IX. Get Connected

With Biology

The protoplasm that makes up our cells is a complex colloid that comprises a dispersed phase of protein, fat and other complex molecules in a continuous aqueous phase.

With History

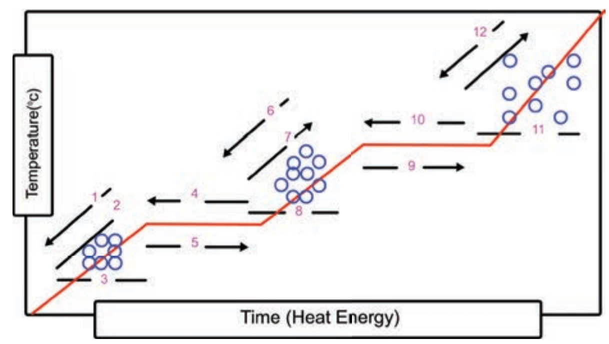
Alloys are mixtures of metals. The art of alloying was known to early man and this forms an important part of history and rise and fall of civilisations. The copper age followed the Bronze Age and later Iron Age. Read up more on these different ages.

With Home

List out three things you may do to dry your wet T -Shirt quickly.

HOTS

1. Fill in the numbered blanks to make the heating curve meaningful.



1. 'Shake well before use'. This is the instruction on a bottle of medicine. What kind of a mixture is contained in the bottle? Give reason.
2. What produces more severe burns, boiling water or steam? Why?

EXERCISE 2

I. Choose the correct answer

1. Difference in __________________ is the principle used in fractional distillation
   a) solubility b) melting point
   c) boiling point d) adsorption
2. The separation of denser particles from lighter particles done by rotation at high speed is called ______________
   a) Filtration b) sedimentation
   c) decantation d) centrifugation
3. ______________ is essential to perform separation by solvent extraction method.
   a) Separating funnel
   b) centrifuge machine
   c) filter paper
   d) sieve
4. Filtration method is effective in separating ___________________ mixture
   a) Solid-solid b) solid-liquid
   c) liquid-liquid d) liquid-gas
5. For a simple distillation process we need to have
   a) an evaporating dish.
   b) a separating funnel.
   c) a filter with filter paper.
   d) a Liebig condenser.

II. State whether the following statements are true or false. If false give the correct statement

1. Butter from curd can be separated by centrifugation.
2. Oil and water are immiscible in each other.

3) Sublimation is the property of a substance to directly change from liquid to solid state.
4) Liquid – liquid colloids are called gels.
5) Fractional distillation is used when the boiling point of the components have large difference

III. Match the following

	A	B	C
i	Sand and camphor	Ink	Distillation
ii	Acetone and water	Miscible liquids	Chromatography
iii	Pigments	Immiscible liquids	Separating funnel
iv	Salt and water	Mixture of two solids	Fractional distillation
v	Water and kerosene	Soluble	Sublimation

IV. Fill in the blanks

1. Alcohol can be separated from water by ___________________
2. Sand is removed from naphthalene by _____________________ method.
3. In petroleum refining, the method of separation used is _______________
4. Chromatography is based on the principle of _______________
5. The solubility of solid in water ____________ with an increase in temperature

V. Very Short answer

1. Name the method you would adopt to separate a mixture of ammonium chloride and common salt.
2. Define a solute and a solvent.
3. Name the sublimate that you will be getting when you heat a mixture of
   i. Iodine and sand
   ii. Sodium chloride and ammonium chloride.
4. What is meant by desalination of sea water?

VI. Short answer

1. What is an adsorbate and adsorbent?
2. What is meant by Rf value?
3. Differentiate between filtrate and distillate.
4. Name the apparatus that you will use to separate the components of mixtures containing two, i. miscible liquids, ii. immiscible liquids.
5. How will you separate a mixture containing saw dust, naphthalene and iron filings?

VII. Long Answer

How is a mixture of common salt, oil and water separated? You can use a combination of different methods.

1. Group activity (group of four): Use your research skills (including the Internet) to find out what is forensic science and obtain information about the use of chromatography in forensic science.

2. Field Trip: Visit a milk dairy and note down the at least two separating techniques used there.

Connect with Environmental Science:

November 2017 - BREAKING NEWS

…There's no fresh air in the Indian capital right now. Pollution in Delhi, which spikes during winter, hit almost 30 times the World Health Organisation's (WHO) safe limits with the concentration of harmful PM 2.5 particles topping 700 micrograms per cubic metre (mpcm). Smog in the capital (November 2017) Read up on the cause and hazardous effects of smog.

Pollution in Delhi

Connect with Geography

Formation of delta: A river delta is a landform that is formed when river water meets the sea water. Clay particles and constituents of sea water 'coagulate' leading to the deposition of sediment which is called the delta. Read more on deltas of India especially -The Sundarbans!

HOTS

1.

Two immiscible liquids are taken in the above funnel for separation. Which is denser, X or Y? Suggest any one example for X and one for Y. A third liquid Z which is soluble only in Y is added to the mixture and contents in the funnel are shaken well. How many layers will you observe now? How will you separate the three liquids? Boiling point of X is 98° C, that of Y is 43° C and that of Z is 75° C.

2. The most appropriate labelling of X and Y in a filtration set up are

	X	Y
a.	precipitate	solvent
b.	solvent	solute
c.	residue	filtrate.
d.	filtrate	residue

FURTHER REFERENCE

1. A TEXTBOOK OF PHYSICAL CHEMISTRY, K.K. Sharma & L.K. Sharma S.Chand publishing ISBN: 9789352590421
2. Materials, Matter and Particles A Brief History By (author): Michael M Woolfson (University of York, UK) ISBN: 978-1-84816-459-8 ISBN: 978-1-908978-23-3 (ebook)
3. Suresh S, Keshav A. "Textbook of Separation Processes", Studium Press (India) Pvt. Ltd (ISBN: 978-93-80012-32-2), 1-459, 2012.
4. Biochemical Techniques Theory and Practice Paperback – 2005 by Robyt J.F. ISBN 10: 0881335568 / ISBN 13: 9780881335569 Published by Waveland Press, Inc., Prospect Heights, IL, 1990

UNIT 4

Periodic classification of elements

BN8AZY

Learning Objectives

After studying this chapter, 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 periodic table.
- study about the position of Rare Gases (Noble gases) in the periodic table.
- distinguish between metals and non-metals.
- know about the metalloids and alloys.

Introduction

Think of a morning prayer in your school. Students stand in rows which are horizontal as well as vertical. Each class stands in a single line, height wise. Generally, height of students of class I is the shortest and that of class 12 is the tallest.

The vendor in a medical store could locate the medicines we seek in a flash of time with the use of a pattern they are arranged. We can easily identify the books in the library as quickly as possible.

There is a pattern in all these cases and this pattern makes the selection easy. (Pattern: regular arrangement)

We live in the world of substances with great diversity. The 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.

4.1. Early Concepts Of Classification Of Elements

4.1.1. DOBEREINER'S TRIADS

In 1817, Johann Wolfgang Dobereiner, a German chemist, suggested a method of grouping of 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 4.1 shows the law of triads proposed by Dobereiner:

Example: In the triad group (1), arithmetic mean of atomic masses of 1st and 3rd elements, (6.9 + 39.1)/2 = 23. So the atomic mass of Na (middle element) is 23.

DO YOU KNOW?

Johann Wolfgang Dobereiner was a German chemist who is best known for his periodic law of triads of chemical elements. Dobereiner discovered furfural, used platinum as a catalyst and discovered a lighter, known as Dobereiner's lamp.

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 atomic mass and very high atomic mass.

Table 4.1 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

IX_Science Term II Unit-4.indd 59 02-08-2018 17:19:13

4.1.2 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 and 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.

DO YOU KNOW?

John Newlands (1837-1898) was a Scottish analytical chemist. He continued Dobereiner's work with triads and published his 'Law of Octaves' in 1865, which stated that 'any given element will exhibit analogous behaviour to the eighth element following it in the table.' Newlands arranged all the known elements, starting with hydrogen and ending with thorium, into seven groups of eight, which he linked to octaves of music. In Newlands' table, the elements were ordered by the atomic weights that were known at the time and were numbered sequentially to show their order. After Dmitri Mendeleev and Lothar Meyer, he received the prestigious Davy Medal in 1887.

Table 4.2 Newland's table of octaves (oct- eight)

NO.	NO.	NO.	NO.	NO.	NO.	NO.	NO.
H1	F8	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 & V45	Hg 52
BO 4	Al 11	Cr 19	Y 25	Ce & La33	U40	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
O7	S 14	Fe 21	Se 28	Ro&Ru 35	To 43	Au 49	Th 56

- 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.

4.1.3 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 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.

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.
- 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, and 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

Table 4.3 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	

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.

Table 4.4 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	$EsCl_4$	$GeCl_4$

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).
- 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

Activity 2

Name the class rooms in your school from the first element of the periodic table Hydrogen, Helium .... instead of numbering them. (*Example: Room no: 1- Hydrogen, Room no:2- Helium and so on*)

Dmitri Ivanovich Mendeleev (1834 - 1907) was a Russian chemist and inventor. He formulated the Periodic Law, and used it to correct the properties of some already discovered elements and also to predict the properties of eight elements yet to be discovered. Mendeleev also investigated the composition of petroleum and helped to establish the first oil refinery in Russia. He recognized the importance of petroleum as a source for petrochemicals. He is called as 'Father of Modern Periodic Table'.

4.2 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.

4.2.1 Modern Periodic Law

Atomic number of an element (Z) not only indicates the number of protons (positive charge) but also 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

PERIODIC TABLE OF THE ELEMENTS

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

Metal | Semimetal | Nonmetal

Alkali metal | Alkaline earth metal | Transition metals | Lanthanide | Actinide

Chalcogens element | Halogens element | Noble gas

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

PERIOD	GROUP 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

electrons and their arrangements (electronic configuration) in atoms. Hence, the modern periodic law can be stated as follows: "The Chemical and Physical properties of elements are periodic functions of their atomic numbers". Based on the modern periodic law, the modern periodic table is derived.

DO YOU KNOW?

Henry Gwyn Jeffreys Moseley (1887-1915) was an English physicist. He developed the chemical concept of atomic number. This concept was developed from his study of X-ray spectra.

Moseley's law advanced atomic physics, nuclear physics and quantum physics by providing the first experimental evidence in favour of Niels Bohr's theory, aside from the hydrogen atom spectrum which the Bohr theory was designed to reproduce. That theory refined Ernest Rutherford's and Antonius van den Broek's model, which proposed that the atom contains in its nucleus a number of positive nuclear charges that is equal to its atomic number in the periodic table. This remains the accepted model today. Moseley redefined the idea of atomic numbers from its previous status to help sorting the elements into an exact sequence of ascending atomic numbers that made the Periodic Table exact. This was later to be the basis of the Aufbau principle in atomic studies.

4.2.2 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 4.5 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

DO YOU KNOW?

The International Union of Pure and Applied Chemistry (IUPAC) is an international federation of Organizations that represents chemists from various countries. IUPAC is registered in Zürich, Switzerland, and the "IUPAC Secretariat", is in United States.

IUPAC

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

Activity 3

List the elements (any five) which are used in our daily life by seeing the Modern Periodic table.

	Element	Use
1.	Flourine	toothpaste
2.	________	________
3.	________	________
4.	________	________
5.	________	________
6.	________	________

DO YOU KNOW?

New elements named by IUPAC

The elements having atomic number 113 to 118 have been named by IUPAC as follows:

Nihonium (Nh) for Element 113. (Earlier it was Uut)

Moscovium (Mc) for Element 115. (Earlier it was Uup)

Tennessine (Ts) for Element 117. (Earlier it was Uus)

Oganesson (Og) for Element 118. (Earlier it was Uuo)

4.2.3 Classification of elements into blocks in Modern Periodic Table

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 manner. These subshells are designated as s, p, d, and f. The maximum number of electrons that can be accommodated in s, p, d, and f are 2, 6, 10 and 14 respectively.

Based on the arrangement of electrons in subshells, the elements of periodic table are classified into four blocks as shown in Table 4.6

(1) s-Block Elements

While arranging the electrons of elements of group 1 and 2, the last electron is added to s subshell. These elements are called s-block elements. The elements of group 1 (except hydrogen) are metals. They react with water to form solutions that change the colour of a vegetable dye 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

Table 4.6 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
The maximum number of electrons in each sub shell	2	2	6	2	6	10	2	6	10	14
The maximum number of electrons in each shell	2	8		18			32			

dissolved in water. Hence, these elements are called alkaline earth metals.

(2) p-Block Elements

The last electron in these elements is filled in p subshells and hence these elements are called 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). 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

The elements of group 3 to 12 have their valence electrons in their outermost d subshells. These elements are called d block 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

Part of the group 3 elements have their valence electrons in inner f subshell. They are known as f block elements or inner transition elements. They are placed at the bottom of the periodic table. There are two series in f block elements. The elements that follow Lanthanum are called "Lanthanides" and that follow Actinium are called "Actinides".

Activity 4

Note down the atomic numbers of Li, Sc, Mg, Be, Al, B, C, Cl, N, O, F and Ne and find out the period that the elements are present.

Element	Atomic Number	Period Number
Li	3 (2,1)	2
Sc	21 (2,8, 8,3)	4

More to Know

- Most of the coloured salts are compounds of d block elements (transition elements).
- Most of the elements in d block accounts for variable oxidation states.
- Transition elements also show catalytic property.
- All the above properties of d block elements are due to the presence of transition ions.

4.2.4 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.

4.2.5 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.

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

(i) Hydrogen can lose its only 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.

4.2.6. 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.

These gases are chemically inert or non-reactive in nature because they have stable electronic structures which are very difficult to change.

Though they are found rare, they have many uses.

1. Helium is used for filling weather balloon, as it has very low density.
2. Neon gas is used in discharge lamps for the orange column.
3. Argon gas is filled in electrical bulbs to prevent evaporation of the filament.
4. Radon is a radioactive gas.

More to Know

Hydrogen is the most abundant element in the universe, and makes up four-fifths of all ordinary matter. It is believed to be the fuel of the future, but it remains difficult to produce, transport and store. At extreme temperatures and pressures, like those at the core of a gas-giant planet, hydrogen can become metallic. (A gas giant is a large planet composed mostly of gases, such as hydrogen and helium, with a relatively small rocky core. The gas giants of our solar system are Jupiter, Saturn, Uranus and Neptune.)

Table 4.7 Electronic structure of Rare gases.

Element	Symbol	Atomic Number	Electronic Structure
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, 8, 32, 18, 8

4.3 METALS, NON-METALS AND METALLOIDS

4.3.1 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. Sodium and Potassium

(ii) Alkaline earth metals e.g: Calcium and Magnesium

(iii) Transition Metals e.g: Iron and Nickel

(iv) Other Metals e.g: Aluminium and Tin

4.3.2. Non-metals

A non-metal is an element that does not have the characters of hard, shiny, malleable, suitable and ductile. In other words, a non-metal is an element that does not have the properties of metal. E.g. Oxygen, Nitrogen

4.3.3 Metalloids

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

4.4 Alloys

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.

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.

BNH72L

4.4.1 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 whereas 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

Table 4.8 Comparison of the physical properties of metals and non-metals

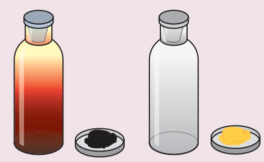
S. No	Properties	Metals	Non-metals
1.	Appearance	Have a lustre, known as metallic lustre. The surface is polishable.  Platinum Gold Silver	Have no lustre and I.k dull. Surface cannot be polished. (Exceptions: Graphite and iodine are lustrous).  Yellow - Sulphur,White - Phosphorous. Red - Bromine, Black-Carbon
2.	Physical state	In genral, they are hard crystaline solids.(Exception: Mercury is a liquid)	They exist as soft solids or gases. (Expections: Diamond is a hard solid and bromine is a liquid)
3.	Density	They have a high density. (Exceptions: Sodium and Potassium).	They have a low density.
4.	Melting and boiling points	Usually they have high melting and boling points. (Exceptions: Sodium and Potassium).	They have low melting and boiling points (Exceptions: diamond and graphite)
5.	Malleability and ductility	They are malleable and ductile.	Solid non-metals are brittle.
6.	Heat conductivity	They are good conductors.	They are bad conductors. (Exceptions: diamond)
7.	Electrical conductivity	They are good conductors	They are bad conductors. (Exception: Graphite)
8.	Sonority (phenornenon of producing a characteristic sound when a material is struck)	They are sonorous	They are non-sonorous. (Exception: Iodine crystals produce a soft metallic clink when they are shaken in a bottle)
9.	Alloy formation	Metals form alloys with each other and also with some non-metals	Non-metals usually do not form alloys. (Exception: B, C, Si and P from alloys with metals)

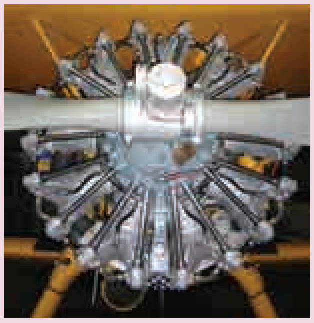
Table 4.9 Comparison of the chemical properties of metals and non-metals

S. No.	Chemical Property	Metals	Nonmetals
1.	Electro Positive / Electro Negative	Electro Positive. Metals lose electrons and form cation eg.) $Na \rightarrow Na^{+} + e^{-}$ $Al \rightarrow Al^{3+} + 3e^{-}$	Electro Negative. Nonmetals gain electrons and form anion $Cl + e^{-} \rightarrow Cl^{-}$ $O + 2e^{-} \rightarrow O^{2-}$
2.	Reaction with Oxygen	Metals burn with Oxygen to form metal oxides. Generally, these metal oxides are basic.	Nonmetals when heated with oxygen produce covalent oxides. Most of the non-metal oxides are acidic in nature.
3.	Reaction with water a) Cold Water	a) Metals like Sodium and Potassium react with cold water to liberate hydrogen gas.	a) Carbon reacts with water to form carbon monoxide and hydrogen
	b) Steam	b) Metals like Magnesium and Iron react with steam to form their respective oxides and hydrogen ii) Aluminium reacts slowly with steam to form aluminium hydroxide and hydrogen. Note : Copper, Nickel, Silver and Gold do not react with water.	Nonmetals are less reactive with steam
4.	Reaction with Acids	Metals such as Sodium, Magnesium, Aluminium react with dilute hydrochloric acid to give their respective salts.	Generally, nonmetals do not react with acids, but when heated with con. HNO_3 or con H_2SO_4, the respective oxides or oxy acids are formed.
5	Reaction with Halogens	Metals react with halogen to form ionic halides	Nonmetals react with halogens to form covalent halides
6	Oxidation/ Reduction	Metals get oxidized (lose electron) on reaction with nonmetals	Nonmetals get reduced (gain electron) on reaction with metals

Table 4.10 Composition and uses of alloys

S. No	Alloy	Composition	Uses
1	Brass	Cu & Zn (Copper and Zinc)	Decorative articles, taps etc.
2	Bronze	Cu & Sn (Copper and Tin)	Statues and medals
3	Solder	Pb & Sn (Lead and Tin)	Soldering electronic circuits
4	Stainless Steel	Fe, C, Cr and Ni (Iron, carbon , Chromium and Nickel)	Utensils, Surgical instruments
5	German Silver	Cu, Ni, Zn (Copper, Nickel and Zinc)	Artificial jewellery
6	Gun metal	Cu , Sn & Zn (Copper,Tin & Zinc)	Guns and frames of spectacles
7	Duralumin	Al, Mg, Cu & Mn (Aluminium, Magnesium, Copper & Manganese)	Bodies of aircraft
8	Magnalium	Al & Mg (Aluminium & Magnesium)	Kitchen wares
9	Steel	Fe & C (Iron and Carbon)	Ship construction etc

More to Know



Monel is an alloy of nickel (67%) and copper with small amounts of iron, manganese, carbon, and silicon. It is stronger than pure nickel and it is extremely resistant to corrosion even that caused by sea water. It is used in aircraft construction and skins of experimental rocket planes

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 column called 'groups' and seven horizontal rows called 'period'.
- The physical and chemical properties of elements depend not on the number of protons but on the number of electrons and their arrangements (electronic configuration) in atoms.
- 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 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.
- The maximum number of electrons that can be accommodated in s, p, d and f sub shells are 2, 6, 10 and 14 respectively.
- Lanthanides and actinides are kept at the bottom of the periodic table.
- Based on the arrangement of electrons in subshells, the elements of periodic table are classified into four blocks as s, p d and f.
- 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.
- Rare gases are chemically inactive because they have stable electronic structures which are very difficult to change.

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 elements are the periodic functions of their atomic masses.
Modern Periodic Law	The chemical and physical properties of elements are 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 electron is added to s subshell.
p block elements	Elements whose valence electron is filled in p subshells.
d block elements	Elements having their valence electrons in the d subshells.
Noble gases	The elements in group 18 of the periodic table are called as Noble gases or Rare gases.
Metals	Metals are hard, shiny, malleable (can be made as sheet), fusible and ductile (can be drawn into wire) with good electrical and thermal conductivity.

Non metals	A nonmetal is an element that does not have the characters of hardness, shiny, malleable, suitable and ductile.
Metalloids	Elements which have the properties of both metals and nonmetals are called as metalloids. (eg) Boron, Arsenic.
Alloys	Alloys are mixtures of two or more metals and are formed by mixing molten metals thoroughly.

BNR349

TEXT BOOK 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

4. The increasing order of the energy of subshells is
   a) $s>p>d>f$ b) $s<p<d<f$
   c) $s<p<f<d$ d) $p<s<d<f$

5. If the electronic configuration of an element is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$, then it will occupy ________ block of the periodic table
   a) s   b) p   c) d   d) f

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. B, Si, Ge and As are the examples of ________.
5. Example for liquid metal is ________.

III. Match the following

1.	Triads	Newlands
2.	Alkali metal	Calcium
3.	Law of octaves	Henry Moseley
4.	Alkaline earth metal	Sodium
5.	Modern Periodic Law	Dobereiner

IV. State whether True or False

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

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.

VII. Complete the following table

Element	Number of electrons	Sub shell electronic configuration
N	7	$1s^2\ 2s^2\ 2p^3$
F	9	1s 2s p
Na		
Cl		
Ar		

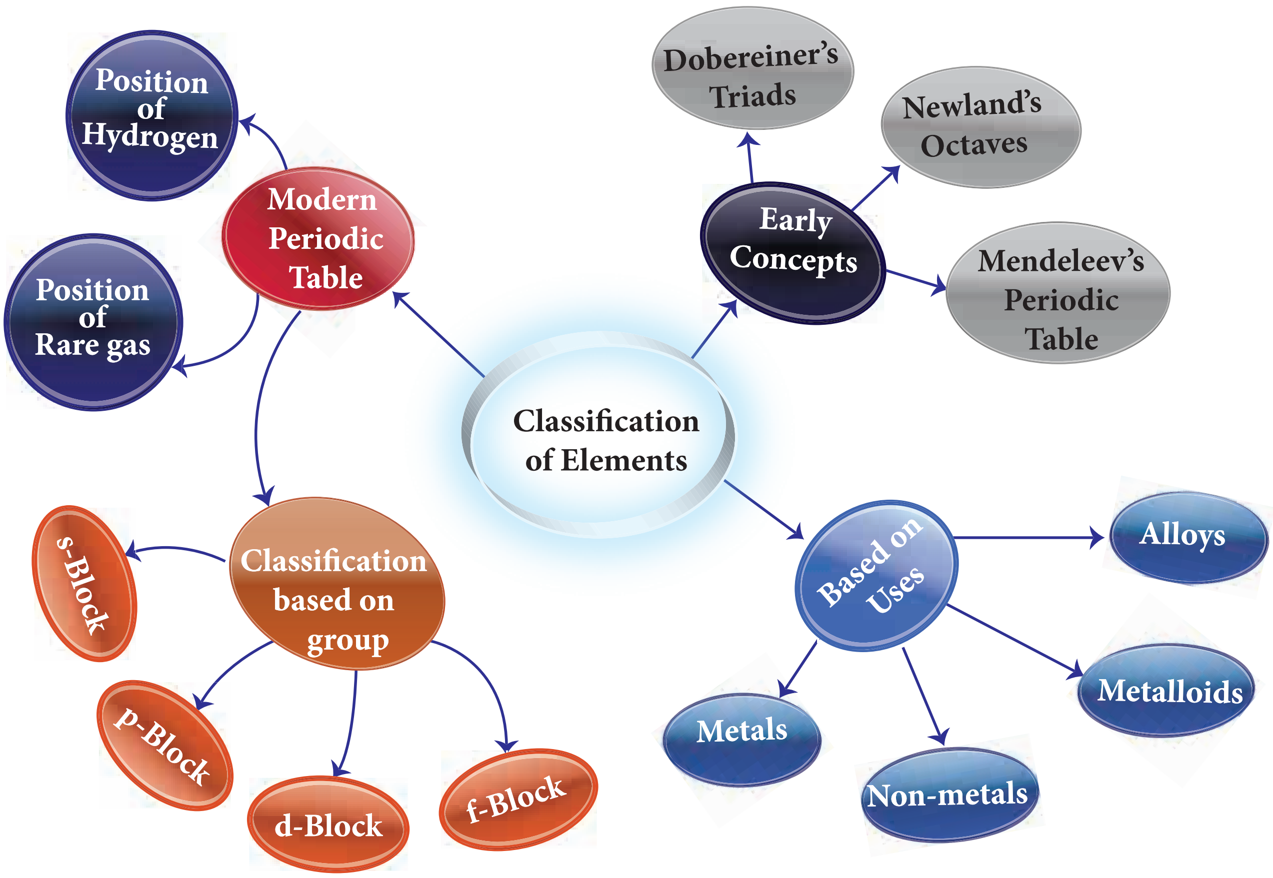
VIII. Arrange the jumbled letters to answer the following

1. We are a family of five and lies in 17th group of periodic table (7 letters)
2. I am being stored in kerosene and be cut by knife (6 letters)
3. I am the most corrosion resistant silvery white metal and lies in group 9 (7 letters)
4. I am being used as refrigerant in liquid form with atomic number 7 (8 letters)
5. I am in your blood as hemoglobin and without me no buildings are possible (4 letters)
6. I am the highly radioactive and newly designated element in the modern periodic table with atomic number 113 (8 letters)
7. I am used as a disinfectant for drinking water. (8 letters)
8. I am mixed with salt and used for thyroid health (6 letters)
9. I am the key part of biological molecules and have the valency of four. (5 letters)
10. I am the first in the noble gas group and used to fill balloons (6 letters)

S.No	Jumbled letters	Answer
1	L A O H S E N G	
2	S D I M U O	
3	R I D M U I I	
4	T I R N G O N E	
5	N R O I	
6	I H N M U I N O	
7	H C L E I R N O	
8	E N I D O I	
9	B A R C O N	
10	E L I H U M	

IX) Complete the following table referring the modern periodic table:

Period number	Total no of elements	Elements		Total no of elements in			
		From	To	s-block	p-block	d-block	f-block
1							
2							
3							
4							
5							
6							
7							



REFERENCE BOOKS

1. CONCISE Inorganic chemistry : 5th Edition by J.D. Lee
2. Inorganic Chemistry by P.L.Soni
3. The Periodic table: Its story and its significance: Eric R. Scerri

INTERNET RESOURCES

1. https://www.ptable.com/
2. https://iupac.org/what-we-do/periodic-table-of-elements/
3. www.rsc.org/periodic-table
4. https://sciencestruck.com/periodic-table-facts
5. https://ww.teachbeside.com/memorize-periodictable

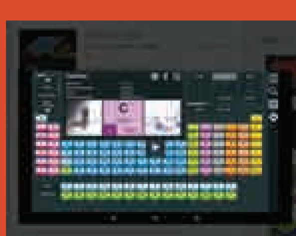
ICT CORNER

Periodic Classification

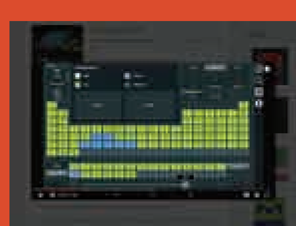
This activity enables to explore the properties of elements.

Steps

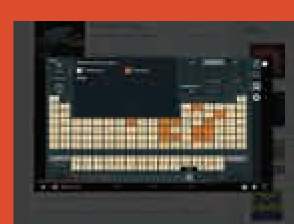
- Type the URL link given below in the browser OR scan the QR code. You can also download the "**Royal society of chemistry**" mobile app from the given app URL.
- Click the element from the table and explore the properties of the element you want to learn.
- On the right top corner click option as shown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



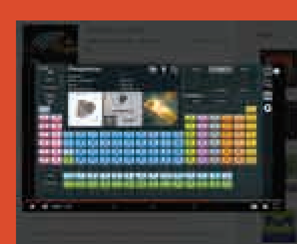
Step1



Step2



Step3



Step4

Browse in the link:

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

B467_SCI_9_T2_EM

*Pictures are indicative only

IX_Science Term II Unit-4.indd 77 02-08-2018 17:19:25

UNIT 5

Chemical bonding

Learning Objectives

After studying the unit, the 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. 5.1 Flowers held together by thread

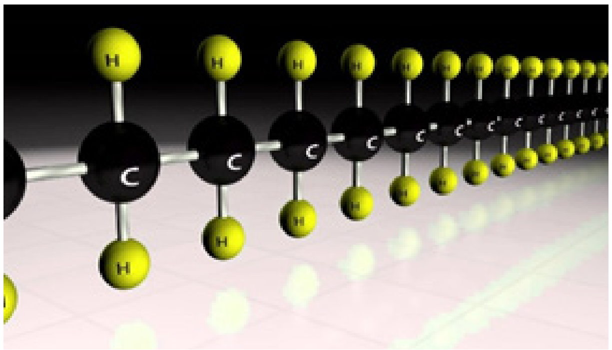


Figure. 5.2 Atoms held together by bond

A Chemical bond may be defined as the force of attraction between the two atoms that binds them together as a unit called molecule.

5.1 Kossel – Lewis approach to chemical bonds

5.1.1 Octet rule

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

- 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 theory 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 5.1.

Table 5.1 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

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

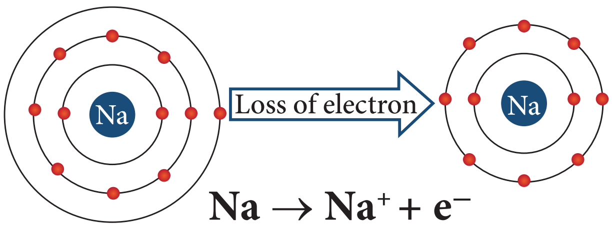
More to Know

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

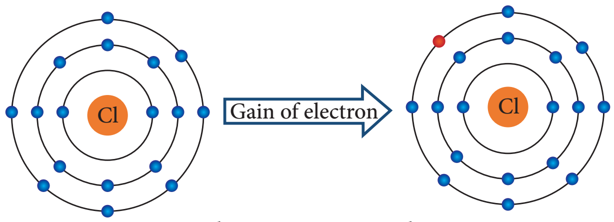
Based on the noble gas electronic configuration, Kossel and Lewis proposed a theory in 1916 to explain chemical combination between atoms and this theory is known as 'Electronic theory of valence' or Octet rule. According to this, atoms of all elements, other than inert gases, combine to form molecules 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. 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. Thus elements tend to have stable valence shell (eight electrons) either by losing or gaining electrons.



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



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

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 whereas atoms having 5,6,7 valence electrons tend to gain.

Table 5.2 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

Activity 1

Write the electronic distribution of the following elements and find out whether they have stable electronic configuration.

Element	Atomic number	Electron distribution	Valence electrons	Stable	Unstable
Hydrogen	1	1	1		✓
Fluorine	9				
Krypton	36				
Xenon	54				

Walther Kossel (1888-1956)

Gilbert N Lewis (1875-1946)

5.2 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 5.3 Lewis dot structure

Element	Atomic number	Electron distribution	Valence electrons	Lewis dot structure
Hydrogen	1	1	1	$\mathrm{H}\cdot$
Helium	2	2	2	$\cdot\mathrm{He}\cdot$
Beryllium	4	2, 2	2	$\cdot\mathrm{Be}\cdot$
Carbon	6	2, 4	4	$\cdot\overset{\cdot}{\underset{\cdot}{\mathrm{C}}}\cdot$
Nitrogen	7	2, 5	5	$\cdot\overset{\cdot\cdot}{\underset{\cdot}{\mathrm{N}}}\cdot$
Oxygen	8	2,6	6	$\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{O}}}\colon$

Activity 2

Write the electronic dot symbol for the following elements.

Element	Atomic number	Electron distribution	Valence electrons	Stable	Lewis dot structure
Boron					
Argon					
Chlorine					
Sodium					
Fluorine					

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.

5.3 Types of chemical bond

All the elements differ with each other in their 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 below. 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.

5.3.1 Ionic (or) Electrovalent bond

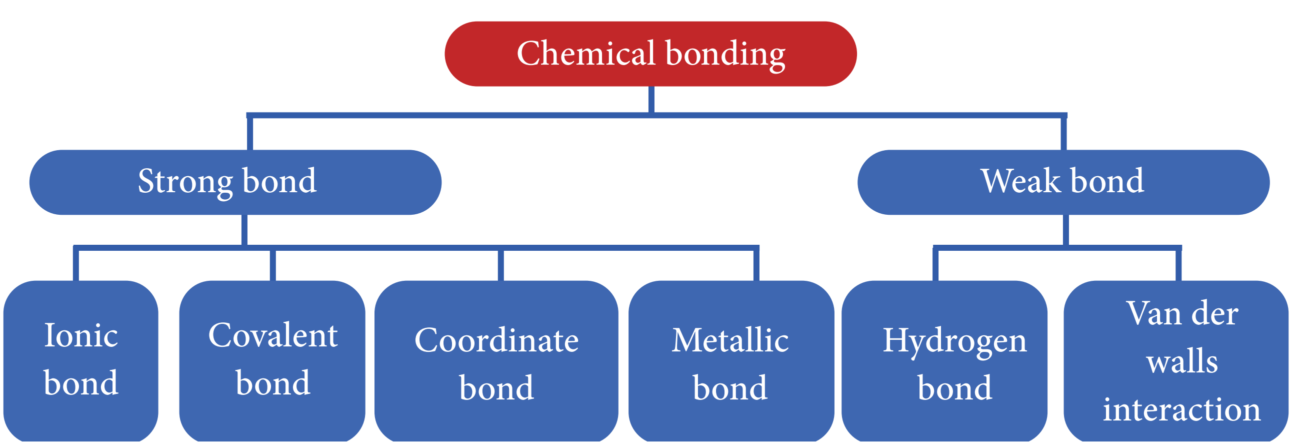
An ionic bond is a chemical bond formed by the electrostatic attraction between positive and negative ions. The bond is formed between two atoms when one or more electrons are transferred from the valence shell of one atom to the valence shell of the other atom. The atom that loses electrons will form 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***.

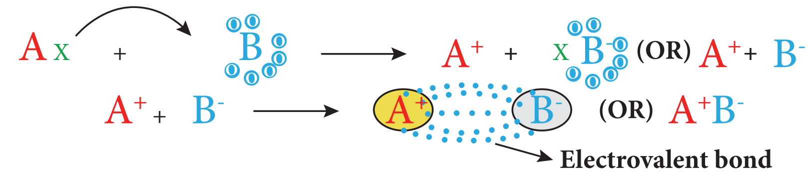
BP9U7J

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 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^-).

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 achieve stable octet electronic configuration.

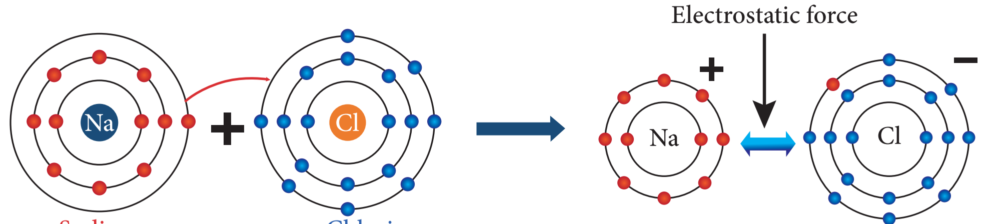
DO YOU KNOW?

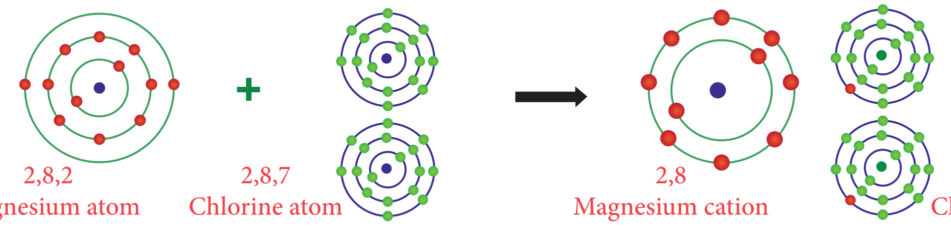
What is the most important food additive you have in your kitchen?

Definitely it is common salt. It is formed by the combination of a highly reactive metal called sodium and a poisonous gas called chlorine. The chemical bonding between sodium and chlorine alters the properties and makes it edible.

Illustration 2 – Formation of 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 ($MgCl_2$)

Activity 3

Try to draw the electron distribution diagram as above for the formation of Calcium Chloride ($CaCl_2$) molecule with the help of given data.

Element	Atomic number	Electron distribution	Valence electrons	Number of electrons lost	Number of electrons gained	Formed Cation / Anion
Calcium	20					
Chlorine	17					

Practice:

Draw the diagram to represent the bonding in the following ionic compounds.

1. Magnesium fluoride (MgF_2)
2. Calcium oxide (CaO)
3. Lithium chloride (LiCl)

Characteristics of Ionic compounds

The nature of bonding between the atoms of a molecule is the primary factor that determine 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:

a. 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.

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

c. 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.

d. 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).

e. 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.

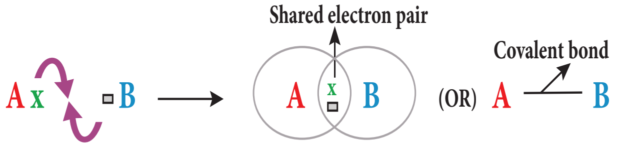
f. Reactions – Ionic compounds undergo ionic reactions which are practically rapid and instantaneous.

5.3.2 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.



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. Each having one valence electron ($1s^1$), it is contributed to the shared pair and both atoms acquire stable completely filled electronic configuration.

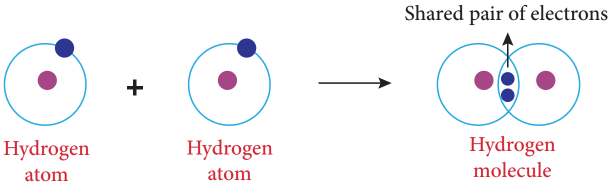
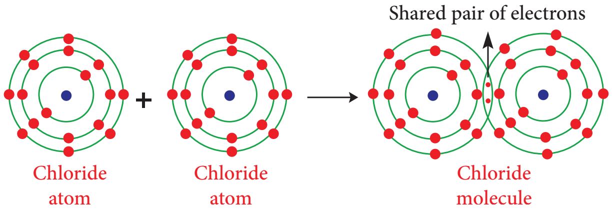


Illustration 2 – Formation of chlorine molecule (Cl_2)

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.



Activity 4

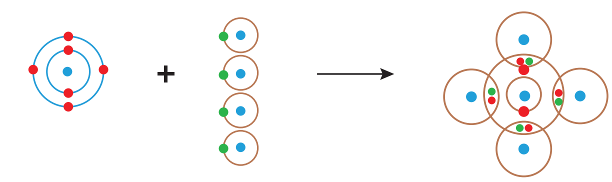
Try to draw the electron distribution diagram as above for the formation of Fluorine (F_2) molecule with the help of given data.

Element	Atomic number	Electron distribution
Fluorine	9	2, 7

Fluorine atom + Fluorine atom → Fluorine molecule

Illustration 3 – Formation of methane molecule (CH_4)

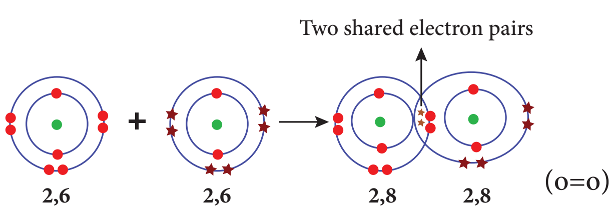
Methane molecule is formed by the combination of one carbon and four hydrogen atoms. The carbon atom has four valence electrons (2, 4). These four electrons are shared with four atoms of hydrogen to achieve a stable electronic configuration (octet) by sharing a pair of electrons.



Carbon atom   4 Hydrogen atoms   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.



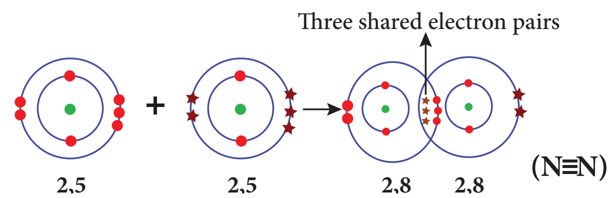
Practice:

Draw the diagram to represent the bonding in the following covalent compounds.

1. Carbon tetrachloride (CCl_4)
2. Carbon di oxide (CO_2)
3. Water (H_2O)
4. Ammonia (NH_3)

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.



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.

a. 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.

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

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

d. 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.

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

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

Activity 5

Take a glass of water and add a spoon of sugar. Take another glass of coconut oil and add a spoon of sugar. Observe the difference in solubility in these two and try to find out the reason with the help of your teacher.

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 electronegativities, 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 combine 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 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

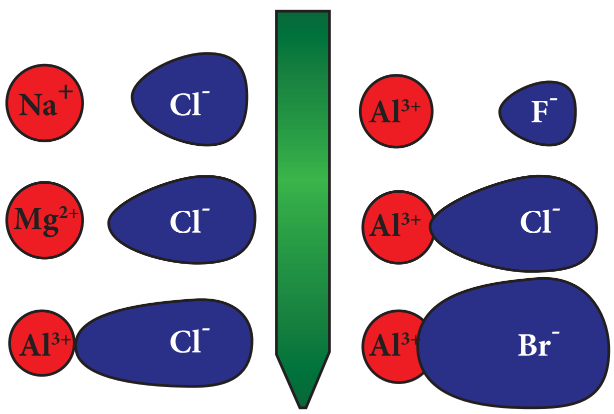
This can be summarized as follows:

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

Table 5.4 Difference between Ionic and Covalent compounds

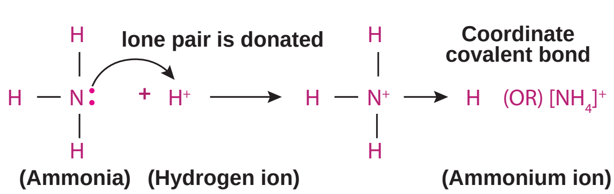
Ionic Compounds	Covalent Compounds
Formed by the transfer of electrons from a metal to a non-metal atom	Formed by sharing of electrons between non-metal atoms
Strong electrostatic force of attraction between cations and anions	Mutual sharing of electrons and so weak force of attraction between atoms
Solids at room temperature	Gases, liquids and soft solids
Conducts electricity in molten state or in solutions	Non-conductors of electricity
Have high melting and boiling points	Have low melting and boiling points
Soluble in polar solvents	Soluble in non-polar solvents
Hard and brittle	Soft and waxy
Undergo ionic reaction which are fast and instantaneous	Undergo molecular reactions which are slow

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:



5.3.3 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

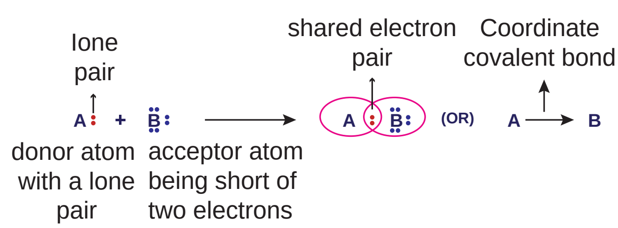


Coordinate covalent bond or Dative bond.

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)



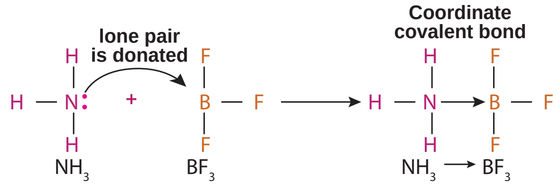
Examples (NH^{4+}, $NH_3 \rightarrow BF_3$)

Illustration 1 – Formation of coordinate covalent bond in ammonium ion ($NH4^+$)

Ammonium ion is formed by one ammonia (NH_3) molecule and one hydrogen (H^+) ion. In ammonia molecule the central nitrogen atom has five valence electrons (2,5) among which three electrons are shared with three hydrogen atoms and still it has an unshared lone pair of electrons. This lone pair electrons are donated to a Hydrogen ion and thus a N→H coordinate covalent bond is formed in ammonium ion molecule (NH_4^+)

Illustration 2 – 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 BF3 (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.

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

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

c. Melting point – These compounds have melting and boiling points higher than those of purely covalent compounds but lower than those of purely Ionic compounds.

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

e. Reactions – Coordinate covalent compounds undergo molecular reactions which are slow.

5.4 Oxidation, Reduction and Redox reactions

Look at the following pictures. 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 are these happening? It is because of a reaction called oxidation.

Oxidation: A 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: A 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.

Ex. 1 : $2\,PbO + C \rightarrow 2\,Pb + CO_2$

Ex. 2 : $Zn + CuSO_4 \rightarrow Cu + ZnSO_4$

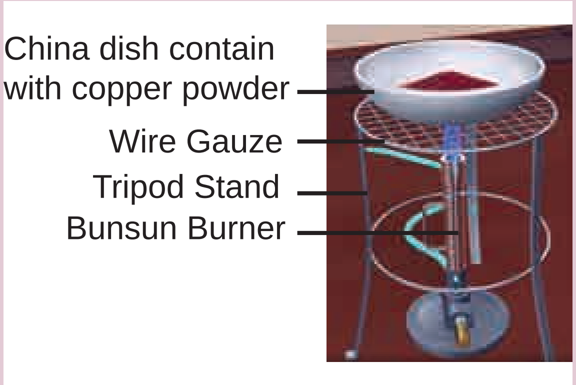
Oxidation (LEO)	addition of Oxygen
	removal of Hydrogen
	loss of electron
Reduction (GER)	removal of Oxygen
	addition of Hydrogen
	gain of electron

Activity 6

Take about one gram of copper powder in a china dish. Place the dish on a tripod stand with wire gauze and heat the copper powder using a Bunsen burner. Is there any change in colour?

Yes, the brown copper turns into black. This is because of the formation of copper oxide. Copper when heated reacts with atmosphere oxygen forming black Copper oxide.

$Cu + O_2 \rightarrow 2\ CuO$ (oxidation reaction)



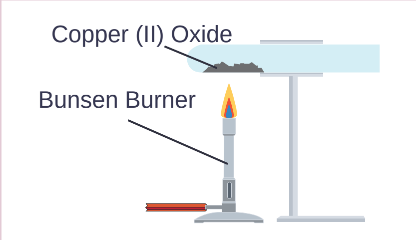
Activity 7

Take the copper oxide obtained from the above activity and pass hydrogen gas over the hot CuO and observe the change in colour. Is there any change in colour?

Yes, the black colour slowly turns into brown. This is because copper oxide loses oxygen to form copper.

$CuO + H_2 \rightarrow Cu + H_2O$ (reduction)

You can also watch the YouTube videos in the below link to know about this reaction.
https://www.youtube.com/watch?v=tEwp2fi1mpI
https://youtu.be/gJWZ8nHn59Y



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 turns brown after some time because of the oxidation of organic 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 formal charge which an atom of that element appears to have when electrons are counted.

More to Know

Painting, oiling, greasing, galvanising and alloying are some of the methods to prevent corrosion.

- The spoilage of food can be prevented by adding preservatives like Vitamin C and Vitamin E.
- Keeping food in air tight containers helps to slow down the oxidation process. Also filling the pouch with Nitrogen gas will remove oxygen like in potato chips bags.

Oxidation number also called Oxidation state, the total number of electrons that an atom either gains or losses in order to form a chemical bond with another atom.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 compounds 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.

For 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

(Oxidation Number = ON)

More to Know

One of the most valuable metals Gold has high resistance to corrosion.

Problems on determination of Oxidation Number

ON 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 X (+1) + 1 X (-2) = 0

(+2) + (-2) = 0 thus, ON of H is +1 and ON of O is -2

Illustration 2 – Oxidation Number of Na and Cl in NaCl

ON of Na = +1 and ON of Cl = -1

(+1) + (-1) = 0 thus, ON of Na is +1 and ON of Cl is -1

Illustration 3 – 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 X (+1) + (x) + 4 X (-2) = 0

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

(x) = +6 therefore, ON of S is +6

Illustration 4 – 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 X (+1) + 2 X (x) + 7 X (-2) = 0

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

2x = +12

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

Illustration 5 – Oxidation Number of Fe in FeSO4

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

(x) + 1 X (+6) + 4 X (-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

- Kossel and Lewis gave explanation based upon the concept of electronic configuration of noble gases about why atoms combine to form molecules.
- Having stable valence electronic configuration, the noble gas atoms neither have any tendency to gain nor lose electrons.
- 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.
- 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 Electrovalent 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

A-Z GLOSSARY

Chemical bond	the force of attraction between the two atoms that binds them together as a unit called molecule.
Octet rule or Rule of eight	The tendency of atoms to have eight electrons in the valence shell
Strong bonds	Ionic bond, Covalent bond, Coordinate covalent bond, Metallic bond
Weak bonds	Hydrogen bond, Van der Walls interactions
Ionic / Electrovalent bond	Bond formed between cation and anion because of the transfer of electrons from one atom to other atom
Covalent bond	Bond formed between atoms by the mutual sharing of electrons
Coordinate covalent bond	Bond formed between atoms by mutual sharing of electrons which are supplied by one atom
Oxidation	chemical reaction which involves in the addition of oxygen or removal of hydrogen or loss of electrons

Reduction	chemical reaction which involves in the addition of hydrogen or removal of oxygen or gain of electrons
Redox reaction	oxidation and reduction occurs in the same reaction simultaneously
Oxidising agents	Substances which have the ability to oxidise other substances
Reducing agents	Substances which have the ability to reduce other substances
Oxidation number	the formal charge which an atom has when electrons are counted

TEXT BOOK EXERCISES

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, 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. Atoms having 1,2 or 3 electrons in its valence shell will readily form ________

   a) cation b) anion

4. The element that would form anion by gaining electrons in a chemical reaction is ________________

   a) Potassium b) Calcium
   c) Fluorine d) Iron

5. Bond formed between a metal and non metal atom is usually __________

   a) ionic bond b) covalent bond
   c) coordinate bond

6. ______________ compounds have high melting and boiling points.

   a) Covalent b) Coordinate c) Ionic

7. Covalent bond is formed by __________

   a) transfer of electrons
   b) sharing of electrons
   c) sharing a pair of electrons

8. Oxidising agents are also called as ___________ because they remove electrons form other substances.

   a) electron donors b) electron acceptors

9. 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 in brief

1. How do atoms attain Noble gas electronic configuration.
2. CCl_4 is insoluble in water but NaCl is soluble in water. Give reason.
3. Explain Octet rule with an example.
4. Write a note on different types on bonds?
5. Find the odd one out.
   a. H_2, Cl_2, NaCl, O_2, N_2
   b. H_2O_2, MnO_4^-, $LiAlH_4$, $Cr_2O_7^{2-}$
6. Correct the wrong statements.
   a. Ionic compounds dissolve in non polar solvents

b. Covalent compounds conduct electricity in molten or solution state.

7. Complete the table give below.

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

8. Draw the electron distribution diagram for the formation of Carbon di oxide (CO_2) molecule.

9. 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

10. Choose the correct answer form the choices given below.

    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

11. Identify the following reactions as oxidation or reduction

    a. $Na \rightarrow Na^+ + e^-$
    b. $Fe^{3+} + 2e^- \rightarrow Fe^+$

12. 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 -

13. 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.

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

15. 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

IV. LIFE SKILLS - Debate

Divide the class into groups. Debate on the following statement.

“Sharing and caring improves human harmony like Chemical bond”

- ionic bond
- covalent bond
- coordinate bond

V. Complete the crossword using the clues.

Left to right:

1) pair of electrons which do not take part in bond formation

2) reaction in which both oxidation and reduction takes place

3) rule which says about eight electrons in outermost shell

Top to bottom:

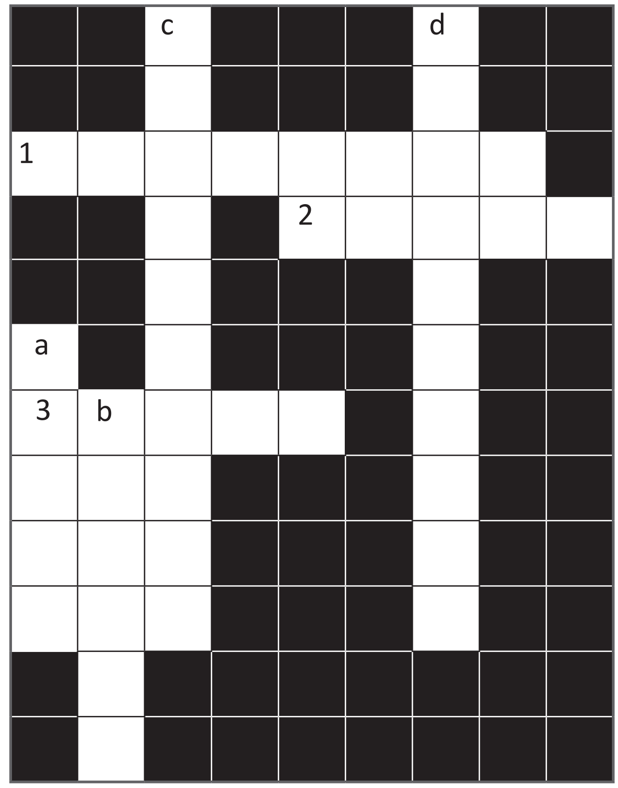
a) bond formed by transfer of electrons from one atom to another

b) ion with positive charge

c) energy required to remove the most loosely bound electron from an isolated gaseous atom of an element

d) loss of electron

(lonepair, redox, octet, ionic, cation, ionisation, oxidation)



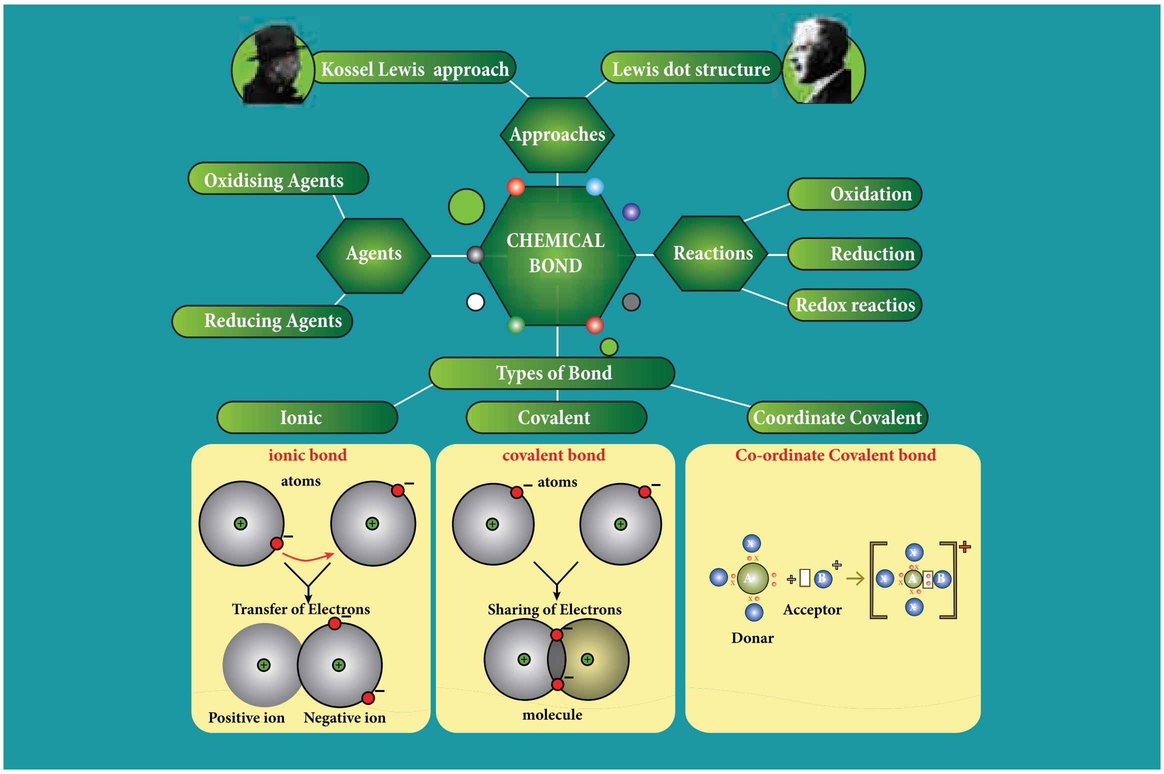
REFERENCE BOOKS

1. Modern Inorganic Chemistry – by R.D.Madan

2. Textbook of Inorganic Chemistry – by Soni, P.L. and Mohan Katyal.

INTERNET RESOURCES

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



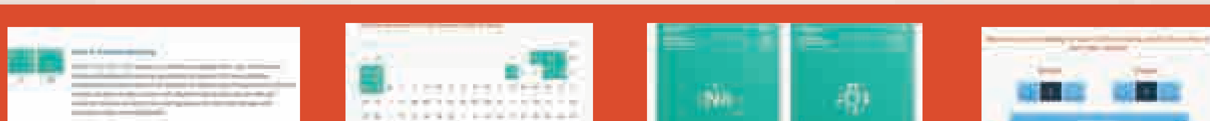
ICT CORNER

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.

B467_SCI_9_T2_EM

*Pictures are indicative only

UNIT 6

Acids, Bases and Salts

BPNYLX

Learning Objectives

After completing this lesson, students will be able to

- know about formation, properties and uses of acids, bases and salts
- know about how they play a vital role in our daily life
- understand how to identify the nature of a solution by using indicators and pH paper
- know how strong are acid or base solutions using pH scale
- 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 the compound which are capable of forming hydrogen ions (H^+) in aqueous solution whereas a base is the 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 these in detail.

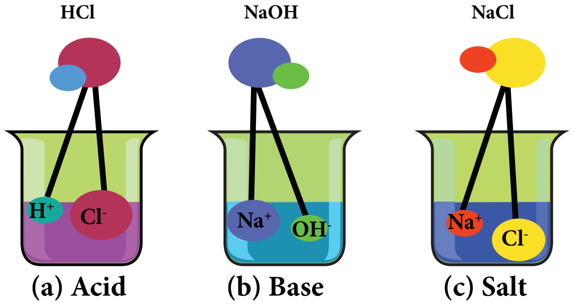


Figure 6.1 Acid, base and salt

6.1 What are Acids?

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

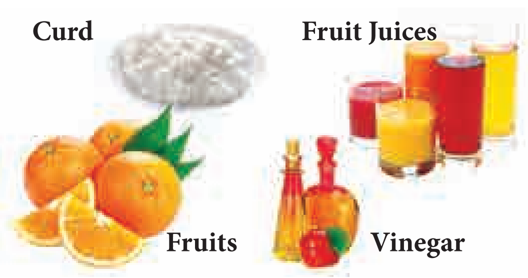


Figure 6.2 Acid, base and salt in food

All these edible items taste similar i.e. sour. What cause 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" which means sour taste. Substances with sour taste are called acids.

Table 6.1 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
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^+)

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

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

Table 6.2 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	H^+	SO_4^{2-}	2
Phosphoric Acid	H_3PO_4	H^+	PO_4^{3-}	3

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.

6.1.1 Classification of Acids

Acids are classified in different ways as follows:

Based on their sources:

(i) Organic acids

(ii) Inorganic acids

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

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

Dibasic Acid:

An acid which gives two hydrogen ions per molecule of the acid in solution.

Example: H_2SO_4, H_2CO_3

Tribasic Acid:

An acid which gives three hydrogen ions per molecule of the acid in solution.

Example: H_3PO_4

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.

Based on Ionisation

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

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.

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

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.

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.

6.1.2 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.

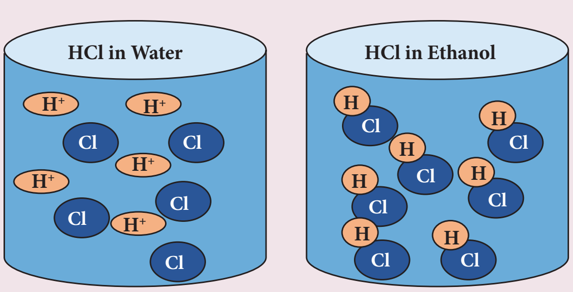
$$HCl + NaOH \rightarrow NaCl + H_2O$$

DO YOU KNOW?

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 solvent like ethanol they do not ionise and remain as molecule.



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.

6.1.3 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.

6.1.4 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 resistant 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.

6.2 What are 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 6.3 enlists various bases and ions formed by them in water.

DO YOU KNOW? 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.

6.2.1 Classification of Bases

Based on their Acidity

a) Monoacidic Base:

It is a base that ionises in water to give one hydroxide ion per molecule.

Example: NaOH, KOH

b) Diacidic Base:

It is a base that ionises in water to give two hydroxide ions per molecule.

Example: $Ca(OH)_2$. $Mg(OH)_2$

Table 6.3 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 oxide	$Al(OH)_3$	Al^{3+}	OH^-	3

c) Triacidic Base:

It is a base that ionises in water to give three hydroxide ions per molecule.

Example: $Al(OH)_3$, $Fe(OH)_3$

Based on concentration

a) Concentrated Alkali

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

b) Dilute Alkali

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

Based on Ionisation

a) Strong Bases:

These are bases which ionise completely in aqueous solution.

Example: NaOH, KOH

b) 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.

6.2.2 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.

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

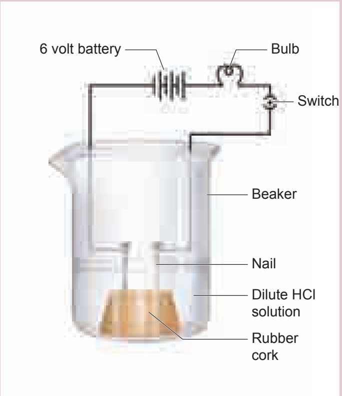
The above reaction between a base and an acid is known as Neutralisation reaction.

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

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

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?



> **DO YOU KNOW?** Few metals do not react with sodium hydroxide. For example: Cu, Ag, Cr

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.

6.2.3 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.

6.3 Tests for Acids and Bases

Take 10 ml of solution in a test tube and test with a litmus paper or indicators like phenolphthalein and methyl orange.

a) Test with a litmus paper:

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

b) Test with an indicator Phenolphthalein:

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

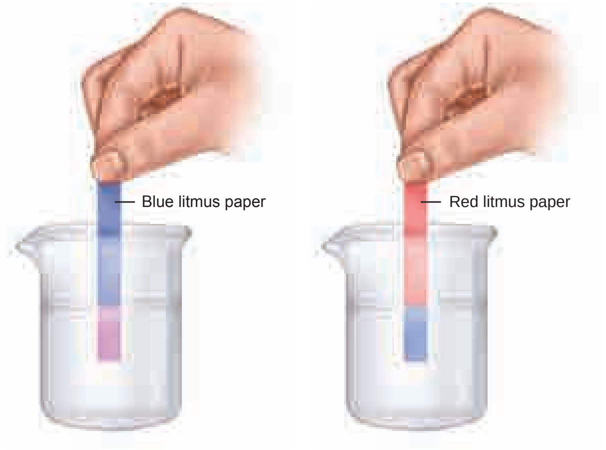


Figure 6.3 Test for acid and base using litmus paper

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.

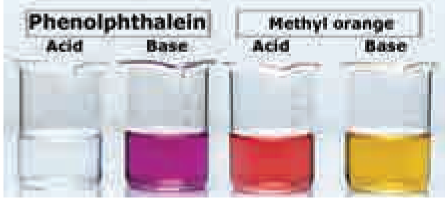
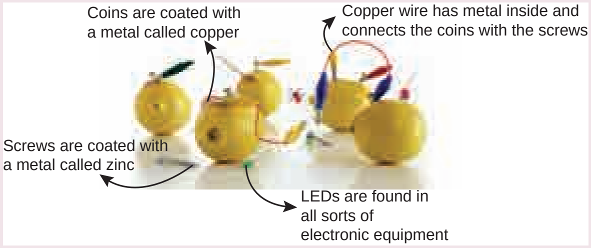


Figure 6.4 Test for acid and base using indicator

Table 6.4 Acid base indicator

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

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



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				

6.4 How strong are Acid or Base 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

6.4.1 How can we measure the pH of a given solution?

The pH of a solution can be determined by using a universal indicator. It contains a mixture of dyes. It comes in the form of a solution or pH paper.

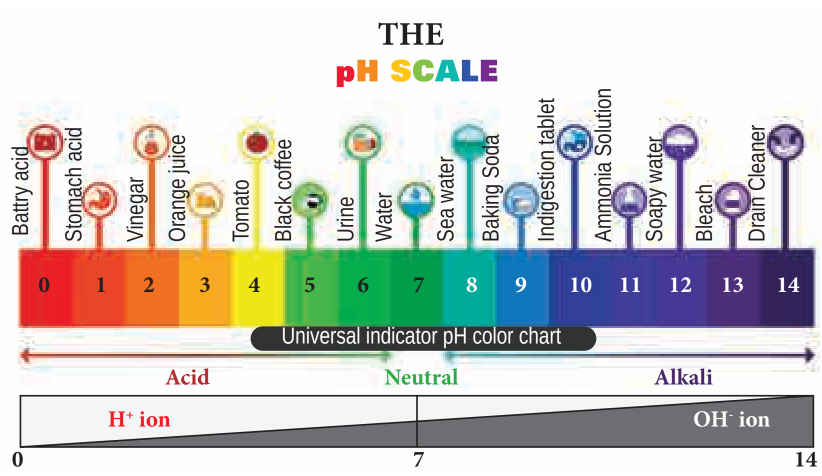


Figure 6.5 pH Scale

A more common method of measuring pH in a school laboratory is by using pH paper. pH paper contains a mixture of indicator.

Figure 6.6 Indicators and pH paper

Activity 4

Take a jar with cabbage leaves and pour boiling water to it. Allow it to cool to room temperature and filter it. It is your own indicator used to find whether the given solution is acidic or basic. This juice produces a red colour when mixed with an acid and a green colour with a base.

Take any tooth paste. Add cabbage juice to it. It changes to green which shows that tooth paste is basic in nature. In the same way, test with lemon juice, tomato juice and pure water.

6.4.2 Importance of pH in everyday life

Are plants and animals pH sensitive?

Our body works within the pH range of 7.0 to 7.8. Living organisms can survive only in narrow range of pH change.

pH in our digestive system

It is very interesting to note that our stomach produces hydrochloric acid. It helps in the digestion of food without harming the stomach. During indigestion the stomach produces too much acid and this causes pain and irritation. pH of stomach fluid is approximately 2.0.

pH changes as the cause of tooth decay

White enamel coating of our teeth is calcium phosphate, the hardest substance in our body. Toothpastes which are generally basic and used for cleaning the teeth can neutralise the excess acid and prevent tooth decay.

pH of soil

In agriculture, the pH of soil is very important. Citrus fruits require slightly alkaline soil, while rice requires acidic soil and sugarcane requires neutral soil.

pH of rain water

The pH of rain water is approximately 7 which means that it is neutral and also represents its high purity. If the atmospheric air is polluted with oxide gases of sulphur and nitrogen, they get dissolved in rainwater and make its pH less than 7. Thus, if the pH of rain water is less than 7, then it is called acid rain. When acid rain flows into the rivers it lowers the pH of the river water. The survival of aquatic life in such rivers becomes difficult.

Table 6.5 pH value of solutions

The Solution	Approximate pH
Blood	7.3 – 7.5
Saliva	6.5 – 7.5
Gastric Juice	1.0 – 3.0
Soft Drinks	3.0
Sea Water	8.5
House hold Ammonia	12.0
Tomato Juice	4.0 – 4.4

6.5 What are Salts?

When you say salt, you may think of the white stuff sprinkled on chips, but that is just one kind of salt called as common salt. Seawater contains many salts dissolved in it. Sodium chloride is separated from these salts.

BPSLAU

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.

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

6.5.1 Types of Salts

(i) Normal Salts

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

$NaOH + HCl \rightarrow NaCl + H_2O$

(ii) 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.

$NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O$

(iii) Basic Salts

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

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

(iv) 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.

$$KAl(SO_4)_2.12H_2O$$

6.5.2 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.

6.5.3 Water of Crystallisation

Many salts are found as crystals with water molecules they contain. 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 the 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.

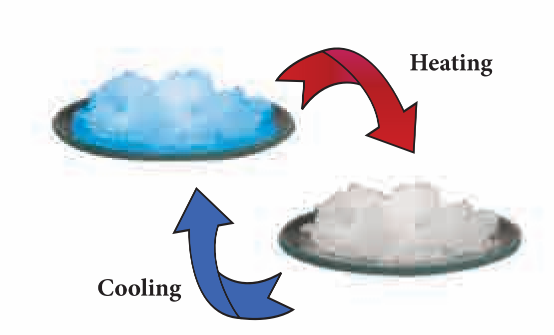


Figure 6.7 Hydrated Salt

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

6.5.4 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.

Activity 5

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

(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^{2+}
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.

6.5.5 Uses of Salts

Common Salt (NaCl)

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

Washing Soda (Sodium Carbonate-)

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 6

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 and in industries.
- 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, Methyl orange are used as indicators to find out the given solution whether acid or base.
- Litmus paper is also used to find out the given solution whether acid or base.
- pH paper is find out the given solution whether 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 hydrogen ion concentration in a solution.

A-Z GLOSSARY

Acids	It is a substance which furnishes H^+ ions H_3O^+ ions when dissolved in water
Bases	It is a substance which furnishes ionizes OH^- ions when dissolved in water
Salts	It is product of reaction between acids and bases
Indicators	Chemical substances used to find out whether the given solution is acid or base.
pH Scale	It is used to find out Hydrogen ion concentration in a solution.
pH Paper	It is used to find out whether the given solution is acidie or basic or neutral in nature.
Sulphuric acid	It is called as "King of Chemicals" and it is used to manufacture of most of the chemicals.
Aquaregia	It is the 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.

TEXT BOOK EXERCISES

BPXUNK

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)

IX_Science Term II Unit-6.indd 107 02-08-2018 17:21:15

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. pH value of human blood is ________ (7.0, 7.4, 7.6)
7. The nature of the tooth paste commonly used is ______ in nature (acidic, basic, neutral)
8. You are given pure water to test the pH value using pH paper. It shows ______colour (White, black, green)
9. The hydrated salt of copper sulphate has ______ colour (Red, White, Blue)

II. Answer in brief

1. Name any two metals which do not react with sodium hydroxide.
2. Write any four uses of acids.
3. Give the significance of pH of soil in agriculture.
4. When does the acid rain occur?
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 the 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.
9. Find the odd one out: Lemon juice, Tomato juice, House hold ammonia, Coffee
10. What is neutralization reaction? Give an example.

III. Answer in detail

1. Why does distilled water not conduct electricity whereas rain water does?
2. Plaster of Paris should be stored in a moisture proof container. why?
3. Write any four uses of bases.
4. The solutions A, B, C, D and E when tested with universal indicator showed pH as 4, 1, 11, 7 and 9 respectively. Among these which solution is
   (i) neutral
   (ii) strongly alkaline
   (iii) strongly acidic
   (iv) weakly acidic
   (v) weakly alkaline
5. Write any five uses of salts.
6. Sulphuric acid is called King of Chemicals. Why is it called so?

REFERENCE BOOKS

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

INTERNET RESOURCES

1. https:/www.thoughtco.com
2. Aquaregia Wikipedia
3. https:/googleweblight.com
4. https:/scienceing.com>Chemistry
5. https:/edurev.in>studytube>Q-you-

UNIT 4

Carbon and its Compounds

GAHQZP

Learning Objectives

After completing this lesson, students will be able to

- explain the special features of carbon.
- know the isomerism of carbon compounds.
- know the three allotropic forms of carbon.
- differentiate between the properties of graphite and diamond.
- recognise the various inorganic carbon compounds with their uses.
- know the few 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 an inseparable chemical entity associated with living things of the earth. The food we eat, the clothes we wear, the cosmetics we use and the fuels by which we run the automobiles all contain carbon compounds. When we burn the materials like cotton, wood, paper, plastics and rubber, they burn with smoky flame and leave some amount of solid or ash at the end. This is nothing but carbon.

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). In spite of this availability of small amount of carbon in nature, carbon compounds have an immense importance in everyday life. For example, we ourselves are made of carbon compounds. About 18 % of the weight of human body is carbon.

- Carbon is present in our muscles, bones, organs, blood and other components of living matter. Carbohydrates (compounds formed primarily of carbon and hydrogen) provide fuel for living organisms, underlie the structure of plants, animals and bacteria and are essential components of DNA and RNA, the molecular blueprints of life.
- A large number of things which we use in our daily life are made up of carbon compounds.
- The most vital photochemical reaction of plants involve carbon compounds (CO_2 and Chlorophyll)

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**.

4.1 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. 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 burned to form carbon dioxide and so it must be another form of carbon.

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.

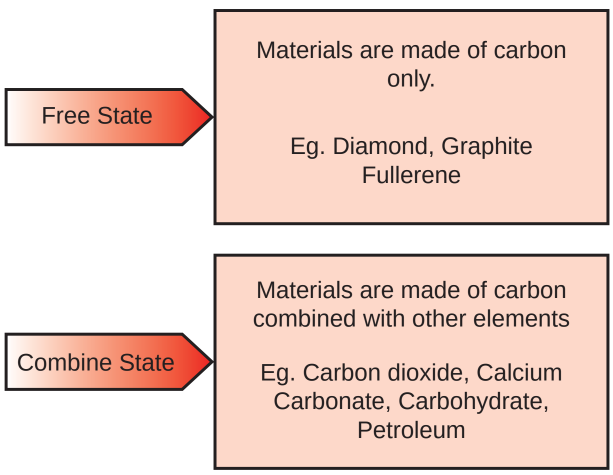
In 1855, English chemist **Benjamin Brodie** produced pure graphite from carbon, proving graphite is a form of carbon.

Although it had been previously attempted without success, in 1955 American scientist **Francis Bundy** and co-workers at 'General Electric' company finally demonstrated that graphite could be transformed into diamond at high temperature and high 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. The most recently discovered allotrope of carbon is **graphene**, which 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.

4.2 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:

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

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

4.2.1 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.

More to Know


Friedrich Wohler (1800 – 1882)

Until the mid – nineteenth century, scientists believed organic compounds came only from live plants and animals. They reasoned that organisms possessed a vital force that enabled them to produce organic compounds. This concept was known as **Vital Force Theory.** In 1829, **Friedrich Wohler** synthesized urea, an organic compound, from inorganic compounds lead cyanate and aqueous ammonia.

$$\underset{\text{Lead cyanate}}{Pb(OCN)_2} + \underset{\text{Aq. Ammonia}}{2NH_4OH} \rightarrow \underset{\text{Urea}}{2\,(NH_2)_2CO} + \underset{\text{Lead hydroxide}}{Pb(OH)_2}$$

Wohler was actually attempting to synthesize ammonium cyanate from the foresaid reaction. But he obtained the crystals of urea and thus urea is the first organic compound synthesized in laboratory. This synthesis was a blow to vital force theory. Following Wohler, chemists synthesized many organic compounds like acetic acid, methane, dyes, etc. in laboratory. Hence Friedrich Wohler is called '**Father of Modern Organic Chemistry**'.

4.2.2 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 the compounds are given in Table 4.1.

Table 4.1 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 CaO and Coke	Greyish black solid	To manufacture graphite and hydrogen To prepare acetylene gas for welding.
Carbon disulphide (CS_2)	Directly prepared from C and S	Colourless Inflammable Highly poisonous gas	Solvent for sulphur To manufacture rayon Fungicide Insecticide
Calcium Carbonate ($CaCo_3$)	Prepared by passing CO_2 into the solution of slaked lime	Crystalline solid Insoluble in water	Antacid
Sodium bicarbonate ($NaHCO_3$)	Formed by NaOH with carbonic acid (H_2CO_3)	White Crystalline substance Sparingly soluble in water	Preparation of sodium carbonate. Backing powder Antacid

Activity 1

With the help of your teacher, try to classify the following compounds and materials and, fill in the table accordingly.

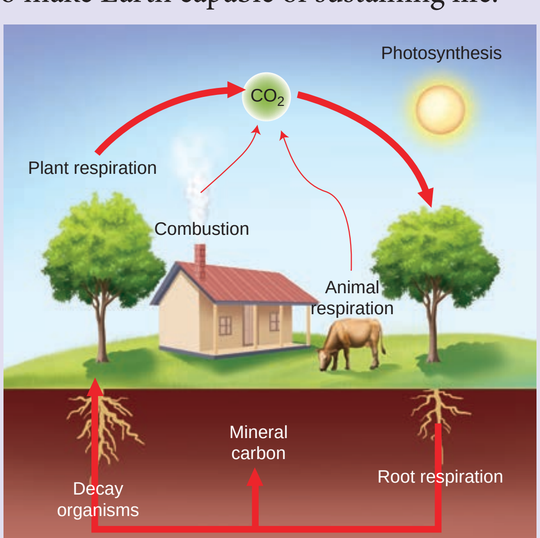
HCN, CO_2, Propane, PVC, CO, Kerosene, LPG, Coconut oil, Wood, Perfume, Alcohol, Na_2CO_3, $CaCO_3$. MgO, Cotton, Petrol.

Inorganic	Organic

DO YOU KNOW?

Carbon cycle

The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, geosphere, hydrosphere and atmosphere of the Earth. Carbon is the main component of biological compounds as well as a major component of many minerals such as limestone. Along with the nitrogen cycle and the water cycle, the carbon cycle comprises a sequence of events that are key to make Earth capable of sustaining life.



4.3 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 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 some unique features such as:

- Catenation
- Tetra valency
- Multiple bonds
- Isomerism
- Allotropy

GAHM2C

4.3.1 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.

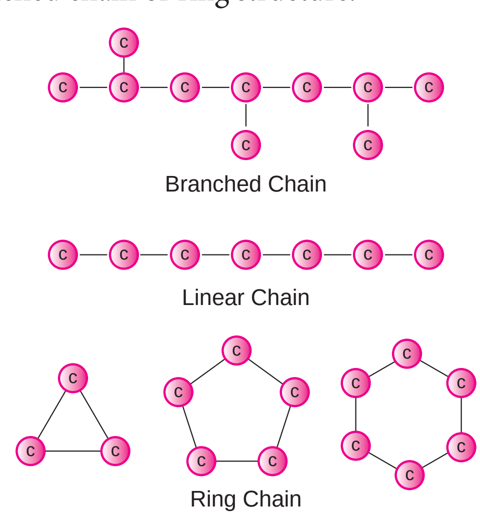


Figure 4.1 Catenation in carbon

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.

For example, Starch and Cellulose contain chains of hundreds of carbon atoms. Even plastics what we use in our daily life are macromolecules of catenated carbon compounds.

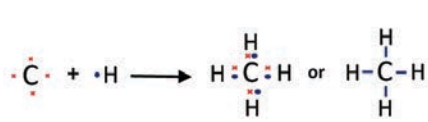
Activity 2

Ask the students to form human chain like catenated carbon compounds of linear, branched and ring structure.

4.3.2 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.

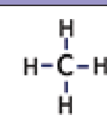
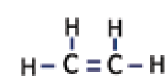
For example, in methane, carbon atom shares its four valence electrons with four hydrogen atoms to form four covalent bonds and hence tetravalent.



4.3.3 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 formation of various classes of carbon compounds. Table 4.2 shows one of such classes of compounds called **'hydrocarbons'** and the type of bonding in them.

Table 4.2 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.

4.3.4 Isomerism

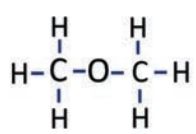
Isomerism is another special feature of carbon compounds especially found in catenated organic compounds. Let us consider the molecular formula of an organic compound C_2H_6O. Can you name the compound? You can't. Because the molecular formula of an organic compound represents only the number of different 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).

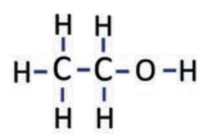
Illustration:

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.

4.3.5 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. Look at the materials given below. They are charcoal, graphite and diamond.

Are they equally hard? Are they cost same? Definitely not. Diamond is shiny, costliest and hardest of all. Charcoal and graphite are soft and dark. But chemically they are all similar. Yes. They are made of only carbon. They are called allotropes of carbon.

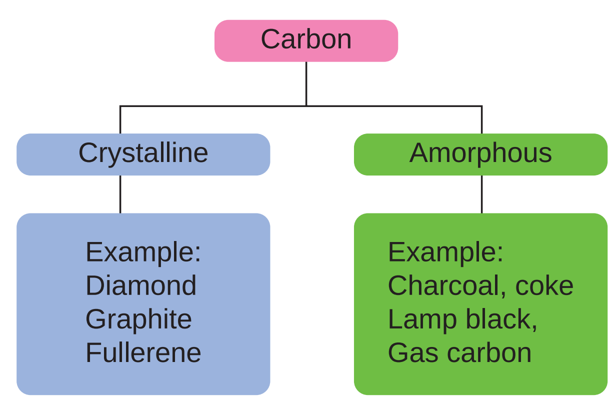
Think yourself:

One gram of diamond costs in thousands where as a kilogram of charcoal costs less than hundred. Even though both are chemically similar, why does diamond cost more?

Why do elements show allotropy?

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.



Charcoal Graphite Diamond

Figure 4.2 Allotropes of carbon

(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.

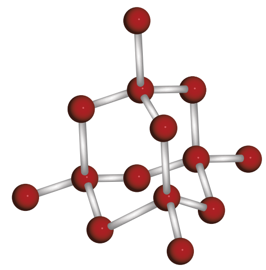


Figure 4.3 Structure of Diamond

Graphite:

- In graphite, each carbon atom is bonded to three other carbon atoms through covalent bonds in the same plane.

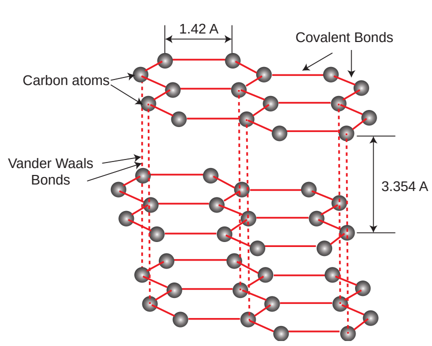


Figure 4.4 Structure of Graphite

- 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.

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 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.

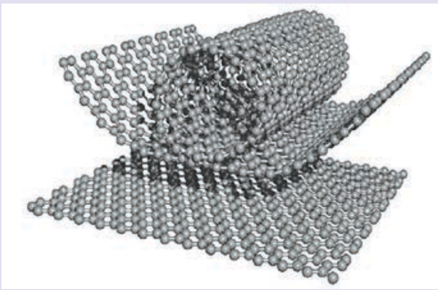


Table 4.3 Difference between Diamond and Graphite

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 non-conductor of heat and electricity.	It is conductor of heat and electricity.

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}.

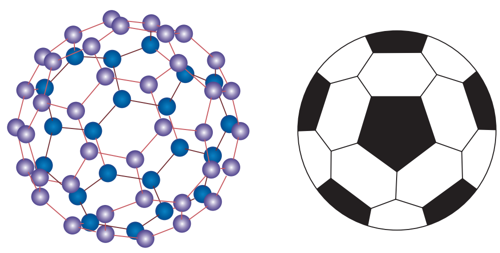


Figure 4.5 Structure of Fullerene

- This allotrope was named as **Buckminster fullerene** after the American architect Buckminster **fuller**. Because its structure remembered 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}.

(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. Table 4.4 enlists some amorphous forms of carbon and their features.

Table 4.4 Preparation, nature and uses of amorphous form of carbon

Amorphous Form	Preparation	Nature	Uses
Charcoal	Prepared from various sources like wood, bone and sugar. Types: wood charcoal bone charcoal, sugar charcoal.	Porous black solid Huge surface area due to porosity	Wood charcoal: Excellent household fuel, as gun powder, reducing agent in metallurgy Bone charcoal: To remove colour in sugarcane juices Sugar charcoal: Extracting metal from oxides
Lamp black	Prepared by burning mustard oil, turpentine oil and petroleum in the absence of oxygen	Greyish black porous solid	Household fuel As reducing agent in the extraction of metals like iron, copper and lead To manufacture graphite and calcium carbide. To manufacture water gas and producer gas.
Coke	Prepared by heating coal in the absence of air at 1300°C. Coal gas is obtained as a biproduct.	Greyish black porous solid.	Household fuel, As reducing agent in the extraction of metals like iron, copper and lead, To manufacture graphite and calcium carbide. To manufacture water gas and producer gas.
Gas Carbon	Prepared by destructive distillation of coal. Thermal vaporization of coal on condensation produces a grey solid.	Dull grey solid. Good conductor of electricity.	Making electrode in dry cell.

Activity 3

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

4.4 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.

4.5 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 Burning.

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

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

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

Reaction with steam

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

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

DO YOU KNOW?

Carbon monoxide is a toxic oxide gas of carbon. When fuels undergo incomplete combustion (insufficient supply of oxygen), it results in the formation of carbon monoxide. It is released into the atmosphere from various sources like vehicle fuels, domestic fuels, industries, furnaces, etc. Cigarette smoking also is a source of carbon monoxide.

How toxic carbon monoxide is?

It is a colourless, odourless toxic gas. When people exposed to CO, it enters into human body through breathing and affects the function of haemoglobin. CO displaces oxygen from haemoglobin thereby stops its function (supply of oxygen to the parts of body) leading to death.

Reaction with sulphur

With sulphur, carbon forms its disulphide at high temperature.

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

Reaction with metals

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

$$W_{(s)} + C_{(g)} \rightarrow WC_{(s)}$$

4.6 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.

4.7 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 technology 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.

4.7.1 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).

DO YOU KNOW?

Plastics in the environment break down into pieces that are smaller than 5mm in diameter. Dangerous pollution in the ocean sticks to microplastics making them harmful to marine life (fish and shrimp) who mistake them as their food.

4.7.2 Identifying different types of plastics

(a) The resin codes

Look at the following pictures.

Figure 4.6 Plastic items used in daily life

One is a plastic sachet in which milk is distributed 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.

(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) How to find 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.

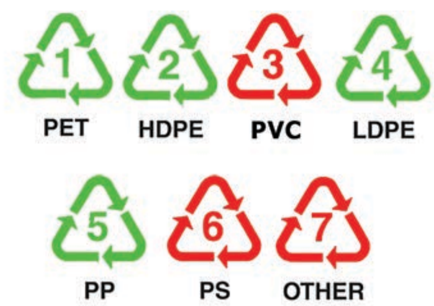


Figure 4.7 Resin codes

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 all plastics with a code can be recycled. The Table 4.5 shows information of various resin codes.

Activity 4

- Collect various plastic materials we use in our day-to-day life and try to find the resin code.
  - Once you have found an everyday plastic item with a resin code – ask yourself the following questions.

What plastic resin codes did you find?

Is this plastic item used to store or serve food or drinks?

Do these types of plastics contain harmful chemicals?

To find out these answers, please refer Table 4.5, Plastic Resin Code Chart. Prepare a report of your observations.

Table 4.5 Plastic Resin Code Chart

PLASTIC RESIN CODE CHART

Plastic resin codes can be found on the label or bottom of most plastic items.
It is a number or acronym found in the middle of a chasing arrow triangle.
There may be other numbers or letters on the plastic items, but these are not resin codes.

KNOW PLASTICS

RESIN CODE	OTHER NAMES	COMMON ITEMS	ABOUT
01 PET	PETE, Polyester	Mineral water or soft drink bottles and plastic jars.	This plastic is designed to be used only ONCE. Reusing PET plastic can release a chemical additive called antimony which is not good for your health.
02 HDPE	PEHD	Bottles (shampoo, detergent, etc.), toys, plastic bags and waste bins.	Considered one of the safer plastics. It is light, very strong and widely recycled.
03 PVC	V, Vinyl	Raincoats, ring binders, shoes, floating pool toys and shiny prints on backpacks.	The most toxic plastic. Do the smell test: some PVC has a new shoe or new car smell. Avoid this type of plastic where possible.
04 LDPE	PELD, LLDPE	Food packaging, plastic bags, food storage containers and plastic coating on the inside of paper cups.	Considered one of the safer plastics. It is very flexible and soft but strong.
05 PP		Bottle caps, straws, food containers, hard pencil cases and plastic chairs.	Considered one of the safer plastics. It feels waxy or greasy. It is light and hard but scratches easily.
06 PS	Thermocol, EPS, XPS and HIPS	Pens, rulers, foam, packaging, toys, disposable cups, plates and cutlery.	One of the unsafe plastics as it has harmful chemicals. Thermocol is very light weight (95% air) and often ends up polluting the oceans.
07 OTHER	Polycarbonate (PC), Acrylonitrile Butadiene Styrene (ABS), acrylic (AC), bioplastics, nylon, polyurethane (PU), etc.	PC: baby bottles, water bottles and food containers. ABS: Lego, helmets, and kitchen appliances. Acrylic: phone screens and paints. Bioplastics: plastic bags and tableware. Nylon: clothes and toothbrush bristles. PU: mattress foam and shoe soles.	This code includes all plastic types that do not fit into the resin codes 1-6. PC and ABS are two of the unsafe plastics and are considered toxic. When you see a #7 plastic try to know more before buying and using it.
NO CODE	Does not have a resin code or an acronym	Can be any plastic item.	The company did not follow the rules and mark what type of plastic was used. It could be harmful but you do not have the information to know for sure. Avoid using plastic without a resin code.

(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.

4.7.3 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 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 or fire and 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 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 4.8 One-time use plastic items

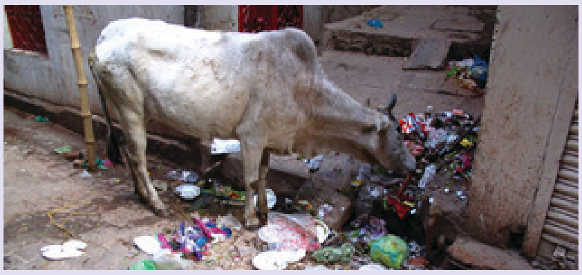
These items take a few seconds to be made in a factory. You will use them for a very short time. Once you throw them away, they can stay in our environment for over a 1,000 years causing plastic pollution for future generations.

We need rules and laws to protect people and the environment from plastic pollution.

More to Know

The impacts of one-time use and throwaway plastics on animals

One-time use and throwaway plastics can cause harm to animals. In the past, restaurants and teashops used banana leaves as a plate and for takeaway food. This was a good source of food for cows that would eat the leftover food and banana leaves, making them the perfect recyclers. They recycled this waste and in return provided us with nutritious milk and valuable cow dung as a fertiliser. Since plastics have been introduced, the banana leaf has been replaced by a plastic sheet (commonly called a 'cut-piece') on top of plates for food. When these are thrown away animals such as cows smell the leftover food. When they try to eat it, they eat the plastic by accident. The chemical composition of plastic does not allow it to be broken down by the cow's digestive system. Instead the plastic gets stuck in the rumen (stomach) of a cow, occupying precious space and reducing the ability of a cow to digest nutrients and provide nutritious milk and valuable cow dung for society.



- How can you make sure that cows do not eat your leftover food in plastic packaging?
- How will the ban on one-time use and throwaway plastics as of 1st January 2019 in Tamil Nadu help animals such as cows?
- What can you do in your day-to-day life to protect animals from the dangers of plastics?

4.8 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.

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

DO YOU KNOW?

If we do not change our habits, one study estimates that our oceans will have more plastic than fish (in weight) by 2050.

4.8.1 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 one-time use plates are made from Polystyrene (resin code # 6) which is harmful to your 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 lightweight 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.

DO YOU KNOW?

A study found that one-time use and throwaway plastic items such as cups, plates, spoons and straws were among the top 10 plastic items found in garbage washed up from the ocean.

4.9 Role of students in the prevention of plastic pollution

Plastics affect all of us. Change starts with you and your family. The first step to change something is to know why you need to change. Equipped with the right knowledge, you can start to take small steps to protect yourself, your family and beautiful Tamil Nadu.

You play a very important role and have the power to minimise plastic pollution. You can start today by reflecting on the plastic you use in your everyday life.

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.

4.9.1 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.

4.9.2 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).

Let us join together to make our nation pollution free.

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.
- ❖ Catenation, tetra valency, multiple bonds, isomerism and allotropy are the unique features of carbon.
- ❖ Carbon atom links repeatedly to itself through covalent bond to form linear chain, branched chain or ring structure.
- ❖ Carbon combines with other elements or with itself through single bond, double bond and triple bond.
- ❖ Charcoal, graphite and diamond are the allotropes of carbon.
- ❖ In diamond atoms are arranged in repeated tetrahedral fashion.
- ❖ In graphite, each carbon atom is bonded to three other carbon atoms through covalent bonds in hexagonal fashion.
- ❖ Buckminster fullerene consists of 60 carbon atoms joined together in series of 5- and 6- membered to form spherical molecule resembling a soccer ball.
- ❖ Buckminster fullerene is named after the American architect Buckminster fuller.
- ❖ All the allotropic forms of carbon are solids whereas its compounds exist in solid, liquid and gaseous state.
- ❖ Carbon monoxide is a toxic oxide gas of carbon. When fuels undergo incomplete combustion (insufficient supply of oxygen), it results in the formation of carbon monoxide.
- ❖ The resin code represents the polymer used in making of plastics. The resin codes are numbered from 1 to 7.
- ❖ The three unsafe plastics are PVC (Polyvinyl chloride), PS (Polystyrene) and PC (Polycarbonate) / ABS (Acrylonitrile Butadiene Styrene).
- ❖ One-time use plastic causes health problems for humans, plants and animals.
- ❖ Government of Tamil Nadu has taken a step forward to ban the usage of some kind of plastics items (Environment and Forests Department, T.N. G.O. No: 84, dated 25/06/2018).
- ❖ Plastic carry bags, cups, plates, straws, water pouches, cutlery and plastic sheets used for food wrapping are one – time use plastics.

A-Z GLOSSARY

Allotropes	Different forms of an element.
Allotropy	Property by which an element can exist in more than one form that are physically different and chemically similar.
Carbon cycle	It is the biogeochemical cycle by which carbon is exchanged among the biosphere, geosphere, hydrosphere and atmosphere of the Earth.

Catenation	It is binding of an element to itself or with other elements through covalent bonds to form open chain or closed chain compounds.
Harmful plastics	Plastic that use toxic and harmful chemicals.
Inorganic carbon compounds	Compounds of carbon obtained from non-living matter.
Isomerism	Phenomenon in which the same molecular formula may exhibit different structural arrangement.
Isomers	Compounds that have the 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.

GB6I3Z

TEXTBOOK EVALUATION

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 Number of free electron(s) in each carbon of graphite is

(a) one (b) Two
(c) Three (d) Four

3 The carbon atoms in fullerene are arranged in mixed

(a) Tetragon and Pentagon
(b) Pentagon and Hexagon
(c) Hexagon and Heptagon
(d) Heptagon and Octagon

4 Carbon forms large number of organic compounds due to

(a) Allotropy (b) Isomerism
(c) Tetravalency (d) Catenation

5 Diamond is not a good conductor of electricity because

(a) it is very hard
(b) it has no free electron
(c) its structure is uniform
(d) it is insoluble in water

6 Which of the following does not contain double bond

(a) CO_2 (b) C_2H_4
(c) HCl (d) O_2

7 Which of the following is highly toxic?
(a) Carbon dioxide
(b) Carbon monoxide
(c) Calcium carbonate
(d) Sodium bicarbonate

8 Raagav 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

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

10 Which of the following plastic items are banned by the Government of Tamil Nadu as of 1st January 2019?
(a) Plastic sheets
(b) Plastic tea cups
(c) Plastic water packets
(d) All the above

11 Graphite is used as lubricant in machines because
(a) it is good conductor of electricity
(b) it is made of slippery layers and has high melting point
(c) it has high density
(d) it is strong and soft

12 The lead pencil contains
(a) Graphite (b) Diamond
(c) Lead (d) Charcoal

13 Graphene is one atom thick layer of carbon obtained from
(a) Diamond (b) Fullerene
(c) Graphite (d) Gas Carbon

14 Plastic resin codes are shown as three chasing arrows in a____________ with a number in the middle or letters (an acronym of that plastic type).
(a) Logo (b) Recycling symbol
(c) Square (d) Triangle

15 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 knows as ___________.
4. Different methods of formation of carbon is the main reason for its ______________.
5. There are ________ plastic resin codes.

III Match the following

Alkyne	-	Bucky Ball
Andre Geim	-	Oxidation
C_{60}	-	Graphene
Thermocol	-	Triple bond
Burning	-	Polystyrene

IV Answer very briefly.

1. How many valence electrons are there in carbon?
2. Who is called 'Father of Modern Organic Chemistry'?
3. Which three resin codes are unsafe?

IV. Answer in brief.

1. Differentiate graphite and diamond
2. What are saturated and unsaturated compounds called?

3. Carbon do not form ionic compounds. Why?
4. What is the valency of carbon in carbon monoxide?
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. HOTS

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?

VII. Answer the following by rearranging the jumbled letters.

1. It is the hardest allotrope of carbon. mnodaid Ans:________________
2. Organic compounds having double bond between carbon atoms are

   knelaes Ans: ________________
3. Reaction of carbon with oxygen gives

   osdiexs Ans: ________________
4. In this molecule, carbon is attached with four hydrogen atoms.

   emathen Ans: ________________
5. Carbon combines with other elements through ________ bond.

   lnaocvet Ans: ________________
6. It is used as gun powder.

   ocahrcla Ans: ________________
7. Plastics made of __________ are represented by resin code #6.

   sytlopynere Ans: ________________
8. One-time use plastics are also known as ____________ plastics.

   awyrhotwa Ans: ________________
9. One-time use plastics cause ____________ damage.

   trnvomenialne Ans: ________________
10. Expanded polystyrene is commercially known as

    mthreolco Ans: ________________

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

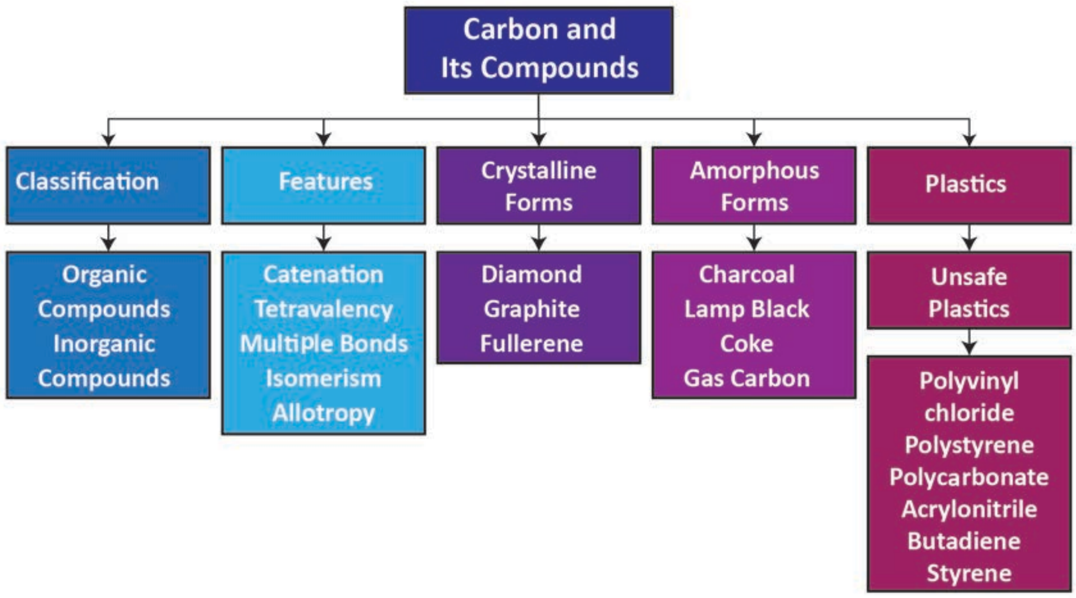
https://en.wikipedia.org/wiki/Carbon

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

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

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

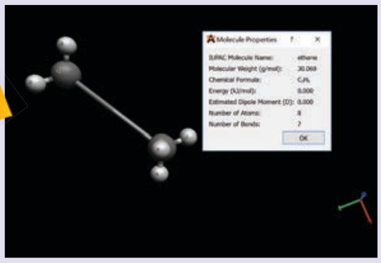
Concept Map



ICT CORNER

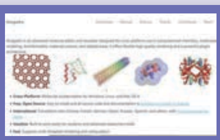
Carbon

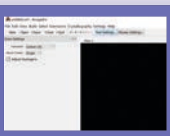
Experiment carbon bonding with an intuitive molecular editor and visualization tool

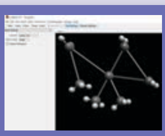


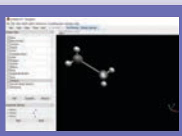
Steps

- 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.


Step1


Step2


Step3


Step4

Avogadro

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

*Pictures are indicative only

B567_9_SCI_EM_T3

UNIT 5

Applied Chemistry

GBFE5H

Learning Objectives

After completing this lesson, students will able to:

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

Introduction

We know that there are three major branches in chemistry namely: Organic chemistry, Inorganic chemistry and Physical chemistry. Organic chemistry deals with carbon and its compounds, inorganic chemistry is the study of minerals and the physical properties of these chemicals are dealt in physical chemistry. Then what is applied chemistry?

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 or involve chemical principles and theories.

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 by 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.

5.1 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.

Nanotechnology is the application of science to manipulate matter to atomic or molecular scale and making use of them to develop specialized materials and devices for use in our day to day life. It deals with the materials which are smaller than 100 nanometres and hence it is so called.

5.1.1 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.
- One nanometre is about one twenty-five-thousandth the diameter of a human hair.
- A cell membrane is around 9 nm across.

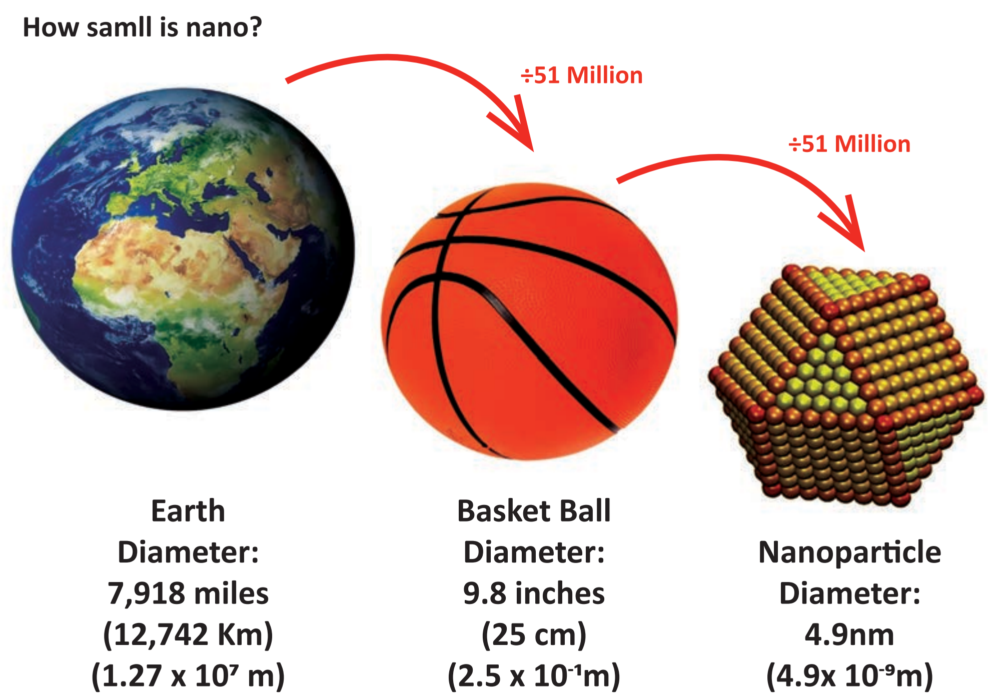


Figure 5.1 Comparisim of nanometre with metre

- The DNA double helix is 2 nm across.
- The diameter of one hydrogen atom is around 0.2 nm.

Activity 1

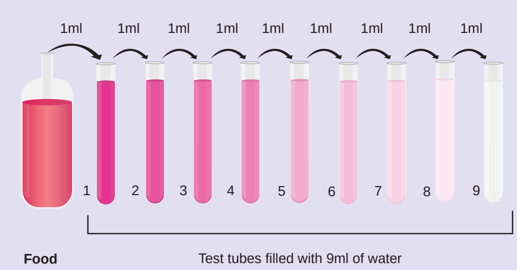
Let us try to understand the size at nanoscale through an example of Serial dilution.

Materials required:

Some scented food colouring materials, a Pasteur pipette, Nine test tubes, numbered 1-9.

Procedure

1. Fill each test tube carefully with 9 ml of water.
2. Using the Pasteur pipette, carefully add 1 ml of food colouring to Tube 1. Mix it thoroughly.
3. Smell the contents. What does it smell of? Does it smell the same as the original food colouring?
4. Now take 1 ml of liquid from Tube 1, add it to Tube 2 and mix thoroughly.
5. Continue the process by repeating steps 3 and 4: dilute Tube 2 into Tube 3, Tube 3 into Tube 4, and so on.



At what point you can no longer see any colour in the tubes?

At what point you can no longer smell anything in the tubes?

How can you explain the difference?

The method you have just used is called a **Serial dilution**. You can notice that in each tube, the food colouring is ten times more diluted than the previous tube. By the time they reach tube 9, the original food colouring would have been diluted to the level of one part of food colouring to a billion parts of water. At this stage, the intensity of colour and smell would be extremely low.

In such a way, when materials are broken down to nanoscale, they show some special surface properties which make them to be used for special kinds of applications. This type of manipulation of materials is done by nanotechnology.

How small is a nanoparticle? Visit the following link: https://www.youtube.com/watch?v=38Vi8Dm0kdY

Try it yourself

If you want to dilute 1 ml of the food dye to the same concentration as in Tube 9, in just one step, how much water would you need?

Figure 5.2 Nanometre sized changes

5.1.2 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. Due to their small dimensions, nanomaterials have extremely large surface area to volume ratio, resulting in more 'surface dependent' material properties. 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.

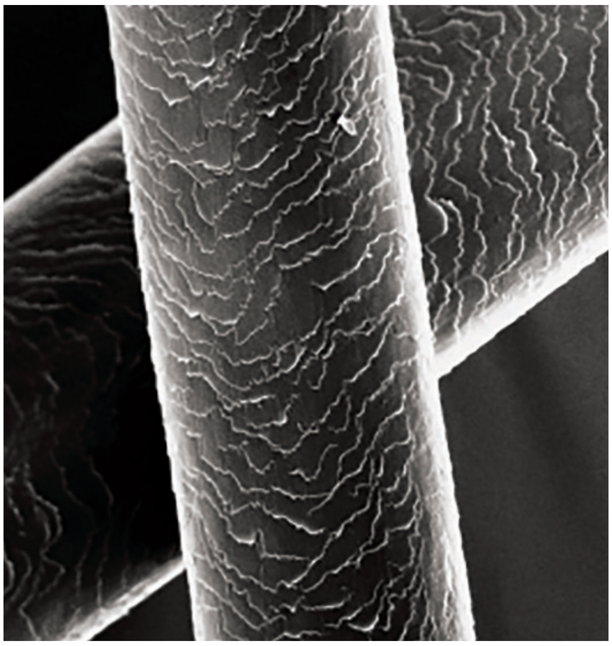


Figure 5.3 SEM image of human hair

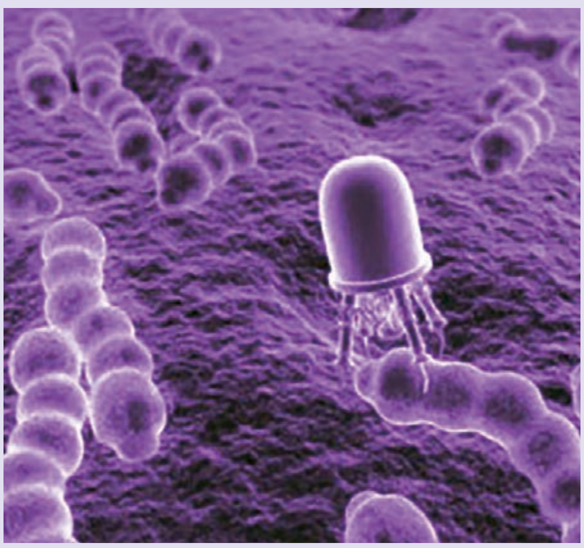
5.1.3 Applications of Nanochemistry

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

- The metallic nanoparticles can be used as very active catalysts.
- Chemical sensors from nanoparticles and nanowires enhance the sensitivity and sensor selectivity.
- Nano coatings and nanocomposites are found useful in making variety of products such as sports equipment, bicycles and automobiles etc.
- These are used as novel UV-blocking coatings on glass bottles which protect beverages from being damaged by sunlight.
- Nanotechnology is being 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 and they are used to improve moisturizers without making them too oily.
- Nanoparticle substances are incorporated in fabrics to prevent the growth of bacteria.

- Biomedical devices like drug infusion pumps, microneedles and glucometer are made from nanomaterials.
- Nanochemistry is used in making space, defence and aeronautical devices

More to Know



Nanorobotics is an emerging branch of nanotechnology which involves creating machines or robots at nanoscale. These devices range from 0.1-10 micrometres and are made up of nano scale or molecular components. Nanorobots can be used in different application areas such as medicine and space technology. Nowadays, these nanorobots play a crucial role in the field of Bio-Medicine, particularly for the treatment of cancer, removal of kidney stones, elimination of defected parts in the DNA structure, and for some other treatments that need utmost support to save human lives. Nanorobots with embedded chemical biosensors are used for detecting the tumor cells in early stages of cancer development inside a patient's body.

DO YOU KNOW?

Sunscreen lotion – Nanochemistry

Prolonged UV exposure causes skin-burns and cancer. Sun-screen lotions containing nano-TiO_2 provide enhanced sun protection factor (SPF). The added advantage of nano skin blocks such as ZnO and TiO_2 is that they protect the skin by sitting onto it rather than penetrating into the skin. Thus they block UV radiation effectively for prolonged duration. Additionally, they are transparent, thus retain natural skin colour while working better than conventional skin-lotions.

5.1.4 Drawbacks of nanomaterials in chemistry

- Nanoparticles are unstable when they contact 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 usually considered biologically harmful and toxic.
- It is difficulty to synthesis, isolate and apply them.
- There are no hard-and-fast safe disposal policies for nanomaterials.

5.2 Pharmaceutical chemistry

People always want to lead healthy life. But due to various reasons such as pollution, life style and natural calamities they are always prone to diseases. So they need to fight against diseases in order to lead healthy life. Do you know how our ancestors treated diseases? There is a long history of plants being used to treat various diseases. They figure in the records of early civilisations of Babylon, Egypt, India and China.

When modern organic chemistry evolved at the beginning of nineteenth century, chemists isolated various alkaloids like morphine, quinine and atropine from plants and used them for treatment of diseases. After 1860, many developments arose from synthesis of medicinally important chemicals and were used for treatment of numerous diseases.

When scientists started using synthetic chemicals as medicines, they started to analyse the effects of those chemicals in human and made necessary modifications. Then another new branch of chemistry was evolved. It is called **Pharmaceutical Chemistry.**

Pharmaceutical chemistry is the chemistry of drugs which utilizes the general laws of chemistry to study drugs. 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, condition of their storage and the therapeutic uses of the drugs. Drug discovery is the core of pharmaceutical chemistry.

5.2.1 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'.

Figure 5.4 Drug store

5.2.2 Characteristics of drugs

Can we use all chemicals as drugs? Definitely not. A drug must possess the following characteristics:

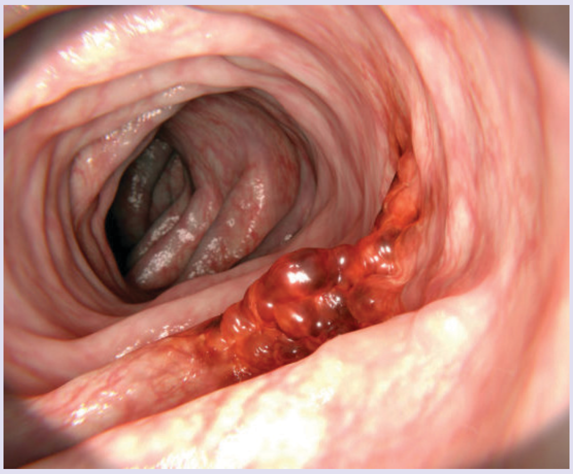
- It should not be toxic.
- It should not cause any side effects.
- It should not affect the receptor tissues.
- It should not affect the normal physiological activities.
- It should be effective in its action.

Chemicals which satisfy the above criteria only are preferred as drugs.

More to Know

Chemotherapy: Treatment of certain diseases by destroying the invading organism without damaging the cells of the host, by the use of certain organic compounds is known as **Chemotherapy.** It is widely used for treating cancer.

As part of the body's natural process, cells are constantly replaced through a process of dividing and growing. When cancer occurs, cells are reproduced in an uncontrolled manner. More and more cells are produced, and they start to occupy an increasing amount of space until they occupy the space previously inhabited by useful cells. Chemotherapy drugs interfere with the cancer cell's ability to divide and reproduce, and thereby prevent their growth. A single drug or a combination of drugs is used.



5.2.3 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 5.1 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

5.2.4 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.

A. 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 the 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, this anaesthetics are given. The patient loses consciousness for specific period of time (depending on the duration of surgery) and get it back later.

Figure 5.5 **General anaesthesia**

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.

Figure 5.6 **Local anaesthesia**

(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 simply 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.

DO YOU KNOW?

Discovery of anaesthesia

A young US dentist named William Morton inspired by the business opportunities afforded by technical advances in artificial teeth, searched for a way to relieve pain and boost dental profits. His efforts were soon rewarded. He discovered that when he or small animals inhaled sulfuric ether (now known as ethyl ether or simply ether) they became unresponsive. A few months after this discovery, on October 16, 1846, Morton anaesthetised a young male patient in a public demonstration at hospital.

The hospital's chief surgeon then removed a tumour on the left side of the jaw. This occurred without the patient apparently moving or complaining, much to the surgeon's and audience's surprise. So began the story of general anaesthesia, which for good reason is now widely regarded as one of the greatest discoveries of all time.

B. 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 headaches, myalgia and arthralgia.

Figure 5.7 Analgesics

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".

Figure 5.8 Pain relieving gel

C. 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.

Figure 5.9 Antipyretics

D. Antiseptics

Antiseptic is a substance that prevents infections caused by disease causing microorganisms or pathogens. Anticeptics either kill the microorganism or prevent their growth. Anticeptics 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 percent 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.

Figure 5.10 Antiseptics

E. 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 5.11 Cinchona Bark

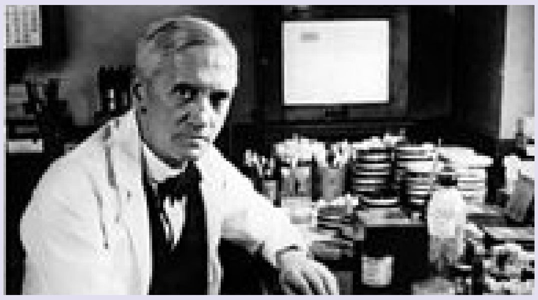
F. Antibiotics

Many microorganisms (bacteria, fungi and molds) produce certain chemicals which inhibit the growth or metabolism of some other disease causing microorganism. 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 in1929, from the mould Penicillium notatum. Penicillin is extensively used for rheumatic fever, narrowing of heart wall, bronchitis, and pneumonia etc.

DO YOU KNOW?

The first commercially available antibacterial was developed in 1932. But mold and plant extracts were used to treat infections by ancient Egyptians and Greeks over 2,000 years ago. Penicillin wasn't actually discovered until 1928, but the ancient Egyptians had the practice of applying moldy bread to infected wounds for treatment. Penicillin was an important antibiotic back in 1941, when it became more popular, because it helped to treat battle wounds for soldiers. It was named as the 'miracle drug'.

More to Know



Alexander Fleming was a doctor and scientist in London, England, in the early 1900s who was trying to figure out how to kill bacteria. Back in those days, many people got sick and died from infections caused by bacteria. In his lab, Fleming was experimenting with bacteria when some of his experiments accidentally got a kind of mold in them called **Penicillium** (pronounced pen-ih-SILL-ee-um). He noticed that the bacteria wasn't growing around the mold and studied it more. Eventually, he separated out small amounts of 'mold juice,' which is now knows as **penicillin.** Although Fleming first recognized how well it could kill dangerous bacteria, he wasn't able to make enough of it to turn it into a life-saving medicine.

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.

Figure 5.12 Sources of Antibiotics

G. 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.

Figure 5.13 Tablet form of antacids

Activity 2

Complete the following table by suggesting suitable type of drug(s) for the given health conditions.

Condition	Type of drug(s)
Ramu's grandfather suffers from knee pain.	
Sudha had spicy food last night and got indigestion.	
When Kavin returned home from school, he got wet in rain. So he suffered from fever.	
Nimmy cut her hand when sharpening her pencil.	

Try to learn: Ask your mother or grandmother, to suggest some home remedies for the fore said situations.

5.3 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.**

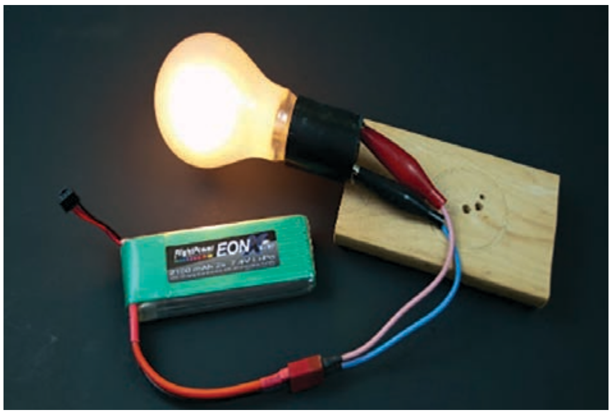


Figure 5.14 Battery-Source of Electric Energy

Thus **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**.

5.3.1 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^-)

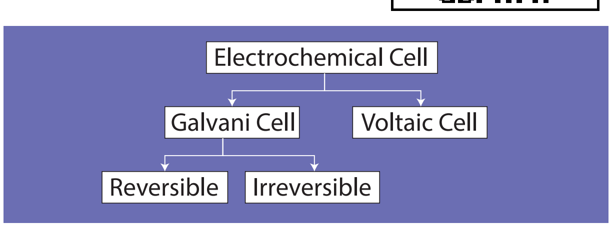
Reduction: It involves gain of electron. Reduction takes place at cathode

Metal ion + electron (e^-) → Metal

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.

Daniel Cell

It is a type of galvanic cell in which zinc metal acts as anode and copper metal as cathode. Aqueous zinc sulphate solution makes the anodic electrolyte whereas aqueous copper sulphate solution makes the cathodic electrolyte. Saturated solution of potassium chloride (KCl) acts as salt bridge. The following figure depicts the construction of Daniel cell.

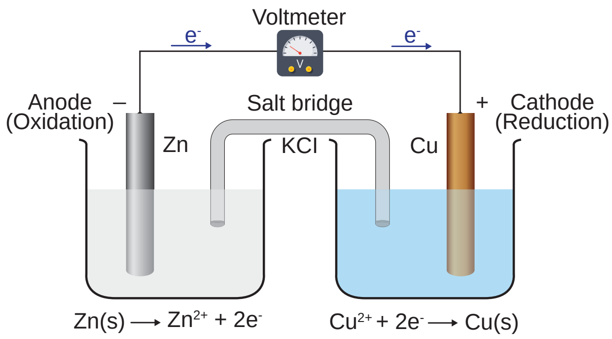


Figure 5.15 **Daniel Cell**

At anode, zinc undergoes oxidation losing its electrons.

$Zn_{(s)} \rightarrow Zn^{2+} + 2e^-$ (Oxidation)

At cathode, copper ions from cathodic electrolyte gain electrons at the surface of cathode and get reduced to copper metal.

$Cu^{2+} + 2e^- \rightarrow Cu_{(s)}$ (Reduction)

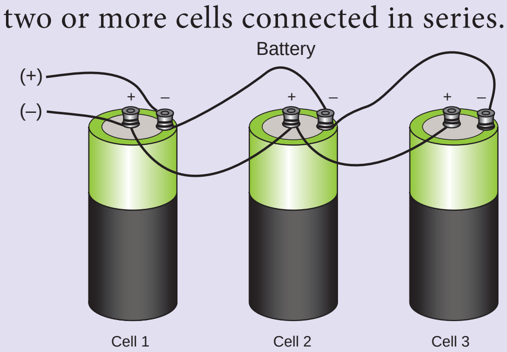
Net reaction: $Zn_{(s)} + Cu^{2+} \rightarrow Zn^{2+} + Cu_{(s)}$

Cell potential of Daniel cell is 1.1 V

DO YOU KNOW?

Are cell and battery same or different?

A cell is a **single unit** consisting of an anode, cathode and electrolyte. Battery is the combination of two or more cells connected in series.



Activity 3

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.

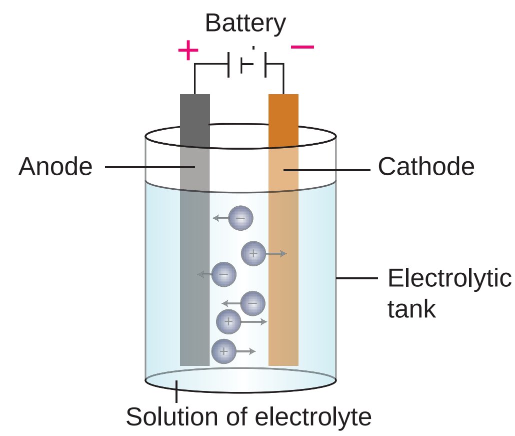


Figure 5.16 **Electrolytic Cell**

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.

(d) Applications of Electrolysis

Electrolysis has wide range of applications both in industry and research. The important applications are given below.

i. Electroplating

The process of depositing a thin layer of one metal over another metal by the process of electrolysis is called electroplating. Electroplating is one of the main processes applied in most of the industries. Some important applications of electroplating are given below.

Figure 5.17 **Chromium plating on iron**

Corrosion prevention: It is done to protect the metal from corrosion. For example, metals like iron are electroplated with tin, nickel or chromium to protect them from rusting.

Decoration: In some cases, electroplating is done to beautify the surface of a metal. For example, the metals like Au or Ag are deposited over metals like Cu to improve their beauty. Gold covering jewels are made by this method in which gold is electroplated over copper, silver or tin.

Figure 5.18 **Gold Covering**

Repairs: In some cases, broken parts of machinery may require electro- deposition of a metal between broken parts.

ii. Electro-refining of metals

It is a process of purifying metals by electrolysis. When metals of very high degree of purity are required, electro refining is done.

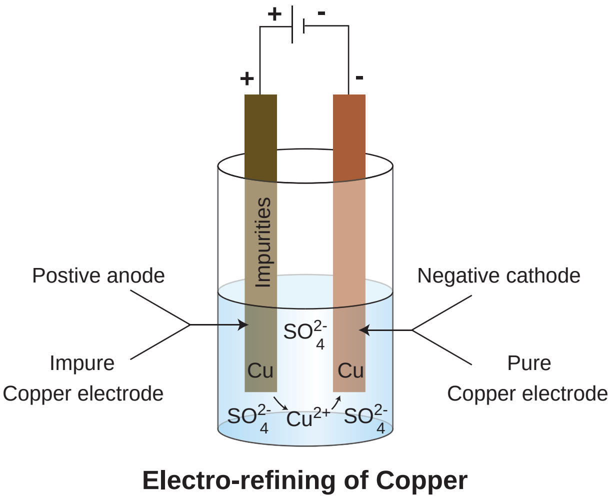


Figure 5.19 Electro-refining of Copper

iii. Electro manufacturing

Electro manufacturing is a process of manufacturing metals, non-metals and compounds by electrolysis. For example a number of metals like Na, Al, Mg, Ca, Cu, etc., non-metal molecules like H_2, O_2, F_2, Cl_2 and compounds like NaOH, $KClO_3$ etc have been manufactured by this method.

(e) 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 has been 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. Diabetes blood sugar metres measure the amount of glucose in the blood through its redox potential.

vi. 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.

5.4 Radiochemistry

You have studied in previous chapters that elements can exist in nature as their isotopes. Isotopes are atoms with the same number of protons and electrons, but 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.

5.4.1 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.

Study of chemical reactions: The nature of some of the chemical reactions can be studied by mixing a radioisotope with non-radioactive isotope of the reactants. The radioisotope used for this purpose is called **radiotracer**. For example, by photosynthesis plants synthesize carbohydrate from carbon dioxide and water as shown in the following reaction.

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} \xrightarrow{\text{Light}} \underset{\text{Sugar}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

Here a question arises that whether the oxygen evolved in this process comes from CO_2 or H_2O. By using radioisotope O-18 as tracer, it was found that the evolved oxygen comes from H_2O.

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

Table 5.2 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

DO YOU KNOW?

Henry Becquerel (France) was awarded Nobel prize for his discovery of spontaneous radioactivity in 1903. In the same year Pierre Curie (France) and Marie Curie (France) were awarded for their research on radiation phenomenon. In 1911, Marie Curie (France) was awarded Nobel prize for the discovery of radium and polonium, and the isolation of radium. They only coined the word Radioactivity. In 1938, Enrico Fermi (Italy) was awarded Nobel Prize for the discovery of nuclear reactions induced by slow neutrons.

Pierre Curie & Marie Curie

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

Table 5.3 Radioisotope in Treatment

Radioisotope	Treatment used for
Gold-198	Cancer
Iodine-131	Hyperthyroidism and cancer
Phosphorous -30	Blood disorder and skin disease
Cobalt-60	Cancer

5.5 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.

Figure 5.20 Dye in various colours

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.

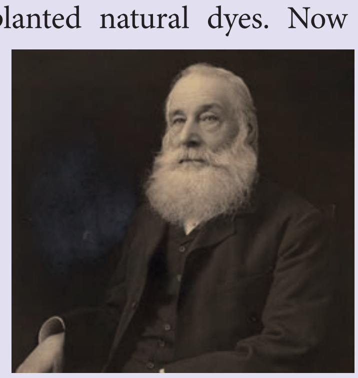
Figure 5.21 Coloured Textiles

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.

DO YOU KNOW?

Synthetic dye manufacturing started in 1856, when the English Chemist **W.H. Perkin** in an attempt to synthesize quinine, obtained instead a bluish substance with excellent dyeing properties that was latter known as aniline purple, Tyrian purple or mauveine. Perkin patented his invention and set up a production line. In the beginning of the 20th century, synthetic dyestuffs had almost completely supplanted natural dyes. Now days, such substances are synthesized in factories through simple chemical reactions.



5.5.1 Colour and Structure of Dyes

Not all the aromatic compounds are coloured. Aromatic compounds which absorb light of wavelength range 350 nm – 700 nm (visible light) only are coloured. This nature of absorption of visible light by aromatic compound depends on their structure. The relationship between the colour of an organic compound and its structure was explained by a German scientist **Otto Witt (1876)** through the **Chromophore and Auxochrome theory**. You will study about this theory in your higher classes.

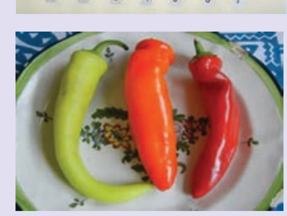
Activity 4

With the help of your teacher, try to find the answer for the following questions:

As the tomato ripens, its starts to change colour from green to yellow and then red at last. Why?

Why does a banana ripen, it turns from green to yellow?

Why does chilly change colour from green to yellow orange and then eventually red?



Why do all these colour changes follow same sequence i.e. green to yellow or orange or red?

5.5.2 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.

More to Know

Many natural dyes have been known for a long time. These were obtained from vegetable sources.

Henna: It is one of the natural dyes. It is a reddish brown dye obtained from plant *Lawsonia inermis* (Tamil: Maruthondri). Paste of these leaves is used as a hair dye and also for colouring palms (Mehandhi).

Turmeric: It is the traditional natural cosmetic in India. It is obtained from the plant *Curcuma longa* (Manjal). It also acts as an antiseptic. Turmeric is mostly used in India for colouring food.

5.5.3 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 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 fibre 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 5.22 Vat dyes

(b) Based on Structure

Based on the structure, dyes are classified as below:

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

5.6 Agricultural and Food Chemistry

5.6.1 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) Role of agricultural chemistry

India is predominantly an agricultural country. Its major source of food production is agriculture. Indian agriculture began in 7000 BC and followed a traditional practice. After independence, rapid growth of population and urbanization made threats to agricultural production and it led to food scarcity.

Figure 5.23 Spraying pesticides

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

Indian chemists and biochemists applied their knowledge and developed modernized agricultural practices which involve use of synthetic fertilizers, genetically modified crops, and equipments.

(b) Goals of agricultural chemistry

The goals of agricultural chemistry are to expand the understanding of the causes and effects of biochemical reactions related to plant and animal growth, to reveal opportunities for controlling those reactions, and to develop chemical products that will provide the desired assistance or control. 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

(c) 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 involve 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.

Figure 5.24 Chemical Fertilizers

More to Know

According to World Health Organization (WHO), "Pesticides are chemical compounds that are used to kill pests, including insects,

rodents, fungi and unwanted plants (weeds). Pesticides are used to kill vectors of disease, such as mosquitoes, and in agriculture, to kill pests that damage crops. By their nature, pesticides are potentially toxic to other organisms, including humans, and need to be used safely and disposed of properly."

Organic Farming: Even though chemical fertilizers and pesticides are used for plant growth and protection, they are harmful to human. So now a days, naturally prepared fertilizers and pesticides from herbs and microorganisms are used. This practice of agriculture is called Organic Farming. **Vermi compost** is one of such natural fertilizers produced from domestic wastes.

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.

5.6.2 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 the foods that supply energy for the functioning of parts human body. E.g. Carbohydrates

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 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.

IX_Science Term III Unit-5.indd 100 08-11-2018 15:40:47

(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 5.4.

Table 5.4 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

More to Know

There are several natural preservatives that you can use to preserve food.

Oil: When food comes into contact with air, it oxidises and starts to go bad. Oil slows down this oxidation process and keeps microorganisms from coming into contact with the food.

Common Salt: Microorganisms that spoil food tend to grow in water, but salt absorbs this water and prevents them from growing. Salt also prevents yeast and bacteria from decaying.

Sugar: Like salt, sugar also preserves food by absorbing the excess water and preventing microorganisms from growing. This is why jams, jellies and other fruits preserves don't go bad even after the jar has been opened. Sugar can even be added to the water in a flower vase – it feeds the flowers and keeps them from going bad.

Lemon juice: Lemon juice contains plenty of citric acid and ascorbic acid, also known as Vitamin C. Acidity prevents microorganisms from growing in the food and spoiling it. Vitamin C is also a powerful antioxidant that prevents food from oxidising.

Vinegar: Like lemon juice, vinegar is also extremely acidic, for it contains high amounts of acetic acid. Made of fermented sugar and water solutions, vinegar is commonly used to preserve pickles and canned foods, as it kills microbes and prevents the food from going bad.

Cloves: Cloves, have been used for thousands of years in Indian and Chinese medicines as a natural preservative. Containing high amounts of phenolic compounds, which have antioxidant properties, they keep food from going bad by preventing the growth of fungus and bacteria.

Cinnamon: Cinnamon, is an aromatic spice that is also used to preserve food. It does not protect food from all the bacteria and microbes that can decay it; it is more organism specific, meaning it kills only certain organisms.

Activity 5

With the help of your mother, know the food materials used in cooking. List out the chemicals present in them.

Food colouring or colour additives are pigments-synthetic or natural-added to food to create a certain colour, enhance a natural colour and improve the overall aesthetic appeal of a dish. Food colouring can make food fun. Food colouring contains one or more of the certified colour additives commonly known by their numbering system. Colour additives are blended to create a brightness or intensity to the base colour. The other basic ingredients of synthetic food colouring are propylparaben, propylene glycol and water.

Figure 5.25 Colour additives in cooldrinks

5.7 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 5.26 Crime detection

5.7.1 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.

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.

5.7.2 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 chemitry 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 5.27 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.

Figure 5.28 Biometrics

Activity 6

Find out the foot print of animals from the following:

DO YOU KNOW?

No two fingerprints are exactly alike! The ridges on your fingers start forming when you are still inside your mother's womb. Our fingers have sweat glands that ooze some oils and salt through tiny pores on the finger surface. This sticky film of sweat and oil trapped in the ridges leaves behind a print when we touch anything. It is difficult to get fingerprints on carpets and clothes as they absorb the oils. Just like fingerprints, our retinal print and tongue prints are also unique and cannot be forged by anyone. It is for this reason that these unique characteristics of the human body are used for authentication of a person's identity.

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.

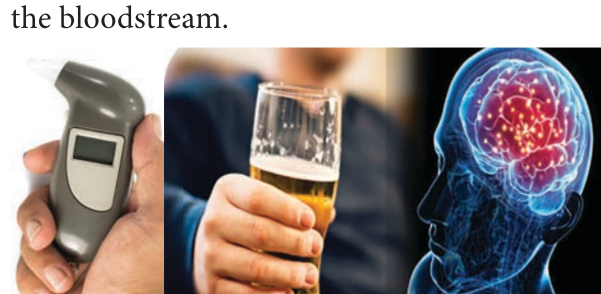


Figure 5.29 Alcohol test

Forensic Toxicology: Toxicologists examine a wide range of materials such as blood stains, urine, and blood gases for traces of poisons or drugs. Even tiny samples of blood, saliva, or semen may be separated and subjected to enzymatic analysis.

Figure 5.30 Forensic Toxicology

5.8 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.
- ❖ Drug 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.
- ❖ Electrochemistry is a branch of chemistry which deals with the relation between electrical energy and chemical change.
- ❖ Galvanic cell is an electrochemical cell which converts chemical energy into electrical energy .
- ❖ 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.
- ❖ Dyes are those coloured compounds which can be firmly fixed to fabrics by chemical or physical bonding.
- ❖ Agricultural chemistry involves the application of chemical and biochemical knowledge to agricultural production, the processing of raw products into foods and beverages, and environmental monitoring and remediation
- ❖ Food chemistry is chemistry of foods which involves the 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.