



A-Z GLOSSARY

Anaesthetics	The drugs which cause loss of sensation.
Antipyretics	The compounds which are used for the purpose of reducing fever (lowering the body temperature to the normal).
Antiseptic	It is the substance that prevents infections caused by disease causing microorganisms or pathogens.
Antibiotics	It is a chemical compounds which was produced by many microorganisms (bacteria, fungi and moulds) which inhibit the growth or metabolism of some other disease causing microorganism.
Antacids	These are certain drug formulations which provide relief from burning sensation.
Balanced diet	The diet that contain all foods in right proportion.
Chemotherapy	Treatment of certain diseases by destroying the invading organism without damaging the cells of the host, by the use of certain organic compounds.
Drug	The chemicals used for treating diseases
Electrochemical Cell	The device that make use of a chemical change to produce electricity or electricity to produce chemical change.
Electrolyte	It is made up of solutions of ions or molten salts which can conduct electricity
Nanotechnology	It involves synthesis and manipulation of materials at atomic and molecular level and study of their physical and chemical properties.
Pharmaceutical Chemistry	It is the study of drugs and it involves drug development.



TEXTBOOK EVALUATION

I. Choose the correct answer.

1. One Nanometre is
(a) 10^{-7} metre (b) 10^{-8} metre
(c) 10^{-6} metre (d) 10^{-9} metre
 2. The antibiotic Penicillin is obtained from _____
(a) plant (b) microorganism
(c) animal (d) sunlight
3. 1% solution of Iodoform is used as
(a) antipyretic (b) antimalarial
(c) antiseptic (d) antacid
 4. The cathode of an electrochemical reaction involves _____
(a) oxidation (b) reduction
(c) neutralisation (d) catenation



GBY68X



5. The age of a dead animal can be determined by using an isotope of _____
(a) carbon (b) iodine
(c) phosphorous (d) oxygen
6. Which of the following does not contain natural dyes?
(a) Potato (b) Beetroot
(c) Carrot (d) Turmeric
7. This type of food protect us from deficiency diseases.
(a) Carbohydrates (b) Vitamins
(c) Proteins (d) Fats
8. Radiochemistry deals with
(a) oxidants (b) batteries
(c) isotopes (d) nanoparticles
9. The groups responsible for the colour of an organic compound is called
(a) isotopes (b) auxochrome
(c) chromogen (d) chromophore
10. Chlorinated hydrocarbons are used as
(a) fertilizers (b) pesticides
(c) food colourants (d) preservatives

II. Fill in the blanks.

1. _____ is an electrochemical cell which converts electrical energy into chemical change(Reaction).
2. Painkiller drugs are called _____
3. Aspirin is an _____
4. _____, _____ and _____ are macronutrients required for plant growth.
5. _____ is a chemical used in finger print analysis.

III. Match the following.

Antipyretics	- Large surface area
Corrosion prevention	- Iodine-131
Hyperthyroidism	- Fever
Nanoparticle	- Cancer cell identification
Nanorobotics	- Electroplating

IV. Answer in brief.

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

V. Answer in detail.

1. Draw the cell diagram of Daniel cell. Give its reactions.
2. Explain the types of dyes based on their method of application.
3. Name various food additives and explain their functions.

VI. HOTS

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



REFERENCE BOOKS

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

INTERNET RESOURCES

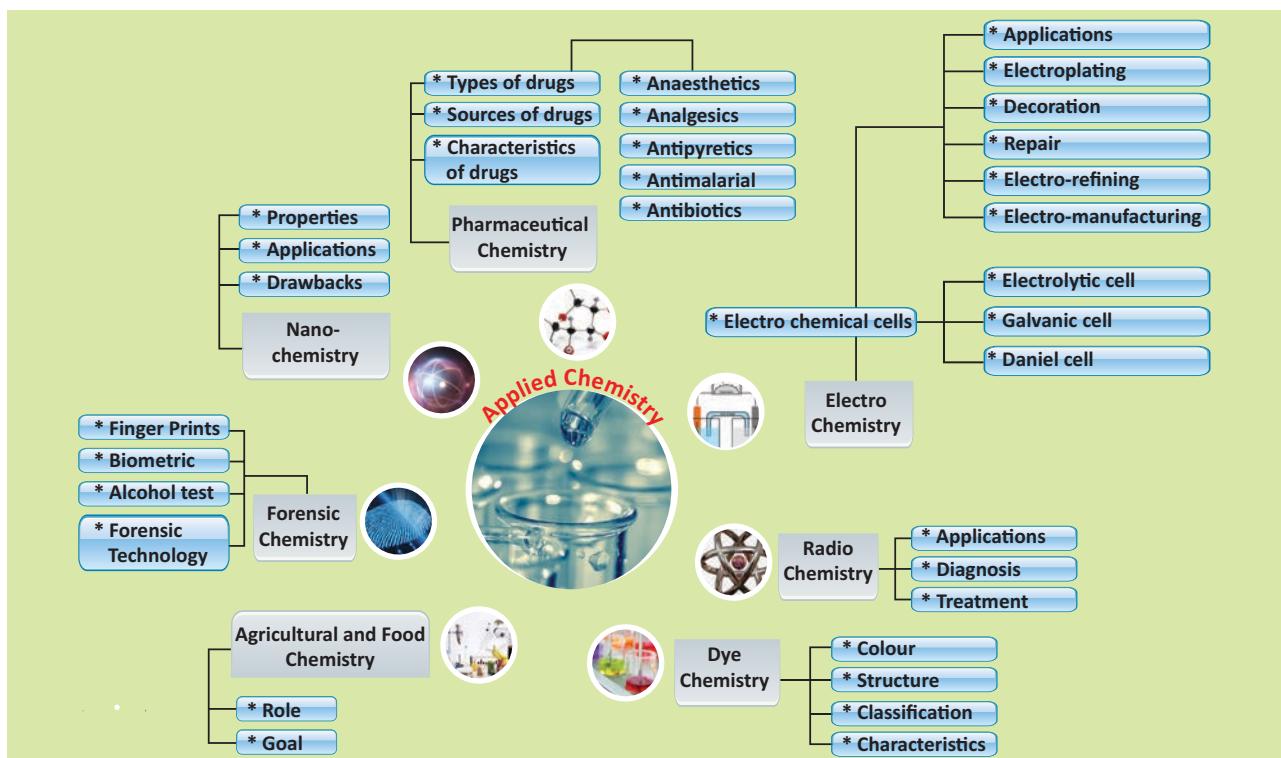
https://en.wikipedia.org/wiki/Agricultural_chemistry

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

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



Concept Map



ICT CORNER

Applied Chemistry

Experiment with radioactive elements to know about its half-life



Steps

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



Step1



Step2



Step3



Step4

Radioactive Atoms Half-Life

URL: http://www.glencoe.com/sites/common_assets/science/virtual_labs/E18/E18.html

*Pictures are indicative only



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UNIT

6

Environmental Science



Learning Objectives

After completing this lesson, students will be able to

- relate different aspects of environmental science.
- describe biogeochemical cycles.
- explain water cycle, nitrogen cycle and carbon cycle.
- analyse the impacts of human activities on water cycle, nitrogen cycle and carbon cycle.
- correlate the adaptations of plants with the habitat.
- explain the adaptations of bat and earthworm.
- explain recycling of water.
- discuss the importance of water conservation and water recycling method.



GC82AK

Introduction

"Nature has the power to refresh and renew"

- Helen Keller

Several environmental issues such as pollution, global warming, ozone layer depletion, acid rain, deforestation, land slide, drought and desertification have gained major focus across the world. Environmental science provides holistic knowledge about natural processes, effects of human intervention and solutions to overcome such environmental issues. Thus, it is defined as the study of patterns, processes in the natural world and their modifications by human activities. Elements of nature continuously undergo changes and transformations. They are recycled over and over again on earth and make themselves always available on earth. In the

same way, all living organisms react with their environment and develop certain morphological, anatomical, physiological and reproductive features to withstand particular conditions. This lesson deals with biogeochemical cycles, adaptations by the plants and animals, water conservation and recycling of water.

6.1 Biogeochemical cycles (bio – life; geo – earth)

Biosphere is the part of the earth where life exists. All resources of biosphere can be grouped into two major categories namely:

- (i) Biotic or living factors which include plants, animals and all other living organisms.
- (ii) Abiotic or non-living factors which include all factors like temperature, pressure,



water, soil, air and sunlight which affect the ability of organisms to survive and reproduce.

There is a constant interaction between biotic and abiotic components in the biosphere and that make the biosphere a dynamic and stable system. Cyclic flow of nutrients between non-living and living factors of the environment are termed as biogeochemical cycles. Some of the important biogeochemical cycles are:

1. Water cycle
2. Nitrogen cycle
3. Carbon cycle

6.1.1 Water cycle

- Can you imagine life without water?
- Have you tried to find out how do we get rain?
- Why do lakes and ponds dry out during summer?
- What is the need for conserving and recycling water?

Water cycle has the answers for all these questions. Water cycle or hydrological cycle is the continuous movement of water on earth. In this process, water moves from one reservoir to another, from river to ocean or from ocean to the atmosphere by processes such as evaporation, sublimation, transpiration, condensation, precipitation, surface runoff and infiltration, during which water converts itself to various forms like liquid, solid and vapour (Fig. 6.1). Let's begin the process of water cycle with evaporation.

Evaporation

Evaporation is a type of vaporization, where liquid is converted to gas before reaching its boiling point. Water evaporates from the surface of the earth and water bodies such as the oceans, seas, lakes, ponds and rivers turn into water vapour.

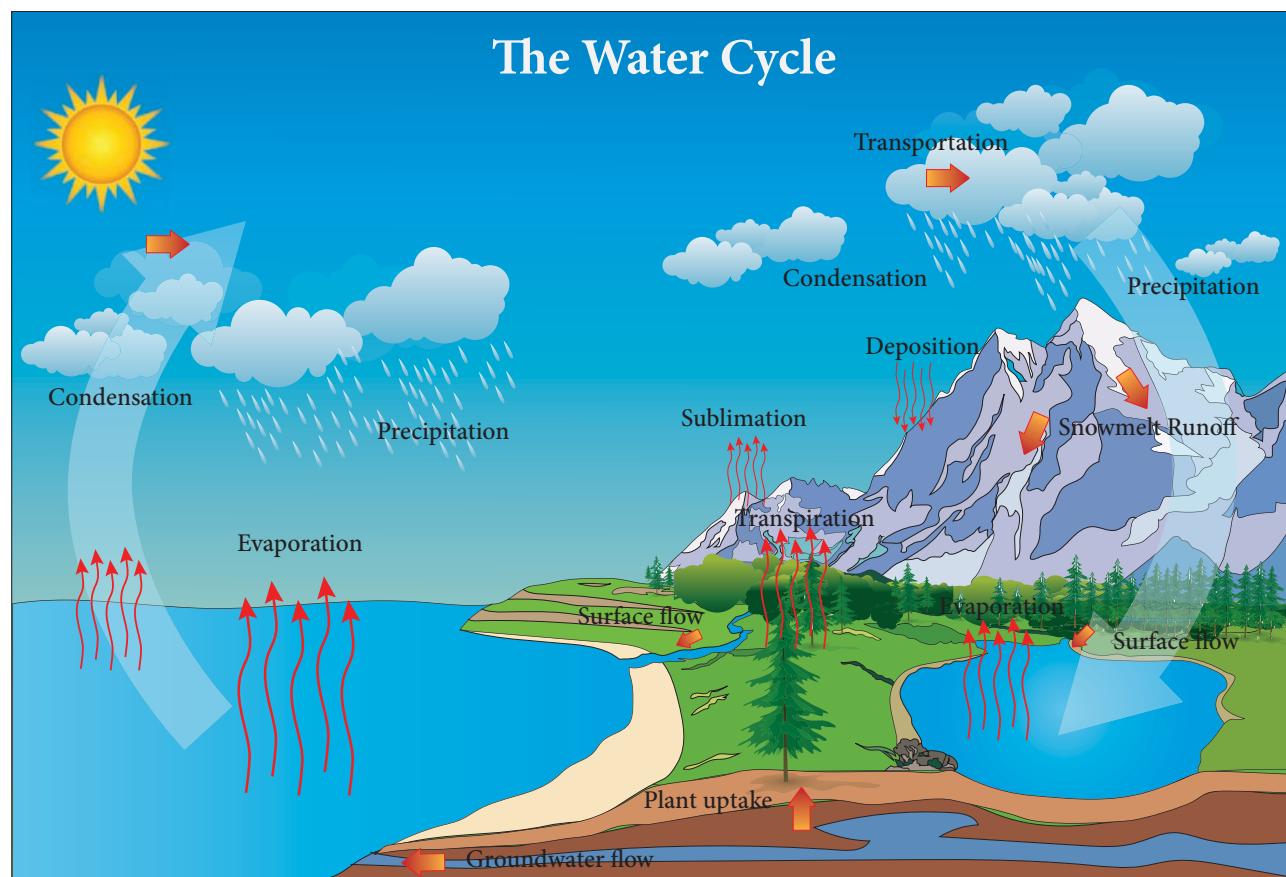


Figure 6.1 Water cycle



Sublimation

Sublimation is conversion of solid to gas, without passing through the intermediate liquid phase. Ice sheets and ice caps from north and south poles, and icecaps on mountains, get converted into water vapour directly, without converting into liquid.

Transpiration

Transpiration is the process by which plants release water vapour to atmosphere through small pores in leaves and stems.

Condensation

Condensation is the changing of gas phase into liquid phase and is the reverse of vaporisation. At higher altitudes, the temperature is low. The water vapour present there condenses to form very tiny particles of water droplets. These particles come close together to form clouds and fog.

Precipitation

Due to change in wind or temperature, clouds combine to make bigger droplets, and pour down as precipitation(rain). Precipitation includes drizzle, rain, snow and hail.

Run off

As the water pours down, it runs over the surface of earth. Runoff water combines to form channels, rivers, lakes and ends up into seas and oceans.

Infiltration

Some of the precipitated water moves deep into the soil. Then it moves down and increases the ground water level.

Percolation

Some of the precipitated water flows through soil and porous or fractured rock:

Infiltration and percolation are two related but different processes describing the movement of water through soil.

Human impacts on water cycle

Major human activities affecting the water cycle on land are urbanisation, dumping of plastic waste on land and into water, polluting water bodies and deforestation.

Activity 1

Create your own water cycle

Aim

To understand utilisation and recycling of water.

Materials

A large transparent bowl, plastic wrap, a stone, a smaller container and a rubber band.

Procedure

The small container is placed in the middle of the large bowl. Water is filled in the large container and it is covered with plastic wrap. The plastic wrap is fastened around the rim of the large container with the rubber band. The stone is placed on the top of the plastic wrap. This is placed under sun for few hours.

Observation

-----.

Inference

-----.

6.1.2 Nitrogen cycle

Nitrogen is primary nutrient important for survival of all living organisms. It is an essential component of proteins, DNA and chlorophyll. Atmosphere is a rich source of nitrogen and contains about 78% nitrogen. Plants and animals cannot utilize atmospheric nitrogen. They can use it only if it is in the form of ammonia, amino acids or nitrates.

Processes involved in nitrogen cycle are explained below.

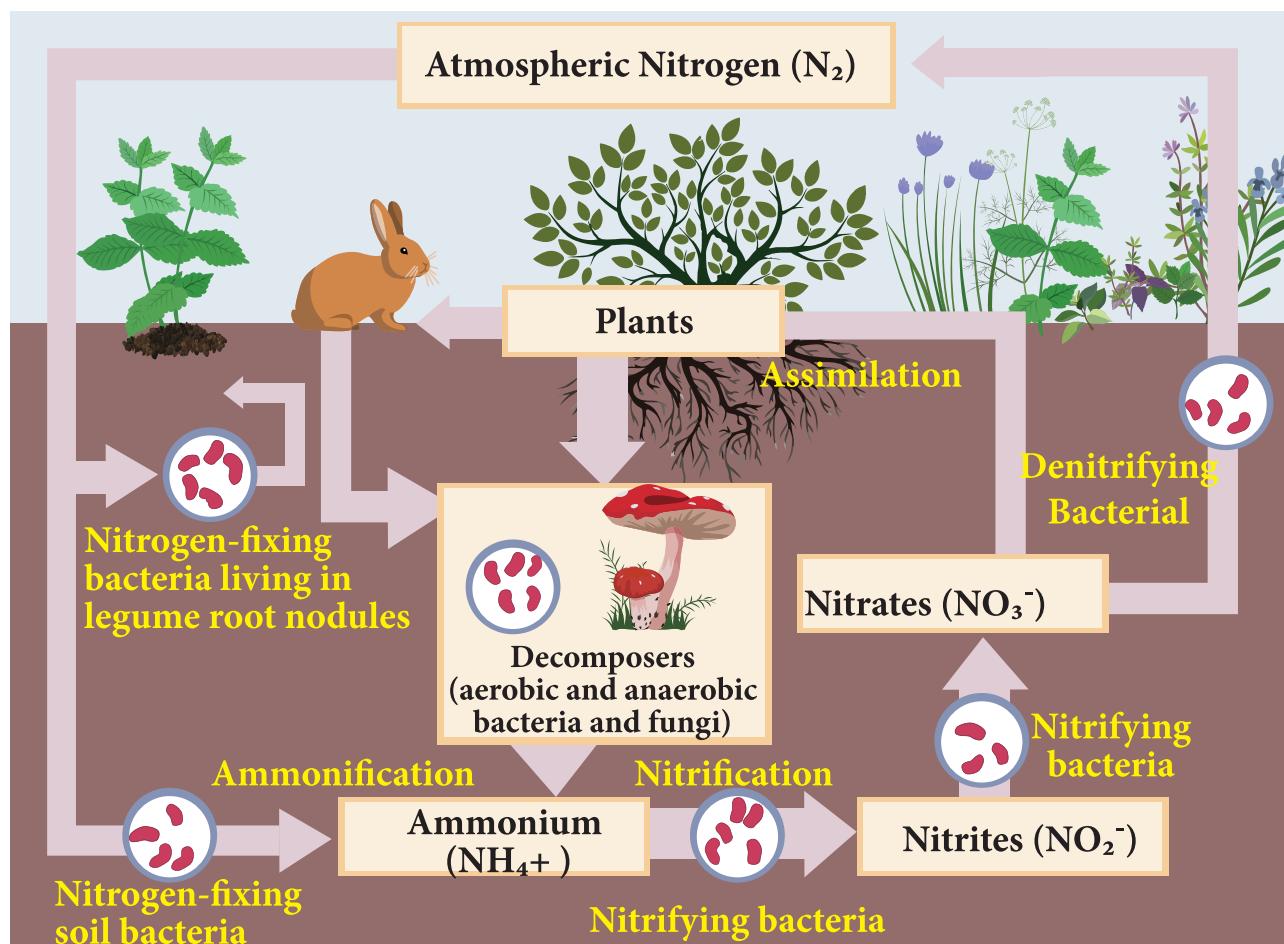


Figure 6.2 Nitrogen cycle

Nitrogen fixation

Nitrogen fixation is the conversion of atmospheric nitrogen, which is in inert form into reactive compounds available to living organisms. This conversion is done by a number of bacteria and blue green algae (Cyanobacteria). Leguminous plants like pea and beans have a symbiotic relationship with nitrogen fixing bacteria *Rhizobium*. Rhizobia occur in the root nodules of leguminous plants and fixes nitrogenous compounds.

Nitrogen assimilation

Plants absorb nitrate ions and use them for making organic matter like proteins and nucleic acids. Herbivorous animals convert plant proteins into animal proteins. Carnivorous animals synthesize proteins from their food.

Ammonification

The process of decomposition of nitrogenous waste by putrefying bacteria and fungi into

ammonium compounds is called ammonification. Animal proteins are excreted in the form of urea, uric acid or ammonia. The putrefying bacteria and fungi decompose these animal proteins, dead animals and plants into ammonium compounds.

Nitrification

The ammonium compounds formed by ammonification process are oxidised to soluble nitrates. This process of nitrate formation is known as nitrification. The bacteria responsible for nitrification are called as nitrifying bacteria.

Denitrification

Free living soil bacteria such as *Pseudomonas* sp. reduce nitrate ions of soil into gaseous nitrogen which enters the atmosphere.

Human impacts on nitrogen cycle

Burning fossil fuels, application of nitrogen-based fertilizers and other activities can increase the amount of biologically available nitrogen in an



ecosystem. Nitrogen applied to agricultural fields enters rivers and marine systems. It alters the biodiversity, changes the food web structure and destroys the general habitat.

Table 6.1 Microorganisms involved in nitrogen cycle

Role played in nitrogen cycle	Name of the microorganisms
Nitrogen fixation	<i>Azotobacter</i> (in soil) <i>Rhizobium</i> (in root nodules) Blue green algae- <i>Nostoc</i>
Ammonification	Putrefying bacteria Fungi
Nitrification	Nitrifying bacteria i. <i>Nitrosomonas</i> ii. <i>Nitrobacter</i>
Denitrification	Denitrifying bacteria <i>Pseudomonas</i>

6.1.3 Carbon cycle

Carbon occurs in various forms on earth. Charcoal, diamond and graphite are elemental forms of carbon. Combined forms of carbon include carbon monoxide, carbon dioxide and carbonate salts. All living organisms are made up of carbon containing molecules like proteins and nucleic acids. The atmospheric carbon dioxide enters into the plants through the process of photosynthesis to form carbohydrates. From plants, it is passed on to herbivores and carnivores. During respiration, plants and animals release carbon into atmosphere in the form of carbon dioxide. Carbon dioxide is also returned to the atmosphere through decomposition of dead organic matter, burning fossil fuels and volcanic activities.

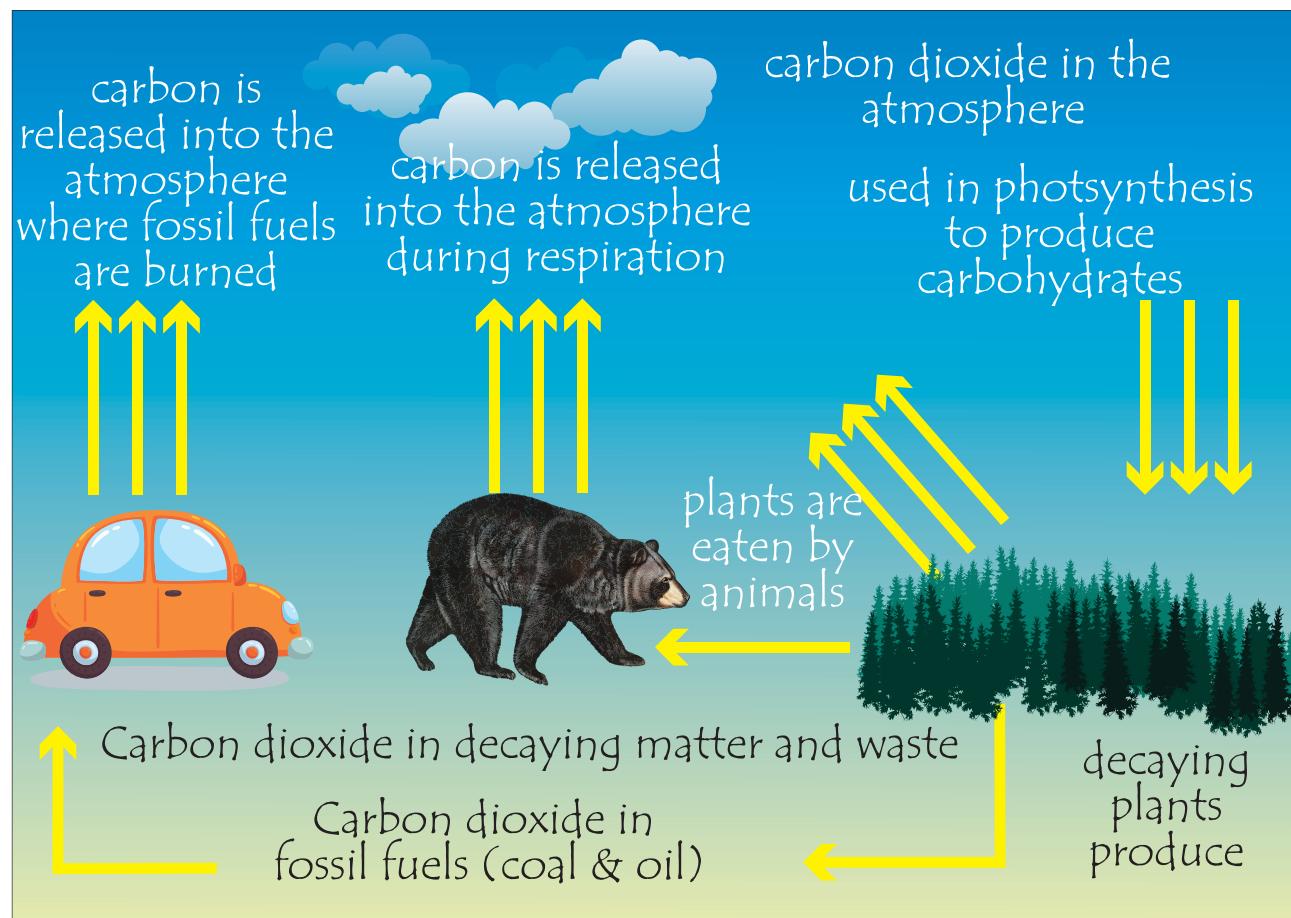


Figure 6.3 Carbon cycle



Human impacts on carbon cycle

More carbon moves into the atmosphere due to burning of fossil fuels and deforestation. Most of the carbon in atmosphere is in the form of carbon dioxide. Carbon dioxide is a greenhouse gas. By increasing the amount of carbon dioxide, earth becomes warmer. This leads to greenhouse effect and global warming.

It is really interesting to know how nature renews itself. At the same time, it also reminds us of our responsibility to reduce and restrain our activities that will affect the natural processes. Living organisms also try to adjust themselves according to their habitat and changes in the ecosystems. The adaptations help them to survive better.

6.2 Adaptations of plants

Any feature of an organism or its part that enables it to exist under conditions of its habitat is called adaptation. On the basis of water availability, plants have been classified as:

- (i) Hydrophytes
- (ii) Xerophytes
- (iii) Mesophytes



Hydrilla



Wolffia



Lemna



Eichhornia



Lily



Lotus

Figure 6.4 Hydrophytes



Water hyacinth (*Eichhornia crassipes*) is a very charming plant. It is called as '*Cindrella of the plant kingdom*'. It covers entire surface of the water resources like ponds and lakes. It will not allow the light to penetrate into the water and increases the **Biological Oxygen Demand** leading to the death of aquatic plants and animals. It also alters the water clarity and decreases phytoplankton production, dissolved oxygen, nitrogen, phosphorus and heavy metals. During monsoon, it blocks the flow of water. During summer, the lake with water hyacinth evaporates nine times faster than the lake with no water hyacinth. Apart from its adverse effects, it is used as a green manure or converted as compost. It is also used as animal fodder. It can be processed to make paper, rope, handbags and even furniture.



Water Hyacinth

6.2.2 Xerophytes

Plants that grow in dry habitat are called xerophytes. These plants develop special structural and physiological characteristics to meet the following conditions:

- To absorb as much water as they can get from the surroundings.
- To retain water in their organs for very long time.
- To reduce the transpiration rate.
- To reduce consumption of water.



Acacia

Calotropis



Opuntia

Figure 6.5 Xerophytes

Adaptations of xerophytes

- They have well developed roots. Roots grow very deep and reach the layers where water is available as in *Calotropis*.
- They store water in succulent water storing parenchymatous tissues. e.g. *Opuntia*, *Aloe vera*.
- They have small sized leaves with waxy coating. e.g. *Acacia*. In some plants, leaves are modified into spines. e.g. *Opuntia*.
- Some of the xerophytes complete their life cycle within a very short period when sufficient moisture is available

6.2.3 Mesophytes

Mesophytes are common land plants which grow in situations that are neither too wet nor too dry. They do not need any extreme adaptations.

Adaptations of mesophytes

- The roots of mesophytes are well developed and are provided with root caps.



2. The stem is generally straight and branched.
3. The leaves are generally broad and thin.
4. The presence of waxy cuticle in leaves traps the moisture and lessens water loss.
5. Leaves have stomata which close in extreme heat and wind to prevent transpiration.

6.3 Adaptations of animals to Habitat, Temperature and Light

Animals can adapt themselves according to their habitat. Temperature and light are forms of energy which influence various stages of life activities such as growth, metabolism, reproduction, movement, distribution and behaviour. Animals develop special features or behaviour patterns to escape from extreme conditions of temperature and light. In this context, let us study the adaptive features of bat and earthworm.



6.3.1 Adaptations of Bat

Bats are the only mammals that can fly. Mostly, bats live in caves. Caves provide them protection during the day from most predators and the temperature here is very stable. Apart from caves, bats also live in trees, hollowed logs and rock crevices. They are extremely important to humans as they reduce insect population and help to pollinate plants. Here, we will see the adaptations of bat in relation to their habitat.

Nocturnality

Bats are active at night. This is a useful adaptation for them, as flight requires a lot of energy during day. Their thin, black wing membrane (Patagium) may cause excessive

heat absorption during the day. This may lead to dehydration.

Flight adaptation

Bat wings are entirely different from those of birds or insects. Modified forelimbs serve as wings. The bones in the wings of bats are elongated fingers and are connected by the flaps of skin on either side of the body known as Patagia. Tail supports and controls movements during flight. Muscles are well developed and highly powerful and achieve in beating of wings. Tendons of hind limbs provide a tight grasp when the animals are suspended upside down at rest.

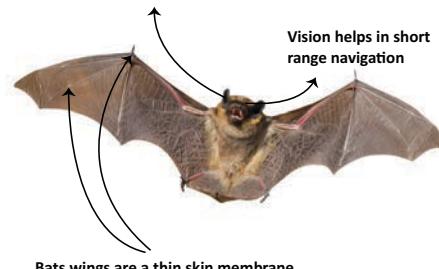
Hibernation

Hibernation is a state of inactivity in which the body temperature drops with a lowered metabolic rate during winter. Bats are warm blooded animals but unlike other mammals, they let their internal temperature reduce when they are resting. They go to a state of decreased activity to conserve energy.

Echolocation

Bats are not blind. But to fly around and hunt for insects in the dark, they use a remarkable high-frequency system called echolocation. Bats give out high-frequency sounds (ultrasonic sounds). These sounds are reflected back from its prey and perceived by the ear. Bats use these echoes to locate and identify the prey.

Bats emit ultrasonic pulses of sound at objects and listen for echoes.



Bats wings are a thin skin membrane stretched between extra long finger bones.

Figure 6.6 Bats



6.3.2 Adaptations of Earthworm

An earthworm is a segmented worm which belongs to Phylum Annelida. It is commonly found living in soil, feeding on live and dead organic matter. The faecal wastes are called worm castings (Vermicasts) which are rich in nitrogenous content adding fertility to the soil. Earthworm plays a large role in keeping soil health facilitating aeration, water infiltration and producing organic matter to increase crop growth. Some of the adaptations of earthworm are explained below.

Stream-lined body

The earthworm has a cylindrical, elongated and segmented body. This helps them to live in narrow burrows underground and for easy penetration into the soil.

Skin

Mucus covers the skin which does not allow soil particles to stick to it. The slippery skin is kept moist as it respires through the skin. Moist skin helps in oxygenation of blood.

Burrowing

Its body is flexible having circular and longitudinal muscles which help in movement and subsoil burrowing. Each segment on the lower surface of the body has number of bristles called setae. They help the earthworm to move through the soil and provide anchor in the burrows.

Aestivation

When the soil becomes too hot or dry, earthworms become inactive and undergo a process called aestivation. Earthworm moves deeper into the soil. It secretes mucus and lowers their metabolic rate in order to reduce water loss. They remain dormant until conditions become

favourable. They come out of their burrow during rainy season. The ideal temperature range is 60-80°F. The ability to tolerate temperature depends on the surrounding moisture in the environment.

Nocturnality

Earthworms are sensitive to light. It has no eyes but can sense light through light sensitive cells (Photo-receptors) present in their skin. They give the skin the capacity to detect light and changes in light intensity. They react negatively to bright light (Photophobic). It remains in its burrow during the day to avoid light.



Figure 6.7 Earthworms



Earthworms are referred as '*Farmer's friend*'. After digesting organic matter, earthworms excrete a nutrient-rich waste product called castings.

Vermicompost is a manure prepared by using earthworms to speed up the process of decomposition of plant and animal waste. Vermicomposting is a fundamental practice of organic gardening. Vermicompost helps better plant growth and crop yield, improves physical structure of soil, increases the water holding capacity of soil and is helpful in elimination of biowastes.





6.4 Water conservation

Water is one of the precious natural resources. Clean and fresh water is essential for almost every human activity. Pollution has decreased our own water supply. We are polluting and decreasing the water for all creatures on earth.

Water conservation is the preservation, control and management of water resources. It also includes activities to protect the hydrosphere and to meet the current and future human demand.

6.4.1 Importance of water conservation

- It creates more efficient use of the water resources.
- It ensures that we have enough usable water.
- It helps in decreasing water pollution.
- It helps in increasing energy saving.

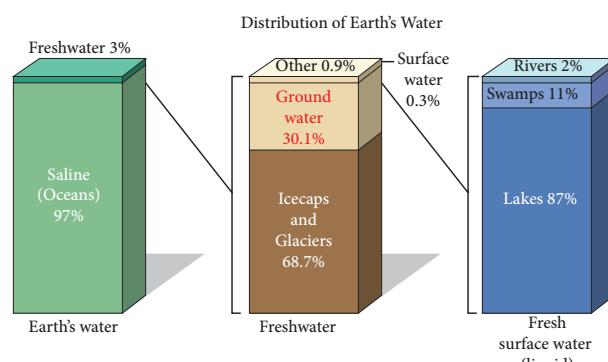


Figure 6.8 Distribution of Earth's water

Activity 2

Write slogans to support conservation of water.

1. _____
2. _____
3. _____

6.4.2 Ways of water conservation

Industrial conservation

Water conservation measures that can be taken by industries are:

- using dry cooling systems.
- if water is used as cooling agent, reusing the water for irrigation or other purposes.

Agricultural conservation

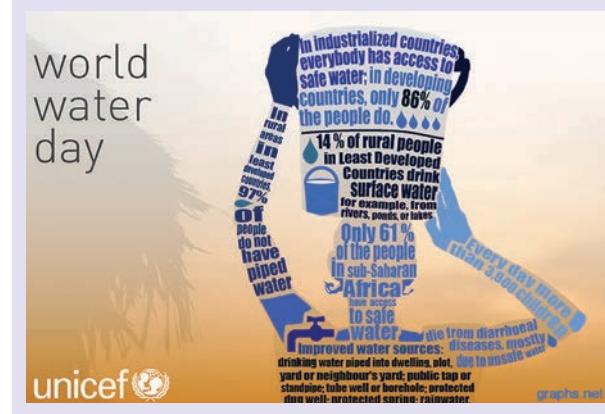
Agricultural water is often lost due to leaks in canals, run off and evaporation. Some of the water conserving methods are:

- using lined or covered canals that reduce loss of water and evaporation.
- using improved techniques such as sprinklers and drip irrigation.
- encouraging the development of crops that require less water and are drought resistant.
- mulching of soil in vegetable cultivation and in horticulture.



World Water Day on 22nd March every year, is about focusing attention on the importance of water.

The theme for World Water Day 2018 is 'Nature for Water'- exploring nature-based solutions to the water challenges we face in the 21st century.





Domestic conservation

All of us have the responsibility to conserve water. We can conserve water by the following activities:

- Using a bucket of water to take bath than taking a shower.
- Using low flow taps.
- Using recycled water for lawns.
- Repairing the leaks in the taps.
- Recycling or reusing water where ever it is possible.

6.4.3 Some of the strategies to support water conservation

- (i) Rain water harvesting.
- (ii) Improved irrigation techniques.
- (iii) Active use of traditional water harvesting structures.
- (iv) Minimising domestic water consumption.
- (v) Awareness on water conservation.
- (vi) Construction of farm ponds.
- (vii) Recycling of water.

6.5 Farm ponds

Farm ponds are used as one of the strategies to support water conservation. Much of the rainfall runs off the ground. The run off not only causes loss of water but also washes away precious top soil. Farm ponds help the farmers to store water and to use it for irrigation.

6.5.1 Layout of a farm pond

Farm pond is a dugout structure with definite shape and size. They have proper inlet and outlet structures for collecting the surface runoff flowing from the farm area. The size and depth of the pond depend upon the amount of land available, the type of soil, water requirement of farmers and the cost of excavation. The stored water is used for irrigation.



Figure 6.9 Farm pond

6.5.2 Advantages of farm ponds

The advantages of farm ponds are:

- They provide water to growing crops, without waiting for rainfall.
- They provide water for irrigation, even when there is no rain.
- They reduce soil erosion.
- They recharge ground water.
- They improve drainage.
- The excavated soil can be used to enrich soil in fields and levelling lands.
- They promote fish rearing.
- They provide water for domestic purposes and livestock.

6.5.3 Limitations of farm ponds

- Farm ponds reduce water flow to other tanks and ponds situated in lower-lying areas.
- They occupy a large portion of farmer's lands.

6.6 Water recycling

Water recycling, apart from rain water harvesting, is also one of the key strategies to conserve water. Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, flushing in toilets and ground water recharge.



Grey water is reusable waste water from residential, commercial and industrial bathroom sinks, bath tub, shower drains and washing of clothes. Use of non-toxic and low sodium soap and personal care products is required to protect vegetation when reusing grey water for irrigation.

6.6.1 Water recycling stages

Conventional waste water treatment consists of a combination of physical, chemical and biological processes which remove solids, organic matter and nutrients from waste water. The waste water treatment involves the following stages:

Primary treatment

Primary treatment involves temporary holding of the waste water in a tank. The heavy solids get settled at the bottom while oil, grease and lighter solids float over the surface. The settled and floating materials are removed. The remaining liquid may be sent for secondary treatment.



Activity 3

Make a poster depicting the ways and importance of conserving water and recycling of water.

Secondary treatment

Secondary treatment is used to remove the biodegradable dissolved organic matter. This is performed in the presence of oxygen by aerobic microorganisms (Biological oxidation). The microorganisms must be separated from treated waste water by sedimentation. After separating the sediments of biological solids, the remaining liquid is discharged for tertiary treatment.

Tertiary treatment

Tertiary or advanced treatment is the final step of sewage treatment. It involves removal of inorganic constituents such as nitrogen, phosphorus and microorganisms. The fine colloidal particles in the sewage water are precipitated by adding chemical coagulants like alum or ferric sulphate.

Inlet - sewage water



Primary treatment(physical)

- Sedimentation (heavy solids)
- Floatation (oil, grease, lighter solids)
- Filtration



Secondary treatment(biological)

- Biological oxidation (biodegradable dissolved organic matter)
- Sedimentation (biological solids)
- Filtration



Tertiary treatment (physio-chemical)

- (nitrogen, phosphorus, suspended solids, heavy metals)
- Disinfection (chlorination 5-15mg/l)



Outlet- recycled water

6.6.2 Uses for recycled water

- Agriculture
- Landscape
- Public parks
- Golf course irrigation
- Cooling water for power plants and oil refineries
- Toilet flushing
- Dust control
- Construction activities



6.7 IUCN (International Union for Conservation of Nature and Natural Resources)

IUCN is an international organization working in the field of nature conservation and sustainable use of natural resources. It provides public, private and non-governmental organizations with the knowledge to enable human progress, economic development and nature conservation to take place together. IUCN is the global authority on the status of the natural world and the measures needed to safeguard it.

Vision of IUCN

The vision of IUCN is 'A just world that values and conserves nature'.

Mission of IUCN

The mission of IUCN is to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. IUCN has widened its focus beyond conservation of ecology and now incorporates issues related to sustainable development in its projects. It tries to influence the actions of governments, business and other stakeholders by providing information and advice.

The organization is best known to the wider public for compiling and publishing the IUCN red list of threatened species, which assesses the conservation status of species worldwide.

India, a mega diverse country with only 2.4 % of world's land area, accounts for 7-8% of all

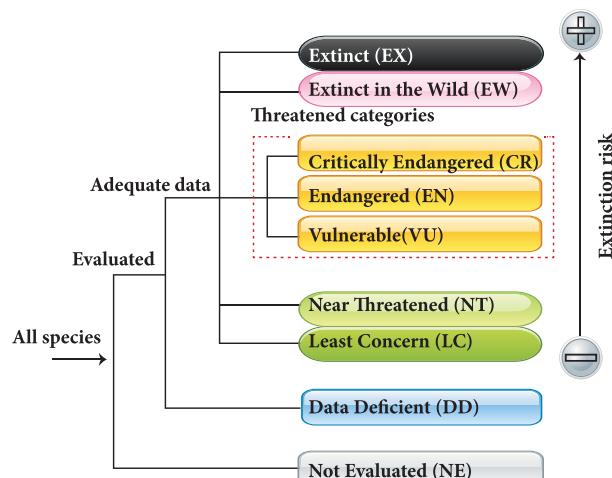


Figure 6.10 Red list categories of IUCN

recorded species. It includes over 45,000 species of plants and 91,000 species of animals. The country's diverse physical features and climatic conditions have resulted in a variety of ecosystems such as forests, wetlands, grasslands, desert, coastal and marine ecosystems. Four of 34 globally identified biodiversity hotspots are found in India.

They are:

- The Himalayas
- The Western ghats
- The North-East
- The Nicobar islands

India became state member of IUCN in 1969, through the Ministry of Environment, Forest and Climate change(MoEFCC). The following data for plants and animals in India is given in Table 6.2 available on the IUCN Red List Version 2017-3 (Table 6 A & B). It has been last updated on 5th December 2017.

DO YOU KNOW? IUCN was founded on 5th October 1948 at Gland, Switzerland.

Table 6.2 IUCN Red List Categories

Category	EX	EW	CR	EN	VU	NT	LR/cd	DD	LC
Plants	6	2	72	175	143	45	1	77	932
Animals	0	0	77	207	391	330	2	784	3774



CR: Himalayan brown/red bear



EN: Red Panda

Figure 6.11 Animals in Red List

Points to Remember

- Environmental science is the study of patterns, processes in the natural world and their modification by human activities.
- Biotic or living factors include plants, animals and all other living organisms.
- Abiotic or non-living factors include all factors which affect ability of organisms to survive and reproduce like water, soil, air and sunlight.
- Cyclic flow of nutrients between non-living environment and living organisms are termed as biogeochemical cycles.
- *Nitrogen fixation* is the conversion of atmospheric nitrogen into reactive compounds available to living organisms.
- The process of decomposition of nitrogenous waste by putrefying bacteria and fungi into ammonium compounds is called *ammonification*.
- The ammonium compounds formed by ammonification process is oxidised to soluble nitrates. The process of nitrate formation is known as *nitrification*.
- Hydrophytes may be free floating or submerged plants living in lakes, ponds, shallow water, marshy lands and marine habitat.
- Plants that grow in dry habitat are called xerophytes.
- Mesophytes are common land plants which grow in situations that are neither too wet nor too dry.
- Animals develop special features or behaviour patterns to escape from the extreme conditions of temperature and light.
- When the soil becomes too hot or dry, earthworms become inactive and undergo a process called Aestivation.
- Hibernation is a state of inactivity in which the body temperature of earthworms drops with a lowered metabolic rate during winter.
- Water conservation is the preservation, control and management of water resources.
- Farm pond is a dugout structure with definite shape and size. They have proper inlet and outlet structures for collecting the surface runoff flowing from the farm area.
- Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing and ground water recharge.
- IUCN is the global authority on the status of the natural world and the measures needed to safeguard it.

**A-Z GLOSSARY**

Aestivation	A state of inactivity and a lowered metabolic rate in animals, during summer.
Assimilation	The conversion of nutrients into usable form that is incorporated into the tissues and organs.
Biogeochemical cycle	The cyclic flow of nutrients between non-living environment and living organisms.
Buoyancy	The capacity to remain afloat in liquid or gas.
Echo location	The use of sound waves and their echoes to determine the location of objects.
Hibernation	A state of inactivity and a lowered metabolic rate in animals, during winter.
Infiltration	The process by which water on the ground surface enters the soil.
Precipitation	Any product of condensation of atmospheric water vapour that falls on earth.
Setae	The hair-like locomotory structure, present in each segment of an earthworm.
Stomata	Minute pores in the epidermis of leaves which facilitate gaseous exchange and transpiration.
Sublimation	The conversion of solid state into vapour state without going through a liquid state.

**TEXTBOOK EVALUATION****I. Choose the correct answer.**

1. All the factors of biosphere which affect the ability of organisms to survive and reproduce are called as _____.
 - a. biological factors
 - b. abiotic factors
 - c. biotic factors
 - d. physical factors
2. The ice sheets from the north and south poles and the icecaps on the mountains, get converted into water vapour through the process of _____.
 - a. evaporation
 - b. condensation
 - c. sublimation
 - d. infiltration
3. Free living soil bacteria such as *Pseudomonas* sp. are responsible for the _____ process in the nitrogen cycle.
 - a. ammonification
 - b. nitrogen fixation
 - c. nitrification
 - d. denitrification
4. The atmospheric carbon dioxide enters into the plants through the process of _____.
 - a. photosynthesis
 - b. assimilation
 - c. respiration
 - d. decomposition



5. Increased amount of _____ in the atmosphere, results in greenhouse effect and global warming
- carbon monoxide
 - sulphur dioxide
 - nitrogen dioxide
 - carbon dioxide
6. Which of the following is not an adaptation of hydrophytes?
- poorly developed root system
 - reduced plant body
 - water storing parenchymatous tissues
 - finely divided submerged leaves
7. In some xerophytes, leaves are modified into spines as an adaptation _____.
a. to reduce transpiration rate
b. to store water
c. to reduce consumption of water
d. all of the above
8. Identify the incorrect statement with respect to adaptations of earthworm.
- Earthworm has a stream lined body with no antennae or fins.
 - Each segment of earthworm has setae.
 - Many earthworms become inactive in a process called hibernation, during winter season.
 - Earthworms remain in its burrow during day time, to avoid sunlight.
9. Which of the following is one of the strategies to conserve water?
- Water recycling
 - Increasing the number of bore wells
 - Using large overhead water tanks
 - Watering the plants using hose
10. Specific constituents such as nitrogen, phosphorus, suspended solids and heavy

metals found in the wastewater are removed during _____ treatment of water recycling process.

- primary
- tertiary
- secondary
- none of the above

II. Match the following.

Microorganism	Role Played
Nitrogen fixation	Nitrosomonas
Ammonification	Azotobacter
Nitrification	Pseudomonas species
Denitrification	Putrefying bacteria

III. State whether the statements are true or false. Correct the false statements.

- Nitrogen is a greenhouse gas.
- Poorly developed root is an adaptation of mesophytes.
- Bats are the only mammals that can fly.
- Earthworms use the remarkable high frequency system called echoes.
- Aestivation is an adaptation to overcome cold condition.

IV. Answer in brief.

- What are the two factors of biosphere?
- According to you, which process of water cycle is adversely affected by human activities?
- How do human activities affect nitrogen cycle?
- What is adaptation?
- What are the challenges faced by hydrophytes in their habitat?



6. Identify the given plant. How does it adapt itself to its habitat?



7. Why is it important to conserve water?
8. List some of the ways in which you could save water in your home and school?
9. What is grey water?
10. What are the uses of recycled water?
11. What is IUCN? What is the vision of IUCN?

VI. Answer in detail.

1. Describe the processes involved in the cyclic flow of water between biotic and abiotic factors of biosphere?
2. Explain carbon cycle with the help of a flow chart? How can you reduce your contribution of carbon dioxide to the atmosphere?
3. What are the conditions in a dry habitat to which plants develop adaptations? List out the adaptations of xerophytes?
4. How does a bat adapt itself to its habitat and also in response to temperature and light?
5. What is water recycling? Explain the conventional wastewater recycling treatment?

VI. Give reason.

1. Roots grow very deep and reach the layers where water is available. Which type of plants develops the above adaptation? Why?

2. Why streamlined bodies and presence of setae is considered as adaptations of earthworm?
3. Echo location serves as an adaptation in bats. Justify the given statement.
4. Farm ponds serve as an excellent water conservation strategy. Why is it impossible for all farmers to construct it in their fields?



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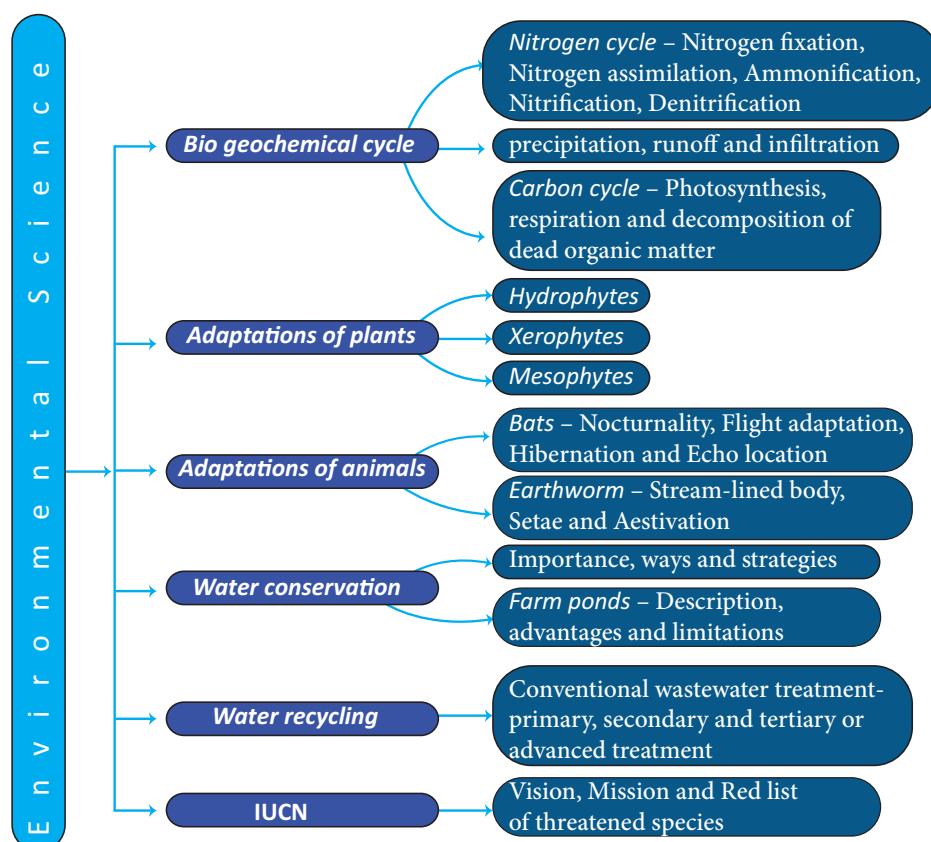


INTERNET RESOURCES

1. www.freerdringkingwater.com
2. www.freesciencefairproject.com
3. www.gissnasa.gov
4. www.nature.com
5. www.sciencefocus.com
6. www.sciencelearn.org
7. www.batsorg.com
8. www.fao.org
9. www.worldwaterday.org
10. www.IUCN.org



Concept Map



ICT CORNER

Environmental Science

Experiment with *Carbon cycle* using virtual simulator.



Steps

- Type the given URL to reach “The Carbon Cycle” simulation page.
- Press “Run Decade” button to observe the carbon cycle accumulating every 10 years.
- Select “Curb Emission” from “lesson” tab and adjust the simulation parameters to watch the effect of cycle.
- Select “Feedback Effects” from “lesson” tab and run the cycle and analyze the carbon accumulation result.



Step1



Step2



Step3



Step4

Carbon cycle

URL: <https://www.learner.org/courses/envsci/interactives/carbon/carbon.html>
or Scan the QR Code.

*Pictures are indicative only



B567_9_SCI_EM_T3



Learning Objectives

After a thorough perusal of this unit, the students will be able to:

- ◆ recognize the basis of the modern periodic law and its development.
- ◆ list the features of groups and periods of the modern periodic table.
- ◆ explain the trend in periodic properties along the periods and groups.
- ◆ distinguish between ores and minerals .
- ◆ list out the types of separation of impurities from the ores.
- ◆ recall the various places of occurrences of minerals in the state of Tamil Nadu.
- ◆ put forth the properties of metals.
- ◆ identify the stages involved in metallurgical processes.
- ◆ think scientifically on alloys and their types.
- ◆ develop an idea on amalgam.
- ◆ understand the reason for corrosion and the methods of its prevention.



INTRODUCTION

The eighteenth and nineteenth centuries witnessed a rapid development in chemistry in all spheres of scientific activities. By 1860, scientists had already discovered 60 elements and determined their atomic masses. They noticed that some elements had similar properties and hence arranged them into groups. During this period, several new elements were discovered. These elements were found to have different properties. It was realized that instead of studying the properties of all these elements individually, it would be more convenient to divide them into groups and

periods in such a way that each group contained a certain number of elements (**like an array of fruits and vegetables showing orderliness**) with similar properties and periods showing a regular gradation. So, scientists made several attempts to arrange elements in a logical way. You have studied about all these early attempts of arrangement of elements in standard IX. In continuation of the knowledge gained in the topic **periodic classification of elements** in standard IX with earlier concepts and their subsequent deliberations, you get set to go ahead with the higher order of thinking to enhance your knowledge on the properties of elements.



8.1 MODERN PERIODIC LAW

Mendeleev's periodic table had some discrepancies, which were difficult to overcome. For example, the atomic mass of argon (39.95 amu) is greater than that of potassium (39.10 amu), but argon comes before potassium in the periodic table. If elements were arranged solely according to increasing atomic mass, argon would appear in the position occupied by potassium in our modern periodic table (see in Figure 8.1). No chemist would place argon, a gas with no tendency to react, in the same group as lithium and sodium, which are two highly reactive metals. This kind of discrepancies suggested that some fundamental property other than atomic mass must be the basis of periodicity. The fundamental property turned out to be the number of protons in an atom's nucleus, something that could not have been known by Mendeleev and his contemporaries.

Henry Moseley, a British scientist in 1912, discovered a new property of elements called atomic number, which provided a better basis for the periodic arrangement of the elements. It is a well-known fact that atomic number of an element is equal to the number of protons or the number of electrons present in the neutral atom of an element. The periodic law was, therefore, modified to frame a **modern periodic law**, which states that

"The physical and chemical properties of the elements are the periodic functions of their atomic numbers".

8.2 MODERN PERIODIC TABLE

With reference to the modern periodic law, the elements were arranged in the increasing order of their atomic numbers to form the modern periodic table. **The modern periodic table is a tabular arrangement of elements in rows and columns, highlighting the regular repetition of properties of the elements.**

Figure 8.1 shows the modern periodic table of 118 elements discovered so far.

As you have studied the features of the modern periodic table in standard IX, here let us confine to the study of the features of periods and groups.

8.2.1 Features of Periods

- ◆ **The horizontal rows are called periods.** There are **seven** periods in the periodic table.
- ◆ **First period** (Atomic number 1 and 2): This is the shortest period. It contains only two elements (Hydrogen and Helium).
- ◆ **Second period** (Atomic number 3 to 10): This is a short period. It contains eight elements (Lithium to Neon).
- ◆ **Third period** (Atomic number 11 to 18): This is also a short period. It contains eight elements (Sodium to Argon).
- ◆ **Fourth period** (Atomic number 19 to 36): This is a long period. It contains eighteen elements (Potassium to Krypton). This includes 8 normal elements and 10 transition elements.
- ◆ **Fifth period** (Atomic number 37 to 54): This is also a long period. It contains 18 elements (Rubidium to Xenon). This includes 8 normal elements and 10 transition elements.
- ◆ **Sixth period** (Atomic number 55 to 86): This is the longest period. It contains 32 elements (Caesium to Radon). This includes 8 normal elements, 10 transition elements and 14 inner transition elements (Lanthanides).
- ◆ **Seventh period** (Atomic number 87 to 118): Like the sixth period, this period also accommodates 32 elements. Recently 4 elements have been included by IUPAC.



PERIODIC TABLE OF THE ELEMENTS

GROUP 1 PERIOD 1	H HYDROGEN 2 <i>1.008</i>	13 GROUP IIIC ALUMINUM 13 <i>26.982</i>	18 VIA He HELIUM <i>4.0026</i>
3 Li LITHIUM <i>6.94</i>	4 Be BERILLIUM <i>9.0122</i>	5 B BORON <i>10.81</i>	13 VIA CHALCOGENS ELEMENT OXYGEN 13 <i>10.81</i>
6 C CARBON <i>12.0106</i>	7 N NITROGEN <i>14.007</i>	8 O OXIDEN <i>15.999</i>	18 VIA HALOGENS ELEMENT FLUORINE <i>18.999</i>
9 Na SODIUM <i>22.989</i>	10 Mg MAGNESIUM <i>24.306</i>	11 Al ALUMINUM <i>26.982</i>	17 VIA NEON <i>20.198</i>
12 Mg MAGNESIUM <i>24.306</i>	13 Al ALUMINUM <i>26.982</i>	14 Si SILICON <i>28.085</i>	18 VIA HELIUM <i>30.198</i>
14 K SODIUM <i>39.098</i>	15 Ca CALCIUM <i>40.078</i>	16 Mn MANGANESE <i>54.938</i>	14 VIA CHLORINE FLUORINE <i>31.998</i>
16 Ca CALCIUM <i>40.078</i>	17 Sc SCANDIUM <i>44.956</i>	18 Fe IRON <i>55.845</i>	15 VIA PHOSPHORUS CHLORINE <i>32.954</i>
18 Sr STRONTIUM <i>87.613</i>	19 Rb RUBIDIUM <i>88.906</i>	20 Tl THALLIUM <i>102.91</i>	16 VIA GERMANIUM GERMANIUM <i>33.952</i>
20 Rb RUBIDIUM <i>88.906</i>	21 K KRYPTON <i>89.03</i>	22 Tl TIN <i>101.07</i>	17 VIA GERMANIUM GERMANIUM <i>34.951</i>
22 K KRYPTON <i>89.03</i>	23 Ti TITANIUM <i>91.234</i>	24 Cr CHROMIUM <i>92.906</i>	18 VIA GERMANIUM GERMANIUM <i>35.951</i>
24 Ti TITANIUM <i>91.234</i>	25 Mn MANGANESE <i>95.936</i>	26 Fe IRON <i>96.808</i>	19 VIA GERMANIUM GERMANIUM <i>36.951</i>
26 Mn MANGANESE <i>95.936</i>	27 Co COBALT <i>97.002</i>	28 Ni NIQUE <i>98.696</i>	20 VIA GERMANIUM GERMANIUM <i>37.951</i>
28 Co COBALT <i>97.002</i>	29 Cu COPPER <i>99.996</i>	30 Zn ZINC <i>101.992</i>	21 VIA GERMANIUM GERMANIUM <i>38.951</i>
30 Cu COPPER <i>101.992</i>	31 Ga GALLIUM <i>102.911</i>	32 Al ALUMINUM <i>103.42</i>	22 VIA GERMANIUM GERMANIUM <i>39.951</i>
32 Ga GALLIUM <i>102.911</i>	33 Ge GERMANIUM <i>103.42</i>	34 P PHOSPHORUS <i>104.42</i>	23 VIA GERMANIUM GERMANIUM <i>40.951</i>
34 P PHOSPHORUS <i>104.42</i>	35 As ARSENIC <i>107.87</i>	36 S SULPHUR <i>112.41</i>	24 VIA GERMANIUM GERMANIUM <i>41.951</i>
35 As ARSENIC <i>107.87</i>	37 Se SELENIUM <i>114.82</i>	38 Cl CHLORINE <i>118.71</i>	25 VIA GERMANIUM GERMANIUM <i>42.951</i>
37 Se SELENIUM <i>114.82</i>	39 Br BROMINE <i>119.90</i>	40 S SULPHUR <i>121.76</i>	26 VIA GERMANIUM GERMANIUM <i>43.951</i>
39 Br BROMINE <i>119.90</i>	41 Kr KRYPTON <i>131.90</i>	42 Ar ARGON <i>136.30</i>	27 VIA GERMANIUM GERMANIUM <i>44.951</i>
41 Kr KRYPTON <i>131.90</i>	43 Xe XENON <i>131.90</i>	44 Rn RADON <i>136.30</i>	28 VIA GERMANIUM GERMANIUM <i>45.951</i>
43 Xe XENON <i>131.90</i>	45 La LANTHANIDE <i>138.91</i>	46 Ce LANTHANIDE <i>140.12</i>	29 VIA GERMANIUM GERMANIUM <i>46.951</i>
45 La LANTHANIDE <i>138.91</i>	47 Pr LANTHANIDE <i>141.91</i>	48 Nd LANTHANIDE <i>144.24</i>	30 VIA GERMANIUM GERMANIUM <i>47.951</i>
47 Pr LANTHANIDE <i>141.91</i>	49 Sm LANTHANIDE <i>145.03</i>	50 Eu LANTHANIDE <i>150.36</i>	31 VIA GERMANIUM GERMANIUM <i>48.951</i>
49 Sm LANTHANIDE <i>145.03</i>	51 Gd LANTHANIDE <i>151.96</i>	52 Tb LANTHANIDE <i>152.50</i>	32 VIA GERMANIUM GERMANIUM <i>49.951</i>
51 Gd LANTHANIDE <i>151.96</i>	53 Dy LANTHANIDE <i>154.53</i>	54 Ho LANTHANIDE <i>157.25</i>	33 VIA GERMANIUM GERMANIUM <i>50.951</i>
53 Dy LANTHANIDE <i>154.53</i>	55 Er LANTHANIDE <i>158.90</i>	56 Tm LANTHANIDE <i>162.25</i>	34 VIA GERMANIUM GERMANIUM <i>51.951</i>
55 Er LANTHANIDE <i>158.90</i>	57 Yb LANTHANIDE <i>164.93</i>	58 Lu LANTHANIDE <i>171.92</i>	35 VIA GERMANIUM GERMANIUM <i>52.951</i>
57 Yb LANTHANIDE <i>164.93</i>	59 Ac ACTINIDE <i>227.04</i>	60 Th ACTINIDE <i>231.94</i>	36 VIA GERMANIUM GERMANIUM <i>53.951</i>
59 Ac ACTINIDE <i>227.04</i>	61 Pa ACTINIDE <i>232.04</i>	62 U ACTINIDE <i>238.03</i>	37 VIA GERMANIUM GERMANIUM <i>54.951</i>
61 Pa ACTINIDE <i>232.04</i>	63 Np ACTINIDE <i>237.94</i>	64 Pu ACTINIDE <i>240.95</i>	38 VIA GERMANIUM GERMANIUM <i>55.951</i>
63 Np ACTINIDE <i>237.94</i>	65 Am ACTINIDE <i>244.97</i>	66 Cm ACTINIDE <i>247.98</i>	39 VIA GERMANIUM GERMANIUM <i>56.951</i>
65 Am ACTINIDE <i>244.97</i>	67 Bk ACTINIDE <i>249.99</i>	68 Fm ACTINIDE <i>251.00</i>	40 VIA GERMANIUM GERMANIUM <i>57.951</i>
67 Bk ACTINIDE <i>249.99</i>	69 Md ACTINIDE <i>252.01</i>	70 No ACTINIDE <i>253.02</i>	41 VIA GERMANIUM GERMANIUM <i>58.951</i>
69 Md ACTINIDE <i>252.01</i>	71 Tb ACTINIDE <i>253.02</i>	72 Lu ACTINIDE <i>257.02</i>	42 VIA GERMANIUM GERMANIUM <i>59.951</i>

LANTHANIDE



ACTINIDE

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www.periodictab.com

(1) Atomic weights of the elements 2013,
Pure Appl. Chem., 88, 295–309 (2016)

Figure 8.1 Modern Periodic Table



8.2.2 Features of Groups

- The 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 common characteristics of elements in each group, they can be grouped as various families.

Group Number	Family
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

- The Lanthanides and Actinides, which form part of Group 3 are called **inner transition elements**.
- Except 'group 0', all the elements present in each group have the same number of electrons in their valence shell and thus have the same valency. For example, all the elements of group 1 have one electron in their valence shells ($1s^1$). So, the valency of all the alkali metals is '1'.
- As the elements present in a group have identical valence shell electronic configurations, they possess similar chemical properties.
- The physical properties of the elements in a group such as melting point, boiling point and density vary gradually.
- The atoms of the 'group 0' elements have stable electronic configuration in their valence shells and hence they are unreactive.

8.3 PERIODIC TRENDS IN PROPERTIES

The electronic configurations of elements help us to explain the periodic recurrence of physical and chemical properties. Anything which repeats itself after a regular interval is called **periodic** and this behaviour is called **periodicity**. Some of the atomic properties of the elements are periodic.



Properties such as atomic radius, ionic radius, ionisation energy, electronegativity, electron affinity, show a regular periodicity and hence they are called **periodic properties**. The main significance of the modern periodic table is that it gives a clear understanding of the general properties and trends within a group or a period to predict with considerable accuracy, the properties of any element, even though that element may be unfamiliar to us. Let us discuss the periodic trend of some of the properties.

8.3.1 Atomic Radius

Atomic radius of an atom is defined as the distance between the centre of its nucleus and the outermost shell containing the valence electron. Direct measurement of the radius of an isolated atom is not possible. Except for noble gases, usually the atomic radius is referred to as **covalent radius** or **metallic radius** depending on the nature of the bonding between the concerned atoms. Atomic radius in metal atoms is known as **metallic radius**. It is defined as **half the distance between the nuclei of adjacent metal atoms** (Figure 8.2)

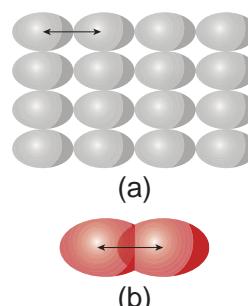


Figure 8.2

(a) Metallic Radius
(b) Covalent Radius



(a)). In non-metallic elements, their atomic radius is known as **Covalent radius**. It is defined as **half the distance between the nuclei of two covalently bonded atoms of the same element in a molecule** (Figure 8.2 (b)). For example, let us consider H_2 molecule. The distance between the two hydrogen nuclei of the molecule is 0.74 \AA . So its covalent radius is $0.74/2 = 0.37 \text{ \AA}$.

When you look at the variation of the atomic radii in the periodic table, there are two distinct trends. Along the period, from left to right, the atomic radius of the elements decreases whereas along the groups, from the top to bottom, the atomic radius increases. The increase, down a group, is due to the increase in the valence shell number down the group. As the shell number increases, the distance between the valence shell and the nucleus increases. In contrast, when you observe along the period, the shell number remains the same but the number of protons (i.e. atomic number) increases. More and more positive charges impose a strong attraction over the electrons and thus the electron cloud shrinks towards the nucleus, which results in the decrease in the atomic size. Figure 8.4 shows how the atomic radius decreases from lithium to boron.

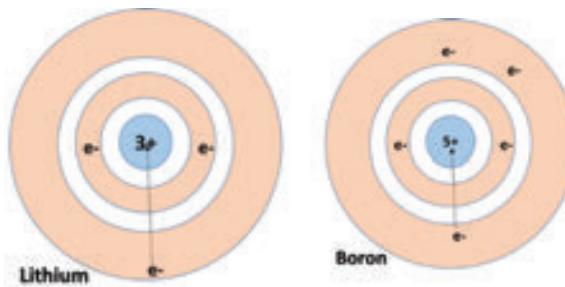


Figure 8.3 Atomic radius

8.3.2 Ionic Radii

It is defined as the distance from the centre of the nucleus of the ion upto the point where it exerts its influence on the electron cloud of

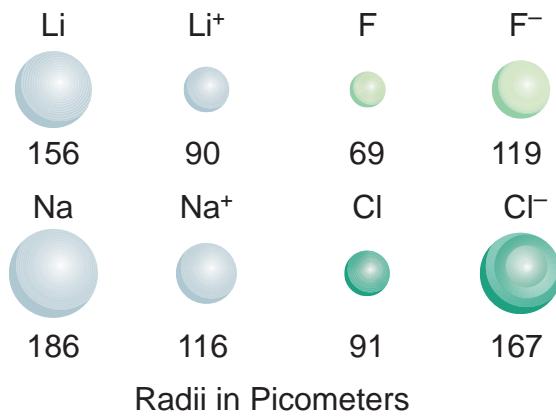


Figure 8.5 Relative ionic radii of cation and anion

the ion. You know that ions are formed when an atom lose or gain electrons. When a neutral atom loses an electron, it becomes a positively charged ion called **cation**, whereas the gain of an electron by a neutral atom forms a negatively charged ion called **anion**. The size of the ions is important to determine their behaviours in solutions and the structure of ionic solids. The size of a cation is always smaller than its corresponding neutral atom. But, the anion is larger than its neutral atom.

For instance, lithium and sodium lose the single electron from their outermost energy level to form cations. The ions so formed are smaller because the remaining electrons are at a inner cells and attracted more strongly by the nucleus. Fluorine and chlorine become negative ions by gaining an electron. When electrons are added, the charge on the nucleus is not great enough to hold the increased number of electrons as closely as it holds the electrons in the neutral atom. So, as seen in atomic radius, ionic radii also decrease along the period from left to right and increase down the group.

8.3.3 Ionisation Energy

Ionisation energy is the minimum energy required to remove an electron from a gaseous atom in its ground state to form a cation. It is otherwise called **ionisation enthalpy**. It is measured in kJ/mol. Higher



the ionisation energy, it is more difficult to remove the electron.

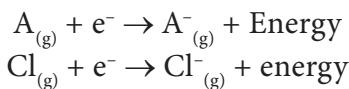
As the atomic size decreases from left to right in a period, more energy is required to remove the electrons. **So, the ionisation energy increases along the period.** But, down the group, the atomic size increases and hence the valence electrons are loosely bound. They require relatively less energy for the removal. **Thus, ionisation energy decreases down the group in the periodic table.**

Note: As the positive charge increases the size of the cation decreases

As the negative charge increases the size of the anion increases

8.3.4 Electron Affinity

Electron affinity is the amount of energy released when a gaseous atom gains an electron to form its anion. It is also measured in kJ/mol and represented by the following equation:



Like ionisation energy, electron affinity also increases from left to right in a period and decreases from top to bottom in a group.

More to Know

Noble gases show no tendency to accept electrons because the outer s and p orbitals of noble gases are completely filled. No more electrons can be added to them and hence their electron affinities are zero.

8.3.5 Electronegativity

Electronegativity of an element is the measure of the tendency of its atom to attract the shared pair of electrons towards itself in a covalent bond. Let us consider HCl molecule. Both the hydrogen and chlorine atoms share one electron each to form the covalent bond between them. chlorine atom has a higher electronegativity

and hence it pulls the shared electrons towards itself more strongly than hydrogen. Thus, when the bond breaks, the bonding electrons are left with chlorine forming H^+ and Cl^- ions. It is represented, diagrammatically, as shown below:

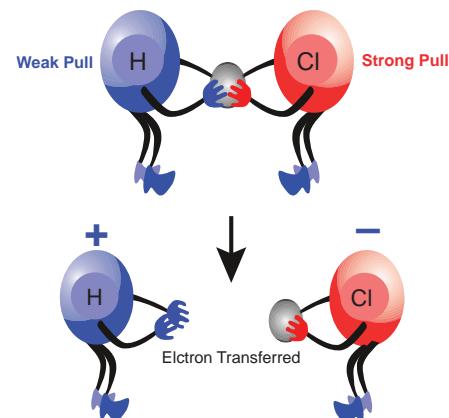


Figure 8.6 Relative electronegativity of H and Cl

Electronegativity is based on various experimental data such as bond energy, ionization potential, electron affinity, etc.

Pauling scale is the widely used scale to determine the electronegativity, which in turn predicts the nature of bonding (ionic or covalent) between the atoms in a molecule.

Electronegativity of some of the elements are given below

$$F = 4.0, Cl = 3.0, Br = 2.8, I = 2.5, H = 2.1, Na = 1$$

If the difference in electronegativity between two elements is 1.7, the bond has 50% ionic character and 50% covalent character.

If the difference is less than 1.7, the bond is considered to be covalent.

If the difference is greater than 1.7, the bond is considered to be ionic.

Along the period, from left to right in the periodic table, the electronegativity increases because of the increase in the nuclear charge which in turn attracts the electrons more strongly. On moving down a group, the electronegativity of the elements decreases because of the increased number of energy levels.



Periodic Property	In Periods	In Groups
Atomic radius	Decreases	Increases
Ionic radius	Decreases	Increases
Ionisation energy	Increases	Decreases
Electron affinity	Increases	Decreases
Electronegativity	Increases	Decreases

Test yourself

Predict the nature of the bond in the following molecules.

- (i) NaCl (ii) NaBr (iii) NaI
- (iv) NaF (v) NaH

8.4 METALLURGY

Human life is associated with various metals. We use metals in our day to day activities. It is the utmost need to have some metals like sodium, potassium, calcium, iron, etc. in the human body. Deficiency of these metals affects the metabolic activities thereby causing diseases. So, metals play a vital role in our life. In this section, let us discuss how metals are obtained from various sources by the process of metallurgy.



Metallurgy is a science of extracting metals from their ores and modifying the metals into alloys for various uses, based on their physical and chemical properties and their structural arrangement of atoms. A metallurgical process involve three main steps as follows:

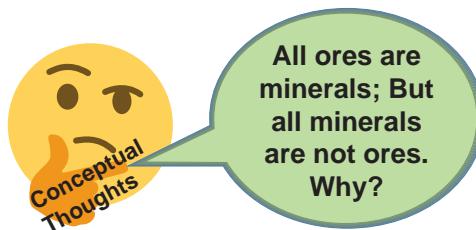
- (i) **Concentration or Separation of the ore:** It is the process of removal of impurities from the ore.
- (ii) **Production of the metal:** It is the conversion of the ore into metal.

- (iii) **Refining of the metal:** It is the process of purification of the metal.

8.4.1 Terminology in metallurgy

Minerals: A mineral may be a single compound or a complex mixture of various compounds of metals found in the Earth.

Ore: The mineral from which a metal can be readily and economically extracted on a large scale is said to be an ore.



For example: Clay ($\text{Al}_2\text{O}_3 \cdot 2 \text{SiO}_2 \cdot 2 \text{H}_2\text{O}$) and bauxite ($\text{Al}_2\text{O}_3 \cdot 2 \text{H}_2\text{O}$) are the two minerals of aluminium, but aluminium can be profitably extracted only from bauxite. Hence, bauxite is an ore of aluminium and clay is its mineral.

Mining: The process of extracting the ores from the Earth's crust is called mining.

Gangue or Matrix: The rocky impurity associated with an ore is called gangue or matrix.

Flux: It is the substance added to the ore to reduce the fusion temperature and to remove the impurities. E.g. Calcium oxide (basic), Silica (acidic). If the gangue is acidic, then basic flux is added and vice versa.

Slag: It is the fusible product formed when a flux reacts with a gangue during the extraction of metals.



Smelting: Smelting is the process of reducing the roasted metallic oxide from the metal in its molten condition. In this process, impurities are removed as slag by the addition of flux.

8.4.2 Types of separation or concentration of an ore

There are four major types of separation of ores based on the nature of the ore. The



different kinds of ores of metals are given in Table 8.1

Concentration of the crushed ore is done mainly by the following methods:-

(i) Hydraulic (Gravity Separation) method

Principle: The difference in the densities or specific gravities of the ore and the gangue is the main principle behind this method. Oxide ores are purified by this method. e.g., Haematite Fe_2O_3 , the ore of iron.

Method: The ore is poured over a sloping, vibrating corrugated table with grooves and a jet of water is allowed to flow over it. The denser ore particles settle down in the grooves and lighter gangue particles are washed down by water.

(ii) Magnetic separation method

Principle: The magnetic properties of the ores form the basis of separation. When either the ore or the gangue is magnetic, this method is employed. e.g., Tinstone SnO_2 , the ore of tin.

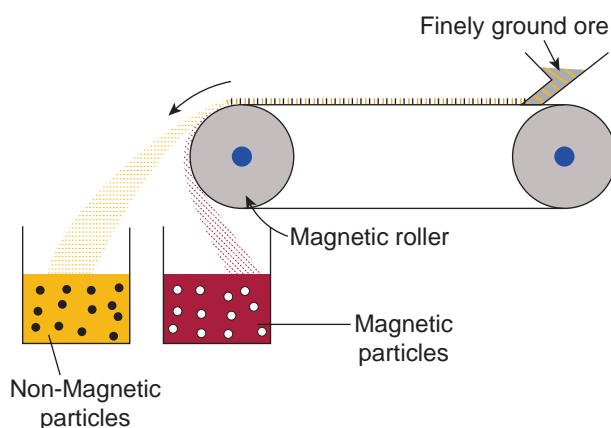


Figure 8.8 Magnetic separation

Method: The crushed ore is placed over a conveyer belt which rotates around two

metal wheels, one of which is magnetic. The magnetic particles are attracted to the magnetic wheel and fall separately apart from the non-magnetic particles.

(iii) Froth floatation

Principle: This process depends on the preferential wettability of the ore with oil (pine oil) and the gangue particles by water. Lighter ores, such as sulphide ores, are concentrated by this method. e.g., Zinc blende (ZnS).

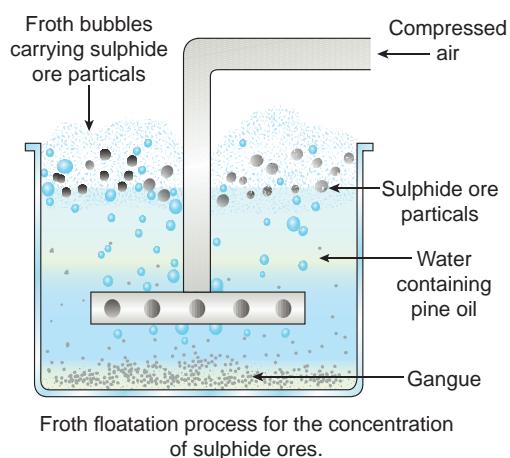


Figure 8.9 Froth floatation

Method: The crushed ore is taken in a large tank containing oil and water and agitated with a current of compressed air. The ore is wetted by the oil and gets separated from the gangue in the form of froth. Since the ore is lighter, it comes on the surface with the froth and the impurities are left behind. e.g., Zinc blende (ZnS).

(iv) Chemical method or Leaching

This method is employed when the ore is in a very pure form.

Table 8.1 Types of ores

Oxide Ores	Carbonate Ores	Halide Ores	Sulphide Ores
Bauxite ($\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$)	Marble (CaCO_3)	Cryolite (Na_3AlF_6)	Galena (PbS)
Cuprite (Cu_2O)	Magnesite (MgCO_3)	Fluorspar (CaF_2)	Iron pyrite (FeS_2)
Haematite (Fe_2O_3)	Siderite (FeCO_3)	Rock salt (NaCl)	Zinc blende (ZnS)



More to Know

Extraction of metal from metal oxide can be categorized into three types.

More reactive metals	Medium reactive metals	Less reactive metals
Na,K,Ca,Mg,Al	Zn,Fe,Pb,Cu	Ag,Hg
Electrolytic reduction of metal oxide into metal	Chemical reduction of metal oxide into metal using coke	Thermal decomposition of metal oxide into metal

The ore is treated with a suitable reagent such that the ore is soluble in it but the impurities are not. The impurities are removed by filtration. The solution of the ore, ie., the filtrate is treated with a suitable reagent which precipitates the ore. E.g. Bauxite $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$, the ore of aluminium.

8.5 OCCURRENCE OF ORES IN TAMIL NADU

Lime stone: Coimbatore, Cuddalore, Dindugul

Gypsum: Tiruchi and Coimbatore Districts

Titanium minerals: Kanyakumari, Tirunelveli and Tuticorin.

Chromite: Coimbatore and Salem district.

Magnetite: Dharmapuri, Erode, Salem, Thiruvannamalai.

Tungsten: Madurai and Dindugal.

(Reference: mineral resources of Tamil Nadu-ENVIS Centre, Tamil Nadu)

8.6 PROPERTIES OF METALS

8.6.1 Physical properties

- Physical state:** All metals are solids at room temperature except mercury and gallium.
- Lustre:** Metals possess a high lustre (called metallic lustre).
- Hardness:** Most of the metals are hard and strong (exceptions: sodium and potassium can be cut with a knife)
- Melting point and Boiling point:** Usually, metals possess high melting and

boiling points and vaporize only at high temperatures (exceptions: gallium, mercury, sodium and potassium).

- Density:** Metals have a high density (exceptions: sodium and potassium are less dense than water).
- Ductility:** Metals are usually ductile. In other words, they can be drawn into thin wires without breaking.
- Malleability:** Metals are usually malleable, i.e, they can be beaten into thin sheets without cracking (except zinc and mercury).
- Conduction of heat and electricity:** Metals are good conductors of heat and electricity; silver and copper excel in this property (exception: tungsten)
- Solubility:** Usually, metals do not dissolve in liquid solvents.

8.6.2 Chemical Properties

- Valence electrons:** Atoms of metals usually have 1,2 or 3 electrons in their outermost shell.
- Formation of ions:** Metals form Positive ions by the loss of electrons and hence they are electro positive.
- Discharge of ions:** Metals are discharged at the cathode during the electrolysis of their compounds.
- Atomicity:** Molecules of metals in their vapour state are usually monoatomic.
- Nature of oxides:** Oxides of metals are usually basic.



8.7 EXTRACTIVE METALLURGY OF ALUMINIUM

Aluminium is the metal found most abundantly in the Earth's crust. Since it is a reactive metal, it occurs in the combined state. The important ores of aluminium are as follows

Ores of Aluminium	Formula
Bauxite	$\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$
Cryolite	Na_3AlF_6
Corundum	Al_2O_3

Bauxite is the chief ore of aluminium. The extraction of aluminium from bauxite involves two steps:

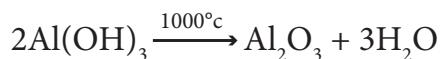
(i) Conversion of bauxite into alumina – Baeyer's Process

The conversion of Bauxite into Alumina involves the following steps:

Bauxite ore is finely ground and heated under pressure with a solution of concentrated caustic soda solution at 150°C to obtain sodium meta aluminate.

On diluting sodium meta aluminate with water, a precipitate of aluminium hydroxide is formed.

The precipitate is filtered, washed, dried and ignited at 1000°C to get alumina.



(ii) Electrolytic reduction of alumina – Hall's Process

Aluminium is produced by the electrolytic reduction of fused alumina (Al_2O_3) in the electrolytic cell.

Cathode: Iron tank linked with graphite

Anode: A bunch of graphite rods suspended in molten electrolyte.

Electrolyte: Pure alumina + molten cryolite + fluorspar (fluorspar lowers the fusion temperature of electrolyte)

Temperature: $900 - 950^\circ\text{C}$

Voltage used: 5-6 V

Overall reaction: $2\text{Al}_2\text{O}_3 \rightarrow 4\text{Al} + 3\text{O}_2 \uparrow$

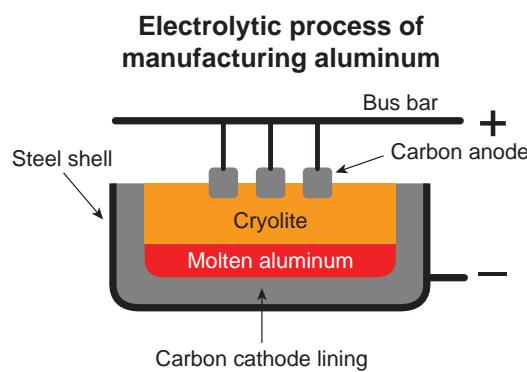


Figure 8.10 Hall's Process

Aluminium is deposited at the cathode and oxygen gas is liberated at the anode. Oxygen combines with graphite to form CO_2 .

Physical Properties of Aluminium

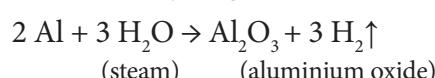
- It is a silvery white metal
- It has low density (2.7) and it is light
- It is malleable and ductile
- It is a good conductor of heat and electricity.
- Its melting point is 660°C .
- It can be polished to produce a shiny attractive appearance.

Chemical Properties of Aluminium

- Reaction with air:** It is not affected by dry air. On heating at 800°C , aluminium burns very brightly forming its oxide and nitride.

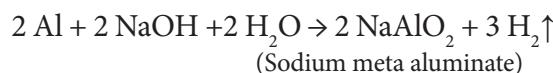


- Reaction with water:** Water does not react with aluminium due to the layer of oxide on it. When steam is passed over red hot aluminium, hydrogen is produced.

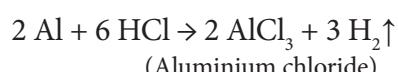




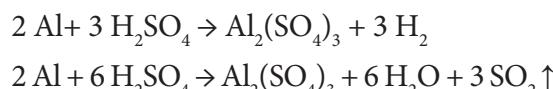
iii. Reaction with alkalis: It reacts with strong caustic alkalis forming aluminates.



iv. Reaction with acids: With dilute and conc. HCl it liberates H₂ gas.



Aluminium liberates hydrogen on reaction with dilute sulphuric acid. Sulphur dioxide is liberated with hot concentrated sulphuric acid



More to Know

Dilute or concentrated nitric acid does not attack aluminium, but it renders aluminium passive due to the formation of an oxide film on its surface.

v. As reducing agent: Aluminium is a powerful reducing agent. When a mixture of aluminium powder and iron oxide is ignited, the latter is reduced to metal. This process is known as **aluminothermic process**.



Uses

Aluminium is used in

- household utensils
- electrical cable industry
- making aeroplanes and other industrial machine parts

8.8 EXTRACTIVE METALLURGY OF COPPER

Occurrence:

It was named as cuprum by the Romans because they got it from the Island of Cyprus. Copper is found in the native state as well as combined state.

Ores of copper	Formula
Copper pyrites	CuFeS ₂
Cuprite or ruby copper	Cu ₂ O
Copper glance	Cu ₂ S

The chief ore of copper is copper pyrite. It yields nearly 76% of the world production of copper. Extraction of copper from copper pyrites involves the following steps

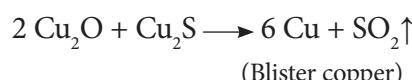
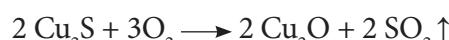
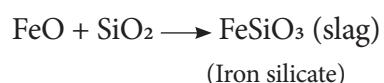
i. Concentration of ore: The ore is crushed and the concentrated by froth floatation process.

ii. Roasting: The concentrated ore is roasted in excess of air. During the process of roasting, the moisture and volatile impurities are removed. Sulphur, phosphorus, arsenic and antimony are removed as oxides. Copper pyrite is partly converted into sulphides of copper and iron.



iii. Smelting: The roasted ore is mixed with powdered coke and sand and is heated in a blast furnace to obtain matte (Cu₂S + FeS) and slag. The slag is removed as waste.

iv. Bessemerisation: The molten matte is transferred to Bessemer converter in order to obtain blister copper. Ferrous sulphide from matte is oxidized to ferrous oxide, which is removed as slag using silica.



v. Refining: Blister copper contains 98% of pure copper and 2% of impurities and is purified by **electrolytic refining**. This method is used to get metal of a high degree of purity. For electrolytic refining of copper, we use:



Cathode: A thin plate of pure copper metal.

Anode: A block of impure copper metal.

Electrolyte: Copper sulphate solution acidified with sulphuric acid.

When electric current is passed through the electrolytic solution, pure copper gets deposited at the cathode and the impurities settle at the bottom of the anode in the form of sludge called anode mud.

Physical Properties of Copper

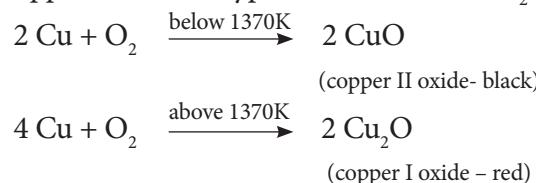
Copper is a reddish brown metal, with high lustre, high density and high melting point (1356°C).

Chemical Properties of Copper

i. **Action of Air and Moisture:** Copper gets covered with a green layer of basic copper carbonate in the presence of CO_2 and moisture.



ii. **Action of Heat:** On heating at different temperatures in the presence of oxygen, copper forms two types of oxides CuO , Cu_2O .



iii. **Action of Acids:**

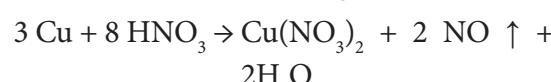
a) **With dilute HCl and dilute H_2SO_4 :**

Dilute acids such as HCl and H_2SO_4 have no action on these metals in the absence of air. Copper dissolves in these acids in the presence of air.



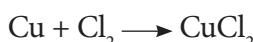
b) **With dil. HNO_3 :**

Copper reacts with dil. HNO_3 with the liberation of Nitric Oxide gas.



iv) Action of Chlorine:

Chlorine reacts with copper, resulting in the formation of copper(II) chloride.



v) Action of Alkalies:

Copper is not attacked by alkalies.

Uses of Copper:

- i. It is extensively used in manufacturing electric cables and other electric appliances.
- ii. It is used for making utensils, containers, calorimeters and coins,
- iii. It is used in electroplating.
- iv. It is alloyed with gold and silver for making coins and jewels

8.9 EXTRACTIVE METALLURGY OF IRON

Occurrence:

Iron is the second most abundant metal available next to aluminium. It occurs in nature as oxides, sulphides and carbonates. The ores of iron are as follows:

Ores of iron	Formula
Haematite	Fe_2O_3
Magnetite	Fe_3O_4
Iron pyrite	FeS_2

Iron is chiefly extracted from haematite ore (Fe_2O_3)

- i. **Concentration by Gravity Separation:** The powdered ore is washed with a stream of water. As a result, the lighter sand particles and other impurities are washed away and the heavier ore particles settle down.
- ii. **Roasting and Calcination:** The concentrated ore is strongly heated in a limited supply of air in a reverberatory furnace. As a result, moisture is driven out and sulphur, arsenic and phosphorus impurities are oxidized off.



iii. Smelting (in a Blast Furnace): The charge consisting of roasted ore, coke and limestone in the ratio 8:4:1 is smelted in a blast furnace by introducing it through the cup and cone arrangement at the top. There are three important regions in the furnace.

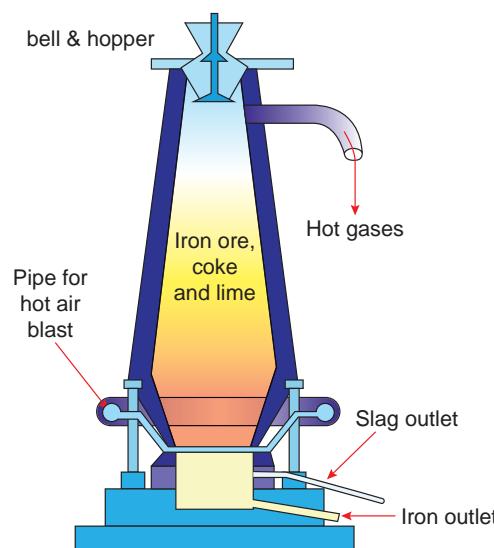
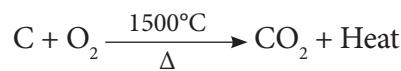


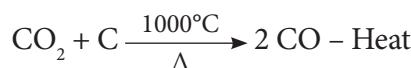
Figure 8.11 Blast Furnace

(a) The Lower Region (Combustion Zone)- The temperature is at 1500°C . In this region, coke burns with oxygen to form CO_2 when the charge comes in contact with a hot blast of air.

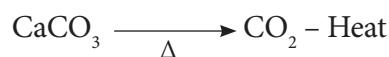


It is an exothermic reaction since heat is liberated.

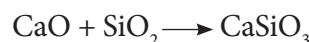
(b) The Middle Region (Fusion Zone) – The temperature prevails at 1000°C . In this region, CO_2 is reduced to CO .



Limestone decomposes to calcium oxide and CO_2 .



These two reactions are endothermic due to absorption of heat. Calcium oxide combines with silica to form calcium silicate slag.



(c) The Upper Region (Reduction Zone)- The temperature prevails at 400°C . In this region carbon monoxide reduces ferric oxide to form a fairly pure spongy iron.



The molten iron is collected at the bottom of the furnace after removing the slag.

The iron thus formed is called pig iron. It is remelted and cast into different moulds. This iron is called cast iron.

Physical properties:

- It is a lustrous metal, greyish white in colour.
- It has high tensility, malleability and ductility.
- It can be magnetized.

Chemical properties:

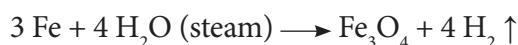
i. **Reaction with air or oxygen:** Only on heating in air, iron forms magnetic oxide.



ii. **Reaction with moist air:** When iron is exposed to moist air, it forms a layer of brown hydrated ferric oxide on its surface. This compound is known as rust and the phenomenon of formation of rust is known as **rusting**.



iii. **Reaction with steam:** When steam is passed over red hot iron, magnetic oxide is formed.



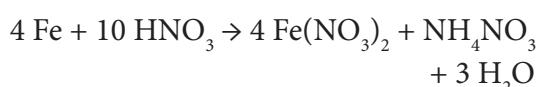
iv. **Reaction with chlorine:** Iron combines with chlorine to form ferric chloride.



v. **Reaction with acids:** With dilute HCl and dilute H_2SO_4 it liberates H_2 gas.

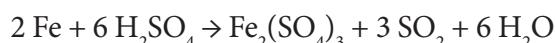


With dilute HNO_3 in cold condition it gives ferrous nitrate.





With con. H_2SO_4 it forms ferric sulphate.



When iron is dipped in con. HNO_3 , it becomes chemically passive or inert due to the formation of a layer of iron oxide (Fe_3O_4) on its surface.

Uses of iron

Pig iron (Iron with 2-4.5% of carbon): It is used in making pipes, stoves, radiators, railings, manhole covers and drain pipes.

Steel (Iron with < 0.25% of carbon): It is used in the construction of buildings, machinery, transmission cables and T.V towers and in making alloys.

Wrought iron (Iron with 0.25-2% of wraught carbon): It is used in making springs, anchors and electromagnets.

8.10 ALLOYS

An alloy is a homogeneous mixture of two or more metals or of one or more metals with certain non-metallic elements.

The properties of alloys are often different from those of its components. Pure gold is too soft to be used. The addition of small percentage of copper enhances its strength and utility.

8.10.1 Amalgam

An amalgam is an alloy of mercury with another metal. These alloys are formed through metallic bonding with the electrostatic force of attraction between the electrons and the positively charged metal ions. Silver tin amalgam is used for dental filling.

Reasons for alloying:

- To modify appearance and colour
- To modify chemical activity.
- To lower the melting point.
- To increase hardness and tensile strength.
- To increase resistance to electricity.

8.10.2 Method of making alloys

(a) By fusing the metals together. E.g. Brass is made by melting zinc and copper.

(b) By compressing finely divided metals. E.g. Wood metal: an alloy of lead, tin, bismuth and cadmium powder is a fusible alloy.

Alloys as solid solutions:

Alloys can be considered solid solutions in which the metal with high concentration is solvent and other metals are solute.

For example, brass is a solid solution of zinc (solute) in copper (solvent).

8.10.3 Types of Alloys

Based on the presence or absence of Iron, alloys can be classified into:

- Ferrous alloys: Contain Iron as a major component. A few examples of ferrous alloys are Stainless Steel, Nickel Steel etc.
- Non-ferrous alloys: These alloys do not contain Iron as a major component. For example, Aluminium alloy, Copper alloy etc.

Copper Alloys (Non- ferrous)

Alloys	Uses
Brass (Cu, Zn)	Electrical fittings, medal, decorative items, hardware
Bronze (Cu, Sn)	Statues, coins, bells, gongs

Aluminium Alloys (Non- ferrous)

Alloys	Uses
Duralumin (Al, Mg, Mn, Cu)	Aircrafts, tools, pressure cookers
Magnalium (Al, Mg)	Aircraft, scientific instruments

Iron Alloys(Ferrous)

Alloys	Uses
Stainless steel (Fe,C, Ni, Cr)	Utensils, cutlery, automobile parts
Nickel steel (Fe,C,Ni)	Cables , aircraftparts, propeller



8.11 CORROSION

It is the gradual destruction of metals by chemical or electrochemical reaction with the environment. It is a natural process which converts a metal into its oxide, hydroxide or sulphide so that it loses its metallic characteristics.

Rusting

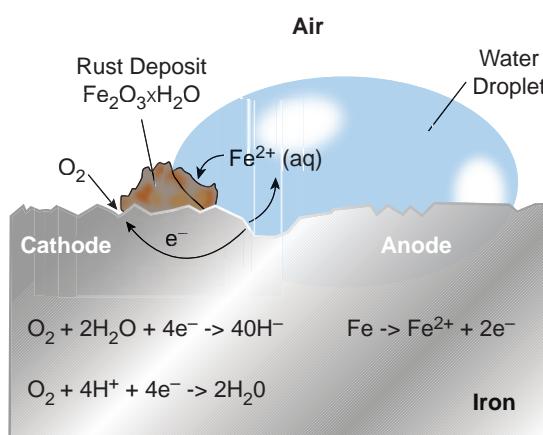


Figure 8.12 Rusting

Rust is chemically known as hydrated ferric oxide (it is formulated as $\text{Fe}_2\text{O}_3 \cdot \text{xH}_2\text{O}$). Rusting results in the formation of scaling reddish brown hydrated ferric oxide on the surface of iron and iron containing materials.

8.11.1 Types of Corrosion

- Dry Corrosion or Chemical Corrosion:** The corrosive action in the absence of moisture is called dry corrosion. It is the process of a chemical attack on a metal by a corrosive liquids or gases such as O_2 , N_2 , SO_2 , H_2S etc. It occurs at high temperature. Of all the gases mentioned above O_2 is the most reactive gas to impart the chemical attack.
- Wet Corrosion or Electrochemical Corrosion:** The corrosive action in the presence of moisture is called wet corrosion. It occurs as a result of electrochemical reaction of metal with water or aqueous solution of salt or acids or bases.

8.11.2 Methods of preventing corrosion

- Alloying:** The metals can be alloyed to prevent the process of corrosion. E.g: Stainless Steel
- Surface Coating:** It involves application of a protective coating over the metal. It is of the following types:
 - Galvanization:** It is the process of coating zinc on iron sheets by using electric current.
 - Electroplating:** It is a method of coating one metal over another metal by passing electric current.
 - Anodizing:** It is an electrochemical process that converts the metal surface into a decorative, durable and corrosion resistant. Aluminium is widely used for anodizing process.
 - Cathodic Protection:** It is the method of controlling corrosion of a metal surface protected is coated with the metal which is easily corrodible. The easily corrodible metal is called Sacrificial metal to act as anode ensuring cathodic protection.

8.12 PAMBAN BRIDGE

It is a railway bridge which connects the town of Rameshwaram on Pamban Island to mainland India. Opened on 1914, it was India's first sea bridge in India until the opening of the BandraWorli Sea Link in 2010. We can control the corrosion and renovation of historical pamban bridge by a periodical protective coating which will be the strong example for applied chemistry to uphold our history.



Figure 8.12 Pamban Bridge



Points to Remember

- ❖ Modern periodic law states that, the physical and chemical properties of the elements are the periodic functions of their atomic numbers.
- ❖ The table in which elements are arranged in rows and columns in regular gradation is called periodic table.
- ❖ Smelting is the process of reducing the roasted metallic oxide into metal in molten condition.
- ❖ Dilute or con. HNO_3 does not attack aluminium metal, as it renders aluminium passive due to oxide film formation on its surface.

- ❖ The charge used in the metallurgy of iron consists of roasted ore, coke and limestone in the ratio, 8:4:1.
- ❖ Copper vessel on exposure to air and moisture forms a green layer on its surface due to basic copper carbonate.
- ❖ An alloy is a homogeneous mixture of two or more metals.
- ❖ An amalgam is an alloy of mercury with another metal. E.g. Ag-Sn amalgam is used for dental filling.
- ❖ The chemical name of rust is hydrated ferric oxide and its formula is $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$.



TEXTBOOK EVALUATION



FBKZ2Y

I. Choose the best answer.

1. The number of periods and groups in the periodic table are _____.
a) 6,16 b) 7,17
c) 8,18 d) 7,18
2. The basis of modern periodic law is _____.
a) atomic number
b) atomic mass
c) isotopic mass
d) number of neutrons
3. _____ group contains the member of halogen family.
a) 17th b) 15th
c) 18th d) 16th
4. _____ is a relative periodic property
a) atomic radii b) ionic radii
c) electron affinity d) electronegativity
5. Chemical formula of rust is _____.
a) $\text{FeO} \cdot x\text{H}_2\text{O}$ b) $\text{FeO}_4 \cdot x\text{H}_2\text{O}$
c) $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ d) FeO

6. In the alumino thermic process the role of Al is _____.
a) oxidizing agent
b) reducing agent
c) hydrogenating agent
d) sulphurising agent
7. The process of coating the surface of metal with a thin layer of zinc is called _____.
a) painting b) thinning
c) galvanization d) electroplating
8. Which of the following have inert gases 2 electrons in the outermost shell.
a) He b) Ne
c) Ar d) Kr
9. Neon shows zero electron affinity due to _____.
a) stable arrangement of neutrons
b) stable configuration of electrons
c) reduced size
d) increased density



10. _____ is an important metal to form amalgam.
- a) Ag b) Hg
c) Mg d) Al

II. Fill in the blanks

- If the electronegativity difference between two bonded atoms in a molecule is greater than 1.7, the nature of bonding is _____.
- _____ is the longest period in the periodical table.
- _____ forms the basis of modern periodic table.
- If the distance between two Cl atoms in Cl_2 molecule is 1.98 Å, then the radius of Cl atom is _____.
- Among the given species A^- , A^+ , and A, the smallest one in size is _____.
- The scientist who propounded the modern periodic law is _____.
- Across the period, ionic radii _____ (increases, decreases).
- _____ and _____ are called inner transition elements.
- The chief ore of Aluminium is _____.
- The chemical name of rust is _____.

III. Match the following

- | | |
|----------------------|---------------------------------|
| 1. Galvanisation | : Noble gas elements |
| 2. Calcination | : Coating with Zn |
| 3. Redox reaction | : Silver-tin amalgam |
| 4. Dental filling | : Alumino thermic process |
| 5. Group 18 elements | : Heating in the absence of air |

IV. True or False: (If false give the correct statement)

- Moseley's periodic table is based on atomic mass.
- Ionic radius increases across the period from left to right.

- All ores are minerals; but all minerals cannot be called as ores;
- Al wires are used as electric cables due to their silvery white colour.
- An alloy is a heterogenous mixture of metals.

V. Assertion and Reason

Answer the following questions using the data given below:

- A and R are correct, R explains the A.
- A is correct, R is wrong.
- A is wrong, R is correct.
- A and R are correct, R doesn't explain A.

- Assertion :** The nature of bond in HF molecule is ionic

Reason : The electronegativity difference between H and F is 1.9

- Assertion :** Magnesium is used to protect steel from rusting

Reason : Magnesium is more reactive than iron

- Assertion :** An uncleaned copper vessel is covered with greenish layer.

Reason : copper is not attacked by alkali

VI. Short answer questions

- A is a reddish brown metal, which combines with O_2 at $< 1370 \text{ K}$ gives B, a black coloured compound. At a temperature $> 1370 \text{ K}$, A gives C which is red in colour. Find A, B and C with reaction.
- A is a silvery white metal. A combines with O_2 to form B at 800°C , the alloy of A is used in making the aircraft. Find A and B
- What is rust? Give the equation for formation of rust.
- State two conditions necessary for rusting of iron.

VII. Long answer questions

- a) State the reason for addition of caustic alkali to bauxite ore during purification of bauxite.
b) Along with cryolite and alumina, another substance is added to the electrolyte



mixture. Name the substance and give one reason for the addition.

2. The electronic configuration of metal A is 2,8,18,1.

The metal A when exposed to air and moisture forms B a green layered compound. A with con. H_2SO_4 forms C and D along with water. D is a gaseous compound. Find A,B,C and D.

3. Explain smelting process.

VIII. HOT questions

- Metal A belongs to period 3 and group 13. A in red hot condition reacts with steam to form B. A with strong alkali forms C. Find A,B and C with reactions
- Name the acid that renders aluminium passive. Why?
- a) Identify the bond between H and F in HF molecule.

b) What property forms the basis of identification?

c) How does the property vary in periods and in groups?



REFERENCE BOOKS

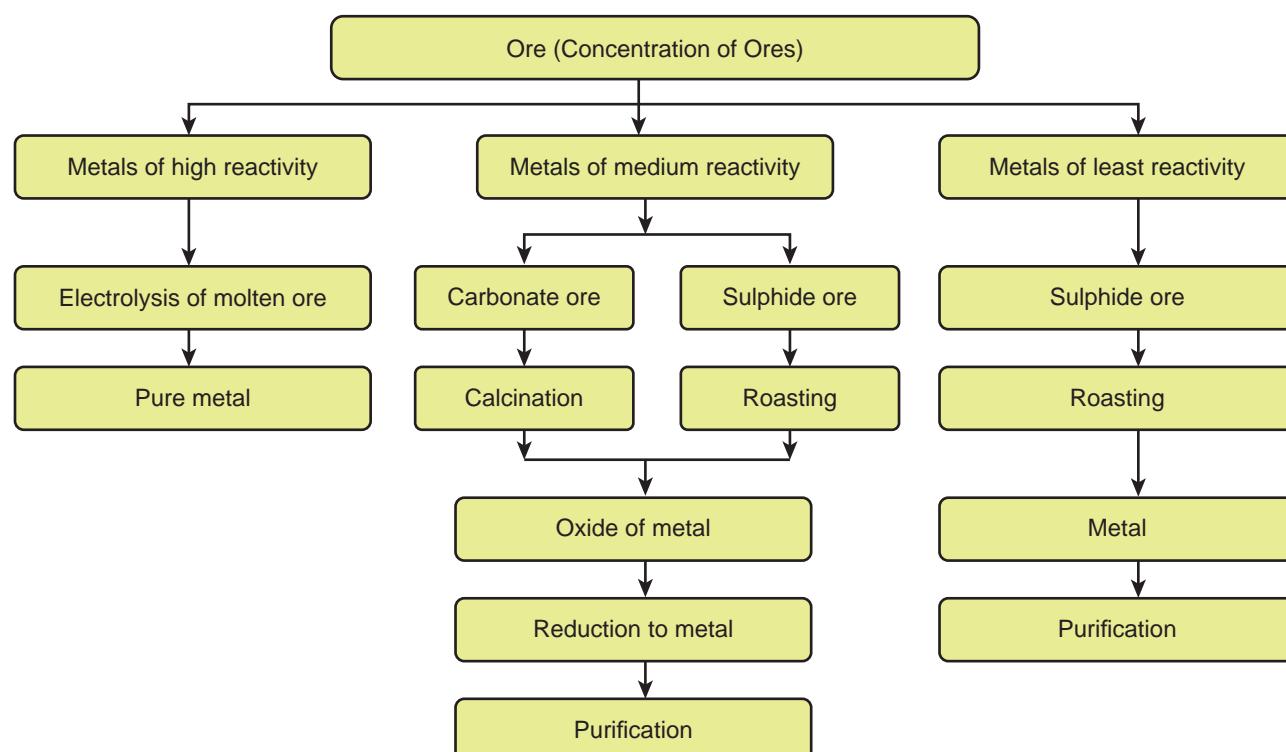
- Inorganic chemistry by PL Soni
- Physical chemistry by Puri and Sharma
- Inorganic chemistry by Atkins
- Oxford Inorganic chemistry



INTERNET RESOURCES

- <https://www.webelements.com>
- www.rsc.org/periodic-table
- <https://www.tcyonline.com>

CONCEPT MAP





Learning Objectives

After studying this lesson, students will be able to

- ◆ define solution.
- ◆ recognize the types of solutions.
- ◆ analyse the factors influencing solubility.
- ◆ explain the various modes of expression of concentration of solution.
- ◆ calculate the solubility of solutes in solvents.
- ◆ correlate the hydrated salts and anhydrous salts.
- ◆ distinguish between deliquescent and hygroscopic substances.



INTRODUCTION

You have learnt about mixtures in your lower classes. Most of the substances that we encounter in our daily life are mixtures of two or more substances. The substances present in a mixture may exist in one or more physical state. For example, when we burn wood, the smoke released is a mixture of solid carbon and gases like CO₂, CO, etc.

In some cases of mixtures, their components can be separated easily whereas in some other cases they cannot be. Consider the two mixtures, one which contains salt and water, and the other which contains sand and water. Water is the one of the components in both the mixtures. In the first case salt dissolves in water. In the second case the sand does not dissolve in water. Sand in water can be separated by filtration but salt cannot be separated as it dissolves in water to form a homogeneous

mixture. This kind of homogenous mixtures are termed as “solutions”.



Salt + water



Sand + Water

Figure 9.1 Homogeneous and heterogeneous mixtures

9.1 SOLUTIONS IN DAY-TO-DAY LIFE

One of the naturally existing solutions is sea water. We cannot imagine life on earth without sea water. It is a mixture of many dissolved salts. The another one is air. It is a mixture of gases like nitrogen, oxygen, carbon dioxide and other gases.



All the life forms on the earth are associated with solutions. Plants take solutions of nutrients for their growth from the soil. Most of the liquids found in human body including blood, lymph and urine are solutions. Day to day human activities like washing, cooking, cleaning and few other activities involve the formation of solutions with water. Similarly, the drinks what we take, like fruit juice, aerated drinks, tea, coffee etc. are also solutions. Therefore, the ability of water to form solutions is responsible for sustenance of life. On the other hand, the same characteristic forms the basic cause of the addition of pollutants to water. However, the ability of water to form solutions influences the survival of man on the earth. In this lesson, let us learn the science of solutions.

9.2 COMPONENTS OF SOLUTIONS

We know that, a **solution is a homogeneous mixture of two or more substances**. In a solution, the component which is present in lesser amount (by weight), is called **solute** and the component, which is present in a larger amount (by weight) is called **solvent**. The solute gets distributed uniformly throughout the solvent and thus forming the mixture homogeneous. So, the solvent acts as a dissolving medium in a solution. The process of uniform distribution of solute into solvent is called **dissolution**. Figure 9.2 shows the schematic representation of solution.

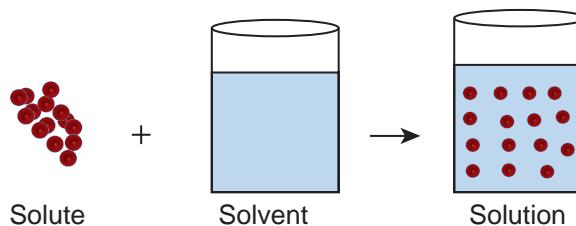


Figure 9.2 Formation of solution



A solution must at least be consisting of two components (a solute and a solvent). Such solutions which are made of one solute and one solvent (two components) are called **binary solutions**. e.g. On adding copper sulphate crystals to water, it dissolves in water forming a solution of copper sulphate as shown in Figure 9.3. It contains two components i.e. one solute- copper sulphate and one solvent-water. So it is a binary solution. Similarly, a solution may contain more than two components. For example if salt and sugar are added to water, both dissolve in water forming a solution. Here two solutes are dissolved in one solvent. Such kind of solutions which contain three components are called **ternary solutions**.



Figure 9.3 Formation of Copper sulphate solution

9.3 Types of Solutions

9.3.1 Based on the physical state of the solute and the solvent

We know that substances normally exist in three physical states (phases) i.e., solid, liquid and gas. In binary solutions, both the solvent and solute may exist in any of these physical states. But the solvent constitutes the major part of the solution. Its physical state is the primary factor which determine the characteristics of the solution. Therefore, there are different types of binary solutions as listed in Table 9.1.

**Table 9.1** Types of binary solutions

Solute	Solvent	Example
Solid solution		
Solid	Solid	Copper dissolved in gold (Alloys)
Liquid	Solid	Mercury with sodium (amalgam)
Liquid solution		
Solid	Liquid	Sodium chloride dissolved in water
Liquid	Liquid	Ethyl alcohol dissolved in water
Gas	Liquid	carbon-di-oxide dissolved in water (Soda water)
Gaseous solution		
Liquid	Gas	Water vapour in air (cloud)
Gas	Gas	Mixture of Helium-Oxygen gases,

9.3.2 Based on the type of solvent

Most of the substances are soluble in water. That is why, water is called as ‘Universal solvent’. However some substances do not dissolve in water. Therefore, other solvents such as ethers, benzene, alcohols etc., are used to prepare a solution. On the basis of type of solvent, solutions are classified into two types. They are aqueous solutions and non-aqueous solutions.

a) Aqueous solution:

The solution in which water acts as a solvent is called aqueous solution. In general, ionic compounds are soluble in water and form aqueous solutions more readily than covalent compounds. E.g. Common salt in water, Sugar in water, Copper sulphate in water etc.

b) Non – Aqueous solution:

The solution in which any liquid, other than water, acts as a solvent is called non-aqueous solution. Solvent other than water is referred to as non-aqueous solvent. Generally, alcohols, benzene, ethers, carbon disulphide, acetone, etc., are used as non-aqueous solvents. Examples for non-aqueous solutions: Sulphur dissolved in carbon disulphide, Iodine dissolved in carbon tetrachloride.



Figure 9.4 Sulphur in carbon-di-sulphide (Soluble), Sulphur in water (Insoluble)

9.3.3 Based on the amount of solute

The amount of the solute that can be dissolved in the given amount of solvent is limited under any given conditions. Based on the amount of solute, in the given amount of solvent, solutions are classified into the following types:

- (i) Saturated solution
- (ii) Unsaturated solution
- (iii) Super saturated solution

(i) Saturated solution: A solution in which no more solute can be dissolved in a definite amount of the solvent at a given temperature is called saturated solution. e.g. 36 g of sodium chloride in 100 g of water at 25°C forms saturated solution.



Further addition of sodium chloride leave it undissolved.

(ii) **Unsaturated solution:** Unsaturated solution is one that contains less solute than that of the saturated solution at a given temperature. e.g. 10 g or 20 g or 30 g of Sodium chloride in 100 g of water at 25°C forms an unsaturated solution.

(iii) **Super saturated solution:** Supersaturated solution is one that contains more solute than the saturated solution at a given temperature. e.g. 40 g of sodium chloride in 100 g of water at 25°C forms super saturated solution. This state can be achieved by altering any other conditions like temperature, pressure. Super saturated solutions are unstable, and the solute is reappearing as crystals when the solution is disturbed.



You are given two samples of solutions of NaCl. Can you identify which one is saturated? and How?

9.3.4 Concentrated and dilute solutions

It is another kind of classification of unsaturated solutions. It expresses the relative concentration of two solutions with respect to their solutes present in the given amount of the solvent. For example, you are given two cups of tea. When you taste them, you feel that one is sweeter than the other. What do you infer from it? The tea which sweet more contains higher amount of sugar than the other. How can you express your observation? You can say that the tea is stronger. But a chemist would say that it is 'concentrated'.

When we compare two having same solute and solvent in a solutions, the one which contains higher amount of solute per the given amount of solvent is said to be 'concentrated'

solution' and the another is said to be 'dilute solution'. They are schematically represented by Figure 9.5.

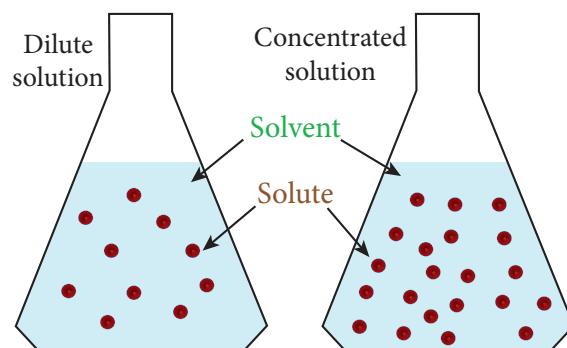


Figure 9.5 Dilute and Concentrated Solution

Differentiating solutions as dilute and concentrated is a qualitative representation. It does not imply the quantity of the solute. This difference is observed by means of some physical characteristics such as colour, density, etc.

Activity 1

Look at the following pictures. Label them as dilute and concentrated solution and justify your answer.



Tea



Copper sulphate

9.4 Solubility

Usually, there is a limit to the amount of solute that can be dissolved in a given amount of solvent at a given temperature. When this limit is reached, we have a saturated solution and any excess solute that is added, simply resides at the bottom of the solution. The extent of dissolution of a solute in a solvent can be better explained by its solubility. Solubility is measure of how much of a solute can be dissolved in a specified amount of a solvent.



Solubility is defined as the number of grams of a solute that can be dissolved in 100 g of a solvent to form its saturated solution at a given temperature and pressure. For example, 36 g of sodium chloride need to be dissolved in 100 g of water to form its saturated solution at 25°C. Thus the solubility of NaCl in water is 36 g at 25°C. The solubility is mathematically expressed as

$$\text{Solubility} = \frac{\text{Mass of the solute}}{\text{Mass of the solvent}} \times 100$$

Table 9.2 Solubility's of some common substances in water at 25°C

Name of the solute	Formula of the solute	Solubility g/100 g water
Calcium carbonate	CaCO ₃ (s)	0.0013
Sodium chloride	NaCl (s)	36
Ammonia	NH ₃ (g)	48
Sodium hydroxide	NaOH(s)	80
Glucose	C ₆ H ₁₂ O ₆ (s)	91
Sodium bromide	NaBr(s)	95
Sodium iodide	NaI(s)	184

9.4.1 Factors affecting solubility

There are three main factors which govern the solubility of a solute. They are:

- (i) Nature of the solute and solvent
- (ii) Temperature
- (iii) Pressure



(i) Nature of the solute and solvent

The nature of the solute and solvent plays an important role in solubility. Although water dissolves an enormous variety of substances, both ionic and covalent, it does not dissolve everything. The phrase that scientists often use when predicting solubility is “like dissolves

like.” This expression means that dissolving occurs when similarities exist between the solvent and the solute. For example: Common salt is a polar compound and dissolves readily in polar solvent like water.

Non-polar compounds are soluble in non-polar solvents. For example, Fat dissolved in ether. But non-polar compounds, do not dissolve in polar solvents; polar compounds do not dissolve in non-polar solvents.

(ii) Effect of Temperature

Solubility of Solids in Liquid:

Generally, solubility of a solid solute in a liquid solvent increases with increase in temperature. For example, a greater amount of sugar will dissolve in warm water than in cold water.

In endothermic process, solubility increases with increase in temperature.

In exothermic process, solubility decreases with increase in temperature.

Solubility of Gases in liquid

Do you know why is it bubbling when water is boiled? Solubility of gases in liquid decrease with increase in temperature. Generally, water contains dissolved oxygen. When water is boiled, the solubility of oxygen in water decreases, so oxygen escapes in the form of bubbles.

Aquatic animals live more in cold regions because, more amount of dissolved oxygen is present in the water of cold regions. This shows that the solubility of oxygen in water is more at low temperatures.

(iii) Effect of Pressure

Effect of pressure is observed only in the case of solubility of a gas in a liquid. When the pressure is increased, the solubility of a gas in liquid increases.

The common examples for solubility of gases in liquids are carbonated beverages, i.e. soft drinks, household cleaners containing



aqueous solution of ammonia, formalin-aqueous solution of formaldehyde, etc.

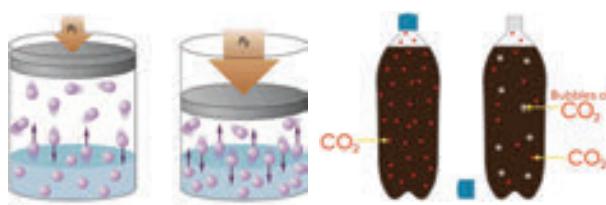


Figure 9.6 Effect of pressure on solubility

More to know

The effect of pressure on the solubility of a gas in liquid is given by **Henry's law**. It states that, the solubility of a gas in a liquid is directly proportional to the pressure of the gas over the solution at a definite temperature.

9.5 Concentration of a Solution

So far, we discussed what is a solution? what does it consist of and its types. Most of the chemical reactions take place in solutions form. So it is essential to quantify the solute in solvent to study the reactions. To quantify the solute in a solution, we can use the term “concentration”.

Concentration of a solution may be defined as the amount of solute present in a given amount of solution or solvent.

Quantitatively, concentration of a solution may be expressed in different methods. But here, we shall discuss percentage by mass (% mass) and percentage by volume (% volume).

9.5.1 Mass percentage

Mass percentage of a solution is defined as the percentage by mass of the solute present in the solution. It is mostly used when solute is solid and solvent is liquid.

$$\text{Mass Percentage} = \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100$$

$$\text{Mass Percentage} = \frac{\text{Mass of the solute}}{\text{Mass of the solute} + \text{Mass of the solvent}} \times 100$$

For example: 5% sugar solution (by mass) means 5 g of sugar in 95 g of water. Hence it is made 100g of solution.

Usually, mass percentage is expressed as w/w (weight / weight); mass percentage is independent of temperature.

9.5.2 Volume percentage

Volume percentage is defined as the percentage by volume of solute (in ml) present in the given volume of the solution.

$$\text{Volume Percentage} = \frac{\text{Volume of the solute}}{\text{Volume of the solution}} \times 100$$

$$\text{Volume Percentage} = \frac{\text{Volume of the solute}}{\text{Volume of the solute} + \text{volume of the solvent}} \times 100$$

For example, 10% by volume of the solution of ethanol in water, means 10 ml of ethanol in 100 ml of solution (or 90 ml of water)

Usually volume percentage is expressed as v/v (volume / volume). It is used when both the solute and solvent are liquids. Volume percentage decreases with increases in temperature, because of expansion of liquid.

You can notice that in the commercial products that we come across in our daily life such as a solution of syrups, mouth wash, antiseptic solution, household disinfectants etc., the concentration of the ingredients is expressed as v/v. Similarly, in ointments, antacid, soaps, etc., the concentration of solutions are expressed as w/w.

Ointment

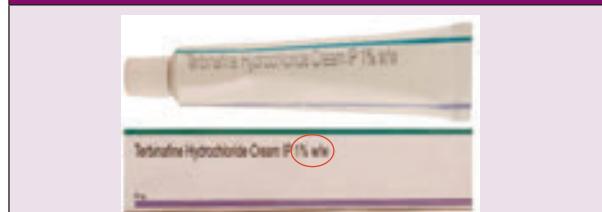


Figure 9.7 Ointment (w/w percent)



9.6 Hydrated salts and Water of Crystallization

When ionic substances are dissolved in water to make their saturated aqueous solution, their ions attract water molecules which then attach chemically in certain ratio. This process is called hydration. These ionic substances crystallize out from their saturated aqueous solution with a definite number of molecules of water. The number of water molecules found in the crystalline substance is called **water of crystallization**. Such salts are called hydrated salts.

On heating these hydrated crystalline salts, they lose their water of crystallization and become amorphous or lose their colour (if they are coloured). Table 9.3 shows some common hydrated salts:

Table 9.3 Hydrated salts

Common Name	IUPAC Name	Molecular Formula
Blue Vitriol	Copper (II) sulphate pentahydrate	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
Epsom Salt	Magnesium sulphate heptahydrate	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
Gypsum	Calcium sulphate dihydrate	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
Green Vitriol	Iron (II) sulphate heptahydrate	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
White Vitriol	Zinc sulphate heptahydrate	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$

9.6.1 Copper sulphate pentahydrate $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (Blue vitriol)

The number of water molecules in blue vitriol is five. So its water of crystallization is 5. When blue coloured copper sulphate crystals are gently heated, it loses its five water

molecules and becomes colourless anhydrous copper sulphate.

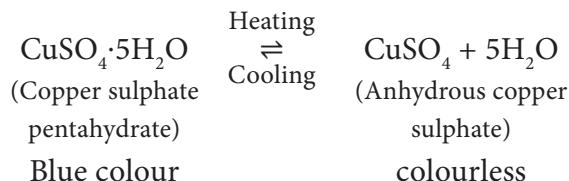


Figure 9.8 Copper sulphate heating before and after

If you add few drops of water or allow it to cool, the colourless anhydrous salt again turns back into blue coloured hydrated salt.



Figure 9.9 Hydrated copper sulphate and anhydrous copper sulphate

9.6.2 Magnesium sulphate heptahydrate $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (Epsom salt)

Its water of crystallization is 7. When magnesium sulphate heptahydrate crystals are gently heated, it loses seven water molecules, and becomes anhydrous magnesium sulphate.

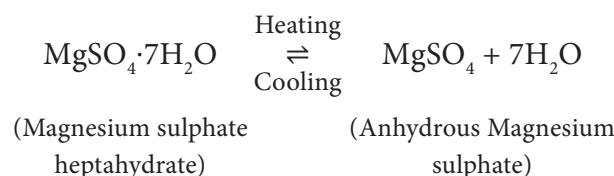




Figure 9.10 Crystalline hydrated salt,
Amorphous anhydrous salt

If you add few drops of water or allow it to cool, the colourless anhydrous salt again turns back into hydrated salt.

9.7 Hygroscopy

Certain substances, when exposed to the atmospheric air at ordinary temperature, absorb moisture without changing their physical state. Such substances are called **hygroscopic substances** and this property is called hygroscopy.

Hygroscopic substances are used as drying agents.

- Example:**
1. Conc. Sulphuric acid (H_2SO_4).
 2. Phosphorus Pentoxide (P_2O_5).
 3. Quick lime (CaO).
 4. Silica gel (SiO_2).
 5. Anhydrous calcium chloride (CaCl_2).

9.8 Deliquescence

Certain substances which are so hygroscopic, when exposed to the atmospheric

air at ordinary temperatures, absorb enough water and get completely dissolved. Such substances are called **deliquescent substances** and this property is called **deliquescence**.

Deliquescent substances lose their crystalline shape and ultimately dissolve in the absorbed water forming a saturated solution.

Deliquescence is maximum when:

- 1) The temperature is low
- 2) The atmosphere is humid

Examples: Calcium chloride (CaCl_2), Caustic soda (NaOH), Caustic potash (KOH) and Ferric chloride (FeCl_3).

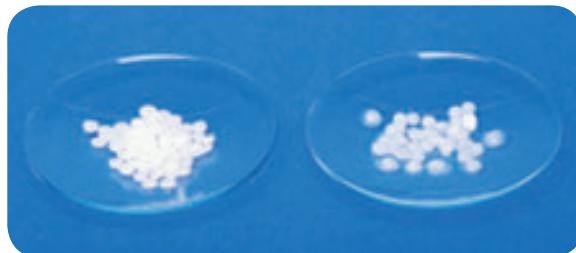


Figure 9.7 Deliquescence in Sodium hydroxide

9.9 Problems Based on Solubility and Percentage by Mass and Volume

I. Problems based on solubility

- 1) 1.5 g of solute is dissolved in 15 g of water to form a saturated solution at 298K. Find out the solubility of the solute at the temperature.

Table 9.3 Difference between hygroscopic substances and deliquescence.

Hygroscopic substances	Deliquescent substances
When exposed to the atmosphere at ordinary temperature, they absorb moisture and do not dissolve.	When exposed to the atmospheric air at ordinary temperature, they absorb moisture and dissolve.
Hygroscopic substances do not change its physical state on exposure to air.	Deliquescent substances change its physical state on exposure to air.
Hygroscopic substances may be amorphous solids or liquids.	Deliquescent substances are crystalline solids.



Mass of the solute = 1.5 g

Mass of the solvent = 15 g

$$\text{Solubility of the solute} = \frac{\text{Mass of the solute}}{\text{Mass of the solvent}} \times 100$$

$$\begin{aligned}\text{Solubility of the solute} &= \frac{1.5}{15} \times 100 \\ &= 10 \text{ g}\end{aligned}$$

- 2) Find the mass of potassium chloride would be needed to form a saturated solution in 60 g of water at 303 K? Given that solubility of the KCl is 37/100 g at this temperature.

Mass of potassium chloride in 100 g of water in saturated solution = 37 g

$$\begin{aligned}\text{Mass of potassium chloride in } 60 \text{ g of water in saturated solution} &= \frac{37}{100} \times 60 \\ &= 22.2 \text{ g}\end{aligned}$$

- 3) What is the mass of sodium chloride that would be needed to form a saturated solution in 50 g of water at 30°C. Solubility of sodium chloride is 36 g at 30°C?

At 30°C, 36 g of sodium chloride is dissolved in 100 g of water.

∴ Mass of sodium chloride that would be needed for 100 g of water = 36 g

$$\begin{aligned}\therefore \text{Mass of sodium chloride dissolved in } 50 \text{ g of water} &= \frac{36 \times 50}{100} \\ &= 18 \text{ g}\end{aligned}$$

- 4) The solubility of sodium nitrate at 50°C and 30°C is 114 g and 96 g respectively. Find the amount of salt that will be thrown out when a saturated solution of sodium nitrate containing 50 g of water is cooled from 50°C to 30°C?

Amount of sodium nitrate dissolved in 100 g of water at 50°C is 114 g

$$\begin{aligned}\therefore \text{Amount of sodium nitrate dissolving in } 50 \text{ g of water at } 50^\circ\text{C} &= \frac{114 \times 50}{100} \\ &= 57 \text{ g}\end{aligned}$$

Similarly amount of sodium nitrate $= \frac{96 \times 50}{100}$
dissolving in 50g of water at 30°C is
 $= 48 \text{ g}$

Amount of sodium nitrate thrown when 50g of water is cooled from 50°C to 30°C is

$$57 - 48 = 9 \text{ g}$$

II. Problem based on mass percentage

- 1) A solution was prepared by dissolving 25 g of sugar in 100 g of water. Calculate the mass percentage of solute.

Mass of the solute = 25 g

Mass of the solvent = 100 g

$$\text{Mass Percentage} = \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100$$

$$\begin{aligned}\text{Mass Percentage} &= \frac{\text{Mass of the solute}}{\text{Mass of the solute} + \text{Mass of the solvent}} \times 100 \\ &= \frac{25}{25+100} \times 100\end{aligned}$$

$$\begin{aligned}&= \frac{25}{125} \times 100 \\ &= 20\%\end{aligned}$$

- 2) 16 grams of NaOH is dissolved in 100 grams of water at 25°C to form a saturated solution. Find the mass percentage of solute and solvent.

Mass of the solute (NaOH) = 16 g

Mass of the solvent H₂O = 100 g

(i) Mass percentage of the solute

$$\text{Mass percentage} = \frac{\text{Mass of the solute}}{\text{Mass of the solute} + \text{Mass of the solvent}} \times 100$$

$$\begin{aligned}&= \frac{16 \times 100}{16 + 100} \\ &= \frac{1600}{116}\end{aligned}$$



Mass percentage of the solute = 13.79 %

$$\begin{aligned}\text{(ii) Mass percentage of solvent} &= 100 \\ &\quad - (\text{Mass percentage of the solute}) \\ &= 100 - 13.79 \\ &= 86.21\%\end{aligned}$$

- 3) Find the amount of urea which is to be dissolved in water to get 500 g of 10% w/w aqueous solution?

$$\text{Mass percentage (w/w)} = \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100$$

$$10 = \frac{\text{Mass of the urea}}{500} \times 100$$

$$\text{Mass of urea} = 50\text{g}$$

(iii) **Problem based on Volume – volume percentage.**

- 1) A solution is made from 35 ml of Methanol and 65 ml of water. Calculate the volume percentage.

$$\text{Volume of the ethanol} = 35 \text{ ml}$$

$$\text{Volume of the water} = 65 \text{ ml}$$

$$\text{Volume percentage} = \frac{\text{Volume of the solute}}{\text{Volume of the solution}} \times 100$$

$$\text{Volume percentage} = \frac{\text{Volume of the solute}}{\text{Volume of the solute} + \text{Volume of the solvent}} \times 100$$

$$\text{Volume percentage} = \frac{35}{35+65} \times 100$$

$$\begin{aligned}\text{Volume percentage} &= \frac{35}{100} \times 100 \\ &= 35\%\end{aligned}$$

- 2) Calculate the volume of ethanol in 200 ml solution of 20% v/v aqueous solution of ethanol.

Volume of aqueous solution = 200 ml

Volume percentage = 20%

$$\text{Volume percentage} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

$$20 = \frac{\text{Volume of ethanol}}{200} \times 100$$

$$\text{Volume of ethanol} = \frac{20 \times 200}{100} = 40 \text{ ml}$$

Points to Remember

- ❖ A solution is a homogeneous mixture of two or more substances.
- ❖ An aqueous solution is a solution in which the solvent is water.
- ❖ A non-aqueous solution is a solution in which the solvent is a liquid, other than water
- ❖ A solution in which no more solute can be dissolved in a definite amount of the solvent at a given temperature is called saturated solution.
- ❖ An unsaturated solution is one that contains less solute than the saturated solution at a given temperature.
- ❖ A supersaturated solution is one that contains more solute than the saturated solution at a given temperature.
- ❖ Polar compounds are soluble in polar solvents.
- ❖ Non-polar compounds are soluble in non-polar solvents.
- ❖ In endothermic process, solubility of solid solute increases with increase in temperature.
- ❖ In exothermic process, solubility of solid solute decreases with increase in temperature.



TEXTBOOK EVALUATION



I. Choose the correct answer.

1. A solution is a _____ mixture.
 - a. homogeneous
 - b. heterogeneous
 - c. homogeneous and heterogeneous
 - d. non homogeneous
2. The number of components in a binary solution is _____.
 - a. 2
 - b. 3
 - c. 4
 - d. 5
3. Which of the following is the universal solvent?
 - a. Acetone
 - b. Benzene
 - c. Water
 - d. Alcohol
4. A solution in which no more solute can be dissolved in a definite amount of solvent at a given temperature is called _____.
 - a. Saturated solution
 - b. Un saturated solution
 - c. Super saturated solution
 - d. Dilute solution
5. Identify the non aqueous solution.
 - a. sodium chloride in water
 - b. glucose in water
 - c. copper sulphate in water
 - d. sulphur in carbon-di-sulphide
6. When pressure is increased at constant temperature the solubility of gases in liquid _____.
 - a. No change
 - b. increases
 - c. decreases
 - d. no reaction
7. Solubility of NaCl in 100 ml water is 36 g. If 25 g of salt is dissolved in 100 ml of water how much more salt is required for saturation _____.
 - a. 12g
 - b. 11g
 - c. 16g
 - d. 20g

8. A 25% alcohol solution means
 - a. 25 ml alcohol in 100 ml of water
 - b. 25 ml alcohol in 25 ml of water
 - c. 25 ml alcohol in 75 ml of water
 - d. 75 ml alcohol in 25 ml of water
9. Deliquescence is due to _____.
 - a. Strong affinity to water
 - b. Less affinity to water
 - c. Strong hatred to water
 - d. Inertness to water
10. Which of the following is hygroscopic in nature?
 - a. ferric chloride
 - b. copper sulphate penta hydrate
 - c. silica gel
 - d. none of the above

II. Fill in the blanks

1. The component present in lesser amount, in a solution is called _____.
2. Example for liquid in solid type solution is _____.
3. Solubility is the amount of solute dissolved in _____ g of solvent.
4. Polar compounds are soluble in _____ solvents.
5. Volume percentage decreases with increases in temperature because _____.

III. Match the following

- | | |
|------------------|---|
| 1. Blue vitriol | - $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ |
| 2. Gypsum | - CaO |
| 3. Deliquescence | - $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ |
| 4. Hygroscopic | - NaOH |



IV. True or False: (If false give the correct statement)

1. Solutions which contain three components are called binary solution.
2. In a solution the component which is present in lesser amount is called solvent.
3. Sodium chloride dissolved in water forms a non-aqueous solution.
4. The molecular formula of green vitriol is $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
5. When Silica gel is kept open, it absorbs moisture from the air, because it is hygroscopic in nature

V. Short answer

1. Define the term: Solution
2. What is mean by binary solution
3. Give an example each i) gas in liquid ii) solid in liquid iii) solid in solid iv) gas in gas
4. What is aqueous and non-aqueous solution? Give an example.
5. Define Volume percentage
6. The aquatic animals live more in cold region Why?
7. Define Hydrated salt.
8. A hot saturated solution of copper sulphate forms crystals as it cools. Why?
9. Classify the following substances into deliquescent, hygroscopic.
Conc. Sulphuric acid, Copper sulphate penta hydrate, Silica gel, Calcium chloride, and Gypsum salt.

VI. Long answer:

1. Write notes on i) saturated solution
ii) unsaturated solution
2. Write notes on various factors affecting solubility.

3. a) What happens when $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ is heated? Write the appropriate equation
- b) Define solubility
4. In what way hygroscopic substances differ from deliquescent substances.
5. A solution is prepared by dissolving 45 g of sugar in 180 g of water. Calculate the mass percentage of solute.
6. 3.5 litres of ethanol is present in 15 litres of aqueous solution of ethanol. Calculate volume percent of ethanol solution.

VII. HOT

1. Vinu dissolves 50 g of sugar in 250 ml of hot water, Sarath dissolves 50 g of same sugar in 250 ml of cold water. Who will get faster dissolution of sugar? and Why?
2. 'A' is a blue coloured crystalline salt. On heating it loses blue colour and to give 'B'. When water is added, 'B' gives back to 'A'. Identify A and B, write the equation.
3. Will the cool drinks give more fizz at top of the hills or at the foot? Explain



REFERENCE BOOKS

1. Properties Liquids Solutions John Murrell 2nd Edition.
2. Fundamental Interrelationships Between Certain Soluble Salts and Soil Colloids (Classic Reprint) Hardcover, by Leslie Theodore Sharp

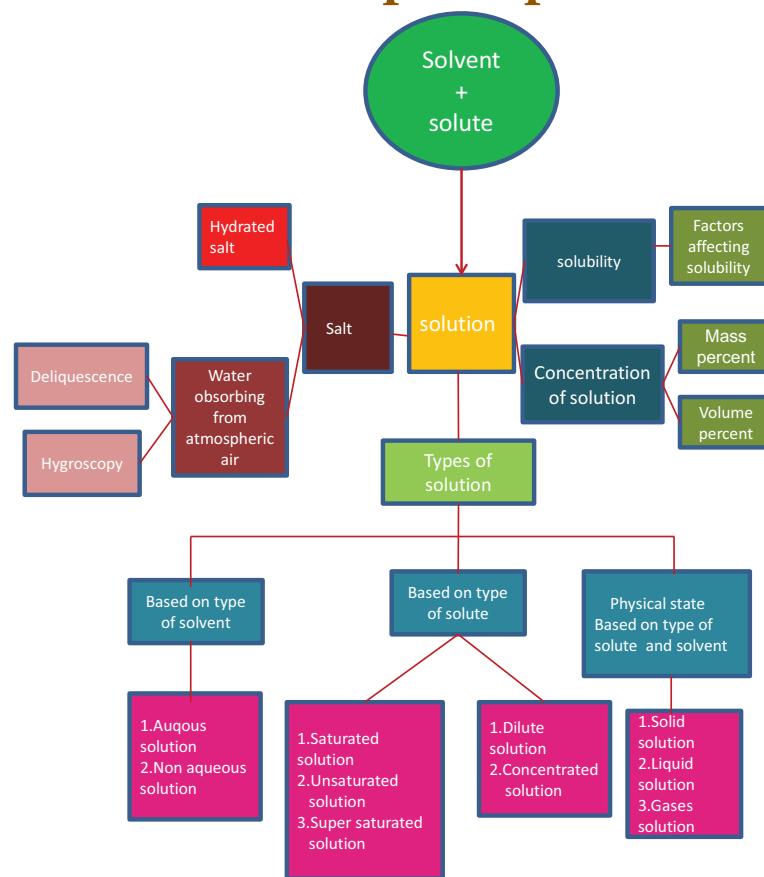


INTERNET RESOURCES

1. <https://www.cwcboe.org/cms/lib/NJ01001185/Centricity/Domain/203/Solutions%20Suspensions%20and%20Colloids.pdf>



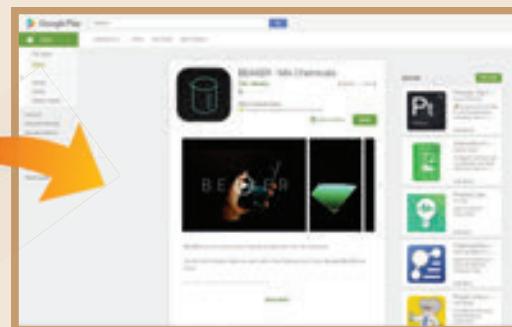
Concept Map



ICT CORNER

Solutions

BEAKER application enable the students to use their mobile as virtual chemistry laboratory and also to do various experiments on their own.



Steps

- Access the application “BEAKER – Mix Chemicals” with help of the URL or QR code, Install it in the mobile. You can see that the screen will act like a beaker after opening the application.
- If you click the round button, you can see many elements and compounds.
- If you click any elements and compounds, it will be added to the beaker in the home screen.
- By clicking Menu at the left side, You can see lid, match stick, burner and chemist. Use those whenever necessary.

URL: <https://play.google.com/store/apps/details?id=air.thix.sciencesense.beaker>
or Scan the QR Code.



UNIT 10

TYPES OF CHEMICAL REACTIONS



GKWN5A



Learning Objectives

After completing this lesson learners will be able to

- ◆ infer different types of chemical reaction.
- ◆ acquire knowledge about combination reaction and skill to perform a combination reaction using quick lime and water.
- ◆ identify and differentiate between reversible and irreversible reactions.
- ◆ explain the reversible reaction occurring at the equilibrium state.
- ◆ list and explain characteristics of equilibrium state.
- ◆ define rate of reaction.
- ◆ discuss the dependence of rate of reactions on concentration, temperature and catalyst.
- ◆ define pH.
- ◆ correlate the concentration of hydrogen ions and pH with neutral, acidic and basic nature of aqueous solutions.
- ◆ recognize the importance of pH in everyday life.
- ◆ explain the term ionic product of water.

INTRODUCTION

As you know from your earlier studies, a chemical reaction involves breaking of old chemical bonds and formation of new chemical bonds. This change may happen spontaneously or it may be facilitated by external forces or energy. Chemistry is all about chemical reactions. In your day to day life, you could observe many chemical reactions. A clear understanding of these reactions is essential in order to manipulate them for the sake of human life and environment. So, chemistry mainly focuses on chemical reactions. Let us try to find the answer for the following questions:

- ◆ You need energy to play, walk, run or to perform various physical activities. Where do you get the energy from?

- ◆ How do plants grow and get their food?
- ◆ How does a car move using fuel?
- ◆ Why does iron rust on its exposure to water or air?

You get energy from the digestion of the food you eat. Plants grow by absorbing nutrients from the Earth and get their food by photosynthesis. The combustion of a fuel makes the car to move. Oxidation of iron causes rusting. So, all these processes are chemical changes i.e. the materials, which undergo changes are converted into some other new materials. For example, by burning petrol, the hydrocarbons present in it are converted into carbon dioxide and water. In this chapter, let us discuss the nature and types of chemical reactions.



What happens during a chemical reaction?

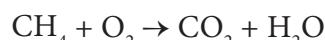
- ◆ In a chemical reaction, the atoms of the reacting molecules or elements are rearranged to form new molecules.
- ◆ Old chemical bonds between atoms are broken and new chemical bonds are formed.
- ◆ Bond breaking absorbs energy whereas bond formation releases energy

How are chemical reactions represented?

When methane reacts with oxygen, it forms carbon dioxide and water. How can you represent this reaction? It can be written as a word equation as shown below:

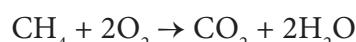


But, this equation does not give the chemical composition of the reactants and products. So, to learn the characteristics of a chemical reaction, it is represented by a chemical equation. In the chemical equation, the chemicals of the reaction are represented by their chemical formulas. The compounds or elements, which undergo reactions (reactants) are shown to the left of an arrow and the compounds formed (products) are shown to the right of the arrow. The arrow indicates the direction of the reaction. Thus, the aforesaid reaction can be written as follows:

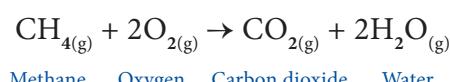


But, this is also an incomplete chemical equation. Because, the law of conservation of matter states that matter cannot be created or destroyed. You cannot create new atoms by a chemical reaction. In contrast, they are rearranged in different ways by a chemical reaction to form a new compound. So, in a chemical equation, the number of atoms of the reactants and that of the products must be equal. The number of hydrogen and oxygen atoms in the reactants and the products are not

equal in the given equation. On balancing the number of atoms, the following equation can be obtained:



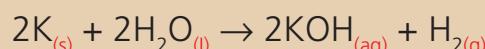
Further, the chemical equation provides information on the physical state of the substances and the conditions under which the reaction takes place.



A balanced chemical equation is the simplified representation of a chemical reaction which describes the chemical composition, physical state of the reactants and the products, and the reaction conditions.

MORE TO KNOW

The phases or the physical state of the substances in a chemical reaction are denoted in short form within a bracket, as the subscript of the formula, of the respective substances. For example, when solid potassium reacts with liquid water, it produces hydrogen gas and potassium hydroxide solution. All these information of the reaction is given in the chemical equation as shown below:



Symbol	Phase or physical state
s	Solid
l	Liquid
g	Gas
aq	Aqueous Solution



10.1 TYPES OF CHEMICAL REACTIONS

Classification based on the nature of rearrangements of atoms

So far you studied about a chemical reaction and how it can be described as a chemical equation. A large number of chemical reactions are taking place around us every day. Are they taking place in a similar way? No. Each reaction involves different kinds of atoms and hence the way they react also differs. Thus, based on the manner by which the atoms of the reactants are rearranged, chemical reactions are classified as follows.

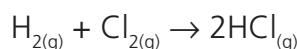


(a) Combination reactions

A combination reaction is a reaction in which two or more reactants combine to form a compound. It is otherwise called 'synthesis reaction' or 'composition reaction'. When a reactant 'A' combines with 'B', it forms the product 'AB'. The generalised scheme of a combination reaction is given below:



Example: Hydrogen gas combines with chlorine gas to form hydrogen chloride gas.

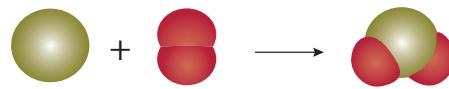


Depending on the chemical nature of the reactants, there are **three classes** of combination reactions:

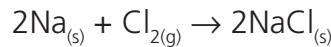
❖ Element + Element \rightarrow Compound

In this type of combination reaction, two elements react with one other to form a compound. The reaction may take place between a metal and a non-metal or two non-metals.

Example 1: When solid sulphur reacts with oxygen, it produces sulphur dioxide. Here both the reactants are non-metals.



Example 2: Sodium, a silvery-white metal, combines with chlorine, a pale yellow green gas, to form sodium chloride, an edible compound. Here one of the reactants is a metal (sodium) and the other (chlorine) is a non-metal.



Test Yourself:

Identify the possible combination reactions between the metals and non-metals given in the following table and write their balanced chemical equations:

Metals	Non-metals
Na, K, Cs, Ca, Mg	F, Cl, Br, I

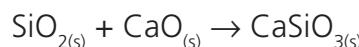
❖ Compound + Element \rightarrow Compound

In this case, a compound reacts with an element to form a new compound. For instance, phosphorous trichloride reacts with chlorine gas and forms phosphorous pentachloride.



❖ Compound + Compound \rightarrow Compound

It is a reaction between two compounds to form a new compound. In the following reaction, silicon dioxide reacts with calcium oxide to form calcium silicate.



Most of the combination reactions are exothermic in nature. Because, they involve the formation of new bonds, which releases a huge amount of energy in the form of heat.



(b) Decomposition reactions

In a decomposition reaction, a single compound splits into two or more simpler substances under suitable conditions. It is the opposite of the combination reaction. The **generalised scheme** of a decomposition reaction is given below:



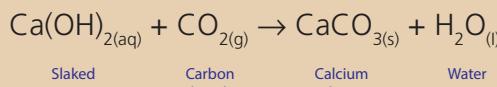
Breaking of bonds is the major phenomenon in a decomposition reaction and hence it requires energy to break the bonds, depending on the nature of the energy used in the decomposition reaction.

There are three main classes of decomposition reactions. They are

- Thermal Decomposition Reactions
- Electrolytic Decomposition Reactions
- Photo Decomposition Reactions



A solution of slaked lime is used for white washing walls. Calcium hydroxide reacts slowly with the carbon dioxide in air to form a thin layer of calcium carbonate on the walls. Calcium carbonate is formed after two to three days of white washing and gives a shiny finish to the walls. It is interesting to note that the **chemical formula for marble is also** CaCO_3 .



Slaked Lime

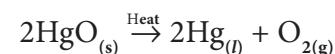
Carbon dioxide

Calcium Carbonate

Water

(i) Thermal Decomposition Reactions

In this type of reaction, the reactant is decomposed by applying heat. For example, on heating mercury (II) oxide is decomposed into mercury metal and oxygen gas. As the molecule is dissociated by the absorption of heat, it is otherwise called '**Thermolysis**'. It is a class of compound to element/element decomposition. i.e. a compound (HgO) is decomposed into two elements (Hg and Oxygen).



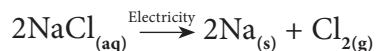
Similarly, when calcium carbonate is heated, it breaks down into calcium oxide and carbon dioxide. It is a type of compound to compound/compound decomposition.



In thermal decomposition reaction, heat is supplied to break the bonds. Such reactions, in which heat is absorbed, are called '**Endothermic reactions**'.

(ii) Electrolytic Decomposition Reactions

In some of the decomposition reactions, electrical energy is used to bring about the reaction. For example, decomposition of sodium chloride occurs on passing electric current through its aqueous solution. Sodium chloride decomposes into metallic sodium and chlorine gas. This process is termed as '**Electrolysis**'.



Here, a compound (NaCl) is converted into elements (Na and chlorine). So it is a type of compound to element/element decomposition.

(iii) Photo Decomposition Reactions

Light is another form of energy, which facilitates some of the decomposition reactions. For example, when silver bromide is exposed to light, it breaks down into silver metal and bromine gas. As the decomposition is caused by light, this kind of reaction is also called '**Photolysis**'.

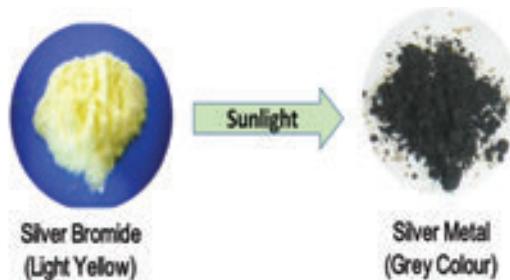
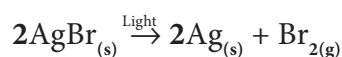


Figure 10.1 Photo decomposition of silver bromide



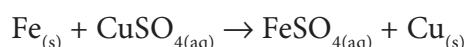
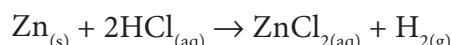
The yellow coloured silver bromide turns into grey coloured silver metal. It is also a compound to element;element decomposition.

(c) Single Displacement Reactions

It is a reaction between an element and a compound. When they react, one of the elements of the compound-reactant is replaced by the element-reactant to form a new compound and an element. The general schematic representation of a single displacement reaction is given as:



'A' displaces element 'B' from the compound 'BC' and hence a single displacement reaction occurs. If zinc metal is placed in hydrochloric acid, hydrogen gas is evolved. Here, hydrogen is displaced by zinc metal and zinc chloride is formed.



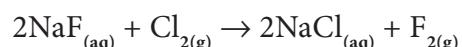
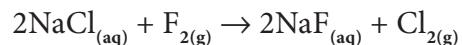
If an iron nail is placed in an aqueous solution of copper (II) sulphate as shown in Fig. 10.2, the iron displaces copper from its aqueous solution and the so formed copper deposits over the iron nail.



Figure 10.2 Displacement of copper

It is easy to propose so many reactions of this kind with different combinations of

reactants. Will they all occur in practice? No. This is most easily demonstrated with halogens. Let us consider the following two reactions:



The first reaction involves the displacement of chlorine from NaCl, by fluorine. In the second reaction, chlorine displaces fluorine from NaF. Out of these two, the second reaction will not occur. Because, fluorine is more active than chlorine and occupies the upper position in the periodic table. So, in displacement reactions, the activity of the elements and their relative position in the periodic table are the key factors to determine the feasibility of the reactions. More active elements readily displace less active elements from their aqueous solution.

The activity series of some elements is given below:

To remember	Activity Series
• Please	Potassium (K)
• Send	Sodium (Na)
• Lions	Lithium (Li)
• Cats	Calcium (Ca)
• Monkeys	Magnesium (Mg)
• And	Aluminium (Al)
• Zebras	Zinc (Zn)
• Into	Iron (Fe)
• Lovely	Lead (Pb)
• Hot	Hydrogen (H) non-metal
• Countries	Copper (Cu)
• Signed	Silver (Ag)
• General	Gold (Au)
• Penguin	Platinum (Pt)

By referring the activity series, try to answer the following questions:

Which of the metals displaces hydrogen gas from hydrochloric acid? Silver or Zinc. Give the chemical equation of the reaction and Justify your answer.

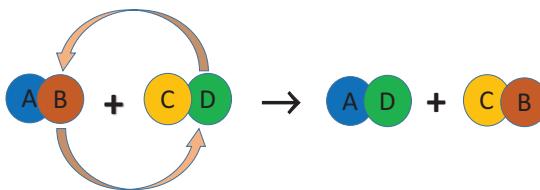


Activity 10.1

- ❖ Take about 50 ml of toilet cleaning acid in a beaker
- ❖ Place a small iron nail in it
- ❖ Wait for about 10 minutes
- ❖ Observe what happen in the beaker
- ❖ Do you recognize any change?
- ❖ Report your observations with the chemical equation.

(d) Double Displacement Reactions

When two compounds react, if their ions are interchanged, then the reaction is called double displacement reaction. The ion of one compound is replaced by the ion of the another compound. Ions of identical charges are only interchanged, i.e., a cation can be replaced by other cations. This reaction is also called '**Metathesis Reaction**'. The schematic representation of a double displacement reaction is given below:



For a double displacement reaction to take place, one of the products must be a precipitate or water. By this way, there are major classes of double displacement reactions. They are:

- Precipitation Reactions
- Neutralization Reactions

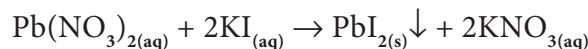
(i) Precipitation Reactions

When aqueous solutions of two compounds are mixed, if they react to form an insoluble compound and a soluble compound, then it is called precipitation reaction. Because the insoluble compound, formed as one of the products, is a precipitate and hence the reaction is so called.

Table 10.1 Differences between combination and decomposition reactions

COMBINATION REACTIONS	DECOMPOSITION REACTIONS
One or more reactants combine to form a single product	A single reactant is decomposed to form one or more products
Energy is released	Energy is absorbed
Elements or compounds may be the reactants	Single compound is the reactant

When the clear aqueous solutions of potassium iodide and lead (II) nitrate are mixed, a double displacement reaction takes place between them.



Potassium and lead displace or replace one other and form a yellow precipitate of lead (II) iodide as shown in Fig. 10.3.



Figure 10.3 Precipitation of PbI_2

Activity 10.2

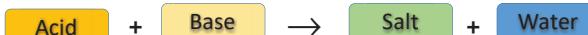
- ❖ Take a pinch of silver nitrate crystals.
- ❖ Collect about 5 ml of tap water in a test tube.
- ❖ Add the silver nitrate crystals to water and shake well.
- ❖ Observe what happen in the test tube.
- ❖ Report your observations and what you infer from that?

(ii) Neutralization Reactions

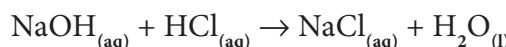
In your lower classes, you have learned the reaction between an acid and a base. It is



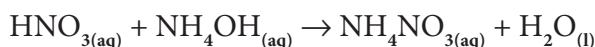
another type of displacement reaction in which the acid reacts with the base to form a salt and water. It is called 'neutralization reaction' as both acid and base neutralize each other.



Reaction of sodium hydroxide with hydrochloric acid is a typical neutralization reaction. Here, sodium replaces hydrogen from hydrochloric acid forming sodium chloride, a neutral soluble salt.

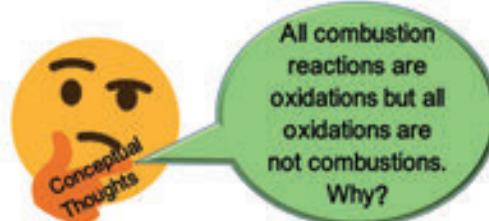


Similarly, when ammonium hydroxide reacts with nitric acid, it forms ammonium nitrate and water.



(e) Combustion Reactions

A combustion reaction is one in which the reactant rapidly combines with oxygen to form one or more oxides and energy (heat). So in combustion reactions, one of the reactants must be oxygen. Combustion reactions are majorly used as heat energy sources in many of our day to day activities. For instance, we use LPG gas for domestic cooking purposes. We get heat and flame from LPG gas by its combustion reaction of its constituent gases. LPG is a mixture of hydrocarbon gases like propane, butane, propylene, etc. All these hydrocarbons burn with oxygen to form carbon dioxide and water.



Since heat is evolved, it is an exothermic reaction. As oxygen is added, it is also an oxidation. So, combustion may be called as an

exothermic oxidation. If a flame is formed (as shown in Fig. 10.4), then it is called **burning**.



Figure 10.4 Combustion of LPG gas

Which of the following is a combustion?

- (i) Digestion of Food
- (ii) Rusting of iron

Many thousands of reactions fall under these five categories and further you will learn in detail about these reactions in your higher classes.

10.1.2 Classification based on the direction of the reaction

You know that innumerable changes occur every day around us. Are all they permanent? For example, liquid water freezes into ice, but then ice melts into liquid water. In other words, freezing is reversed. So, it is not a permanent change. Moreover, it is a physical change. Physical changes can be reversed easily. Can chemical changes be reversed? Can the products be converted into reactants? Let us consider the burning of a wood. The carbon compounds present in the wood are burnt into carbon dioxide gas and water. Can we get back the wood immediately from carbon dioxide and water? We cannot. So, it is a permanent change. In most of the cases, we cannot. But, some chemical reactions can be reversed. Our mobile phone gets energy from its lithium ion battery by chemical reactions. It is called discharging. On recharging the mobile, these chemical reactions are reversed. Thus, chemical reactions may be reversed under suitable conditions. Hence, they are



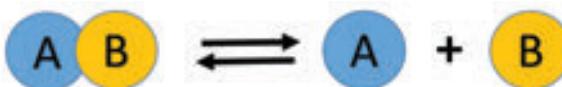
grouped into two categories such as reversible and irreversible reactions.



Figure 10.5 Burning of wood and recharging of mobile battery

Reversible Reactions

A reversible reaction is a reaction that can be reversed, i.e., the products can be converted back to the reactants. A reversible reaction is represented by a double arrow with their heads in the direction opposite to each other. Thus, a reversible reaction can be represented by the following equation:



Explanation: Here, the compound 'AB' undergoes decomposition to form the products 'A' and 'B'. It is the **forward reaction**. As soon as the products are formed, they combine together to form 'AB'. It is the **backward reaction**. So, the reaction takes place in both the directions. Do you think then that no products are formed in the aforesaid reaction? If you think so, you are wrong. Because, even though the reaction takes place in both the directions, at the initial stage the rates (speed) of these reactions are not equal. Consider the following decomposition reaction of phosphorous pentachloride into phosphorous trichloride and chlorine.



The forward reaction is the decomposition of PCl_5 and the backward reaction is the combination of PCl_3 and Cl_2 . Initially, the forward reaction proceeds faster than the

backward reaction. After sometimes, the speed of both the reactions become equal. So, PCl_5 cannot be completely converted into the products as the reaction is reversed. It is a reversible reaction. The actual measurements of the given reaction show that the reaction is at equilibrium, but the amount of PCl_5 is more than that of PCl_3 and Cl_2 .

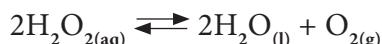
MORE TO KNOW

If hydrogen peroxide is poured on a wound, it decomposes into water and oxygen. The gaseous oxygen bubbles away as it is formed and thus prevent the formation of H_2O_2 .



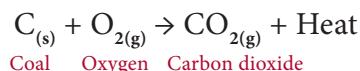
Hydrogen peroxide on a wound

Thus, more amount of products can be obtained in a reversible reaction by the periodical removal of one of the products or the periodical addition of the reactants.



Irreversible Reactions

The reaction that cannot be reversed is called **irreversible reaction**. The irreversible reactions are unidirectional, i.e., they take place only in the forward direction. Consider the combustion of coal into carbon dioxide and water.



In this reaction, solid coal burns with oxygen and gets converted into carbon dioxide gas and water. As the product is a gas, as soon as it is formed it escapes out of the reaction container. It is extremely hard to decompose a gas into a solid. Thus, the backward reaction is not possible in this case. So, it is an irreversible reaction. Table 10.2 provides the



main differences between a reversible and an irreversible reaction:

Table 10.2 Differences between reversible and irreversible reactions

REVERSIBLE REACTION	IRREVERSIBLE REACTION
It can be reversed under suitable conditions.	It cannot be reversed.
Both forward and backward reactions take place simultaneously.	It is unidirectional. It proceeds only in forward direction.
It attains equilibrium.	Equilibrium is not attained.
The reactants cannot be converted completely into products.	The reactants can be completely converted into products.
It is relatively slow.	It is fast.

You will learn more about these reactions in your higher classes.

10.2 RATE OF A CHEMICAL REACTION

So far we discussed various types of chemical reactions and the nature of the reactants and products. Let us consider the following reactions:

- ◆ Rusting of iron
- ◆ Digestion of food
- ◆ Burning of petrol
- ◆ Weathering of rock

How fast is each reaction? Rank them from the slowest to fastest. How will you determine, which is the fastest and which is the slowest? One of the ways to find out how fast a reaction is as follows: Measure the amount of reactants or products before and after a specific period of time. For example, let us assume that 100 g

of a substance 'A' undergoes a reaction and after an hour 50 g of 'A' is left.



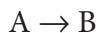
In another instance, 100 g of substance 'C' undergoes a reaction and after an hour, 20 g of 'C' is left.



Can you say which is the faster reaction? In the first reaction, 50 g of the reactant (A) is converted into products whereas in the second reaction 80 g of the reactant is converted into products in one hour. So, the second reaction is faster. This measurement is called 'the reaction rate'.

"Rate of a reaction is the change in the amount or concentration of any one of the reactants or products per unit time".

Consider the following reaction



The rate of this reaction is given by

$$\text{Rate} = -\frac{d[A]}{dt} = +\frac{d[B]}{dt}$$

Where,

[A] – Concentration of A

[B] – Concentration of B

The negative sign indicates the decrease in the concentration of A with time.

The positive sign indicates the increase in the concentration of B with time.

Note: '[]' represents the concentration, 'd' represents the infinitesimal change in the concentration.

Why is reaction rate important?

Faster the reaction, more will be the amount of the product in a specified time. So, the rate of a reaction is important for a chemist for designing a process to get a good yield of a product. Rate of reaction is also important for a food processor who hopes to slow down the reactions that cause food to spoil.

10.2.1 Factors influencing the rate of a reaction

Can the rate of a reaction be changed? The rate of a reaction can be changed. For

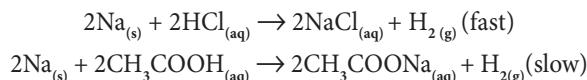


example, iron gets rusted faster in an acid than in water. Important factors that affect rate of a reaction are

- (i) Nature of the reactants
- (ii) Concentration of the reactants
- (iii) Temperature
- (iv) Catalyst
- (v) Pressure
- (vi) Surface area of the reactants

(i) Nature of the reactants

The reaction of sodium with hydrochloric acid is faster than that with acetic acid. Do you know why? Hydrochloric acid is a stronger acid than acetic acid and thus more reactive. So, the nature of the reactants influence the reaction rate.



(ii) Concentration of the reactants

Changing the amount of the reactants also increases the reaction rate. The amount of the substance present in a certain volume of the solution is called '**concentration**'. More the concentration, more particles per volume exist in it and hence faster the reaction. Granulated zinc reacts faster with 2M hydrochloric acid than 1M hydrochloric acid.

(iii) Temperature

Most of the reactions go faster at higher temperature. Because adding heat to the reactants provides energy to break more bonds and thus speed up the reaction. Calcium carbonate reacts slowly with hydrochloric acid at room temperature. When the reaction mixture is heated the reaction rate increases.



Food kept at room temperature spoils faster than that kept in the refrigerator. In the refrigerator, the temperature is lower than the room temperature and hence the reaction rate is less.

(iv) Pressure

If the reactants are gases, increasing their pressure increases the reaction rate. This is because, on increasing the pressure the reacting particles come closer and collide frequently.

(v) Catalyst

A catalyst is a substance which increases the reaction rate without being consumed in the reaction. In certain reactions, adding a substance as catalyst speeds up the reaction. For example, on heating potassium chlorate, it decomposes into potassium chloride and oxygen gas, but at a slower rate. If manganese dioxide is added, it increases the reaction rate.

(vi) Surface area of the reactants

When solid reactants are involve in a reaction, their powdered form reacts more readily. For example, powdered calcium carbonate reacts more readily with hydrochloric acid than marble chips. Because, powdering of the reactants increases the surface area and more energy is available on collision of the reactant particles. Thus, the reaction rate is increased.

You will study more about reaction rate in you higher classes.

10.3 STATE OF EQUILIBRIUM

In a reversible reaction, both forward and backward reactions take place simultaneously. When the rate of the forward reaction becomes equal to the rate of backward reaction, then no more product is formed. This stage of the reaction is called '**equilibrium state**'. After this stage, no net change in the reaction can occur and hence in the amount of the reactants and products. Since this equilibrium is attained in a chemical reaction, it is called '**Chemical Equilibrium**'. **Chemical Equilibrium:** It is state of a reversible chemical reaction in which no change in the amount of the reactants and products takes place. At equilibrium,

Rate of forward reaction = Rate of backward reaction



Explanation: Initially the rate of the forward reaction is greater than the rate of the backward reaction. However, during the course of reaction, the concentration of the reactants decreases and the concentration of the products increases. Since the rate of a reaction is directly proportional to the concentration, the rate of the forward reaction decreases with time, whereas the rate of the backward reaction increases.

At a certain stage, both the rates become equal. From this point onwards, there will be no change in the concentrations of both the reactants and the products with time. This state is called as equilibrium state.

Let us consider the decomposition of calcium carbonate into lime and carbon dioxide. It is a reversible reaction. The speed of each reaction can be determined by how quickly the reactant disappears. If the reaction is carried out in a closed vessel, it reaches a chemical equilibrium. At this stage,



The rate of decomposition of CaCO_3 = The rate of combination of CaO and CO_2

Not only chemical changes, physical changes also may attain equilibrium. When water kept in a closed vessel evaporates, it forms water vapour. No water vapour escapes out of the container as the process takes place in a closed vessel. So, it builds up the vapour pressure in the container. At one time, the water vapour condenses back into liquid water and when the rate of this condensation becomes equal to that of vapourisation, the process attains equilibrium.

At this stage, the volume of the liquid and gaseous phases remain constant. Since it is a physical change, the equilibrium attained is called '**Physical Equilibrium**'. Physical equilibrium is a state of a physical change at which the volume of all the phases remain unchanged.

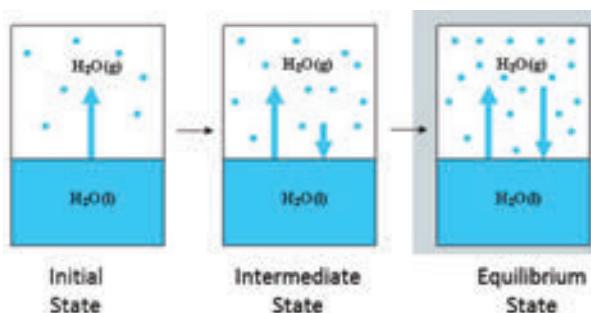
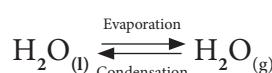


Figure 10.6 State of physical equilibrium

Characteristics of equilibrium

- ◆ In a chemical equilibrium, the rates of the forward and backward reactions are equal.
- ◆ The observable properties such as pressure, concentration, colour, density, viscosity etc., of the system remain unchanged with time.
- ◆ The chemical equilibrium is a dynamic equilibrium, because both the forward and backward reactions continue to occur even though it appears static externally.
- ◆ In physical equilibrium, the volume of all the phases remain constant.

Aerated soft drinks contain dissolved carbon dioxide in a pop bottle (Soda).

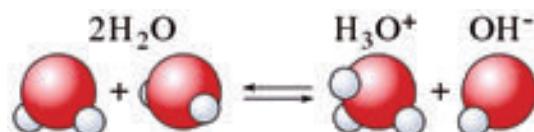
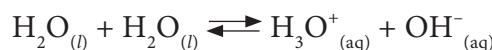


When the bottle is sealed, the dissolved carbon dioxide (in the form of carbonic acid) and gaseous CO_2 are in equilibrium with each other. When you open the bottle, the gaseous CO_2 can escape. So, the dissolved CO_2 begins to undissolve back to the gas phase trying to replace the gas that was lost, when you opened the bottle. That's why if you leave it open long enough, it will go flat. All the CO_2 will be gone, blown away in the air.



10.4 IONIC PRODUCT OF WATER

Although pure water is often considered as a non-conductor of electricity, precise measurements show that it conducts electricity to a little extent. This conductivity of water has resulted from the self-ionisation of water. Self-ionisation or auto ionisation is a reaction in which two like molecules react to give ions. In the process of ionisation of water, a proton from one water molecule is transferred to another water molecule leaving behind an OH^- ion. The proton gets dissolved in water forming the hydronium ion as shown in the following equation:



The hydronium ion formed is a strong acid and the hydroxyl ion is a strong base. So as fast as they are formed, they react again to produce water. Thus, it is a reversible reaction and attains equilibrium very quickly. So, the extent of ionisation is very little and the concentration of the ions produced is also very less. The product of the concentration of the hydronium ion and the hydroxyl ion is called '**ionic product of water**'. It is denoted as ' K_w '. It is mathematically expressed as follows:

$$K_w = [\text{H}_3\text{O}^+] [\text{OH}^-]$$

$[\text{H}_3\text{O}^+]$ may be simply written as $[\text{H}^+]$. Thus the ionic product of water may also be expressed as

$$K_w = [\text{H}^+] [\text{OH}^-]$$

Its unit is $\text{mol}^2 \text{dm}^{-6}$. At 25°C , its value is 1.00×10^{-14} .

10.5 pH SCALE

All the aqueous solutions may contain hydrogen and hydroxyl ions due to self-ionisation of water. In addition to this ionisation, substances dissolved in water also may produce hydrogen ions or hydroxyl ions. The concentration of these ions decides whether the solution is acidic or basic. pH scale is a scale for measuring the hydrogen ion concentration in a solution. The 'p' in pH stands for 'Potenz' in German meaning 'power'. pH notation was devised by the Danish biochemist Sorenson in 1909. 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

The pH is the negative logarithm of the hydrogen ion concentration

$$\text{i.e } \text{pH} = -\log_{10}[\text{H}^+]$$

COMMON ACIDS	pH	COMMON BASES	pH
HCl (4%)	0	Blood plasma	7.4
Stomach acid	1	Egg white	8
Lemon juice	2	Sea water	8
Vinegar	3	Baking soda	9
Oranges	3.5	Antacids	10
Soda, grapes	4	Ammonia water	11
Sour milk	4.5	Lime water	12
Fresh milk	5	Drain cleaner	13
Human saliva	6-8	Caustic soda 4% (NaOH)	14
Pure water	7	Milk of magnesia	10
Tomato juice	4.2	Coffee	5.6

How can we measure the pH of a given solution using pH Paper



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 a pH paper.

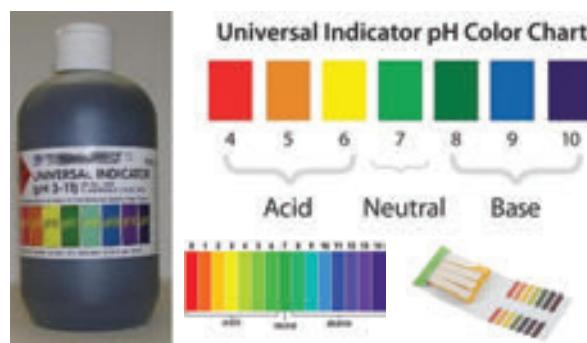


Figure 10.7 pH Indicator

A more common method of measuring pH in a school laboratory is by using the pH paper. A pH paper contains a mixture of indicators. It shows a specific colour at a given pH. A colour guide is provided with the bottle of the indicator or the strips of paper impregnated with it, which are called pH paper strips. The test solution is tested with a drop of the universal indicator, or a drop of the test solution is put on the pH paper. The colour of the solution on the pH paper is compared with the colour chart and the pH value is read from it. The pH values thus obtained are only approximate values.

10.6 ROLE 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 a narrow range of pH change. Different body fluids have different pH values. For example, pH of blood is ranging from 7.35 to 7.45. Any increase or decrease in this value leads to diseases. The ideal pH for blood is 7.4.

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 the stomach fluid is approximately 2.0.

pH changes as the cause of tooth decay

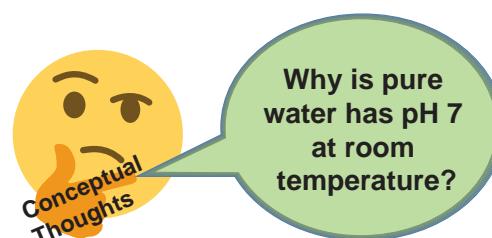
pH of the saliva normally ranges between 6.5 to 7.5. White enamel coating of our teeth is calcium phosphate, the hardest substance in our body. When the pH of the mouth saliva falls below 5.5, the enamel gets weathered. Toothpastes, which are generally basic are used for cleaning the teeth that can neutralise the excess acid and prevent tooth decay.

pH of soil

In agriculture, the pH of the 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 the rain water 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 also.



The survival of aquatic life in such rivers becomes difficult.



10.7 pH CALCULATION

The pH is the negative logarithm of the hydrogen ion concentration

$$\text{pH} = -\log_{10} [\text{H}^+]$$

Example: Calculate the pH of 0.01 M HNO₃?

Solution:

$$[\text{H}^+] = 0.01$$

$$\text{pH} = -\log_{10} [\text{H}^+]$$

$$\text{pH} = -\log_{10} [0.01]$$

$$\text{pH} = -\log_{10} [1 \times 10^{-2}]$$

$$\text{pH} = -(1 - 2 \log_{10} 10)$$

$$\text{pH} = 0 + 2 \times \log_{10} 10$$

$$\text{pH} = 0 + 2 \times 1 = 2$$

$$\text{pH} = 2$$

pOH: The pOH of an aqueous solution is related to the pH.

The pOH is the negative logarithm of the hydroxyl ion concentration

$$\text{pOH} = -\log_{10} [\text{OH}^-]$$

Example: The hydroxyl ion concentration of a solution is 1×10^{-9} M. What is the pOH of the solution?

Solution

$$\text{pOH} = -\log_{10} [\text{OH}^-]$$

$$\text{pOH} = -\log_{10} [1 \times 10^{-9}]$$

$$\text{pOH} = -(1.0 + \log_{10} 10^{-9})$$

$$\text{pOH} = -(0 - 9 \log_{10} 10)$$

$$\text{pOH} = -(0 - 9)$$

$$\text{pOH} = 9$$

Relationship between pH and pOH

The pH and pOH of a water solution at 25°C are related by the following equation.

$$\text{pH} + \text{pOH} = 14$$

If either the pH or the pOH of a solution is known, the other value can be calculated.

Example: A solution has a pOH of 11.76. What is the pH of this solution?

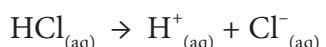
$$\text{pH} = 14 - \text{pOH}$$

$$\text{pH} = 14 - 11.76 = 2.24$$

10.8 PROBLEMS

Example 1: Calculate the pH of 0.001 molar solution of HCl.

Solution: HCl is a strong acid and is completely dissociated in its solutions according to the process:



From this process it is clear that one mole of HCl would give one mole of H⁺ ions. Therefore, the concentration of H⁺ ions would be equal to that of HCl, i.e., 0.001 molar or 1.0×10^{-3} mol litre⁻¹.

$$\text{Thus, } [\text{H}^+] = 1 \times 10^{-3} \text{ mol litre}^{-1}$$

$$\begin{aligned}\text{pH} &= -\log_{10} [\text{H}^+] = -\log_{10} 10^{-3} \\ &= -(3 \times \log_{10} 1) = -(3 \times 1) = 3\end{aligned}$$

$$\text{Thus, pH} = 3$$

Example 2: What would be the pH of an aqueous solution of sulphuric acid which is 5×10^{-5} mol litre⁻¹ in concentration.

Solution: Sulphuric acid dissociates in water as:



Each mole of sulphuric acid gives two mole of H⁺ ions in the solution. One litre of H₂SO₄ solution contains 5×10^{-5} moles of H₂SO₄ which would give $2 \times 5 \times 10^{-5} = 10 \times 10^{-5}$ or 1.0×10^{-4} moles of H⁺ ion in one litre of the solution.

Therefore,

$$[\text{H}^+] = 1.0 \times 10^{-4} \text{ mol litre}^{-1}$$

$$\begin{aligned}\text{pH} &= -\log_{10} [\text{H}^+] = -\log_{10} 10^{-4} = -(4 \times \log_{10} 10) \\ &= -(4 \times 1) = 4\end{aligned}$$

Example 3: Calculate the pH of 1×10^{-4} molar solution of NaOH.

Solution: NaOH is a strong base and dissociates in its solution as:



One mole of NaOH would give one mole of OH⁻ ions. Therefore,

$$[\text{OH}^-] = 1 \times 10^{-4} \text{ mol litre}^{-1}$$



$$\begin{aligned}\text{pOH} &= -\log_{10}[\text{OH}^-] = -\log_{10} \times [10^{-4}] \\ &= -(-4 \times \log_{10} 10) = -(-4) = 4\end{aligned}$$

Since, $\text{pH} + \text{pOH} = 14$

$$\begin{aligned}\text{pH} &= 14 - \text{pOH} = 14 - 4 \\ &= 10\end{aligned}$$

Example 4: Calculate the pH of a solution in which the concentration of the hydrogen ions is $1.0 \times 10^{-8} \text{ mol litre}^{-1}$.

Solution: Here, although the solution is extremely dilute, the concentration given is not of an acid or a base but that of H^+ ions. Hence, the pH can be calculated from the relation:

$$\begin{aligned}\text{pH} &= -\log_{10}[\text{H}^+] \\ \text{given } [\text{H}^+] &= 1.0 \times 10^{-8} \text{ mol litre}^{-1} \\ \text{pH} &= -\log_{10} 10^{-8} = -(-8 \times \log_{10} 10) \\ &= -(-8 \times 1) = 8\end{aligned}$$

Example 5: If the pH of a solution is 4.5, what is its pOH?

Solution:

$$\begin{aligned}\text{pH} + \text{pOH} &= 14 \\ \text{pOH} &= 14 - 4.5 = 9.5 \\ \text{pOH} &= 9.5\end{aligned}$$

Points to Remember

- ❖ A chemical change is a change in which one or more new substances are formed.
- ❖ Aerobic: Presence of oxygen.
- ❖ Anaerobic: Absence of oxygen
- ❖ Most combination reactions are exothermic
- ❖ Electrolytic decomposition reaction may occur in the presence of heat or light.
- ❖ All photo decomposition reaction are endothermic reactions.
- ❖ Double displacement reaction or metathesis may occur by the mutual exchange of ions.
- ❖ Precipitation reaction gives an insoluble salt as the product.
- ❖ Neutralisation reactions are reactions between an acid and a base that forms salt and water.
- ❖ Plants can not grow in an acidic soil.
- ❖ Neutralisation prevents tooth decay.
- ❖ Most reactions in chemistry are irreversible reactions.
- ❖ Chemical equilibrium—the rate of the forward reaction is equal to rate of the backward reactions.
- ❖ Equilibrium is possible in a closed system.
- ❖ Temperature increases the reaction rate.
- ❖ Pressure increases the reaction rate.
- ❖ The term pH means power of hydrogen.
- ❖ pH plays a vital role in everyday life.
- ❖ In humans all bio chemical reactions take place between the pH value of 7.0 to 7.8.
- ❖ If pH of rain water is below 5.6 it's called acid rain.
- ❖ Pure water is a weak electrolyte.



TEXTBOOK EVALUATION



I. Choose the correct answer.

1. $\text{H}_{2(g)} + \text{Cl}_{2(g)} \rightarrow 2\text{HCl}_{(g)}$ is a
 - a. Decomposition Reaction
 - b. Combination Reaction
 - c. Single Displacement Reaction
 - d. Double Displacement Reaction
2. Photolysis is a decomposition reaction caused by _____
 - a. heat
 - b. electricity
 - c. light
 - d. mechanical energy
3. A reaction between carbon and oxygen is represented by $\text{C}_{(s)} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} + \text{Heat}$. In which of the type(s), the above reaction can be classified?
 - (i) Combination Reaction
 - (ii) Combustion Reaction
 - (iii) Decomposition Reaction
 - (iv) Irreversible Reaction
 - a. i and ii
 - b. i and iv
 - c. i, ii and iii
 - d. i, ii and iv
4. The chemical equation
$$\text{Na}_2\text{SO}_{4(aq)} + \text{BaCl}_{2(aq)} \rightarrow \text{BaSO}_{4(s)} \downarrow + 2\text{NaCl}_{(aq)}$$
represents which of the following types of reaction?
 - a. Neutralisation
 - b. Combustion
 - c. Precipitation
 - d. Single displacement
5. Which of the following statements are correct about a chemical equilibrium?
 - (i) It is dynamic in nature
 - (ii) The rate of the forward and backward reactions are equal at equilibrium
 - (iii) Irreversible reactions do not attain chemical equilibrium
 - (iv) The concentration of reactants and products may be different

- a. i, ii and iii
- b. i, ii and iv
- c. ii, iii and iv
- d. i, iii and iv

6. A single displacement reaction is represented by $\text{X}_{(s)} + 2\text{HCl}_{(aq)} \rightarrow \text{XCl}_{2(aq)} + \text{H}_{2(g)}$. Which of the following(s) could be X.

(i) Zn (ii) Ag (iii) Cu (iv) Mg.

Choose the best pair.

- a. i and ii
- b. ii and iii
- c. iii and iv
- d. i and iv

7. Which of the following is not an “element + element \rightarrow compound” type reaction?

- a. $\text{C}_{(s)} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)}$
- b. $2\text{K}_{(s)} + \text{Br}_{2(l)} \rightarrow 2\text{KBr}_{(s)}$
- c. $2\text{CO}_{(g)} + \text{O}_{2(g)} \rightarrow 2\text{CO}_{2(g)}$
- d. $4\text{Fe}_{(s)} + 3\text{O}_{2(g)} \rightarrow 2\text{Fe}_2\text{O}_{3(s)}$

8. Which of the following represents a precipitation reaction?

- a. $\text{A}_{(s)} + \text{B}_{(s)} \rightarrow \text{C}_{(s)} + \text{D}_{(s)}$
- b. $\text{A}_{(s)} + \text{B}_{(aq)} \rightarrow \text{C}_{(aq)} + \text{D}_{(l)}$
- c. $\text{A}_{(aq)} + \text{B}_{(aq)} \rightarrow \text{C}_{(s)} + \text{D}_{(aq)}$
- d. $\text{A}_{(aq)} + \text{B}_{(s)} \rightarrow \text{C}_{(aq)} + \text{D}_{(l)}$

9. The pH of a solution is 3. Its $[\text{OH}^-]$ concentration is

- a. $1 \times 10^{-3} \text{ M}$
- b. 3 M
- c. $1 \times 10^{-11} \text{ M}$
- d. 11 M

10. Powdered CaCO_3 reacts more rapidly than flaky CaCO_3 because of _____.

- a. large surface area
- b. high pressure
- c. high concentration
- d. high temperature

II. Fill in the blanks

1. A reaction between an acid and a base is called _____.
2. When lithium metal is placed in hydrochloric acid, _____ gas is evolved.



3. The equilibrium attained during the melting of ice is known as _____.
4. The pH of a fruit juice is 5.6. If you add slaked lime to this juice, its pH _____ (increase/decrease)
5. The value of ionic product of water at 25°C is _____.
6. The normal pH of human blood is _____.
7. Electrolysis is type of _____ reaction
8. The number of products formed in a synthesis reaction is _____
9. Chemical volcano is an example for _____ type of reaction
10. The ion formed by dissolution of H⁺ in water is called _____

III. Match the following

1. Identify the types of reaction

REACTION	TYPE
$\text{NH}_4\text{OH}_{(\text{aq})} + \text{CH}_3\text{COOH}_{(\text{aq})} \rightarrow \text{CH}_3\text{COONH}_{4(\text{aq})} + \text{H}_2\text{O}_{(\text{l})}$	Single Displacement
$\text{Zn}_{(\text{s})} + \text{CuSO}_{4(\text{aq})} \rightarrow \text{ZnSO}_{4(\text{aq})} + \text{Cu}_{(\text{s})}$	Combustion
$\text{ZnCO}_{3(\text{s})} \xrightarrow{\text{Heat}} \text{ZnO}_{(\text{s})} + \text{CO}_{2(\text{g})}$	Neutralisation
$\text{C}_2\text{H}_{4(\text{g})} + 4\text{O}_{2(\text{g})} \rightarrow 2\text{CO}_{2(\text{g})} + 2\text{H}_2\text{O}_{(\text{g})} + \text{Heat}$	Thermal decomposition

IV. True or False: (If false give the correct statement)

1. Silver metal can displace hydrogen gas from nitric acid.
2. The pH of rain water containing dissolved gases like SO₃, CO₂, NO₂ will be less than 7.
3. At the equilibrium of a reversible reaction, the concentration of the reactants and the products will be equal.
4. Periodical removal of one of the products of a reversible reaction increases the yield.
5. On dipping a pH paper in a solution, it turns into yellow. Then the solution is basic.

V. Short answer questions:

1. When an aqueous solution of potassium chloride is added to an aqueous solution of silver nitrate, a white precipitate is formed. Give the chemical equation of this reaction.
2. Why does the reaction rate of a reaction increase on raising the temperature?

3. Define combination reaction. Give one example for an exothermic combination reaction.
4. Differentiate reversible and irreversible reactions

VI. Answer in detail

1. What are called thermolysis reactions?
2. Explain the types of double displacement reactions with examples.
3. Explain the factors influencing the rate of a reaction
4. How does pH play an important role in everyday life?
5. What is a chemical equilibrium? What are its characteristics?

VII. HOT questions

1. A solid compound 'A' decomposes on heating into 'B' and a gas 'C'. On passing the gas 'C' through water, it becomes acidic. Identify A, B and C.



2. Can a nickel spatula be used to stir copper sulphate solution? Justify your answer.

VIII. Solve the following problems

- Lemon juice has a pH 2, what is the concentration of H^+ ions?
- Calculate the pH of 1.0×10^{-4} molar solution of HNO_3 .
- What is the pH of 1.0×10^{-5} molar solution of KOH?
- The hydroxide ion concentration of a solution is $1 \times 10^{-11} M$. What is the pH of the solution?



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- Text book of inorganic chemistry-P.L.Soni-S.Chand & sons publishers, New Delhi.
- Principles of Physical Chemistry- B.R.Ruri, L.R. Sharma, Vishal publishing Co Punjab.

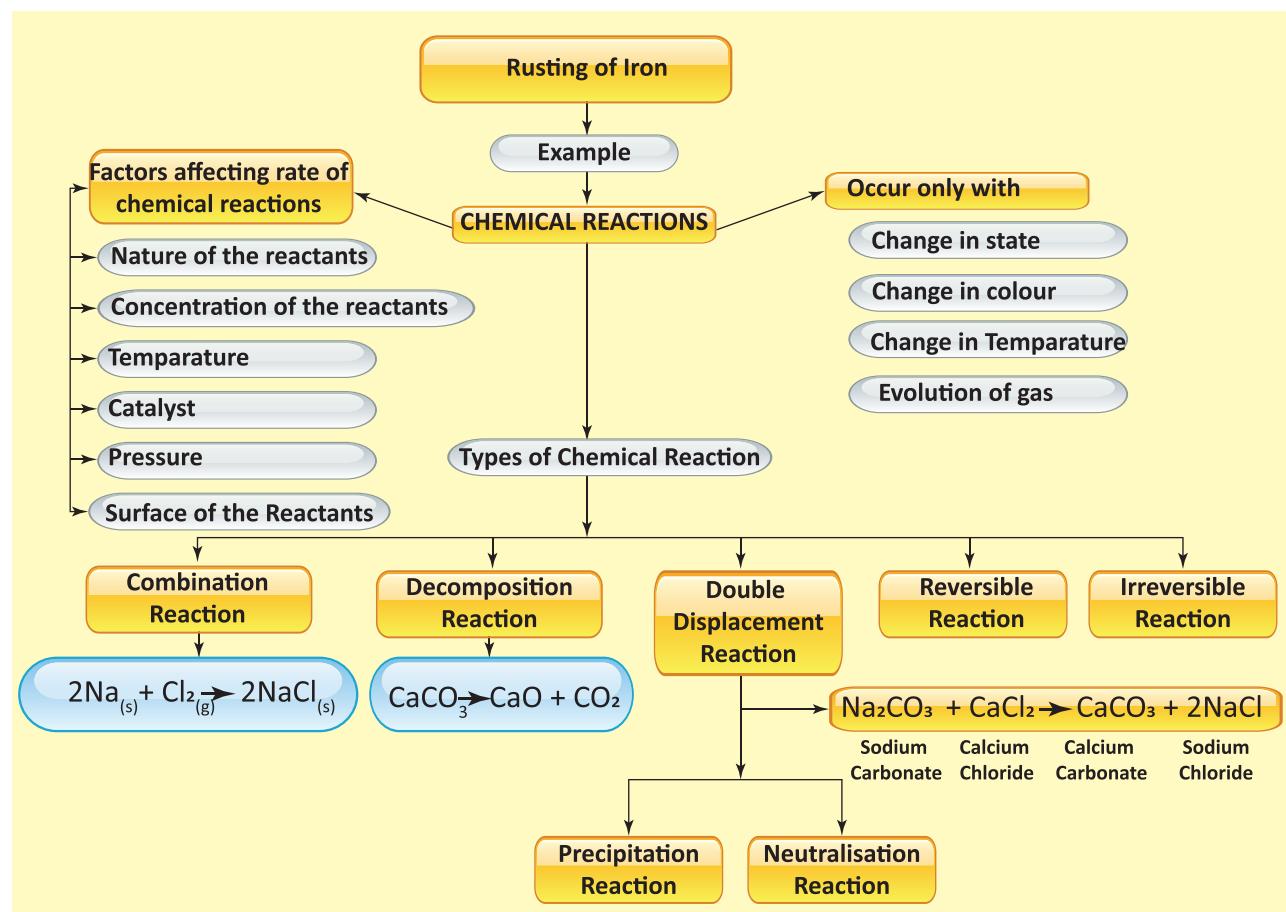


INTERNET RESOURCES

Webliography:www.chem4kids.com

<http://aravindguptatoys.com/filims.html>

Concept Map





UNIT 11

CARBON AND ITS COMPOUNDS



Learning Objectives



After studying this lesson, the student will be able to:

- ◆ know the importance of organic compounds.
- ◆ classify the organic compounds and name them based on IUPAC rules.
- ◆ identify the functional groups of organic compounds.
- ◆ explain the preparation, properties and uses of ethanol and ethanoic acids.
- ◆ know the composition and preparation of soap and detergent.
- ◆ understand the cleansing action of soap and detergents.
- ◆ differentiate soap and detergents.

INTRODUCTION

You have studied, in your lower classes, that carbon is an inseparable element in human life as we use innumerable number of carbon compounds in our day to day life. Because, the food we eat, medicines we take when ill, clothes we wear; domestic and automobile fuels, paint, cosmetics, automobile parts, etc., that we use contain carbon compounds. The number of carbon compounds found in nature and man-made, is much higher than that of any other element in the periodic table. Infact there are more than 5 million compounds of carbon. The unique nature of carbon, such as catenation, tetravalency and multiple bonding, enables it to combine with itself or other elements like hydrogen, oxygen, nitrogen, sulphur etc., and hence form large number of compounds. All these compounds are made of covalent bonds. These compounds

are called **organic compounds**. In this lesson, you will learn about carbon compounds.

11.1 GENERAL CHARACTERISTICS OF ORGANIC COMPOUNDS

Everything in this world has unique character, similarly organic compounds are unique in their characteristics. Some of them are given below:

- ◆ Organic compounds have a high molecular weight and a complex structure.
- ◆ They are mostly insoluble in water, but soluble in organic solvents such as ether, carbon tetrachloride, toluene, etc.
- ◆ They are highly inflammable in nature
- ◆ Organic compounds are less reactive compared to inorganic compounds. Hence, the reactions involving organic compounds proceed at slower rates.



- ◆ Mostly organic compounds form covalent bonds in nature.
- ◆ They have lower melting point and boiling point when compared to inorganic compounds
- ◆ They exhibit the phenomenon of isomerism, in which a single molecular formula represents several organic compounds that differ in their physical and chemical properties
- ◆ They are volatile in nature.
- ◆ Organic compounds can be prepared in the laboratory

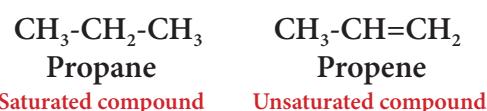
11.2 CLASSIFICATION OF ORGANIC COMPOUNDS BASED ON THE PATTERN OF CARBON CHAIN

What is the significance of classification? There are millions of organic compounds known and many new organic compounds are discovered every year in nature or synthesized in laboratory. This may mystify organic chemistry to a large extent. However, a unique molecular structure can be assigned to each compound and it can be listed by using systematic methods of classification and eventually named on the basis of its structural arrangements. In early days, chemists recognised that compounds having similar structural features have identical chemical properties. So they began to classify compounds based on the common structural arrangements found among them.

Organic chemistry is the chemistry of catenated carbon compounds. The carbon atoms present in organic compounds are linked with each other through covalent bonds and thus exist as chains. By this way, organic compounds are classified into two types as follows:

1. Acyclic or Open chain compounds: These are the compounds in which the carbon

atoms are linked in a linear pattern to form the chain. If all the carbon atoms in the chain are connected by single bonds, the compound is called as **saturated**. If one or more double bonds or triple bonds exist between the carbon atoms, then the compound is said to **unsaturated**.



2. Cyclic Compounds: Organic compounds in which the chain of carbon atoms is closed or cyclic are called **cyclic compounds**. If the chain contains only carbon atoms, such compounds are called **carbocyclic compounds**. If the chain contains carbon and other atoms like oxygen, nitrogen, sulphur, etc., these compounds are called **heterocyclic compounds**. Carbocyclic compounds are further subdivided into **alicyclic** and **aromatic compounds**. Aromatic compounds contain one or more carbocyclic rings which may be saturated or unsaturated whereas aromatic compounds contain one or more benzene rings (ring containing alternate double bonds between carbon atoms). E.g.

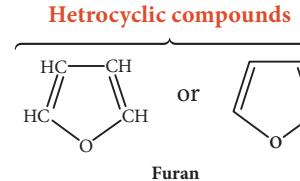
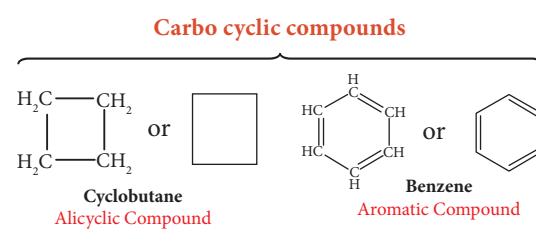


Figure 11.1 depicts the classification of organic compounds based on the pattern of carbon arrangements and their bonding in organic compounds:

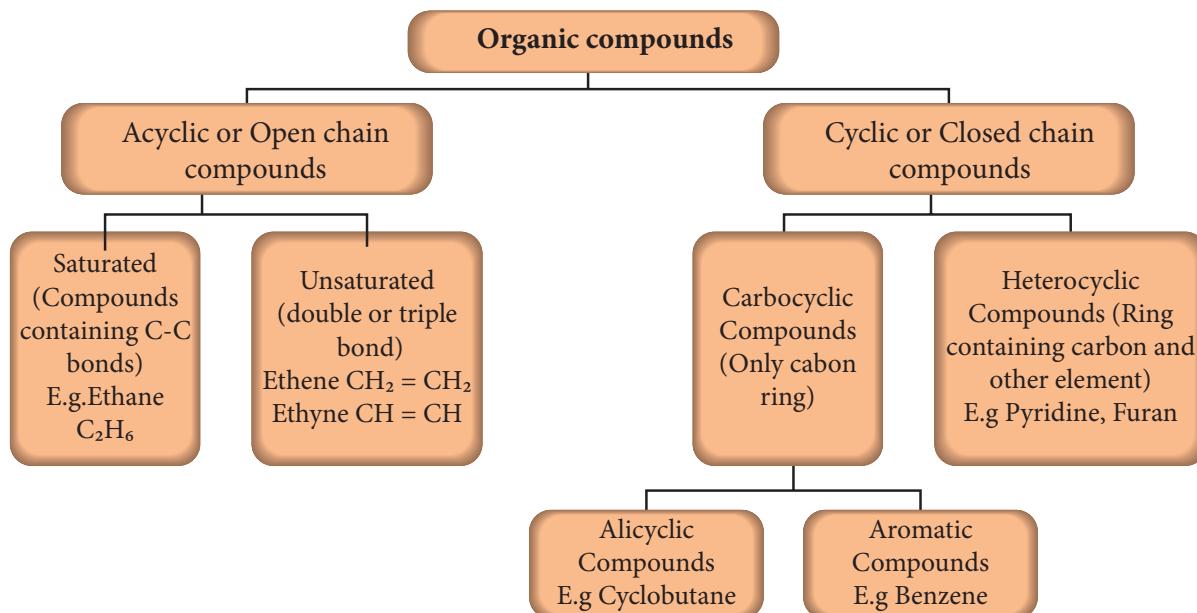


Figure 11.1 Classification of organic compounds

11.3 CLASSES OF ORGANIC COMPOUNDS (BASED ON THE KIND OF ATOMS)

Other than carbon, organic compounds contain atoms like hydrogen, oxygen, nitrogen, etc., bonded to the carbon. Combination of these kinds of atoms with carbon gives different classes of organic compounds. In the following section, let us discuss various classes of organic compounds.

11.3.1 Hydrocarbons

The organic compounds that are composed of only carbon and hydrogen atoms are called **hydrocarbons**. The carbon atoms join together to form the framework of the compounds. These are regarded as the parent organic compounds and all other compounds are considered to be derived from hydrocarbons by replacing one or more hydrogen atoms with other atoms or group of atoms. Hydrocarbons are, further, subdivided into three classes such as:

(a) **Alkanes:** These are hydrocarbons, which contain only single bonds. They are represented by the general formula C_nH_{2n+2} (where $n = 1, 2, 3, \dots$). The simplest alkane (for $n=1$) is methane (CH_4). Since, all are single bonds in alkanes, they are saturated compounds.

(b) **Alkenes:** The hydrocarbons, which contain one or more $C=C$ bonds are called alkenes. These are unsaturated compounds. They are represented by the general formula C_nH_{2n} . The simplest alkene contains two carbon atoms ($n=2$) and is called ethylene (C_2H_4).

(c) **Alkynes:** The hydrocarbons containing carbon to carbon triple bond are called **alkynes**. They are also unsaturated as they contain triple bond between carbon atoms. They have the general formula C_nH_{2n-2} . Acetylene (C_2H_2) is the simplest alkyne, which contains two carbon atoms. Table 11.1 lists the first five hydrocarbons of each class:

Table 11.1 Hydrocarbons containing 1 to 5 carbon atoms

No. of carbon atoms	Alkane (C_nH_{2n+2})	Alkene (C_nH_{2n})	Alkyne (C_nH_{2n-2})
1	Methane (CH_4)	-	-
2	Ethane (C_2H_6)	Ethene (C_2H_4)	Ethyne (C_2H_2)
3	Propane (C_3H_8)	Propene (C_3H_6)	Propyne (C_3H_4)
4	Butane (C_4H_{10})	Butene (C_4H_8)	Butyne (C_4H_6)
5	Pentane (C_5H_{12})	Pentene (C_5H_{10})	Pentyne (C_5H_8)



11.3.2 Characteristics of hydrocarbons:

- ◆ Lower hydrocarbons are gases at room temperature E.g. methane, ethane are gases.
- ◆ They are colourless and odourless.
- ◆ The boiling point of hydrocarbons increases with an increase in the number of carbon atoms.
- ◆ They undergo combustion reaction with oxygen to form CO_2 and water.
- ◆ Alkanes are least reactive when compared to other classes of hydrocarbons.
- ◆ Alkynes are the most reactive due to the presence of the triple bond.
- ◆ Alkanes are saturated whereas alkenes and alkynes are unsaturated.
- ◆ They are insoluble in water.

Test to identify saturated and unsaturated compounds:

- ◆ Take the given sample solution in a test tube.
- ◆ Add a few drops of bromine water and observe any characteristic change in colour.
- ◆ If the given compound is unsaturated, it will decolourise bromine water.
- ◆ Saturated compounds do not decolourise bromine.

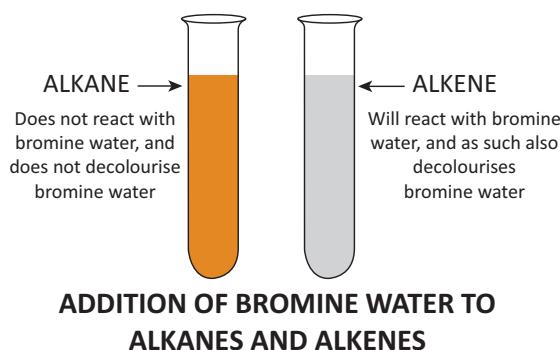


Figure 11.2 Test to identify unsaturated compounds

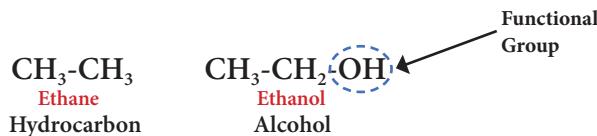
11.3.3 Classification of organic compounds based on functional groups

The structural frameworks of organic compounds are made of carbon and hydrogen, which are relatively less reactive. But, the presence of some other atoms or group of atoms makes the compounds more reactive and thus determines the chemical properties of the compound. These groups are called **functional groups**.

A functional group is an atom or group of atoms in a molecule, which gives its characteristic chemical properties.

The chemical properties of an organic compound depend on its functional group whereas its physical properties rely on remaining part of the structure. Carbon to carbon multiple bonds ($\text{C}=\text{C}$, $\text{C}\equiv\text{C}$) also are considered as functional groups as many of the properties are influenced by these bonds. Other functional groups include atoms of halogens, $-\text{OH}$, $-\text{CHO}$, $-\text{COOH}$, etc.

For example, ethane is a hydrocarbon having molecular formula C_2H_6 . If one of its hydrogen is replaced by $-\text{OH}$ group, you will get an alcohol. Leaving the functional group, the rest of the structure is represented by 'R'. Thus an alcohol is represented by 'R-OH'



A series of compounds containing the same functional group is called a **class of organic compounds**. Table 11.2 shows various classes or families of organic compounds and their functional groups:

**Table 11.2** Classes of organic compounds based on functional group

Class of the compound	Functional group	Common Formula	Examples
Alcohols	-OH	R-OH	Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$
Aldehydes	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{H} \end{array}$	R-CHO	Acetaldehyde, CH_3CHO
Ketones	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}- \end{array}$	R-CO-R	Acetone, CH_3COCH_3
Carboxylic acids	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{OH} \end{array}$	R-COOH	Acetic acid, CH_3COOH
Ester	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{OR} \end{array}$	R-COOR	Methyl acetate, $\text{CH}_3\text{COOCH}_3$
Ether	-O-R	R-O-R	Dimethyl ether, CH_3OCH_3

11.4 HOMOLOGOUS SERIES

Homologous series is a group or a class of organic compounds having same general formula and similar chemical properties in which the successive members differ by a -CH_2 group.

Let us consider members of alkanes given in Table 11.1. Their condensed structural formulas are given below:

Methane	-	CH_4
Ethane	-	CH_3CH_3
Propane	-	$\text{CH}_3\text{CH}_2\text{CH}_3$
Butane	-	$\text{CH}_3(\text{CH}_2)_2\text{CH}_3$
Pentane	-	$\text{CH}_3(\text{CH}_2)_3\text{CH}_3$

If you observe the above series, you can notice that each successive member has one methylene group more than the precedent member of the series and hence they are called homologs.

11.4.1 Characteristics of homologous series

- ◆ Each member of the series differs from the preceding or succeeding member by one methylene group ($-\text{CH}_2$) and hence by a molecular mass of 14 amu.
- ◆ All members of a homologous series contain the same elements and functional group.
- ◆ They are represented by a general molecular formula. e.g. Alkanes, $\text{C}_n\text{H}_{2n+2}$.
- ◆ The members in each homologous series show a regular gradation in their physical properties with respect to their increase in molecular mass.
- ◆ Chemical properties of the members of a homologous series are similar.
- ◆ All the members can be prepared by a common method.



11.5 NOMENCLATURE OF ORGANIC COMPOUNDS

11.5.1 Why do we need nomenclature?

In ancient days, the names of organic compounds were related to the natural things from which they were obtained. For example, the formic acid was initially obtained by distillation of 'red ants'. Latin name of the red ant is 'Formica'. So, the name of the formic acid was derived from the Latin name of its source. Later, the organic compounds were synthesized from sources other than the natural sources. So scientists framed a systematic method for naming the organic compounds based on their structures. Hence, a set of rules was formulated by IUPAC (**International Union of Pure and Applied Chemistry**) for the nomenclature of chemical compounds.

11.5.2 Components of an IUPAC name

The IUPAC name of any organic compound consists of three parts:

- i. Root word
- ii. Prefix
- iii. Suffix

These parts are combined as per the following sequence to get the IUPAC name of the compound:

Prefix + Root Word + Suffix → IUPAC Name

(i) Root word: It is the basic unit, which describes the carbon skeleton. It gives the number of carbon atoms present in the parent chain of the compound and the pattern of their arrangement. Based on the number of carbon atoms present in the carbon skeleton, most of the names are derived from Greek numerals (except the first four). Table 11.3 shows the root words for the parent chain of hydrocarbons containing 1 to 10 carbon atoms:

Table 11.3 Root words of hydrocarbons

No. of carbon atoms	Root word
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-
7	Hept-
8	Oct-
9	Non-
10	Dec-

(ii) Prefix: The prefix represents the substituents or branch present in the parent chain. Atoms or group of atoms, other than hydrogen, attached to carbon of the parent chain are called substituents. Table 11.4 presents the major substituents of organic compounds and respective prefix used for them:

Table 11.4 Prefix for IUPAC Name

Substituent	Prefix used
-F	Fluoro
-Cl	Chloro
-Br	Bromo
-I	Iodo
-NH ₂	Amino
-CH ₃	Methyl
-CH ₂ CH ₃	Ethyl

(iii) Suffix

The suffix forms the end of the name. It is divided into two parts such as (a) **Primary suffix** and (b) **Secondary suffix**. The primary suffix comes after the root word. **It represents the nature in carbon to carbon bonding of the parent chain.** If all the bonds between the carbon atoms of the parent chain are single, then suffix '**ane**' has to be used. Suffix '**ene**' and '**yne**' are used for the compounds containing double



and triple bonds respectively. **The secondary suffix describes the functional group of the compound.**

Table 11.5 Suffix for IUPAC Name

Class of the Compound	Functional group	Suffix used
Alcohols	-OH	-ol
Aldehydes	-CHO	-al
Ketones	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}- \end{array}$	-one
Carboxylic acids	-COOH	-oic acid

11.5.3 IUPAC rules for naming organic compounds:

- ◆ **Rule 1:** Identify the longest chain of carbon atoms to get the parent name (root word).
- ◆ **Rule 2:** Number the carbon atoms of the parent chain, **beginning at the closest end of the substituent or functional group**. These are called **locant numbers**. *If both functional group and substituent are present, then the priority will be given to the functional group.*
- ◆ **Rule 3:** In case of alkenes and alkynes, locate the double bond or triple bond and use its locant number followed by a dash and a primary suffix. The carbon chain is numbered in such a way that the multiple bonds have the lowest possible locant number.
- ◆ **Rule 4:** If the compound contains functional group, locate it and use its locant number followed by a dash and a secondary suffix.
- ◆ **Rule 5:** When the primary and secondary suffixes are joined, the terminal 'e' of the primary suffix is removed.
- ◆ **Rule 6:** Identify the substituent and use a number followed by a dash and a prefix to

specify its location and identity.

11.5.4 IUPAC Nomenclature of hydrocarbons – Solved examples

Let us try to name, systematically, some of the linear and substituted hydrocarbons by following IUPAC rules:

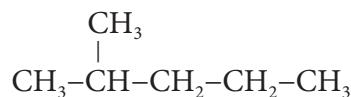
Example 1: CH₃-CH₂-CH₂-CH₂-CH₃

Step 1: It is a five- carbon chain and hence the root word is 'Pent'. (Rule 1)

Step 2: All the bonds between carbon atoms are single bonds, and thus the suffix is 'ane'.

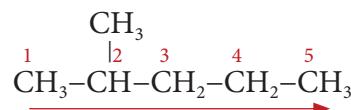
So, its name is **Pent + ane = Pentane**

Example 2:



Step 1: The longest chain contains five carbon atoms and hence the root word is 'Pent'.

Step 2: There is a substituent. So, the carbon chain is numbered from the left end, which is closest to the substituent. (Rule 2)



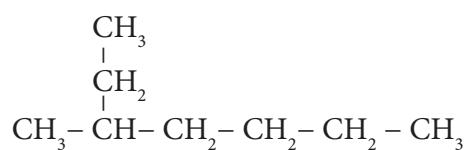
Step 2: All are single bonds between the carbon atoms and thus the suffix is 'ane'.

Step 3: The substituent is a methyl group and it is located at second carbon atom. So, its locant number is 2. Thus the prefix is '2-Methyl'. (Rule 6).

The name of the compound is

2-Methyl + pent +ane = 2-Methylpentane

Example 3:

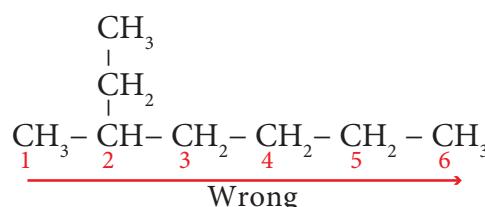
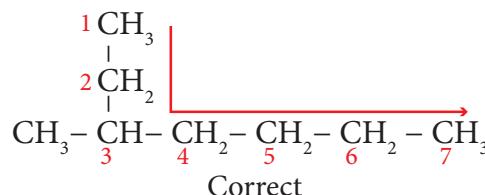


Step 1: The longest chain contains seven carbon atoms and hence the root word is 'Hept'.

Step 2: There is a substituent. So, the



carbon chain is numbered from the end, which is closest to substituent. (Rule 2)



Step 2: All are single bonds between the carbon atoms and thus the suffix is 'ane'.

Step 3: The substituent is a methyl group and it is located at third carbon. So, its locant number is 3. Thus the prefix is '3-Methyl'. (Rule 6)

Hence the name of the compound is
3-Methyl + hept + ane = 3 -Methylheptane

Example 4: $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH=CH}_2$

Step 1: It is a 'five- carbon atoms chain' and hence the root word is 'Pent'. (Rule 1)

Step 2: There is a carbon to carbon double bond. The suffix is 'ene'.

Step 3: The carbon chain is numbered from the end such that double bond has the lowest locant number as shown below: (Rule 3):



Step 4: The locant number of the double bond is 1 and thus the suffix is '-1-ene'.

So, the name of the compound is
Pent + (-1-ene) = Pent-1-ene

11.5.5 IUPAC Nomenclature of other classes – Solved examples

Example 1: $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-OH}$

Step1: The parent chain consists of 3 carbon atoms. The root word is 'Prop'.

Step 2: There are single bonds between the carbon atoms of the chain. So, the **primary suffix** is 'ane'.

Step 3: Since, the compound contains –OH group, it is an alcohol. The carbon chain is numbered from the end which is closest to –OH group. (Rule 3)



Step 4: The locant number of –OH group is 1 and thus the secondary suffix is '1-ol'.

The name of the compound is
Prop + ane + (1-ol) = Propan-1-ol

Note: Terminal 'e' of 'ane' is removed as per Rule 5

Example 2: CH_3COOH

Step1: The parent chain consists of 2 carbon atoms. The root word is 'Eth'.

Step 2: All are single bonds between the carbon atoms of the chain. So the primary suffix is 'ane'.

Step 3: Since the compound contains the–COOH group, it is a carboxylic acid. The secondary suffix is 'oic acid'

The name of the compound is
Eth + ane + oic acid) = Ethanoic acid

Table 11.6 lists IUPAC names homologs of various classes of organic compounds

Test yourself:

Obtain the IUPAC name of the following compounds systematically:

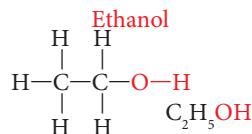
- (a) CH_3CHO
- (b) $\text{CH}_3\text{CH}_3\text{COCH}_3$
- (c) $\text{ClCH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$

**Table 11.6 IUPAC Name of various classes of compounds**

No. of carbons atoms	IUPAC Name			
	Alcohols	Aldehydes	Ketones	Carboxylic acid
1	Methanol (CH ₃ OH)	Methanal (HCHO)	-	Methanoic acid (HCOOH)
2	Ethanol (CH ₃ CH ₂ OH)	Ethanal (CH ₃ CHO)	-	Ethanoic acid (CH ₃ COOH)
3	Propanol (CH ₃ CH ₂ CH ₂ OH)	Propanal (CH ₃ CH ₂ CHO)	Propanone (CH ₃ COCH ₃)	Propanoic acid (CH ₃ CH ₂ COOH)
4	Butanol (CH ₃ CH ₂ CH ₂ CH ₂ OH)	Butanal (CH ₃ CH ₂ CH ₂ CHO)	Butanone (CH ₃ COCH ₂ CH ₃)	Butanoic acid (CH ₃ CH ₂ CH ₂ COOH)
5	Pentanol (CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ OH)	Pentanal (CH ₃ CH ₂ CH ₂ CH ₂ CHO)	Pentanone (CH ₃ COCH ₂ CH ₂ CH ₃)	Pentanoic acid (CH ₃ CH ₂ CH ₂ CH ₂ COOH)

11.6 ETHANOL (CH₃CH₂OH)

Ethanol is commonly known as alcohol. All alcoholic beverages and some cough syrups contain ethanol. Its molecular formula is C₂H₅OH. Its structural formula is



11.6.1 Manufacture of ethanol

Ethanol is manufactured in industries by the fermentation of molasses, which is a by-product obtained during the manufacture of sugar from sugarcane. Molasses is a dark coloured syrupy liquid left after the crystallization of sugar from the concentrated sugarcane juice. Molasses contain about 30% of sucrose, which cannot be separated by crystallization. It is converted into ethanol by the following steps:

(i) Dilution of molasses

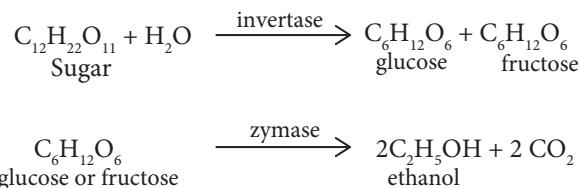
Molasses is first diluted with water to bring down the concentration of sugar to about 8 to 10 percent.

(ii) Addition of Nitrogen source

Molasses usually contains enough nitrogenous matter to act as food for yeast during the fermentation process. If the nitrogen content of the molasses is poor, it may be fortified by the addition of ammonium sulphate or ammonium phosphate.

(iii) Addition of Yeast

The solution obtained in step (ii) is collected in large 'fermentation tanks' and yeast is added to it. The mixture is kept at about 303K for a few days. During this period, the enzymes invertase and zymase present in yeast, bring about the conversion of sucrose into ethanol.



The fermented liquid is technically called wash.

(iv) Distillation of 'Wash'

The fermented liquid (i.e. wash), containing 15 to 18 percent alcohol, is now subjected to fractional distillation. The main fraction drawn is an aqueous solution of ethanol which contains



95.5% of ethanol and 4.5% of water. This is called **rectified spirit**. This mixture is then refluxed over quicklime for about 5 to 6 hours and then allowed to stand for 12 hours. On distillation of this mixture, pure alcohol (100%) is obtained. This is called **absolute alcohol**.

More to know

Yeast and Fermentation: Yeasts are single-celled microorganisms, belonging to the class of fungi. The enzymes present in yeasts catalyse many complex organic reactions. Fermentation is conversion of complex organic molecules into simpler molecules by the action of enzymes. E.g. Curdling of milk

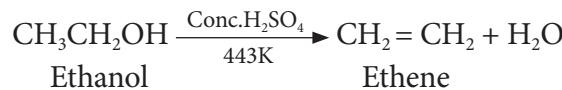
11.6.2 Physical properties

- Ethanol is a colourless liquid, having a pleasant smell and a burning taste.
- It is a volatile liquid. Its boiling point is 78°C (351K), which is much higher than that of its corresponding alkane, i.e. ethane (Boiling Point = 184 K).
- It is completely miscible with water in all proportions.

11.6.3 Chemical Properties

(i) Dehydration (Loss of water)

When ethanol is heated with conc H_2SO_4 at 443K , it loses a water molecule i.e. dehydrated to form ethene.



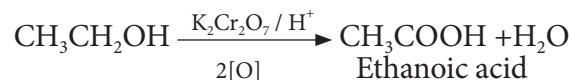
(ii) Reaction with sodium:

Ethanol reacts with sodium metal to form sodium ethoxide and hydrogen gas.



(iii) Oxidation:

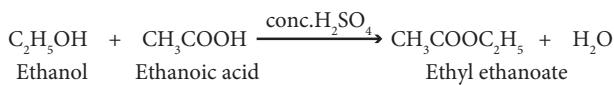
Ethanol is oxidized to ethanoic acid with alkaline KMnO_4 or acidified $\text{K}_2\text{Cr}_2\text{O}_7$



During this reaction, the orange colour of $\text{K}_2\text{Cr}_2\text{O}_7$ changes to green. Therefore, this reaction can be used for the identification of alcohols.

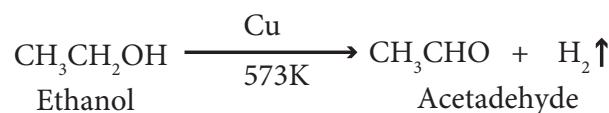
(iv) Esterification:

The reaction of an alcohol with a carboxylic acid gives a compound having fruity odour. This compound is called an **ester** and the reaction is called esterification. Ethanol reacts with ethanoic acid in the presence of conc. H_2SO_4 to form ethyl ethanoate, an ester.



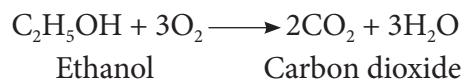
(v) Dehydrogenation:

When the vapour of ethanol is passed over heated copper, used as a catalyst at 573 K , it is dehydrogenated to acetaldehyde.



(vi) Combustion:

Ethanol is highly inflammable liquid. It burns with oxygen to form carbon dioxide and water.



11.6.4 Uses of ethanol

Ethanol is used

- ◆ in medical wipes, as an antiseptic.
- ◆ as an anti-freeze in automobile radiators.
- ◆ for effectively killing micro organisms like bacteria, fungi, etc., by including it in many hand sanitizers.

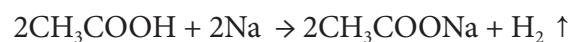
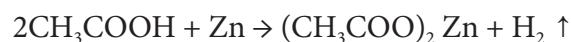


- ◆ as an antiseptic to sterilize wounds in hospitals.
- ◆ as a solvent for drugs, oils, fats, perfumes, dyes, etc.
- ◆ in the preparation of **methylated spirit** (mixture of 95% of ethanol and 5% of methanol) **rectified spirit** (mixture of 95.5% of ethanol and 4.5% of water), power alcohol (mixture of petrol and ethanol) and denatured spirit (ethanol mixed with pyridine).
- ◆ to enhance the flavour of food extracts, for example vanilla extract; a common food flavour, which is made by processing vanilla beans in a solution of ethanol and water.

- (ii) It is sour in taste.
- (iii) It is miscible with water in all proportions.
- (iv) Its boiling point is higher than the corresponding alcohols, aldehydes and ketones.
- (v) On cooling, pure ethanoic acid is frozen to form ice like flakes. They look like glaciers, so it is called **glacial acetic acid**.

11.7.3 Chemical Properties

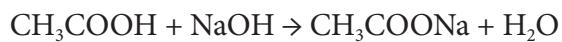
(i) **Reaction with metal:** Ethanoic acid reacts with active metals like Na, Zn, etc., to liberate hydrogen and form sodium ethanoate.



(ii) **Reaction with carbonates and bicarbonates:** Ethanoic acid reacts with sodium carbonate and sodium bicarbonate, which are weaker bases and liberates CO_2 , with brisk effervescence.

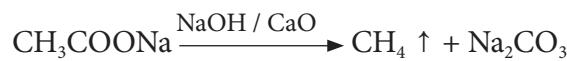


(iii) **Reaction with base:** Ethanoic acid reacts with sodium hydroxide to form sodium ethanoate and water.



(iv) **Decarboxylation (Removal of CO_2):**

When a sodium salt of ethanoic acid is heated with soda lime (solid mixture of 3 parts of NaOH and 1 part of CaO), methane gas is formed.

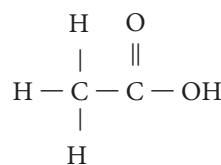


11.7.4 Uses of ethanoic acid

Acetic acid, in lower concentration, is used as a food additive, a flavoring agent and a preservative.

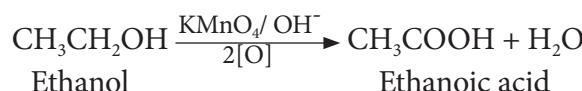
11.7 ETHANOIC ACID (CH_3COOH)

Ethanoic acid or acetic acid is one of the most important members of the carboxylic acid family. Its molecular formula is $\text{C}_2\text{H}_4\text{O}_2$. Its structural formula is



11.7.1 Manufacture of ethanoic acid

Ethanoic acid is prepared in large scale, by the oxidation of ethanol in the presence of alkaline potassium permanganate or acidified potassium dichromate.



11.7.2 Physical Properties

(i) Ethanoic acid is a colourless liquid having an unpleasant odour.



Ethanoic acid is used

- ◆ in the manufacture of plastic.
- ◆ in making dyes, pigments and paint.
- ◆ in printing on fabrics.
- ◆ as a laboratory reagent.
- ◆ for coagulating rubber from latex.
- ◆ in the production of pharmaceuticals.

11.8 ORGANIC COMPOUNDS IN DAILY LIFE

Organic compounds are inseparable in human life. They are used by mankind or associated at all stages of life right from one's birth to death. Various classes of organic compounds and their uses in our daily life as follows:

Hydrocarbons

- ◆ Fuels like LPG, Petrol, Kerosene.
- ◆ Raw materials for various important synthetic materials.
- ◆ Polymeric materials like tyre, plastic containers.

Alcohols

- ◆ As a solvent and an antiseptic agent.
- ◆ Raw materials for various important synthetic materials.

Aldehydes

- ◆ Formaldehyde as a disinfectant.
- ◆ Raw materials for synthetic materials.

Ketones

- ◆ As a solvent.
- ◆ Stain Remover.

Ethers

- ◆ Anaesthetic agents.
- ◆ Pain Killer.

Esters

- ◆ All the cooking oils and lipids contain esters.

11.9 SOAPS AND DETERGENTS

Soaps and the Detergents are materials that are used by us for cleaning purposes because pure water alone cannot remove all types of dirt or any oily substance from our body or clothes. They contain 'surfactants', which are compounds with molecules that line up around water to break the 'surface tension'. Both of them having a different chemical nature. **Soap** is a cleaning agent that is composed of one or more salts of fatty acids. **Detergent** is a chemical compound or a mixture of chemical compounds, which is used as a cleaning agent, also. They perform their cleaning actions in certain specific conditions. You will learn more about this in detail, in the following units.

11.9.1 Soap

Soaps are sodium or potassium salts of some long chain carboxylic acids, called fatty acids. Soap requires two major raw materials: i) fat and ii) alkali. The alkali, most commonly used in the preparation of soap is sodium hydroxide. Potassium hydroxide can also be used. A potassium-based soap creates a more water-soluble product than a sodium-based soap. Based on these features, there are two types of soaps:

A. HARD SOAP

Soaps, which are prepared by the **saponification of oils or fats with caustic soda** (sodium hydroxide), are known as hard soaps. They are usually used for washing purposes.

B. SOFT SOAP

Soaps, which are prepared by the **saponification of oils or fats with potassium salts**, are known as soft soaps. They are used for cleansing the body.

Manufacture of soap

KETTLE PROCESS:

This is the oldest method. But, it is still widely used in the small scale preparation of



soap. There are mainly, two steps to be followed in this process.

i) Saponification of oil:

The oil, which is used in this process, is taken in an iron tank (kettle). The alkaline solution (10%) is added into the kettle, a little in excess. The mixture is boiled by passing steam through it. The oil gets hydrolysed after several hours of boiling. This process is called Saponification

ii) Salting out of soap:

Common salt is then added to the boiling mixture. Soap is finally precipitated in the tank. After several hours the soap rises to the top of the liquid as a ‘curdy mass’. The neat soap is taken off from the top. It is then allowed to cool down.

Effect of hard water on soap

Hard water contains calcium and magnesium ions (Ca^{2+} and Mg^{2+}) that limit the cleaning action of soap. When combined with soap, hard water develops a thin layer (precipitates of the metal ions) called ‘scum’, which leaves a deposit on the clothes or skin and does not easily rinse away. Over time, this can lead to the deterioration of the fabric and eventually ruin the clothes. On the other hand, detergents are made with chemicals that are not affected by hard water.



Why ordinary soap is not suitable for using with hard water?

Ordinary soaps when treated with hard water, precipitate as salts of calcium and magnesium. They appear at the surface of the cloth as sticky grey scum. Thus, the soaps cannot be used conveniently in hard water.

11.9.2 Detergents

Development of synthetic detergents is a big achievement in the field of cleansing.

These soaps possess the desirable properties of ordinary soaps and also can be used with hard water and in acidic solutions. These are salts of sulphonic acids or alkyl hydrogen sulphates in comparison to soap, which are salts of carboxylic acids. The detergents do not form precipitates with Ca^{2+} and Mg^{2+} present in hard water. So, the cleansing action of detergents is better than that of soaps.

Preparation of detergents

Detergents are prepared by adding sulphuric acid to the processed hydrocarbon obtained from petroleum. This chemical reaction result in the formation of molecules similar to the fatty acid in soap. Then, an alkali is added to the mixture to produce the ‘surfactant molecules’, which do not bond with the minerals present in the hard water, thus preventing the formation of their precipitates.

In addition to a ‘surfactant’, the modern detergent contains several other ingredients. They are listed as follows:

- i) Sodium silicate, which prevents the corrosion and ensures that the detergent does not damage the washing machine.
- ii) Fluorescent whitening agents that give a glow to the clothes.
- iii) Oxygen bleaches, such as ‘sodium perborate’, enable the removal of certain stains from the cloth.
- iv) Sodium sulphate is added to prevent the caking of the detergent powder.
- v) Enzymes are added to break down some stains caused by biological substances like blood and vegetable juice.
- vi) Certain chemicals that give out a pleasant smell are also added to make the clothes fragrant after they are washed with detergents.

11.9.3 Cleansing action of soap

A soap molecule contains two chemically distinct parts that interact differently with



water. It has one **polar end**, which is a *short head* with a carboxylate group ($-COONa$) and one **non-polar end** having the *long tail made of the hydrocarbon chain*.



The polar end is **hydrophilic (Water loving)** in nature and this end is attracted towards water. The non-polar end is **hydrophobic (Water hating)** in nature and it is attracted towards dirt or oil on the cloth, but not attracted towards water. Thus, the hydrophobic part of the soap molecule traps the dirt and the hydrophilic part makes the entire molecule soluble in water.

When a soap or detergent is dissolved in water, the molecules join together as clusters called '**micelles**'. Their long hydrocarbon chains attach themselves to the oil and dirt. The dirt is thus surrounded by the non-polar end of the soap molecules (Figure 11.3). The charged carboxylate end of the soap molecules makes the micelles soluble in water. Thus, the dirt is washed away with the soap.

Advantages of detergents over soaps

Detergents are better than soaps because they:

- can be used in both hard and soft water and can clean more effectively in hard water than soap.
- can also be used in saline and acidic water.
- do not leave any soap scum on the tub or clothes.
- dissolve freely even in cool water and rinse freely in hard water.
- can be used for washing woollen garments, where as soap cannot be used.
- have a linear hydrocarbon chain, which is biodegradable.
- are active emulsifiers of motor grease.

- do an effective and safe cleansing, keeping even synthetic fabrics brighter and whiter.

Biodegradable and Non-biodegradable detergents:

a) Biodegradable detergents:

They have straight hydrocarbon chains, which can be easily degraded by bacteria.

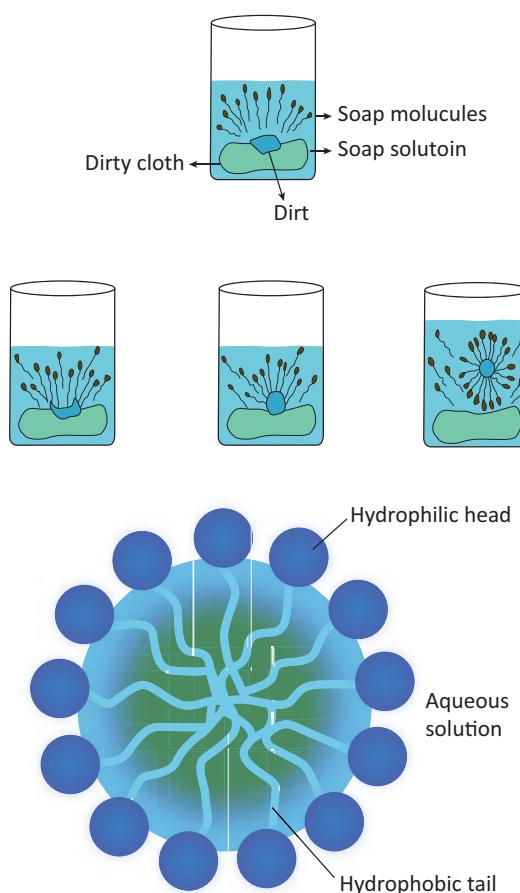


Figure 11.3 Cleansing action of soap

b) Non-biodegradable detergents:

They have highly branched hydrocarbon chains, which cannot be degraded by bacteria.

Disadvantages of Detergents

1. Some detergents having a branched hydrocarbon chain are not fully biodegradable by micro-organisms present in water. So, they cause water pollution.
2. They are relatively more expensive than soap.



11.9.4 Comparison between soap and detergents

Soap	Detergent
It is a sodium salt of long chain fatty acids.	It is sodium salts of sulphonic acids.
The ionic part of a soap is $\text{COO}^- \text{Na}^+$.	The ionic part in a detergent is $\text{SO}_3^- \text{Na}^+$.
It is prepared from animal fats or vegetable oils.	It is prepared from hydrocarbons obtained from crude oil.
Its effectiveness is reduced when used in hard water.	It is effective even in hard water.
It forms a scum in hard water.	Does not form a scum in hard water.
It has poor foaming capacity.	It has rich foaming capacity.
Soaps are biodegradable.	Most of the detergents are non-biodegradable.

Have you noticed the term "TFM" in soap



TFM means TOTAL FATTY MATTER. It is the one of the important factors to be considered to assess the quality of soap. A soap, which has higher TFM, is a good bathing soap.

- ❖ Functional group may be defined as an atom or group of atoms or reactive part which is responsible for the characteristic properties of the compounds
- ❖ Ethanoic acid is most commonly known as acetic acid and belongs to a group of acids called carboxylic acids.
- ❖ Acetic acid is present in many fruits and it renders a sour taste to those fruits.
- ❖ Ethanol or ethyl alcohol or simply alcohol is one of the most important members of the family of alcohols.
- ❖ The slow chemical change that takes place in complex organic compounds by the action of enzymes leading to the formation of simple molecules is called fermentation.
- ❖ Soaps are sodium or potassium salts of some long chain carboxylic acids.
- ❖ Detergents are sodium salts of sulphonic acids. Thus instead of COOH group in soaps, detergents contain SO_3H group

Points to Remember

- ❖ A group or class of organic compounds related to each other by a general molecular formula constitutes homologous series.
- ❖ The IUPAC name of any organic compound consists of three parts. **ROOTWORD, PREFIX and / or SUFFIX.**



TEXTBOOK EVALUATION



IQA2A9

I. Choose the best answer.

1. The molecular formula of an open chain organic compound is C_3H_6 . The class of the compound is
 - a. alkane
 - b. alkene
 - c. alkyne
 - d. alcohol
2. The IUPAC name of an organic compound is 3-Methyl butan-1-ol. What type compound it is?
 - a. Aldehyde
 - b. Carboxylic acid
 - c. Ketone
 - d. Alcohol
3. The secondary suffix used in IUPAC nomenclature of an aldehyde is _____.
 - a. - ol
 - b. - oic acid
 - c. - al
 - d. - one
4. Which of the following pairs can be the successive members of a homologous series?
 - a. C_3H_8 and C_4H_{10}
 - b. C_2H_2 and C_2H_4
 - c. CH_4 and C_3H_6
 - d. C_2H_5OH and C_4H_8OH
5. $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ is a
 - a. Reduction of ethanol
 - b. Combustion of ethanol
 - c. Oxidation of ethanoic acid
 - d. Oxidation of ethanal
6. Rectified spirit is an aqueous solution which contains about _____ of ethanol
 - a. 95.5 %
 - b. 75.5 %
 - c. 55.5 %
 - d. 45.5 %
7. Which of the following are used as anaesthetics?
 - a. Carboxylic acids
 - b. Ethers
 - c. Esters
 - d. Aldehydes
8. TFM in soaps represents _____ content in soap
 - a. mineral
 - b. vitamin
 - c. fatty acid
 - d. carbohydrate

9. Which of the following statements is wrong about detergents?

- a. It is a sodium salt of long chain fatty acids
- b. It is sodium salts of sulphonic acids
- c. The ionic part in a detergent is $-SO_3Na^+$
- d. It is effective even in hard water.

II. Fill in the blanks

1. An atom or a group of atoms which is responsible for chemical characteristics of an organic compound is called _____.
2. The general molecular formula of alkynes is _____.
3. In IUPAC name, the carbon skeleton of a compound is represented by _____ (root word / prefix / suffix)
4. (Saturated / Unsaturated) _____ compounds decolourize bromine water.
5. Dehydration of ethanol by conc. Sulphuric acid forms _____ (ethene/ ethane)
6. 100 % pure ethanol is called _____
7. Ethanoic acid turns _____ litmus to _____
8. The alkaline hydrolysis of fatty acids is termed as _____
9. Biodegradable detergents are made of _____(branched / straight) chain hydrocarbons

III. Match the following

Functional group -OH	-	Benzene
Heterocyclic	-	Potassium stearate
Unsaturated	-	Alcohol
Soap	-	Furan
Carbocyclic	-	Ethene



IV. Assertion and Reason:

Answer the following questions using the data given below:

- i) A and R are correct, R explains the A.
- ii) A is correct, R is wrong.
- iii) A is wrong, R is correct.
- iv) A and R are correct, R doesn't explain A.

1. **Assertion:** Detergents are more effective cleansing agents than soaps in hard water.

Reason: Calcium and magnesium salts of detergents are water soluble.

2. **Assertion:** Alkanes are saturated hydrocarbons.

Reason: Hydrocarbons consist of covalent bonds.

V. Short answer questions

1. Name the simplest ketone and give its structural formula.
2. Classify the following compounds based on the pattern of carbon chain and give their structural formula: (i) Propane (ii) Benzene (iii) Cyclobutane (iv) Furan
3. How is ethanoic acid prepared from ethanol? Give the chemical equation.
4. How do detergents cause water pollution? Suggest remedial measures to prevent this pollution?
5. Differentiate soaps and detergents.

VI. Long answer questions

1. What is called homologous series? Give any three of its characteristics?
2. Arrive at, systematically, the IUPAC name of the compound: $\text{CH}_3\text{—CH}_2\text{—CH}_2\text{—OH}$.
3. How is ethanol manufactured from sugarcane?
4. Give the balanced chemical equation of the following reactions:
(i) Neutralization of NaOH with ethanoic acid.

(ii) Evolution of carbon dioxide by the action of ethanoic acid with NaHCO_3 .

(iii) Oxidation of ethanol by acidified potassium dichromate.

(iv) Combustion of ethanol.

5. Explain the mechanism of cleansing action of soap.

VII. HOT questions

1. The molecular formula of an alcohol is $\text{C}_4\text{H}_{10}\text{O}$. The locant number of its —OH group is 2.
 - (i) Draw its structural formula.
 - (ii) Give its IUPAC name.
 - (iii) Is it saturated or unsaturated?
2. An organic compound 'A' is widely used as a preservative and has the molecular formula $\text{C}_2\text{H}_4\text{O}_2$. This compound reacts with ethanol to form a sweet smelling compound 'B'.
 - (i) Identify the compound 'A'
 - (ii) Write the chemical equation for its reaction with ethanol to form compound 'B'.
 - (iii) Name the process.



REFERENCE BOOKS

1. Organic chemistry - B.S.Bahl & Arun Bahl S.Chand publishers, New delhi.
2. Organic chemistry - R.T.Morrison & R.MN. Boyd - Prentice Hall Publishers. New Delhi



INTERNET RESOURCES

<https://www.tutorvista.com/>

<https://www.topperlearning.com/>

<http://www.chem4kids.com/>

PERIODIC CLASSIFICATION OF ELEMENTS

"An awareness of the periodic table is essential to anyone who wishes to disentangle the word and see how it is built up from the fundamental building blocks of the chemistry, the chemical elements "

- Glenn T. Seaborg



Glenn T. Seaborg

Glenn Theodore Seaborg received Nobel Prize in 1951 in chemistry for the discoveries of trans-uranium elements. He was the co-discoverer of plutonium and other trans-uranium elements. He along with his colleagues has discovered over a hundred isotopes of other elements. He demonstrated that actinide elements are analogues to rare earth series of lanthanide elements.

Learning Objectives



After studying this unit, students will be able to

- recognise the development of the periodic table
- explain the work of Mosley's and modern periodic law
- outline the concept of grouping elements
- name the elements with atomic number greater than 100 using IUPAC nomenclature
- classify the elements into s, p, d and f blocks
- recognise the periodic trends and describe qualitatively the variation in periodic properties such as atomic radius, ionisation energy etc.
- explain the anomalies in the expected trend in the periodic properties
- calculate the effective nuclear charge using Slater's rule
- calculate the ionic radius using Pauling's method
- predict the probable position for a given element in the periodic table
- explain the anomalous properties of second period elements and the diagonal relationship



3QLHTZ

Introduction

There are millions of chemical compounds existing in nature with different compositions and properties, formed from less than 100 naturally occurring elements.

The discovery of elements is linked with human civilization. In stone age man has used some metals to suit his needs without knowing that they are elements. Soon he learnt to extract elements from ores and fashion them into his daily life. Over the years, more and more elements were discovered. In 1789, Lavoisier from France, published the first list of chemical elements containing 23 elements after several experimental investigations.

Antoine Lavoisier classified the substances into four groups of elements namely acid-making elements, gas-like elements, metallic elements and earthy elements

Table 3.1 Lavoisier table

acid-making elements	gas-like elements
sulphur	light
phosphorus	caloric (heat)
charcoal (carbon)	oxygen
	azote (nitrogen)
	hydrogen

metallic elements	earthy elements
cobalt, mercury, tin	lime (calcium oxide)
copper, nickel, iron	magnesia (magnesium oxide)
gold, lead, silver, zinc	barytes (barium sulphate)
manganese, tungsten	argilla (aluminium oxide)
platinum (platinum)	silex (silicon dioxide)

3.1 Classification of Elements

During the 19th century, scientists have isolated several elements and the list of known elements increased. Currently, we have 118 known elements. Out of 118 elements, 92 elements with atomic numbers 1 to 92 are found in nature. Scientists have found out there are some similarities in properties among certain elements. This observation has led to the idea of classification of elements based on their properties. In fact, classification will be beneficial for the effective utilization of these elements. Several attempts were made to classify the elements. However, classification based on the atomic weights led to the construction of a proper form of periodic table.

In 1817, J. W. Döbereiner classified some elements such as chlorine, bromine and iodine with similar chemical properties into the group of three elements called as triads. In triads, the atomic weight of the middle element nearly equal to the arithmetic mean of the atomic weights of the remaining two elements. However, only a limited number of elements can be grouped as triads.

Table 3.2 Döbereiner Triads

S. No.	Elements in the Triad	Atomic weight of middle element	Average atomic weight of the remaining elements
1	Li, Na, K	23	$\frac{7+39}{2} = 23$
2	Cl, Br, I	80	$\frac{35.5+127}{2} = 81.25$
3	Ca, Sr, Ba	88	$\frac{40+137}{2} = 88.5$

This concept can not be extended to some triads which have nearly same atomic masses such as [Fe, Co, Ni], [Ru, Rh, Pd] and [Os, Ir, Pt].

In 1862, A. E. B. de Chancourtois reported a correlation between the properties of the elements and their atomic weights. He said ‘the properties of bodies are the properties of numbers’. He intended the term numbers to mean the value of atomic weights. He designed a helix by tracing at an angle 45° to the vertical axis of a cylinder with circumference of 16 units. He arranged the elements in the increasing atomic weights along the helix on the surface of this cylinder. One complete turn of a helix corresponds to an atomic weight increase of 16. Elements which lie on the 16 equidistant vertical lines drawn on the surface of cylinder shows similar properties. This was the first reasonable attempt towards the creation of periodic table. However, it did not attract much attention.

In 1864, J. Newland made an attempt to classify the elements and proposed the law of octaves. On arranging the elements in the increasing order of atomic weights, he observed that the properties of every

eighth element are similar to the properties of the first element. This law holds good for lighter elements up to calcium.

Table 3.3 Newlands’ Octaves

^7Li	^9Be	^{11}B	^{12}C	^{14}N	^{16}O	^{19}F
^{23}Na	^{24}Mg	^{27}Al	^{29}Si	^{31}P	^{32}S	$^{35.5}\text{Cl}$
^{39}K	^{40}Ca					

3.1.1 Mendeleev's Classification

In 1868, Lothar Meyer had developed a table of the elements that closely resembles the modern periodic table. He plotted the physical properties such as atomic volume, melting point and boiling point against atomic weight and observed a periodical pattern.

During same period Dmitri Mendeleev independently proposed that “the properties of the elements are the periodic functions of their atomic weights” and this is called periodic law. Mendeleev listed the 70 known elements at that time in several vertical columns in order of increasing atomic weights. Thus, Mendeleev constructed the first periodic table based on the periodic law.

Table 3.4 Mendeleev's periodic table

Series	Group of Elements							
	0	1	II	III	IV	V	VI	VII
1	-	Hydrogen H 1.0008	-	-	-	-	-	-
2	Heitum Ge 4.0	Lithium Li 7.03	Beryllium Be 9.1	Boron B 11.0	Carbon C 12.0	Nitrogen N 14.04	Oxygen O 16.00	Fluorine F 19.0
3	Neon Ne 19.9	Sodium Na 23.5	Magnesium Mg 24.3	Aluminium Al 27.0	Silicon Si 28.04	Phosphorus P 31.0	Sulphur S 32.06	Chlorine Cl 35.45
4	Argon Ar 38	Potassium K 39.1	Calcium Ca 40.1	Scandium Sc 44.1	Titanium Ti 48.1	Vanadium V 51.4	Chromium Cr 51.99	Manganese Mn 55.0
5		Copper Cu 63.6	Zinc Zn 65.4	Gallium Ga 70.0	Germanium Ge 72.3	Arsenic As 75	Selenium Se 79	Bromine Br 79.95
6	Krypton Kr 81.8	Rubidium Rb 85.4	Strontrium Sr 87.6	Yttrium Y 89.0	Zirconium Zr 90.6	Niobium Nb 94.0	Molybdenum Mo 96.0	Ruthenium Ru 101.7
7		Silver Ag 107.9	Cadmium Cd 112.4	Indium In 114.0	Tin Sn 119.0	Antimony Sb 120.0	Tellurium Te 127.6	Iodine I 126.9
8	Xenon Xe 128	Caesium Cs 132.9	Barium Ba 137.4	Lanthanum La 139	Cerium Ce 140	-	-	-
9	-	-	-	-	-	-	-	-
10	-	-	-	Ytterbium Yb 173	-	Tantalum Ta 183	Tungsten W 184	-
11		Gold Au 197.2	Mercury Hg 200.0	Thallium Tl 204.1	Lead Pb 206.9	Bismuth Bi 208	-	-
12		Radium Ra 224	-	Thorium Th 232	-	Uranium U 239	-	-
					Higher Saline Oxides			
	R	R ₂ O R ₂ O ₃	RO ₂	R ₂ O ₅	RO ₃	R ₂ O ₇	RO ₄	
			Higher Gaseous Hydrogen Compounds		RH ₃	RH ₂	RH	

As shown in the periodic table, he left some blank spaces since there were no known elements with the appropriate properties at that time. He and others predicted the physical and chemical properties of the missing elements. Eventually these missing elements were discovered and found to have the predicted properties. For example, Gallium (Ga) of group III and germanium (Ge) of group IV were unknown at that time. But Mendeleev predicted their existence and properties. He referred the predicted elements as eka-aluminium and eka-silicon. After discovery of the actual elements, their properties were found to match closely to those predicted by Mendeleev (Table 3.4).

Table 3.5 Properties predicted for Eka-aluminium and Eka-silicon

S.No.	Property	Eka-aluminium (Predicted)	Gallium (Observed)	Eka-silicon (Predicted)	Germanium (Observed)
1.	Atomic weight	68	70	72	72.59
2.	Density (g/cm ³)	5.9	5.94	5.5	5.35
3.	Melting point	low	29.78°C	High	947°C
4.	Formula of oxide	E ₂ O ₃	Ga ₂ O ₃	EO ₂	GeO ₂
5.	Formula of chloride	ECl ₃	GaCl ₃	ECl ₄	GeCl ₄

3.1.2 Anomalies of Mendeleev's Periodic Table

Some elements with similar properties were placed in different groups and those with dissimilar properties were placed in same group.

Example: Tellurium (127.6) was placed in VI group but Iodine (127.0) was placed in VII group.

Similarly elements with higher atomic weights were placed before lower atomic weights based on their properties in contradiction to his periodic law. Example ⁵⁹Co₂₇ was placed before ^{58.7}Ni₂₈

3.2 Moseley's Work and Modern Periodic Law

In 1913, Henry Moseley studied the characteristic X-rays spectra of several elements by bombarding them with high energy electrons and observed a linear correlation between atomic number and the frequency of X-rays emitted which is given by the following expression.

$$\sqrt{\nu} = a(Z - b)$$

Where, ν is the frequency of the X-rays emitted by the element with atomic number 'Z'; a and b are constants and have same values for all the elements.

The plot of $\sqrt{\nu}$ against Z gives a straight line. Using this relationship, we can determine the atomic number of an unknown (new) element from the frequency of X-ray emitted.

Based on his work, the modern periodic law was developed which states that, “the physical and chemical properties of the elements are periodic functions of their atomic numbers.” Based on this law, the elements were arranged in order of their increasing atomic numbers. This mode of arrangement reveals an important truth that the elements with similar properties recur after regular intervals. The repetition of physical and chemical properties at regular intervals is called periodicity.

3.2.1 Modern Periodic Table

The physical and chemical properties of the elements are correlated to the arrangement of electrons in their outermost shell (valence shell). Different elements having similar outer shell electronic configuration possess similar properties. For example, elements having one electron in their valence shell s-orbital possess similar physical and chemical properties. These elements are grouped together in the modern periodic table as first group elements.

Table 3.6 Electronic configuration of alkali metals (ns^1)

Elements in Group 1	Atomic number	Number of electrons in various shells in the order K L M N P	Valence shell configuration
Li	3	2, 1	$2s^1$
Na	11	2, 8, 1	$3s^1$
K	19	2, 8, 8, 1	$4s^1$
Rb	37	2, 8, 18, 8, 1	$5s^1$
Cs	55	2, 8, 18, 18, 8, 1	$6s^1$
Fr	87	2, 8, 18, 32, 18, 8, 1	$7s^1$

Similarly, all the elements are arranged in the modern periodic table which contains 18 vertical columns and 7 horizontal rows. The vertical columns are called groups and the horizontal rows are called periods. Groups are numbered 1 to 18 in accordance with the IUPAC recommendation which replaces the old numbering scheme IA to VIIA, IB to VIIB and VIII.

Each period starts with the element having general outer electronic configuration ns^1 and ends with np^6 . Here ‘n’ corresponds to the period number (principal quantum number). The aufbau principle and the electronic configuration of atoms provide a theoretical foundation for the modern periodic table.

Evaluate Yourself

- What is the basic difference in approach between Mendeleev's periodic table and modern periodic table ?



Table 3.7 Modern periodic table

PERIOD NUMBER		GROUP NUMBER																		Noble gases		
		Representative elements		Representative elements										Noble gases								
1		1		1		1		1		1		1		1		1		1		1		
2	Li	3	4	1	IA	2	IIA	1	IA	2	IIA	1	IA	2	IIA	1	IA	2	IIA	1	IA	2
3	Na	11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	18
4	K	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	0
5	Rb	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	0
6	Cs	87	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	Fr	Ra	0
7	Fr	7s ¹	7s ²	6d ¹ 7s ²																	Og	
<i>d</i> -Transition elements																						
<i>f</i> - Inner transition elements																						
Lanthanoids $4f^n 5d^{11} 6s^2$	Ce	58	59	60	61	62	63	64	65	66	67	68	69	70	71							
Actinoids $5f^n 6d^{10} 7s^2$	Th	90	91	92	93	94	95	96	97	98	99	100	101	102	103							

3.3 Nomenclature of Elements with Atomic Number Greater than 100

Usually, when a new element is discovered, the discoverer suggests a name following IUPAC guidelines which will be approved after a public opinion. In the meantime, the new element will be called by a temporary name coined using the following IUPAC rules, until the IUPAC recognises the new name.

1. The name was derived directly from the atomic number of the new element using the following numerical roots.

Table 3.8 Notation for IUPAC Nomenclature of elements

Digit	0	1	2	3	4	5	6	7	8	9
Root	nil	un	bi	tri	quad	pent	hex	sept	oct	enn
Abbreviation	n	u	b	t	q	p	h	s	o	e

2. The numerical roots corresponding to the atomic number are put together and ‘ium’ is added as suffix
3. The final ‘n’ of ‘enn’ is omitted when it is written before ‘nil’ (enn + nil = enil) similarly the final ‘i’ of ‘bi’ and ‘tri’ is omitted when it is written before ‘ium’ (bi + ium = bium; tri + ium = trium)
4. The symbol of the new element is derived from the first letter of the numerical roots.

The following table illustrates these facts.

Table 3.9 Name of elements with atomic number above 100

Atomic number	Temporary Name	Temporary Symbol	Name of the element	Symbol
101	Unnilunium	Unu	Mendelevium	Md
102	Unnilbium	Unb	Nobelium	No
103	Unniltrium	Unt	Lawrencium	Lr
104	Unnilquadium	Unq	Rutherfordium	Rf
105	Unnilpentium	Unp	Dubnium	Db
106	Unnilhexium	Unh	Seaborgium	Sg
107	Unnilseptium	Uns	Bohrium	Bh
108	Unniloctium	Uno	Hassium	Hs

Atomic number	Temp. Name	Temp. Symbol	Name of the element	Symbol
109	Unnilennium	Une	Meitnerium	Mt
110	Ununnilium	Uun	Darmstadtium	Ds
111	Unununium	Uuu	Roentgenium	Rg
112	Ununbium	Uub	Copernicium	Cn
113	Ununtrium	Uut	Nihonium	Nh
114	Ununquadium	Uuq	Flerovium	Fl
115	Ununpentium	Uup	Moscovium	Mc
116	Ununhexium	Uuh	Livermorium	Lv
117	Ununseptium	Uus	Tennessine	Ts
118	Ununoctium	Uuo	Oganesson	Og

Evaluate Yourself



2. The element with atomic number 120 has not been discovered so far. What would be the IUPAC name and the symbol for this element? Predict the possible electronic configuration of this element.

3.4 Grouping of Elements based on Electronic Configurations

In the modern periodic table, the elements are organised in 7 periods and 18 groups based on the modern periodic law. The placement of element in the periodic table is closely related to its outer shell electronic configuration. Let us analyse the change in the electronic configuration of elements along the periods and down the groups.

3.4.1 Variation of Electronic Configuration along the periods

We have already learnt that each period starts with the element having general outer electronic configuration ns^1 and ends with ns^2, np^6 where n is the period number. The first period starts with the filling of valence electrons in 1s orbital, which can accommodate only two electrons. Hence, the first period has two elements, namely hydrogen and helium. The second period starts with the filling of valence electrons in 2s orbital followed by three 2p orbitals with eight elements from lithium to neon. The third period starts with filling of valence electrons in the 3s orbital followed by 3p orbitals. The fourth period starts with filling of valence electrons from 4s orbital followed by 3d and 4p orbitals in accordance with Aufbau principle. Similarly, we can explain the electronic configuration of elements in the subsequent periods (Table 3.10).

Table 3.10 Electronic configuration of elements in a period

Period number (n)	Filling of electrons in orbitals		Number of elements	Outer shell Electronic configuration	
	Starts from	Ends with		First element	Last element
1	1s	1s	2	H – 1s ¹	He – 1s ²
2	2s	2p	8	Li – 2s ¹	Ar – 2s ² 2p ⁶
3	3s	3p	8	Na – 3s ¹	Ne – 3s ² 3p ⁶
4	4s	3d 4p	18	K – 4s ¹	Kr – 4s ² 4p ⁶
5	5s	4d 5p	18	Rb – 5s ¹	Xe – 5s ² 5p ⁶
6	6s	4f 5d 6p	32	Cs – 6s ¹	Rn – 6s ² 6p ⁶
7	7s	5f 6d 7p	32	Fr – 7s ¹	Og – 7s ² 7p ⁶

In the fourth period the filling of 3d orbitals starts with scandium and ends with zinc. These 10 elements are called first transition series. Similarly 4d, 5d and 6d orbitals are filled in successive periods and the corresponding series of elements are called second, third and fourth transition series respectively.

In the sixth period the filling of valence electrons starts with 6s orbital followed by 4f, 5d and 6p orbitals. The filling up of 4f orbitals begins with Cerium (Z=58) and ends at Lutetium (Z=71). These 14 elements constitute the first inner-transition series called Lanthanides. Similarly, in the seventh period 5f orbitals are filled, and it's -14 elements constitute the second inner-transition series called Actinides. These two series are placed separately at the bottom of the modern periodic table.

3.4.2 Variation of Electronic Configuration in the Groups:

Elements of a group have similar electronic configuration in the outer shell. The general outer electronic configurations for the 18 groups are listed in the Table 3.11. The groups can be combined as s, p, d and f block elements on the basis of the orbital in which the last valence electron enters.

The elements of group 1 and group 2 are called s-block elements, since the last valence electron enters the ns orbital. The group 1 elements are called alkali metals while the group 2 elements are called alkaline earth metals. These are soft metals and possess low melting and boiling points with low ionisation enthalpies. They are highly reactive and form ionic compounds. They are highly electropositive in nature and most of the elements imparts colour to the flame. We will study the properties of these group elements in detail in subsequent chapters.

The elements of groups 13 to 18 are called p-block elements or representative elements and have a general electronic configuration ns^2, np^{1-6} . The elements of the group 16 and 17 are called chalcogens and halogens respectively. The elements of 18th group contain completely filled valence shell electronic configuration (ns^2, np^6) and are called inert gases or nobles gases. The elements of p-block have high negative electron gain enthalpies. The ionisation energies are higher than that of s-block elements. They form mostly covalent compounds and shows more than one oxidation states in their compounds.

The elements of the groups 3 to 12 are called d-block elements or transition elements with general valence shell electronic configuration $ns^{1-2}, (n-1)d^{1-10}$. These elements also show more than one oxidation state and form ionic, covalent and co-ordination compounds. They can form interstitial compounds and alloys which can also act as catalysts. These elements have high melting points and are good conductors of heat and electricity.

The lanthanides ($4f^{1-14}, 5d^{0-1}, 6s^2$) and the actinides ($5f^{0-14}, 6d^{0-2}, 7s^2$) are called f-block elements. These elements are metallic in nature and have high melting points. Their compounds are mostly coloured. These elements also show variable oxidation states.

Table 3.11 General outer electronic configuration of elements in groups:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ns^1	ns^2	$ns^2(n-1)d^1$	$ns^2(n-1)d^2$	$ns^2(n-1)d^3$	$ns^1(n-1)d^5$	$ns^2(n-1)d^5$	$ns^2(n-1)d^6$	$ns^2(n-1)d^7$	$ns^2(n-1)d^8$	$ns^1(n-1)d^{10}$	$ns^2(n-1)d^{10}$	$ns^2 np^1$	$ns^2 np^2$	$ns^2 np^3$	$ns^2 np^4$	$ns^2 np^5$	$ns^2 np^6$
s Block elements	d-Block elements												p-Block elements				
f block elements	Lanthanides $4f^{1-14} 5d^{0-1} 6s^2$																
	Actinides $5f^{0-14} 6d^{0-2} 7s^2$																

Evaluate Yourself



3. Predict the position of the element in periodic table satisfying the electronic configuration $(n-1)d^2, ns^2$ where $n=5$

3.5 Periodic Trends in Properties

As discussed earlier, the electronic configuration of the elements shows a periodic variation with increase in atomic numbers. Similarly a periodic trend is observed in physical and chemical behaviour of elements. In this section, we will study the periodic trends in the following properties of elements.

1. Atomic radius
2. Ionic radius
3. Ionisation enthalpy (energy)
4. Electron gain enthalpy (electron affinity)
5. Electronegativity

3.5.1 Atomic radius

Atomic radius of an atom is defined as the distance between the centre of its nucleus and the outermost shell containing the valence electron.

It is not possible to measure the radius of an isolated atom directly. Except for noble gases, usually atomic radius is referred to as covalent radius or metallic radius depending upon the nature of bonding between the concerned atoms.

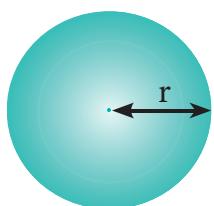


Figure 3.1 (a) Atomic radius

Covalent radius

It is one-half of the internuclear distance between two identical atoms linked together by a single covalent bond. Inter nuclear distance can be determined using x-ray diffraction studies.

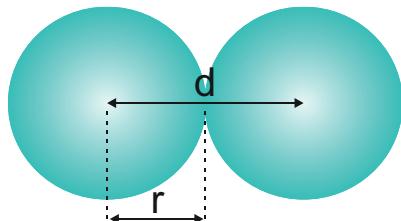


Figure 3.1 (b) Atomic and covalent radius

Example:

The experimental internuclear distance in Cl_2 molecule is 1.98 Å. The covalent radius of chlorine is calculated as below.

$$\begin{aligned} d_{\text{Cl-Cl}} &= r_{\text{Cl}} + r_{\text{Cl}} \\ \Rightarrow d_{\text{Cl-Cl}} &= 2r_{\text{Cl}} \\ \Rightarrow r_{\text{Cl}} &= \frac{d_{\text{Cl-Cl}}}{2} \\ &= \frac{1.98}{2} = 0.99\text{\AA} \end{aligned}$$

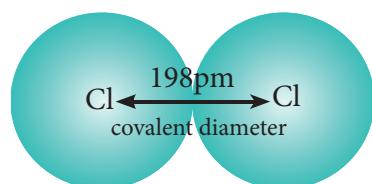


Figure 3.1 (c) Covalent radius of Cl

$$\begin{aligned} \text{The covalent radius of chlorine} &= \frac{198}{2} \text{ pm} \\ &= 99 \text{ pm} \end{aligned}$$

The formation of covalent bond involves the overlapping of atomic orbitals and it reduces the expected internuclear distance. Therefore covalent radius is always shorter than the actual atomic radius.

The covalent radius of individual atom can also be calculated using the internuclear distance (d_{A-B}) between two different atoms A and B. The simplest method proposed by Schomaker and Stevenson is as follows.

$$d_{A-B} = r_A + r_B - 0.09 (\chi_A - \chi_B)$$

where χ_A and χ_B are the electronegativities of A and B respectively in Pauling units. Here $\chi_A > \chi_B$ and radius is in Å.

Let us calculate the covalent radius of hydrogen using the experimental d_{H-Cl} value is 1.28 Å and the covalent radius of chlorine is 0.99 Å. In pauling scale the electronegativity of chlorine and hydrogen are 3 and 2.1 respectively.

$$\begin{aligned} d_{H-Cl} &= r_H + r_{Cl} - 0.09 (\chi_{Cl} - \chi_H) \\ 1.28 &= r_H + 0.99 - 0.09 (3 - 2.1) \\ 1.28 &= r_H + 0.99 - 0.09 (0.9) \\ 1.28 &= r_H + 0.99 - 0.081 \\ 1.28 &= r_H + 0.909 \\ \therefore r_H &= 1.28 - 0.909 = 0.317 \text{ Å} \end{aligned}$$

Metallic radius

It is defined as one-half of the distance between two adjacent metal atoms in the closely packed metallic crystal lattice.

For example, the distance between the adjacent copper atoms in solid copper is 2.56 Å and therefore the metallic radius of copper is

$$\frac{2.56}{2} = 1.28 \text{ Å}$$

The metallic radius can be calculated using the unit cell length of the metallic crystal. You will study the detailed calculation procedure in XII standard solid state unit.

Periodic Trends in Atomic Radius

Variation in Periods

Atomic radius tends to decrease in a period. As we move from left to right along a period, the valence electrons are added to the same shell. The simultaneous addition of protons to the nucleus, increases the nuclear charge, as well as the electrostatic attractive force between the valence electrons and the nucleus. Therefore atomic radius decreases along a period.

Effective nuclear charge

In addition to the electrostatic forces of attraction between the nucleus and the electrons, there exists repulsive forces among the electrons. The repulsive force between the inner shell electrons and the valence electrons leads to a decrease in the electrostatic attractive forces acting on the valence electrons by the nucleus. Thus, the inner shell electrons act as a shield between the nucleus and the valence electrons. This effect is called shielding effect.

The net nuclear charge experienced by valence electrons in the outermost shell is called the effective nuclear charge. It is approximated by the below mentioned equation.

$$Z_{\text{eff}} = Z - S$$