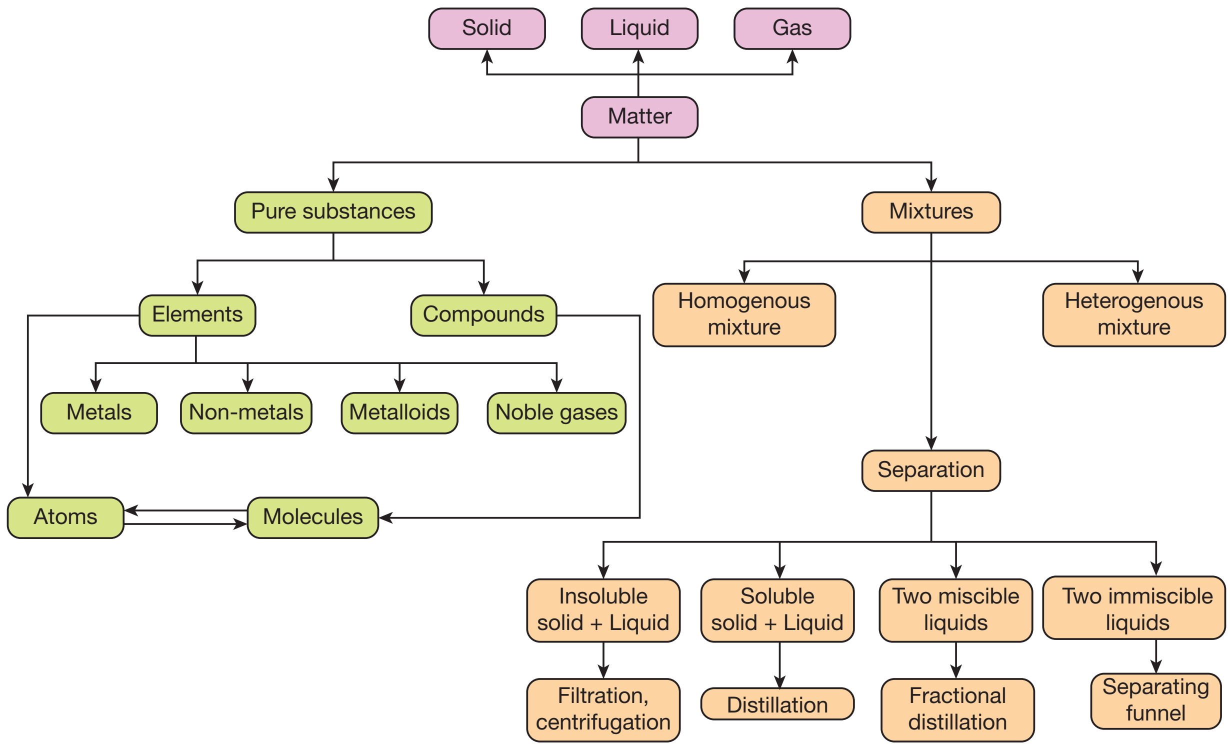
Concept Map



UNIT 11

ATOMIC STRUCTURE

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Learning Objectives

After studying this chapter, students will be able to

- understand Rutherford's gold foil experiment.
- identify the limitations of Rutherford's model.
- explain the main postulates of Bohr's atomic model.
- compare the charge and mass of sub-atomic particles.
- calculate number of protons, neutrons and electrons from the given atomic number and mass number of an element.
- draw the atomic structure of first 20 elements.
- differentiate isotopes, isobars and isotones.
- assign valency of various elements based on the number of valence electrons.
- recognize the significance of quantum numbers.
- state and illustrate the laws of multiple proportion, reciprocal proportion and combining volumes.

Introduction

Just as a small child wants to take a toy apart to find out what is inside, scientists have for long been curious about the internal structure of an atom. They wanted to find out what are the particles present inside an atom and how are these particles arranged in an atom. For explaining this many scientists proposed various atomic models.

We have learnt Dalton's atomic theory and J.J. Thomson's model in class VIII. Now we will learn about sub-atomic particles and the other atomic models to explain how these particles are arranged within an atom.

11.1 Discovery of Nucleus

In 1911, Lord Rutherford, a scientist from New Zealand, performed his famous experiment of bombarding a thin gold foil with very small positively charged particles called alpha(α) particles. He selected a gold foil because, he wanted as thin layer as possible and gold is the most malleable metal.

He observed that:

1. Most of the alpha particles passed straight through the foil.
2. Some alpha particles were slightly deflected from their straight path.
3. Very few alpha particles completely bounced back.

Figure 11.1 Deflected α-particle

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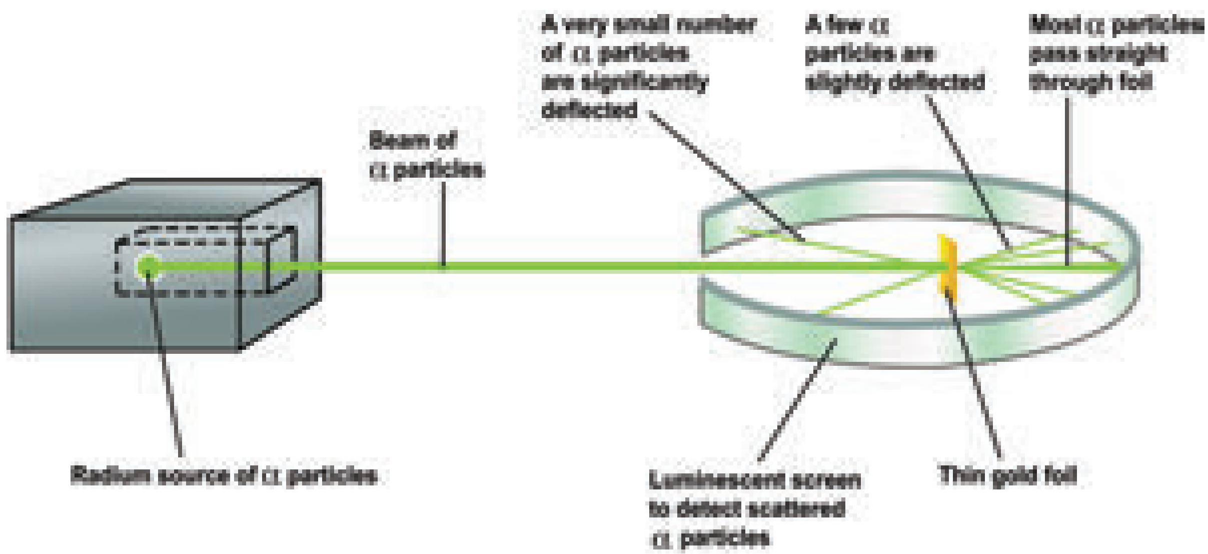


Figure 11.2 Deflection of α-particle by a gold leaf

Later, Rutherford generalized these results of alpha particles scattering experiment and suggested a model of the atom that is known as Rutherford's Atomic model.

11.1.1 Rutherford's Atomic model

According to this model :

i. The atom contains large empty space.

ii. There is a positively charged mass at the centre of the atom, known as nucleus.

iii. The size of the nucleus of an atom is very small compared to the size of an atom.

iv. The electrons revolve around the nucleus in close circular paths called orbits.

v. An atom as a whole is electrically neutral, i.e., the number of protons and electrons in an atom are equal.

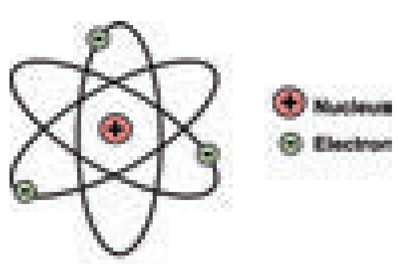


Figure 11.3 Rutherford's model of the atom was some what like that of the solar system.

Rutherford's model of atomic structure is similar to the structure of the solar system. Just as in the solar system, the Sun is at the centre and the planets revolve around it, similarly in an atom the nucleus present at the centre and the electrons revolve around it in orbits or shells.

11.1.2 Limitations in Rutherford's model

According to Electromagnetic theory, a moving electron should accelerate and continuously lose energy. Due to the loss of energy, path of electron may reduce and finally the electron should fall into the nucleus. If it happens so, atom becomes unstable. But atoms are stable. Thus, Rutherford's model failed to explain the stability of an atom.

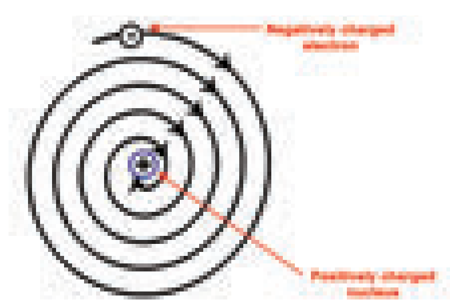


Figure 11.4 Showing an atom losing energy.

11.2 Bohr's model of an atom

In 1913, Neils Bohr, a Danish physicist, explained the causes of the stability of the atom in a different manner. The main postulates are:

i. In atoms, the electron revolve around the nucleus in stationary circular paths called orbits or shells or energy levels.

ii. While revolving around the nucleus in an orbit, an electron neither loses nor gains energy.

iii. An electron in a shell can move to a higher or lower energy shell by absorbing or releasing a fixed amount of energy.

iv. The orbits or shells are represented by the letters K,L,M,N,… or the numbers, n= 1,2,3,4,….

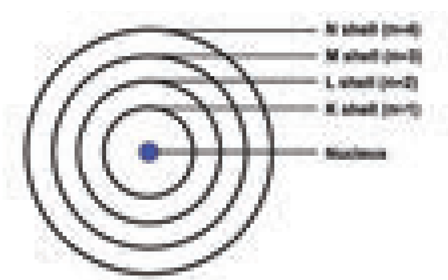


Figure 11.5 Energy levels around the nucleus of an atom: Bohr's model.

The orbit closest to the nucleus is the K shell. It has the least amount of energy and the electrons present in it are called K electrons, and so on with the successive shells and their electrons. These orbits are associated with fixed amount of energy , so Bohr called them as **energy level** or **energy shells**.

11.2.1 Limitations of Bohr's model

One main limitation was that this model was applicable only to hydrogen and hydrogen like ions (example, He^{+}, Li^{2+}, Be^{3+}, and so on). It could not be extended to multi electron nucleus.

11.3 Discovery of Neutrons

In 1932 James Chadwick observed when Beryllium was exposed to alpha particles, particles with about the same mass as protons were emitted.

Beryllium + alpha ray ⟶ carbon + neutron

These emitted particles carried no electrical charges. They were called as neutrons. It is denoted by $_0n^1$. The superscript 1 represents its mass and subscript 0 represents its electric charge.

Properties of Neutrons

1. This particle was not found to be deflected by any magnetic or electric field, proving that it is electrically neutral.
2. Its mass is equal to 1.676×10^{-24} g (**1 amu**).

DO YOU KNOW?

In 1920 Rutherford predicted the presence of another particle in the nucleus as neutral. James Chadwick, the inventor of neutron was student of Rutherford

11.4 Characteristics of Fundamental particles

The atom is built up of a number of sub-atomic particles. The three sub-atomic particles of great importance in understanding the structure of an atom are electrons, protons and neutrons, the properties of which are given in Table 11.1.

Table 11.1 Properties of sub-atomic particles

Particle	Symbol	Charge (electronic units)	mass (amu)	mass (grams)
Electron	$_{-1}e^0$	−1	1/1837	9.1×10^{-28}
Proton	$_1H^1$	+1	1	1.6×10^{-24}
Neutron	$_0n^1$	0	1	1.6×10^{-24}

There are two structural parts of an atom, the nucleus and the empty space in which there are imaginary paths called **orbits**.

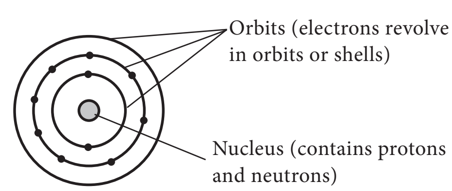


Figure 11.6 Showing structure of an atom.

Nucleus: The protons and neutrons [collectively called **nucleons**]are found in the nucleus of an atom.

Orbits: Orbit is defined as the path, by which electrons revolve around the nucleus.

DO YOU KNOW?

Besides the fundamental particles like protons, electrons and neutrons some more particles are discovered in the nucleus of an atom. They include mesons, neutrino, antineutrino, positrons etc.

11.5 Atomic number and Mass number

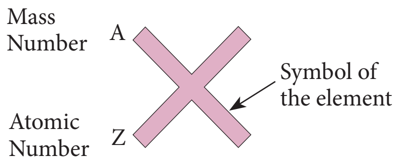
Only hydrogen atoms have one proton in their nuclei. Only helium atoms have two protons. Indeed, only gold atoms have 79 protons. This shows that the number of protons in the nucleus of an atom decides which element it is. This very important number is known as the **atomic number** (proton number, given the symbol Z) of an atom.

Atomic number(Z) = Number of protons = Number of electrons

Protons alone do not make up all of the mass of an atom. The neutrons in the nucleus also contribute to the total mass. The mass of the electron can be regarded as so small that it can be ignored. As a proton and a neutron have the same mass, the mass of a particular atom depends on the total number of protons and neutrons present. This number is called the **mass number** (or nucleon number, given the symbol A) of an atom.

Mass number = Number of protons + Number of neutrons

For any element, the atomic numbers are shown as subscripts and mass number are shown as superscripts.



For example, nitrogen is written as $^{14}_{7}N$

Here **7** is its atomic number and **14** is its mass number.

Activity 1

Symbolically represent the following atoms using atomic number and mass number. [Refer table 11.1]

a) Carbon b) Oxygen
c) Silicon d) Beryllium

The difference between the mass number of an element and its atomic number gives the number of neutrons present in one atom of the element.

Number of neutrons (n) = Mass number (A) – Atomic number (z)

For example, the number of neutrons in one atom of $^{24}_{12}Mg$ is

Number of neutrons (n) = $\underset{(A)}{24} - \underset{(Z)}{12} = 12$

Test Yourself

Calculate the number of neutrons in the following atoms:

a) $^{27}_{13}Al$ b) $^{31}_{15}P$ c) $^{190}_{76}Os$ d) $^{54}_{24}Cr$

DO YOU KNOW?

Atomic number is designated as Z why?

Z stands for Zahl, which means NUMBER in German.

Z can be called Atomzahl or atomic number

A is the symbol recommened in the ACS style guide instead of M (massenzahl in German).

Problem 1

Calculate the atomic number of an element whose mass number is 39 and number of neutrons is 20. Also find the name of the element.

Solution

Mass Number = Atomic number + Number of neutrons

Atomic Number = Mass number – Number of neutrons

= 39 – 20

Atomic Number = 19

Element having atomic number 19 is Potassium (K)

11.5.1 Electronic configuration of atoms

You already know that electrons occupy different energy levels called orbits or shells. The distribution of electrons in different shells is called electronic configuration. This distribution of electrons is governed by certain rules or conditions, known as Bohr and Bury Rules of electronic configuration.

Rule 1: The maximum number of electrons that can be accommodated in a shell is equal to $2n^2$ where 'n' is the serial number of the shell from the nucleus.

Shell	Value of (n)	Maximum number of electrons ($2n^2$)
K	1	$2 \times 1^2 = 2$
L	2	$2 \times 2^2 = 8$
M	3	$2 \times 3^2 = 18$
N	4	$2 \times 4^2 = 32$

Rule 2: Shells are filled in a **stepwise manner** in the increasing order of energy.

Rule 3: The outermost shell of an atom cannot have more than 8 electrons , even if it has capacity to accomodate more electrons. For example, electronic arrangement in calcium having 20 electrons is,

K	L	M	N
2	8	8	2

Problem 2

What is the Electronic configuration of Aluminium?

Solution

Electronic configuration of Aluminium atom: (Z = 13) **K shell = 2 , L shell = 8 and M shell = 3 electron**.

So its electronic configuration is 2, 8, 3

DO YOU KNOW? The forces between the protons and the neutrons in the nucleus are of special kind called Yukawa forces. This strong force is more powerful than gravity.

Geometric Representation of atomic structure of elements

Knowing the mass number and atomic number of an element we can represent atomic structure.

Example:

Geometric Representation of oxygen atom ${}^{16}_{8}O$

Mass number A = 16

Atomic number Z = 8

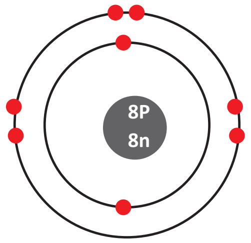
Number of neutrons = A – Z = 16 – 8 = 8

Number of protons = 8

Number of electron = 8

Electronic configuration = 2, 6

Atom of Oxygen ${}^{16}_{8}O$



Electronic configuration 2, 6

Figure 11.7 Atom of oxygen.

DO YOU KNOW? Atoms are so tiny their mass number cannot be expressed in grams but expressed in amu (atomic mass unit). New unit is U. Size of an atom can be measured in nano metre (1 nm = 10^{-9} m) Even though atom is an invisible tiny particle now-a-days atoms can be viewed through SEM that is Scanning Electron Microscope.

11.5.2 Valence electrons

In the above example, we can see that there are six electrons in the outermost shell of oxygen atom. These six electrons are called as valence electrons.

The outermost shell of an atom is called valence shell and the electrons present in the valence shell are known as valence electrons. The chemical properties of elements are decided by these valence electrons, since they are the ones that take part in chemical reactions.

The elements with same number of electrons in the valence shell show similar properties and those with different number of valence electrons show different chemical properties. Elements, which have 1 or 2 or 3 valence electrons (except Hydrogen) are **metals.** Elements with 4 to 7 electrons in their valence shell are **non-metals**.

11.5.3 Valency

Valency of an element is the combining capacity of the element with other elements and is equal to the number of electrons that take part in a chemical reaction. Valency of the elements having valence electrons 1, 2, 3, 4 is 1, 2, 3, 4 respectively.

EH95JN

Valency of an element with 5, 6 and 7 valence electrons is 3, 2 and 1 (8–valence electrons) respectively. Because 8 is the number of electrons required by an element to attain stable electronic configuration. Elements having completely filled outermost shell show **Zero valency**.

For example: The electronic configuration of Neon is 2,8 (completely filled). So valency is **0**.

Problem 3

Find the valency of Magnesium and Sulphur.

Solution

Electronic configuration of magnesium is 2, 8, 2. So valency is 2.

Electronic configuration of sulphur is 2, 8, 6. So valency is 2 i.e.(8 – 6).

Activity 2

Assign the valency for Phosphorus, Chlorine, Silicon and Argon

Table 11.2 Arrangement of electrons in atoms of elements having atomic from 1 to 20.

Elements	Symbol	Atomic No (Z) No. of protons/ No. of electrons	Mass No. (A) No. of protons + neutrons	No. of neutrons (A – Z)	Electronic configuration				Valency	Metal/ non-metal/ noble gas
					1st or K-shell	2nd or L-shell	3rd or M-shell	4th or N-shell		
Hydrogen	H	1	1	–	1				1	Non-metal
Helium	He	2	4	2	2				0	Noble gas
Lithium	Li	3	7	4	2	1			1	Metal
Beryllium	Be	4	9	5	2	2			2	Metal
Boron	B	5	11	6	2	3			3	Non-metal
Carbon	C	6	12	6	2	4			4	Non-metal
Nitrogen	N	7	14	7	2	5			3	Non-metal
Oxygen	O	8	16	8	2	6			2	Non-metal
Fluorine	F	9	19	10	2	7			1	Non-metal
Neon	Ne	10	20	10	2	8			0	Noble gas
Sodium	Na	11	23	12	2	8	1		1	Metal
Magnesium	Mg	12	24	12	2	8	2		2	Metal
Aluminium	Al	13	27	14	2	8	3		3	Metal
Silicon	Si	14	28	14	2	8	4		4	Non-metal
Phosphorus	P	15	31	16	2	8	5		3	Non-metal
Sulphur	S	16	32	16	2	8	6		2	Non-metal
Chlorine	Cl	17	35, 37	18, 20	2	8	7		1	Non-metal
Argon	Ar	18	40	22	2	8	8		0	Noble gas
Potassium	K	19	39	20	2	8	8	1	1	Metal
Calcium	Ca	20	40	20	2	8	8	2	2	Metal

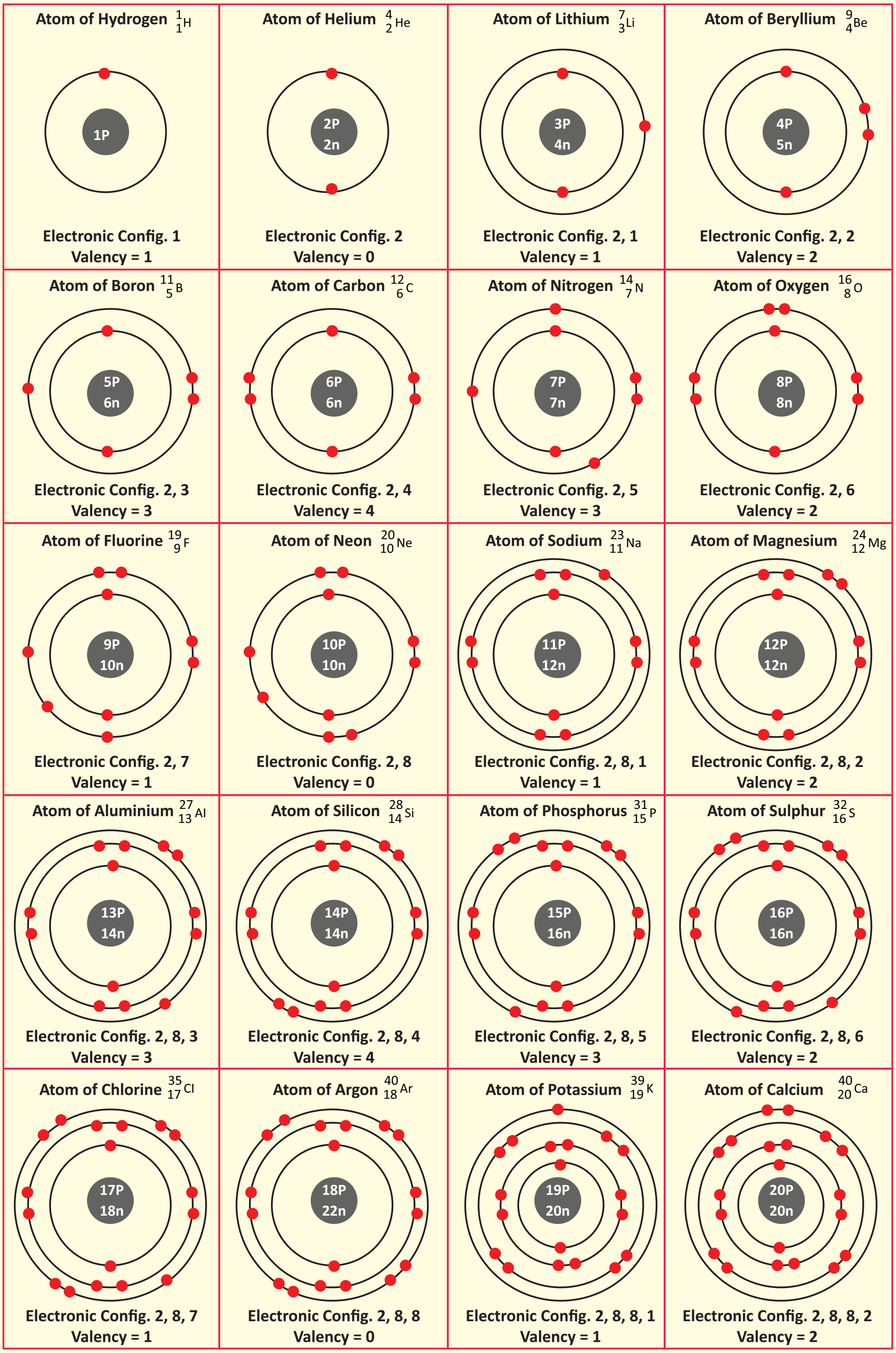
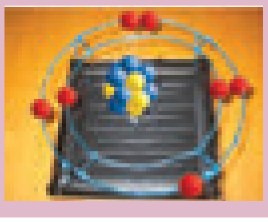


Figure 11.8 Geometric representation of atoms of the first twenty elements.

Activity 3

Look at the model given below. Make groups of five. Each group can make models of 4 elements by using available materials like balls, beads, string etc.



Activity 4

Draw the structures of the isotopes of oxygen O^{16} and O^{18}

Atomic number of oxygen = 8

11.6 Isotopes, Isobars and Isotones

11.6.1 Isotopes

In nature, a number of atoms of elements have been identified, which have the same atomic number but different mass numbers. For example, take the case of hydrogen atom, it has three atomic species as shown below:

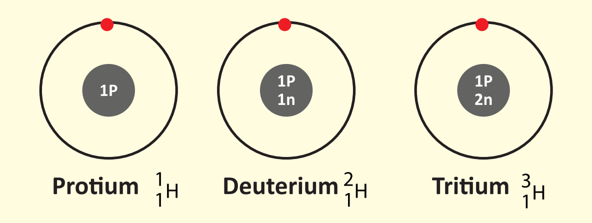


Figure 11.9 Isotopes

The atomic number of all the three isotopes is 1, but the mass number is 1, 2 and 3, respectively. Other such examples are: i) carbon, $^{12}_{6}C$, $^{13}_{6}C$ ii) Chlorine $^{35}_{17}Cl$ $^{37}_{17}Cl$

On the basis of these examples, isotopes are defined as the different atoms of the same element, having same atomic number but different mass numbers. There are two types of isotopes: **stable** and **unstable**. The isotopes which are unstable, as a result of the extra neutrons in their nuclei are radioactive and are called **radioisotopes**. For example, uranium-235, which is a source of nuclear reactors, and cobalt-60, which is used in radiotherapy treatment are both radioisotopes.

11.6.2 Isobars

Let us consider two elements – calcium (atomic number 20), and argon (atomic number 18).

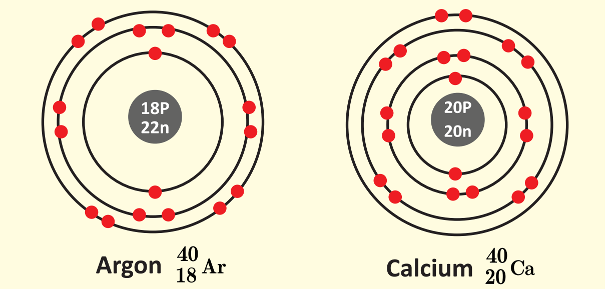


Figure 11.10 Isobars

They have (Fig. 11.10) different number of protons and electrons. But, the mass number of both these elements is 40. It follows that the total number of nucleons in both the atoms are the same. They are called isobars. Atoms of different elements with different atomic numbers, and same mass number are known as isobars.

More to Know

Thumb rule for isotopes and isobars. Remember **t** for top and **b** for bottom.
Isotope: Top value changes – Atomic mass
Isobars: Bottom value changes – Atomic number

11.6.3 Isotones

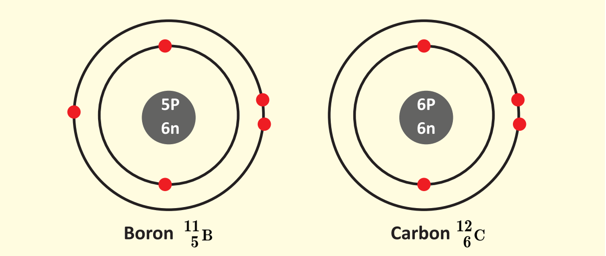


Figure 11.11 Isotones

No of neutrons in boron = 11 – 5 = 6

No of neutrons in carbon = 12 – 6 = 6

The above pair of elements Boron and Carbon has the same number of neutrons but different number of protons and hence different atomic numbers. Atoms of different elements with different atomic numbers and different mass numbers, but with same number of neutrons are called isotones

Activity 5

Draw the model of the following pairs of isotones:

(i)Fluorine & Neon (ii) Sodium & Magnesium (iii) Aluminum and Silicon

11.7 Laws of Chemical combination

In the seventeenth century, scientists had been trying to find out methods for converting one substance into another. During their studies of chemical changes, they made certain generalisations. These generalisations are known as laws of chemical combination. These are :

1. Law of conservation of mass
2. Law of constant proportions
3. Law of multiple proportions
4. Law of reciprocal proportions
5. Gay Lussac's law of gaseous volumes

Out of these five laws you have already learnt the first two laws in class VIII. Let us see the next three laws in detail in this chapter.

11.7.1 Law of multiple proportions

This law was proposed by **John Dalton in 1804.**

It states that, **"When two elements A and B combine together to form more than one compound, then different masses of A which separately combine with a fixed mass of B are in simple ratio".**

To illustrate the law let us consider the following example.

Carbon combines with oxygen to form two different oxides, carbon monoxide(CO) and carbon dioxide (CO_2). The ratio of masses of oxygen in CO and CO_2 for fixed mass of carbon is 1: 2.

	Mass of carbon (g)	Mass of oxygen (g)	Ratio of O in CO to O in CO_2
CO	12	16	1:2
CO_2	12	32	

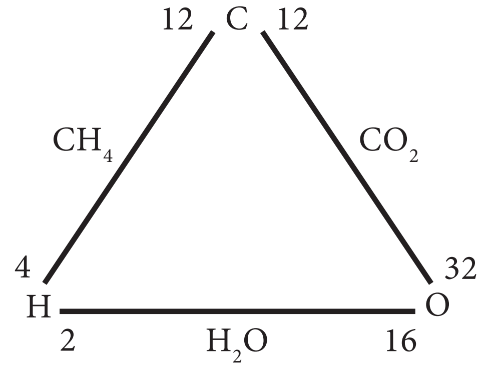
Let us take one more example, Sulphur combines with oxygen to form sulphur dioxide and sulphur trioxide. The ratio of masses of oxygen in SO_2 and SO_3 for fixed mass of Sulphur is 2:3.

11.7.2 Law of Reciprocal Proportions

The **law of reciprocal proportions** was proposed by Jeremias Ritcher in 1792.

It states that, "**If two different elements combine separately with the same weight of a third element, the ratio of the masses in which they do so are either same or a simple multiple of the mass ratio in which they combine among themselves.**"

Consider the three elements hydrogen, oxygen and water as shown below:



Here, hydrogen and oxygen combine separately with the same weight of carbon to form methane (CH_4) and carbon dioxide (CO_2)

Compounds	Combining elements		Combining weights	
CH_4	C	H	12	4
CO_2	C	O	12	32

Ratio of different mass of hydrogen (4g) and oxygen (32g) that combines with same mass of carbon } 4:32 (or) 1:8——(1)

Now, hydrogen and oxygen combine to form water (H_2O).

Ratio of mass of hydrogen to oxygen = 2:16 (or) 1:8 ———(2)

From 1 and 2, the ratio is the same as that of the first obtained. Thus, the law of reciprocal proportion is illustrated.

11.7.3 Gay Lussac's Law of Combining Volumes

According to Gay Lussac's Law, whenever gases react together, the volumes of the reacting gases bear a simple ratio, and the ratio is extended to the product when the product is also in gaseous state, provided all the volumes are measured under similar conditions of temperature and pressure.

This law may be illustrated by the following example.

It has been experimentally observed that two volumes of hydrogen reacts with one volume of oxygen to form two volumes of water as shown in the figure 11.12.

The ratio of volume which gases bears is **2:1:2** which is a simple whole number ratio.

Activity 6

Nitrogen combines with hydrogen to form ammonia (NH_3). Illustrate Gay Lussac's law using this example.

11.8 Quantum Numbers

When you specify the location of a building, you usually list which country it is in, which state and city it is in that country.

Just like we have four ways of defining the location of a building (country, state, city, and street address), we have four ways of defining the properties of an electron, i.e.four quantum numbers.

Thus, the numbers which designate and distinguish various atomic orbitals and electrons present in an atom are called quantum numbers.

Four types of Quantum number are as follows:

Quantum Number	Symbol	Information conveyed
Principal quantum number	*n*	Main energy level
Azimuthal quantum number	*l*	Sub shell/ shape of orbital
Magnetic quantum number	*m*	Orientation of orbitals
Spin quantum number	*s*	Spin of the electron

You will learn more details about this in higher classes.

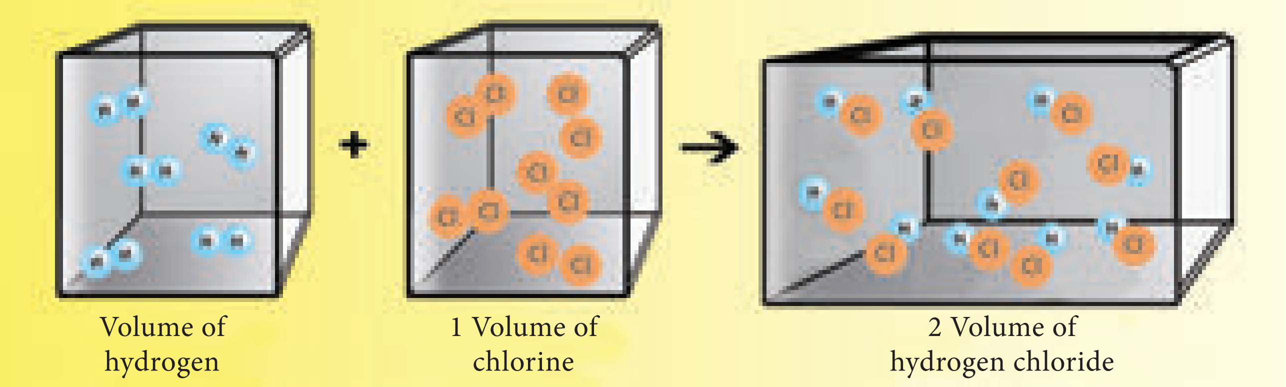


Figure 11.12 One volume of hydrogen react with one volume of chlorine to give two volumes of hydrogen chloride.

Points to Remember

- ❖ Rutherford's alpha-particle scattering experiment led to the discovery of the atomic nucleus.
- ❖ J.Chadwick discovered the presence of neutrons in the nucleus.
- ❖ Mass number of an element is the total number of protons and neutrons.
- ❖ Valence electrons are the electrons in the outermost orbit.
- ❖ Valency is the combining capacity of an atom.
- ❖ Isotopes are atoms of the same element, which have same atomic number but different mass numbers.
- ❖ Isobars are the atoms of the different element with same mass number but different atomic number.
- ❖ Isotones are the atoms of different elements having same number of neutron but different atomic number and mass number.

A-Z GLOSSARY

Atom	The smallest component of an element which takes part in a chemical reaction.
Electron	A stable subatomic particle with a charge of negative electricity, found in all atoms and acting as the primary carrier of electricity in solids.
Neutron	A subatomic particle of about the same mass as a proton but without an electric charge, present in all atomic nuclei except those of ordinary hydrogen.
Orbitals	Atomic orbitals are region of space around the nucleus of an atom where an electron is likely to be found.
Proton	A stable subatomic particle occurring in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron.
Quantum numbers	The numbers which designate and distinguish various atomic orbitals and electrons present in an atom.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. Among the following the odd pair is

   a) $^{18}_{8}O$, $^{19}_{9}F$ b) $^{40}_{18}Ar$, $^{14}_{7}N$

   c) $^{30}_{14}Si$, $^{31}_{15}P$ d) $^{40}_{20}Cr$, $^{39}_{19}K$

2. Change in the number of neutrons in an atom changes it to

   a) an ion. b) an isotope.

   c) an isobar. d) another element.

3. The term nucleons refer to

   a) protons and electrons

   b) only neutrons

   c) electrons and neutrons

   d) protons and neutrons

4. The number of protons, neutrons and electrons present respectively in $^{80}_{35}Br$ are

   a) 80, 80, 35

   b) 35, 55,80

   c) 35, 35, 80

   d) 35, 45, 35

5. The correct electronic configuration of potassium is

   a) 2,8,9 b) 2,8,1

   c) 2,8,8,1 d) 2,8,8,3

EHI1LB

II. State true or false. If false, correct the statement.

1. In an atom, electrons revolve around the nucleus in fixed orbits.
2. Isotopes of an element have different atomic numbers.
3. Electrons have negligible mass and charge.
4. Smaller the size of the orbit, lower is the energy of the orbit.
5. The maximum number of electron in L Shell is 10.

III. Fill in the blanks.

1. Calcium and Argon are examples of a pair of ________________
2. Total number of electrons that can be accommodated in an orbit is given by ______________
3. _____________ isotope is used in the nuclear reactors.
4. The number of neutrons present in $_{3}^{7}Li$ is ___________
5. The valency of Argon is ___________

IV. Match the following.

a) Dalton	1. Hydrogen atom model
b) Chadwick	2. Discovery of nucleus
c) Rutherford	3. First atomic theory
d) Neils Bohr	4. Plum pudding model
	5. Discovery of neutrons

VI. Answer very briefly.

1. Name an element which has the same number of electrons in its first and second shell.
2. Write the electronic configuration of K and Cl
3. Write down the names of the particles represented by the following symbols and explain the meaning of superscript and subscript numbers attached.

$$_{1}H^{1},\ _{0}n^{1},\ _{-1}e^{0}$$

4. For an atom 'X', K, L and M shells are completely filled. How many electrons will be present in it?
5. What is the same about the electron structures of:
   a. Lithium, Sodium and Potassium.
   b. Beryllium, Magnesium and Calcium.

VII. Answer briefly.

1. How was it shown that atom has empty space?
2. Why do $_{17}^{35}Cl$ and $_{17}^{37}Cl$ have the same chemical properties? In what respect do these atoms differ?
3. Draw the structure of oxygen and sulphur atoms.
4. Calculate the number of neutrons, protons and electrons: (i) atomic number 3 and mass number 7 (ii)atomic number 92 and mass number 238.
5. What are nucleons? How many nucleons are present in Phosphorous? Draw its structure.

V. Complete the following table.

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Element
9	-	10	-	-	-
16	-	16	-	-	-
-	24	-	-	12	Magnesium
-	2	-	1	-	-
-	1	0	1	1	-

VIII. Answer in detail.

1. What conclusions were made from the observations of Gold foil experiment?
2. Explain the postulates of Bohr's atomic model.
3. State the Gay Lussac's law of combining volumes. Explain with an illustration.

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INTERNET RESOURCES

https://www.youtube.com/watch?v=t4xgvlNFQ3c
https://www.youtube.com/watch?v=P6DMEgE8CK8
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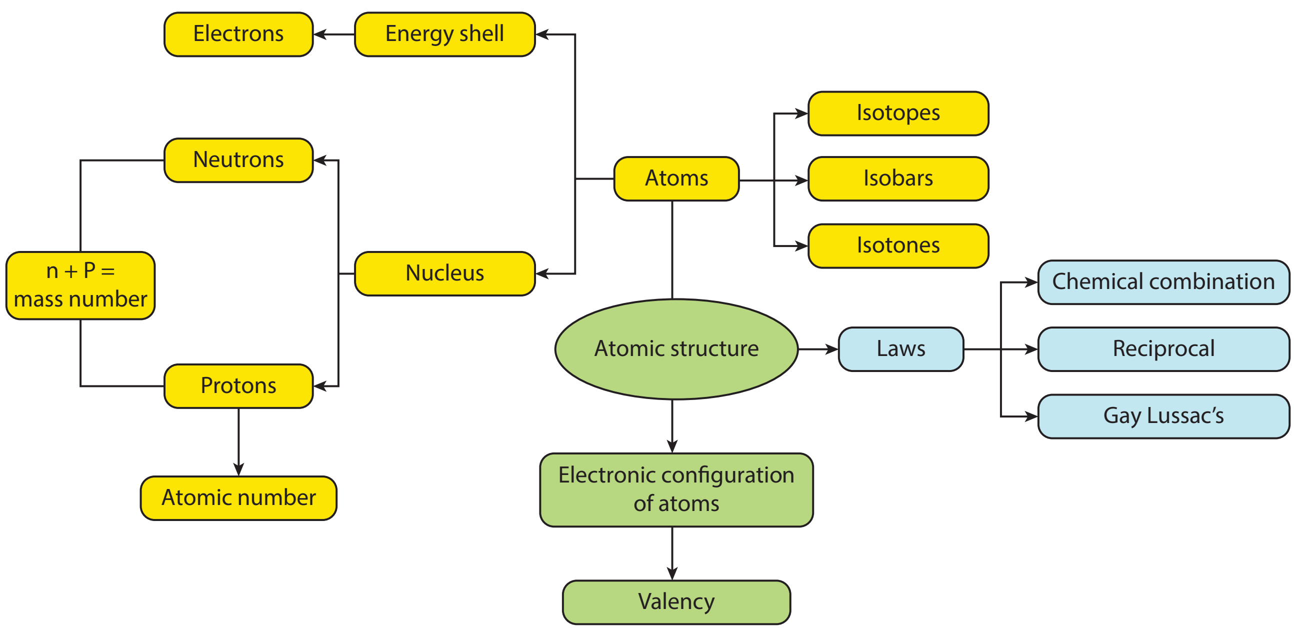
Concept Map



ICT CORNER

ATOMIC STRUCTURE

Atoms are building blocks. They are made of neutrons, protons and electrons.
This activity help the students to explore more about atoms and its components.

Step 1. Type the following URL in the browser or scan the QR code from your mobile.You can see on the screen. Click that.

Step 2. Select atom. Atomic orbit you can see with multiple options. Select protons, neutrons and electrons to their respective places. According to their numbers name of the elements appear on the periodic table. You can also find out whether the selected element is neutral or charged(ions)

Step 3. click"**symbol**"now. When you arrange electrons, neutrons and protons on the orbits you can see the name of the element, it's atomic number, atomic mass and number of electrons.

Step 4. Third option is games. It's an evaluation one to test your understanding

URL: https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html

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UNIT 12

PERIODIC CLASSIFICATION OF ELEMENTS

BN8AZY

Learning Objectives

After completing this lesson, students will be able to

- know the concept of classification of elements in early days.
- understand the postulates, advantages and limitations of modern periodic table.
- understand the classification of elements based on the electronic configuration.
- learn about the position of hydrogen in the periodic table.
- study about the position of rare gases (Noble gases) in the periodic table.
- distinguish between metals and non-metals.
- know about metalloids and alloys.

Introduction

We live in the world of substances with great diversity. Substances are formed by the combination of various elements. All the elements are unique in their nature and property. To categorize these elements according to their properties, scientists started to look for a way. In 1800, there were only 31 known elements. By 1865, their number became 63. Now 118 elements have been discovered. As different elements were being discovered, scientists gathered more and more information about the properties of these elements. They found it difficult to organize all that was known about the elements. They started looking for some pattern in their properties, on the basis of which they could study such a large number of elements with ease. Let us discuss the concepts of classification of elements proposed by various scientists from early to modern period.

12.1. Early Concepts of Classification of Elements

12.1.1. Dobereiner's Triads

In 1817, Johann Wolfgang Dobereiner, a German chemist, suggested a method of grouping elements based on their relative atomic masses. He arranged the elements into groups containing three elements each. He called these groups as 'triads' (tri – three).

Dobereiner showed that when the three elements in a triad are arranged in the ascending order of their atomic masses, the atomic mass of the middle element is nearly the same as average of atomic masses of other two elements. This statement is called the Dobereiner's law of triads. Table 12.1 shows the law of triads proposed by Dobereiner.

Example: In the triad group (1), arithmetic mean of atomic masses of 1st and 3rd elements,

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Table 12.1 Dobereiner's law of triads

Triad Group (1)		Triad Group (2)		Triad Group (3)	
Element	Atomic Mass	Element	Atomic Mass	Element	Atomic Mass
Li	6.9	Cl	35.5	Ca	40.1
Na	23	Br	79.9	Sr	87.6
K	39.1	I	126.9	Ba	137.3

(6.9 + 39.1)/2 = 23. So the atomic mass of Na (middle element) is 23.

Limitations:

- Dobereiner could identify only three triads from the elements known at that time and all elements could not be classified in the form of triads.
- The law was not applicable to elements having very low and very high atomic mass.

12.1.2 Newlands' Law of Octaves

In 1866, John Newlands arranged 56 known elements in the increasing order of their atomic mass. He observed that every eighth element had properties similar to those of the first element like the eighth note in an octave of music is similar to the first. This arrangement was known as 'law of octaves'.

The octave of Indian music system is sa, re, ga, ma, pa, da, ni, sa. The first and last notes of this octave are same i.e. sa. Likewise, in the Newlands' table of octaves, the element 'F' is eighth from the element 'H', thus they have similar properties.

Activity 1

Find the pair of elements having similar properties by applying Newlands' law of Octaves (Example: Mg & Ca):
Set I : F, Mg, C, O, B
Set II: Al, Si, S, Cl, Ca

Limitations:

- There are instances of two elements being fitted into the same slot, e.g. cobalt and nickel.
- Some elements, totally dissimilar in their properties, were fitted into the same group. (Arrangement of Co, Ni, Pd, Pt and Ir in the row of halogens)
- The law of octaves was not valid for elements that had atomic masses higher than that of calcium.
- Newlands' table was restricted to only 56 elements and did not leave any room for new elements.
- Discovery of inert gases (Neon. Argon….) at later stage made the 9th element similar to the first one. Eg: Neon between Fluorine and Sodium.

12.1.3 Mendeleev's Periodic Table

In 1869, Russian chemist, Dmitri Mendeleev observed that the elements of similar properties repeat at regular intervals when the elements are arranged in the order of their atomic masses. Based on this, he proposed the law of periodicity which states that "the physical and chemical properties of the elements are the periodic functions of their atomic masses". He arranged 56 elements known at that time according to his law of periodicity. This was best known as the short form of periodic table.

(a) Features of Mendeleev's Periodic Table:

- It has eight vertical columns called 'groups' and seven horizontal rows called 'period'.
- Each group has two subgroups 'A' and 'B'. All the elements appearing in a group were found to have similar properties.
- For the first time, elements were comprehensively classified in such a way that elements of similar properties were placed in the same group.

Table 12.2 Newland's table of octaves (oct- eight)

No.		No.		No.		No.		No.		No.		No.		No.	
H	1	F	8	Cl	15	Co & Ni	22	Br	29	Pd	36	I	42	Pt & Ir	50
Li	2	Na	9	K	16	Cu	23	Rb	30	Ag	37	Cs	44	Os	51
G	3	Mg	10	Ca	17	Zn	24	Sr	31	Cd	38	Ba & V	45	Hg	52
Bo	4	Al	11	Cr	19	Y	25	Ce & La	33	U	40	Ta	46	Ti	53
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Pb	54
N	6	P	13	Mn	20	As	27	Di & Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Ro & Ru	35	To	43	Au	49	Th	56

- It was noticed that certain elements could not be placed in their proper groups in this manner. The reason for this was wrongly determined atomic masses. Consequently those wrong atomic masses were corrected. Eg: The atomic mass of beryllium was known to be 14. Mendeleev reassessed it as 9 and assigned beryllium a proper place.
- Columns were left vacant for elements which were not known at that time and their properties also were predicted. This gave motivation to experiment in Chemistry. Eg: Mendeleev gave names Eka Aluminium and Eka Silicon to those elements which were to be placed below Aluminium and Silicon respectively in the periodic table and predicted their properties. The discovery of Germanium later on, during his life time, proved him correct.

(b) Limitations:

- Elements with large difference in properties were included in the same group. Eg: Hard metals like copper (Cu) and silver (Ag) were included along with soft metals like sodium (Na) and potassium (K).

Table 12.3 Mendeleev's Periodic Table

Group	I	II	III	IV	V	VI	VII	VIII
Oxide: Hydride:	R_2O RH	RO RH_4	R_2O_3 RH_4	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_2	R_2O_7 RH	RO_4
Periods	A B	A B	A B	A B	A B	A B	A B	Transition series
1	H 1.008							
2	Li 6.939	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.988	
3	Na 22.99	Mg 22.99	Al 24.31	Si 28.09	P 30.974	S 32.06	Cl 35.453	
4 First Series Second series	K 39.102 Cu 63.54	Ca 40.08 Zn 65.54	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 55.85 Co 58.93 Ni 58.71
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 121.60	Mo 95.94 Te 127.60	Tc 99 I 126.90	Ru 101.07 Rh 102.91 Pd 106.4
6 First Series Second series	Cs 132.90 Au 196.97	Ba 137.34 Hg 200.59	La 138.91 Tl 204.37	Hf 178.40 Pb 207.19	Ta 180.95 Bi 208.98	W 183.85		Os 190.2 Ir 192.2 Pt 195.05
7	Rn 222	Fr 223	Ra 226	Ac 227	Th 232	Pa 231	U 238	

- No proper position could be given to the element hydrogen. Non-metallic hydrogen was placed along with metals like lithium (Li), sodium (Na) and potassium (K).
- The increasing order of atomic mass was not strictly followed throughout. Eg. Co & Ni, Te & I.
- No place for isotopes in the periodic table.

Table 12.4 Properties of Germanium

Property	Mendeleev's prediction (1871)	Actual property (1886)
Atomic Mass	About 72	72.59
Specific Gravity	5.5	5.47
Colour	Dark grey	Dark grey
Formula of Oxide	EsO_2	GeO_2
Nature of Chloride	$EsCl_4$	$GeCl_4$

12.2 Modern Periodic Table

In 1913, the English Physicist Henry Moseley, through his X-ray diffraction experiments, proved that the properties of elements depend on the atomic number and not on the atomic mass. Consequently, the modern periodic table was prepared by arranging elements in the increasing order of their atomic number.

This modern periodic table is the extension of the original Mendeleev's periodic table and known as the long form of periodic table.

12.2.1 Modern Periodic Law

Atomic number of an element (Z) indicates the number of protons (positive charge) or the number of electrons (negative charge). The physical and chemical properties of elements depend not only on the number of protons but also on the number of electrons and their arrangements (electronic configuration) in atoms. Hence, the modern periodic law can be stated as follows: "The chemical and physical properties of the elements are the periodic functions of their atomic numbers". Based on the modern periodic law, the modern periodic table is derived.

12.2.2 Features of Modern Periodic Table

- All the elements are arranged in the increasing order of their atomic number.
- The horizontal rows are called periods. There are seven periods in the periodic table.
- The elements are placed in periods based on the number of shells in their atoms.
- Vertical columns in the periodic table starting from top to bottom are called groups. There are 18 groups in the periodic table.
- Based on the physical and chemical properties of elements, they are grouped into various families.

Table 12.5 Groups in modern periodic table

Group	Families
1	Alkali metals
2	Alkaline earth metals
3 to 12	Transition metals
13	Boron Family
14	Carbon Family
15	Nitrogen Family
16	Oxygen Family (or) Chalcogen Family
17	Halogens
18	Noble gases

12.2.3 Classification of elements into blocks

We know that the electrons in an atom are accommodated in shells around the nucleus. Each shell consists of one or more subshells in which the electrons are distributed in certain

PERIODIC TABLE OF THE ELEMENTS

GROUP (IUPAC) 1, GROUP (CAS) IA, ATOMIC NUMBER 1, RELATIVE ATOMIC MASS (1) 1.008, SYMBOL H, ELEMENT NAME HYDROGEN

Metal	Semimetal	Nonmetal
Alkali metal		Chalcogens element
Alkaline earth metal		Halogens element
Transition metals		Noble gas
Lanthanide		
Actinide		

STANDARD STATE (25 °C; 101 kPa)
Ne - gas **Fe** - solid
Hg - liquid Tc - synthetic

PERIOD	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.008 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.94 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.81 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.085 Si SILICON	15 30.974 P PHOSPHORUS	16 32.06 S SULPHUR	17 35.45 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.38 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.971 Se SELENIUM	35 79.904 Br BROMINE	36 83.798 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.95 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (267) Rf RUTHERFORDIUM	105 (268) Db DUBNIUM	106 (271) Sg SEABORGIUM	107 (272) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (276) Mt MEITNERIUM	110 (281) Ds DARMSTADTIUM	111 (280) Rg ROENTGENIUM	112 (285) Cn COPERNICIUM	113 (285) Nh NIHONIUM	114 (287) Fl FLEROVIUM	115 (289) Mc MOSCOVIUM	116 (291) Lv LIVERMORIUM	117 (294) Ts TENNESSINE	118 (294) Og OGANESSON

LANTHANIDE

57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.05 Yb YTTERBIUM	71 174.97 Lu LUTETIUM

ACTINIDE

89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

manner. These subshells are designated as s, p, d, and f. Based on the arrangement of electrons in subshells, the elements of periodic table are classified into four blocks namely s, p, d and f blocks.

(1) s-Block Elements: It includes group 1 (alkali metals) and group 2 (alkaline earth metals) elements. They are also called as representative elements. The elements of group 1 (except hydrogen) are metals. They react with water to form solutions that change the colour of a litmus paper from red to blue. These solutions are said to be highly alkaline or basic. Hence they are called alkali metals.

The elements of group 2 are also metals. They combine with oxygen to form oxides, formerly called 'earths', and these oxides produce alkaline solutions when they are dissolved in water. Hence, these elements are called alkaline earth metals.

(2) p-Block Elements: These elements are in group 13 to 18 in the periodic table. They include boron, carbon, nitrogen, oxygen, fluorine families in addition to noble gases (Except helium). They are also called as representative elements. The p-block is home to the biggest variety of elements and is the only block that contains all three types of elements: metals, nonmetals, and metalloids.

(3) d-Block Elements: It includes group 3 to group 12 elements. They are found in the centre of the periodic table. Their properties are intermediate to that of s block and p block elements and so they are called transition elements.

(4) f – Block Elements: It includes 14 elements after (Lanthanum) La (57), called Lanthanoides and 14 elements after (Actinium) Ac (89), called Actinoides. They are placed at the bottom of the periodic table. They are also called as inner Transition elements.

12.2.4 Advantages of the Modern Periodic Table

- The table is based on a more fundamental property i.e., atomic number.
- It correlates the position of the element with its electronic configuration more clearly.
- The completion of each period is more logical. In a period, as the atomic number increases, the energy shells are gradually filled up until an inert gas configuration is reached.
- It is easy to remember and reproduce.
- Each group is an independent group and the idea of subgroups has been discarded.
- One position for all isotopes of an element is justified, since the isotopes have the same atomic number.
- The position of the eighth group (in Mendeleev's table) is also justified in this table. All transition elements have been brought in the middle as the properties of transition elements are intermediate between left portion and right portion elements of the periodic table.
- The table completely separates metals from nonmetals. The nonmetals are present in upper right corners of the periodic table.
- The positions of certain elements which were earlier misfit (interchanged) in the Mendeleev's periodic table are now justified because it is based on atomic number of the elements.
- Justification has been offered for placing lanthanides and actinides at the bottom of the periodic table.

12.2.5 Position of hydrogen in the periodic table

Hydrogen is the lightest, smallest and first element of the periodic table. Its electronic configuration ($1s^1$) is the simplest of all the elements. It occupies a unique position in the periodic table. It behaves like alkali metals as well as halogens in its properties.

Table 12.6 Number of electrons in subshell

Shell number (Symbol)	1 (K)	2 (L)		3 (M)			4 (N)			
Sub shell	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f
Maximum number of electrons in each sub shell	2	2	6	2	6	10	2	6	10	14
Maximum number of electrons in each shell	2	8		18			32			

In the periodic table, it is placed at the top of the alkali metals.

(i) Hydrogen can lose its only one electron to form a hydrogen ion (H^+) like alkali metals.

(ii) It can also gain one electron to form the hydride ion (H^-) like halogens.

(iii) Alkali metals are solids while hydrogen is a gas.

Hence the position of hydrogen in the modern periodic table is still under debate as the properties of hydrogen are unique.

12.2.6. Position of Rare Gases

The elements Helium, Neon, Argon, Krypton, Xenon and Radon of group 18 in the periodic table are called as Noble gases or Rare gases. They are monoatomic gases and do not react with other substances easily, due to completely filled subshells. Hence they are called as inert gases. They are found in very small quantities and hence they are called as rare gases.

12.3 Metals, Non-Metals and Metalloids

12.3.1 Metals

Metals are typically hard, shiny, malleable (can be made as sheet), fusible and ductile (can be drawn into wire) with good electrical and thermal conductivity. Except mercury, most of the metals are solids at room temperature. Metals occupy larger area in the periodic table and are categorized as:

(i) Alkali metals. e.g. Lithium to Francium (top to bottom)

(ii) Alkaline earth metals. e.g: Beryllium to Radium (top to bottom)

(iii) Transition Metals. Group 3 to 12

(iv) p-block metals. e.g: Al, Ga, In, Tl, Sn, Pb and Bi.

4.3.2. Non-metals

A non-metal is an element that does not have the characters like hardness, shiny, malleable, suitable and ductile. In other words, a non-metal is an element that does not have the properties of metal. All non metals are arranged in p-block only. E.g. C, N, O, P, S, Se, Halogen (F, Cl, Br and I) and inert gases (He to Rn).

12.3.3 Metalloids

Elements which have the properties of both metals and non-metals are called as metalloids. (eg) Boron, Arsenic.

12.4 Alloys

BNH72L

During 3500 BC(BCE), people used an alloy named 'bronze'. The idea of making an alloy was quite old. The majority of the metallic substances used today are alloys. Alloys are mixtures of two or more metals and are formed by mixing molten metals thoroughly. Rarely nonmetals are also mixed with metals to produce alloys.

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It is generally found that alloying produces a metallic substance that has more useful properties than the original pure metals from which it is made. For example, the alloy brass is made from copper and zinc.

12.4.1 Advantages of alloys

- Alloys do not get corroded or get corroded to very less extent.
- They are harder and stronger than pure metals (Example: Gold is mixed with copper and it is harder than pure gold).
- They have less conductance than pure metals (Example: Copper is good conductor of heat and electricity where as brass and bronze are not good conductors).
- Some alloys have lower melting point than pure metals (Example: Solder is an alloy of lead and tin which has lower melting point than each of the metals).
- When metal is alloyed with mercury, it is called amalgam.

Points to Remember

- Dobereiner grouped the elements based on their relative atomic masses in a group of three (triads).
- John Newlands arranged 56 known elements in the increasing order of their atomic mass.
- Dmitri Mendeleev proposed the law of periodicity.
- Mendeleev's Periodic Table has eight vertical columns called 'groups' and seven horizontal rows called 'period'.
- In the modern periodic table all the elements are arranged in the increasing order of their atomic number.
- There are seven periods and 18 groups in the modern periodic table.
- The elements are placed in periods based on the number of shells in their atoms.
- Based on the common characteristics of elements in each group, they are grouped as various families.

A-Z GLOSSARY

Dobereiner's Law of Triads	The atomic mass of the middle element is nearly the same as average of atomic masses of other two elements.
Newlands' Law of Octaves	Every eighth element had properties similar to those of the first element like the eighth note in an octave of music is similar to the first.
Mendeleev's Law of Periodicity	The physical and chemical properties of the elements are the periodic functions of their atomic masses.
Modern Periodic Law	The chemical and physical properties of the elements are the periodic functions of their atomic numbers.
Periods	Horizontal rows in the modern periodic table.
Columns	Vertical columns in the modern periodic table
s block elements	Elements whose valence electrons are added to s subshell.
p block elements	Elements whose valence electrons are filled in p subshells.
d block elements	Elements having their valence electrons in the d subshells.
f block elements	Elements having their valence electrons in the f subshells.

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TEXTBOOK EXERCISES

I. Choose the correct answer.

1. If Dobereiner is related with 'law of triads', then Newlands is related with
   a) Modern periodic law b) Hund's rule
   c) Law of octaves
   d) Pauli's Exclusion principle
2. Modern periodic law states that the physical and chemical properties of elements are the periodic functions of their ___________
   a) atomic numbers b) atomic masses
   c) similarities d) anomalies
3. Elements in the modern periodic table are arranged in _____ groups and _____ periods.
   a) 7, 18 b) 18, 7 c) 17, 8 d) 8, 17

II. Fill in the blanks.

1. In Dobereiner's triads, the atomic weight of the middle element is the __________ of the atomic masses of 1st and 3rd elements.
2. Noble gases belong to __________ group of the periodic table.
3. The basis of the classifications proposed by Dobereiner, Newlands and Mendeleev was __________.
4. Example for liquid metal is __________.

III. Match the following.

Triads	Newlands
Alkali metal	Calcium
Law of octaves	Henry Moseley
Alkaline earth metal	Sodium
Modern Periodic Law	Dobereiner

IV. State whether true or false. If false, correct the statement.

1. Newlands' periodic table is based on atomic masses of elements and modern periodic table is based on atomic number of elements.
2. Metals can gain electrons.
3. Alloys bear the characteristics of both metals and nonmetals.
4. Lanthanides and actinides are kept at the bottom of the periodic table because they resemble each other but they do not resemble with any other group elements.
5. Group 17 elements are named as Halogens.

V. Assertion and reason type questions.

Statement: Elements in a group generally possess similar properties but elements along a period have different properties.

Reason: The difference in electronic configuration makes the element differ in their chemical properties along a period.

a) Statement is true and reason explains the statement.

b) Statement is false but the reason is correct.

VI. Answer the following.

1. State modern periodic law.
2. What are groups and periods in the modern periodic table?
3. What are the limitations of Mendeleev's periodic table?
4. State any five features of modern periodic table.

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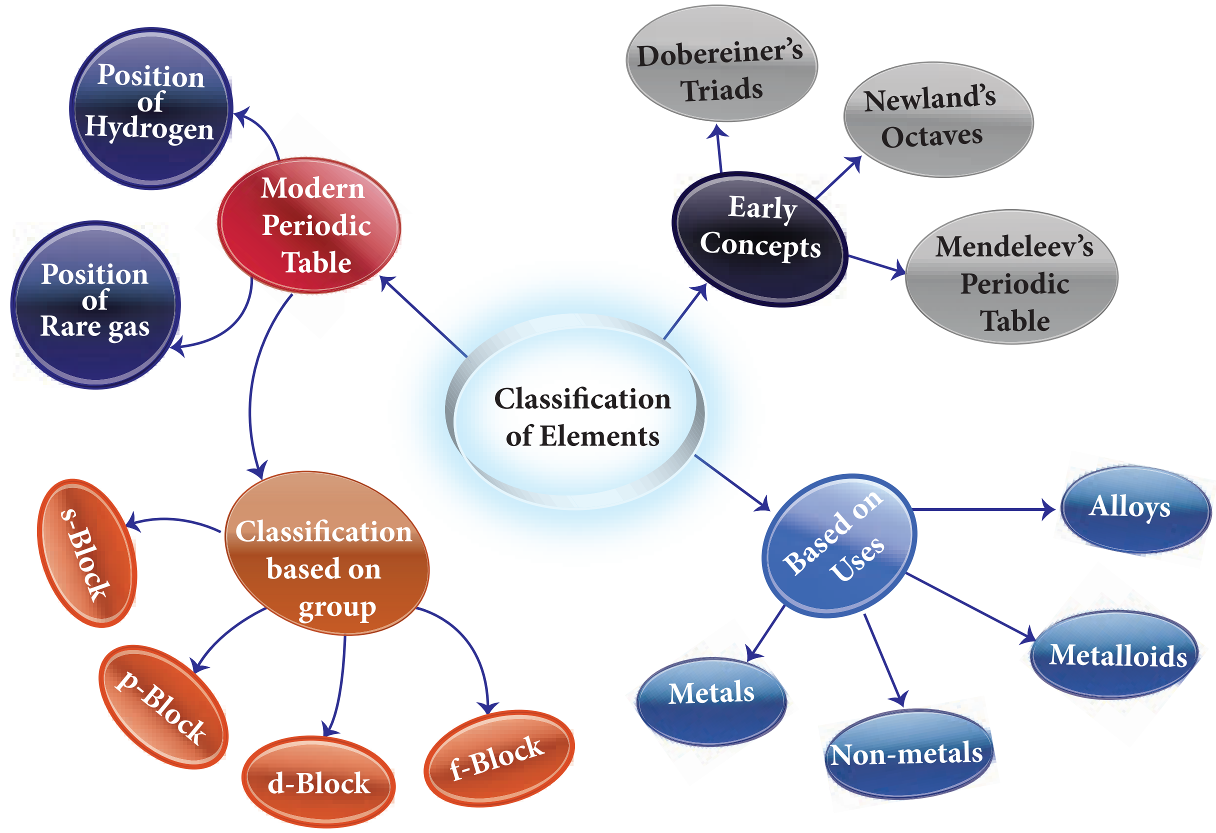
Concept Map



ICT CORNER

Periodic Classification

Steps

1. Type the URL link given below in the browser OR scan the QR code. You can also download the "**Royal society of chemistry**" mobile app from the given app URL.
2. Click the element from the table and explore the properties of the element you want to learn.
3. On the right top corner click option as shown to learn the uses and properties.
4. For every element we can understand the uses and the properties of elements.

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URL: https://play.google.com/store/apps/details?id=org.rsc.periodictable or Scan the QR Code.

UNIT 13

CHEMICAL BONDING

BNZY5H

Learning Objectives

After completing this lesson, student will be able to

- understand how molecules are formed and what is a chemical bond.
- explain Octet rule.
- draw Lewis dot structure of atoms.
- understand different types of bonds.
- differentiate the characteristics of ionic bond, covalent bond and coordinate bond.
- understand redox reactions.
- find out the oxidation number of different elements.

Introduction

We already know that atoms are the building blocks of matter. Under normal conditions no atom exists as an independent (single) entity in nature, except noble gases. However, a group of atoms is found to exist together as one species. Such a group of atoms is called molecule. Obviously there should be a force to keep the constituent atoms together as the thread holds the flowers together in a garland. This attractive force which holds the atoms together is called a bond.

Figure. 13.1 Flowers held together by thread

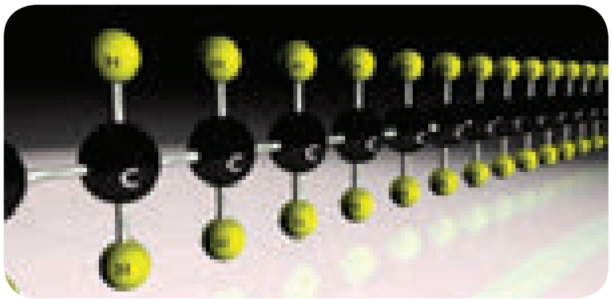

Figure. 13.2 Atoms held together by bond

A chemical bond may be defined as the force of attraction between the atoms that binds them together as a unit called molecule In this unit, we will study about Kossel-Lewis approach to chemical bonds, Lewis dot structure and different types of reactions.

13.1 Kossel – Lewis approach to chemical bonds

13.1.1 Octet rule

Atoms of various elements combine together in different ways to form chemical compounds. This phenomenon raised many questions.

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- Why do atoms combine?
- How do atoms combine?
- Why do certain atoms combine while others do not?

To answer such questions different theories have been put forth from time to time and one of such theories which explained the formation of molecules is Kossel-Lewis theory.

Kossel and Lewis gave successful explanation based upon the concept of electronic configuration of noble gases about why atoms combine to form molecules. Atoms of noble gases have little or no tendency to combine with each other or with atoms of other elements. This means that these atoms must be having stable electronic configurations. The electronic configurations of noble gases are given in Table 13.1.

Table 13.1 The electronic configurations of noble gases

Name of the element	Atomic number	Shell electronic configuration
Helium (He)	2	2
Neon (Ne)	10	2,8
Argon (Ar)	18	2,8,8
Krypton (Kr)	36	2,8,18,8
Xenon (Xe)	54	2,8,18,18,8
Radon (Rn)	86	2,8,18,32,18,8

Except Helium, all other noble gases have eight electrons in their valence shell. Even helium has its valence shell completely filled and hence no more electrons can be added. Thus, by having stable valence shell electronic configuration, the noble gas atoms neither have any tendency to gain nor to lose electrons and hence their valency is zero. They are so inert that they even do not form diatomic molecules and exist as monoatomic gaseous atoms.

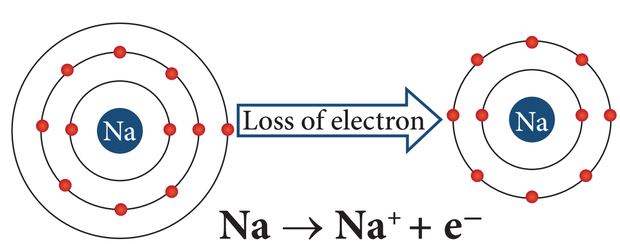
More to Know

The number of electrons lost from a metal atom is the valency of the metal and the number of electrons gained by a non-metal is the valency of the non-metal

Based on the noble gas electronic configuration, Kossel and Lewis proposed a theory in 1916 to explain chemical combination between atoms and this theory is known as 'Electronic theory of valence' or Octet rule. According to this, atoms of all elements, other than inert gases, combine to form molecules because they have incomplete valence shell and tend to attain a stable electronic configuration similar to noble gases. Atoms can combine either by transfer of valence electrons from one atom to another or by sharing of valence electrons in order to achieve the stable outer shell of eight electrons.

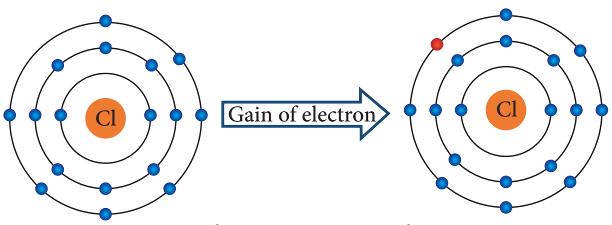
The tendency of atoms to have eight electrons in the valence shell is known as the 'Octet rule' or the 'Rule of eight'

For example, sodium with atomic number 11 will readily loose one electron to attain neon's stable electronic configuration (Figure 13.3). Similarly, chlorine has electronic configuration 2,8,7. To get the nearest noble gas (i.e. argon) configuration, it need one more electron. So, chlorine readily gains one electron from other atom and obtains stable electronic configuration (Figure 13.4). Thus elements tend to have stable valence shell (eight electrons) either by losing or gaining electrons.



$$Na \rightarrow Na^{+} + e^{-}$$

Figure. 13.3 Formation of sodium ion



$$Cl + e^- \rightarrow Cl^-$$

Figure. 5.4 Formation of chloride ion

Which atoms tend to lose electrons? Which are tend to gain electrons? Atoms that have 1, 2, 3 electrons in their valence shell tend to lose electrons whereas atoms having 5, 6, 7 valence electrons tend to gain electrons.

Table 13.2 Unstable electronic configuration

Element	Atomic number	Electron distribution	Valence electrons
Boron	5	2, 3	3
Nitrogen	7	2, 5	5
Oxygen	8	2,6	6
Sodium	11	2, 8, 1	1

13.2 Lewis dot structure

When atoms combine to form compounds, their valence electrons involve in bonding. Therefore, it is helpful to have a method to depict the valence electrons in the atoms. This can be done using Lewis dot symbol method. The Lewis dot structure or electron dot symbol for an atom consists of the symbol of the element surrounded by dots representing the electrons of the valence shell of the atom. The unpaired electron in the valence shell is represented by a single dot whereas the paired electrons are represented by a pair of dots.

Symbols other than dots, like crosses or circles may be used to differentiate the electrons of the different atoms in the molecule.

Table 13.3 Lewis dot structure

Element	Atomic number	Electron distribution	Valence electrons	Lewis dot structure
Hydrogen	1	1	1	H•
Helium	2	2	2	He:
Beryllium	4	2, 2	2	•Be•
Carbon	6	2, 4	4	•Ċ• (one dot on each side)
Nitrogen	7	2, 5	5	•N̈• (pair above, one dot on each other side)
Oxygen	8	2,6	6	:Ö• (pairs on two sides, one dot on each other side)

More to Know

Note that dots are placed one to each side of the letter symbol until all four sides are occupied. Then the dots are written two to a side until all valence electrons are accounted for. The exact placement of the single dots is immaterial.

13.3 Types of chemical bond

All the elements have different valence shell electronic configuration. So the way in which they combine to form compounds also differs. Hence, there are different types of chemical bonding possible between atoms which make the molecules. Depending on the type of bond, they show different characteristics or properties. Such types of bonding, that are considered to exist in molecules, are categorized as shown Figure 13.5. Among these, let us learn about the Ionic bond, Covalent bond and Coordinate bond in this chapter and other types of bond in the higher classes.

13.3.1 Ionic (or) Electrovalent bond

An ionic bond is a chemical bond formed by the electrostatic attraction between positive and negative ions. The bond is formed between two atoms when one or more electrons are transferred from the valence shell of one atom to the valence shell of the other atom. The atom that loses electrons will form a cation (positive ion) and the atom that gains electrons will form an anion (negative ion). These oppositely charged ions come closer to each other due to electrostatic force of attraction and thus form an ionic bond. As the bond is between the ions, it is called ***Ionic bond*** and the attractive forces being electrostatic, the bond is also called ***Electrostatic bond***. Since the valence concept has been explained in terms of electrons, it is also called as ***Electrovalent bond***.

Formation of ionic bond

Let us consider two atoms A and B. Let atom A has one electron in excess and atom B has one electron lesser than the stable octet electronic configuration. If atom A transfer one electron to atom B, then both the atoms will acquire stable octet electronic configuration. As the result of this electron transfer, atom A will become positive ion (cation) and atom B will become negative ion (anion). These oppositely charged ions are held together by electrostatic force of attraction which is called ***Ionic bond*** or ***Electrovalent bond***.

In general, ionic bond is formed between a metal and non-metal. The compounds containing ionic bonds are called ionic compounds. Elements of Group 1 and 2 in periodic table, i.e. alkali and alkaline earth metals form ionic compounds when they react with non-metals.

More to Know

The number of electrons that an atom of an element loses or gains to form an electrovalent bond is called its **Electrovalency**.

Illustration 1 – Formation of ionic bonding in sodium chloride (NaCl)

The atomic number of Sodium is 11 and its electronic configuration is 2, 8, 1. It has one electron excess to the nearest stable electronic configuration of a noble gas - Neon. So sodium has a tendency to lose one electron from its outermost shell and acquire a stable electronic configuration forming sodium cation (Na^+).

The atomic number of chlorine is 17 and its electronic configuration is 2, 8, 7. It has one electron less to the nearest stable electronic configuration of a noble gas - Argon. So chlorine has a tendency to gain one electron to acquire a stable electronic configuration forming chloride anion (Cl^-).

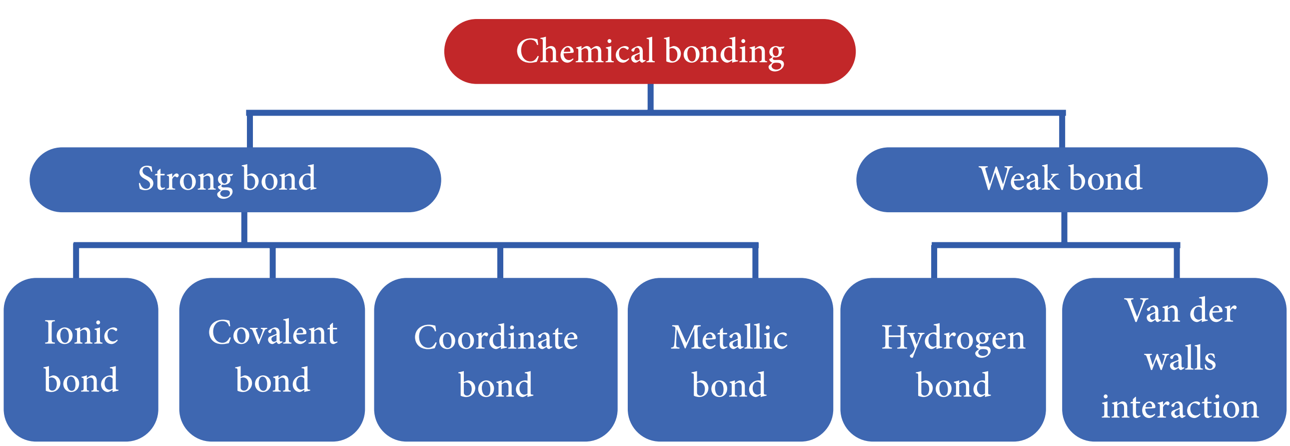
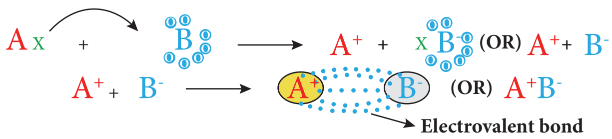


Figure. 13.5 Classification of chemical bond



When an atom of sodium combines with an atom of chlorine, an electron is transferred from sodium atom to chlorine atom forming sodium chloride molecule thus both the atoms attain stable octet electronic configuration.

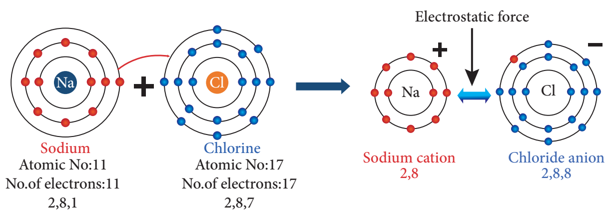


Figure. 13.6 Formation of ionic bond in sodium chloride

Illustration 2 – Formation of ionic bond in magnesium chloride ($MgCl_2$)

The atomic number of magnesium is 12 and the electronic configuration is 2, 8, 2. It has two electron excess to the nearest stable electronic configuration of a noble gas - Neon. So magnesium has a tendency to lose two electrons from its outermost shell and acquire a stable electronic configuration forming magnesium cation (Mg^{2+}).

As explained earlier two chlorine atoms will gain two electrons lost by the magnesium atom forming magnesium chloride molecule ($MgCl_2$) as shown in Figure 13.7.

Characteristics of Ionic compounds

The nature of bonding between the atoms of a molecule is the primary factor that determines the properties of compounds. By this way, in ionic compounds the atoms are held together by a strong electrostatic force that makes the compounds to have its characteristic features as follows:

Physical state: These compounds are formed because of the strong electrostatic force between cations and anions which are arranged in a well-defined geometrical pattern. Thus ionic compounds are crystalline solids at room temperature.

Electrical conductivity: Ionic compounds are crystalline solids and so their ions are tightly held together. The ions, therefore, cannot move freely, and they do not conduct electricity in solid state. However, in molten state their aqueous solutions conduct electricity.

Melting point: The strong electrostatic force between the cations and anions hold the ions tightly together, so very high energy is required to separate them. Hence ionic compounds have high melting and boiling points.

Solubility: Ionic compounds are soluble in polar solvents like water. They are insoluble in non-polar solvents like benzene (C_6H_6), carbon tetra chloride (CCl_4).

Density, hardness and brittleness: Ionic compounds have high density and they are quite hard because of the strong electrostatic force between the ions. But they are highly brittle.

Reactions: Ionic compounds undergo ionic reactions which are practically rapid and instantaneous.

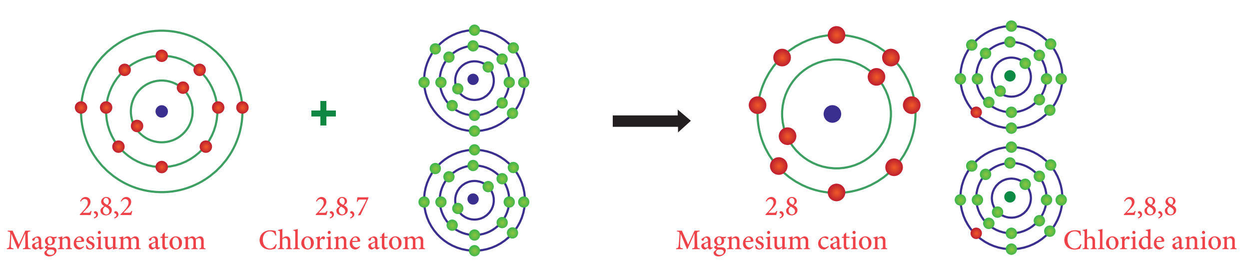


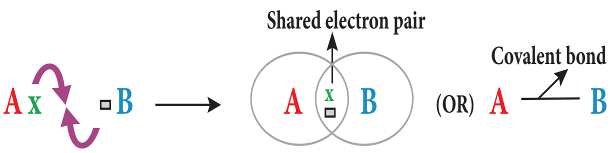
Figure. 13.7 Formation of ionic bond in magnesium chloride

13.3.2 Covalent bond

Atoms can combine with each other by sharing the unpaired electrons in their outermost shell. Each of the two combining atoms contributes one electron to the electron pair which is needed for the bond formation and has equal claim on the shared electron pair. According to Lewis concept, when two atoms form a covalent bond between them, each of the atoms attains the stable electronic configuration of the nearest noble gas. Since the covalent bond is formed because of the sharing of electrons which become common to both the atoms, it is also called as ***atomic bond***.

Formation of Covalent bond

Let us consider two atoms A and B. Let atom A has one valence electron and atom B has seven valence electrons. As these atoms approach nearer to each other, each atom contributes one electron and the resulting electron pair fills the outer shell of both the atoms. Thus both the atoms acquire a completely filled valence shell electronic configuration which leads to stability.



vFigure. 13.8 Schematic representation of covalent bond

More to Know

Covalent bonds are of three types:

1. Single covalent bond represented by a line (—) between the two atoms. Eg. H—H
2. Double covalent bond represented by a double line (=) between the two atoms. Eg. O=O
3. Triple covalent bond represented by a triple line (≡) between the two atoms. Eg. N ≡ N

Illustration 1 – Formation of hydrogen molecule (H_2)

Hydrogen molecule is formed by two hydrogen atoms. While forming the molecule, both hydrogen atoms contribute one electron each to the shared pair and both atoms acquire stable and completely filled electronic configuration (resembly He).

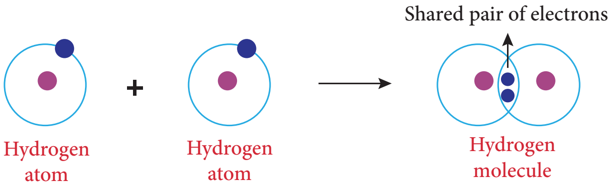


Figure. 13.9 Formation of covalent bond in H_2 molecule

Illustration 2 – Formation of chlorine molecule (Cl_2)

Chlorine molecule is formed by two chlorine atoms. Each chlorine atom has seven valence electrons (2,8,7). These two atoms achieve a stable completely filled electronic configuration (octet) by sharing a pair of electrons.

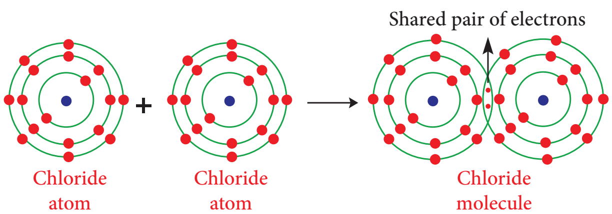


Figure. 13.10 Formation of covalent bond in Cl_2 molecule

Illustration 3 – Formation of methane molecule (CH_4)

Methane molecule is formed by the combination of one carbon and four hydrogen atoms. The carbon atom has four valence electrons (2, 4). These four electrons are shared with four atoms of hydrogen to achieve a stable electronic configuration (octet) by sharing a pair of electrons.

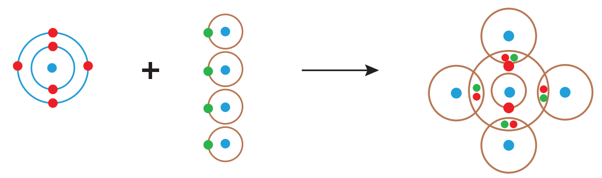


Figure. 13.11 Formation of covalent bond in methane molecule

Illustration 4 – Formation of oxygen molecule (O_2)

Oxygen molecule is formed by two oxygen atoms. Each oxygen atom has six valence electrons (2, 6). These two atoms achieve a stable electronic configuration (octet) by sharing two pair of electrons. Hence a double bond is formed in between the two atoms.

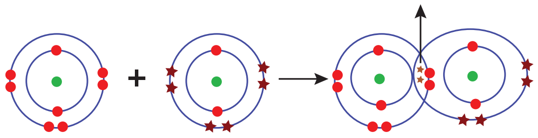


Figure. 13.12 Formation of covalent bond in oxygen molecule

Illustration 5 – Formation of nitrogen molecule (N_2)

Nitrogen molecule is formed by two nitrogen atoms. Each nitrogen atom has five valence electrons (2, 5). These two atoms achieve a stable completely filled electronic configuration (octet) by sharing three pair of electrons. Hence a triple bond is formed in between the two atoms.

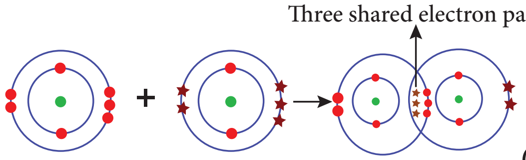


Figure. 13.13 Formation of covalent bond in nitrogen molecule

Characteristics of Covalent compounds

As said earlier, the properties of compounds depend on the nature of bonding between their constituent atoms. So the compounds containing covalent bonds possess different characteristics when compared to ionic compounds.

Physical state: Depending on force of attraction between covalent molecule the bond may be weaker or stronger. Thus covalent compounds exists in gaseous, liquid and solid form. Eg. Oxygen-gas; Water-liquid: Diamond-solid.

Electrical conductivity: Covalent compounds do not contain charged particles (ions), so they are bad conductors of electricity.

Melting point: Except few covalent compounds (Diamond, Silicon carbide), they have relatively low melting points compared to ionic compounds.

Solubility: Covalent compounds are readily soluble in non-polar solvents like benzene (C_6H_6), carbon tetra chloride (CCl_4). They are insoluble in polar solvents like water.

Hardness and brittleness: Covalent compounds are neither hard nor brittle. But they are soft and waxy.

Reactions: Covalent compounds undergo molecular reactions in solutions and these reactions are slow.

More to Know

Polar solvents contain bonds between atoms with very different electronegativities, such as oxygen and hydrogen. Ionic compounds are soluble in polar solvents. Ex: water, ethanol, acetic acid, ammonia

Non polar solvents contain bonds between atoms with similar electro negativities, such as carbon and hydrogen. Covalent compounds are soluble in non-polar solvents. Ex: acetone, benzene, toluene, turpentine

Fajan's Rule:

As we know, a metal combines with a non-metal through ionic bond. The compounds so formed are called ionic compounds. A compound is said to be ionic when the charge of the cation and anion are completely separated. But in 1923, Kazimierz Fajans found, through his X-Ray crystallographic studies, that some of the ionic compounds show covalent character. Based on this, he formulated a set of rules to predict whether a chemical bond is ionic or covalent. Fajan's rules are formulated by considering the charge of the cation and the relative size of the cation and anion.

- When the size of the cation is small and that of anion is large, the bond is of more covalent character
- Greater the charge of the cation, greater will be the covalent character

Ionic	Covalent
Low positive charge	High positive charge
Large cation	Small cation
Small anion	Large anion

For example, in sodium chloride, low positive charge (+1), a fairly large cation and relatively small anion make the charges to separate completely. So it is ionic. In aluminium triiodide, higher is the positive charge (+3), larger is the anion and thus no complete charge separation. So is covalent. The following picture depicts the relative charge separation of ionic compounds:

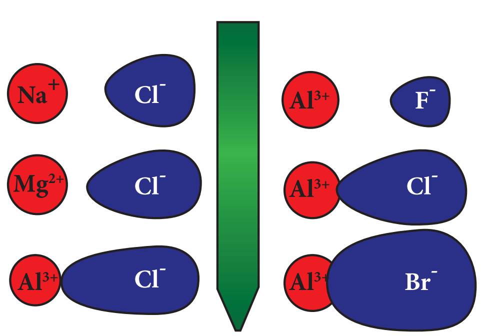


Figure. 13.14 Relatice charge separation of ionic compounds

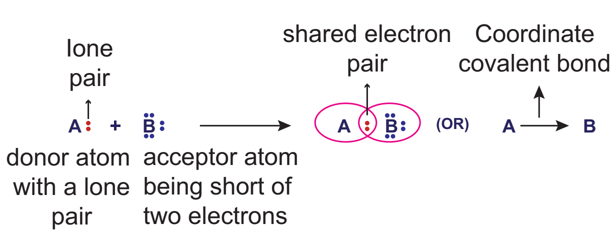
13.3.3 Coordinate covalent bond

In the formation of normal covalent bond each of the two bonded atoms contribute one electron to form the bond. However, in some compounds, the formation of a covalent bond between two atoms takes place by the sharing of two electrons, both of which comes from only one of the combining atoms. This bond is called ***Coordinate covalent bond or Dative bond***.

Mostly the lone pair of electrons from an atom in a molecule may be involved in the dative bonding. The atom which provides the electron pair is called **donor atom** while the other atom which accepts the electron pair is called **acceptor atom**. The coordinate covalent bond is represented by an arrow (→) which points from the donor to the acceptor atom.

Formation of coordinate covalent bond

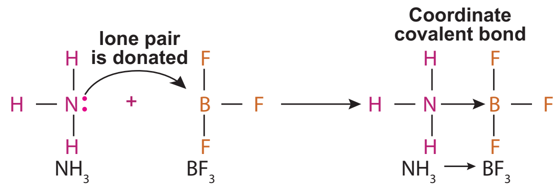
Let us consider two atoms A and B. Let atom A has an unshared lone pair of electrons and atom B is in short of two electrons than the octet in its valence shell. Now atom A donates its lone pair while atom B accepts it. Thus the lone pair of electrons originally belonged to atom A are now shared by both the atoms and the bond formed by this mutual sharing is called Coordinate covalent bond. (A→B)



Examples (NH^{4+}, $NH_3 \rightarrow BF_3$)

Illustration 1 – Formation of coordinate covalent bond between $NH_3 \rightarrow BF_3$ molecules

In some cases, the donated pair of electrons comes from a molecule as a whole which is already formed to another acceptor molecule. Here the molecule ammonia (NH_3) gives a lone pair of electrons to Boron tri fluoride (BF_3) molecule which is electron deficient. Thus, a coordinate covalent bond is formed between NH_3 (donor molecule) and BF_3 (acceptor molecule) and is represented by $NH_3 \rightarrow BF_3$.



Characteristics of coordinate covalent compounds

The compounds containing coordinate covalent bonds are called coordinate compounds.

Physical state: These compounds exist as gases, liquids or solids.

Electrical conductivity: Like covalent compounds, coordinate compounds also do not contain charged particles (ions), so they are bad conductors of electricity.

Melting point: These compounds have melting and boiling points higher than those of purely covalent compounds but lower than those of purely ionic compounds.

Solubility: Insoluble in polar solvents like water but are soluble in non-polar solvents like benzene, CCl_4, and toluene.

Reactions: Coordinate covalent compounds undergo molecular reactions which are slow.

13.4 Oxidation, Reduction and Redox reactions

When an apple is cut and left for sometimes, its surface turns brown. Similarly, iron bolts and nuts in metallic structures get rusted. Do you know why these are happening? It is because of a reaction called oxidation.

Oxidation: The chemical reaction which involves addition of oxygen or removal of hydrogen or loss of electrons is called oxidation.

$2\ Mg + O_2 \rightarrow 2\ MgO$ (addition of oxygen)
$CaH_2 \rightarrow Ca + H_2$ (removal of hydrogen)
$Fe^{2+} \rightarrow Fe^{3+} + e^-$ (loss of electron)

Reduction: The chemical reaction which involves addition of hydrogen or removal of oxygen or gain of electrons is called reduction.

$2\ Na + H_2 \rightarrow 2\ NaH$ (addition of hydrogen)
$CuO + H_2 \rightarrow Cu + H_2O$ (removal of oxygen)
$Fe^{3+} + e^- \rightarrow Fe^{2+}$ (gain of electron)

Redox reactions: Generally, the oxidation and reduction occurs in the same reaction (simultaneously). If one reactant gets oxidised, the other gets reduced. Such reactions are called oxidation-reduction reactions or Redox reactions.

$$2\ PbO + C \rightarrow 2\ Pb + CO_2$$
$$Zn + CuSO_4 \rightarrow Cu + ZnSO_4$$

Oxidation	Addition of oxygen
	Removal of hydrogen
	Loss of electron
Reduction	Removal of oxygen
	Addition of hydrogen
	Gain of electron

Oxidising agents and Reducing agents

Substances which have the ability to oxidise other substances are called oxidising agents.

These are also called as electron acceptors because they remove electrons from other substances.

Example: H_2O_2, MnO_4^-, CrO_3, $Cr_2O_7^{2-}$

Substances which have the ability to reduce other substances are called Reducing agents. These are also called as electron donors because they donate electrons to other substances.

Example: $NaBH_4$, $LiAlH_4$ and metals like Palladium, Platinum.

Oxidation reactions in daily life:

In nature, the oxygen present in atmospheric air oxidises many things, starting from metals to living tissues.

- The shining surface of metals tarnishes due to the formation of respective metal oxides on their surfaces. This is called corrosion.
- The freshly cut surfaces of vegetables and fruits turn brown after some time because of the oxidation of compounds present in them.
- The oxidation reaction in food materials that were left open for a long period is responsible for spoiling of food. This is called Rancidity.

Oxidation number

Oxidation number of an element is defined as the total number of electrons that an atom either gains or loses in order to form a chemical bond with another atom. Oxidation number is also called oxidation state. If the oxidation number is positive then it means that the atom loses electron, and if it is negative it means that the atom gains electrons. If it is zero then the atom neither gains nor loses electrons. The sum of oxidation numbers of all the atoms in the formula for a neutral compound is ZERO. The sum of oxidation numbers of an ion is the same as the charge on that ion. Negative oxidation number in a compound of two unlike atoms is assigned to the more electronegative atom.

More to Know

Electronegativity is the tendency of an atom in a molecule to attract towards itself the shared pair of electrons.

Example:

- Oxidation number of K and Br in KBr molecule is +1 and –1 respectively.
- Oxidation number of N in NH_3 molecule is –3.
- Oxidation number of H is +1 (except hydrides).
- Oxidation number of oxygen in most cases is –2.

Problems on determination of Oxidation Number

ON (Oxidation Number) of neutral molecule is always zero

Illustration 1

Oxidation Number of H and O in H_2O

Let us take ON of H = +1 and ON of O = –2

$2 \times (+1) + 1 \times (-2) = 0$

$(+2) + (-2) = 0$

Thus, ON of H is +1 and ON of O is –2

Illustration 2

Oxidation Number of S in H_2SO_4

Let ON of S be x and we know ON of H = +1 and O = –2

$2 \times (+1) + x + 4 \times (-2) = 0$

$(+2) + x + (-8) = 0$

$x = +6$ Therefore, ON of S is +6

Illustration 3

Oxidation Number of Cr in $K_2Cr_2O_7$

Let ON of Cr be x and we know ON of K = +1 and O = –2

$2 \times (+1) + 2 \times x + 7 \times (-2) = 0$

$(+2) + 2x + (-14) = 0$

$2x = +12$

$x = +6$ Therefore, ON of Cr in $K_2Cr_2O_7$ is +6

Illustration 4

Oxidation Number of Fe in $FeSO_4$

Let ON of Fe be x and we know ON of S = +6 and O = –2

$x + 1 \times (+6) + 4 \times (-2) = 0$

$x + (+6) + (-8) = 0$

$x = +2$ Therefore, ON of Fe in $FeSO_4$ is +2

Problems:

1. Find the oxidation number of Mn in $KMnO_4$
2. Find the oxidation number of Cr in $Na_2Cr_2O_7$
3. Find the oxidation number of Cu in $CuSO_4$
4. Find the oxidation number of Fe in FeO

Points to Remember

- The tendency of atoms to have eight electrons in the valence shell is known as the 'Octet rule' or the 'Rule of eight'.
- The Lewis dot structure or electron dot symbol for an atom consists of the symbol of the element surrounded by dots representing the electrons of the valence shell of the atom.
- There are different types of chemical bonding possible between atoms which make the molecules. Depending on the type of bond they show different characteristics or properties.
- An ionic bond is formed by the electrostatic attraction between positive and negative ions. It is also called as Electrochemical bond.
- The covalent bond is formed because of the sharing of electrons which become common to both the atoms. It is also called as Atomic bond.
- In some compounds the formation of a covalent bond between two atoms takes place by the sharing of two electrons, both of which comes from only one of the combining atoms. This bond is called Coordinate covalent bond or Dative bond.
- Substances which have the ability to oxidise other substances are called Oxidising agents. These are also called as electron acceptors because they remove electrons form other substances.
- Substances which have the ability to reduce other substances are called Reducing agents. These are also called as electron donors because they donate electrons to other substances.
- Oxidation number also called Oxidation State.

A-Z GLOSSARY

Chemical bond	Force of attraction between the two atoms that binds them together as a unit.
Coordinate covalent bond	Bond formed between atoms by mutual sharing of electrons which are supplied by one atom.
Covalent bond	Bond formed between atoms by the mutual sharing of electrons.
Ionic / Electrovalent bond	Bond formed between cation and anion because of the transfer of electrons from one atom to other atom.
Octet rule or Rule of eight	The tendency of atoms to have eight electrons in the valence shell.
Oxidation	Chemical reaction which involves in the addition of oxygen or removal of hydrogen or loss of electrons.
Oxidation number	The formal charge which an atom has when electrons are counted.
Oxidising agents	Substances which have the ability to oxidise other substances.
Redox reaction	Oxidation and reduction occurs in the same reaction simultaneously.
Reducing agents	Substances which have the ability to reduce other substances.
Reduction	Chemical reaction which involves in the addition of hydrogen or removal of oxygen or gain of electrons.

TEXTBOOK EXERCISES

BPIQ97

I. Choose the correct answer.

1. Number of valence electrons in carbon is
   a) 2 b) 4 c) 3 d) 5

2. Sodium having atomic number 11, is ready to ____________________ electron/ electrons to attain the nearest noble gas electronic configuration.
   a) gain one b) gain two
   c) lose one d) lose two

3. The element that would form anion by gaining electrons in a chemical reaction is ________________
   a) potassium b) calcium
   c) fluorine d) iron

4. Bond formed between a metal and non metal atom is usually __________
   a) ionic bond b) covalent bond
   c) coordinate bond

5. _______________ compounds have high melting and boiling points.
   a) Covalent b) Coordinate c) Ionic

6. Covalent bond is formed by __________
   a) transfer of electrons
   b) sharing of electrons
   c) sharing a pair of electrons

7. Oxidising agents are also called as ___________ because they remove electrons form other substances.
   a) electron donors b) electron acceptors

8. Elements with stable electronic configurations have eight electrons in their valence shell. They are ___
   a) halogens b) metals
   c) noble gases d) non metals

II. Answer briefly.

1. How do atoms attain Noble gas electronic configuration?
2. NaCl is insoluble in carbon tetrachloride but soluble in water. Give reason.
3. Explain Octet rule with an example.
4. Write a note on different types on bonds.
5. Correct the wrong statements.
   a. Ionic compounds dissolve in non polar solvents.
   b. Covalent compounds conduct electricity in molten or solution state.
6. Complete the table give below.

Element	Atomic number	Electron distribution	Valence electrons	Lewis dot structure
Lithium	3			
Boron	5			
Oxygen	8			

7. Draw the electron distribution diagram for the formation of Carbon di oxide (CO_2) molecule.
8. Fill in the following table according to the type of bonds formed in the given molecule. $CaCl_2$, H_2O, CaO, CO, KBr, HCl, CCl_4, HF, CO_2, Al_2Cl_6

Ionic bond	Covalent bond	Coordinate covalent bond

9. The property which is characteristics of an Ionic compound is that
   a. it often exists as gas at room temperature.
   b. it is hard and brittle.
   c. it undergoes molecular reactions.
   d. it has low melting point.

10. Identify the following reactions as oxidation or reduction
    a. $Na \rightarrow Na^{+} + e^{-}$
    b. $Fe^{3+} + 2e^{-} \rightarrow Fe^{+}$

11. Identify the compounds as Ionic/Covalent/Coordinate based on the given characteristics.
    a. Soluble in non polar solvents
    b. Undergoes faster/instantaneous reactions
    c. Non conductors of electricity
    d. Solids at room temperature

12. An atom X with atomic number 20 combines with atom Y with atomic number 8. Draw the dot structure for the formation of the molecule XY.

13. Considering $MgCl_2$ as ionic compound and CH_4 as covalent compound give any two differences between these two compounds.

14. Why are Noble gases inert in nature?

III. Answer in detail

1. List down the differences between Ionic and Covalent compounds.

2. Give an example for each of the following statements.
   a. A compound in which two Covalent bonds are formed.
   b. A compound in which one ionic bond is formed.
   c. A compound in which two Covalent and one Coordinate bonds are formed.
   d. A compound in which three covalent bonds are formed.
   e. A compound in which coordinate bond is formed.

3. Identify the incorrect statement and correct them.
   a. Like covalent compounds, coordinate compounds also contain charged particles (ions). So they are good conductors of electricity.
   b. Ionic bond is a weak bond when compared to Hydrogen bond.
   c. Ionic or electrovalent bonds are formed by mutual sharing of electrons between atoms.
   d. Loss of electrons is called Oxidation and gain of electron is called Reduction.
   e. The electrons which are not involved in bonding are called valence electrons.

4. Discuss in brief about the properties of coordinate covalent compounds.

5. Find the oxidation number of the elements in the following compounds.
   a. C in CO_2
   b. Mn in $MnSO_4$
   c. N in HNO_3

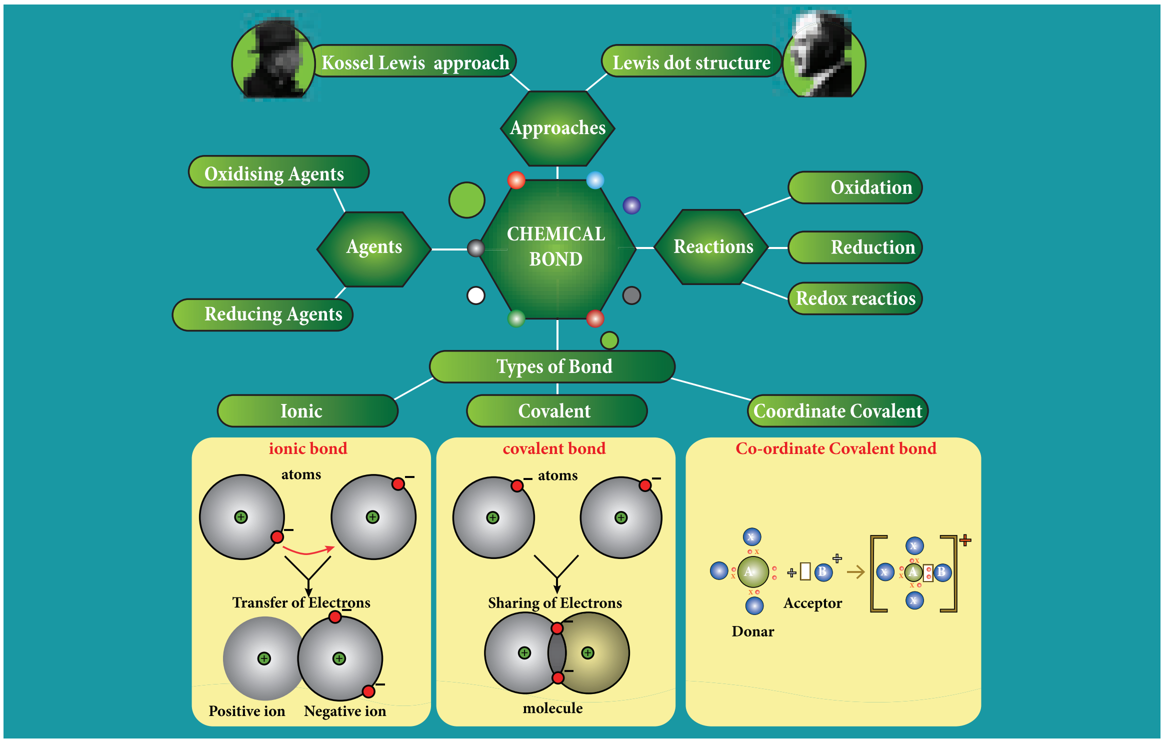
REFERENCE BOOKS

1. Modern Inorganic Chemistry -R.D.Madan.
2. Textbook of Inorganic Chemistry -Soni, P.L. and Mohan Katyal.

INTERNET RESOURCES

1. https://youtu.be/G08rZ6xiIuA
2. https://youtu.be/LkAykOv1foc
3. https://youtu.be/DEdRcfyYnSQ

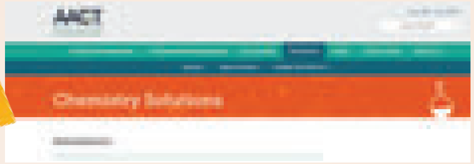
Concept Map



ICT CORNER

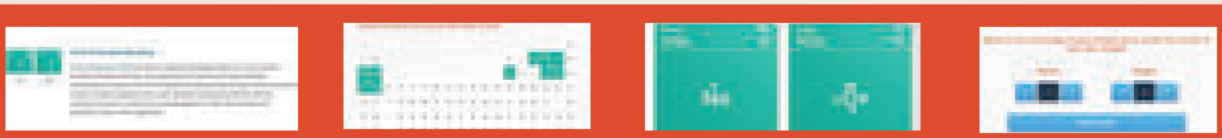
Chemical Bonding

Explore this activity to know about the various types of Chemical bonding in compounds and to learn chemical formulae.



Steps

- Copy and paste the link given below or type the URL in the browser.
- In the Simulations section, scroll down and select Ionic & Covalent Bonding option.
- Select any two elements which are highlighted in the periodic table.
- Once selected, two options called Ionic Bond or Covalent Bond will appear. In it, click any one of the options to find number of atoms option. Select the numbers and submit the answers to verify.



Step1 Step2 Step3 Step4

Browse in the link:

URL: https://teachchemistry.org/periodical/simulations or Scan the QR Code.

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*Pictures are indicative only

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UNIT 14

ACIDS, BASES AND SALTS

Learning Objectives

After completing this lesson, students will be able to

- know about formation, properties and uses of acids, bases and salts.
- know the importance of acids, bases and salts in daily life.
- understand how to identify the nature of a solution by using indicators and pH paper.
- know the strength of acid or base solutions.
- define pH scale and explain the significance of pH in everyday life.
- know aquaregia and its properties.

Introduction

We know that the physical world around us is made of large number of chemicals. Soil, air, water, all the life forms and the materials that they use are all consist of chemicals. Out of such chemicals, acids, bases and salts are mostly used in everyday life. Let it be a fruit juice or a detergent or a medicine, they play a key role in our day-to-day activities. Our body metabolism is carried out by means of hydrochloric acid secreted in our stomach. An acid is a the compound which is capable of forming hydrogen ions (H^+) in aqueous solution whereas a base is a compound that forms hydroxyl ions (OH^-) in solution. When an acid and a base react with each other, a neutral product is formed which is called salt. In this lesson let us discuss about them in detail.

14.1 Acids

Look at the pictures of some of the materials used in our daily life, given below:

All these edible items taste similar i.e. sour. What causes them to taste sour? A certain type of chemical compounds present in them gives sour taste. These are called acids. The word 'acid' is derived from the Latin name "acidus"

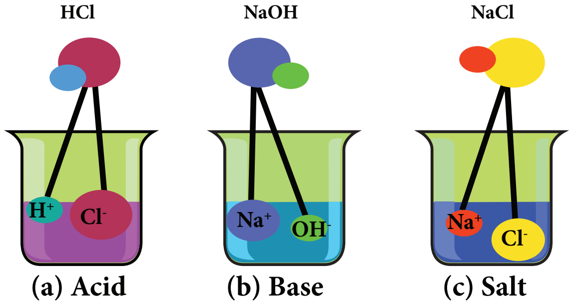

Figure 14.1 Acid, base and salt

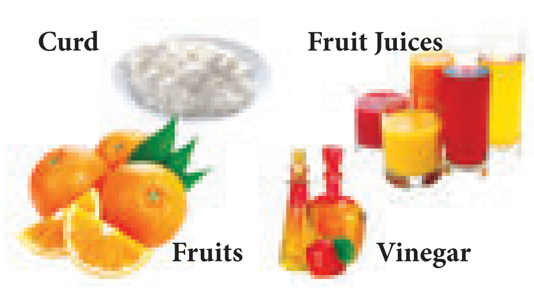

Figure 14.2 Acid, base and salt in food

which means sour taste. Substances with sour taste are called acids.

Table 14.1 Acid and its source

Source	Acid Present
Apple	Malic acid
Lemon	Citric acid
Grape	Tartaric acid
Tomato	Oxalic acid
Vinegar	Acetic acid
Curd	Lactic acid
Orange	Ascorbic acid
Tea	Tannic acid
Stomach juice	Hydrochloric acid
Stings of Ant, Bee	Formic acid

In 1884, a Swedish chemist Svante Arrhenius proposed a theory on acids and bases. According to Arrhenius theory, an acid is a substance which furnishes H^+ ions or H_3O^+ ions in aqueous solution. They contain one or more replaceable hydrogen atoms. For example, when hydrogen chloride is dissolved in water, it gives H^+ and Cl^- ions in water.

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

What happens to an acid or a base in water? Do acids produce ions only in aqueous solution? Hydrogen ions in HCl are produced in the presence of water. The separation of H^+ ion from HCl molecules cannot occur in the absence of water.

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

Hydrogen ions cannot exist alone, but they exist in combined state with water molecules. Thus, hydrogen ions must always be H^+ (or) Hydronium (H_3O^+).

$$H^+ + H_2O \rightarrow H_3O^+$$

DO YOU KNOW?

All acids essentially contain one or more hydrogens. But all the hydrogen containing substances are not acids. For example, methane (CH_4) and ammonia (NH_3) also contain hydrogen. But they do not produce H^+ ions in aqueous solution.

The following table enlists various acids and the ions formed by them in water.

Table 14.2 Ions formed by acids

Acid	Molecular Formula	Ions formed		No. of replaceable hydrogen
Acetic Acid	CH_3COOH	H^+	CH_3COO^-	1
Formic Acid	HCOOH	H^+	$HCOO^-$	1
Nitric Acid	HNO_3	H^+	NO_3^-	1
Sulphuric Acid	H_2SO_4	$2H^+$	SO_4^{2-}	2
Phosphoric Acid	H_3PO_4	$3H^+$	PO_4^{3-}	3

14.1.1 Classification of Acids

Acids are classified in different ways as given below:

(a) Based on their sources:

Organic Acids: Acids present in plants and animals (living things) are organic acids. Example: HCOOH, CH_3COOH

Inorganic Acids: Acids prepared from rocks and minerals are inorganic acids or mineral acids. Example: HCl, HNO_3, H_2SO_4

(b) Based on their Basicity

Monobasic Acid: Acid that contain only one replaceable hydrogen atom per molecule is called monobasic acid. It gives one hydrogen ion per molecule of the acid in solution. Example: HCl, HNO_3

DO YOU KNOW?

For acids, we use the term basicity that refers to the number of replaceable hydrogen atoms present in one molecule of an acid. For example, acetic acid (CH_3COOH) has four hydrogen atoms but only one can be replaced. Hence it is monobasic.

Dibasic Acid: An acid which gives two hydrogen ions per molecule of the acid in solution. Example: H_2SO_4, H_2CO_3

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Tribasic Acid: An acid which gives three hydrogen ions per molecule of the acid in solution. Example: H_3PO_4

(c) Based on Ionisation

Acids get ionised in water (produce H^+ ions) completely or partially. Based on the extent of ionisation acids are classified as below.

Strong Acids: These are acids that ionise completely in water. Example: HCl

Weak Acids: These are acids that ionise partially in water. Example: CH_3COOH.

DO YOU KNOW?

Ionisation is the condition of being dissociated into ions by heat or radiation or chemical reactions or electrical discharge.

(d) Based on Concentration

Concentrated Acid: It has relatively large amount of acid dissolved in a solvent.

Dilute Acid: It has relatively smaller amount of acid dissolved in solvent.

14.1.2 Properties of Acids

a) They have sour taste.

b) Their aqueous solutions conduct electricity since they contain ions.

c) Acids turns blue litmus red.

d) Acids react with active metals to give hydrogen gas.

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2\uparrow$$

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$$

DO YOU KNOW?

Few metals do not react with acid and liberate hydrogen gas. For example: Ag, Cu.

e) Acids react with metal carbonate and metal hydrogen carbonate to give carbon dioxide.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2\uparrow$$

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2\uparrow$$

f) Acids react with metallic oxides to give salt and water.

$$CaO + H_2SO_4 \rightarrow CaSO_4 + H_2O$$

g) Acids react with bases to give salt and water.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The reaction is known as neutralisation reaction.

Activity 1

Take about 10 ml of dilute hydrochloric acid in a test tube and add a few pieces of zinc granules into it. What do you observe? Why are bubbles formed in the solution? Take a burning candle near a bubble containing hydrogen gas, the flame goes off with a 'Popping' sound. This confirms that metal displaces hydrogen gas from the dilute acid.

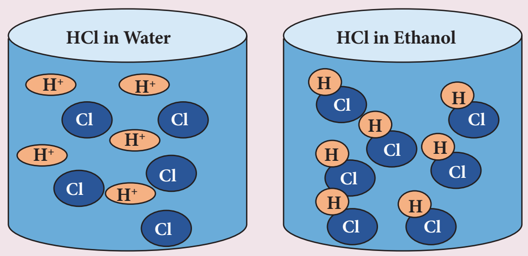
Caution: Care must be taken while mixing any concentrated inorganic acid with water. The acid must be added slowly and carefully with constant stirring to water since it generates large amount of heat. If water is added to acid, the mixture splashes out of the container and it may cause burns.

14.1.3 Uses of Acids

- Sulphuric acid is called King of Chemicals because it is used in the preparation of many other compounds. It is used in car batteries also.
- Hydrochloric acid is used as a cleansing agent in toilets.
- Citric acid is used in the preparation of effervescent salts and as a food preservative.
- Nitric acid is used in the manufacture of fertilizers, dyes, paints and drugs.
- Oxalic acid is used to clean iron and manganese deposits from quartz crystals. It is also used as bleach for wood and removing black stains.
- Carbonic acid is used in aerated drinks.
- Tartaric acid is a constituent of baking powder.

Role of water in acid solution

Acids show their properties only when dissolved in water. In water, they ionise to form H^+ ions which determine the properties of acids. They do not ionise in organic solvents. For example, when HCl is dissolved in water it produces H^+ ions and Cl^- ions whereas in organic solvents like ethanol they do not ionise and remain as molecule.



14.1.4 Aquaregia

We know that metals like gold and silver are not reactive with either HCl or HNO_3. But the mixture of these two acids can dissolve gold. This mixture is called Aquaregia. It is a mixture of hydrochloric acid and nitric acid prepared optimally in a molar ratio of 3:1. It is a yellow-orange fuming liquid. It is a highly corrosive liquid, able to attack gold and other substances.

Chemical formula	:	$3\ HCl + HNO_3$
Solubility in Water	:	Miscible in water
Melting point	:	- 42°C (- 44°F, 231K)
Boiling point	:	108°C (226°F, 381K)

The term aquaregia is a Latin phrase meaning 'King's Water'. The name reflects the ability of aquaregia to dissolve the noble metals such as gold, platinum and palladium.

Uses of Aquaregia

1. It is used chiefly to dissolve metals such as gold and platinum.
2. It is used for cleaning and refining gold.

14.2 Bases

According to Arrhenius theory, bases are substances that ionise in water to form hydroxyl ions (OH^-). There are some metal oxides which give salt and water on reaction with acids. These are also called bases. Bases that are soluble in water are called alkalis. A base reacts with an acid to give salt and water only.

Base + Acid → Salt + Water

For example, zinc oxide (ZnO) reacts with HCl to give the salt zinc chloride and water.

$$ZnO_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_2O_{(l)}$$

Similarly, sodium hydroxide ionises in water to give hydroxyl ions and thus get dissolved in water. So it is an alkali.

$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

Bases contain one or more replaceable oxide or hydroxyl ions in solution. Table 14.3 enlists various bases and ions formed by them in water.

All alkalis are bases but not all bases are alkalis. For example: NaOH and KOH are alkalis whereas $Al(OH)_3$ and $Zn(OH)_2$ are bases.

Table 14.3 Ions formed by bases in water.

Base	Molecular Formula	Ions formed		No. of replaceable hydroxyl ion
Calcium oxide	CaO	Ca^{2+}	O^{2-}	1
Sodium oxide	Na_2O	Na^+	O^{2-}	1
Potassium hydroxide	KOH	K^+	OH^-	1
Calcium hydroxide	$Ca(OH)_2$	Ca^{2+}	OH^-	2
Aluminium hydroxide	$Al(OH)_3$	Al^{3+}	OH^-	3

14.2.1 Classification of Bases

(a) Based on their Acidity

Monoacidic Base: It is a base that ionises in water to give one hydroxide ion per molecule. Example: NaOH, KOH

Diacidic Base: It is a base that ionises in water to give two hydroxide ions per molecule. **Example:** $Ca(OH)_2$. $Mg(OH)_2$

Triacidic Base: It is a base that ionises in water to give three hydroxide ions per molecule. **Example:** $Al(OH)_3$, $Fe(OH)_3$

(b) Based on concentration

Concentrated Alkali: It is an alkali having a relatively high percentage of alkali in its aqueous solution.

Dilute Alkali: It is an alkali having a relatively low percentage of alkali in its aqueous solution.

(c) Based on Ionisation

Strong Bases: These are bases which ionise completely in aqueous solution.
Example: NaOH, KOH

Weak Bases: These are bases that ionise partially in aqueous solution.
Example: NH_4OH, $Ca(OH)_2$

DO YOU KNOW? The term acidity is used for base, which means the number of replaceable hydroxyl groups present in one molecule of a base.

14.2.2 Properties of Bases

a) They have bitter taste.
b) Their aqueous solutions have soapy touch.
c) They turn red litmus blue.
d) Their aqueous solutions conduct electricity.
e) Bases react with metals to form salt with the liberation of hydrogen gas.

$$Zn + 2\,NaOH \rightarrow Na_2ZnO_2 + H_2\uparrow$$

f) Bases react with non-metallic oxides to produce salt and water. Since this is similar to the reaction between a base and an acid, we can conclude that non-metallic oxides are acidic in nature.

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

g) Bases react with acids to form salt and water.

$$KOH + HCl \rightarrow KCl + H_2O$$

The above reaction between a base and an acid is known as Neutralisation reaction.

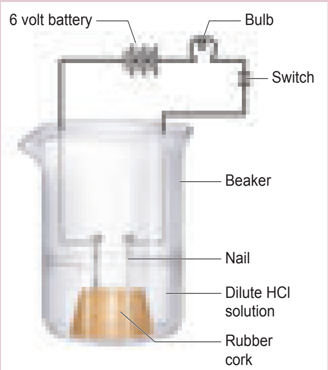
h) On heating with ammonium salts, bases give ammonia gas.

$$NaOH + NH_4Cl \rightarrow NaCl + H_2O + NH_3\uparrow$$

DO YOU KNOW? Few metals do not react with sodium hydroxide. Example: Cu, Ag, Cr

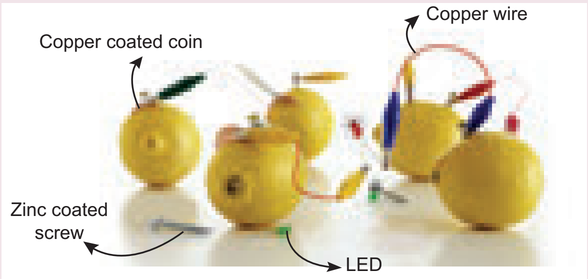
Activity 2

Take solutions of hydrochloric acid or sulphuric acid. Fix two nails on a cork and place the cork in a 100 ml beaker. Connect the nails to the two terminals of a 6V battery through a bulb and a switch as shown in Figure. Now pour some dilute HCl in the beaker and switch on the current. Repeat the activity with dilute sulphuric acid, glucose and alcohol solutions.What do you observe now? Does the bulb glow in all cases?



In the above activity you can observe that the bulb will start glowing only in the case of acids. But, you will observe that glucose and alcohol solution do not conduct electricity. Glowing of the bulb indicates that there is a flow of electric current through the solution. The electric current is carried through the solution by ions. Repeat the same activity using alkalis such as sodium hydroxide and calcium hydroxide.

Try Yourself: Construct a Lemon cell as shown in picture.



14.2.3 Uses of Bases

(i) Sodium hydroxide is used in the manufacture of soap.

(ii) Calcium hydroxide is used in white washing of building.

(iii) Magnesium hydroxide is used as a medicine for stomach disorder.

(iv) Ammonium hydroxide is used to remove grease stains from cloths.

14.3 Tests for Acids and Bases

a) Test with a litmus paper:

An acid turns blue litmus paper into red. A base turns red litmus paper into blue.

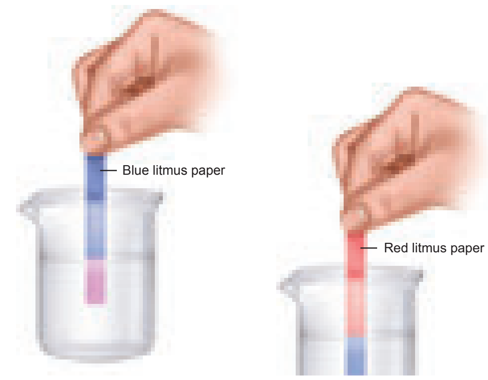


Figure 14.3 Test for acid and base using litmus paper

b) Test with an indicator Phenolphthalein:

In acid medium, phenolphthalein is colourless. In basic medium, phenolphthalein is pink in colour.

c) Test with an indicator Methyl orange:

In acid medium, methyl orange is pink in colour. In basic medium, methyl orange is yellow in colour.

Figure 14.4 Test for acid and base using indicator

Table 14.4 Acid base indicator

Indicator	Colour in acid	Colour in base
Litmus	Blue to Red	Red to Blue
Phenolphthalein	Colourless	Pink
Methyl orange	Pink	Yellow

Activity 3

Collect the following samples from the science laboratory – Hydrochloric acid, Sulphuric acid and Nitric acid, Sodium hydroxide, Potassium hydroxide. Take 2 ml of each solution in a test tube and test with a litmus paper and indicators phenolphthalein and Methyl orange. Tabulate your observations.

Sample Solutions	Litmus Paper		Indicators	
	Blue	Red	Phenolphthalein	Methyl Orange
Hydrochloric acid				
Sulphuric acid				
Nitric acid				
Sodium hydroxide				
Potassium hydroxide				

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14.4 Strenght of Acidic or Basic solutions

pH Scale

A scale for measuring hydrogen ion concentration in a solution is called pH scale. The 'p' in pH stands for 'potenz' in German meaning power. pH scale is a set of numbers from 0 to 14 which is used to indicate whether a solution is acidic, basic or neutral.

- ✓ Acids have pH less than 7
- ✓ Bases have pH greater than 7
- ✓ A neutral solution has pH equal to 7

14.5 Salts

When you say salt, you may think of the common salt. Sea water contains many salts dissolved in it. Sodium chloride is separated from these salts. There are many other salts used in other fields. Salts are the products of the reaction between acids and bases. Salts produce positive ions and negative ions when dissolved in water.

$$\boxed{\text{Acid}} + \boxed{\text{Base}} \rightarrow \boxed{\text{Salt}} + \boxed{\text{Water}}$$

14.5.1 Types of Salts

Normal Salts: A normal salt is obtained by complete neutralization of an acid by a base.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

Acid Salts: It is derived from the partial replacement of hydrogen ions of an acid by a metal. When a calculated amount of a base is added to a polybasic acid, acid salt is obtained.

$$NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O$$

Basic Salts: Basic salts are formed by the partial replacement of hydroxide ions of a diacidic or triacidic base with an acid radical.

$$Pb(OH)_2 + HCl \rightarrow Pb(OH)Cl + H_2O$$

Double Salts: Double salts are formed by the combination of the saturated solution of two simple salts in equimolar ratio followed by crystallization. For example, potash alum is a mixture of potassium sulphate and aluminium sulphate. $KAl(SO_4)_2 \cdot 12H_2O$

14.5.2 Properties of Salts

- ✓ Salts are mostly solids which melt as well as boil at high temperature.
- ✓ Most of the salts are soluble in water. For example, chloride salts of potassium and sodium are soluble in water. But, silver chloride is insoluble in water
- ✓ They are odourless, mostly white, cubic crystals or crystalline powder with salty taste.
- ✓ Salt is hygroscopic in nature.

14.5.3 Water of Crystallisation

Many salts are found as crystals with water molecules. These water molecules are known as water of crystallisation. Salts that contain water of crystallisation are called hydrated salts. The number of molecules of water hydrated to a salt is indicated after a dot in its chemical formula. For example, copper sulphate crystal have five molecules of water for each molecule of copper sulphate. It is written as $CuSO_4.5H_2O$ and named as copper sulphate pentahydrate. This water of crystallisation makes the copper sulphate blue. When it is heated, it loses its water molecules and becomes white.

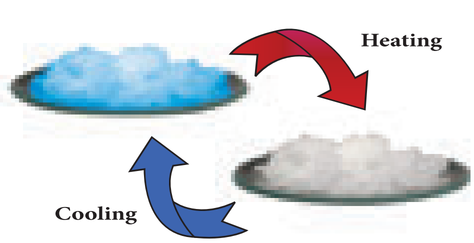


Figure 6.7 Hydrated Salt

Salts that do not contain water of crystallisation are called anhydrous salt. They are generally found as powders. Fill in the blanks in the following table based on the concept of water of crystallisation.

Activity 4

Fill in the blanks in the following table based on the concept of water of crystallisation.

Salt	Formula of anhydrous salt	Formula of hydrated salt	Name of hydrated salt
Zinc sulphate	$ZnSO_4$	$ZnSO_4 . 7H_2O$	
Magnesium chloride	$MgCl_2$		Magnesium chloride hexahydrate
Iron (II) sulphate		$FeSO_4.7H_2O$	Iron (II) sulphate heptahydrate
Calcium chloride	$CaCl_2$	$CaCl_2.2H_2O$	
Sodium thiosulphate	$Na_2S_2O_3$		Sodium thiosulphate pentahydrate

14.5.4 Identification of Salts

(i) Physical examination of the salt.

The physical examination of the unknown salt involves the study of colour, smell and density. This test is not much reliable.

(ii) Dry heating Test.

This test is performed by heating a small amount of salt in a dry test tube. After all the water get evaporated, the dissolved salts are sedimented in the container.

(iii) Flame Test.

Certain salts on reacting with concentrated hydrochloric acid (HCl) form their chlorides. The paste of the mixture with con. HCl is introduced into the flame with the help of platinum wire.

Colour of the flame	Inference
Brick red	Ca^{2+}
Golden Yellow	Na^{+}
Pink Violet	K^{+}
Green Fleshes	Zn^{2+}

(iv) When HCl is added with a carbonate salt, it gives off CO_2 gas with brisk effervescence.

14.5.5 Uses of Salts

Common Salt (Sodium Chloride - NaCl)

It is used in our daily food and used as a preservative.

Washing Soda (Sodium Carbonate-Na_2CO_3)

i. It is used in softening hard water.

ii. It is used in glass, soap and paper industries.

Baking Soda (Sodium bicarbonate -$NaHCO_3$)

i. It is used in making of baking powder which is a mixture of baking soda and tartaric acid.

ii. It is used in soda-acid fire extinguishers.

iii. Baking powder is used to make cakes and bread, soft and spongy.

iv. It neutralizes excess acid in the stomach and provides relief.

Bleaching powder
(Calcium Oxychloride - $CaOCl_2$)

i. It is used as disinfectant.

ii. It is used in textile industry for bleaching cotton and linen.

Plaster of Paris (Calcium Sulphate Hemihydrate - $CaSO_4 .½ H_2O$)

i. It is used for plastering bones.

ii. It is used for making casts for statues.

Activity 5

Boil about 100 ml of ground water in a vessel to dryness. After all the water get evaporated observe the inner wall of the vessel. Can you observe any deposits? This is the deposit of dissolved salts present in water.

Points to Remember

- Acid is a substance which furnishes H^+ ions or H_3O^+ ions when dissolved in water.
- Base is a substance which releases OH^- ions when dissolved in water.
- Salt is the product of reaction between acids and bases.
- Acids and bases neutralize each other to form corresponding salts and water.
- Salts have various uses in everyday life.
- Acidic and basic solutions in water conduct electricity because they produce hydrogen and hydroxide ions respectively.
- When an acid reacts with a metal, hydrogen gas is evolved and a corresponding salt is formed.
- Phenolphthalein and Methyl orange are used as indicators to find out whether the given solution is acid or base.
- Litmus paper is also used to find out whether the given solution is acid or base.
- pH paper is find out the given solution wheth-er acidic or basic in nature.
- Aquaregia is a mixture of hydrochloric acid and nitric acid optimally in a molar ratio of 3:1
- pH Scale is used to find out the power of hy-drogen ion concentration in a solution.

A-Z GLOSSARY

Acids	Substance which furnishes H^+ ions H_3O^+ ions when dissolved in water.
Bases	Substance which furnishes OH^- ions when dissolved in water.
Salts	Product of reaction between acids and bases.
Indicators	Chemical substances used to find out whether the given solution is acid or base.
pH Scale	Scale used to find out Hydrogen ion concentration in a solution.
pH Paper	Paper used to find out whether the given solution is acidie or basic or neutral in nature.
Aquaregia	Mixture of hydrochloric acid and nitric acid prepared optimally in a molar ratio of 3 : 1.
Hygroscopic substance	Substance which absorbs water from the surroundings.

BPXUNK

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. $Zn + 2\ HCl \rightarrow ZnCl_2 + \ldots\uparrow (H_2, O_2, CO_2)$
2. Apple contains malic acid. Orange contains ______ (citric acid, ascorbic acid).
3. Acids in plants and animals are organic acids. Whereas Acids in rocks and minerals are ______ (Inorganic acids, Weak acids).
4. Acids turn blue litmus paper to ______ (green, red, orange).
5. Since metal carbonate and metal bicarbonate are basic, they react with acids to give salt and water with the liberation of ______ (NO_2, SO_2, CO_2).
6. The hydrated salt of copper sulphate has ______ colour (red, white, blue).

II. Answer briefly.

1. Classify the various types of Acids based on their sources.
2. Write any four uses of acids.
3. Give the significance of pH of soil in agriculture.
4. What are the various uses of Aquaregia.
5. What are the uses of Plaster of Paris?
6. Two acids 'A' and 'B' are given. Acid A gives one hydrogen ion per molecule of the acid in solution. Acid B gives two hydrogen ions per molecule of the acid in solution.

(i) Find out acid A and acid B. (ii) Which acid is called the King of Chemicals?

7. Define aquaregia.
8. Correct the mistakes:
   a) Washing soda is used for making cakes and bread soft, spongy.
   b) Calcium sulphate hemihydrate is used in textile industry for bleaching cloths.
9. What is neutralization reaction? Give an example.

III. Answer in detail.

1. Differentiate hydrate and anhydrous salts with examples.
2. Give the tests to identify Acids and Bases.
3. Write any four uses of bases.
4. Write any five uses of salts.
5. Sulphuric acid is called King of Chemicals. Why is it called so?

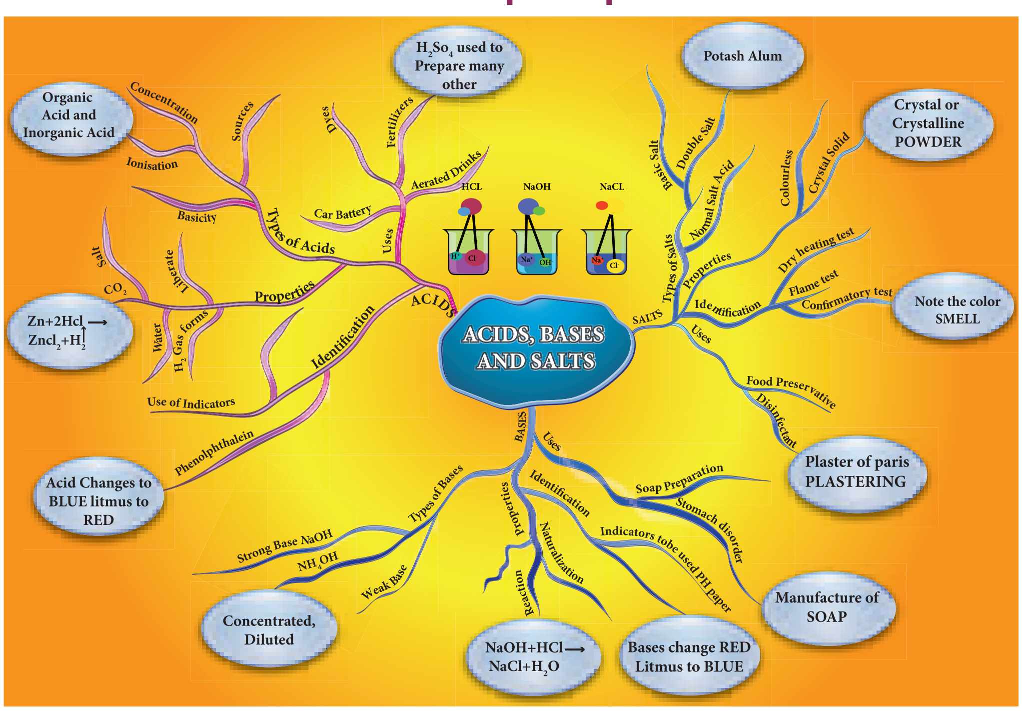
REFERENCE BOOKS

1. Chemistry-Lakhmir Singh & Manjit Kaur
2. Practical Chemistry-Dr. N.K. Verma

INTERNET RESOURCES

1. https:/www.thoughtco.com
2. Aquaregia Wikipedia
3. https:/scienceing.com>Chemistry

Concept Map



ICT CORNER

Acids, Bases and Salts.

Steps

- Type the URL link given below in the browser or scan the QR code. You can view **"Acids and bases"**.
- Click the **'pH meter'** to explore the properties based on the pH value.
- Click the **'pH paper'** to explore the properties based on the colour of pH paper .
- Also you can see the nature of the acids, bases using the conductivity.

Browse in the link:

URL: https://phet.colorado.edu/en/simulation/acid-base-solutions

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UNIT 15

CARBON AND ITS COMPOUNDS

GANQZP

Learning Objectives

After completing this lesson, students will be able to

- explain the special features of carbon.
- know about the isomerism and allotropic forms of carbon compounds.
- differentiate between the properties of graphite and diamond.
- recognise the various inorganic carbon compounds with their uses.
- know the common properties of carbon compounds.
- identify the codes of various plastics.
- understand the effects of plastics on human life and environment.
- know the legal measures to prevent plastic pollution.

Introduction

Carbon is one of the most important **non-metallic** element. Antoine Lavoisier named Carbon from the Latin word **'Carbo'** meaning coal. This is because carbon is the main constituent of coal. Coal is a fossil fuel developed from prolonged decomposition of buried plants and animals. So, it is clear that all the life forms contain carbon. The earth's crust contains only 0.032% of carbon (i.e.320 parts per million by weight) in the form of minerals like carbonates, coal and petroleum and the atmosphere has only 0.03% of carbon dioxide (i.e.300 parts per million by weight). Even though available in small amount in nature, carbon compounds have an immense importance in everyday life.

Carbon is present in our muscles, bones, organs, blood and other components of living matter. A large number of things which we use in our daily life are made up of carbon compounds. So, without carbon there is no possibility for the existence of plants and animals including human. Thus, **Carbon Chemistry** is also called as **Living Chemistry.** In this lesson we will study about the special features of carbon, its properties and also about plastic which are the catenated long chain compounds.

15.1 Discovery of Carbon-Milestones

Carbon has been known since ancient times in the form of soot, charcoal, graphite and diamonds. Ancient cultures did not realize, of course, that these substances were different forms of the same element.

In 1772, French scientist **Antoine Lavoisier** pooled resources with other chemists to buy a diamond, which they placed in a closed glass jar.

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They focused the Sun's rays on the diamond with a remarkable giant magnifying glass and saw the diamond burn and disappear. Lavoisier noted that the overall weight of the jar was unchanged and that when it burned, the diamond had combined with oxygen to form carbon dioxide. He concluded that diamond and charcoal were made of the same element – carbon.

In 1779, Swedish scientist **Carl Scheele** showed that graphite also burned to form carbon dioxide. In 1796, English chemist **Smithson Tennant** established that diamond is pure carbon and not a compound of carbon and it burned to form only carbon dioxide. Tennant also proved that when equal weights of charcoal and diamonds were burned, they produced the same amount of carbon dioxide.

In 1855, English chemist **Benjamin Brodie** produced pure graphite from carbon, proving graphite is a form of carbon. Although it had been previously attempted without success, in 1955 American scientist **Francis Bundy** and his co-workers at 'General Electric' company finally demonstrated that graphite could be transformed into diamond at high temperature and pressure.

In 1985, **Robert Curl, Harry Kroto and Richard Smalley** discovered fullerenes, a new form of carbon in which the atoms are arranged in soccer-ball shapes. **Graphene**, consists of a single layer of carbon atoms arranged in hexagons. Graphene's discovery was announced in 2004 by **Kostya Novoselov and Andre Geim**, who used adhesive tape to detach a single layer of atoms from graphite to produce the new allotrope. If these layers were stacked upon one other, graphite would be the result. Graphene has a thickness of just one atom.

15.2 Compounds of Carbon – Classification

Carbon is found both in free state as well as combined state in nature. In the pre-historic period, ancients used to manufacture charcoal by burning organic materials. They used to obtain carbon compounds both from living things as well as non-living matter. Thus, in the early 19th century, Berzelius classified carbon compounds based on their source as follows:

Organic Carbon Compounds: These are the compounds of carbon obtained from living organisms such as plants and animals. e.g. Ethanol, cellulose, Starch.

Inorganic Carbon Compounds: These are the compounds containing carbon but obtained from non-living matter. e.g. Calcium Carbonate, Carbon Monoxide, Carbon dioxide.

15.2.1 Organic Compounds of Carbon

There are millions of organic carbon compounds available in nature and also synthesized manually. Organic carbon compounds contain carbon connected with other elements like hydrogen, oxygen, nitrogen, sulphur etc. Thus, depending on the nature of other elements and the way in which they are connected with carbon, there are various classes of organic carbon compounds such as hydrocarbons, alcohols, aldehydes and ketones, carboxylic acids, amino acids, etc. You will study about organic carbon compounds in your higher classes.

15.2.2 Inorganic Compounds of Carbon

As compared to organic compounds, the number of inorganic carbon compounds are limited. Among them oxides, carbides, sulphides, cyanides, carbonates and bicarbonates are the major classes of inorganic carbon compounds. Formation, properties and uses of some of these compounds are given in Table 15.1.

15.3 Special Features of Carbon

The number of carbon compounds known at present is more than 5 million. Many newer carbon compounds are being isolated or prepared every day. Even though the abundance

Table 15.1 **Inorganic carbon compounds**

Compounds	Formation	Properties	Uses
Carbon monoxide (CO)	Not a natural component of air. Mainly added to atmosphere due to incomplete combustion of fuels.	Colourless, odourless, highly toxic, sparingly soluble in water.	Main component of water gas ($CO+H_2$). Reducing agent.
Carbon dioxide (CO_2)	Occurs in nature as free and combined forms. Combined form is found in minerals like limestone, magnesite. Formed by complete combustion of carbon or coke.	Colourless, odourless, tasteless Stable, highly soluble in water, takes part in photosynthesis.	Fire extinguisher, preservative for fruits, making bread, to manufacture urea, carbonated water, nitrogenous fertilizers, dry ice in refrigerator
Calcium Carbide (CaC_2)	Prepared by heating calcium oxide and coke.	Greyish black solid.	To manufacture graphite and hydrogen. To prepare acetylene gas for welding.
Carbon disulphide (CS_2)	Directly prepared from Carbon and Sulphur	Colourless, inflammable, highly poisonous gas.	Solvent for sulphur. To manufacture rayon, fungicide, insecticide
Calcium Carbonate ($CaCO_3$)	Prepared by passing Carbondioxide into the solution of slaked lime	Crystalline solid, insoluble in water.	Antacid
Sodium bicarbonate ($NaHCO_3$)	Formed by treating sodium hidroxide with carbonic acid (H_2CO_3)	White crystalline substance, sparingly soluble in water	Preparation of sodium carbonate, baking powder, antacid

of carbon is less, the number of carbon compounds alone is more than the number of compounds of all the elements taken together. Why is it that this property is seen in carbon and in no other elements? Because, carbon has the following unique features.

GAHM2C

15.3.1 Catenation

Catenation is **binding of an element to itself or with other elements through covalent bonds** to form open chain or closed chain compounds. Carbon is the most common element which undergoes catenation and forms long chain compounds. Carbon atom links repeatedly to itself through covalent bond to form linear chain, branched chain or ring structure.

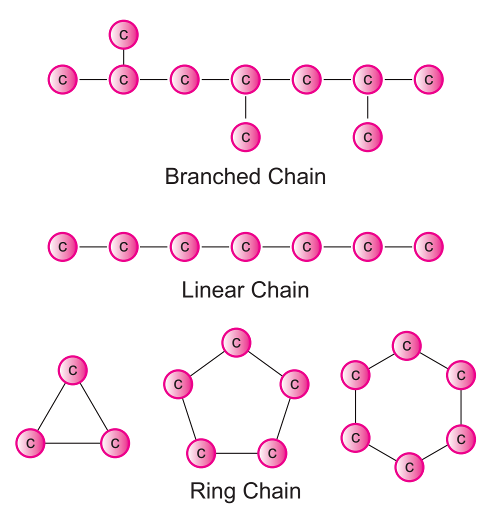


Figure 15.1 Catenation in carbon

This property of carbon itself is the reason for the presence of large number of organic carbon compounds. So organic chemistry essentially deals with catenated carbon compounds.

Activity 1

With the help of your teacher, try to classify the following as organic and inorganic compounds.

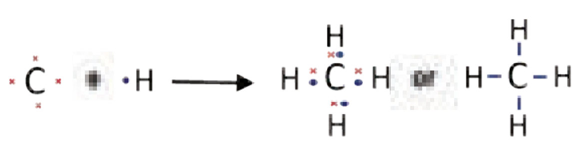
HCN, CO_2, Propane, PVC, CO, Kerosene, LPG, Coconut oil, Wood, Perfume, Alcohol, Na_2CO_3, $CaCO_3$. MgO, Cotton, Petrol.

For example, starch and cellulose contain chains of hundreds of carbon atoms. Even plastics we use in our daily life are macro molecules of catenated carbon compounds.

15.3.2 Tetravalency

Another versatile nature of carbon is its tetravalency. The shell electronic configuration of carbon is 2,4 (Atomic no: 6). It has four electrons in its outermost orbit. According to Octet Rule, carbon requires four electrons to attain nearest noble gas (Neon) electronic configuration. So carbon has the tendency to share its four electrons with other atoms to complete its octet. This is called its **tetravalency.** Thus, carbon can form four covalent bond with other elements.

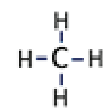
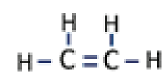
For example, in methane, carbon atom shares its four valence electrons with four hydrogen atoms to form four covalent bonds and hence tetravalent.



15.3.3 Multiple Bonds

As seen above, the tetravalent carbon can form four covalent bonds. With this tetravalency, carbon is able to combine with other elements or with itself through **single bond, double bond and triple bond**. As we know, the nature of bonding in a compound is the primary factor which determines the physical and chemical characteristics of a compound. So, the ability of carbon to form multiple bonds is the main reason for the existance of various classes of carbon compounds. Table 15.2 shows one of such classes of compounds called **'hydrocarbons'** and the type of bonding in them.

Table 15.2 Hydrocarbon

Type of bond	Example	Class of the compound
Single Bond	 Methane	**Alkane**
Double Bond	 Ethene	**Alkene**
Triple Bond	H-C ≡ C-H Ethyne	**Alkyne**

When one or more hydrogen in hydrocarbons is replaced by other elements like O, N, S, halogens, etc., a variety of compounds having different functional groups are produced. You will study about them in your higher class.

15.3.4 Isomerism

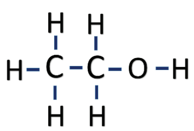
Isomerism is another special feature of carbon compounds especially found in catenated organic compounds. Let us consider the molecular formula of an organic compound C_2H_6O. Can you name the compound? You can't. Because the molecular formula of an organic compound represents only the number of different atoms present in that compound. It does not tell about the way in which the atoms are arranged and hence its structure. Without knowing the structure, we can't name it.

A given molecular formula may lead to more than one arrangement of atoms. Such compounds are having different physical and chemical properties. This phenomenon in which the **same molecular formula may exhibit different structural arrangement** is called isomerism. Compounds that have the same molecular formula but different structural formula are called isomers (Greek, isos = equal, meros = parts).

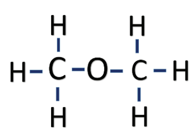
Illustration:

The given formula C_2H_6O is having two kinds of arrangement of atoms as shown below.

(a) CH_3-CH_2-OH



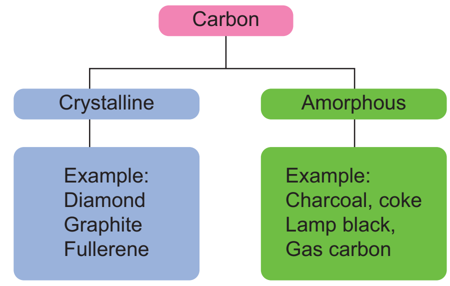
(b) CH_3-O-CH_3



Both the compounds have same molecular formula but different kind of arrangements. In compound 'a', the oxygen atom is attached to a hydrogen and a carbon. It is an alcohol. Whereas in compound 'b', the oxygen atom is attached to two carbon atoms and it is an **ether**. These compounds have different physical and chemical properties. You will study about isomerism in detail in higher classes.

15.3.5 Allotropy

Allotropy is a property by which an element can exist in more than one form that are physically different and chemically similar. The different forms of that element are called its allotropes. The main reason for the existence of allotropes of an element is its method of formation or preparation. Carbon exists in different allotropic forms and based on their physical nature they are classified as below.



(a) Crystalline forms of Carbon

Diamond:

- In diamond, each carbon atom shares its four valence electrons with four other carbon atoms forming four covalent bonds.
- Here the atoms are arranged in repeated **tetrahedral** fashion which leads to a **three dimensional structure accounting** for its hardness and rigidity.

Graphite:

- In graphite, each carbon atom is bonded to three other carbon atoms through covalent bonds in the same plane.
- This arrangement forms hexagonal layers which are held together one over other by weak Vander Waals forces.
- Since the layers are held by weak forces, graphite is softer than diamond.

Fullerene:

- The third crystalline allotrope of carbon is fullerene. The best known fullerene is **Buckminster fullerene,** which consists of 60 carbon atoms joined together in a series of 5- and 6- membered to form spherical molecule resembling a soccer ball. So its formula is C_{60}.
- This allotrope was named as **Buckminster fullerene** after the American architect

Table 15.3 Difference between Diamond and Graphite

Diamond	Graphite
Each carbon has four covalent bonds.	Each carbon has three covalent bonds.
Hard, heavy and transparent.	Soft , slippery to touch and opaque.
It has tetrahedral units linked in three dimension.	It has planar layers of hexagon units.
It is a non-conductor of heat and electricity.	It is a conductor of heat and electricity.

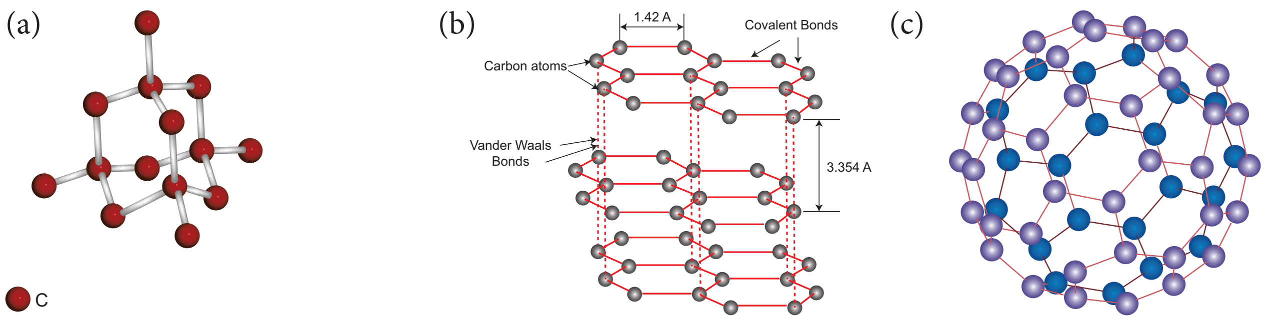


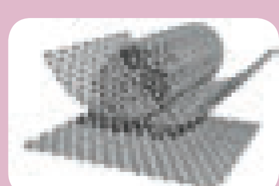
Figure 15.2 Crystalline forms of Carbon

Buckminster **fuller**. Because its structure reminded the framework of **dome shaped halls** designed by Fuller for large international exhibitions, it is called by the pet name **Bucky Ball**. A large family of fullerenes exists, starting at C_{20} and reaching up to C_{540}.

Activity 2

Take a football since it resembles to Buckminster fullerene. Count how many hexagonal and pentagonal panels are in it. Every corner is considered as one carbon. Compare your observation with fullerene and discuss with your friends.

More to Know



Graphene is most recently produced allotrope of carbon which consists of honeycomb shaped hexagonal ring repeatedly arranged in a plane. Graphene is the thinnest compound known to man at one atom thick. It is the lightest material known (with 1 square metre weighing around 0.77 milligrams) and the strongest compound discovered (100-300 times stronger than steel). It is a best conductor of heat at room temperature. Layers of graphene are stacked on top of each other to form graphite, with an inter planar spacing of 0.335 nanometres. The separate layers of graphene in graphite are held together by Vander Waals forces.

(b) Amorphous forms of carbon

In amorphous form of carbon, carbon atoms are arranged in random manner. These form of carbon are obtained when wood is heated in the absence of air. E.g., charcoal

15.4 Physical properties of Carbon and its compounds

- ❖ Carbon is a non-metal found in various allotropic forms from soft powder to hard solid.
- ❖ All the allotropic forms of carbon are solids whereas its compounds exist in solid, liquid and gaseous state.
- ❖ Amorphous forms of carbon and graphite are almost black in colour and opaque. Diamond is transparent and shiny.
- ❖ Its amorphous forms have low melting and boiling point compared to crystalline forms.
- ❖ Carbon is insoluble in water and other common solvents. But some of its compounds are soluble in water and other solvents. e.g., Ethanol, CO_2 are soluble in water.

15.5 Chemical properties of Carbon and its compounds

Elemental carbon undergoes no reaction at room temperature and limited number of reactions at elevated temperatures. But its compounds undergo large number of reactions even at room temperature.

Oxidation – (Reaction with oxygen)

Carbon combines with oxygen to form its oxides like carbon monoxide (CO) and carbon dioxide (CO_2) with evolution of heat. Organic carbon compounds like hydrocarbon also undergo oxidation to form oxides and steam with evolution of heat and flame. This is otherwise called combustion.

$$2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)} + \text{heat}$$

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + \text{heat}$$

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)} + \text{heat}$$

Reaction with steam

Carbon reacts with steam to form carbon monoxide and hydrogen. This mixture is called water gas.

$$C_{(s)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2(g)}$$

Reaction with sulphur

With sulphur, carbon forms its disulphide at high temperature.

$$C_{(s)} + 2S_{(g)} \rightarrow CS_{2(g)}$$

Reaction with metals

At elevated temperatures, carbon reacts with some metals like iron, tungsten, titanium, etc. to form their carbides.

Tungsten + Carbon → Tungsten carbide

$$W + C \rightarrow WC$$

15.6 Carbon compounds in everyday life

It is impossible to think of our daily life without carbon compounds. Over time, a large number of carbon compounds have been developed for the improvement of our lifestyle and comfort. They include carbon-based fuels, carbon nanomaterials, plastics, carbon filters, carbon steel, etc.

Even though carbon and its compounds are vital for modern life, some of its compounds like CO, cyanide and certain types of plastics are harmful to humans. In the following segment, let us discuss the role of plastics in our daily life and how we can become aware of the toxic chemicals that some plastics contain.

15.7 Plastics – Catenated long chain carbon compounds

Plastics are a major class of catenated organic carbon compounds. They are made from long chain organic compounds called 'polymer resins' with chemical additives that give them different properties. Different kinds of polymers are used to make different types of plastics. Plastics are everywhere. They are convenient, cheap and are used in our everyday life. Plastics have changed the way we live. They have helped improve health care, transport and food safety. Plastics have allowed many breakthroughs in technologies such as smartphones, computers and the internet. It is clear that plastic has given our society many benefits. But these benefits have come at a cost.

15.7.1 Drawbacks of plastics

- Plastics take a very long time to fully break down in nature.
- The microbes that break down plastic are too few in nature to deal with the quantity of plastics we produce.
- A lot of plastic does not get recycled and ends up polluting the environment.
- Some types of plastics contain harmful chemical additives that are not good for human health.
- Burning of plastics releases toxic gases that are harmful to our health and contribute to climate change.
- One-time use and throwaway plastics end up littering and polluting the environment.

In order to know which plastics are harmful, you will need to learn the secret 'language' of plastics (resin codes).

15.7.2 Identifying different types of plastics

(a) The resin codes

Look at the following pictures. One is a plastic sachet in which milk is distributed

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to consumers and the other is a plastic food container. Observe the code shown on it (circled). Do you know what this code means? It is called a '**resin code**'. The resin code represents the type of polymer used to make the plastic.

Figure 15.3 Plastic items used in daily life

(b) Need for resin codes

Plastics should be recycled or disposed of safely. Certain types of plastics should be avoided so that they do not end up polluting the environment or harming our health. Each plastic is composed of a different polymer or set of molecules. Different molecules do not mix when plastics are recycled, it is like trying to recycle paper and glass together. For this reason, they need to be separated. The resin codes of plastics were designed in 1988 and are a uniform way of classifying the different types of plastic which help recyclers in the sorting process.

(c) Find in the resin code on plastic items

The secret resin codes are shown as **three chasing arrows in a triangle**. There is a **number in the middle or letters under the triangle** (an acronym of that plastic type). This is usually difficult to find. It can be found on the label or bottom of a plastic item.

The resin codes are numbered from 1 to 7. Resin codes #1 to #6 each identify a certain type of plastic that is often used in products. Resin code #7 is a category which is used for every other plastic (since 1988) that does not fit into the categories #1 to #6. The resin codes look very similar to the recycling symbol, but this does not mean that all plastics with a code can be recycled.

Figure 15.4 Resin codes

(d) Where will the resin code be shown on plastic items?

Flip a plastic item to find the resin code on the bottom.

Sometimes the bottom of plastic item will only have an acronym or the full name of that plastic type.

If you do not find it on the bottom, search for the code on the label.

Some plastics do not have a code. The company did not follow the rules and you do not know if it is safe to use.

15.7.3 Harmful effects of plastics

Plastics in our everyday life can be harmful for two reasons. The first reason is that some types of plastic contain chemicals that are harmful to our health. The second reason is that a lot of plastics are designed to be used just for one time. This use and throwaway plastic causes pollution to our environment.

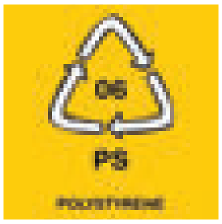
(a) Harmful plastics

There are three types of plastic that use toxic and harmful chemicals. These chemicals are added to plastics to give them certain qualities such as flexibility, strength, colour and fire or UV resistance. The three unsafe plastics are: PVC (resin code #3), PS (resin code #6 also commonly called Thermocol) and PC/ABS (resin code #7).

PVC – Polyvinyl Chloride plastics

- Heavy metals (cadmium & lead) are added to PVC.
- Phthalates (chemical additive) copy our hormones.
- Burning PVC releases dioxins (one of the most toxic chemicals known to humans).

PS – Polystyrene plastics



- Styrene is a building block of this plastic and may cause cancer.
- It takes very long time to break-down (100- 1 million years).
- Higher amounts of toxic styrene leak into our food and drinks when they are hot or oily.

PC – Polycarbonate plastics

- PC plastic contains Bisphenol A (BPA).
- BPA leaks out of PC products used for food and drinks.
- BPA increases or decreases certain hormones and changes the way our bodies work.

ABS – Acrylonitrile Butadiene Styrene

- Styrene causes problems for our eyes, skin, digestive system and lungs.
- Brominated Flame Retardants (BFRs) are often added.
- Studies show that toxic chemicals leak from this plastic.

(b) One-time use plastic

Use and throwaway plastics cause short and long-term environmental damage. Half of all the plastic made today is used for throwaway plastic items. These block drains and pollute water bodies. One-time use plastic causes health problems for humans, plants and animals. Some examples are plastic carry bags, cups, plates, straws, water pouches, cutlery and plastic sheets used for food wrapping.

Figure 15.5 One-time use plastic items

These items take a few seconds to be made in a factory. You will use them for a very short time. Once you throw them away, they can stay in our environment for over a 1,000 years causing plastic pollution for future generations. We need rules and laws to protect people and the environment from plastic pollution.

15.8 New rules to make Tamil Nadu plastic free

As we know, the Government of India is progressively taking various legal initiatives to stop plastic pollution by making some provisions and amendments in the Environment (Protection) Act, 1988. With reference to this act, Government of Tamil Nadu has taken a step forward to ban the usage of some kind of plastic items (Environment and Forests Department, T.N. G.O. No: 84, dated 25/06/2018).

As per the government order cited above, the Tamil Nadu Government has banned the usage of one-time use and throwaway plastics from 1st January 2019. This excellent legislation is designed to protect Tamil Nadu from plastic pollution.

Rules which ban the production, storage, supply, transport, sale and distribution of one-time use plastics are extremely effective. They are successful because they target all sections of society–manufacturer, supplier, shopkeeper and customer. This progressive initiative taken by the State of Tamil Nadu leads by example for the rest of the nation.

You can find below some key aspects of the new rules along with science-based facts why these items have been banned in Tamil Nadu.

15.8.1 Banned items

Plastic carry bags

- Globally we use 2 million plastic bags each minute.
- 97% of plastic bags do not get recycled.
- Animals eat plastic bags by accident as they contain food. A cow was found with over 70 kilos of plastic in its stomach.

Plastic plates

- Dirty plastics (like a used plate) are difficult to recycle.
- Most of the one-time use plates are made from Polystyrene (resin code # 6) which is harmful to our health.
- Plates will be used for just 20 minutes but stay in the environment for over a 1,000 years.

Water pouches

- Water pouches are often littered, increasing plastic pollution.
- The blue print (ink) on the clear plastic pouch decreases the recycling value.
- Once a water pouch is used, it is difficult to recycle as it contains leftover water and gets covered in dirt.

Plastic straws

- Plastic straws are too light and small to be recycled.
- Straws are one of the top 10 items which are found in the plastic pollution in oceans.
- 90% of seabirds have ingested plastics such as straws.

Plastic sheets

- Plastic sheets used on top of plates get dirty and cannot be recycled.
- More chemicals leak from plastic into food when it is hot, spicy or oily.
- Animals such as cows, goats, and dogs eat plastic by accident because it smells like food.

15.9 Role of students in the prevention of plastic pollution

You play a very important role and have the power to minimise plastic pollution. Ask yourself, is this plastic safe or harmful plastic? If it is not a harmful plastic type, is it a one-time use plastic item? These questions and the science-based knowledge will help you to reduce unnecessary plastic pollution.

15.9.1 What can you do to prevent plastic pollution?

- As a student, you can share your scientific knowledge on plastics and their effects with your parents, relatives and friends to make them aware of plastic pollution.
- You can help by teaching them how to avoid harmful plastics by searching for the resin codes.
- You can educate them about the new rules and how important it is to stop one-time use plastics.

15.9.2 Practice in your daily life

- Do not litter the environment by throwing plastic items.
- Do not use Thermocol (resin code #6 PS) for your school projects.
- Do not use one-time use or throwaway plastics like plastics bags, tea cups, Thermocol plates and cups, and plastic straws.
- Do not burn plastics since they release toxic gases that are harmful to our health and contribute to climate change.
- Burning PVC plastic releases dioxins which are one of the most dangerous chemicals known to humans.
- Do not eat hot or spicy food items in plastic containers.
- Segregate your plastic waste and hand this over to the municipal authorities so that it can be recycled.
- Educate at least one person per day about how to identify the resin codes and avoid unsafe plastics (resin code #3 PVC, #6 PS and #7 ABS/PC).

Points to Remember

- ❖ Carbon is an inseparable chemical entity associated with living things.
- ❖ Carbon chemistry is also called as living chemistry.
- ❖ Carbon is found both in free state as well as combined state in nature.
- ❖ Friedrich Wohler is called Father of Modern Organic Chemistry.
- ❖ Carbon atom links repeatedly to itself through covalent bond to form linear chain, branched chain or ring structure.
- ❖ Charcoal, graphite and diamond are the allotropes of carbon.
- ❖ In diamond atoms are arranged in repeated tetrahedral fashion.
- ❖ All the allotropic forms of carbon are solids whereas its compounds exist in solid, liquid and gaseous state.
- ❖ The resin code represents the polymer used in making of plastics. The resin codes are numbered from 1 to 7.
- ❖ One-time use plastic causes health problems for humans, plants and animals.

A-Z GLOSSARY

Allotropes	Different forms of an element.
Allotropy	Property by which an element can exist in more than one form.
Catenation	Binding of an element to itself or with other elements through covalent bonds.
Harmful plastics	Plastic in which toxic and harmful chemicals are used.
Isomerism	Phenomenon in which same molecular formula may exhibit different structural arrangement.
Isomers	Compounds that have same molecular formula but different structural formula.
One-time use plastic	Use and throwaway plastics.
Organic carbon compounds	Compounds of carbon obtained from living organisms.
Plastics	Major class of catenated organic carbon compounds made from liquid polymers called 'resins' added with some additives.
Tetravalency	Tendency of carbon to share its four electrons with that of other atoms to complete its octet.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1 A phenomenon in which an element exists in different modification in same physical state is called
   (a) isomerism (b) allotropy
   (c) catenation (d) crystallinity

2 Carbon forms large number of organic compounds due to
   (a) Allotropy (b) Isomerism
   (c) Tetravalency (d) Catenation

3 Nandhini brings his lunch every day to school in a plastic container which has resin code number 5. The container is made of
   (a) Polystyrene (b) PVC
   (c) Polypropylene (d) LDPE

4 Plastics made of Polycarbonate (PC) and Acrylonitrile Butadiene Styrene (ABS) are made of resin code ________
   (a) 2 (b) 5 (c) 6 (d) 7

5 Graphene is one atom thick layer of carbon obtained from
   (a) diamond (b) fullerene
   (c) graphite (d) gas carbon

6 The legal measures to prevent plastic pollution come under the ______________ Protection Act 1988.
   (a) Forest (b) Wildlife
   (c) Environment (d) Human rights

II. Fill in the blanks.

1. ______________ named carbon.
2. Buckminster Fullerene contains ______ carbon atoms.
3. Compounds with same molecular formula and different structural formula are known as ____________.
4. ________________ is a suitable solven for sulphur.
5. There are ________ plastic resin codes.

III. Match the following.

1. Alkyne	-	Bucky Ball
2. Andre Geim	-	Oxidation
3. C_{60}	-	Graphene
4. Thermocol	-	Triple bond
5. Combution	-	Polystyrene

IV. Answer briefly.

1. Differentiate graphite and diamond
2. Write all possible isomers of C_4H_{10}.
3. Carbon forms only covalent compounds. Why?
4. Define Allotrophy.
5. Why are one-time use and throwaway plastics harmful?

V. Answer in detail.

1. What is catenation? How does carbon form catenated compounds?
2. What are the chemical reactions of carbon?
3. Name the three safer resin codes of plastics and describe their features.

VI. Higher Order Thinking Skills

1. Why do carbon exist mostly in combined state?
2. When a carbon fuel burns in less aerated room, it is dangerous to stay there. Why?
3. Explain how dioxins are formed? Which plastic type they are linked to and why they are harmful to humans?
4. Yugaa wants to buy a plastic water bottle. She goes to the shop and sees four different kinds of plastic bottles with resin codes 1, 3, 5 and 7. Which one should she buy? Why?

REFERENCE BOOKS

1. Modern Inorganic Chemistry by R.D Madan
2. Fundamentals of Organic Chemistry by B.S.Bahl et.al
3. Organic Chemistry by Paula Bruise, 6th Edition

INTERNET RESOURCES

http://www.chemicool.com/elements/carbon.html

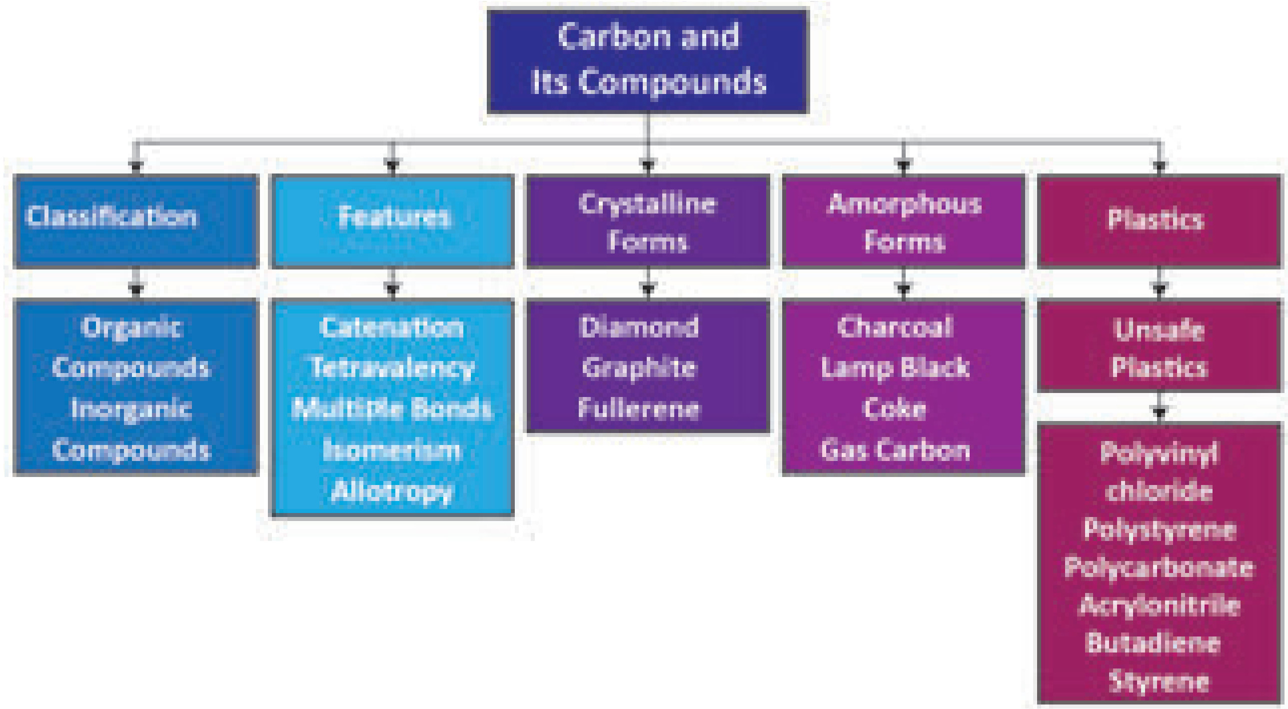
https://en.wikipedia.org/wiki/Carbon

https://courses.lumenlearning.com/introchem/chapter/allotropes-of-carbon/

https://plastics.americanchemistry.com/Plastic-Resin-Codes-PDF/

https://www.youtube.com/watch?v=8Obb982Sg84

Concept Map



ICT CORNER

Carbon

Steps

- Reach the given URL to download and install the “Avogadro” cross platform application in your computer.
- Open the Avogadro application and select carbon from “Element” tab and select the available bond type “Single” or “Double” or “Triple”.
- Place the mouse pointer on the black screen and click and drag the mouse to draw the carbon structure. Extend the bonding by dragging repeatedly. Build the structure of Ethane, Methane etc.
- Select “Auto Rotation” from the tools and rotate the molecular structure by dragging the mouse on the bond. To view various properties of the drawn bonding go to menu View -> Properties.

Avogadro

URL: https://avogadro.cc/ or Scan the QR Code.

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UNIT 16

APPLIED CHEMISTRY

GBFE5H

Learning Objectives

After completing this lesson, students will able to:

- understand the various branches of applied chemistry.
- know the technology of Nanochemistry.
- know the various types of drugs.
- understand the various uses of electrochemistry.
- understand the applications of radiochemistry.
- understand various types of dyes and their application.
- acquire knowledge about food chemistry and agricultural chemistry.
- understand some basic ideas about forensic chemistry.

Introduction

Food, medicines, cosmetics, dress materials and gold covering ornaments are some of the items used in our day to day life. They may differ in nature and applications. But all these are associated with chemistry. They are made of synthetic / natural chemicals.

We face lot of difficulties in different means to lead our day to day life. Such difficulties make chemists to come out of new ideas and theories. For example, when people suffered from diseases, new chemical compounds were synthesized and used as drugs. New techniques were also developed to diagnose diseases. When farmers suffered due to low crop yield and pest-related problems in crop field, chemists developed new chemical fertilizers and pesticides to combat these issues. Thus chemical principles and theories are applied to various fields in order to achieve specific results or to solve real-world problems. This is called **applied chemistry.** In this lesson, let us discuss various branches of applied chemistry and their significance.

16.1 Nanochemistry

We know that the size and shape of materials influence their characteristics. Scientists found that materials having size about 1/1,000,000,000 metre show special characteristics. Then they started producing such kind of materials and studied the effect of size on properties. Thus a new branch of chemistry called 'Nanochemistry' was developed.

Nanochemistry is a branch of nanoscience, that deals with the chemical applications of nanomaterials in nanotechnology. It involves synthesis and manipulation of materials at atomic and molecular level and the study of their physical and chemical properties.

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16.1.1 Size of Nanoparticles

The word, Nano has been derived from the Greek word 'Nanos' which is designated to represent billionth fraction of a unit. For instance, 1 Nanometre = 1/ 1,000,000,000 metre. Can you imagine how small is a nanoparticle?

The following examples may help to illustrate how small the nanoscale is.

- One nanometre (nm) is 10^{-9} or 0.000,000,001 metre.
- A nanometre and a metre can be understood as the same size-difference as between golf ball and the Earth.
- Our nails grow 1 nm each second.
- The virus most usually responsible for the common cold has a diameter of 30 nm.
- A cell membrane is around 9 nm across.
- The DNA double helix is 2 nm across.
- The diameter of one hydrogen atom is around 0.2 nm.

16.1.2 Properties of nanomaterials

Nanomaterials have the structural features in between those of atoms and the bulk materials. The properties of materials with nanometre dimensions are significantly different from those of atoms and bulk materials. This is mainly because the nanometre size of the materials render them, larger surface area, high surface energy, spatial confinement and reduced imperfections, which do not exist in the corresponding bulk materials. As the surface characteristics of nanoparticles are the main criteria to be considered for applications, highly sophisticated instruments like Scanning Electron Microscope (SEM), Tunneling Electron Microscope (TEM) and Atomic Force Microscope (AFM) are used to analyse the surface properties of a nanoparticle with high resolution.

16.1.3 Applications of Nanochemistry

The range of commercial products available today is very broad, including stain-resistant and wrinkle-free textiles, cosmetics, sun screens, electronics, paints and varnishes. Nanochemistry is applied in all these substances. Some of them are given below.

- The metallic nanoparticles can be used as very active catalysts.
- Nano coatings and nanocomposites are found useful in making variety of products such as sports equipment, bicycles and automobiles etc.
- Nanotechnology is applied in the production of synthetic skin and implant surgery.
- Nanomaterials that conduct electricity are being used in electronics as minute conductors to produce circuits for microchips.
- Nanomaterials have extensive applications in the preparation of cosmetics, deodorants and sun screen lotion.
- Nanoparticle substances are incorporated in fabrics to prevent the growth of bacteria.
- Nanochemistry is used in making space, defence and aeronautical devices.

16.1.4 Drawbacks of nanomaterials in chemistry

- Nanoparticles are unstable when they react with oxygen.
- Their exothermic combustion with oxygen can easily cause explosion.
- Because nanoparticles are highly reactive, they inherently interact with impurities as well.
- Nanomaterials are biologically harmful and toxic.
- It is difficult to synthesis, isolate and apply them.
- There are no hard-and-fast safe disposal policies for nanomaterials.

16.2 Pharmaceutical chemistry

Pharmaceutical chemistry is the chemistry of drugs which utilizes the general laws of chemistry to study drugs. Pharmaceutical chemistry deals with preparation of drugs and the study of chemical composition, nature, behavior, structure and influence of the drug in an organism, condition of their storage and the therapeutic uses of the drugs. Drug discovery is the core of pharmaceutical chemistry.

16.2.1 Drugs

Even though we use so many chemicals in our daily life, the chemicals used for treating diseases are termed as **drug.** The word drug is derived from the French word 'droque' which means a dry herb.

According to World Health Organisation, a drug is defined as follows: 'It is a substance or product that is used or intended to be used to modify or explore physiological systems or pathological states for the benefits of the recipient'.

16.2.2 Characteristics of drugs

A drug must possess the following characteristics:

- It should not be toxic.
- It should not cause any side effects.
- It should not affect the receptor tissues.
- It should not affect the normal physiological activities.
- It should be effective in its action.

16.2.3 Sources of drugs

The main sources of drugs are animals and plants. The modern manufacturers adopt many chemical strategies to synthesize drugs for specialized treatments which are more uniform than natural materials. The following table shows various sources of drugs.

Table 16.1 Sources of drugs

Source or Process	Drug
Plants	Morphine, Quinine
Chemical Synthesis	Aspirin, Paracetamol
Animal	Insulin, Heparin
Minerals	Liquid Paraffin
Microorganism	Penicillin
Genetic Engineering	Human growth Hormone

16.2.4 Types of Drugs

Drugs fall into two general categories:

i) The drugs that are used in the treatment and cure of any specific disease.

ii) The drugs that have some characteristic effect on the animal organism, but do not have any remedial effect for a particular disease. This class includes, morphine, cocaine etc.

1. Anaesthetics

The drugs which cause loss of sensation are called **Anaesthetics.** They are given to patients when they undergo surgery.

(a) Types of Anaesthetics

When patients undergo a major surgery in internal organs, some anaesthetics are given so that they lose sensation completely. But when they undergo a minor surgery in a specific part of the body, anaesthetic is given to loose sensation around that particular part. Based on this, there are two classes of anaesthetics as given below.

General anaesthetics: They are the agents, which bring about loss of all modalities of sensation, particularly pain along with 'reversible' loss of consciousness. For example, when a surgery is carried out on internal organs, these anaesthetics are given. The patient loses consciousness for specific period of time (depending on the duration of surgery) and get it back later.

Local anaesthetics: They prevent the pain sensation in localised areas without affecting the degree of consciousness. For example, dentist give patients this kind of anaesthetics when carry out a minor surgery in teeth.

(b) Chemicals as Anaesthetics:

There are three major chemicals which are used as anaesthetics. They are:

Nitrous Oxide (N_2O): It is a colourless, non-irritating, inorganic gas. It is the safest of the anaesthetic agents. This is used after mixing general anaesthetics like ether.

Chloroform ($CHCl_3$): It is a volatile liquid. It has pleasant smell and sweet taste. With oxygen it forms a toxic carbonyl chloride. Hence it is not used now.

Ether: Diethyl ether or simple ether ($C_2H_5–O–C_2H_5$) is a volatile liquid. This is mixed with a stabilizer, 0.002% propyl halide. After absorption by tissues it attacks the central nervous system and makes the patient unconscious.

2. Analgesics

Analgesics are the compounds which relieve all sorts of pains without the loss of consciousness. These are also called as *pain killer* or *pain relievers*. These are effective in healing headaches, myalgia and arthralgia.

Aspirin and Novalgin are the commonly used analgesics. Aspirin acts both as antipyretic as well as analgesic. Certain narcotics (which produce sleep and unconsciousness) are also used as analgesics. The analgesics are given either **orally or applied externally**. In general, externally applicable pain killers come as 'gels'.

3. Antipyretics

Antipyretics are the compounds which are used for the purpose of reducing fever (lowering the body temperature to the normal). They are taken orally as tablets and capsules. The most common antipyretics are, aspirin, antipyrine, phenacetin, and paracetamol.

4. Antiseptics

Antiseptic is a substance that prevents infections caused by disease causing microorganisms or pathogens. Antiseptics either kill the micro-organism or prevent their growth. Antiseptics are used externally to cleanse wounds and internally to treat infections of the intestine and bladder.

- Iodoform (CHI_3) is used as an antiseptic and its 1% solution is a disinfectant.
- 0.2 % solution of phenol acts as an antiseptic and its 1% solution is a disinfectant.
- Hydrogen peroxide is a minor antiseptic mainly used for cleansing wounds.

5. Antimalarial

Malaria is a vector borne disease which causes shivering and fever. It raises the body temperature to 103-106 °F. It causes **physical weakness** with the side-effects in liver and also causes **aneamia**.

Extracts of roots and stems of certain plants are extensively used as antimalarial. Quinine is a natural antimalarial obtained from Cinchona bark. The last antimalarial discovered in 1961 is pyrimethamine. However, quinine, primaquine and chloroquine are some of the best antimalarials. Chloroquine is used specially to control malarial parasites such as plasmodium ovale, plasmodium vivax etc. It is not used in curing the disease. It is used as an additive with other antimalarial drugs.

Figure 16.1 Cinchona Bark

6. Antibiotics

Many microorganisms (bacteria, fungi and molds) produce certain chemicals which inhibit the growth or metabolism of some other disease causing micro organisms. Such chemical compounds are known as *antibiotics*. These need to be present only in low concentration to be effective in their antibiotic action. The first antibiotic 'penicillin' was discovered by Alexander Fleming in 1929, from the mold Penicillium notatum. Penicillin is extensively used for rheumatic fever, narrowing of heart wall, bronchitis, and pneumonia etc.

There are three main sources of antibiotics: (i) Bacteria (ii) Fungi and (iii) Actinomycetes. The original antibiotics, like a lot of today's antibiotics, are derived from natural sources. Certain plant extracts, essential oils, and even foods have antibiotic properties. Example: Honey, garlic, ginger, clove, neem and turmeric.

7. Antacids

Quite often, after eating oily and spicy food, one may feel uncomfortable due to some burning sensation in stomach / food pipe. This is due to imbalance in the acidity in the stomach. Certain drug formulations provide relief from such burning sensation. These are known as **antacids.** Antacids are available in tablet as well as gel / syrup forms. These antacids contain magnesium and aluminium hydroxides, in addition to flavouring agents and colour.

16.3 Electrochemistry

We use so many electronic devices like mobile phone, and electrical devices like torch light, in our daily life. Electricity produced by the battery is the key factor which makes these devices to function. But how does battery produce electricity? Because it contains some chemicals in it. The chemical reactions (chemical energy) that take place in the battery produce electricity (electrical energy). So, when scientists realized that chemical energy can be converted into electrical energy and vice versa, another branch of applied chemistry was developed. It is **Electrochemistry.**

Electrochemistry is a branch of chemistry which deals with the relation between electrical energy and chemical change. It is mainly concerned with the processes taking place between the electrode and solution having ions called **electrolyte**.

16.3.1 Electrochemical Cell

So many chemical reactions take place around us. Do all they produce electricity? No. Only redox reactions that take place in a specific device can produce electricity. The device that make use of a chemical change to produce electricity or electricity to produce chemical change is called **Electrochemical Cell.**

(a) Components of Electrochemical Cell

An electrochemical cell may comprise of the following two major components.

Electrode: It is a solid electrical conductor made of metal (sometimes non-metal like graphite). A cell consists of two electrodes. One is called **Anode** and the other is called **Cathode.**

Electrolyte: It is made up of solutions of ions or molten salts which can conduct electricity.

(b) Cell reactions

An electrochemical cell involves two reactions simultaneously.

Oxidation: As we know already, an oxidation is **loss of electron**. In electrochemical cells, oxidation takes place at anode.

Metal → Metal ion + electron (e^-)

Reduction: It involves gain of electron. Reduction takes place at cathode

Metal ion + electron (e^-) → Metal

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Since both the reactions take place simultaneously, the inter conversion of electrical and chemical energy in electrochemical cells involves a **redox reaction.**

(c) Types of Electrochemical Cell

Based on the nature of the energy conversion, electrochemical cells are broadly classified as below.

Galvanic Cell

- It is an electrochemical cell which converts chemical energy into electrical energy i.e. it produces electricity from chemical reactions.
- It consists of two half cells namely **anodic half-cell** and **cathodic half-cell.**
- In anodic half-cell, the anode is in contact with its electrolyte whereas in cathodic half-cell, the cathode is in contact with its electrolyte.
- The anode and cathode are connected by a conductor wire. The electrolytes of half-cells are connected through a tube containing a saturated salt solution. It is called **salt bridge**. Thus in galvanic cell, both the half-cells are kept separately but stay connected electrically.

How does a galvanic cell produce electricity?

At anode, oxidation takes place which releases electrons. These electrons are attracted by cathode and hence the electrons flowing from anode to cathode are gained in reduction reaction. As long as the redox reaction proceeds, there is a flow of electrons and hence electricity.

Activity 1

With the help of your teacher, construct the galvanic cell using lemon and potato. Identity their anode, cathode and electrolyte.

Electrolytic Cell

- It is an electrochemical cell which converts electrical energy into chemical energy i.e. in electrolytic cells, electricity is used to bring about chemical reactions.
- Here, both anode and cathode are in contact with same electrolyte and thus the half-cells are not separated. As seen in galvanic cells, electrolytic cell also involves redox reaction.

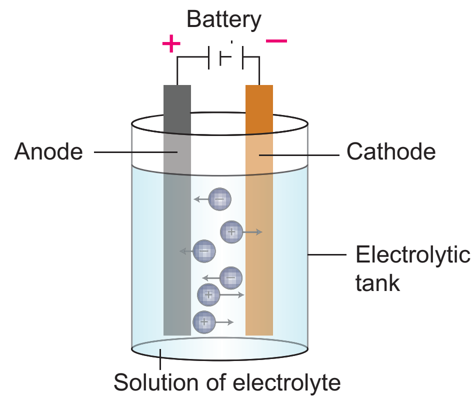


Figure 16.2 Electrolytic Cell

We get electricity from galvanic cells. But electrolytic cells use electricity. Then how are they useful?

In electrolytic cells, when electricity is passed to the electrolyte, it dissociates into its constituent ions. These ions undergo redox reaction forming the respective elements. This phenomenon is called **Electrolysis.** So, electrolysis is a process by which an electrolyte is decomposed into its constituent elements by passing electricity through its aqueous solution or fused (molten) state.

(b) Significance of electrochemistry

The subject of electro chemistry is of great significance. Some of its applications are given below.

i. It has been used to discover important technical processes for the production and purification of non-ferrous metals, and for the electro- synthesis of organic compounds.

ii. Electrochemistry is used to predict whether a particular reaction will occur or not.

iii. The detection of alcohol in drunken drivers is possible through the electrochemical redox reaction of ethanol.

iv. Production of metals like aluminum and titanium from their ores involve electrochemical reactions.

v. Lead acid batteries, lithium-ion batteries and fuel cells are based on electrochemical cells. Fuel cell is used to bring about direct conversion of chemical energy into electrical energy.

16.4 Radiochemistry

You have studied in previous chapters that elements can exist in nature as their isotopes. Isotopes are atoms with same number of protons and electrons and a different number of neutrons. Some isotopes are stable and stay forever. These are the elements that we see around us and find in nature. However, some isotopes are unstable and they undergo disintegration by losing their energy in the form of radiation. As we studied earlier, every element tries to attain stability by sharing, losing or gaining electrons (octet rule). Thus, the unstable isotopes of elements lose their energy in the form of radiation to become stable.

This phenomenon is called **radioactive decay**. The isotope which undergoes radioactive decay is called **radioactive isotope** or **radioisotope**. This property of isotopes is known as **radioactivity**.

DO YOU KNOW?

Uranium in the ground can decay into radon gas which can be very dangerous to humans. It is thought to be the second leading isotope to cause lung cancer.

Radiochemistry is the study of chemistry of radioactive and non-radioactive isotopes. It includes both natural and artificial isotopes. Radiochemistry mainly deals with application of radioisotopes to study the nature of chemical reactions of non-radioactive isotopes of elements and applications of radioisotopes to various fields.

16.4.1 Applications of Radiochemistry

Radioisotopes can easily be detected and estimated quantitatively. So they are used in radiochemistry for various applications. Radiochemistry mainly deals with study of chemical reactions of non-radioactive isotopes using radioisotopes. In addition to that it could find applications in medical field and environmental management also. Let us list important applications of radioisotopes.

Radiocarbon dating: It is a method by which the age of fossil wood or animal is determined using C-14 isotope.

Diagnosis: Radioisotopes are found very useful to diagnose and understanded many diseases.

Table 16.2 Radioisotope in Diagnosis

Radioisotope	Diagnosis used for
Iodine-131	Location and detection of brain tumor, thyroid gland disorder.
Sodium-24	Location of blood clot and circulation disorders, pumping action of heart.
Iron-59	Diagnosis of anaemia, pregnancy disorder.
Cobalt-60	Diagnosis of cancer.
Hydrogen-3	Water content of the human body.

Radiotherapy: Radioactive isotopes are used in the treatment of many diseases. This kind of treatment is called radiotherapy.

Table 16.3 Radioisotope in Treatment

Radioisotope	Treatment used for
Gold-198	Cancer
Iodine-131	Hyperthyroidism and cancer
Phosphorous-32	Blood disorder and skin disease
Cobalt-60	Cancer

16.5 Dye Chemistry

Human is always fascinated by colours, because we are living in a colourful world. We could see so many colours in plants and their flowers. We eat coloured food stuffs and use numerous coloured materials in our daily life. Do you know how do they get coloured? Because they contain some kind of chemicals in them which are called colourants.

The uses of colourants by mankind for painting and dyeing dates back to the dawn of civilization. Until the middle of the 19th century, all colourants applied were from natural origin. For example, inorganic pigments such as soot, manganese oxide, hematite were used as colourants. Organic natural colourants have also a timeless history of application, especially for colouring textiles. The organic compounds that are used as colourants are called **dyes**. These dyes are all aromatic compounds, originating from plants and also from insects, fungi and lichens.

After the evolution of modern organic chemistry, many kinds of synthetic dyes were prepared and used by mankind. **Dye chemistry** is the study of such kind of dyes. It provides us information on theory, structure, synthesis and applications of synthetic dyes.

16.5.1 Characteristics of Dyes

All coloured compounds are not dyes. Dyes are those coloured compounds which can be firmly fixed in fabrics by chemical or physical bonding. So, a dye should have the following characteristics:

- It should have a suitable colour.
- It should be able to fix itself or be capable of being fixed to the fabric.
- It should be fast to light.
- It should be resistant to the action of water, dilute acids and alkalies.

16.5.2 Classification of dyes

Now a days, practically all the dyes are synthetic, and are prepared from aromatic compounds obtained from coal tar. Therefore, such dyes are sometimes called as coal tar dyes. But, they may differ in their basic structure and the way of application. So, dyes are classified in two ways: one, based on the method of application and other based on their parent structure.

(a) Based on method of application

Acid dyes: These are acidic in nature and used for dyeing animal fibres and synthetic fibres. These can be used for protein fibres such as wool and silk. E.g. Picric acid, Naphthol yellow-s

Basic dyes: These are basic dyes containing basic group (-NH_2,- NHR, - NR_2). They are used for dyeing animal fibres and plant fibres.

Mordant dyes or Indirect dyes: These dyes have a poor affinity for cotton fabrics and hence do not dye directly. They require pretreatment of the fibre with a mordant. Mordant (latin : mordere = to bite) is a substance which can be fixed to the fibre and then can be combined with the dye to form an insoluble complex called lake. Aluminium, chromium, and iron salts are widely used as mordants. E.g. alizarin.

Direct dyes: They have high affinity for cotton, rayon and other cellulose fibre. So, they are applied directly as they fix firmly on the fabric. E.g. Congo red

Vat dyes: It can be used only on cotton and, not on silk and wool. This dyeing is a continuous process and is carried out in a large vessel called vat. So, it is called as vat dye. E.g. Indigo

Figure 16.3 Vat dyes

(b) Based on Structure

Based on the structure, dyes are classified as:

- Azo dyes
- Diphenyl methane dye
- Triphenyl methane dye
- Phthalein dye
- Anthraquinone dye
- Indigo dyes
- Phthalo cyanine dye
- Nitro and nitroso dyes

16.6 Agricultural and Food Chemistry

16.6.1 Agricultural Chemistry

Agricultural chemistry involves the application of chemical and biochemical knowledge to agricultural production, processing of raw materials into foods and beverages, and environmental monitoring and remediation. It deals with scientific relation between plants, animals, bacteria and environment.

(a) Goals of agricultural chemistry

Indian chemists and biochemists applied their knowledge and developed modernized agricultural practices which involve use of synthetic fertilizers, genetically modified crops, and equipments. It aims at producing sufficient nutritious food and feed the population in a sustainable way while being responsible stewards of our environment and ecosystem. Based on the issues and challenges in agricultural production, agricultural chemistry mainly focusses to achieve the following:

- Increase in crop yield and livestock
- Improvement of food quality
- Reducing cost of food production

(b) Applications of Agricultural Chemistry

Chemical principles and reactions are most widely used in agriculture in order to increase yield, to protect crops from diseases and to simplify the practice of agriculture. Various applications are give below.

Soil Testing: Crop lands may have different kinds of soil with varying pH. Soil pH is one of the main criteria to be considered for the selection of crop or remediation of soil. Soil testing involves determination of pH, porosity and texture.

Chemical Fertilizers: Fertilizers are chemical compounds added to crop field for supplying essential micro and macro nutrients required for crop growth. Ammonium nitrate, calcium phosphate, urea, NPK (Nitrogen, Phosphorous and Potassium), etc. are some of the fertilizers. Depending on the nature of soil, these fertilizers are used singly or as mixtures.

Pesticides and Insecticides: Crops are prone to diseases caused by pests and insects. Chemically synthesized pesticides and insecticides are used to solve these issues. Chlorinated hydrocarbons, organophosphates and carbamates are used as pesticides and insecticides.

16.6.2 Food Chemistry

Food is one of the basic needs of human and animal. The food we eat also are made of chemicals. Any human might require the following three kinds of food:

Body building foods: These are required for physical growth of body. E.g. Proteins

Energy giving foods: These are the foods that supply energy for the functioning of parts human body. E.g. Carbohydrates and Fats.

Protective foods: These protect us from deficiency diseases. E.g. Vitamins and Minerals

Every human requires all these three kind of foods in right proportion for the smooth functioning of the body. The diet that contain all these three foods in right proportion is called **Balanced diet**.

Food chemistry is the chemistry of foods which involves the analysis, processing, packaging, and utilization of materials including bioenergy for food safety and quality.

(a) Goals of food chemistry

The main goal of food chemistry is to cater the needs of quality food to the population in a sustainable way. In basic research, food chemists study the properties of proteins, fats, starches, and carbohydrates, as well as micro components such as additives and flavourants, to determine how each works in a food system. In application research, they often develop new ways to use ingredients or new ingredients altogether, such as fat or sugar replacements.

(b) Chemicals in Food

Food we eat in our day to day life contains natural or synthetic chemicals. They serve different functions in human body.

Nutrients: They are the most essential chemicals present in food. They are required for the growth, physiological and metabolic activities of body. They are natural or synthetic. E.g. Carbohydrates, proteins, vitamins and minerals.

Food additives: These are the chemicals added to food for specialized functions. The various types of additives of foods are given in Table 16.4.

DO YOU KNOW?

40% of today's global population works in agriculture, making it the single largest employment in the world.

16.7 Forensic Chemistry

Forensic chemistry applies scientific principles, techniques, and methods to the investigation of crime. Our daily newspaper is carrying a lot of news on incidents of criminal activities such as robbery, murder, sexual harassment, etc. How the crime department investigate and analyse it? In real life the collection and analysis of evidence involve painstaking care and rigorous application of scientific principles.

Figure 16.4 Crime detection

16.7.1 Forensic Chemists in Criminal Investigation

In general, forensic chemists work in four steps in the investigation of crime.

Collection of Evidences: They collect physical evidences such as knife, instruments, materials, etc in a systematic way and uncover their information using chemistry.

Analysis of evidences: In criminal cases, chemists analyze substances such as blood and DNA to attempt to determine when and by whom the crime was committed.

Table 16.4 Food additives

Type of additive	Function of the additive	Example
Preservatives	They protect food from spoilage by microorganism in storage.	Vinegar, Sodium benzoate, benzoic acid, sodium nitrite
Colourants	They give pleasant colours to food	Carotenoids, Anthocyanin, Curcumin
Artificial Sweeteners	They add sweet taste to food	Saccharin, Cyclamate
Flavor enhancers	They are used to enhance the flavour of food items	Monosodium glutamate, Calcium diglutamate
Antioxidants	They prevent the oxidation of food. They protect us against cardiovascular disease.	Vitamin C, Vitamin E, Carotene

Collaboration: To solve the crime, they discuss with other fellow investigators like police officers, detective and other forensic scientists.

Report of findings: Finally, they prepare a report of the conclusion of the analysis.

16.7.2 Method of Forensic Chemistry

The world of forensic chemistry, focusing on the theory and processes of chemistry in forensic analysis shows the role that chemistry plays in criminal investigations. The following are some methods used in crime investigation by a forensic chemistry lab.

Finger print: Finger print is one of the most important evidences in crime investigation. Fingerprints on smooth surfaces can often be made visible by the application of light or dark powder, but fingerprints on cheque or other documents are often occult (hidden). Occult fingerprints are sometimes made visible by the use of ninhydrin, which turns purple due to reaction with amino acids present in perspiration. Fingerprints or other marks are also sometimes made visible by exposure to high-powered laser light. Cyanoacrylate ester fumes from glue are used with fluorescent dyes to make the fingerprints visible.

Figure 16.5 Finger print

Biometrics: The science that involves the study and analysis of human body prints is known as **biometrics**. The biometric system compares the body prints to the specimen data stored in the system to verify the identity of a person.

Alcohol test: Drinkers can be easily identified by the use of applied chemistry. The person being tested blows through a tube, which bubbles the breath through a solution of chemicals containing sulfuric acid, potassium dichromate, water, and silver nitrate. Oxidation of the alcohol results in the reduction of dichromate to chromic ion, with a corresponding change in colour from orange to green. An electrical device employing a photocell compares the colour of the test solution with a standard solution, giving a quantitative determination of the alcohol content. The test provides a quick and reproducible determination of the amount of alcohol in a person's breath and is a numerical measure of the amount of alcohol in the bloodstream.

Figure 16.6 Alcohol test

16.8 Applications of Applied Chemistry

- Many of the advantages of applied chemistry are around us. It is inevitable.
- Applied chemistry has given us innumerous synthetic materials to lead our day to day life.
- The applied chemistry makes a most important contribution to our society.
- It makes a major contribution to the country's economic development, and plays vital role worldwide.
- The products of applied chemistry are so widespread that they are used in our daily.

Points to Remember

❖ Nanochemistry is a branch of nanoscience, that deals with the chemical applications of nanomaterials in nanotechnology.
1 Nanometre = 1/ 1,000,000,000 metre.

- Pharmaceutical chemistry deals with the preparation of drugs and study of the chemical composition, nature, behavior, structure and influence of the drug in an organism.
- Electrochemistry is a branch of chemistry which deals with the relation between electrical energy and chemical change.
- Radiochemistry is the study of chemistry of radioactive and non-radioactive isotopes.
- Dye chemistry is the study of dyes. It provides us information on theory, structure, synthesis and applications of synthetic dyes.
- Agricultural chemistry involves the application of chemical and biochemical knowledge to agricultural production.
- Food chemistry is chemistry of foods which involves analysis, processing, packaging, and utilization of materials including bioenergy for food safety and quality.
- Forensic chemistry applies scienctific principles, techniques, and methods to the investigation of crime.

A-Z GLOSSARY

Anaesthetics	Drugs which cause loss of sensation.
Antipyretics	Compounds which are used for the purpose of reducing fever.
Antiseptic	Substance that prevents infections caused by disease causing microorganisms or pathogens.
Antibiotics	Chemical compounds which was produced by many microorganisms (bacteria, fungi and moulds) which inhibit the growth or metabolism of some other disease causing microorganism.
Antacids	These are certain drug formulations which provide relief from burning sensation.
Drug	The chemicals used for treating diseases
Electrochemical Cell	The device that make use of a chemical change to produce electricity or electricity to produce chemical change.
Electrolyte	Solutions of ions or molten salts which can conduct electricity
Pharmaceutical Chemistry	It is the study of drugs and it involves drug development.

TEXTBOOK EXERCISES

I. Choose the correct answer.

1. One Nanometre is
   (a) 10^{-7} metre (b) 10^{-8} metre
   (c) 10^{-6} metre (d) 10^{-9} metre

2. The antibiotic Penicillin is obtained from ________
   (a) plant (b) microorganism
   (c) animal (d) sunlight

3. 1% solution of Iodoform is used as
   (a) antipyretic (b) antimalarial
   (c) antiseptic (d) antacid

4. The cathode of an electrochemical reaction involves ________
   (a) oxidation (b) reduction
   (c) neutralisation (d) catenation

5. The age of a dead animal can be determined by using an isotope of _______________
   (a) carbon (b) iodine
   (c) phosphorous (d) oxygen

6. Which of the following does not contain natural dyes?
   (a) Potato (b) Beetroot
   (c) Carrot (d) Turmeric

7. This type of food protect us from deficiency diseases.
   (a) Carbohydrates (b) Vitamins
   (c) Proteins (d) Fats

8. Radiochemistry deals with
   (a) oxidants (b) batteries
   (c) isotopes (d) nanoparticles

9. The groups responsible for the colour of an organic compound is called
   (a) isotopes (b) auxochrome
   (c) chromogen (d) chromophore

10. Chlorinated hydrocarbons are used as
    (a) fertilizers (b) pesticides
    (c) food colourants (d) preservatives

II. Fill in the blanks.

1. ______________ is an electrochemical cell which converts electrical energy into chemical change(Reaction).
2. Painkiller drugs are called ___________
3. Indigo is a ________________ dye.
4. _________, _________ and __________ are macronutrients required for plant growth.
5. _______________ is a chemical used in finger print analysis.

III. Match the following.

Antipyretics	-	Large surface area
Corrosion prevention	-	Iodine-131
Hyperthyroidism	-	Fever
Nanoparticle	-	Body building
Proteins	-	Electroplating

IV. Answer briefly.

1. What is Radio Carbon Dating?
2. What are called Anaesthetics? How are they classified?
3. What is the need for chemical fertilizers in crop fields?
4. What is Forensic chemistry related to?

V. Answer in detail.

1. Explain the types of dyes based on their method of application.
2. Name various food additives and explain their functions.

VI. Higher Order Thinking Skills.

1. Batteries that are used in mobile phone can be recharged. Likewise, can you recharge the batteries used in watches? Justify your answer.
2. Sudha met with a fire accident. What kind of drug(s), she must take?
3. The soil pH of a crop land is 5. What kind of fertilizers should be used in that land?

REFERENCE BOOKS

1. Nanomaterials and Nanochemistry by Catherine Brechignac
2. Nuclear and Radiochemistry – Fundamentals and applications by Karl Heinrich Lieser
3. Food Chemistry (Third Edition) by Owen Fennema

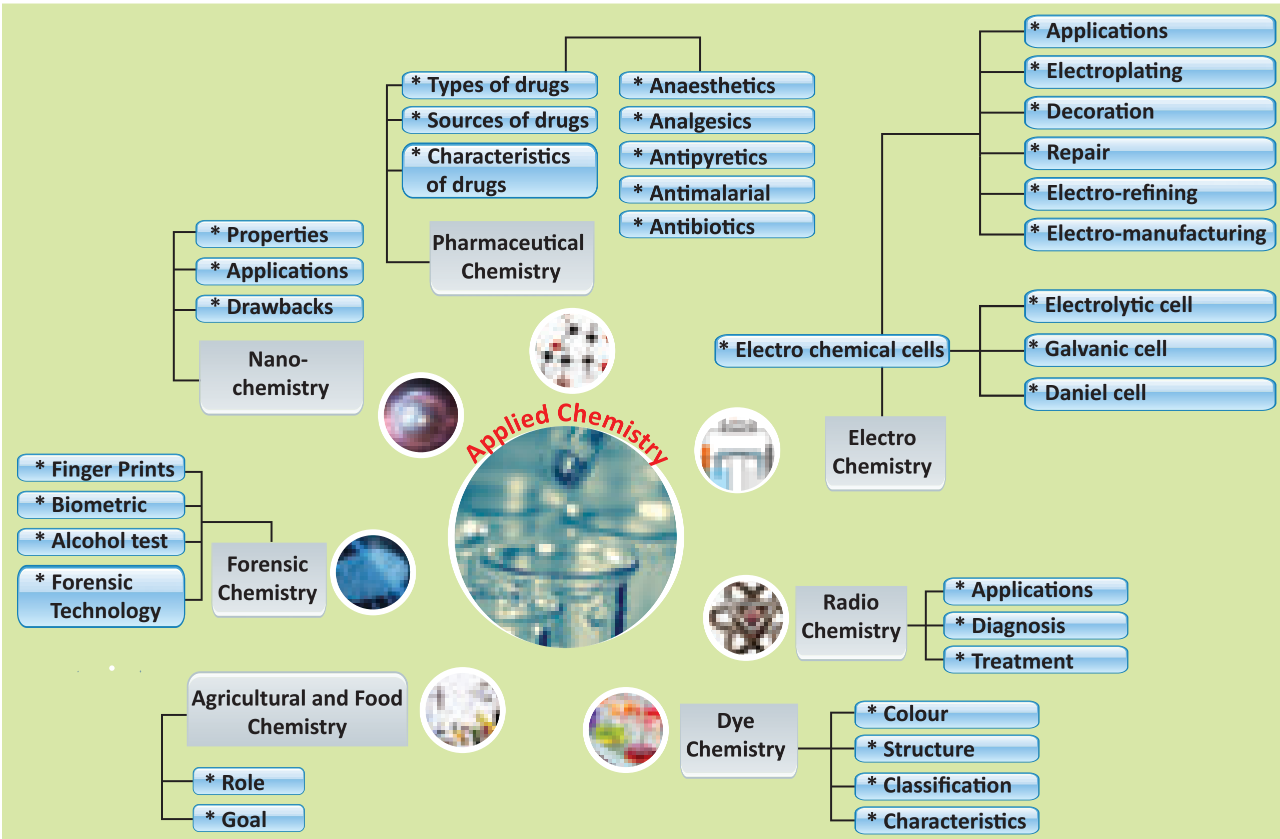
INTERNET RESOURCES

https://en.wikipedia.org/wiki/Agricultural_chemistry

https://www.medicalnewstoday.com/articles/321108.php

https://www.youtube.com/watch?v=kC1aPOqoYWc

Concept Map



ICT CORNER

Applied Chemistry

Experiment with radioactive elements to know about its half-life

Steps

- Use the given URL to open the simulation page and allow the “javascript” to play, if asks. Read the given description on how to perform the half-life simulation.
- Click the “Years Passed” button to increase the years by 1000 and press “Count the Remaining Atom” to know how much of the atoms have become “Daughter atoms”.
- Use the “Table/Graph” button situated below the description to record your observations.
- Press the “video” button to view the process of degradation of radioactive atoms and its calculation

Radioactive Atoms Half-Life

URL: http://www.glencoe.com/sites/common_assets/science/virtual_labs/E18/E18.html

*Pictures are indicative only

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