ENGINEERING CHEMISTRY I & II

DIPLOMA COURSE IN ENGINEERING AND TECHNOLOGY

FIRST AND SECOND SEMESTER

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Untouchability is a sin
Untouchability is a crime
Untouchability is in human

DIRECTORATE OF TECHNICAL EDUCATION
GOVERNMENT OF TAMILNADU

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THE NATIONAL ANTHEM

FULL VERSION

Jana-gana-mana-adhinayaka jaya he
Bharata-bhagya-vidhata
Punjaba-Sindhu-Gujarata-Maratha-
Dravida-Utkala-Banga
Vindhya-Himachala-Yamuna-Ganga
Uchchhala-jaladhi-taranga
Tava Subha name jage,TavaSubhaasisa mage,
Gahe tava jaya-gatha.
Jana-gana-mangala-dayaka jaya he
Bharata-bhagya-vidhata.
Jaya he, jaya he, jaya he,
Jaya jaya jaya jaya he.

- **Rabindranath Tagore**

SHORT VERSION

Jana-gana-mana-adhinayaka jaya he
Bharata-bhagya-vidhata.
Jaya he, jaya he, jaya he,
Jaya jaya jaya jaya he.

AUTHENTIC ENGLISH TRANSLATION OF THE NATIONAL ANTHEM

Thou art the ruler of the minds of all people,
Thou dispenser of India's destiny.
Thy name rouses the hearts of the Punjab, Sind,
Gujarat and Maratha, of Dravida, Orissa and Bengal
It echoes in the hills of the Vindhyas and Himalayas,
mingles in the music of the Yamuna and Ganges
and is chanted by the waves of the Indian Sea.
They pray for Thy blessings and sing Thy praise
The saving of all people waits in Thy hand,
Thou dispenser of India's destiny.
Victory, Victory, Victory to Thee

THE NATIONAL INTEGRATION PLEDGE

"I solemnly pledge to work with dedication to preserve and strengthen the
freedom and integrity of the nation."
"I further affirm that I shall never resort to violence and that all differences and
disputes relating to religion, language, region or other political or
economic grievances should be settled by peaceful and
constitutional means."

INVOCATION TO GODDESS TAMIL

Bharat is like the face beauteous of Earth clad in wavy seas;
Deccan is her brow crescent-like on which the fragrant 'Tilak' is the blessed
Dravidian land.
Like the fragrance of that 'Tilak' plunging the world in joy supreme reigns
goddess Tamil with renown spread far and wide.
Praise unto You, goddess Tamil, whose majestic youthfulness, inspires awe and
ecstasy

PREFACE

Engineering is the application of the principles of basic science. The three subjects viz. Mathematics, Physics and Chemistry, contribute to the basic science. Now a days, Engineering, also exploit the biological principles, particularly in the field of biotechnology, nanotechnology, artificial intelligence and genetic engineering.

Chemistry is a branch of science which deals with the matter in and around us. It answers many fundamental questions like, What is air? What is water? What is this earth made up of? and so on. After all everything comes under the boundary of 118 elements – a Chemist says. However, deeper questions arise in our mind and the science expands its horizon.

The present book Engineering Chemistry compiled for Diploma Engineering students restrict itself to certain limits, where it concentrates on useful applications viz. softening of hard water, nuclear chemistry, metallurgy, electrochemistry, construction of battery, preventions of corrosion. and engineering materials like cement, ceramics, abrasives and composite materials. Enriching social awareness is an important component of education, hence, environmental engineering aspects like air pollution, water pollution, green chemistry are also included, Meticulous care is taken, in the correctness and clarity of concepts and data provided. To have a complete understanding of all the elements composed in this vast universe, periodic classification of elements is again introduced in the content. Every concept is explained in simple words in a precise manner that suits the understanding of students passed out from school.

On behalf my co-authors I would like to express my gratitude to Shri. K. Vivekanandan, IAS, Commissioner of Technical Education for having given this responsibility of bringing out this text book successfully and to his valuable suggestions. He has taken personal care and insisted to introduce value additions in the form many exercises like activity, fact store, QR code etc. which will definitely help the students for thorough understanding. It will also help the students to think out of box and they can prepare themselves for the project in future.

Thanks are also due to the Additional Director of Technical Education (exam), Dr. M. Arularasu, Dr. Sriram Babu, Additional Director (Planning), and the Coordinator. We would like to thank the Government press for successful printing of this text book. Last, but not least our thanks to the Special Officers Mr. A.M. Rafeek , Dr. V. Rajkumar and to his team of curriculum development cell of Directorate of Technical Education, without their team effort this publication would not have become complete.

This book is prepared with utmost care in accordance with the N – Scheme, provided by the State Board of Technical Education and Training, Tamil Nadu. Comments and suggestions are most welcome in the improvement of the book. Mail your suggestions to dote.nscheme@gmail.com.

- Authors

ANNEXURE

STATE BOARD OF TECHNICAL EDUCATION & TRAINING, TAMILNADU DIPLOMA IN ENGINEERING / TECHNOLOGY SYLLABUS

N-SCHEME

(Implements from the Academic year 2020-21 onwards)

Course Name : **All branches of Diploma in Engineering and Technology and Special Programmes except DMOP, HMCT and film &TV.**

Subject Code: **40014**

Semester : **I –Semester**

Subject Title : **ENGINEERING CHEMISTRY –I**

TEACHING AND SCHEME OF EXAMINATION:

No. of Weeks per Semester: 16 Weeks

Subject	Instructions		Examination			
	Hours / Week	Hours / Semester	Marks			Duration
			Internal Assessment	Board Examination	Total	
ENGINEERING CHEMISTRY - I	**5**	**80**	**25**	**100**	**100**	**3 Hrs**

Topics and Allocation of Hours:

Sl. No	Topics	Time (Hrs)
1	**Basic Concepts in Chemistry**-Atomic Structure and Chemical Bonding, Periodic Table, Acids and Bases	**15 Hours**
2	**Surface Chemistry** -Colloids, Nanotechnology, Catalysis	**15 Hours**
3	**Minerals and Metallurgy -** Metallurgy of Iron, Metallurgy of Tungsten and Titanium, Powder metallurgy	**15 Hours**
4	**Industrial Chemistry -** Nuclear Chemistry, Cement, Ceramics, Refractories and Glass	**15 Hours**
5	**Chemistry of Engineering Materials** Polymer, Abrasives, Composite Materials	**13 Hours**
	Test and Model Examinations	**7 Hours**
	Total	**80 Hours**

RATIONALE:

The subject Engineering Chemistry-I lay foundation of all the elements, structure and periodic classification. The latest trends on nano technology, its application on various fields of engineering is also dealt with. It provides basic concepts about minerals and its resources, the metal extraction, heat treatment and powder metallurgy. It also imparts knowledge about few Engineering Materials like cement, ceramics, refractory and glass. It also dealt with polymers, abrasives and composite materials.

OBJECTIVES:

The objective of this Course is to make the student:

1. Know about atomic structure, chemical bonding, periodic classification and acids and bases.
2. Learn about surface chemistry, colloidal particles and nano-particles and their application.
3. Know about the mineral resources of Tamil Nadu and the fundamentals of metal extraction, iron and steel manufacture, heat treatment and powder metallurgy.
4. Study about the importance of Engineering Chemistry in industry.
5. Know about Engineering materials like cement, ceramics, refractory, glass, rubber, plastic and composites.

ENGINEERING CHEMISTRY–I

DETAILED SYLLABUS

Unit	Name of the Topic	Hours
I	**BASIC CONCEPTS IN CHEMISTRY** **1.1 Atomic Structure and Chemical Bonding** Fundamental particles – proton–electron–neutron–atomic number – mass number – extra nuclear part – filling up of electrons –aufbau principle–s–p–d–f orbital – electronic configuration-definition of atomic mass, molecular mass, equivalent mass, valency – octet rule – electrovalent bond –sodium chloride formation – covalent bond – formation of ammonia	6 Hrs
	1.2 Periodic Table Modern periodic law – periodic classification of elements – features of modern periodic table – properties of s–p–d–f block elements.	4 Hrs
	1.3 Acids and Bases Properties of acids and bases–Lewis concept of acids and bases – advantages–pH and pOH– Definition – Numerical problems – Indicator – Definition – Buffer solution – Definition – Types of buffer solution with examples– Application of pH in industries	5 Hrs
II	**SURFACE CHEMISTRY**	
	2.1 Colloids Colloids – Definition-True solution and Colloidal solution –– Differences – Types of colloids –Lyophilic and Lyophobic colloids Differences – Properties – Tyndall effect – Brownian movement – Electrophoresis and Coagulation – Industrial applications of colloids Smoke Precipitation by Cottrell's method, Purification of water, Cleansing action of soap, Sewage disposal – tanning–and artificial rain.	6 Hrs
	2.2 Nanotechnology Nano particles – definition – properties – application of Nanotechnology – Engineering – medicine – biomaterial.	4 Hrs
	2.3 Catalysis Catalyst – Definition-Positive – Negative catalyst – Definition – Types of catalysis – Homogeneous and Heterogeneous – Promoter – Catalyst poison – active centre – Definition – Characteristics of a catalyst – Industrial applications of catalysts.	5 Hrs

Unit	Name of the Topic	Hours
III	**MINERALS AND METALLURGY** **3.1 Minerals and Metallurgy** Minerals – Minerals of Tamil Nadu – Sources and Uses (Basic concepts only) - Extraction of iron-Blast furnace – cast iron – steel manufacture – Bessemer converter – heat treatment of steel – hardening – annealing – tempering	7 Hrs
	3.2 Metallurgy of Tungsten and Titanium Extraction and uses of Tungsten and Titanium.	4 Hrs
	3.3 Powder metallurgy Definition – Powder metallurgical process – Preparation of Metal Powder – Atomization – Reduction of Metal Oxide – blending – compacting – sintering – finishing – Applications of Powder Metallurgy.	4 Hrs
IV	**INDUSTRIAL CHEMISTRY** **4.1 Nuclear Chemistry** Nuclear reaction-Differences between nuclear reaction and ordinary chemical reaction- Radioactive decay – alpha emission – beta emission – gamma emission – half life period – simple problems – Nuclear fission – nuclear fusion – chain reaction – components of nuclear reactor –reactor core – nuclear reactor coolant – Control rods – neutron moderator – steam turbine, Application of radioactive isotopes.	6 Hrs
	4.2 Cement and ceramics Definition – Manufacture of Portland Cement – Wet Process – Setting of Cement (No equation) –Ceramics – White pottery – Definition – Manufacture of White pottery – Uses – Definition of glazing – purpose – Method – Salt glazing – liquid glazing.	5 Hrs
	4.3 Refractories and Glass Definition – requirements of a good refractory – types with examples and uses–uses of silica, fireclay and alumina. Composition of glass – Manufacture of glass – annealing of glass – Varieties – of Glass – Optical glass, Wind shield glass and Photo chromatic glass	4 Hrs

Unit	Name of the Topic	Hours
V	**CHEMISTRY OF ENGINEERING MATERIALS** **5.1 Polymer** Definition – Natural polymer – Rubber – Defects of natural rubber – Compounding of rubber – Ingredients and their functions – Vulcanization – Plastics – types – Thermoplastics and Thermo set plastics – Differences – Mechanical properties of plastics – Polymers in Surgery – Biomaterials – Definition – Biomedical uses of Polyurethane, PVC, Polypropylene and Polyethylene.	**6 Hrs**
	5.2 Abrasives Definition – classification – hardness in Moh's scale – Natural abrasives – Diamond, Corundum, Emery, and Garnet. – Synthetic abrasives – Carborundum – Boron carbide manufacture – properties and uses.	**4 Hrs**
	5.3 Composite Materials Definition–examples – Classification of composites – Advantages over metals and polymers – General application.	**3 Hrs**

STATE BOARD OF TECHNICAL EDUCATION & TRAINING, TAMILNADU
DIPLOMA IN ENGINEERING / TECHNOLOGY SYLLABUS
N-SCHEME

(Implements from the Academic year 2020-21 onwards)

Course Name : **All branches of Diploma in Engineering and Technology and Special Programmes except DMOP, HMCT and film & TV.**

Subject Code: **40024**

Semester: **II Semester**

Subject Title: **ENGINEERING CHEMISTRY – II**

TEACHING AND SCHEME OF EXAMINATION:

No. of Weeks per Semester: 16 Weeks

Subject	Instructions		Examination			
			Marks			**Duration**
	Hours / Week	**Hours / Semester**	**Internal Assessment**	**Board Examination**	**Total**	
ENGINEERING CHEMISTRY - II	4	64	25	100	100	3 Hrs

Topics and Allocation of Hours:

Sl. No	Topics	Time (Hrs)
1	**Electro Chemistry:** Electro Chemistry-I, Electro Chemistry-II, Energy Sources	12 Hours
2	**Chemistry of Corrosion and Prevention :** Corrosion –theory of corrosion-Methods of Prevention of Corrosion, Organic Coatings	11 Hours
3	**Energy Chemistry:** Fuels, Combustion, Rocket Propellants	11 Hours
4	**Applied Chemistry:** Technology of water – I, Technology of water –II	11 Hours
5	**Environmental Chemistry:** Air Pollution, Water Pollution, Solid Waste Management and Green Chemistry	12 Hours
	Test and Model Examinations	7 Hours
	Total	**64 Hours**

RATIONALE:

The subject Engineering Chemistry – II develop basic understanding about electro chemistry, energy resources, corrosion, methods of prevention of corrosion and its organic coatings.

Energy chemistry explains various aspects with regard to fuels, combustion and rocket propellants.

Prime importance is given to technology of water, its analysis of few parameters like pH, TDS, Hardness, dissolved chlorine, e-coli etc.

Environmental chemistry explains environmental pollution, solid waste management and green chemistry.

OBJECTIVES:

The objective of this Course is to make the student:

1. To acquire knowledge about electro chemistry, electro chemical cell.
2. To know about corrosion and prevention.
3. To acquire knowledge about fuels, combustion of fuels and rocket propellants.
4. To know about water and its analysis.
5. To acquire knowledge about Environmental Chemistry.

40024 ENGINEERING CHEMISTRY–II

DETAILED SYLLABUS

Contents : Theory

Unit	Name of the Topic	Hours
I	**ELECTRO CHEMISTRY** **1.1 Electrochemistry-I** Electronic concept of oxidation and reduction-Faradays laws of electrolysis-simple problems-electrolytes-non electrolytes-electrolysis-definition-Mechanism – Industrial applications of Electrolysis –electroplating-chrome plating	**5 Hrs.**
	1.2 Electro Chemistry-II Electrochemical cell – Definition Galvanic cell – Formation of Daniel cell – Electrochemical series – Definition – significance	**4 Hrs**
	1.3 Energy Sources Primary Battery – Secondary Battery – Definition and example – cell – Construction, Working principle and Uses of Lead – acid Storage battery – Lithium ion-battery- Non – conventional Energy Sources – Solar Cell – Definition – working principle.	**3 Hrs**
II	**CHEMISTRY OF CORROSION AND PREVENTION** **2.1 Corrosion** Definition – types of corrosion – theories of corrosion – galvanic cell formation theory – differential aeration theory – factors influencing rate of corrosion.	**4 Hrs**
	2.2 Methods of Prevention of Corrosion Galvanization – tinning – anodisation – cathodic protection – sacrificial anode method and impressed voltage method.	**4 Hrs**
	2.3 Organic Coatings Paint – definition – Components of paints – Varnish – definition –Preparation of oil varnish – differences between paint and varnish – Special Paints – Luminescent paint, fire retardant paint, Aluminum paint and distemper.	**3 Hrs**

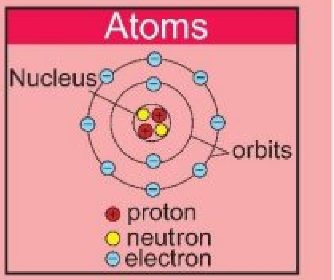
Unit	Name of the Topic	Hours
III	**ENERGY CHEMISTRY** **3.1 Fuels** Fuel – Definition – Calorific value – calorie – Liquid fuels – liquid hydrogen – power alcohol – uses – Refining of Petroleum – Fractional distillation – Cracking (Concept only) – Gaseous fuels – Preparation, composition and specific uses of Producer gas and Water gas – Composition and uses of CNG and LPG – advantages of gaseous fuels.	**4 Hrs**
	3.2 Combustion Definition – Combustion calculation by mass (for solid and liquid fuels) – Stoichiometric calculations – Volume of air required – Definition of Flue gas – Flue gas Analysis – Orsat Apparatus – Simple numerical problems.	**4 Hrs**
	3.3 Rocket Propellants Definition – characteristics – Classification of propellants – brief idea of solid and liquid propellants.	**3 Hrs**
IV	**APPLIED CHEMISTRY** **4.1 Technology of Water – I** Sources of water – depletion of underground water – Reasons – Rain water harvesting (Basic ideas) – advantages – Hard water and soft water – Hardness of water – Carbonate and Non – carbonate hardness – Methods of expressing hardness – mg/lit and ppm – Simple problems – Disadvantages of hard water – Estimation of total hardness by EDTA method – Problems involving Total, Carbonate and Non – carbonate hardness in ppm – Disadvantages of using hard water in boilers – Scale formation, Corrosion of boiler metal, Caustic Embrittlement – Priming and Foaming.	**6 Hrs**
	4.2 Technology of Water –II Softening of hard water–Ion – Exchange method and Reverse Osmosis method – Municipal supply – purification of drinking water–Quality of potable water (WHO standard)– parameters of potable water – pH–TDS – Residual Chlorine permissible limits – determination of e-coli (preliminary idea)	**5 Hrs**

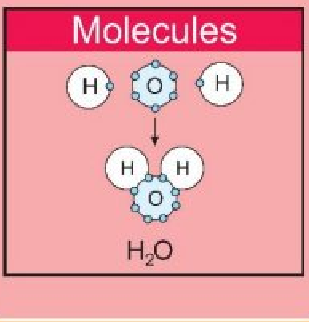
Unit	Name of the Topic	Hours
V	**ENVIRONMENTAL CHEMISTRY** **5.1 Air Pollution** Pollution and Air pollution – Definition – Air pollutants (SO_2, H_2S, HF, CO and Dust) – Sources and Harmful effects – smog& types – Formation of Acid Rain – Harmful effects – Green House Effect – Causes – Global warming – Harmful effects – Ozone Layer – Importance – Causes for Depletion of Ozone Layer (No equations) – Harmful effects of Ozone Layer Depletion – Control of Air Pollution.	**4 Hrs**
	5.2 Water Pollution Causes of Water Pollution – Sewage, Effluents, Algae and Microorganisms – Harmful effects –Definition – Sewage– Sewerage – Disposal– Industrial Effluents – Harmful effects of Effluents Treatment of Effluents – Eutrophication–definition–harmful effects.	**4 Hrs**
	5.3 Solid Waste Management and Green Chemistry Solid Waste – Definition – Problems – Types of Solid Waste – Methods of disposal – Land fill and Incineration – Recycling –Definition – Examples – Advantages of Recycling (Basic ideas**)** Green Chemistry Definition – Goals of Green Chemistry (Basic ideas)	**4 Hrs**

CONTENTS

FIRST SEMESTER

SECOND SEMESTER





□ **Solid**

○ **Liquid**

⬭ **Gas**

at room temperature

The colour of the symbol is the colour of element in its most common pure form.

Examples ▨ metallic solid
● red liquid
○ colourless gas

Human Body
top ten elements by weight

Earth's Crust
top eight elements by weight

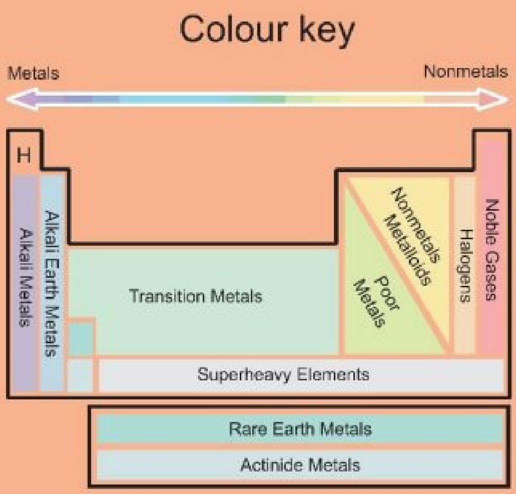
Magnetic
ferromagnetic at room temperature

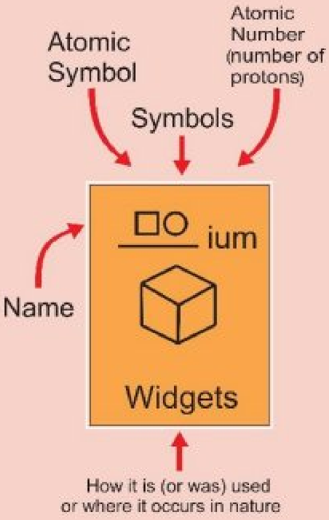
Noble Metals
corrosion-resistant

☢ **Radioactive**
all isotopes are radioactive

Only Traces Found in Nature
less than a millionth percent of earth's crust

✗ **Never Found in Nature**
only made by people





UNIT

1 BASIC CONCEPTS IN CHEMISTRY

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1.1 ATOMIC STRUCTURE AND CHEMICAL BONDING

Fundamental particles – proton–electron–neutron–atomic number – mass number – extra nuclear part – filling up of electrons –aufbau principle–s–p–d–f orbitals–electronic configuration-atomic mass, molecular mass, equivalent mass, valency (definitions only)– octet rule – electrovalent bond –sodium chloride formation – covalent bond – formation of ammonia **- 6 Hours**

Introduction

Chemistry is a branch of science that deals with the study of the nature of matter, its composition, occurrence, and isolation, methods of preparation, properties and uses.

Matter

Anything which occupies some space or anything that you can see, hear, smell, taste or touch is called matter. John Dalton, an English school teacher in the year 1807 revived the ancient view of matter and formulated the first atomic theory as "matter is composed of extremely small particles (in the order of 10^{-8} cm) called atoms". We should feel proud to mention here that old Tamil scriptures uses the term called 'anu' in early 2nd century, particularly in — Vinayagar Agaval The word 'atom' also comes from the Greek word 'atomos', meaning 'unable to cut'.

Atom

An **atom** is the smallest particle that retains the properties of the atom. It is the smallest particle, chemically indivisible. Now we know how to divide atoms into sub-atomic particles. An Atom is the smallest invisible particle of element, having all the characteristics of the parent element, which can neither be created nor be destroyed by any chemical change. It cannot exist freely. It is the ultimate particle of an element, which may or may not have independent existence.

All elements are composed of atoms ; the atoms of certain elements such as hydrogen, oxygen, nitrogen, etc. do not have independent existence whereas atoms of helium, neon, argon, etc. do have independent existence.

Fundamental particles of an atom

The atoms of all elements are made up of three main particles known as fundamental particles. They are electrons, protons and neutrons. Hydrogen is the only element that do not have neutron.

Proton

1. The proton is present in atoms of all the elements.
2. The protons is a positively charged particle.
3. It has unit a positive charge and unit mass. The mass of proton is approximately equal to the mass of one hydrogen atom. It is equal to 1.00732 amu. (atomic mass unit).
4. The proton is present inside the nucleus of an atom.
~~~~~~

Electron

1. The electron is a negatively charged particle.
2. It has unit negative charge and negligible mass.
3. The mass of an electron is about 1/1837 of mass of a hydrogen atom.
4. Electrons are present in all the atoms.
5. Electrons are revolving around the nucleus in definite orbits (shell).

Neutron

1. The neutron is a neutral particle. Hence, it has no charge. It has a unit mass.
2. The neutron is present in atoms of all elements except hydrogen. The mass of a neutron is slightly greater than the mass of a proton. It is equal to 1.00871 amu.
3. Neutron is present inside the nucleus of an atom.

Atomic number (Z)

The atomic number is the number protons present in the nucleus of an atom or number of electrons revolving around the nucleus in an atom.

Atomic number= Number of protons = Number of electrons

Mass number (A)

The mass number of an element is given by the total number of protons and neutrons present in the nucleus of an atom.

A= (P+N)

Therefore the number of neutrons is = A-Z.

Structure of an atom:

An atom consists of two parts. They are 1. The central nucleus 2. The outer extra nuclear part.

1. The central Nucleus:

The nucleus is the central part of an atom consists of protons and neutrons. They are together called nucleons. Since the protons are positively charged particle and neutrons are neutral, the nucleus is always positive part of an atom. The entire weight of an atom relies only on the nucleus.

2. The outer extra nuclear part

1. It is the part around the nucleus. It contains all electrons of an atom. It is the negative part of the atom. The electrons are revolving around the nucleus in a regular path called shells or orbits or energy levels.
2. These shells are numbered, as 1,2,3,4 etc. from the nucleus. This number is called principal quantum number(n). They are also designated as K, L, M, N shells, etc.
3. Each shell can accommodate only certain number of electron, which is given by the formula $2n^2$**,** where 'n' is the principal quantum number. Therefore, the numbers of electrons that can be accommodated in the 1st, 2nd, 3rd,4th shell respectively are 2,8,18, 32 etc.
4. Each shell has sub energy level or sub shell, they are called s, p, d, f etc.
5. Thus s-sub shell has only one orbital, p-sub shell has 3 orbitals, d sub shell has 5 orbitals, and f sub shell has 7 orbitals. Each orbital can accommodate only two electrons.

Shell	Principal quantum number(n)	Number of electrons ($2n^2$)	Number of sub shells	Name of the sub shells
K	**1**	**2**	**1**	**s**
L	**2**	**8**	**2**	**s, p**
M	**3**	**18**	**3**	**s, p, d**
N	**4**	**32**	**4**	**s, p, d, f**

6. Thus s shell can accommodate 2 electrons, p-sub shell can have 6 electrons, d-sub shell can have 10 electrons and f-sub shells can have 14 electrons.

Sub shell	orbitals	Number of electrons
s	□	**2**
p	□□□	**6**
d	□□□□□	**10**
f	□□□□□□□	**14**

7. The electrons present in the outer most orbit are called **valence electrons**.

8. Since the number of protons (positively charges) is equal to the number of electrons (negative charges) an atom as whole is a neutral one. **The atomic structure of Sodium atom is given here.**

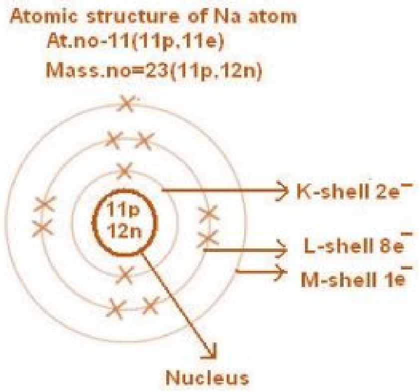


Fig.1.1.1. Structure of sodium atom

Aufbau principle states that in the ground state of an atom, the orbitals are filled in the increasing order of the energy.

In other words, electrons first occupy the lowest possible energy orbital available and enter into higher energy orbital only after the lower energy orbital is filled. As you have learnt above, energy of a given orbital depends upon effective nuclear charge and the type of orbitals. Thus, there is no single ordering of energies of orbitals which is universally correct for all atoms.However, following order orbitals is extremely useful:

1*s*, 2*s*, 2*p*, 3*s*, 3*p*, 4*s*, 3*d*, 4*p*, 5*s*, 4*d*, 5*p*, 6s, 4*f*, 5*d*, 6*p*, 7*s*...

The orbitals s, p, d, f are called sub shells. The order may be remembered by using the method given in Fig. 1.1.2. Starting from the top, the direction of the arrows gives the order of filling of orbitals, that is starting from top right to bottom left.

With respect to placement of outer most valence electrons, it is remarkably accurate for all atoms. For example, valence electron in potassium must choose between 3*d* and 4*s* orbitals and as predicted by this sequence, it is found in 4*s* orbital.

K_{19} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

Sc_{21} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$

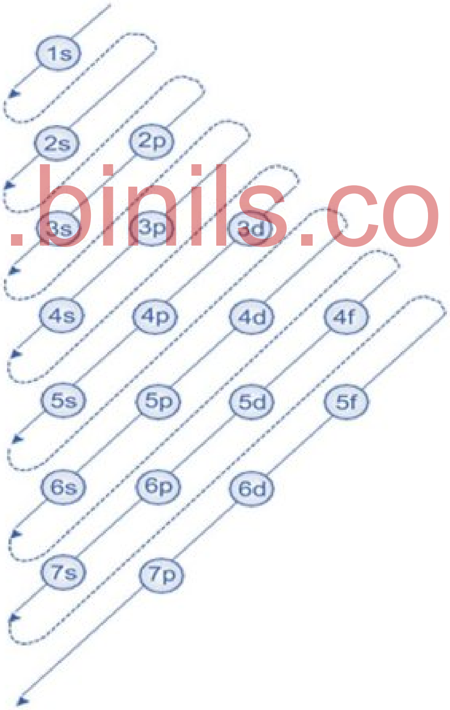
The above order should be assumed to be a rough guide to the filling of energy levels. In many cases, the orbital similar in energy and small changes in atomic structure may bring about a change in the order of filling.

For example

Cr_{24} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

Cu_{29} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$

The reason being any orbital when it is completely filled or exactly half filled it has lower energy and higher stability



Atomic mass: Atomic mass of an element is the ratio of the mass an atom of that element to 1/12th mass of an atom of carbon-12

Molecular mass: Molecular mass of an element is the mass of the molecule of that element to 1/12th mass of an atom of carbon-12.

Equivalent mass: Equivalent mass of an element is the number of parts by weight of that element which can combine with or displaces 1.008 parts by weight of hydrogen or 8 parts by weight of oxygen or 35.45 parts by weight of chlorine or one equivalent mass of any other active element.

Valency: Valency is the combining capacity of an element. It is a mere number.

Chemical bonding

When two atoms in a molecule strongly tend to remain together, they are said to be in chemical bonding with each other. In other words, it is said that a chemical bond has been established between the two atoms. Thus,

"A chemical bond may be defined as an attraction between the two atoms in a molecule" The nucleus of one atom attracts the electrons of the neighboring atom

Why do atoms combine?

There is a deep relationship between the properties and the electrons lying in their outermost orbits. The elements having same number of valence electrons have similar properties. The elements in the zero groups have two or eight electrons in the outermost orbital are chemically inactive. The electronic configuration of the inert gas elements reveal the reason for the inactive nature.

Octet rule

The inert gases have the stable configuration of eight electrons (octet structure) in their outer most orbits except helium which has only 2 electrons. They all have closed shell configuration. Due to their stable octet structure, these gases are inert in nature. They do not chemically react with other elements. According to Lewis –**octet theory, all the elements with an unstable or incomplete electronic configuration have a tendency to attain the stable electronic configuration of the nearest inert gas configuration. They obtain eight electron in the outer most orbital either by complete transfer of valence electron from one atom to another or by mutual sharing of valence electron between the atoms".** This tendency to attain the stable electronic configuration is responsible for the formation of **chemical bonding**.

Inert gases or noble gases

Element	Symbol	Atomic number	Electronic configuration
Helium	He	2	**2**
Neon	Ne	10	2, **8**
Argon	Ar	18	2, 8, **8**
Krypton	Kr	36	2, 8, 18, **8**
Xenon	Xe	54	2, 8, 18, 18, **8**
Radon	Rn	86	2, 8, 18, 32, 18, **8**

Types of bonding

The process by which unstable atoms acquire a stable configuration has been found to take place in two different ways.

1. The complete transfer of valence electron(s) from one atom to another. This is called ionic bond (or) electrovalent bond.
2. The mutual sharing of (pair of) valence electrons between the combining atoms. The shared pair of electrons is given by both atoms. This is called as covalent bond.

Ionic (or) Electrovalent Bond

This type of bond is formed as a result of the complete transfer of one or more electrons from the outermost orbit one atom to other. This bond is generally present in inorganic compounds

Example: Formation of Sodium Chloride Explanation:

The atomic number of sodium is 11. It has 11 protons and 11 electrons i.e., 11 positive charges and 11 negative charges. Thus the electronic configuration is

Z = 11 Na $1S^2$, $2s^2$, $2p^6$, $3s^1$

2, 8, 1

K L M

The electron dot formula of Na is,

Na*

Sodium has only one electron in its outermost orbital. The atomic number of chlorine is 17. Its electronic configuration is

Z = 17 Cl $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^5$

2, 8, 7

K L M

In the third quantum shell, i.e., M-shell has seven electrons. Thus the dot formula can be drawn as. .

$:\dot{Cl}:$

$\cdot\cdot$

Sodium has one electron in excess of the stable neon configuration (2, 8) and chlorine is one electron short of the stable argon configuration (2, 8, 8).

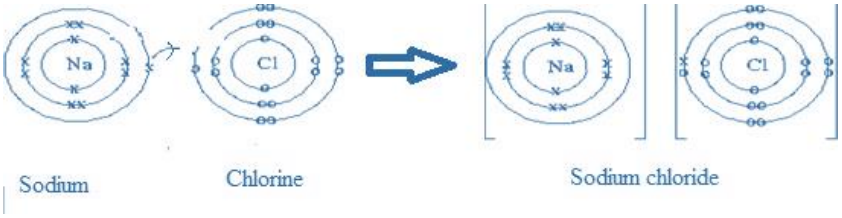


Fig.1.1.3. Formation of sodium chloride

When these atoms are in contact, sodium has a tendency to lose its single valence electron and chlorine has a tendency to accept a single electron to reach the stable electronic configuration of the nearest inert gas. By transferring one electron from sodium to chlorine, sodium acquires a unit positive charge while by gaining the electron; the chlorine atom acquires a unit negative charge.

Now sodium has attained the stable electronic configuration of neon (2,8).Similarly chlorine has attained the stable electronic configuration of neon(2,8,8). Thus sodium ion is more stable than sodium atom and chloride ion is more stable than chorine atom.

These charged ions are held together by electrostatic attraction and form a neutral molecule of sodium chloride.

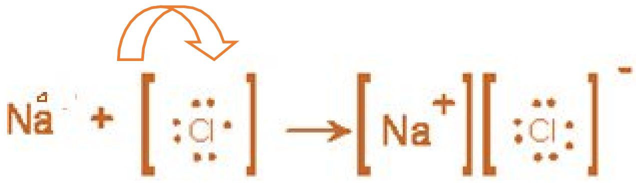


Fig.1.1.4. Formation of ionic bond

Compounds formed in this way are called electrovalent or ionic compounds and the bond is called Ionic bond or electrovalent bond.

Covalent bond- Formation of ammonia (NH_3):

A covalent bond is formed by the equal and mutual sharing a pair of electron between two bonded atoms

Z = The atomic number of nitrogen is 7. Thus the electronic configuration is

N $1s^2$, $2s^2$, $2p^3$. There are 5 electrons in the outermost orbit. It can be shown as

K	L
2	5

Hydrogen has only one electron; the electronic configuration hydrogen is $1s^1$.

To get stable electronic configuration Nitrogen shares its three electrons with electrons of three hydrogen atoms. Ammonia is formed by the covalent bonding between one atom of nitrogen and three atoms of hydrogen. Therefore, it needs three electrons to attain stable inert gas configuration and hydrogen needs one electron to attain the stable inert gas configuration of helium. The nitrogen atom shares three of its valence electron with three hydrogen atom forming three covalent bonds. All the four atoms attain stable configuration. Thus three covalent bonds are formed.

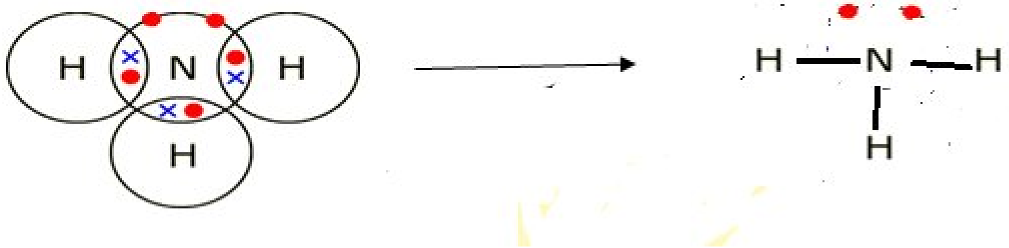


Fig.1.1.5 Formation of ammonia

RECAP

We have studied about the followings:

- Fundamental particles – proton, electron, neutron
- atomic number, mass number
- extra nuclear part – filling up of electrons
- aufbau principle–s–p–d–f orbitals– electronic configuration
- atomic mass, molecular mass, equivalent mass, valency
- octet rule – electrovalent bond ,sodium chloride formation
- covalent bond – formation of ammonia

ENGINEERING CONNECTION

Engineers and scientists not only have the ability to change one element into another, but also to discover elements that do not known to exist in nature. The last few elements on the periodic table are all discovered later. Engineers can make use these elements to serve a specific design purpose, such as making a stronger metal alloy for a bridge or building, or designing a new medicine. All types of advanced technologies are possible because engineers study the physical and chemical properties of the atom to alter their natural properties.

ACTIVITY

Identify the elements and write the symbol of metals, non-metals and metalloid and also in terms of solid, liquid and gases from the p-block of the Modern periodic table

EXERCISE FOR BETTER UNDERSTANDING

ORAL TESTING

1. Which atom does not have any neutron in the nucleus and why?
2. What is the formula for calculating the number of electrons present in the shell of an atom?
3. Comparing the orbitals of 4s and 3d, which is lower in energy?
4. Name the type of bonds present in Ammonium chloride.

TEST PAPER-1

PART-A

1. Calculate the number of neutrons of the element X, if the atomic number is 6 and mass number is 14.
2. Write the electronic configuration of chlorine atom (Z=17).
3. Draw the Lewis dot formula for Ammonia molecule.

PART-B

1. Define the terms : a) Equivalent mass b) Valency
2. What is meant by Ionic bond. Give an example.
3. Write down the electronic configuration of Zinc, whose atomic number is 30.

PART-C

1. Write notes on structure of an atom.
2. By taking an example, apply the concept of Covalent bond and explain.

TEST PAPER-2

PART-A

1. Helium atom is more stable than He^+. Give reason.
2. Define Octet rule.
3. Why do atoms combine?

PART-B

1. Write a short note on types of bonding.
2. Explain briefly about proton.
3. Write down the electronic configuration of Titanium whose atomic number is 22.

PART-C

1. What is meant by Aufbau principle? Write any three elements electronic configuration.
2. Apply the concept of electrovalent bond in the formation of sodium chloride and explain.

FACT STORE

Elements found on earth and in Mars are exactly the same

Hydrogen is the most common element found in the universe.

Democritus was a Greek philosopher who was the first person to use the term atom (atomos: meaning indivisible). He thought that if you take a piece of matter and divide it continuously, you will eventually come to a point where you could not divide it any more.

Atoms are extremely small; typical sizes are around 100 picometers (1×10^{-10} m, a ten-millionth of a millimeter, or 1/254,000,000 of an inch).

BROADEN YOUR UNDERSTANDING

Click the following link or scan the QR code

https://www.youtube.com/watch?v=tNaqCtxzZYw&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4

https://www.youtube.com/watch?v=MudEc9Fbd2M&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=2

1.2 PERIODIC TABLE

Modern periodic law-periodic classification of elements-features of modern periodic table-properties of s,p,d,f block elements. **– 4 Hours**

In the year 1913, a group of scientists headed by **Henry Moseley** observed regularities in the characteristic *X-ray spectra* of the elements. A plot of *frequency* (v) of X-rays emitted against atomic number (Z) gave a straight line and not the plot of frequency *versus* atomic mass. He thereby showed that the atomic number is a more fundamental property of an element than its atomic mass. **Mendeleev's Periodic Law** was, therefore, accordingly modified. This is known as the **Modern Periodic Law** and can be best stated as:

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

The atomic number is equal to the nuclear charge (*i.e.*, number of protons) or the number of electrons in a neutral atom. It is then easy to visualize the significance of quantum numbers and electronic configurations in periodicity of elements. In fact, it is now recognised that the Periodic Law is essentially the consequence of the periodic variation in electronic configurations, which indeed determine the physical and chemical properties of elements and their compounds.

Features of Modern periodic table:

A modern version, the so called "**long form**" of the **Periodic Table** of the elements (Fig. 1.2.1), is the most convenient form and widely used. Look at the figure and observe the following features:

- The horizontal rows are called **Periods** and the vertical columns are called **Groups**.
- The period number is the of the ultimate shell number (Principal Quantum Number)
- Elements having similar outer electronic configurations in their atoms are arranged in vertical columns, referred as **groups** or **families**. There are 18 groups. According to the recommendation of International Union of Pure and Applied Chemistry (IUPAC), the groups are numbered from 1 to 18.
- There are seven periods. The period number corresponds to the highest principal quantum number (n) of the elements in the period. The first period contains 2 elements. The subsequent periods consists of 8, 8, 18, 18 32 and 32 elements, respectively. The seventh period was incomplete and found later and filled. The sixth and seventh period have a theoretical maximum (on the basis of quantum numbers) of 32 elements. In this long form of the Periodic Table, 14 elements of both sixth and seventh periods (Lanthanoids and Actinoids, respectively) are placed at the bottom[1] of the periodic table.

Electronic Configurations in Periods

The period indicates the value of n for the outermost or valence shell. In other words, successive period in the Periodic Table is associated with the filling of the next higher principal energy level (n=1, n=2, etc.). It can be readily seen that the number of elements in each period is twice the number of atomic **orbital** available in the energy level that is being filled.

- The first period (n = 1) starts with the filling of the lowest level (1s) and therefore has two elements - hydrogen ($1s^1$) and helium ($1s^2$) when the first shell (K) is completed.

---

[1] Inner transition elements

- The second period (n=2) starts with lithium and the third electron enters the 2s orbital. The next element, beryllium has four electrons and has the electronic configuration $1s^2\ 2s^2$. Starting from the next element boron, the 2p orbital is filled with electrons when the L shell is completed at neon ($2s^2\ 2p^6$). Thus, there are 8 elements in the second period.
- The third period (n=3) begins from sodium, and the added electron enters the 3s orbital. Successive filling of 3s and 3p orbital give rise to the third period of 8 elements from sodium to argon
- The fourth period (n=4) starts from potassium, and the added electrons fill the 4s orbital. Now you may note that before the 4p orbital is filled, filling up of 3d orbital becomes energetically favorable and we come across the so called 3d **transition series** of elements. This starts from scandium (Z = 21) which has the electronic configuration $3d^1\ 4s^2$. The 3d orbital is filled at zinc (Z=30) with electronic configuration $3d^{10}\ 4s^2$. The fourth period ends at krypton with the filling up of the 4p orbitals. Altogether we have 18 elements in this fourth period
- The fifth period (n = 5) beginning with rubidium is similar to the fourth period and contains the 4d **transition series** starting from yttrium (Z = 39). This period ends with xenon with the filling up of the 5p orbital.
- The sixth period (n = 6) contains 32 elements and successive electrons enter 6s, 4f, 5d and 6p orbital, in the order — filling up of the 4f orbital begins with cerium (Z = 58) and ends at lutetium(Z = 71) to give the 4f-**inner transition series** which is called the **lanthanide series.**
- The seventh period (n = 7) is similar to the sixth period with the successive filling up of the 7s, 5f, 6d and 7p orbital and includes most of the man-made radioactive elements. This period will end at the element with atomic number 118 which would belong to the noble gas family. Filling up of the 5f orbital after actinium (Z=89) gives the 5f-**inner transition series** known as the **actinide series**. The 4f- and 5f-**inner transition series** of elements are placed separately in the Periodic Table to maintain its structure and to preserve the principle of classification by keeping elements with similar properties in a single column.

Group wise Electronic Configurations

We have studied about the filling of electrons into different sub shells, also referred to as orbital (*s, p, d, f*) in an atom. The distribution of electrons into the orbital of an atom is called its electronic configuration. In this section we will observe a direct connection between the electronic configurations of the elements and the long form of the Periodic Table.

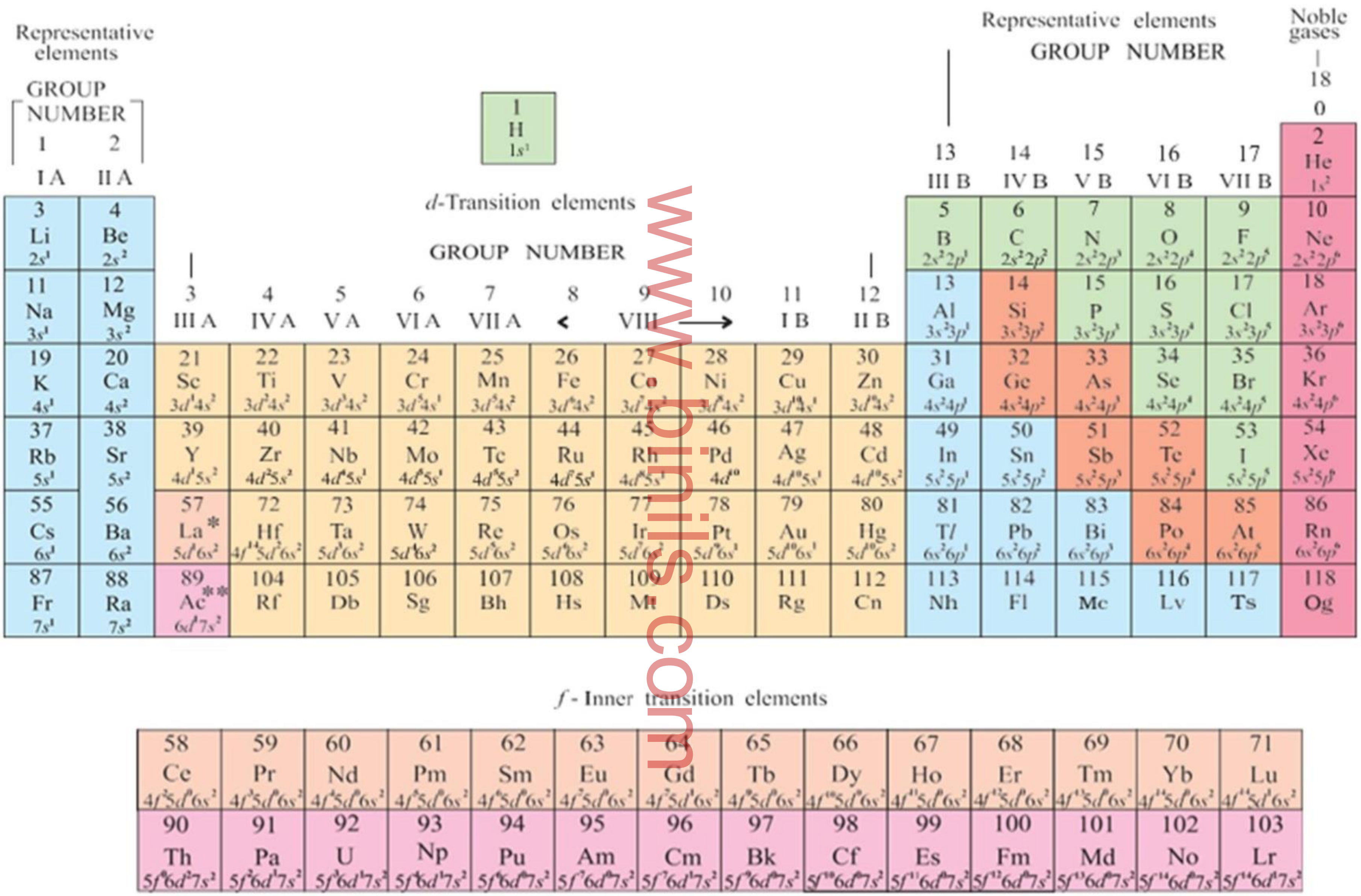
Electronic Configurations and Types of Elements: *s-, p-, d-, f*-Blocks

The *aufbau* (build up) principle and the electronic configuration of atoms provide a theoretical foundation for the periodic classification. The elements in a vertical column of the Periodic Table constitute a group or family and exhibit similar chemical behavior. This similarity arises because these elements have the same number and same distribution of electrons in their outermost orbital. We can classify the elements into four blocks *viz*., ***s*-block, *p*-block, *d*-block** and ***f*-block** depending on the type of atomic orbital that is being filled with ultimate electrons.

Properties of s-block elements:

- The first two groups namely IA and II A are called s-block elements.
- Hydrogen is placed in the IA group . The ultimate electron in these groups goes to s-sub shell **and** these group of elements are called s-block elements.

- The common electronic configuration of the Group IA is ns^1 and that of Group IIA is ns^2
- The IA group is called alkaline metals and the IIA group is called alkaline earth metals.
- The valency is 1 for Group IA and 2 for Group IIA (eg. $MgCl_2$, $CaCl_2$).
- They are soft metals and they have low density and low melting point. The density of lithium, sodium, potassium are 0.534, 0.968, 0.89 respectively. They all float in water and their melting points are 180, 97 and 63 degree Celsius.
- They show distinguishable colour in flame test and emission spectra. Lithium shows crimson red, sodium-yellow, potassium-violet, barium-apple green, calcium-brick red. Remember sparkles in crackers.
- They are all highly reactive and possess high electron reduction potentials.



Representative elements

GROUP NUMBER

d-Transition elements

GROUP NUMBER

Representative elements

GROUP NUMBER

Noble gases

1	H	$1s^1$

1 IA	2 IIA	3 IIIA	4 IVA	5 VA	6 VIA	7 VIIA	8	9 VIII	10	11 IB	12 IIB	13 IIIB	14 IVB	15 VB	16 VIB	17 VIIB	18 0
																	2 He $1s^2$
3 Li $2s^1$	4 Be $2s^2$											5 B $2s^22p^1$	6 C $2s^22p^2$	7 N $2s^22p^3$	8 O $2s^22p^4$	9 F $2s^22p^5$	10 Ne $2s^22p^6$
11 Na $3s^1$	12 Mg $3s^2$											13 Al $3s^23p^1$	14 Si $3s^23p^2$	15 P $3s^23p^3$	16 S $3s^23p^4$	17 Cl $3s^23p^5$	18 Ar $3s^23p^6$
19 K $4s^1$	20 Ca $4s^2$	21 Sc $3d^14s^2$	22 Ti $3d^24s^2$	23 V $3d^34s^2$	24 Cr $3d^54s^1$	25 Mn $3d^54s^2$	26 Fe $3d^64s^2$	27 Co $3d^74s^2$	28 Ni $3d^84s^2$	29 Cu $3d^{10}4s^1$	30 Zn $3d^{10}4s^2$	31 Ga $4s^24p^1$	32 Ge $4s^24p^2$	33 As $4s^24p^3$	34 Se $4s^24p^4$	35 Br $4s^24p^5$	36 Kr $4s^24p^6$
37 Rb $5s^1$	38 Sr $5s^2$	39 Y $4d^15s^2$	40 Zr $4d^25s^2$	41 Nb $4d^45s^1$	42 Mo $4d^55s^1$	43 Tc $4d^55s^2$	44 Ru $4d^75s^1$	45 Rh $4d^85s^1$	46 Pd $4d^{10}$	47 Ag $4d^{10}5s^1$	48 Cd $4d^{10}5s^2$	49 In $5s^25p^1$	50 Sn $5s^25p^2$	51 Sb $5s^25p^3$	52 Te $5s^25p^4$	53 I $5s^25p^5$	54 Xe $5s^25p^6$
55 Cs $6s^1$	56 Ba $6s^2$	57 La* $5d^16s^2$	72 Hf $4f^{14}5d^26s^2$	73 Ta $5d^36s^2$	74 W $5d^46s^2$	75 Re $5d^56s^2$	76 Os $5d^66s^2$	77 Ir $5d^76s^2$	78 Pt $5d^96s^1$	79 Au $5d^{10}6s^1$	80 Hg $5d^{10}6s^2$	81 Tl $6s^26p^1$	82 Pb $6s^26p^2$	83 Bi $6s^26p^3$	84 Po $6s^26p^4$	85 At $6s^26p^5$	86 Rn $6s^26p^6$
87 Fr $7s^1$	88 Ra $7s^2$	89 Ac** $6d^17s^2$	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

f - Inner transition elements

58 Ce $4f^25d^06s^2$	59 Pr $4f^35d^06s^2$	60 Nd $4f^45d^06s^2$	61 Pm $4f^55d^06s^2$	62 Sm $4f^65d^06s^2$	63 Eu $4f^75d^06s^2$	64 Gd $4f^75d^16s^2$	65 Tb $4f^95d^06s^2$	66 Dy $4f^{10}5d^06s^2$	67 Ho $4f^{11}5d^06s^2$	68 Er $4f^{12}5d^06s^2$	69 Tm $4f^{13}5d^06s^2$	70 Yb $4f^{14}5d^06s^2$	71 Lu $4f^{14}5d^16s^2$
90 Th $5f^06d^27s^2$	91 Pa $5f^26d^17s^2$	92 U $5f^36d^17s^2$	93 Np $5f^46d^17s^2$	94 Pu $5f^66d^07s^2$	95 Am $5f^76d^07s^2$	96 Cm $5f^76d^17s^2$	97 Bk $5f^96d^07s^2$	98 Cf $5f^{10}6d^07s^2$	99 Es $5f^{11}6d^07s^2$	100 Fm $5f^{12}6d^07s^2$	101 Md $5f^{13}6d^07s^2$	102 No $5f^{14}6d^07s^2$	103 Lr $5f^{14}6d^17s^2$

Fig.1.2.1 Long form of the Periodic Table (MODERN PERIODIC TABLE)

Properties of p-Block elements:

- The six groups from column 13-18 or otherwise the groups IIIB, IVB,VB,VIB,VIIB and zero group elements are called p-block elements.
- While filling up of atomic orbital, the ultimate electron goes to the p-sub shell.
- Thus the common electronic configuration can be written as ns^2, np^{1-6}, n, being the period number or the principal quantum number of outermost electron.
- They are mostly non-metals, metalloids and few metals.
- The last group is called zero group or noble gases

Properties of d-block elements:

- The 10 groups from IB, IIB, IIIA to VIIA and VIII are called d-block elements.
- The three groups 8, 9 and 10 are together called VIII group.
- They are all metals, also called transition elements.
- The ultimate electron goes to the penultimate shell which is d-sub shell
- The common electronic configuration is $ns^{1-2}(n-1))d^{1-10}$, for example Sc_{21} **[Ar]** $3d^1 4s^2$
- They are all hard metals, have high density.
- The melting point is high and are all good conductors.
- They have variable valency and different oxidation state.
- They show distinguishable colour in the flame test.

Properties of f-block elements:

- These groups of elements are called inner transition elements.
- The ultimate electron goes to the f-sub shell.
- There are 14 groups, IB to VII B, IVA to VIIA and VIII
- The ultimate electron goes to the pre-penultimate or anti penultimate shell.
- Thus the common electronic configuration of elements is $n\ s^2(n\text{-}1)d^{0-1}(n\text{-}2)f^{1\text{-}14}$
- They are less abundant metals on earth crest and so also called rare earths.
- The 14 elements after lanthanum with atomic number 58 to 71 are called **Lanthanoids** or **Lanthenons**.
- The 14 elements after actinium, with atomic number 90 to 103 are highly radioactive also called **Actinoids or Actinons.**
- The elements after uranium are called **Transuranium Elements**.

Periodic Properties

There are various physical properties of elements such as melting and boiling points, heats of fusion and vaporization, energy of atomization, etc. which show periodic variations. However, the complete discussion of the periodic trends with respect to atomic size, ionization enthalpy, electron gain enthalpy and electro negativity is beyond the scope of this book.

RECAP

We have discussed the following:

- Modern periodic law
- Periodic classification of elements
- Features of modern periodic table
- Properties of s, p, d, f block elements.

ENGINEERING CONNECTION

Why do Engineers must understand Periodic Table? Elements information in the periodic table helps engineers in all the disciplines, because they use elements in all facets of materials design, exploiting the characteristics of the various elements. It helps engineers to design stronger bridges, lighter aero planes, non-corrosive buildings, as well as agriculture, food, drinking water, and medicinal products. Since everything known to humans is composed of these elements, everything that engineers make use of this knowledge for their applications in real life.

ACTIVITY

- Look at the group 1 of the Modern Periodic Table, and name the elements present in it.
- Write down the electronic configuration of the first three elements of group 1.
- What similarity do you find in their electronic configurations?
- How many valence electrons are present in these three elements?
- Play a game with Periodic Table, by raising a question about period number, group number etc.

EXERCISE FOR BETTER UNDERSTANDING

ORAL TESTING

1. Why was it necessary to change the basis of classification of elements from atomic mass to atomic number?
2. How many groups and periods are there in periodic table?
3. Name the Noble gas which has two electrons in the valence shell?
4. Name an alkali metal which is radioactive.
5. Identify the element which follows Nitrogen in the same group of the periodic table.
6. What do you understand by penultimate and antipenultimate shell?

TEST PAPER-1

PART - A

1. Which is the fundamental property of Modern Periodic table. Why?
2. Write the name of elements present in the alkali metals.
3. Name certain metals they float in water?
4. Give any two properties of p-block elements.

PART - B

1. How elements are classified on the basis of period?
2. Write any three properties f block elements.

PART - C

3. Elaborate the properties of d-block elements.
4. Write briefly about Modern periodic table.

TEST PAPER-2

PART-A

1. What is Transuranium elements?
2. What are Lanthanoids and Actinoids?
3. In the modern periodic table, which are the metals among the first ten elements**?**

PART-B

1. How elements are classified on the basis of group?
2. Explain any three properties of s-block elements.

PART-C

1. Describe how elements are classified on the basis of electronic configuration.
2. Explain the properties of f-block elements.
3. Compare the properties of ‘s’ and ‘d’ block elements.

FACT STORE

- Hydrogen is the most common element found in the universe
- ‘J’ Is the only letter not found in the periodic table
- Francium is the rarest element on earth

BROADEN YOUR UNDERSTANDING

Click the following link or scan the QR code

https://youtu.be/gipOu5jEiqQ

https://www.rsc.org/periodictable

1.3 ACIDS AND BASES

Properties of Acids and Bases — Lewis concept of acids and bases Theory – advantages – pH and pOH – Definition – Numerical problems – Indicator – Definition – Buffer solution – Definition – Types of buffer solution with examples – Application of pH in Industries **- 5 Hours**

Introduction

Water is considered to be neutral and all the other compounds can be regarded as acids or bases. Compounds having increasing hydrogen ion concentration than water are termed an acid and compounds having decreasing hydrogen ion concentration than water are termed bases. The acidic and basic nature of matter is more essential to study about the chemical reactions.

Properties of Acids and Bases

Acids

Acids are Sour to taste, and turn blue litmus paper red. They react with metals, react with carbonates. An acid is a substance that gives hydrogen ions (H^+) by itself or in aqueous solution.

$$HCl \rightleftarrows H^+ + Cl^-$$

$$HNO_3 \rightleftarrows H^+ + NO_3^-$$

$$CH_3COOH \rightleftarrows CH_3COO^- + H^+$$

Bases

Bases are bitter to taste, feel slippery, and turn red litmus paper blue. They do not react with OH^- carbonates A base is a substance that gives ions (OH^-) by itself or in aqueous solution.

Example:

$$KOH \rightleftarrows K^+ + OH^-$$

$$NaOH \rightleftarrows Na^+ + OH^-$$

Lewis concept of acids and bases(1923)-(Electronic concept)

Lewis concept is known as electronic concept because it involves electron pair transfer during base formation.

Lewis Acid – Electron Acceptor

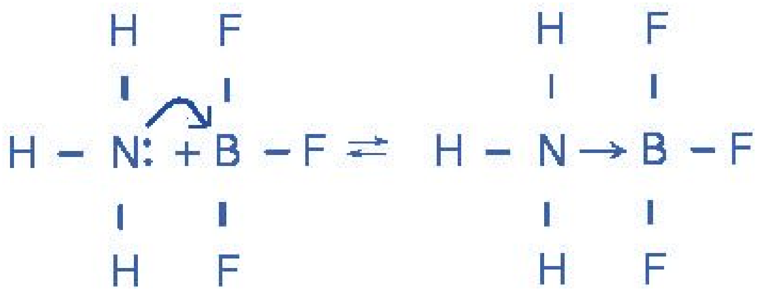
Lewis Base – Electron Donor

Illustration with Example: 1

According to this theory, an acid is a substance that accepts a pair of electrons. So, acid is an **electron pair acceptor.**

A base is a substance that donates a pair of electrons. So, a base is an **electron Pair donor**.

There are three N-H covalent bonds in ammonia, and a pair of electros over nitrogen available called a non-bonded pair or lone pair; Boron has a vacant orbital after the formation of BF_3.

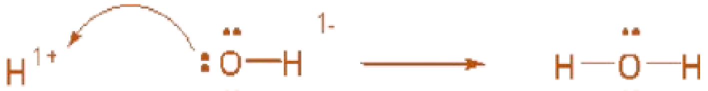


Ammonia donates a pair of electron to Boron trifluride and is called as Lewis base. Hence, it is called as electron pair donor.

Born trifluride accepts the electron pair from ammonia. Hence it is called as Lewis acid (electron pair acceptor).

Example: 2

A **Lewis base** is an electron pair donor. This definition is more general than those we have seen to this point; any Arrhenius acid or base and any Bronsted-Lowry acid or base can also be viewed as a Lewis acid or base. The reaction of H^{1+} with OH^{1-}, for instance, involves donation and acceptance of a proton, so it is certainly legitimate to call it a Bronsted-Lowry acid-base reaction. But if we look at the Lewis structures for the reactants and products, we see that it is also legitimate to call this a Lewis acid-base reaction.



Here, OH^- donates pair of electrons. So, it is a base. H^+ accepts a pair of electrons. So, it is an acid.

Advantages

1. It explains the acid base reactions by way of electron transfer.
2. It gives an idea about the acidic character of substances that do not contain hydrogen. The acidic nature of the following substances like BF_3, $FeCl_3$, and $AlCl_3$ can be easily explained by this concept.
3. The neutralization of acidic oxides and basic oxides can also be easily explained by this concept.

   $CaO + SO_2 \longrightarrow CaSO_3$

   Acid Base

4. The concept can be easily understood.

Concept of pH AND pOH(S.P.L Sorenson):

S.P.L Sorenson introduced pH scale in 1909. pH is a convenient way of expressing acidity or the concentration of H^+ in solution. It helps to avoid the use of large of negative power of10.

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

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

Higher the concentration of H^+, lower will be the value of pH.

Definition pH and pOH

pH of a solution is defined as negative of logarithm to the base 10 of the hydrogen ion concentration $[H^+]$

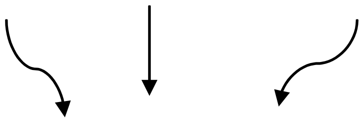
$$pH = -\log_{10}[\mathbf{H^+}].$$

Similarly,

POH of a solution is defined as negative of logarithm to the base 10 of the hydroxyl ion concentration [OH]

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

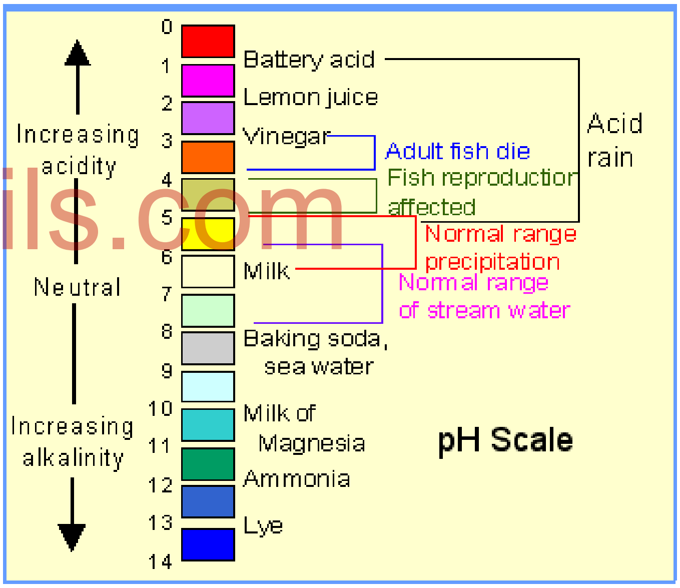
Acid *neutral* *Base*



pH = 0-------------7 ----------14

pOH= 14 --------------7---- ----- -0

For any acid pH varies from 0 to 7 and for any base it varies from 7 to 14. Similarly pOH is 7 to 14 for an acid and pOH is 0 to 7 for a base and the pH of pure water is 7.



Ionic product of water

Water contains equal concentration of $[H^+]$ and $[OH^-]$ which is equal to $[1\times10^{-7}]$g ions/litre. Thus, the product of $[H^+]$ and $[OH^-]$ is known as ionic product of water. The value is 1×10^{-14}.

$K_W(298K) = [H^+][OH^-]$

$=[1 \times 10^{-7}][1 \times 10^{-7}]$

$= 1 \times 10^{-14}$ g ions/litre.

$[H^+] = [OH^-] = [1\times10^{-7}]$gm ions/litre.

$[H^+] = [H^+] = [OH^-] = [1\times10^{-7}][1\times10^{-7}]$

$[H^+] [OH^-] = 1 \times 10^{-14}$ Taking log,

$\log_{10}[H^+] + \log_{10}[OH^-] = \log10^{-14}$

$\log[H^+] + \log[OH^-] = -14.$

Multiplying by (-1) on both sides

$-\log[H^+] - \log[OH^-] = 14$ So,

$$\boxed{\mathbf{pH + pOH = 14}}$$

Problem.

1. **If pH of a solution is 5, what is its pOH? (Oct 2014).**

$pH + pOH = 14$

$5 + pOH = 14 \quad pOH = 14 - 5$

$pOH = 9$

Points to be remembered

1. For pure water, pH and pOH values = 7
2. The sum of pH and pOH should be equal to 14; i.e. pH+ pOH = 14.
3. Ionic product of water is $1 \times 10^{-14.}$
4. pH is < 7 Acid

   pH = 7 Neutral

   pH is > 7 Base

Problems

1. Calculate the pH of a solution whose hydrogen ion concentration is 4.6×10^{-4} g ions/litre.

$pH = -\log10\,[H+]$

$= -\log_{10}[4.6 \times 10^{-4}]$

$= -[\log_{10} 4.6] + [\log_{10} 10^{-4}]$

$= -[0.6627 - 4]$

$= -[-3.3373]$

$pH = 3.3372$

2. Calculate the pH of 0.003M HCl solutions. The hydrogen ion concentration is 0.003

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

$= -\log_{10}[1 \times 10^{-3}]$

$= -\log_{10}[1] + \log_{10}[10^{-3}]$

$= -(0\text{-}3)\ pH$

$pH = 2.5229$

3. Calculate the hydrogen ion concentration of a solution whose pH is 4.45.

$pH = 4.45$

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

$= 4.45 = -\log_{10}[H^+]$

$\log_{10}[H^+] = -4.45 = (-4 - 1) + (-0.45) + 1$

$= -5 + 0.55$

$[H^+] = \text{Antilog of } 0.55 \times 10^{-5}$

$[H^+] = 3.548 \times 10^{-5}$ g ions/litre.

4. If the pH of a solution is 5.25, calculate the hydrogen ion concentration of the solution.

pH = 5.25

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

5.25 = $- \log_{10} [H^+]$ $\log [H^+] = - 5.25 = (-6 + 0.75)$

$[H^+)$ = antilog (0.75) x 10^{-6}

= 5.623×10^{-6} g ions/litre.

5. Calculate the pH of 0.1 m NaOH solution.

0.1 m NaOH means

= 0.1g ions/litre.

pOH = $- \log_{10} [0\ H^-]$

= $- \log_{10}[0.1]$

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

= $- [- 1]$

= 1.

pH + pOH = 14

pH + 1 = 14

pH = 14 – 1 = 13

Indicators

An indicator is a substance, which has a specific colour in an acid solution and a different colour in an alkaline solution. Indicator is a substance, which indicates the exact completion of a chemical reaction by changing its colour at the end point.

Example:

Phenolphthalein, Methyl Orange, Methyl Red

Indicators are used in titrations to determine the end point. During the acid-bass titration, if certain pH is reached, indicator changes its colour.

Indicator	***Colour Change***	***pH Range***
Phenolphthalein	Colorless to Pink (Acid) (Base)	8 - 9.5
Methyl Orange	Red to Yellow (Acid) (Base)	4.5 – 6.5

It is very clear from a study of the above table that phenolphthalein which becomes colorless when pH = 8, indicates that the solutions is acidic. Methyl orange shows a yellow colour, when pH = 4.5 indicates the solution is basic. Therefore selection of indicators is more important for acid-base titrations. It depends upon the nature of acid and the base involved in that titration. For a titrating a strong acid and strong base phenolphthalein or methyl orange can be used, while titration of strong acid against a weak base methyl orange can only be used. In the same way while titrating a weak acid versus strong base only phenolphthalein can be used.

Acid	Base	Indicator	Example
Strong acid	Strong base	Methyl orange / phenolphthalein	HCl/H_2SO_4 - $NaOH/KOH$
Strong acid	Weak base	Only methyl orange	HCl/H_2SO_4 - Na_2CO_3/NH_4OH
Weak acid	Strong base	Only phenolphthalein	Acetic acid/Oxalic acid - NaOH/KOH

A weak acid and weak base cannot be titrated by ordinary titration methods, it requires conduct metric titration which is beyond the scope of this book.

BUFFER SOLUTION

Maintaining of pH is more important in many industries. For that buffer solution is needed. **Buffer solution** is one which maintains a constant pH when a small amount of acid or alkali are added to the solution. Buffer solutions play a vital role in biological systems.

Buffer solution is classified into two types.

1. Acidic buffer
2. Basic buffer

Acidic buffer is obtained by mixing a weak acid with a salt of the same weak acid.

Example

CH_3COOH + CH_3COONa

Acetic acid sodium acetate

Basic buffer is obtained by mixing a weak base with a salt of the same weak base.

Example

NH_4OH + NH_4Cl

Ammonium Hydroxide Ammonium chloride.

INDUSTRIAL APPLICATIONS OF pH

pH is more important in many industries to get high yield and the quality products. pH plays a vital role in the following industries.

1. Textile Industry:

   In textile industry, the pH of the dye has to be maintained otherwise dying will not be uniform and permanent.
2. Sugar Industry: The pH of the sugarcane juice should be maintained between 8 and 9. Otherwise crystallization of sugar will not be better.
3. Leather Industry: The pH of solution for Tanning purpose should be 2.5 to 3.5. If not, the hides will putrefy.
4. The pH of liquid chlorine is more effective in the pH range of 5 to 6.5 in water treatment.
5. The pH of the soil should be alkaline for plants to grow and to get better yield.
6. The pH of human blood is 7.2. If not, it causes acidosis / alkalosis leading to health hazards.
7. The pH of a gastric juice is 1.4 to 2. Otherwise it may cause vomiting and stomach disorder.

8. The pH plays a vital role in many industries viz., Paper industry, Alcohol industry, Medicine and Chemical industry, Food production industry etc.
9. EDTA titrations are very sensitive to pH.
10. The pH of human saliva varies from 6.2 -7.6 before and after meal.

RECAP

We have learnt the following:

- Properties of Acids and Bases
- Lewis concept of acids and bases Theory –advantages
- pH and pOH
- Numerical problems
- Indicator
- Buffer solution
- Types of buffer solution with examples
- Application of pH in Industries

ACTIVITY-1

- Take some finely chopped onions in a plastic bag along with some strips of clean cloth. Tie up the bag tightly and leave overnight in the fridge. The cloth strips can now be used to test for acids and bases
- Take two of these cloth strips and check their odour. Keep them on a clean surface and put a few drops of dilute HCl solution on one strip and a few drops of dilute NaOH solution on the other
- Rinse both cloth strips with water and again check their odour.
- Note your observations.
- Now take some dilute vanilla essence and clove oil and check their odour.
- Take some dilute HCl solution in one test tube and dilute NaOH solution in another. Add a few drops of dilute vanilla essence to both test tubes and shake well. Check the odour once again and record changes in odour, if any. Similarly, test the change in the odour of clove oil with dilute HCl and dilute NaOH solutions and record your observations.(Hint: olfactory indicators – smell based)

ACTIVITY-2

- Put about 2 g soil in a test tube and add 5 mL water to it.
- Shake the contents of the test tube.
- Filter the contents and collect the filtrate in a test tube.
- Check the pH of this filtrate with the help of universal indicator paper.
- What can you conclude about the ideal soil pH for the growth of plants in your region?

ENGINEERING CONNECTION

Measuring pH is fundamental science that is used by many engineers: Environmental and chemical engineers examine pollutant substances to find out whether they are acid or base to know what kind of reactions they cause. Electrical engineers design batteries. Chemical engineers design everything from pharmaceuticals to soap, glue to bubble gum. Civil engineers design water and waste treatment plants for towns and factories. Using the basic concept of acids and bases, engineers are able to create a lot of things that contribute to the health, happiness and safety of society.

EXERCISE FOR BETTER UNDERSTANDING

ORAL TESTING

1. What will happen if HCl acid is poured over egg shells?
2. What acids are present in oranges and tomatoes?
3. Why dry HCl gas does not turn dry blue litmus red but it turns moist blue litmus red?
4. Two solutions have pH equal to 8 and 11 respectively. which one is more basic and why?
5. Why tooth decay begins when we eat too much sweets?

TEST PAPER-1

PART-A

1. Define Lewis acid.
2. Which is the suitable indicator for titrating strong acid and weak base?
3. Ammonia does not contain hydroxyl group, then why is it a base?

PART-B

1. Define pH. The pH of rain water collected from two cities Coimbatore and Thanjavur was found to be 6 and 6.5 respectively. The water of which city is more acidic?
2. Solutions X, Y and Z have pH values 8,9 and 10 respectively. Arrange them in increasing order of basic nature giving reasons.

PART-C

1. Describe about Buffer solutions with examples.
2. The pH of an aqueous solution decreases from 3 to 2. Calculate how many times the hydrogen ion concentration of the solution will change?
3. What are the applications of pH in industries?

TEST PAPER-2

PART-A

1. Define Lewis base.
2. Titration of weak acid and strong base. Suggest a suitable indicator ?
3. BF_3 is an acid even though it does not contain Hydrogen atom. Justify

PART-B

1. Pure distilled water shows pH value 7, whereas rain water of Chennai shows 6.5. why?
2. Calculate the pH of 0.01M NaOH.

PART-C

1. Describe the concept of Lewis acid and base with examples.
2. Define Indicator. Explain the various types of indicators.

BROADEN YOUR UNDERSTANDING

https://www.youtube.com/watch?v=eQWmobEbgf0&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=4

https://www.youtube.com/watch?v=MudEc9Fbd2M&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=3

FACT STORE:

The normal pH of arterial blood is 7.4. Whenever the pH falls within the range of slightly less than 7.4-7.0, a person is said to have acidosis caused by the increase in hydrogen ion concentration. Even a slight lowering induces vomiting sensation as the buffer action is lost by some means. Alkalosis occurs within the range of 7.4-7.8 due to the decrease in hydrogen ion concentration. This is called acid-base balance. This is balanced by the body by the body fluids in three ways. Kidney reabsorbs hydrogen and the urine becomes acidic or alkaline

- Pulmonary ventilation is altered, changing the rate at which CO2 is removed from body fluids.
- Buffers, a special system of hydrogen ion acceptors and donors present body alters the pH.

FREQUENTLY ASKED QUESTIONS

ATOMIC STRUCTURE & CHEMICAL BONDING, PERIODIC TABLE, ACIDS AND BASES

UNIT – I

PART-A

1. Which is the smallest particle of an element?
2. What is the name of the subatomic particle having neutral charge?
3. What is the charge of an anion?
4. How is a positive ion formed?
5. Name the type of bond where the electrons are mutually shared?
6. Give reason, Helium atom is more stable than He^+.
7. Define Octet rule.
8. Why do atoms combine to form molecule?
9. Calculate the number of neutrons of the element X, if the atomic number is six and mass number is fourteen.
10. Write the electronic configuration of chlorine atom (Z=17).
11. Draw the Lewis dot formula for Ammonia molecule.
12. What is the name for horizontal rows in the periodic table?
13. What is the name for vertical column in the periodic table?
14. Which is the fundamental function by which the periodic table is classified?
15. What is Transuranium elements?
16. What are Lanthanoids and Actinoids?
17. In the modern periodic table ,which are the metals among the first ten elements?
18. Write the name of elements present in the alkali metals.
19. Why certain metals float in water?
20. Give any two properties of p-block elements.
21. Define Lewis base.
22. Titration of weak acid and strong base. Suggest a suitable indicator ?
23. BF_3 is an acid even though it does not contain Hydrogen atom. Justify
24. Define Lewis acid.
25. Which is the suitable indicator for titrating strong acid and weak base?
26. Ammonia does not contain hydroxyl group, then why is it a base?
27. Define pH.
28. Who developed the pH scale?
29. Give an example for acidic buffer?
30. Give an example for basic buffer?

31. What is the name of a substance which changes colour in acid or a base?

32. What is the pH value for human blood?

PART – B

1. We can call H^+ ion as a proton. How?
2. Atomic number and mass number of an element is 9 and 19 respectively. What is the number of neutrons?
3. Define ionic bond with an example?
4. Define covalent bond with an example?
5. Write a short note on types of bonding.
6. Explain briefly about proton.
7. Define the terms : a) Equivalent mass b) Valency
8. What is meant by chemical bond. Give an example.
9. State modern periodic law.
10. Write a note on period wise classification of periodic table?
11. Write a note on group wise classification of periodic table?
12. How are elements classified on the basis of group?
13. Explain any three properties of s-block elements.
14. How are elements classified on the basis of period?
15. Write any three properties of block elements.
16. What is an Indicator? Give examples.
17. What is Lewis concept of an acid and a base?
18. Pure distilled water shows pH value 7, whereas rain water of Chennai shows 6.5. Why?
19. Calculate the pH of 0.01M NaOH.
20. Define pH. The pH of rain water collected from two cities Coimbatore and Thanjavur was found to be 6 and 5 respectively. The water of which city is more acidic?
21. Solutions X, Y and Z have pH values 8,9 and 10 respectively. Arrange them in increasing order of basic nature and give reasons.

PART-C

1. Which is more stable Na or Na^+ Why?
2. Explain the Ionic bond formation of NaCl?
3. Explain the covalent bond formation of NH_3?
4. Which is more stable Cl or Cl^- ; Why?
5. What is meant by Aufbau principle? Write any three elements electronic configuration.
6. Apply the concept of electrovalent bond in the formation of sodium chloride and explain.
7. By taking an example, apply the concept of Covalent bond and explain.
8. What are the main features of modern periodic table?
9. Distinguish between s-block and d-block elements.

10. What are the properties of f-block elements?
11. Write notes on p-block elements.
12. Describe how elements are classified on the basis of electronic configuration.
13. Explain the properties of f-block elements.
14. Elaborate the properties of d-block elements.
15. Write notes on Modern periodic table.
16. Explain the Lewis concept of acids and bases with examples. Mention its advantages.
17. Write a note on applications of PH in industries.
18. The hydrogen ion concentration of a solution is $2x10^{-4}$ g ions/litre. Calculate the pH of the solution.
19. The hydroxyl ion concentration of a solution is $1x10^{-9}$ g ion/litre. Calculate the PH of the solution.
20. The pH of a solution is 4.28. Calculate the hydrogen ion concentration of the solution. The pH of a solution is 11.5. Calculate the hydrogen ion concentration of the solution.
21. Describe the concept of Lewis acid and base with examples.
22. Define Indicator. Explain the various types of indicators.
23. Describe about Buffer solutions with examples.
24. The pH of an aqueous solution decreases from 3 to 2. Calculate how many times the hydrogen ion concentration of the solution will change?

UNIT
2

SURFACE CHEMISTRY

2.1 COLLOIDS

Colloids – True solution and Colloidal solution – Definition – Differences – Types of colloids – Lyophilic and Lyophobic colloids – Differences – Properties – Optical – mechanical – electrical – Electrophoresis and Coagulation – Industrial applications of colloids – Smoke Precipitation by Cottrell's method, Purification of water, Cleansing action of soap, Sewage disposal – tanning–and artificial rain. **– 6 Hours**

Introduction

An aqueous solution of salt or sugar is homogeneous and it contains the solute particles as single molecules or ions. Here after this is called a true solution. The diameter of the dispersed particles ranges from 1Å to 10Å [1Å = 10^{-8} cm]; whereas in a suspension of sand stirred in water, the diameter of the dispersed particles will be more than 2000Å. The particles which are larger than a molecule of true solution and smaller than suspended particle are said to be colloids and such solutions are called colloidal solutions or sol.

Molecular size	<	**colloids**	<	**suspension**
(1Å - 10Å)		(10Å - 2000Å)		(More than 2000 Å)

Colloid which means glue like, which diffuse very slowly in solution and whose solution cannot pass through animal or vegetable membranes.

E.g. Starch, glue, albumin etc.,

A colloid is heterogeneous system in which one substance is dispersed (dispersed phase analogous to solute) as very fine particles in another substance called dispersion medium (analogous to solvent)

Colloids have many industrial applications. Even our body can easily absorb food and medicine in a colloidal form.

True solution

True solution is a homogeneous mixture of two or more substance E.g. Sugar solution

Colloids

It is a heterogeneous mixture of two immiscible phases (Dispersed phase and dispersion medium)

Differences between true solution and colloidal solutions

Properties	True solution	Colloidal solution
1. Nature	Homogeneous system	Heterogeneous system
2. Diameter of the particle	Ranges from 1 Åto 10Å	Ranges from 10 Å to 2000 Å

3. Filtration by ultra filtration	Cannot be filtered	Can be filtered using vegetable / animal membrane.
4. Osmotic pressure	Low	High
5. Tyndall effect	Does not show	Shows Tyndall effect.
6. Brownian movement	Does not exhibit	Exhibits Brownian movement,
7. Electrophoresis	Does not show	Shows electrophoresis
8. Coagulation	Cannot be coagulated	Can be easily coagulated

Classification of colloids

Colloids are classified on the basis of following criteria:

i. Physical state of dispersed phase and dispersion medium

ii. Nature of interaction between dispersed phase and dispersion medium

iii. Type of particles of the dispersed phase

Depending upon whether the dispersed phase and dispersion medium are solids, liquids or gases, eight types of colloidal systems are possible Depending upon the nature of interaction between the dispersed phase and dispersion medium, colloidal sols are divided into

1. Lyophilic (Solvent attracting) 2. Lyophobic (Solvent repelling)

1. Lyophilic colloids

'Lyophilic' means liquid-loving. Colloidal sols directly formed by mixing substances like gum, gelatine, starch, rubber etc., with a suitable liquid are called lyophilic colloids.

2. Lyophobic colloids

'Lyophobic' means liquid-hating. Substances like metals their sulphides etc., when simply mixed with their dispersion medium do not form the colloidal sol. Their colloidal sols can be prepared only by special methods such sols are called lyophobic colloids.

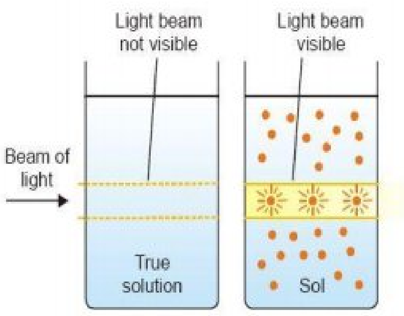
Difference between Lyophilic and Lyophobic colloids

Properties	Lyophilic colloids	Lyophobic colloids
1. Nature	Solvent loving	Solvent hating
2. Preparation	Easy	Difficult
3. Separation	Difficult	Easy
4. Coagulation	Large amount of electrolytes are required.	A little amount of electrolytes is enough to bring down the coagulation.
5. Viscosity	Higher than that of medium	Same as the medium
6. Surface tension	Lower than that of medium	Same as the medium
7. Example	Starch solution	Colloidal gold

Properties of colloids

1. *Optical property (Tyndall effect)*

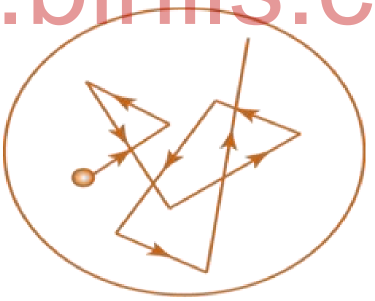
When the beam of light is passed through a true solution, and that is observed at right angles to the direction of the beam, path of the light is not clear. If a beam of light is passed through a colloidal solution placed in a darkroom, the path of light is quite distinct. This is due to the scattering of light by colloidal particles. **The phenomenon of scattering of light by the colloidal particles is known as "Tyndall effect".**



Example: The sky appears blue colour due to the scattering of blue ray in the sunlight by the colloidal particles present in the atmosphere.

2. *Mechanical property (Brownian movement)*

When colloidal solutions are viewed under a powerful ultra-microscope the colloidal particles appear to be in a state of continuous Zig-Zag motion. This motion was first observed by the British botanist Robert Brown and is known as Brownian movement. This is due to the collision of colloidal particles with medium.



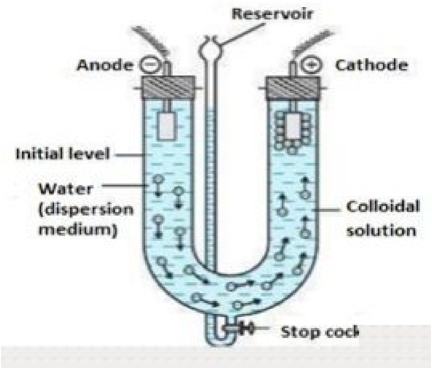
Brownian Movement

The motion becomes rapid when the temperature of the dispersion medium is more and less viscous. This motion depends on the size of the particles, viscosity and temperature of the solution.

3. *Electrical property (Electrophoresis)*

All the colloidal particles are electrically charged. They are all positively or negatively charged. Hence the particles repel each other and remain stable for days together, If an electric potential is applied across two platinum electrodes immersed in a colloidal solution, the colloidal particles move in a particular direction, depending upon the charge of the particles. **Thus, the movement of colloidal particles under the influence of electricity is called electrophoresis**. Positively charged particles move towards the cathode while negatively charged particles move towards the anode.

This can be demonstrated by the following experimental setup.



4. *Coagulation*

The entire colloidal particles are electrically charged; all are positively charged or negatively charged. Therefore, every colloidal particle repel each other and remains stable. In order to coagulate a colloid, first of all these charges have to be nullified. The phenomenon of precipitation of a colloidal solution is called 'Coagulation' and the solid which separates is called the 'Coagulum'.

Coagulation can be done by three ways:

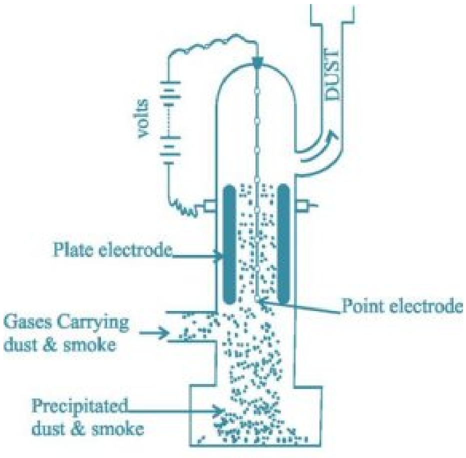
1. By adding an electrolyte in excess.
2. Addition of oppositely charged particles.
3. Introducing an electrode of opposite charge.

Industrial applications of colloids

Smoke precipitation

Smoke is a negatively charged colloid, consisting of carbon particles dispersed in air. It is passed through a highly positively charged metallic knob. On coming in contact with knob carbon particles lose their charge and get precipitated.

They are scrapped mechanically. The precipitator is called Cottrell's precipitator. Click the following link: https://youtu.be/eu4T080dsG8



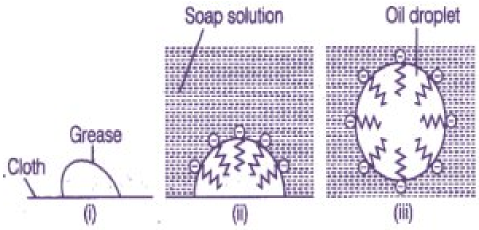
Cottrel's Precipitator

1. *Purification of drinking water*

The water obtained from natural sources often contains colloidal impurities. Alum is added to such water to coagulate the colloidal impurities and water after filtration fit for drinking purposes.

2. *Cleansing action of soaps and detergents*

Soap used for washing is a colloidal solution in water which removes dirt's by adsorption of greasy materials by emulsion formation. Most of the dirt is oily in nature and oil does not dissolve in water. The molecule of soap constitutes sodium or potassium salts of long chain carboxylic acids. In the case of soaps the carbon chain dissolves in oil and the ionic end dissolves in water. Thus the soap molecules form structures called **micelle**. That is soap is a kind of molecule in which both the ends have different properties. The first one is the hydrophilic end which dissolves water and is attracted towards it whereas the second one is the hydrophobic end that is dissolved in hydrocarbons and is water repulsive in nature.. Therefore, it forms emulsion in water and helps in dissolving the dirt when we wash our clothes.



(i) Grease or oil on surface of cloth.
(ii) Stearate ions arranged around the grease or oil droplet.
(iii) Grease or oil droplet surrounded by stearate ions
(ionic micelle formed).

- Soap has two ends, polar end and non-polar end
- Soap forms a colloid with water, leads to the formation of bubbles/foam.
- Colloids have adhering(sticking) property. Dirt particles stick to non-polar end and they are washed away. For better understanding watch the following link https://youtu.be/ga2ff1nO0uo

3. Removal of dirt from sewage

Sewage contains dirt particles in water when sewage passed through a system fitted with opposite charged metallic electrodes, dirt particles get deposited. The deposited dirt is then used as manure.

4. Tanning

Animal hides are positively charged colloid. When it is soaked in a negatively charged tannin solution, coagulation takes place. This result in hardening of leather this process is termed as tanning. Animal hides are colloidal in nature.Traditionally, tanning used tannin, an acidic chemical compound from which the tanning process draws its name. When a hide positively charged particle, soaked in tannin a negatively charged particle mutual coagulation takes place. This results in hardening of leather. Chromium (III) sulfate ($[Cr(H_2O)_6]_2(SO_4)_3$) has long been regarded as the most efficient and effective tanning agent.

5. Artificial rain

Colloids find another application in producing artificial rain. It is possible to cause artificial rain by throwing electrically charged sand or spraying a sol (silver iodide) carrying opposite charge into the clouds. Cloud consists of charged particles of water dispersed in air. These particles are neutralized by spraying oppositely charged particles over a cloud. These neutralized particles of water combine to form large water drops. Thus, artificial rain is caused by the aggregation of minute particles of water to form large particles

RECAP

In this chapter following topics are dealt with

- Difference between true solution and colloidal solution
- Types of colloids
- Properties of colloids
- Industrial application of colloids

ACTIVITY

- See the day to day colloidal materials like milk, ink, ice cream etc.,
- Milk can be coagulated by adding few drops of lemon juice.
- Observe the Tyndall Effect that causes Blue Colour of sky
- Watch scattering light in cinema theatres from the projector room.
- Watch the preparation of mayonnaise, a colloid, in YOUTUBE.
- Observe the churning of butter milk to coagulate butter.

Exercise for better understanding

1. Sugar solution is a colloid :True/False
2. Colloidal gold is an example for lyophobic colloid True/False
3. Sky appears blue colour due to scattering of blue ray: True/False
4. ZIG-ZAG motion of colloid is called electrophoresis is: True/False

Test Paper–1

Part-A

1. What is a colloid?
2. What is lyophilic colloid?
3. Give an example for lyophobic colloid?

Part-B

4. Write a note on Tyndall effect?
5. What is meant by coagulation of colloid?

Part-C

6. What are the difference between true solution and colloidal solution?
7. Give the differences between lyophilic and lyophobic colloids?

Test Paper– 2

Part–A

1. What is a lyophobic colloid?
2. Give example for lyophilic colloids?
3. Give one difference between colloidal solution and true solution

Part–B

4. Write a note on mechanical properties of colloid
5. What is called electrophoresis?
6. Give any two differences between lyophilic and lyophobic colloids?

Part–C

7. Explain the properties of colloids?
8. Give the industrial applications of colloids?

FACT STORE

Sir C.V. Raman was awarded with Nobel Prize in Physics for his work on scattering of light. The discovery was later christened as "Raman Effect".

Born: November 7, 1888
Died: November 21, 1970

Achievements:

He was the first Indian scholar who studied wholly in India received the Nobel Prize.

C.V. Raman is one of the most renowned scientists from our country. His full name was Chandrasekhara Venkata Raman. Chandra-shekhara Venkata Raman was born on November 7, 1888 in Tiruchinapalli. He studied in the Presidency College, Madras, in 1902, and in 1904 passed his B.A. examination, winning the first place and the gold medal in physics. In 1907, C.V. Raman passed his M.A. obtaining the highest distinctions.

Broaden your understanding:

Click the following link or scan the QR code

https://www.youtube.com/watch?v=hzDFCUKos4U&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=6

https://www.youtube.com/watch?v=oCp6-pu3xuM&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=7

2.2 NANOTECHNOLOGY

Nano particles – definition – properties – application of Nanotechnology – Engineering – medicine – biomaterial. **– 4 Hours**

Introduction

Nano means "billionth" (1x10^{-9}m = 1nm). Nano technology is the study of matter on an atomic and molecular scale. One nano meter (nm) is one billionth or 10^{-9}m. The carbon-carbon bond length is in the range of 0.12-0.15 nm and the DNA double helix has a diameter of 2nm and the bacteria will be around 200nm. Nanotechnology is highly a inter disciplinary field, with contributions from all fields: physics, chemistry, biology, material science and engineering. Materials reduced to nanometer scale show unique characteristics: for instance, opaque substance become transparent (copper); stable materials turn combustible (aluminium); insoluble materials become soluble (gold).

Nanotechnology emerges from nano science to design, fabricate and characterise application of materials at the nano scale level (1-100nm) and convert them into a useful devices.

Nanoparticles

Strong and chemically active materials having grain size range from 1 to 100 nanometer or (10^{-9}m) are called nanoparticles.

Importance of nanoparticles

Nanomaterials have created high interest in recent years by virtue of their unusual mechanical, electrical, optical and magnetic properties.

i. Nano phase ceramics are more ductile.
ii. Nano structured semiconductors shows optical properties.
iii. Nano sized metallic powders are used in production of gas tight materials.
iv. Nano-structured metal clusters are used in Catalytic applications.
v. Nano metal oxide thin films are used in sensors and rechargeable batteries.

Properties

The properties of Nano materials are differing from the bulk form.

Property	Example	Bulk material	Nano materials
1. Appearance	Copper	Opaque	transparent
2. Colour	Gold	Yellow	Red
3. Combustibility	Aluminium	non combustible	Combustible
4. Conductivity	Silicon	non-conductor	Conductor
5. Phase	Gold	Solid	Liquid
6. Reactivity	Platinum & Gold	Inert	Catalyst

Applications of Nanotechnology in Engineering

1. The use of Nanotechnology makes concrete more stronger, durable more easily placed.
2. In automobiles, incorporation of small amount of nanoparticles in steel material which can make them stronger.
3. Carbon Nano Tubes (CNT) is used in storage devices like fuel cells and in Lithium batteries.

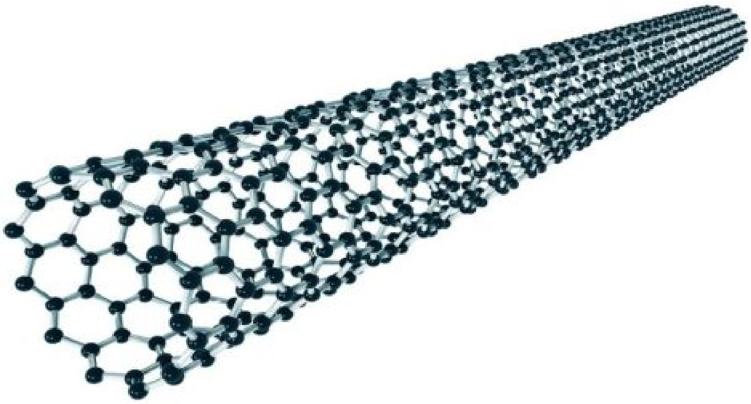


Fig. 2.2.1 Carbon nanotube

4. CNTs are used to manufacture integrated memory circuits which are used in high speed computers.

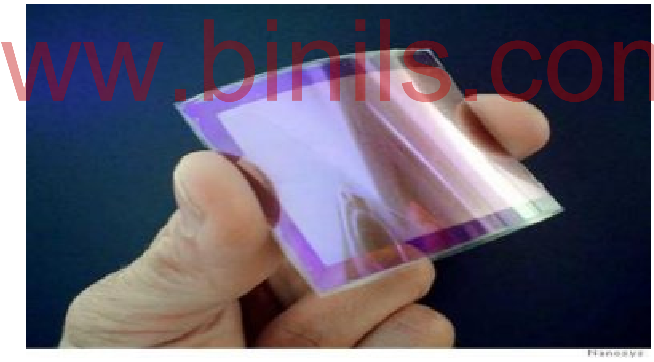


Fig. 2.2.2 Solar Cell

5. CNT acts as a sensor for gases.
6. In Solar power generation unit, nano-materials reduce the fabrication cost of photoelectric cells.
7. Silicon nanowires are used in transistors.
8. Heavy metals present in waste water are removed by using magnetic Nanoparticles.
9. In Fabric Technology, nano-materials are used as a stain repellent.
10. Nano-materials are also used for the manufacturing of memory devices (Cu-Fe alloy).
11. Nano-materials are used for the manufacturing of computer chips which are used to prepare transistor, resistors and capacitors.
12. Ultra-thin nanosheets, just a few atoms thick, can make fuel cells for hydrogen cars cheaper in the future.

Applications of Nano-particles in Medicine

1. This may replace conventional treatment like organ replacement/artificial implant
2. Nano materials are used as a drug for curing cancer.
3. Gold coated nano cells are used for the destruction of tumours.
4. Gold nano cells are used to analyse the protein and blood content.
5. Nano silica is used to deliver chemotherapy drugs.
6. Nano aluminium silicate used to enhance blood clotting.
7. Nano materials are used to repair neurological damage.
8. Nano materials are used as bone cement and joint replacement. **Natural bone surface is 100 nm across; if the artificial bone implant is smooth, the body rejects; so nano sized finishing of hip and knee would help body to accept the implant.**
9. Nano materials are used for manufacture of heart valves, contact lens etc.,
10. Nano materials are also used in dental implants and breast implants

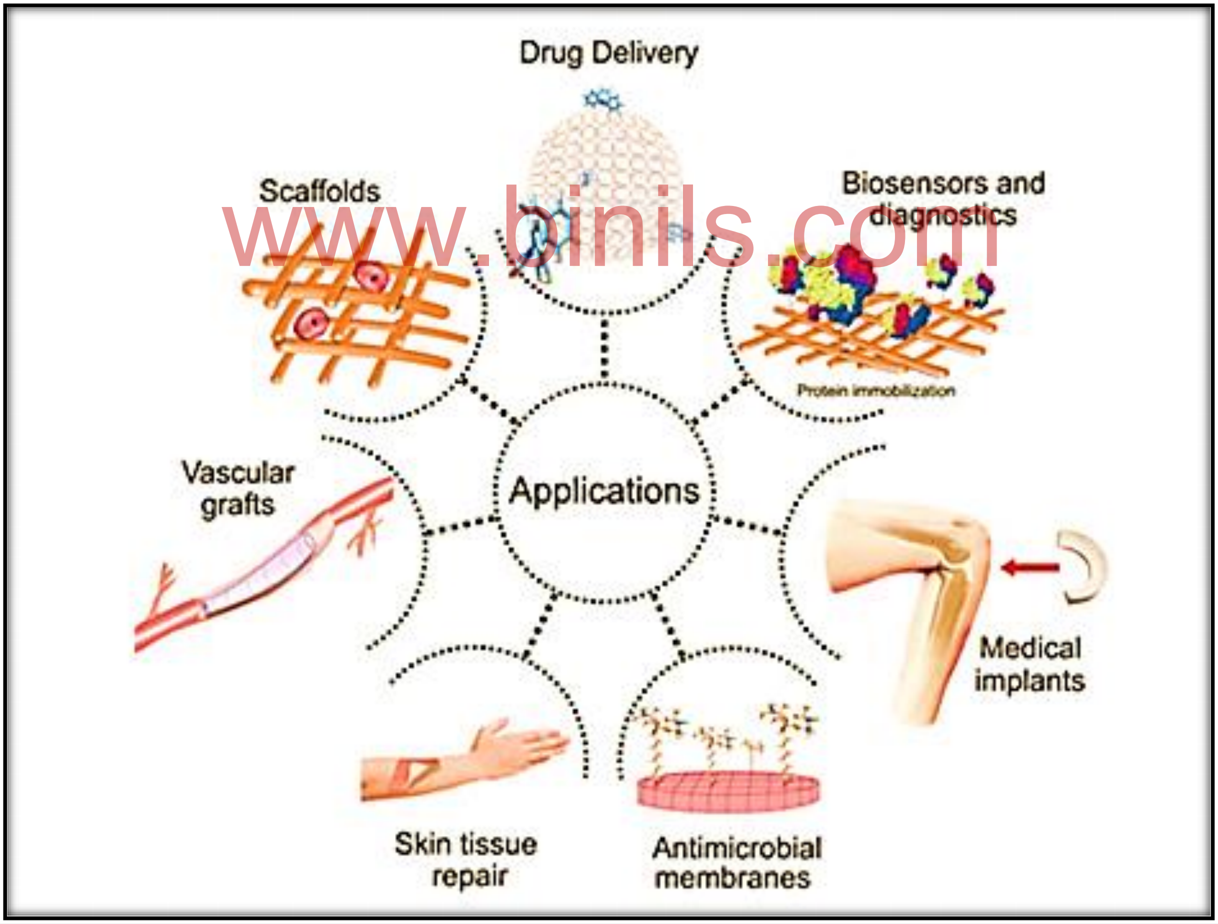


Fig. 2.2.3 Medical Applications using nano technology

Applications of Nanoparticles in Biomaterials

1. Nanoparticles of TiO_2 are used in cosmetics as sunscreen.
2. Nanoparticles of silver are used in antibacterial and antifungal agents.
3. Problems in food and bio processing industry to produce quality food can be solved using nanotechnology.
4. Nano biosensors are used for bacterial identification and food quality monitoring.
5. Nano composite coating acts as anti microbial agents.
6. Nano foods are used to carry vitamins and minerals to digestive system.

RECAP

In this chapter following topics are dealt with

- Importance of nano-particles
- Properties of nano-particles
- Applications of nano-particles in engineering
- Application of nano-particles in medicines

ACTIVITY

Study the different potencies of homeopathic medicines. You can observe higher the potency more the dilution and greater the activity.

EXERCISE FOR BETTER UNDERSTANDING

1. Nano size copper become transparent : True / False
2. Materials having size 10^{-9}m are nano-particles : True / False
3. Colour of Nano size is gold is red : True / False
4. Carbon Nano tubes (CNT) is used in storage device : True / False
5. Gold Nano cells used to enhance blood clotting : True / False

Test Paper–1

Part-A

1. What are Nanoparticles?
2. Name the Nanoparticles used to destroy tumour?

Part-B

3. Give any two characteristic of nano-particles?
4. Why nano-particles are used as bone cement?

Part-C

5. What is the importance of nano-particles?
6. Compare the properties of nano-particles?

Test Paper– 2

Part–A

1. What is CNT?
2. What is the colour of Nano gold?

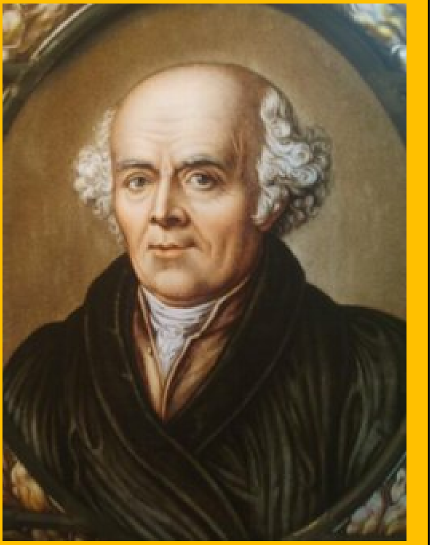
Part–B

3. Compare any two properties of nano-particles with bulk material?
4. Give two electronic use of nano-particles?

Part–C

5. Give the application of Nanotechnology in engineering?
6. List out the application of Nano technology in medicine?

FACT STORE



Christian Friedrich Samuel Hahnemann (10 April 1755 – 2 July 1843) was a German physician, well known for creating the system of medicine called Homeopathy. Hahnemann studied medicine and graduated MD at the University of Erlangen on 10 August 1779. In 1781, he took a village doctor's position and became dissatisfied with the state of medicine in his time, particularly with practices such as bloodletting and leaching. He claimed that the medicine he had been taught to practice sometimes did more harm than good to patients. This principle, like cures like, became the basis for an approach to medicine which he gave the name **Homeopathy.**

https://www.nhp.gov.in/homeopathy-hahnemann-and-homeopathy_mtl

Broaden your understanding

Click the following link or scan the QR code

https://www.youtube.com/watch?v=g8ftdqCVh5I&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=8

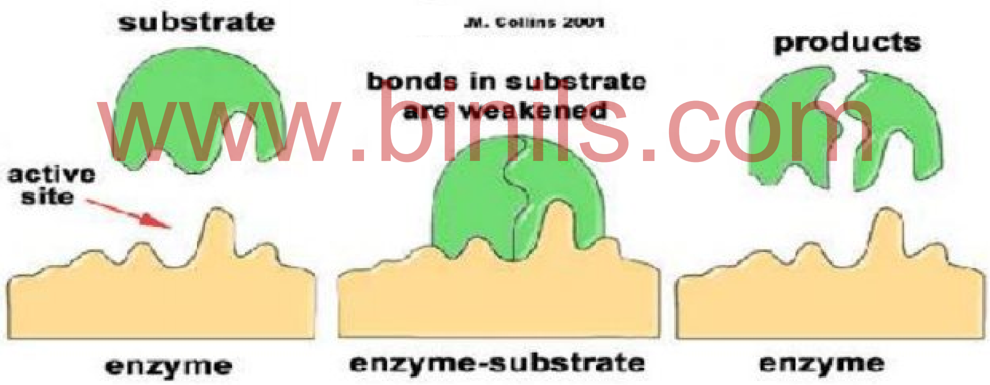
2.3 CATALYSIS

Catalyst – Positive – Negative catalyst – Definition – Types of catalysis – Homogeneous and Heterogeneous – Promoter – Catalyst poison – active centre – Definition – Characteristics of a catalyst – Industrial applications of catalysts. **- 5 Hours**

Introduction

All the chemical reactions will not occur in the same pace. Some reactions take place in less than a second and some reactions require more than hours or even few days to complete. The rate of a chemical reactions can be altered by the mere presence of a foreign substance. The systematic study of the effect of various foreign substances on the rates of chemical reactions was first made Berzelius in 1835. He suggested the term catalyst. Catalyst mainly used to accelerate the rate of a chemical reaction and remain chemically and quantitatively unchanged before and after the reactions are known as catalyst. The phenomenon of changing of the rate of a chemical reaction in presence of a catalyst is known as catalysis.

The catalytic action is a surface phenomenon, most catalysts are not just flat surfaces, they have complex three dimensional shapes. The substrate often has to bind to the catalyst in a very specific way in order to speed up the catalysed reaction to take place. This is called **catalyst active centre**.



A few catalyst increases the rate of a reaction and a few may decrease the rate of a chemical reaction. Based on this fact they are classified:

Positive catalyst

A *positive catalyst* is a substance *which increases the rate of a chemical reaction.*

Such catalyst decreases activation energy by accepting a smaller path, so the rate of reaction is increased.

$$2SO_2(g) + O_2(g) \xrightarrow{Pt(s)} 2SO_3(g)$$

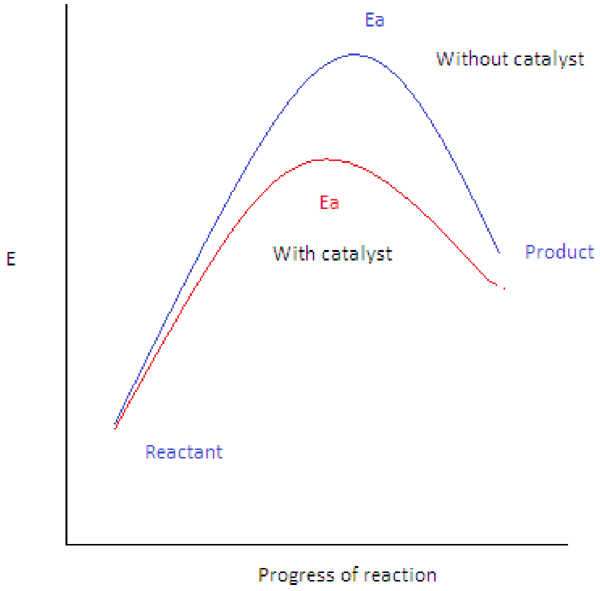


Fig 2.3.1 Progress of a reaction with a positive catalyst

Look at the figure 2.3.1, you can observe the energy of activation (Ea), is reduced due to the presence of a positive catalyst. Energy of activation is the energy an intermediate state, before the product is formed and it has a maximum energy.

Reaction	Catalyst
1. <u>**Haber's process:**</u> **Manufacture of ammonia from Nitrogen and Hydrogen** $N_2 + 3H_2 \longrightarrow 2NH_3$	Iron (Fe)
2. <u>**Contact process:**</u> **Oxidation of SO_2 to SO_3** $2SO_2 + O_2 \longrightarrow 2\,SO_3$	Platinum (Pt)
3. **Decomposition of Potassium chlorate** $2KClO_3 \longrightarrow 2KCl + 3O_2$	Manganese dioxide (MnO_2)

Negative catalyst

A *negative catalyst* is a substance *which retards(decreases) the rate of a chemical reaction*

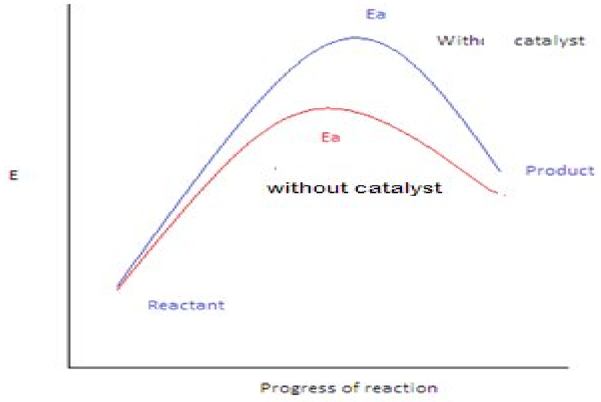


Fig 2.3.2 Progress of a reaction with a negative catalyst

Look at the figure 2.3.2, you can observe the energy of activation (Ea) is increased due to the presence of a negative catalyst.

Reaction	Catalyst
1. Decomposition of Hydrogen peroxide $2H_2O_2 \longrightarrow 2H_2O + O_2$	Glycerine
2. Oxidation of sodium sulphite $2Na_2SO_3 + O_2 \longrightarrow 2Na_2SO_4$	Alcohol
3. Ignition of petrol	Tetraethyl lead (TEL)

Based on the nature of the state of a catalyst and reactants they are further classified as homogeneous catalysis and heterogeneous catalysis

Homogeneous catalysis

In Homogeneous catalysis, the catalyst and the reactants are in the same phase.

Reaction	Catalyst
1. Oxidation of SO_2 to SO_3 $2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$	Nitric oxide$_{(g)}$ (NO)
2. Hydrolysis of Cane sugar to glucose and Fructose $C_{12}H_{22}O_{11(liq)} + H_2O_{(liq)} \longrightarrow C_6H_{12}O_{6(liq)} + C_6H_{12}O_{6(liq)}$	Acid$_{(liq)}$ (HCl)

Heterogeneous catalysis

In the heterogeneous catalyst, the catalyst and the reactants are in different phases.

Reaction	Catalyst
1. <u>Haber's process:</u> Manufacture of ammonia $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$	Iron (Fe) (Solid)
2. <u>Contact process:</u> Oxidation of SO_2 to SO_3 $2SO_{2(g)} + O_{2(g)} \longrightarrow 2\,SO_{3(g)}$	Platinum (Pt) (Solid)

The catalytic activity can further be accelerated or retarded using a fourth substance, called promoter or catalytic poison.

Promoters

A promoter is a substance which increases the catalytic activity of a catalyst.

Example:

Reaction	Catalyst	Promoter
<u>Haber's process:</u> Manufacture of ammonia $N_2 + 3H_2 \longrightarrow 2NH_3$	Iron (Fe)	Molybdenum (Mo)

Catalyst poison

A catalyst poison is a substance, which reduces or even completely destroys the activity of catalyst.

Example:

Reaction	Catalyst	catalytic poison
Haber's process: Manufacture of ammonia $N_2 + 3H_2 \longrightarrow 2NH_3$	Iron (Fe)	CO (or) H_2S

Characteristics of catalyst:

A catalyst should have the following characteristics.

1. Catalyst remains unchanged in mass and chemical composition at the end of the reaction.
2. A catalyst does not initiate a chemical reaction. It can only alter the speed of a reaction.
3. A small amount of the catalyst is sufficient to catalyse the reaction.
4. A catalyst cannot alter the nature of the products.
5. A catalyst can be poisoned by certain substances.
6. A catalyst does not alter the position of equilibrium in a reversible reaction.
7. The catalyst is usually specific in its action.
8. There is an optimum temperature for every catalyst at which its catalytic activity is maximum.

Industrial application of catalysis

There are many industrial applications in Engineering for process design, catalyst design, alternate fuel and so on:

Reaction	Catalyst
1. Haber's process: Manufacture of ammonia	Iron (Fe)
2. Contact process: Manufacture of H_2SO_4 **Oxidation of SO_2 to SO_3**	Platinum (Pt)
3. Hydrogenation of vegetable oils to vanaspathi (dalda)	Finely divided Ni & Cu
4. Hydrolysis of cane sugar to glucose and Fructose	Acid
5. Decon's Process: Manufacture of Chlorine	$CuCl_2$
6. Bosch Method: Manufacture of hydrogen	Ferric oxide
7. Cracking process of heavy petroleum fractions	Silica
8. Manufacture of Ethyl alcohol by fermentation	Invertase and Zymase

RECAP

In this chapter following topics are dealt with

- Types of catalysis reaction
- Types of catalyst
- Characteristics of a catalyst
- Industrial applications of catalyst

ACTIVITY

I. Catalysis is the change in speed of a chemical reaction due to the help of catalyst. Observe the oxidation of ferrous sulphate titration against potassium permanganate in the absence of sulphuric acid.

II. A low temperature oxidation catalysts used to convert carbon monoxide to non-toxic carbondioxide at room temperature, it can also remove formaldehyde from the air. Observe the oxidation of oxalic acid with $KMnO_4$ with and without heating.

Exercise for better understanding

1. A positive catalyst is substance which decreases the rate of chemical reaction :True/False
2. In Homogeneous catalysis, the catalyst and reactants are in the same phase :True/ False
3. Catalytic poison reduces or destroys the activity of catalyst :True/ False
4. Catalyst initiate a chemical reaction :True/ False
5. Manufacture of ammonia requires platinum catalyst :True/ False

Test Paper–1

Part-A

1. What is positive catalyst?
2. What is catalytic poison?
3. What is homogeneous catalysis?

Part-B

4. Heterogeneous catalysis – give an example
5. What is a promoter? Give an example.

Part-C

6. Write a note on Positive & Negative catalyst with an example
7. List out the characteristics of catalyst

Test Paper–2

Part – A

1. What is catalysis?
2. What are catalysts?
3. Define Promoter?

Part – B

4. Explain negative catalyst with an example?
5. Catalytic poison – give an example.
6. What is catalyst active centre?

Part – C

7. Write a note on homogeneous and heterogeneous catalysis with an example
8. What are the industrial applications of catalyst?

FACT STORE

Enzymes accelerate reactions million times or even more. Indeed, most reactions in biological systems do not take place at perceptible rates in the absence of enzymes. Even a reaction as simple as the hydration of carbon dioxide is catalyzed by an enzyme—namely, carbonic anhydrase . The transfer of CO_2 from the tissues into the blood and then to the alveolar air would be less complete in the absence of this enzyme. In fact, carbonic anhydrase is one of the fastest enzymes known. Each enzyme molecule can hydrate 10^6 molecules of CO_2 *per second.* This catalysed reaction is 10^7 times as fast as the uncatalysed.

Broaden your understanding:

https://www.youtube.com/watch?v=lS0aqaVX1h4&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=12

FREQUENTLY ASKED QUESTIONS:

UNIT II

Part A

1. What is a colloid?
2. What are lyophilic colloids?
3. What are lyophobic colloids?
4. Give an example for lyophilic colloids.
5. Give an example for lyophobic colloids.
6. What is a positive catalyst?
7. What is a negative catalyst?
8. What is catalysis?
9. What are nanoparticles?
10. What is Carbon Nano Tube?
11. Compare the size of colloid with molecule..
12. What happens to the energy of activation of chemical reaction in the presence of a catalyst?
13. What is the catalyst used for the production of ammonia?
14. What is the use of invertase and zymase?
15. What happens to energy of activation in the presence of a positive catalyst?
16. What happens to energy of activation in the presence of a negative catalyst?
17. What catalyst used for the hydrogenation of vegetable oil?

Part B

1. What is Tyndall effect?
2. What is called Brownian movement?
3. Define electrophoresis.
4. What is coagulation?
5. Give any two unique characteristics of nanoparticles?
6. Define catalyst.
7. Define promoters.
8. What is a catalytic poison?
9. Draw the pictorial representation of a positive catalyst?
10. Draw the progress of a chemical reaction that increases energy of activation (Ea) in the presence of a negative catalyst?
11. What is meant by catalytic active centre?

Part C

1. Write down the distinction between true solution and colloidal solution.
2. What are the differences between Lyophilic and Lyophobic colloids?
3. Write a note on the properties of colloids.
4. Write down the industrial applications of colloids.
5. Give the importance of nanoparticles.
6. Compare the properties of nanoparticles and Bulk materials.
7. Mention the application of nanotechnology in Engineering.
8. How is nanotechnology useful in medical field
9. Explain homogeneous and heterogeneous catalysis with an example.
10. List out the characteristics of a catalyst.
11. Give the industrial applications of catalyst.
12. Write notes on catalytic reaction, and explain in detail with a neat diagram. What is the role of catalytic active centre? Give example.
13. Explain the function of soap in cleansing action. Explain in detail about the Cottrell's electrostatic precipitator.

UNIT
3
MINERALS AND METALLURGY

3.1 MINERALS AND METALLURGY

Minerals – Minerals of Tamil Nadu - Sources and Uses - Extraction of iron - blast furnace - cast iron - steel manufacture - bessemer converter - heat treatment of steel - hardening annealing - tempering **- 7 Hours**

Introduction

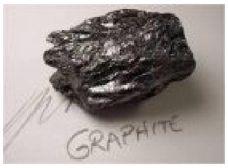
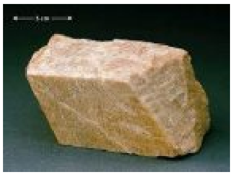
A mineral is a naturally occurring substance having a definite chemical composition, constant physical properties, and a characteristic crystalline form. Ores are a mixture of minerals: they are processed to yield an industrial mineral or treated chemically to yield a single or several metals. Ores that are generally processed for only a single metal are those of iron, aluminium, chromium, tin, mercury, manganese, tungsten, and some ores of copper. Gold ores may yield only gold, but silver is a common associate. Nickel ores are always associated with cobalt, while lead and zinc always occur together in ores. All other ores are complex yielding a number of metals.

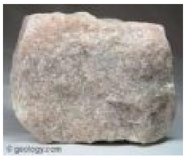
Mineral Resources of Tamil Nadu

Tamil Nadu is the leading holder of country's resources of vermiculite, magnetite, dunite, rutile, garnet, molybdenum and ilmenite. The State accounts for the country's 81% lignite, 75% vermiculite, 69% dunite, 59% garnet, 52% molybdenum and 30% titanium minerals resources. Important minerals that are found to occur in the State are as follows:

OCCURRENCE OF INDUSTRIAL MINERALS IN TAMIL NADU AND THEIR USAGE

Name of the mineral	Mineral Image	Place of Occurrence	Usage
Magnesite		1. Salem 2. Namakkal 3. Karur	1. The refractory material. 2. Magnesium cement. 3. Catalyst and filler.
Dunite		1. Salem 2. Namakkal 3. Karur	1. The refractory material. 2. Catalyst and filler. 3. Using as flux in the Iron & Steel 4. industry.

Graphite		1. Sivaganga 2. Madurai	1. Insulator. 2. Electrode. 3. Atomic reactor 4. Crucibles 5. Carbon brushes.
Lignite		1. Cuddalore 2. Ramanathapuram	1. Fuel. 2. Power station.
Bauxite		1. Salem 2. Namakkal	1. Ore of Aluminium. 2. Used as metal alloy for aircraft.
Iron Ore		1. Salem 2. Tiruvannamalai	1. Iron metal.
Limestone		1. Ariyalur 2. Perambalur 3. Tirunelveli 4. Virudhunagar 5. Madurai 6. Salem 7. Karur 8. Dindigul	1. Cement. 2. Chemical Industries. 3. Pharmaceuticals. 4. Metal Industries.
Quartz		1. Salem 2. Namakkal 3. Karur 4. Dharmapuri	1. Silicon Chips. 2. Glass Industries.
Feldspar		1. Salem 2. Namakkal 3. Karur 4. Dharmapuri	1. Ceramic article. 2. Decorative titles.
Garnet Sand		1. Kanyakumari 2. Tirunelveli 3. Tuticorin 4. Trichy	1. Abrasives,. 2. Semiconductor. 3. Sand plastering.

Silica Sand		1. Nagapattinam	1. Glass Industries. 2. Foundry moulding catalysts.
Fireclay		1. Ariyalur 2. Cuddalore	*1. Refractory.* *2. Decorative tiles.* *3.* Ceramic article.
Molybdenum		1. Dharmapuri 2. Krishnagiri	1. Electrical conductor. 2. Used in petroleum industries. 3. Heating Elements.
Gypsum		1. Perambalur 2. Coimbatore	1. Plaster of Paris. 2. Cement. 3. Manure and Pesticides.
Calcite		1. Salem	1. Cement. 2. Chemical industries. 3. Metal Alloy 4. Pharmaceutical.

Source : Department of Geology and Mining, Government of Tamil Nadu

Extraction of Iron

The extraction of metal from its ore and modifying the properties of metal is dealt in metallurgy. The natural occurrence of the sediment of the metal in the form of its oxide, carbonate, sulphide etc. along with other elements is called **mineral**. The impurities and earthy substances found along with minerals called **gangue** particles. **Ore** is the one from which the metal can economically be extracted. A large amount of metal is present, or more simply the percentage of metals is more in the ore than mineral.

Iron is most abundant element on the earth crest. It atomic number is 26 and atomic weight is 56.85, **Iron ores** usually rich in iron oxides vary in colour from dark grey to bright yellow, or rusty red.

Iron is extracted from the ore **heametite** on large scale using blast furnace. Haematite contains **iron** oxide. Iron is obtained by reduction process.

Fig.3.1.1 Heamatite Ore

Ores of iron :

Heametite (Fe_2O_3) contains 70% iron

Magnetite(Fe_3O_4) contains 72% iron

Siderite-$FeCO_3$ contains 48 % Iron

Extraction of iron:

The iron ore is concentrated by gravity separation. It is then roasted so as to remove sulphur as sulphur di-oxide and arsenic as arsenic oxide.

$$S + O_2 \longrightarrow SO_2$$

$$4\,As + 3O_2 \longrightarrow 2\,As_2O_3$$

After roasting, the ore becomes porous and is smelted in blast furnace.

Smelting:

Smelting is carried out in blast furnace. It is a process of reduction of metal oxide to metal.

Modern blast furnace is 25-35m tall with 6-14m diameter at the hearth. The temperature may go upto 1650^{o} C and so the hearth is lined with carbon type refractory blocks and the stack is made up with fireclay or silica. There is cup and cone arrangement for charging. Tuyeres are provided at the bottom of the furnace to blow air. There is a hole provided for tapping slag and molten iron at the bottom. It can produce 1000 to 10000 tons of pig iron per day. **The furnace is charged with roasted iron ore, coke and limestone in the ratio 8:4:1.**

Reduction:

The metal is fused with the flux and a reducing agent. The flux removes the slag. Coke burns to give carbon monoxide which acts as a reducing agent. The following reactions take place:

$$Fe_2O_3 + 3C \longrightarrow 2\,Fe + 3CO$$

$$CaCO_3 \longrightarrow CaO + CO_2$$

Flux

$$Fe_2O_3 + 3CO \longrightarrow 2\,Fe + 3CO_2$$

$$CaO + SiO_2 \longrightarrow CaSiO_3$$

Slag

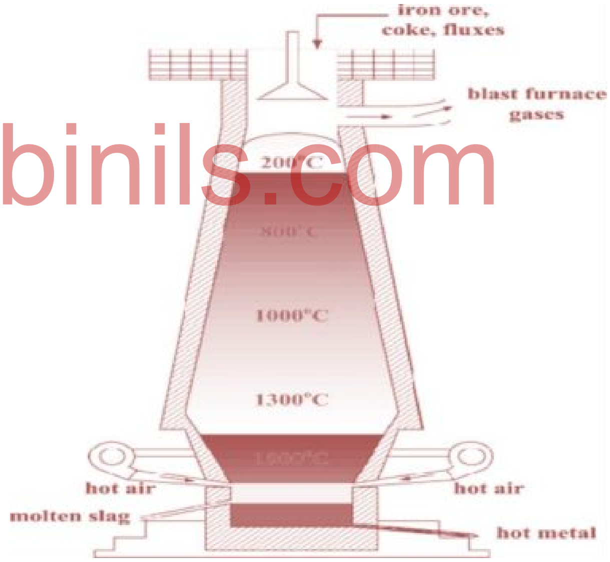


Fig.3.1.2 Modern blast furnace

At the bottom of the furnace molten iron settles down. The slag floats above the molten metal. The molten iron is casted into small pigs and hence called pig iron. The percentage of carbon vary from 2-4% in pig iron.

Manufacture of steel:

Bessemer process was the first inexpensive very old method for the large scale production of steel from pig iron. The principle is removal of impurities from the iron by oxidation with air blown through the molten iron. The excess carbon is first removed and calculated quantity of carbon is added. The process was named after the inventor Henry Bessemer in 1856.

Steel contains 0.15 to 1.5 % carbon. This is manufactured using Bessemer convertor. It is a large pear shaped steel vessel lined inside with silica bricks. It can be tilted to any desired position. Air can be blown from the bottom.

The convertor is brought to a horizontal position and charged with pig iron. It is then brought to vertical position and hot air is blown from the bottom. During the initial time the manganese and silicon is oxidized. The carbon is oxidized to CO and burns with a blue flame. When the flame dies off, air is cut off. The Slag floats at the top is removed. A calculated quantity of ***manganese, carbon and iron called 'spiegel'*** is added. The molten steel is poured into moulds.

$$Si + O_2 \longrightarrow SiO_2$$

$$Mn + O_2 \longrightarrow MnO_2$$

$$MnO + SiO_2 \longrightarrow MnSiO_3$$

$$2C + O_2 \longrightarrow 2\,CO$$

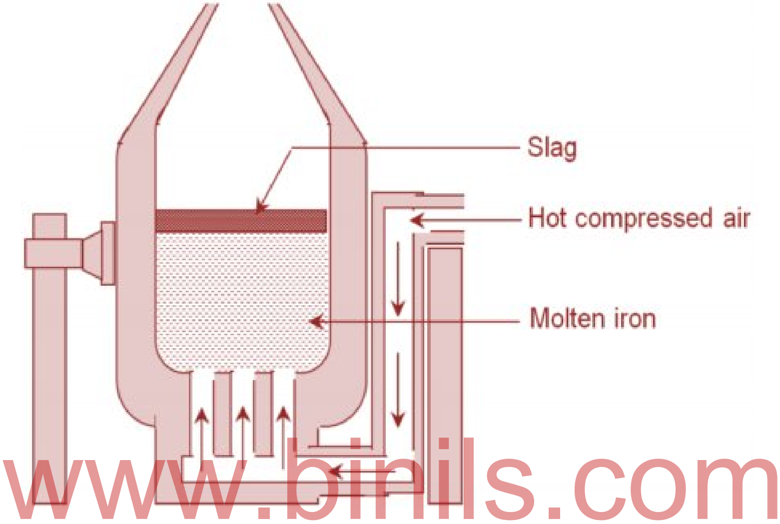


Fig. 3.1.3 Bessemer Converter

Heat treatment of steel: Heat treatment alter the physical properties of the metal. Heat treatment involves heating and cooling, to achieve a desired result such as hardening or softening of a material. Heat treatment techniques are:

- Annealing
- Hardening
- Tempering

Annealing:

Annealing means softening**.** The metal is heated to a specific temperature and then cooled slowly in a controlled manner. Annealing is most often used to soften a metal for to improve machinability, or to enhance properties like electrical conductivity.

In ferrous alloys, annealing is usually accomplished by heating the metal beyond the upper critical temperature and then cooling very slowly. Annealing removes the hardness caused by cold working. The metal is heated to a temperature where re-crystallization can occur while cooling, thereby repairing the defects and produce a refined microstructure. The annealing temperature vary according to the various steel. The annealing temperature for **high carbon steel** is around 780°C, **for medium carbon steel** it is between 780-840°C and **for mild carbon steel** the annealing temperature is around 840°C.

Hardening:

Hardening is also called quenching because the steel is heated around 30 to 50°C beyond the critical temperature and suddenly cooled at a faster rate. As the name implies this will produce a very hard steel. Sudden cooling can be done by plunging into oil or brine solution. This will transform to a hard, brittle crystalline structure. The quenched hardness of a metal depends on its chemical composition and quenching method. Hardening increases abrasion resistance. Hardened steel is useful for making cutting tools.

Tempering:

Already hardened steel is heated below the critical temperature and allowed to cool slowly. Tempering removes the stress developed during quenching. This is useful for making chisels, blades, tool bits etc.

RECAP

In his chapter following topics are dealt with:

- extraction of iron from its ore using blast furnace
- manufacture of steel using Bessemer converter
- heat treatment of steel and their uses

ACTIVITY

Collect some samples of iron material, steel, and few hardened tools. Write down their uses. Try to note down the percentage of carbon and other metals present in it.

EXERCISE FOR BETTER UNDERSTANDING

1. The percentage of metal is rich in ore than mineral- True/false
2. The Spiegel is a kind of gel obtained from jelly fish-True/false
3. Quenching is a process of sudden cooling of heated steel beyond critical temperature.-True/false
4. Iron and steel are one and the same.-True/false
5. Annealing is process of slow cooling True/false

Test Paper 1

PART A

1. Define Minerals.
2. Name any two ores of iron.
3. Name any two types of heat treatment.
4. What is meant by annealing of steel?

PART B

1. Write a note on roasting of iron ore.
2. What is the purpose of heat treatment of steel?

PART C

1. Explain the extraction of iron in blast furnace with a neat diagram.
2. Describe the manufacture of steel with a neat diagram

Test Paper 2

Part A

1. What is called quenching?
2. Define tempering?
3. What are the uses of tempered steel?
4. What is called a "Spiegel"

Part B

1. Write notes on annealing of steel.
3. Write notes on hardening of steel.
4. What is called tempering of steel.

Part C

1. Write notes on heat treatment of steel.
2. Write the reactions involved in the blast furnace.
3. Explain briefly about Minerals of Tamil Nadu and their sources and uses.

FACT STORE (Beyond the scope of examination)

Iron Age:

The Iron Age was a period in human history that started between 1200 B.C. and 600 B.C., depending on the region, and followed the Stone Age and Bronze Age. During the Iron Age, people across much of Europe, Asia and parts of Africa began making tools and weapons from iron and steel.

3.2 METALLURGY OF TUNGSTEN AND TITANIUM

Metallurgy of Tungsten and Titanium-Extraction and uses of Tungsten and Titanium **- 4 hours**

Metallurgy of Tungsten

Tungsten is a transition element with symbol W, derived from its Latin name, Wolfram and its atomic number is 74. It belongs to d-block elements present in Group VIA and 6th period of the periodic table. It was found in the year 1781 AD. It is also found in bio molecules of certain bacteria**.** The chief minerals of Tungsten is present about 10% in the lithosphere

Ores:

Wolframite (FeMn) WO_4

Scheelite $CaWO_4$

Concentration: (i) Ore is powdered well. (ii) Concentrated by magnetic separation method.

Extraction

Concentrated ore is fused with a mixture of sodium carbonate and sodium nitrate. The fusion is done in an oxidizing atmosphere. The fused mass is extracted with water. Then the solution is acidified with HCl. Tungstic acid is precipitated.

$$4\,FeWO_4 + 4\,Na_2CO_3 + O_2 \longrightarrow 4\,Na_2WO_4 + 2\,Fe_2O_3 + 4\,CO_2$$

$$2MnWO_4 + O_2 + 2\,Na_2CO_3 \longrightarrow 2\,Na_2WO_4 + 2\,MnO_2 + 2\,CO_2$$

Sodium tungstate crystals are again dissolved in minimum quantity of water and acidified with HCl acid. Hydrated tungstic acid $WO_3.H_2O$ (**H_2WO_4**) precipitates out.

$$Na_2WO_4 + 2HCl \longrightarrow 2NaCl + H_2WO_4$$

Tungstic acid thus obtained is ignited strongly to remove water.

$$H_2WO_4 \longrightarrow WO_3 + H_2O$$

The WO_3 is then reduced with hydrogen to get tungsten.

$$WO_3 \longrightarrow W + 3H_2O$$

Tungsten thus obtained is purified by converting it into vapours of tungsten hexa chloride and the vapours when passed over a heated tungsten wire give pure tungsten.

Properties

Tungsten is a hard silvery white metal. It is as heavy as gold. It has highest melting point

(3422 °C). Its wire is very hard and has high tensile strength. It is resistant to acids.

Uses

1. Tungsten is mainly used for preparing special type of steels. It is also used for making filaments of electric bulbs, pinpoints, strings for musical instruments etc.,
2. Steel containing 14-22% tungsten and 3-5% Chromium forms a high speed tool steel material, since it retains its hardness even at very high temperature.
3. It is also used as anti cathode in X-ray tubes.
4. Tungsten is also used for making surgical instruments, spark coils, gramophone needles, Voltage regulators, telegraphic keys, contact points etc., Tungsten carbide is used to prepare very hard alloys.

5. Sodium tungstate is used for making fireproof fabrics. It is also used as a mordant in dyeing.
6. WO_3 is used as yellow pigment.
7. Tungsten's hardness and high density give it military applications in penetrating projectiles.

Titanium (Ti)

Titanium is a transition metal with the symbol **Ti** and atomic number 22. It belongs to d-block elements in group IVA and 4th period of the periodic table. It is lustrous with a silver colour, low density, and high strength. Titanium is resistant to corrosion to sea water, aquaregia and chlorine. It is a 7th abundant element in the earth crest, present in igneous rocks and its sediments are found in water bodies.

Titanium was discovered in Cornwall, Great Britain by William Gregor in 1791 and was named by Martin Heinrich Klaproth after Titans of Greek mythology.

The main ores of Titanium are

Rutile –TiO_2

Ilmenite –$FeTiO_3$

Extraction

Stage I: The ores of Titanium (Rutile or Ilmenite) is converted into titanium tetra chloride **($TiCl_4$)** by heating them at 900°C with carbon in a current of Chlorine.

$$TiO_2 + C + Cl_2 \longrightarrow TiCl_4 + CO_2$$

Stage II: The vapour of **$TiCl_4$** is collected and condensed to get **$TiCl_4$** liquid. **$TiCl_4$** liquid, which boils at 136°C, is purified by distillation.

Stage III: **$TiCl_4$** is then reduced with sodium metal in an argon atmosphere to get titanium.

The metal thus obtained is washed with 3% nitric acid to remove impurities.

$$TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$$

Stage IV: Finally the metal is purified by Van Arkel method. In this method impure Titanium is heated with iodine vapour to get Titanium tetra iodide.

$$Ti + I_2 \longrightarrow TiI_4$$

Titanium tetra iodide is taken to a different chamber and passed over a heated tungsten wire at 140°C. **TiI_4** decomposes to give pure Titanium.

$$TiI_4 \longrightarrow Ti + I_2$$

Properties

Titanium is a shining white metal. It has low density and high melting point. It has high strength to weight ratio. It is paramagnetic and has fairly low electrical and thermal conductivity compared to other metals. Titanium is super conducting metal when cooled below its critical temperature of 0.49 K.

Uses

1. Titanium has better corrosion resistance and is much lighter in mass when compare to stainless steel. It is therefore used in aircrafts, gas turbine engines, marine equipments etc.
2. It is also used for hardening steel.
3. TiO_2 is used as a semi-precious artificial gem.

RECAP

In this lesson we have understood

- The metallurgy of tungsten
- Metallurgy of titanium
- Uses of tungsten and titanium.

ACTIVITY

- Collect the pictures of orthopaedic implants where titanium is used.
- Surf the internet and find the use of tungsten in electrical equipments.

EXERCISE FOR BETTER UNDERSTANDING

1. Tungsten is also found in bio molecules - TRUE/FALSE
2. Tungsten is concentrated by gravity separation method - TRUE/FALSE
3. Tungsten oxide is a white pigment - TRUE/FALSE
4. Titanium is purified by Van Arkel method - TRUE/FALSE
5. Titanium has very poor corrosion resistance - TRUE/FALSE

TEST PAPER

Part –A

1. Name any two ores of tungsten.
2. Name any two ores of titanium.
3. What type of concentration method used for the extraction of tungsten?

Part –B

1. Mention any two uses of titanium.
2. Titanium is better than stainless steel. Why?
3. Describe Van Arkel method of purification of Titanium

Part C

1. How is tungsten extracted from its ore?
2. Explain the extraction of Titanium from its ore.

FACT STORE

Metallic implants are commonly used in the orthopedic field Prime examples of titanium implants used in orthopedics would include prosthetic hip and knee replacements for various types of arthritis affecting these joints, spinal fusion instruments for stabilizing degenerate and unstable vertebral segments, and fracture fixation devices of various types such as plates, screws.

Through top-down nanofabrication processes, tungsten nano wire have been fabricated and studied since 2002. Due to a particularly high surface to volume ratio, the formation of a surface oxide layer and the single crystal nature of such material, the mechanical properties differ fundamentally from those of bulk tungsten.[1] Such tungsten nanowires have potential applications in nanoelectronics and importantly as pH probes and gas sensors.

Broaden your understanding

https://www.youtubecom/watch?v=IO_KUWj5LuU&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index

3.3 POWDER METALLURGY

Definition – Powder metallurgical process-Preparation of Metal Powder – Atomization – Reduction of Metal Oxide – blending –compacting-sintering-finishing-Applications of Powder Metallurgy. **- 4 Hours**

Powder metallurgy (PM): Powder metallurgy is the art of manufacturing fine metal powders and fabricating them into desired geometrical shape with a little or no melting and compression. Powder metallurgical products contains not only metals but also metals and non–metals. The products can be made at reduced cost with a simple process. The particle size of metal powder vary in the range of 10 to 100 microns (10^{-6}m).

Powder metallurgy involves the following steps:

(i) Production of metal powders

(ii) Blending of metal powders

(iii) Compacting

(iv) Sintering

(v) Finishing

i) Production of metal powder:

The metal or alloy powder can be prepared by one of the following methods

a) Atomization **b) Reduction**

a) Atomization: This method is generally used for metals having low melting point. In this process, the molten metal is forced through an orifice by a stream of compressed air. Then it is cooled into fine powder. Zinc, aluminium, tin, lead and magnesium powder can be prepared by this method. In order to avoid oxidation an inert atmosphere is introduced.

b) Reduction method:

1. Reduction of metal oxide
2. Reduction method is suitable for the metals with high melting point like tungsten, iron, copper, nickel etc.

Metal powder can be obtained by passing reducing agent like carbon monoxide or hydrogen on heated metal oxides. The metal thus obtained is then crushed and ground to particle of desired size.

Example:

1. Copper powder can be obtained by reducing copper oxide using hydrogen.

$$Cu_2O + H_2 \longrightarrow 2\,Cu + H_2O$$

2. Tungsten powder is obtained by passing hydrogen over WO_3.

$$WO_3 + 3H_2 \longrightarrow W + 3H_2O$$

Advantages:

1. The yield is higher in this method.
2. This method is highly convenient and economical

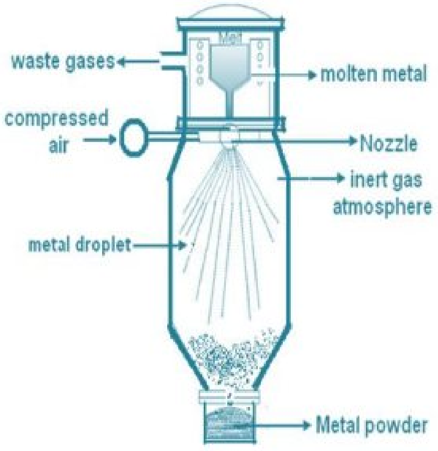


Fig. 3.3.1 Atomization

ii) Blending of metal powders: A single metal powder cannot meet the requirements. So two or metal powders are intimately blended.

iii) Compacting: Compacting is the process of compressing metal powder in a die through the application of high pressures. The powder is then compacted into a shape and then ejected from the die cavity. The density of the compacted powder increases with the amount of pressure applied. Pressure of 10 tons/in² to 50 tons/in² (150 MPa to 700 MPa) are commonly used for metal powder compaction.

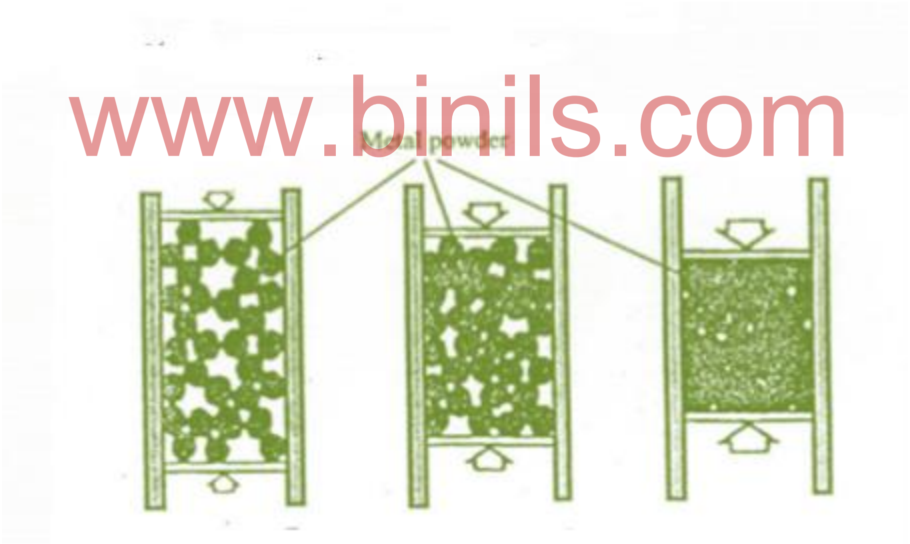


Fig. 3.3.2 Compacting

iv) Sintering:

Sintering gives cohesiveness and strength. The compacted product is heated to a temperature below the melting point of the basic metal. During first stage powder particles remain discrete. During the second, most densification occurs, the structure re-crystallizes and particles diffuse into each other.

v) Finishing:

The finished powder metallurgical product cannot be used as such it requires finishing operations like grinding, sizing etc.

Applications of powder metallurgy

Powder metallurgy is also used to make unique materials impossible to get from melting or forming in other ways. They are porous oil-impregnated bearings, electrical contacts and diamond tools.

1. Used for making compact, complicated geometrical shaped objects.
2. Used for making metal bearings embedded with graphite powder.
3. Generator brush and electrical contact brush composite containing highly conductive copper and graphite with lubricating property is manufactured by powder metallurgy
4. Used for making filaments for bulbs (Tungsten filament).
5. Used for making non lubricated bearings using steel and Teflon.
6. Used to prepare magnetic materials.
7. Very hard cutting tools from carbides of tungsten, titanium, tantalum etc, are manufactured.
8. Used for making diamond impregnated cutting tools.
9. Used for making wear resistance cutting tools (Eg: with cobalt and nickel metal powder).
10. Heat resistant ceramic –metal product known as ‘CERMET’ are used in nuclear energy equipments.

RECAP:

In this chapter we have discussed the followings:

- Powder metallurgical process
- Powder metallurgical applications
- For more understanding type the following link in youtube or scan the QR code:

Broaden your Understanding

https://www.youtube.com/watch?v=DqhL7d22uSc&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=9

ACTIVITY

- **Collect the iron powder from the workshop practical and try to develop few solid shapes using some adhesives.**
- **Collect few powder metallurgical products used in automobiles.**

EXERCISE FOR BETTER UNDERSTANDING

1. **Atomization is a process of making metal powders for low melting metals- True/False**
2. **Sintering is a cooling process- True/False**
3. **Electrical contact points are made using magnets- True/False**
4. **Non-lubricated bearings are powder metallurgical products- True/False**
5. **Cermet is product using glass and metal- True/False**

Test paper-1

PART – A

1. Define powder metallurgy.
2. Mention the methods of preparation of metal powders.
3. What is called cermet?

PART – B

1. Explain the preparation of metal powder by atomization.
2. Explain the preparation of metal powder by reduction of metal oxide.

PART – C

1. Explain the various steps involved in powder metallurgy
2. Explain the two methods of preparation of metal powders.
3. Mention the applications of powder metallurgy.

FACT STORE (Beyond the scope of examination):

The special materials and processes used in powder metallurgy can pose hazards to life and property. The high surface-area-to-volume ratio of the powders can increase their chemical reactivity in biological exposures (for example, inhalation or ingestion), and increases the risk of dust explosions. Materials considered relatively benign in bulk can pose special toxicological risks when in a finely divided form

FREQUENTLY ASKED QUESTIONS

UNIT - III

PART A

1. Name any two ores of iron.
2. Define Minerals.
3. Name any one of the mineral and use.
4. Name any two types of heat treatment.
5. What is meant by annealing of steel?
6. What is called quenching?
7. Define tempering?
8. What are the uses of tempered steel?
9. What is called a “Spiegel
10. Name any two ores of tungsten.
11. Name any two ores of titanium.
12. What type of concentration method used for the extraction of tungsten?
13. Define powder metallurgy.
14. Mention the methods of preparation of metal powders.
15. What is called cermet?
16. What is the use of hardened steel?

PART –B

1. Explain preparation of metal powder by reduction.
2. Distinguish between ore and mineral.
3. What is called smelting?
4. Name the types of heat treatment.
5. Mention any two uses of titanium.
6. Titanium is better than stainless steel. Why?
7. Describe Van Arkel method of purification of titanium
8. Write a note on roasting of iron ore.
9. What is the purpose of heat treatment of steel
10. Explain the preparation of metal powder by atomization.
11. Explain the of metal oxide
12. Write notes on annealing of steel
13. Write notes on hardening of steel.
14. What is called tempering of steel

PART C

1. Explain the extraction of iron in blast furnace with a neat diagram.
2. Explain briefly about Minerals of Tamil Nadu and their sources and uses.
3. Describe the manufacture of steel with a neat diagram
4. How is tungsten extracted from its ore?
5. Explain the extraction of Titanium from its ore
6. Explain the various steps involved in powder metallurgy
7. Explain the two methods of preparation of metal powders.
8. Mention the applications of powder metallurgy
9. Write notes on heat treatment of steel.
10. Write the reactions involved in the blast furnace.

UNIT

4

INDUSTRIAL CHEMISTRY

4.1 NUCLEAR CHEMISTRY

Nuclear reaction-Differences between nuclear reaction and ordinary chemical reaction-Radioactive decay – alpha emission – beta emission – gamma emission – half life period – simple problems – Nuclear fission – nuclear fusion – chain reaction –components of nuclear reactor –reactor core – nuclear reactor coolant – Control rods – neutron moderator – steam turbine – Application of radioactive isotopes. **- 6 Hours**

Introduction

Nuclear chemistry is a branch of chemistry which deals with the composition of nucleus and nuclear reactions. Nuclear reactions usually, involve million times greater energy changes than those involved in chemical reactions.

In 1895 Henri Becquerel, a year after the discovery of X – rays, observed that a photographic plate, wrapped in a thick black paper, which had been placed by chance in a same drawer which contained uranium salts, had become affected or fogged. Becquerel concluded that uranium salts emitted certain rays which had penetrating properties similar to X – rays. He found soon after that these rays also cause ionization of air. He called these rays as radioactive rays and the property of emission of these rays as radioactivity. In 1896 Marie Curie and her husband Pierre Curie, in the course of an examination of the uranium mineral pitchblende, discovered the element polonium which was many times more radioactive than uranium. Two years later, they discovered another element radium from the same mineral. This element was found to be three millions times more radioactive than uranium. Shortly afterwards, G.C. Schmidt and M. Curie independently discovered that thorium compounds were also radioactive.

Nuclear Reaction

Nuclear reaction is a process in which two nuclei or nucleus particles collide to produce different products than the initial particles.

Differences between Chemical reactions and Nuclear reactions

Chemical reactions	Nuclear reactions
1. External electrons are involved	No external electrons are involved
2. Chemical reactions do not involve changes in the nuclei.	Nuclear reactions involve a change in atom's nucleus.
3. They do not produce different element.	They produce different element, along with the emission of radiations like α, β and γ – rays.

4. Different isotopes of an element normally behave similarly in chemical reaction.	The nuclear chemistry of different isotopes varies greatly from each other.
5. Atomic number of element involved do not change.	Atomic number of involved atoms changes.
6. Rates of chemical reactions are affected by temperature, pressure and catalysts.	Rates of nuclear reactions are unaffected by temperature, pressure and catalysts.
7. There is no loss in total mass.	Loss of mass occurs during nuclear fission.
8. Similar products are obtained.	Altogether new entities are formed.
9. Much smaller energy changes are involved.	The energy changes involved during nuclear fission are many million times greater than those during in chemical reaction. Hence, large amount of energy is released according to Einstein's equation, $E = mc^2$.

Radioactivity

The spontaneous and continuous emission of powerful radiations due to disintegration of the nucleus of a heavy element is known as Radioactivity.

Examples of radioactive elements

Heavy elements like uranium, thorium, radium, polonium etc. are radioactive elements.

Radioactive rays

In 1904 Rutherford established that the rays emitted by radioactive substances are of three types designated as alpha (α), beta (β) and gamma rays (γ). He placed a bit of radioactive substance in a cavity and electric field.

The rays which are slightly bent towards the negative electrode carry positive charge and are called alpha (α) rays. The rays which are easily bent towards the positive electrode carry negative charge and are called beta (β) rays. The third type, gamma (γ) rays, are not bent in the electric field and, therefore, neutral.

Alpha (α) rays

They are positively charged particles. They have two positive charges and a mass of four units. They are four times as heavy as hydrogen atom. They are similar to helium nuclei.

Beta (β) rays

They are negatively charged particles. They have one negative charge with negligible mass. They are similar to electrons.

Gamma (γ) rays

They have no charge and mass. They are similar to X – rays and light rays but of shorter wave length and higher frequency.

Isotopes and Isobars

Isotopes

Isotopes are the atoms of same element having the same atomic number but different mass number.

Examples: i) $_{92}U^{235}$, $_{92}U^{236}$ and $_{92}U^{238}$ are the isotopes of Uranium.

ii) $_{90}Th^{228}$ and $_{90}Th^{232}$ are the isotopes of Thorium.

iii) $_{8}O^{16}$, $_{8}O^{17}$ and $_{8}O^{18}$ are the isotopes of Oxygen.

Isobars

Isobars are the atoms of different elements having the same mass number but different atomic number.

Examples: i) $_{90}Th^{234}$ and $_{91}Pa^{234}$

ii) $_{88}Ra^{228}$ and $_{89}Ac^{228}$

Radioactive decay

Atoms of heavy elements like uranium, thorium, radium, polonium etc., are constantly breaking up into fresh radioactive atoms with the emission of α, β and γ – rays from their nuclei. **The spontaneous disintegration of atoms of heavy elements with emission of α particle, β particle or both and transform into a new element is known as Radioactive decay and this is called radioactive transformation or transmutation.**

Emission of α – particle

When an α- particle is emitted from a nucleus, the atomic number is decreased by two units and mass number is decreased by four units.

Example

$$_{92}U^{234} \longrightarrow {}_{90}Th^{230} + {}_{2}He^{4}$$

Emission of β- particle

You can expect a positively charged particle or a neutral particle from the nucleus. How can you expect a negatively charged particle from the nucleus? The possible explanation is that a neutron split into a proton and an electron.

$$_{0}\mathbf{n}^{1} \longrightarrow {}_{+1}\mathbf{p}^{1} + {}_{-1}\mathbf{e}^{0}\ (\beta)$$

When a β - particle is emitted from a nucleus, the atomic number is thus increased by one unit and no change in mass number.

$$_{90}Th^{234} \longrightarrow {}_{91}Pa^{234} + {}_{-1}e^{0}$$

Emission of γ – particle

When γ – particle is emitted from a nucleus, there is no change in atomic number and mass number.

$$_{29}Co^{60} \longrightarrow {}_{29}Co^{60} + \gamma$$

The rate of decay of a radioactive element is directly proportional to the number of atoms present, and is constant for every radioactive element, but independent of all physical and chemical conditions, e.g., temperature, pressure, chemical combination, etc.

Half-life period

Half-life period of a radioactive element is the time taken for the decay of half of its initial amount of the element. It is denoted by $t_{1/2}$.

$$t_{1/2} = \frac{0.693}{\lambda}$$

Where λ is decay constant

Worked out problems

1. The half-life period of Sr-90 is 20 years. Calculate its decay constant.

Given:

Half-life period of Sr-90 = 20 years

Decay constant (λ) = ?

$$t_{1/2} = \frac{0.693}{\lambda}$$

$$20 = \frac{0.693}{\lambda}$$

$$\lambda = \frac{0.693}{20}$$

Therefore, $\lambda = 0.03465$/yrs.

2. The decay constant of Co-60 is 0.132/yr. Calculate its half-life period.

Given:

Decay constant (λ) = 0.132/yr

Half-life period $t_{1/2}$ = ?

$$t_{1/2} = \frac{0.693}{\lambda} = 0.693/0.132 = 5.25 \text{ yrs}$$

Nuclear fission

Nuclear fission is the process of splitting of a heavy nucleus by bombarding it with a neutron particle into two approximately equal parts, with simultaneous liberation of a huge amount of energy.

Image Uranium

For example, fission of U-235 by neutrons:

When U-235 is bombarded with accelerated neutrons, it splits into $Ba^{\mathbf{144}}$ and $Kr^{\mathbf{90}}$ releasing two neutrons and enormous amount of energy.

$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{56}Ba^{144} + {}_{36}Kr^{90} + 2\,{}_{0}n^{1} + \text{Energy}$$

A large amount of energy is released during nuclear fission, because of the loss in mass. The mass thus lost is converted into equivalent amount of energy, in accordance with Einstein’s mass-energy equation, $E = mc^2$, ‘m’ is the mass destroyed and ‘c’ is the velocity of light.

The fission fragments obtained are also radioactive. Fission reaction is a self-propagating chain-reaction, because fission products contain neutrons (called secondary neutrons), which further cause fission in other nuclei, producing more secondary neutrons. Thus, the process of neutron production is multiplied and hence, the fission process is also multiplied.

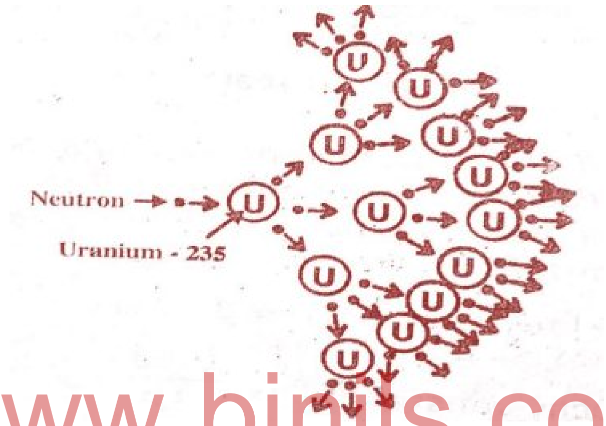


Fig. 4.1.1 Chain Reaction

Every released secondary neutron in uranium fission does strike another nucleus and cause further fission. Atom bomb is an example of chain reactions. Some of them miss their target and some escape into air.

The chain reaction can be controlled and maintained steadily by absorbing a desired number of neutrons using materials like Cadmium, Boron, and Hafnium etc. Thus in average one neutron is made available for further fission reaction. Such reaction is called controlled chain reaction. This type of reaction is initiated, maintained and controlled in Nuclear reactors for production of electric power.

The energy released by fission of one gram uranium is 5.128×10^{23} MeV, which is equivalent to 2.26×10^{4} Kilowatt hour. Energy released in fission is being used for the generation of electricity.

Nuclear fusion

Nuclear fusion is a process of combination of two lighter nuclei to form heavier nuclei with release of enormous amount of energy. For example fusion reactions taking place in Sun may be given as follows.

$${}_{1}H^{2} + {}_{1}H^{2} \longrightarrow {}_{2}He^{4} + \text{energy}$$

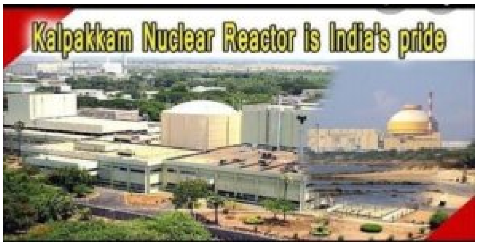
$${}_{1}H^{2} + {}_{1}H^{3} \longrightarrow {}_{2}He^{4} + {}_{0}n^{1} + \text{energy}$$

$$4\,{}_{1}H^{1} \longrightarrow {}_{2}He^{4} + 2\,\underset{\text{positron}}{{}_{+1}e^{0}} + \text{energy}$$

The combination of two nuclei is very difficult operation as all nuclei are positively charged to make them combine. So in order to overcome the strong force of electrostatic force of repulsion, a very high energy is required to initiate a fusion reaction. Indeed, the hydrogen to helium fusion reaction take place in the Sun at about 100 million degree centigrade. Hence the fusion reaction is called thermonuclear reaction. In hydrogen bomb fusion reaction is initiated by performing a fission reaction.

Energy released in the fusion = 23.84 MeV

This principle is used in the explosion of Hydrogen bomb.



Kudunkulam Power Plant in Tamil Nadu

Nuclear Reactor

Nuclear reactor (or a pile) is a device for carrying out fission reaction at a dilute and controlled rate, so that the liberated energy can be utilized for peaceful purpose like generation of electricity.

A typical nuclear of reactor has the following main parts.

1. Reactor core:

In the reactor core controlled fission reaction is made to occur. It consists of an assemblage of fuel elements, control rods, coolants and moderator. The following are the essential components of a nuclear reactor core

i. Fuels: The material containing fissile isotope is called reactor fuel. The fuel used in reactor are (a) natural uranium containing U-238 and lesser percentage of U-235 and(b) Enriched Uranium containing higher percentage of U-235.

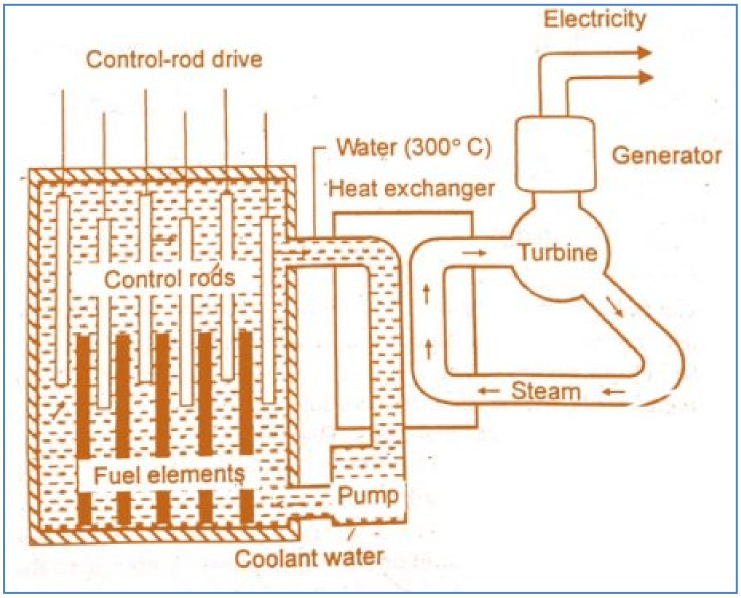


Fig. 4.1.2 Nuclear Reactor

ii. Moderator: The function of moderator is to reduce the kinetic energy of fast fission neutrons to slow neutrons to maintain the chain reaction. Moderators generally used are graphite, heavy water, beryllium etc.

iii. Coolants: Coolants are used to remove the high heat produced in the reactor and to bring it out for utilization. Important coolants are ordinary water, heavy water, liquid sodium, organic liquids and gases (like CO_2). The heat carried by the coolant is used to convert water into steam to run turbines to produce electricity.

iv. Control rods: Control rods are used (a) to bring the reactor up to its normal operating level (b) for maintaining it at normal level (c) for shutting the reactor under normal and emergency conditions and (d) to control the reaction from becoming violent. **Boron and Cadmium rods are used as control rods**.

2. Reflector:

The reflector, is usually, placed around the core to reflect back some of the neutrons that leak out from reactor core. Reflectors are generally made of the same material as the moderator.

Example: H_2O, D_2O and graphite.

3. Pressure-vessel:

The pressure-vessel encloses the core and the reflector. It also provides entrance and exit passage for coolants. The pressure vessel has to withstand a pressure as high as 200Kg/cm^2. The holes present at the top of the pressure vessel are used to insert or pull out the control rods.

4. Shielding:

The purpose of the shield is to reduce the leakage of gamma rays and neutrons which can cause harmful effect on the persons working in the nearest vicinity of the plant in the surrounding. The two types of shields used are (a) thermal shield and (b) biological shield.

(a) Thermal shield is very close to the reactor and is made of iron or steel of 50 to 60 cm thickness. By absorbing most of the gamma radiations, it reduces the heat of the pressure vessel. Further the circulation of water cools the thermal shield.

(b) Biological shield is a concrete wall of few decimeters thickness surrounding the thermal shield. Its main function is to absorb gamma rays and neutrons coming out of inner thermal shield.

5. Heat exchanger:

It transfers the heat given by the reactor to boil water to get steam about 400Kg/cm^2 pressure.

6. Turbines:

The steam at high pressure generated by the heat exchanger is used to operate steam turbines, which drives generator to produce electricity. The exhaust steam is condensed to water and sent back to the heat exchanger.

APPLICATION OF RADIOISOTOPES

Radioisotopes are radioactive isotopes and prepared by bombarding the suitable stable nucleus with a projectile.

For example, radioactive Co-60 is produced by bombarding normal Co-59 with a neutron.

$$_{27}Co^{59} + {}_0n^1 \longrightarrow {}_{27}Co^{60}$$

Radioisotopes are extensively used in the field of medicine, biology, agriculture and industry through tracer technique. They are used to find mechanism of reactions.

I. Medicine

1) Blood circulation in the body can be checked by using NaCl containing radioactive Na-24.
2) Radioactive Iodine-131 is used to diagnose the functioning of thyroid gland.
3) Radioactive Iodine-131 is also used to check the function of various organs like kidney, liver, spleen etc.
4) Radioactive Iron-59 is used to detect the deficiency of red blood cells in the body.
5) Radioactive Phosphorous-32 is used to locate tumours especially brain tumour which is otherwise very difficult to locate.
6) The pumping action of heart can be studied by the radioactive sodium. This helps to find blocks in heart tubes and values.
7) Radio Cobalt is used in the treatment of cancer.

II. In Industry

1) Petroleum companies use the pipelines for the dispatch of their various oil products through the same pipe. Radioactive isotopes can check the flow of oil and also checks any leakage in the system.
2) Alloys are frequently subjected to heat treatment processes such as annealing, quenching, cold rolling etc. The effect of such processes on the crystal structure and properties of alloys can be studied using radioactive isotopes.
3) Self-diffusion is the movement of atoms in metal crystal. This can be studied using radioactive isotopes.

III. Mechanism of photosynthesis in plants

The process involving production of sugar from CO_2 and H_2O by plants using sunlight and chlorophyll is called photosynthesis. In this process oxygen is also given out. By using radioactive CO_2, it was found that the oxygen liberated was given out only from water but not from CO_2. Thus correct mechanism of the reaction was arrived at using radioactive isotope.

IV. Determination of solubility of sparingly soluble salt

The solubility of sparingly soluble salts can be determined by mixing radioactive salt with ordinary salt in the known proportion and by studying the number of radioactive particles present in the solution.

V. In Agriculture

In agriculture the rate absorption of fertilizers by plants can be studied using radioactive phosphorous, P^{32}.

VI. Radio dating

Radio dating is the technique used to determine the age of earth, old trees, rocks etc. using radioactive carbon.

RECAP

In this chapter, the following topics are dealt with

- Differences between Chemical reactions and Nuclear reactions
- Radioactive decay
- Half-life period
- Nuclear fission
- Nuclear fusion
- Nuclear Reactor
- Applications of Radioactive Isotopes in Industries

ACTIVITY

- List out the Nuclear Power Stations in India
- List out the name radioactive isotopes used in different fields
- Name the principle involved in Hydrogen Bomb
- Name the principle involved in Atomic Bomb

EXERCISE FOR BETTER UNDERSTANDING

1) The spontaneous disintegration of atoms of heavy elements with emission of α particle, β particle or both into new element is known as Radioactive decay - True/False
2) Half-life period of a radioactive element is the time taken for the decay of one third of its initial amount of the element- True/False
3) Nuclear fusion is the process of splitting of a heavy nucleus by bombarding it with neutron particle - True/False
4) Nuclear fission is a process of combination lighter nuclei to form heavier nuclei- True/False

Test Paper 1

PART – A

1. Define radioactivity
2. Name any two radioactive elements.
3. What is Radioactive decay?

PART – B

1. Define half-life period.
2. What is nuclear fission?
3. The half-period Th-234 is 24.6 days. Calculate its decay constant.
4. The decay constant of radium-226 is 4.27 x 10^{-4}/yrs. Calculate its half-life period.

PART – C

1. What are the differences between Chemical reactions and Nuclear reactions?
2. Explain the term radioactive decay.
3. Explain nuclear fission with an example.

Test Paper 2

PART – A

1. Name the fuels used in the nuclear reactor.
2. Name the moderators used in nuclear reactor.
3. Name the coolants used in nuclear reactor.
4. Name the control rods used in nuclear reactor.
5. Name the reflectors used in nuclear reactor.
6. Name the radioactive elements used in medicine.

PART – B

1. What is nuclear fusion?
2. What is Nuclear reactor?
3. How is a β particle comes out of the nucleus?

PART – C

1. Explain nuclear fusion with an example.
2. Describe nuclear reactor.
3. Explain the applications of radioisotopes in Industries

FACT STORE

- The science of atomic radiations, atomic change and nuclear fission was developed from 1895 to 1945.
- Over 1935 – 45 most development was focused on the atomic bomb.
- From 1945 attention was given to harnessing this energy in a controlled fashion for naval propulsion and for making electricity.
- Since 1956 the prime focus has been on the technological evolution of reliable nuclear power plant.
- Nuclear Power plants produced 807.1 Billion Kilo Watt Hours of electricity in 2018.

On August 6, 1945, the United States dropped its first atomic bomb from a B-29 bomber plane called the Enola Gay over the city of Hiroshima, Japan. The “Little Boy” exploded with about 13 kilotons of force, leveling five square miles of the city and killing 80,000 people instantly. Tens of thousands more would later die from radiation exposure. When the Japanese did not immediately surrender, the United States dropped a second atomic bomb three days later on the city of Nagasaki. The “Fat Man” killed an estimated 40,000 people on impact. Click to see the story of “Little Boy” https://www.history.com/topics/world-war-ii/atomic-bomb-history

4.2 CEMENT AND CERAMICS

Definition – Manufacture of Portland Cement – Wet Process – Setting of Cement (No equation) –Ceramics – White pottery – Definition – Manufacture of White pottery – Uses – Definition of glazing – purpose – Method – Salt glazing – liquid glazing **- 5 Hours**

CEMENT

Introduction

In ancient days, man started using clay for building their home, later started using lime as a building material and cement is a combination of both. Cement is applied in the form of a soft paste with sand and water and later its sets into a hard mass. It is a mixture of calcareous material (lime) and argillaceous material (clay). Thus **cement is a building material, a mixture of silicates and aluminates of calcium.**

Portland cement

Fig. 4.2.1 Portland stone

A paste of cement with water on setting and hardening gave a hard mass whose colour and hardness were similar to those of stones from Portland in England. Thus, it derived the name Portland cement. Portland cement is a mixture of silicates and aluminates of calcium.

Major constituents of cement

1. Dicalcium silicates ($2CaO.SiO_2$)-28% [C_2S]
2. Tricalcium silicates ($3CaO.SiO_2$)-46% [C_3S]
3. Tricalcium aluminates ($3CaO.Al_2O_3$)-10% [C_3A]
4. Tetra calcium aluminoferrite ($4CaO.Al_2O_3.Fe_2O_3$).9% [C_4AF]
5. Small quantities of CaO and MgO-7%

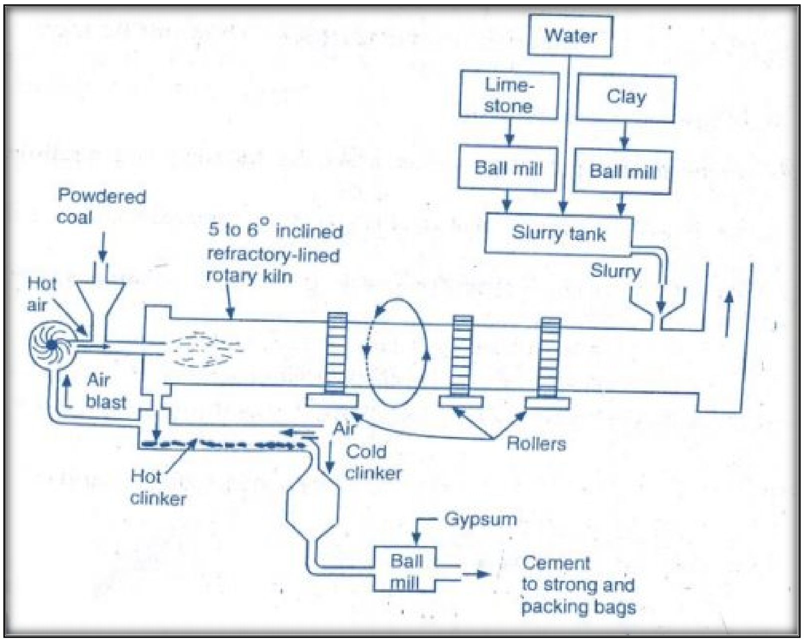
Manufacture of cement by wet process

Raw materials required

1. Calcareous materials – These materials supply lime

   Example: Limestone, chalk, marble
2. Argillaceous materials – These materials supply silica

   Example: Clay
3. Powdered coal (fuel)
4. Gypsum



Rotary kiln Process

The cement is manufactured by wet process as follows.

1. The limestone is crushed and powdered well.
2. The clay is intimately mixed with water in wash mill.
3. The powdered limestone and wet clay are mixed and made into paste in a grinding mill. This paste is known as slurry. The slurry contains 30 to 40% water.
4. The slurry is fed into the top of the rotary kiln. The rotary kiln is made of steel plates lined with fire bricks.
5. The kiln is heated by burning powdered coal which is injected at the lower end by an air blast.
6. In the upper part of the kiln (drying zone) where the temperature is 400^{0}C, the slurry loses all its water.
7. When the charge enters the middle portion of the kiln (calcination zone) where the temperature is about 900 – 1000^{0}C, limestone decomposes to form CaO and CO_2.
8. Then the charge enters lower portion of the kiln (burning zone) where the temperature is about 1400^{0}C. Lime and clay combine to form calcium silicates and aluminates called clinker.
9. The hot clinker is cooled and then grinded with 3 – 4% gypsum in a grinding mill. Gypsum retards the setting of cement. In the absence of gypsum, cement sets rapidly.
10. The cement coming out of the grinding mills is stored in concrete storage tanks and then packed in bags.

Setting of cement

When water is added to cement, sudden setting of cement occurs (flash set). The hardening of cement by the addition of water is known as setting of cement.

The setting and hardening of cement are mainly due to hydration and hydrolysis reactions of the different constituents present in cement.

The dicalcium silicate (C_2S), tricalcium silicate (C_3S), tricalcium aluminate (C_3A) and tetra calcium alumino ferrite (C_4AF) present in cement undergoes hydration.

During this process, anhydrous soluble compounds are converted into hydrated insoluble compounds. The hydrated insoluble gel hardens due dehydration. Finally, after dehydration, the insoluble gel sets into hard mass. It surrounds the sand and binds it strongly with interlocking of crystals of $Ca(OH)_2$. This process is known as setting of cement.

CERAMICS

Introduction

Fig. 4.2.2 Spherical Ceramic (1575-1585)

Fig. 4.2.3 Greek red Ceramic (470 and 460 BC)

Ceramics find wide application in engineering, medical and domestic usage. Ceramics are increasingly used in motor parts (e.g. ceramic disk brakes, ceramic balls etc.,). **Ceramic engine does not require cooling system**. They withstand heat upto 3300^0C. One of the main applications of ceramic is white pottery.

Ceramics

Ceramics are inorganic non-metallic materials that are processed at high temperature and subsequent cooling.

Examples: Ceramic wash basin, ceramic tiles etc.

White pottery

Ceramic material which is white in colour after firing is called white pottery. They consist of a refractory body and glossy coating.

Manufacture of white pottery

Raw materials:

1. China clay (kaolin)[$Al(OH)_4SiO_5$]
2. Feldspar [$KAlSiO_2$]
3. Flint (SiO_2)/quartz.

Step-I

Preparation of body ware

The raw materials are made into fine powder and mixed with water to form paste.

The excess water is removed by filtration. The article is prepared from the paste either by hand moulding or by using potter’s wheel. It is dried and then fired in a ‘biscuit’ oven to get porous ware called ‘Bisque’.

Step-II

Glaze

In order to make the porous ware (Bisque) into water-tight article, it is covered with glaze by melting it over the surface of the body. Slurry of glaze is prepared by mixing Feldspar, silica and boric oxide with water. Now the fired articles are dipped in the slurry of glaze and again fired. Now a smooth, glossy and non-porous surface is formed on the articles.

Step-III

Decoration

To decorate the article, design is made on the article using pigments and fired again.

E.g. Iron oxides give red colour.

Cobalt oxide gives blue colour.

Uses of white ware

They are used for the preparation of

1. Spark plugs
2. Electrical Insulators
3. Laboratory equipment
4. Crucibles, dishes, sanitary wares etc.

Glazing

Glazing is the process of giving a smooth, glossy, non-porous surface on the articles using glazes.

A glaze is a fine powder consisting of glass forming materials like lead silicates, borosilicate etc. They are colourless glazing and colour glazing mixtures. Colourless glazing is done with glass forming materials like lead silicate and borosilicate. Colour glazing is done by mixing coloured metal pigments with glass forming materials.

Example: Iron oxide - red and brown

Copper oxide - green

Cobalt oxide – blue

Purpose of glazing

1. To get decorative effect
2. To make the surface impervious (non-porous) to liquids and water.
3. To improve appearance of the article.
4. To increase the durability of ceramic material.
5. To get a smooth glossy appearance.
6. To protect the surface from atmospheric action.

Methods of glazing

There are two methods of glazing

1. Salt glazing
2. Liquid glazing

1. Salt glazing

In salt glazing, common salt (sodium chloride) is used for getting glossy films over articles. The process consists of throwing sodium chloride into furnace, when the article is in red-hot condition. At high temperature, sodium chloride vapours react with silica in the article to form a smooth glossy and impervious film of 'sodium silicate'. This is known as salt glazing.

2. Liquid glazing

Slurry of glaze is prepared by mixing feldspar, silica and boric oxide with water. Now the fired articles are dipped in the slurry of glaze and again fired. Now a smooth, glossy and non-porous surface is formed on the articles. This is known as liquid glazing.

RECAP

In this chapter, the following topics are dealt with

- Manufacture of cement by wet process
- Setting of cement
- Manufacture of white pottery
- Glazing
- Purpose of glazing
- Methods of glazing

ACTIVITY

- Collect some samples of cement. Try to write the constituents of cement. Try to write the equations involved in setting of cement.
- Collect some samples of different types of Ceramics. Write their uses.

EXERCISE FOR BETTER UNDERSTANDING

1. Raw materials of cement is lime stone, clay, coal and gypsum – True/False
2. Gypsum is added to speed up the setting of cement– True/False
3. Raw materials of White pottery is China clay, Feldspar and quartz – True/False
4. Glazing is the process of giving a smooth, glossy, non-porous surface on the articles True/False
5. Potassium chloride is used in Salt glazing – True/False

Test Paper 1

PART – A

1. What is cement?
2. Why is gypsum added during the manufacture of cement?

PART – B

1. What are the major constituents of cement?
2. What are the raw materials required for the manufacture of Portland cement?
3. Write a note on setting of cement.

PART – C

1. Explain the manufacture of Portland cement by wet process.

Test Paper 2

PART – A

1. What are ceramics?
2. What is white pottery?
3. What is called bisque?
4. What is glazing?

PART – B

1. What are the raw materials required for the manufacture of white pottery?
2. List the uses of white pottery.
3. What is salt glazing?
4. What is liquid glazing?
5. What are the purposes of glazing?

PART – C

1. Describe the manufacture of white pottery.
2. Write a note on glazing.

FACT STORE

Name of Portland cement is derived from its similarity to Portland stone which was quarried on the Isla of Portland in Dorset, England. It was named by Joseph Aspdin who obtained a patent for it in 1824. However, his son William Aspdin is regarded as the inventor of ‘Modern’ Portland cement due to his development in the 1840s.

Broaden your understanding

To know more about cement click the following link or scan QR code

https://www.youtube.com/watch?v=y9tC8I3P45E&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=12

To know more about ceramics click the following link or scan QR code

https://www.youtube.com/watch?v=OUEbwEYYlHQ&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=13

4.3 REFRACTORIES AND GLASS

Definition – requirements of a good refractory – types with examples and uses–uses of silica, fireclay and alumina.

Composition of glass – Manufacture of glass – annealing of glass – Varieties – of Glass – Optical glass, Wind shield glass and Photo chromatic glass. **- 4 Hours**

Introduction

Refractories find wide application in the linings of the furnace, tanks, converters, kilns, crucibles, ladles etc., employed for the manufacture metals, cement, glass, steel, ceramics, paper etc.

Refractories

Refractories are the materials which can withstand very high temperature. They are resistant to heat and corrosive action of gases, metallic liquids and slags.

Example: Fire clay, silica

Fig. 4.3.1 Refractory bricks

Requirements of a good refractory

1. Refractoriness

It is the ability to withstand very high temperature without deformation during operation.

2. Strength or Refractoriness under load (RUL)

They must possess high mechanical strength even at very high temperature and bear maximum possible load without breakage.

3. Thermal expansion

A good refractory should have low thermal expansion under normal conditions.

4. Thermal conductivity

In general, a good refractory should have low thermal conductivity to reduce heat losses by radiation. But, when heat is to be supplied from outside, the refractory must possess good conductivity.

5. Porosity

A good refractory should not be porous. In porous refractory, the molten metal and slag enter and weaken the structure. But porosity helps in the thermal shock-resistance of refractories.

6. Thermal spalling

A good refractory should have low thermal spalling. It is breaking, cracking, peeling off or fracturing of the refractory under high temperature.

7. Chemical composition

A good refractory must be chemical inert.

Classification

The refractories are classified into three types based on the chemical properties.

1. Acid refractories
2. Basic refractories
3. Neutral refractories

Sl. No	Type of refractory	Examples	Uses
1.	Acid refractories	1. Zirconia 2. Silica	Used in furnaces where the charge and slag are acidic in nature
2.	Basic refractories	1. Magnesia 2. Dolomite	Used in furnaces where the charge and slag are basic in nature
3.	Neutral refractories	1. Chromite 2. Alumina	Used in furnaces where the charge and slag are either acidic or basic in nature

Uses of a few refractory bricks

a. Silica bricks

It contains 90-95% silica and about 2% lime.

1. They are used in open hearth furnaces, electric furnaces and glass furnaces.
2. They are used in coke-ovens and gas retort settings.
3. They are also used in lining of acid converters.

b. Fire clay bricks

Fig. 4.3.2 Fireclay refractory brocks

It contains major portion of alumina and silica and small percentage of K_2O, FeO, CuO and MgO.

1. They are used in blast furnace and open hearth furnaces.
2. They are used in stoves, crucibles, furnaces, kilns, regenerators and charging doors.

c. Alumina bricks

It contains more percentage of Al_2O_3.

1. They are used in vertical shaft kilns for burning lime.
2. They are used in linings of rotary kiln in cement manufacture.
3. They are used in brass melting reverberatories, lead-dressing reverberatory furnaces and aluminium melting furnaces and in oil fired furnaces.

GLASS

Introduction:

Glass is an engineering material. It may be defined as an amorphous, rigid, brittle, hard, transparent super cooled liquid. It is resistant to heat. It is a transparent mixture of silicates of potassium or sodium.

It is produced by the fusion of certain basic oxides and acidic oxides, with sand and other materials.

Composition of Glass:

The composition of some common varieties of glass is as follows.

1. Soda lime glass $Na_2O.\ CaO.6SiO_2$.
2. Potash lime Glass: $K_2O.CaO.6SiO_2$.
3. Potash lead glass: $K_2O.PbO.6SiO_2$.

The raw materials for the manufacture of ordinary glass are of two kinds.

1. Acidic oxides: sand (SiO_2). Boron oxides (B_2O_3).
2. Basic oxides: Sodium-oxides (Na_2O),potassium oxides (K_2O),calcium oxides (Ca_2O),Lead Oxide (PbO),Zinc Oxide (ZnO),Magnesium Oxide (MgO) and Aluminum Oxide (Al_2O_3).

Manufacture of Glass:

Raw materials are:

1. Sand
2. Sodium carbonate
3. Calcium carbonate.

Mixing:

The raw materials are powdered well and they are mixed homogeneously. With this, some of the broken glass powders are also added to get an intimate mixture known as" Batch".

Fusion:

The batch is then transferred to the tank or pot furnace. This batch is heated to 1400-1500°C. At this temperature the substances present in the batch react together forming a mixture of silicates. This mixture of silicates is known as glass**.**

Fining:

The molten glass is kept at the highest temperature for some time to remove gas (CO_2) bubbles. This is called fining. Na_2CO_3 is often added to lower the viscosity of the molten glass. The impurities rise to the top as scum and it is removed. Cullet, oxidizing agents, reducing agents and other materials are also added to the molten glass according to the requirements**.**

Fabrication:

Colouring material may be added to the molten glass to get desired coloured glass. Molten glass is then moulded or fabricated into articles of desired shape by blowing, moulding, or pressing.

Colouring Materials

1. Cobalt oxides	- Blue
2. Cuprous salt	- Red
3. Chromium oxide	- Green
4. Ferric iron	- Yellow
5. Potassium dichromate	- Green

Annealing of Glass:

The method of slow cooling of glass is called annealing. If the manufactured hot glass articles are cooled suddenly, it will easily break, since glass is poor conductor of heat. To avoid this, glass is cooled very slowly by passing them through several hot chambers. The temperature of the hot chamber is in the decreasing order gradually. This process of slow cooling of glass is called as annealing. The annealing temperature varies for different types of glasses.

Photo chromatic glass:

Photo chromic lenses darken on exposure to specific types of light, most commonly ultraviolet radiation. Once the light source is removed, the lenses will gradually return to their clear state. Photo chromic lenses may be made of glass, polycarbonate, or plastic. Traditional photo chromic eye glasses are generally alkali Boro-alumino - silicates with 0.01 to 0.1 percent silver halide and a small amount of copper. Upon absorption of light, the silver ion reduces to metallic silver, which nucleates to form colloids about 120 Angstroms in size. This is small enough to keep the glass transparent, but the colloids are dense enough to make the glass look grey or black.

Windshield glass

A framed pane of glass usually curved or other transparent shielding located in front of the occupants of a vehicle to protect them from the wind. A shield placed to protect an object from the wind. Modern windshields are generally made of laminated safety glass, a type of treated glass, which consists of two (typically) curved sheets of glass with a plastic layer laminated between them for safety, and are bonded into the window frame. Motorbike windshields are often made of high-impact acrylic plastic.

Laminated glass is produced by permanently bonding two pieces of glass together with a tough Glass plastic interlayer (Poly Vinyl Butyral, PVB) under heat and pressure. Once bonded together, the glass and which acts as a single unit and generally appears very similar to standard clear glass. The inter layer is virtually invisible when viewed in transmission with glass on either side.

The benefit of laminated glass is that, if broken, glass fragments will adhere to the PVB interlayer rather than falling free, there by reducing the risk of physical injury and property damage. PVB also has properties that effectively filter over 99% of UV. It also reduces transmission of sound. Hence the windshield glass in cars is a safety device just like seatbelts & airbags. Laminated glass is commonly used in automobiles (for windshields), airports, museums, sound studios, schools, greenhouses.

Windshields protect the vehicle's occupants from wind and flying debris such as dust, insects and provide an aerodynamically formed window towards the front.

Optical glass: (Crown glass)

Optical glass is a type of optical glass used in lenses and other optical components. It has relatively low refractive index (≈1.52) and low dispersion Crown glass is produced from alkali-lime (RCH) silicates containing approximately 10% potassium oxide and is one of the earliest low dispersion glasses.

RECAP

In this chapter, the following topics are dealt with

- Requirements of a good refractory
- Classification of refractories and their uses.
- Manufacture of glass,
- types of glasses and uses

ACTIVITY – 1

Collect some samples of different types of refractories. Write down their name and uses.

ACTIVITY - 2

Collect the list of glass producing industries in India.

Ask your teacher and collect information about borosilicate glass.

EXERCISE FOR BETTER UNDERSTANDING

1. Refractories are the materials which can withstand very high temperature – True/False
2. A good refractory should have low thermal expansion – True/False
3. A good refractory should have high thermal conductivity – True/False
4. A good refractory should not be porous – True/False
5. A good refractory should have high thermal spalling – True/False
6. A good refractory must be chemical active – True/False

Test Paper

PART – A

1. Give two examples for acidic refractories.
2. Give two examples for basic refractories.
3. Give two examples for neutral refractories.
4. Define annealing of glass.
5. Name any two varieties of glass.

PART – B

1. What are refractories?
2. What are the types of refractories?
3. List the specific uses of fire clay bricks.
4. List the specific uses of silica clay bricks.
5. List the specific uses of alumina clay bricks.
6. Write a note on optical glass.
7. Write short notes on windshield glass.

PART – C

1. What are the requirements of a good refractory?
2. What are refractories? How are they classified? Explain examples and uses.
3. Write a note on Varieties of glass.

FACT STORE

Refractory technology began in earnest during Iron Age (2000 BC). Furnace used in Iron production featured very elementary refractory lining, usually consisting of unshaped fire clay, carbon-added composite materials, and silica rocks, although blocks cut from natural stones or fireclay brick were also used.

- China produces 35% of the glass used worldwide.
- Asahi Glass is the world’s largest glass company.
- The “Portland Vase” is one of the Most Valuable Glass Art Pieces in the World and is in the British museum.
- When Glass Breaks, the Cracks Move at 3000 mph
- That’s 5 times faster than the average airplane, which travels at 575 mph!

Broaden your understanding

Click the following link or scan the QR code

https://www.youtube.com/watch?v=03vkHCW5Q1s&list=PL1b9Ht9lSqlFsliqREfRjehR2WAs3qCW4&index=13

FREQUENTLY ASKED QUESTIONS

UNIT IV

PART – A

1. Define radioactivity
2. Name any two radioactive elements.
3. Name the fuels used in the nuclear reactor.
4. Name the moderators used in nuclear reactor.
5. Name the coolants used in nuclear reactor.
6. Name the control rods used in nuclear reactor.
7. Name the reflectors used in nuclear reactor.
8. Name the radioactive elements used in medicine.
9. What is cement?
10. Why is gypsum added during the manufacture of cement?
11. What are ceramics?
12. What is white pottery?
13. What is called bisque?
14. What is glazing?
15. Give two examples for acidic refractories.
17. Give two examples for basic refractories.
18. Give two examples for neutral refractories.
19. What are raw material required for manufacturing glass?
20. Define annealing of glass.
21. Name any two varieties of glass.
22. Why sodium carbonate is added into molten silica?

PART – B

1. What is Radioactive decay?
2. Define half-life period.
3. What is nuclear fission?
4. The half-period Th-234 is 24.6 days. Calculate its decay constant.
5. The decay constant of radium-226 is 4.27 x 10^{-4}/yrs. Calculate its half-life period.
6. What is nuclear fusion?
7. What is Nuclear reactor?
8. How is a β particle emitted from the nucleus?

9. What are the major constituents of cement?
10. What are the raw materials required for the manufacture of Portland cement?
11. Write a note on setting of cement.
12. What are the raw materials required for the manufacture of white pottery?
13. List the uses of white pottery.
14. What is salt glazing?
15. What is liquid glazing?
16. What are the purposes of glazing?
17. What are refractories?
18. What are the types of refractories?
19. List the specific uses of fire clay bricks.
20. List the specific uses of silica clay bricks.
21. List the specific uses of alumina clay bricks.
22. Write a note on windshield glass.
23. Write a note on photo chromatic glass.
24. When windshield glass of a bus/car breaking due to accident, it shatters into harmless fragments how?
25. Today windshield in cars is a safety device just like seatbelts & airbags. How?
26. What is annealing of glass? Why is it necessary?

PART – C

1. What are the differences between Chemical reactions and Nuclear reactions?
2. Explain the term radioactive decay.
3. Explain nuclear fission with an example.
4. Explain nuclear fusion with an example.
5. Describe nuclear reactor.
6. Explain the applications of radioisotopes in Industries.
7. Explain the manufacture of Portland cement by wet process.
8. Describe the manufacture of white pottery.
9. Write a note on glazing. Explain the methods of glazing.
10. What are refractories? What are the requirements of a good refractory?
11. What are refractories? How are they classified? Explain examples and uses.
12. How is ordinary glass manufactured?
13. Write a note on Varieties of glass.

UNIT
5

CHEMISTRY OF ENGINEERING MATERIALS

5.1 POLYMER

Definition – Natural polymer – Rubber – Defects of natural rubber – Compounding of rubber – Ingredients and their functions – Vulcanization – Plastics – types – Thermoplastics and Thermo set plastics – Differences – Mechanical properties of plastics – Polymers in Surgery – Biomaterials – Definition – Biomedical uses of Polyurethane, PVC, Polypropylene and Polyethylene **- 6 Hours**

Definition

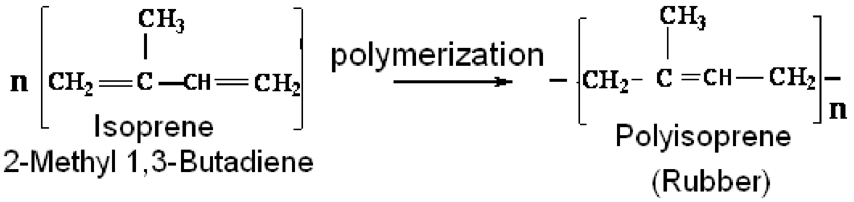
Materials whose molecules are made up of repetition of individual units are called **Polymers.** (Greek : many parts). The single unit substance of which a polymer is made, called a **Monomer.**

A polymer may be defined as high molecular weight compound (giant molecule) called macro molecule **whose molecular weight is in the order of 20000-30000**. The reaction by which monomers combine to form polymers is known as **polymerization.**

It is formed under the condition of high temperature and pressure by the combination of a large number of one or more types of molecules of low molecular weight either by simple addition called **addition polymerization** or by the elimination of simple molecules like hydrogen, water or ammonia. The latter one is called **condensation polymerization.**

Rubber

Rubber is a natural elastic polymer of isoprene (C_5H_8). It is obtained from the milk of rubber called '**Latex'.**



Defects of natural rubber

The natural rubber obtained from latex cannot be used in industries because it has the following defects.

1. It becomes soft and sticky during summer.
2. It becomes hard and brittle during winter.
3. It swells up in oils.
4. It flows plastically due to prolonged stress.
5. Chemicals easily affect natural rubber.

Compounding of rubber

Natural rubber is compounded with certain substances to increase the **quality of rubber.**

1. Reinforcing agents or hardeners

They are compounded with natural rubber to give strength to the rubber.

Example: Carbon powder, zinc oxide, calcium carbonate etc.

2. Softeners

They are added to make the rubber more soft and elastic. Example : Vegetable oils, stearic acid, paraffin oil, etc.

3. Anti-oxidants

They are added to prevent destruction of rubber due to aerial oxidation.

Example: β-naphthol, phenol.

4. Hardening

The hardness of rubber is improved by addition of sulphur, a process called Vulcanization

5. Pigments (Colouring matter)

They are added to give different colours to rubber.

Example: Metallic oxides

Zinc oxide - White Lead chromate -Yellow Chromium oxide - Green Carbon black -Black

6. Accelerators

They are added to speed up the vulcanization reaction of rubber.

Example: Benzothiozole

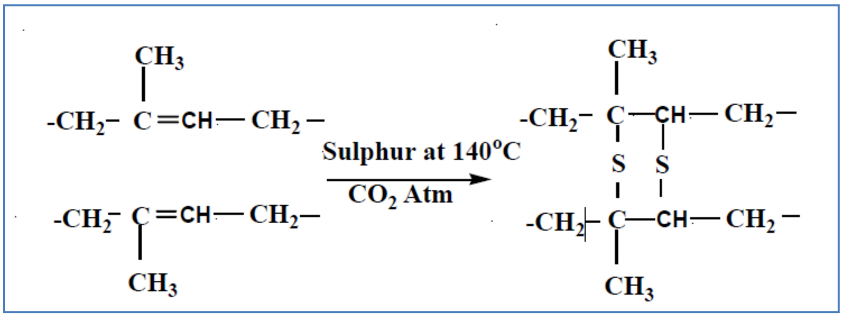
7. Fillers

Fillers are added to increase the quantity without affecting the quality. The production cost is reduced.

Example: Textile wastes, asbestos, mica, gypsum, talc, etc.

Vulcanization of rubber

Vulcanization is compounding of rubber with sulphur. **Vulcanization is the process of heating natural rubber with sulphur at 140°C in CO_2 atmosphere**.The double bonds present in rubber chain are opened and cross linked through sulphur atoms. Hence the vulcanized rubber becomes very hard. The hardness of rubber increases as the percentage of sulphur increases, 2 to 4% sulphur addition gives soft elastic rubber. When sulphur content is more than 30%, hard rubber called ‘Ebonite’ is obtained.



Properties of vulcanized rubber

1. Vulcanized rubber has very little electrical and thermal conductivity. Hence, it is mainly used for electrical insulation purposes.
2. It has high elasticity and tensile strength.
3. Corrosive chemicals and oils do not affect it.
4. It is also not affected by atmosphere.

PLASTICS

Introduction

The name plastics or plastic materials in general is given to organic materials of high molecular mass, which can be moulded into any desired form when subjected to heat and pressure in presence of catalysts.

Polymer resin is the basic binding material, which of plastics. In the recent years, plastics have attained greater importance in every walk of life due to their unique properties.

Now, plastics substitute all engineering materials like wood, metal, glass, etc. because of their special advantages over other conventional materials.

Plastics are organic polymer materials of high molecular mass, which can be moulded into different shapes by using heat and pressure.

Types of plastics

Plastics are classified into two types.

1. Thermoplastics

2. Thermosetting plastics

1. Thermoplastics

They are the polymers which soften on heating and set on cooling to a fusible mass. They are formed by addition polymerization. They can be re-moulded any number of times and used.

Example: Polythene, PVC, nylon, etc.

2. Thermosetting plastics

They are the polymers which set on heating to an infusible mass by cross linkage and cannot be re-softened. They are formed by condensation polymerization. Hence, their scrap cannot be reused.

Example: Bakelite (Phenol-formaldehyde resin), urea-formaldehyde resin, etc.

Differences between thermoplastics and thermosetting plastics

The differences between the two types of plastics arise mainly due to the difference in their chemical structure.

Sl. No.	Property	Thermoplastics	Thermosetting plastics
1	Action of heat	They soften on heating and set on cooling every time	They set on heating and cannot be resoftened

2	Type of bonding	Molecules are held by weak inter molecular forces	Molecules are held by weak inter molecular forces and strong cross linkage
3	Solubility	They are soluble in organic solvents	They are insoluble in organic solvents
4	Expansion due to heating	They expand very much on heating	Their expansion is only marginal on heating
5	Type of polymerization	They are formed by addition polymerization	They are formed by condensation polymerization
6	Type of moulding	They are processed by injection moulding	They are processed by compression moulding
7	Scrap recovery	Scrap can be reused	Scrap cannot be reused
8	Example	Polythene, PVC, nylon	Bakelite

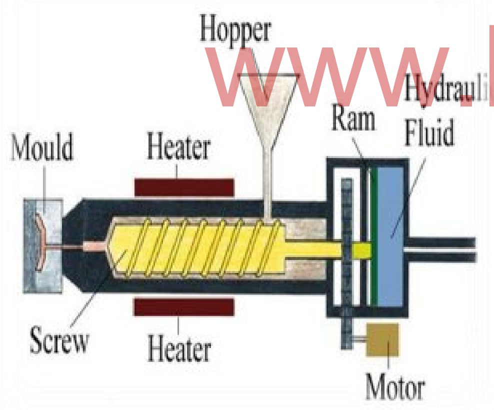


Fig. 5.1.1 Injection Moulding

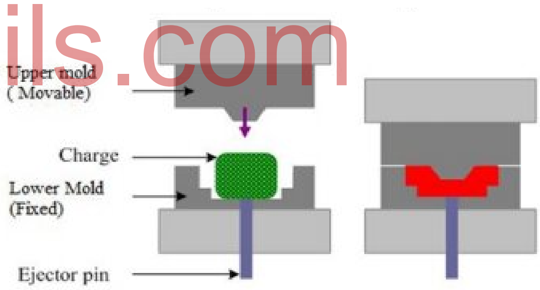


Fig. 5.1.2 Compression Moulding

MECHANICAL PROPERTIES OF PLASTICS

1. Creep or cold flow

Creep is a time dependent continuous deformation of plastics under load. Plastics undergo a change in shape when a load is applied continuously. Creep is due to the displacement of molecules in a polymer structure. Because of this property, plastics cannot be used as load bearing materials.

2. Strength to weight ratio

The stress to strain ratio of a plastic is higher than that of the lightest metals namely Al or Mg. Plastics have good strength when compared to the light weight metals like aluminium, magnesium, etc. Hence, they replace metals like aluminium and magnesium in many fields. Therefore plastics are mainly used for rocket and space ship constructions.

3. Thermal stability

Plastics either degrade or soften at high temperatures. Hence, they cannot be used at high temperatures.

4. Softening temperature

Softening temperature refers to the particular temperature at which a plastic changes from elastic stage to fluid stage. Temperature below which a polymer is hard and above which it is soft is known as ‘Glass transition temperature (T_g).

5. Optical properties

Some of the plastics are transparent like glass. Hence, they can be substituted for glass in optical instruments.

6. Electrical properties

Plastics are good insulators as they are poor conductors of electricity. So, they are mainly used for electrical insulation purposes.

7. Hardness

Hardness is defined as the resistance of the plastics to penetration, scratching etc. Hardness of plastics can be determined by penetration tests. Thermosetting plastics are hard in nature when compared to thermoplastics.

8. Impact strength

When subjected to suddenly applied load or stress, plastics undergo rupture at a particular load or stress. Impact strength of plastics is measured by tests in which a pendulum is allowed to attack the specimen. Plastics have better impact strength when compared to glass. Hence, they are replacing glasses in many places.

9. Tear resistance

The resistance to tearing is an important property when plastic films are used as packing material. It is measured by using a falling pendulum with a striking edge. Plastics have poor tear resistance

Biomaterials (Polymers in medicine and surgery)

Biomaterials are the materials that can be implanted in the body to provide special prosthetic functions and used in diagnostic, surgical and therapeutic applications without causing adverse effect on blood and other tissues.

Use of polymers as biomaterials is increasing day-by-day, since, many polymers have diverse properties which are more similar to the certain organs of the body. Their appeal and acceptability is mainly due to their versatility and the fact is that, they are tailor-made or modified at will, suits specific body functions.

Polymers used for medical application should be biocompatible. It should possess the following characteristics.

1. It should have purity and reproducibility.
2. It should have optimum physical and chemical properties.
3. It should be fabricated into any desired shape without being degraded.
4. It should be sterilized easily.

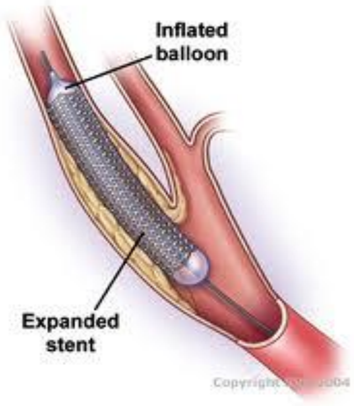
5. Biopolymers that come in contact with blood and tissue should not damage cellular elements of blood, enzymes and proteins.
6. They should not produce toxic and allergic reactions.
7. They should not deplete electrolytes present in the body.

Biomedical uses of polymers

The mostly used polymers in medical applications are silicone rubber and polyurethane. Polymers used in specific medical applications in medicine are given below.

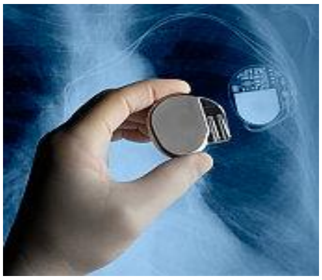
Sl. No.	Polymer	Applications
1	Polyurethane	Heart valves, blood filters, artificial hearts, vascular tubes, etc.
2	Polyvinyl chloride (PVC)	Disposable syringes, etc.
3	Polypropylene	Heart valves, blood filters, etc.
4	**Polyethylene**	Disposable syringes, etc.

Knee replacement



Stent **Urinary catheter**

Surgical glove



Pace maker

RECAP

In this lesson following topics are dealt with

- polymerization,
- defects of natural rubber,
- compounding of rubber
- valcanisation of rubber,
- plastics, types of plastics,
- mechanical properties of plastics and
- bio-medical applications of plastics.

ACTIVITY

- Collect articles from Tamil / English daily related to the harmful effects of plastics
- Divide the class into two groups and conduct a debate on the merits and demerits of plastics.
- Observe and note down the plastic body/spare that replaced the metallic parts of old cars.
- Observe and note down the plastic materials that replaced the construction materials in civil engineering.

GET IT RIGHT

- ➢ **Plastics are bio degradable ----- Myth**
- ➢ **It takes 450 years for plastic to begin decomposing** and then up to another 80 years for it to disappear completely. ---- Fact
- ➢ All the polymers are synthetic ---- Myth
- ➢ Rubber is a natural polymer of isoprene molecules --- Fact

Test Paper 1

PART – A

1. What are the two types of polymerization?
2. What is latex?
3. What is vulcanization?
4. Give an example for thermosetting plastics?
5. Give any two examples of biomaterials.

PART – B

1. Define polymerization? What are the types of polymerization?
2. Give any three defects of natural rubber.
3. Define plastics. Mention the types of plastics.
4. List the biomedical uses of the following.
    a) Polyurethane b) PVC c) polypropylene

PART – C

1. What is meant by compounding of rubber? Mention the ingredients and their functions.
2. List the differences between thermoplastics and thermosetting plastics.
3. What are the characteristics of bio-materials?

Test Paper 2

PART – A

1. What is rubber?
2. What is compounding of rubber.
3. Define plastic?
4. Give an example for thermoplastics?
5. Give any one characteristic property of biomaterials.

PART – B

1. Define polymerization with example.
2. What are the properties of vulcanized rubber?
3. Give mechanical properties of plastics.
4. Give any three characteristic functions of biomaterials?

PART – C

1. Explain vulcanization of rubber and give the properties of vulcanized rubber.
2. Explain the properties of plastics.
3. What are bio-materials? List the biomedical uses of the following.

   a) Polyurethane b) PVC c) Polypropylene d) Polyethylene

FACT STORE

- **Alexander Parkes invented the first plastic substance in the 1850s.**
- Nobel laureate Hermann Staudinger who has been called "the father of polymer chemistry" and Herman Mark, known as "the father of polymer physics".
- Starch is a condensation polymer made up of hundreds of **glucose** monomers.
- The **human body** contains many natural **polymers**, such as proteins and nucleic acids. Cellulose, another natural **polymer**, is the main structural component of plants.
- **Polytetrafluoroethylene** (**PTFE**) is a synthetic fluoropolymer of tetrafluoroethylene that has numerous applications. The well-known brand name of PTFE-based formulas is **Teflon** used for non-stick frying pan.
- **One recycled plastic bottle can save enough energy to light a 60W light-bulb for 6 hours.**

Tech Bytes

- **Plastic is footing innovation in medical science**. In 2011, Swiss chemists produced the largest ever synthetic molecule called PG5. In the future, this polymer could be ingested to deliver an appropriate doses of medicine to the specific areas of the body.

Broaden your understanding:

Click the following link or scan the QR code

https://www.youtube.com/watch?v=bOsivSylohc&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=16

https://www.youtube.com/watch?v=KKH1LJxi8VM&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=17

5.2 ABRASIVES

Definition – classification – hardness in Moh's scale – Natural abrasives – Diamond, Corundum, Emery, and Garnet. – Synthetic abrasives – Carborundum – Boron carbide manufacture – properties and uses. **– 4 Hours**

Introduction:

We have observed different hard and soft substances used for the cutting, grinding and polishing surfaces in day-to-day life.

- Hard silicon carbide discs are used in workshops in shaping machines.
- Emery sheets are used to clean the metal surfaces before painting them.
- Discs are used for sharpening knives and other cutting tools.
- Fine metal powders are used for mosaic polishing.

Abrasives

Abrasives are hard substances which are used for cutting, grinding and polishing the surface of other materials.

Hardness of an abrasive

Hardness is the main property of an abrasive. It is defined as the capacity of an abrasive to grind another substance. Harder the abrasive, better will be its capacity to grind the surface of other substances.

Moh’s scale

Hardness of abrasives is measured in a scale called Moh’s scale. In Moh’s scale, the hardness of Diamond, which is the hardest among all the substances, is taken as 10. The hardness of Talc, which is the softest substance, is taken as 1. Thus, the hardness of other substances in Moh’s scale lies in between 1 and 10.

Hardness of abrasive materials

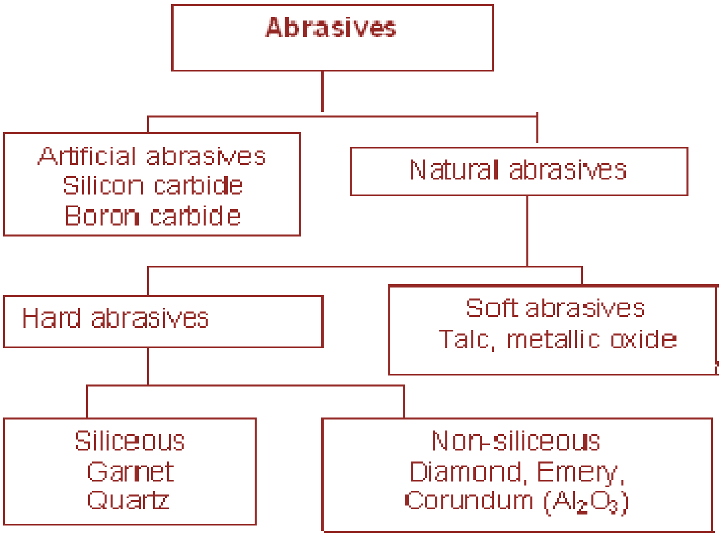
Material	Hardness (Moh's scale)
Talc (hydrated magnesium silicate)	**1**
Gypsum ($CaSO_4.2H_2O$)	**2**
Calcite ($CaCO_3$)	**3**
Fluorite(CaF_2)	**4**
Apatite ($CaPO_4.F_2.Cl_2$)	**5**
Feldspar ($KAlSi_3O_8$, $Na.Al.Si_3O_8$)	**6**
Quartz (SiO_2)	**7**
Topaz ($Al_2SiO_4(FOH)_2$)	**8**
Corundum(Al_2O_3)	**9**
Diamond (C)	**10**

The chemical formula of the abrasives is beyond the scope of the book, however given for complete understanding. Gypsum is $CaSO_4.2H_2O$ where as plaster of Paris $CaSO_4.1/2\ H_2O$ is one of the material used by civil engineers for interior design. It is a soft material where as diamond is the hardest one. Generally, hardness of abrasives is measured by piercing a needle through it using some pressure. Hardness is measured in terms of the distance pierced by the needle in the abrasive material and comparing the same with a standard substance of known hardness.

The other important property of an abrasive is toughness. Abrasive material should be brittle so that it can function effectively. The other important character of an abrasive is its ability to withstand high temperature (Refractoriness).

Classification

Abrasives are classified as natural and artificial abrasives. They are further classified as follows.



Important natural abrasives

1. Diamond

- It is a natural, hard, non-siliceous abrasive.
- It is the hardest substance in the world.
- It is an **allotrope** of carbon.
- It is the purest form of carbon.
- Its hardness in Moh's scale is 10.
- The impure varieties called Bort and carbanado are used as abrasives.

Uses

- It is used for cutting, grinding and polishing purposes.
- It is mainly used in rock drilling.

2. Corundum

- It is a natural, hard, non-siliceous abrasive.
- It is fused aluminium oxide(Al_2O_3).
- It is obtained by fusing the ore of aluminium called Bauxite.
- Its hardness in Moh's scale is 9.

Uses

- It is mainly used in grinding wheels.
- It is specially used for grinding paper pulp.

3. Emery

- It is a natural, hard, non-siliceous abrasive.
- It is a mixture of corundum (Al_2O_3) and magnetite (Fe_3O_4).
- The presence of magnetite decreases the hardness of corundum.
- Its hardness in Moh's scale is 7 to 9.

Uses

- It is mainly used for scratching and rubbing surfaces.
- It is used for making abrasive paper and cloth.

Types of emery

Depending on the percentage of alumina, emery is classified into the following three types. The hardness increases with increase in alumina content.

Sl. No.	Type of emery	% of alumina	uses
1	Grecian emery	85%	In grinding wheels
2	Turkish emery	75%	Grinding and polishing the glass

3	American emery	60%	Used in metal and wood polishing work

4. Garnet

- It is a natural, hard, siliceous abrasive (Ca. Mg. Mn SiO_4.Al.Fe.Cr.SiO_4)
- It consists of trisilicates of alumina, magnesia and iron.
- Its hardness in Moh's scale is 6.5.

Uses

- It is used for grinding glass.
- It is used for making abrasive paper and cloth.

IMPORTANT SYNTHETIC ABRASIVES

1. Silicon carbide(SiC)-carborundum:

It is also known as **carborundum.** It is a siliceous artificial abrasives. In hardness is 9.3, it is almost equivalent to diamond

Preparation

Silicon carbide is prepared by fusing a mixture of silica (sand) and carbon (coke) with some salt and saw dust in an electric arc furnace at 3000°C.

$$\underset{(Sand)}{SiO_2} + \underset{(Coke)}{3\,C} \xrightarrow{3000^\circ C} SiC + 2\,CO$$

Salt and saw dust is added to infuse air into the product so that it can be broken into pieces easily.

The product obtained is first washed with strong acid followed by strong base to remove basic and acidic impurities respectively. Finally, it is washed with water.

Properties

- It is very hard and chemically inert.
- Its hardness in Moh's scale is 9.8.
- It can withstand very high temperature.

Uses

- It is used for making grinding wheels, cast iron and bronze.
- It is used for cutting and grinding glass.
- It is used for grinding granite.
- It is used for grinding carbides.

2. Boron carbide (B_4C)

It is also known as **norbide.** It is also an artificial siliceous abrasives. It is harder than silicon carbide. It's hardness varies from 9.5 to 9.7 on Moh's scale.

Preparation

Boron carbide is prepared by heating a mixture of boron oxide (B_2O_3) and carbon (coke) in an electric arc furnace at 2500°C. The product obtained is first washed with strong acid followed by strong base to remove basic and acidic impurities respectively. Finally, it is washed with water.

$$2B_2O_3 + 7C \xrightarrow{2500^\circ C} B_4C + 6CO\uparrow$$

Properties

- It is chemically inert.
- It is harder than silicon carbide.
- Its hardness in Moh's scale is 9.5 to 9.7

Uses

- It is used for cutting steel.
- It is used for cutting tungsten carbide.
- It is used for grinding other hard materials.

RECAP

In this lesson, we have discussed

- hardness of abrasives,
- classification of abrasives
- applications of abrasives

KEY TERMS

Abrasives- Hardness – Moh's scale

ACTIVITY

- Collect some plaster of paris and add water slowly to it. Note the changes that takes place.

GET IT RIGHT

- Corundum is a hard opaque mineral---- Myth
- Corundum is a hard transparent mineral with high density 4.02.
- This density is unusual for a transparent mineral. ---- Fact

Test Paper 1

PART – A

1. What are abrasives?
2. Mention the important properties of abrasives.
3. How are abrasives classified.
4. Give any two uses of corundum.
5. Give two examples for synthetic abrasives.
6. What is nor bide?

PART – B

1. What are abrasives? What are types of abrasives?
2. What are the types of emery? Give its uses.
3. How is nor bide prepared?

PART – C

1. Write a note on the following abrasives.

   a) Diamond b) Corundum c) Emery d) Garnet
2. How is boron carbide prepared? Explain. Give its properties and uses.

Test Paper 2

PART – A

1. What is Moh's scale?
2. What is the hardness of diamond and talc on Moh's scale.
3. How hard abrasives are classified?
4. Give two examples for siliceous abrasives.
5. What is carborundum?
6. What is garnet?

PART – B

1. How are abrasives classified? Give examples.
2. Define corundum and carborudum.
3. What is carborundum? Give any two uses of carborundum
4. How is carborundum prepared?

PART – C

1. What are abrasives? How are they classified? Give examples.
2. How is silicon carbide prepared? Explain. Give its properties and uses.

FACT STORE

- Silicon Carbide (SiC) was the first synthetic abrasive to be produced and also the first to be commercialized.
- Diamonds form about 100 miles below ground and have been carried to the earth's surface by deep volcanic eruptions.
- Diamonds are the very hardest natural substance. The only thing that can scratch a diamond is another diamond.
- boron carbide is the third hardest substance known, after diamond and cubic boron nitride, and popularly known by the nickname "black diamond".
- Boron Carbide Nano powder is used as neutron absorber in nuclear reactors.

Broaden your understanding

Click the following link or scan the QR code

https://www.youtube.com/watch?v=vCWS9w9dk1U&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index

5.3 COMPOSITE MATERIALS

Definition–examples – Classification of composites – Advantages over metals and polymers – General application **- 3 Hours**

Introduction:

Each class of basic engineering materials like metals, high polymers and ceramics has its own outstanding and distinct characteristics as well as laminates. However very stringent requirements of supersonic aircraft, gas turbines and high temperature reactors have forced to develop a new class of materials called "composites".

The composite materials are generally made by placing the dissimilar materials together in such a manner that they work as a single mechanical unit. The properties of new materials so produced are different in kind and scale from those of any constituents. Thus, it has become possible to incorporate or alter properties, more than that, introduces a combination of properties like high strength and stiffness at elevated temperatures.

Metals for instance, lose their strength at elevated temperatures. High polymeric materials in general can withstand still lower temperatures. Ceramics, due to their brittleness are unsatisfactory structural materials. This led to the exploration of combination of metals and polymers with ceramics resulting in composites having required properties which seems to be the hope for the future.

Composite material

A composite material contains two phases namely 1. Matrix phase, 2. Dispersed phase.

Matrix phase:

A continuous body constituent which encloses the composite and gives a bulk form is called matrix phase. The matrix acts as a medium which protects and binds the dispersed phase. The matrix phase may be metals, ceramics or polymers.

Dispersed phase:

The substance which is dispersed in the matrix phase is called the dispersed phase. It constitutes the internal structure of the composite.

Definition:

A multiphase material consisting of a mixture of two (or) more substances with different properties which are mutually insoluble is called as Composite material.

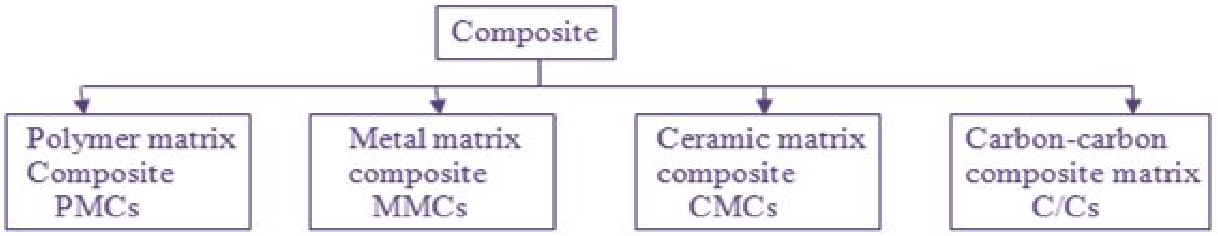
Concrete is the best example for composite.

Thus, using composites it is possible to have such combination of properties like high strength and stiffness, corrosion resistance and ability to withstand extreme high temperature conditions.

Examples

1. Wood (A composite of cellulose fibres and lignin cementing materials)
2. Rain proof cloth (A cloth impregnated with water-proof material)
3. Bone (A composite of soft callogen and brittle and hard material apatite)

Classification of composite



Based on the type of matrix material, composite can be classified into four types.

Advantageous properties of composite materials over metals and polymers

The important advantages of composite materials over metals and polymers are given below.

1. Higher specific strength.
2. Lower specific gravity.
3. Higher specific stiffness.
4. Lower electrical conductivity.
5. Better corrosion and oxidation resistance.
6. Good impact and thermal shock resistance.
7. Can be fabricated easily.
8. Radar transparent
9. Non-magnetic
10. Higher – Durability
11. High creep resistance

General applications of composite materials

1. In fabrication of roof and floors.
2. In aeronautical applications like components of rockets, aircrafts, helicopters, etc.
3. In valves, pump parts, spray nozzles, etc.
4. In communication antennae, electronic circuit boards, etc.
5. In marine applications like propellers, shaft and other ship parts.
6. In automobile industries, turbine engines, etc.

RECAP

In this lesson, advantages and applications of composite materials are discussed.

Key Terms

Composites- Matrix phase – Dispersed phase

Test Paper 1

PART – A

1. Mention the two phases of composite materials.
2. What are composite materials?

PART – B

1. Write any three advantages of composite materials over metals and polymers.
2. How are composites classified?

PART – C

1. Mention the applications of composite materials.

Test Paper 2

PART – A

1. Give an example for composite materials.
2. What is the expansion of CMCs in composite?

PART – B

1. Mention any three applications of composite materials.
2. Give three examples for composite.

PART – C

1. Write a note on advantages of composite materials over metals and polymers.

Tech bytes

- Scientists have invented self-healing plastics. These composite materials contain chemicals which are released and form new plastic when the item becomes damaged.
- Carbon nanotubes can be incorporated into materials to make them extremely strong but lightweight. In the future we may be able to use them to build an elevator into space!
- 3D printing will become more useful in creating composite materials in the future. They can be used to print layers of different materials making new types of composites

FACT STORE

- The Bharathratna awardee and former president Dr. A.P.J. Abdul Kalam and his team developed light weight prosthetics for disabled people from composites (Space age materials) used for rockets. This product has reduced weight from 4 kg to 400g
- Concrete is the most commonly used composite.
- Gore-Tex is a composite which is used to make clothing. It contains layers of different materials which work together to create a fabric which is waterproof and breathable
- Around half of the materials used to make an aeroplane are composites

Broaden your understanding

Click the following link or scan the QR code

https://www.youtube.com/watch?v=u2Z7X3QRbPE&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=18

FREQUENTLY ASKED QUESTIONS

UNIT - V

PART –A

1. What are the two types of polymerization?
2. What is rubber?
3. What is meant by latex of rubber?
4. What is called compounding of rubber?.
5. Define vulcanization of rubber.
6. Define plastic?
7. Give an example for thermosetting plastics?
8. Give an example for thermoplastics?
9. Give any two examples of biomaterials.
10. Give any one of the characteristics of biomaterial.
11. What are abrasives?
12. What is Moh's scale of hardness?
13. Mention the important properties of abrasives.
14. What is the hardness of diamond and talc on Moh's scale.
15. How are abrasives classified?
16. How is hard abrasives classified.?
17. Give any two uses of corundum.
18. Give two examples for siliceous abrasives.
19. Give two examples for synthetic abrasives.
20. What is meant by carborundum?
21. What is called norbide?
22. What is garnet?
23. Mention the two phases of a composite material.
24. Give an example of composite material.
25. What are composite materials?

PART - B

1. Define polymerization? What are the types of polymerization?
2. Define polymerization with an example.
3. Give any there defects of natural rubber.
4. What are the properties of vulcanized rubber?
5. Define plastics. Mention the types of plastics.

6. List the mechanical properties of plastics.
7. Write down the biomedical uses of the following.
   b) Polyurethane b) PVC c) polypropylene
8. Give any three characteristics function of a biomaterials?
9. How are abrasives classified? Give example.
10. What are the types of emery? Give its uses.
11. Define corundum and carborundum.
12. What is carborundum? Give any two uses of carborundum.
13. What are abrasives? What are types of abrasives?
14. How is carborundum prepared?
15. How is norbide prepared?
16. Write any three advantages of composite materials over metals and polymers.
17. Mention any three applications of composite materials.
18. How are composites classified?

PART – C

1. What is called compounding of rubber? Mention the ingredients and their functions.
2. Explain vulcanization of rubber and give the properties of vulcanized rubber.

3. List the differences between thermoplastics and thermosetting plastics.
4. Explain the properties of plastics.
5. What are the characteristics function of a bio-materials?
6. What are bio-materials? List the biomedical uses of the following.
   b) Polyurethane b) PVC c) polypropylene d) Polyethylene
7. What are the characteristics function of a bio-materials?
8. What are abrasives? How are they classified? Give examples.
9. Write a note on the following abrasives.
   b) Diamond b) Corundum c) Emery d) Garnet
10. How is silicon carbide prepared? Explain. Give its properties and uses.
11. How is boron carbide prepared? Explain. Give its properties and uses.
12. Write a note on advantage of composite materials over metals and polymers.
13. Mention the applications of composite materials.

ENGINEERING CHEMISTRY I

MODEL QUESTION PAPER-1

Part A

NB: 1. Answer all questions **5 x 1= 5 Marks**

2. All questions carry equal marks

1. How many electrons are there in the ultimate orbital of any inert gas?
2. What is nanometer?
3. Name an ore of tungsten?
4. What is added to delay the setting of cement?
5. What is the hardness of diamond on Moh's scale?

Part B

NB: 1. Answer any 10 questions **10 x 2= 20 Marks**

2. All questions carry equal marks

6. State octet rule.
7. Write down the modern periodic law.
8. Define Lewis concept of acids and bases.
9. Mention the types of colloids.
10. What are catalytic promoters?
11. Define biomaterial.
12. Mention the composition of stainless steel.
13. Mention the uses of titanium.
14. Define powder metallurgy.
15. What is meant by radio active decay?
16. Write down the importance of glazing in ceramics.
17. Define refractory.
18. What is meant by annealing of glass. Mention the importance of it.
19. Give any 2 defects of natural rubber?
20. How is Carborundum prepared?

Part C

NB: 1. Answer all questions **5 x 15= 75 Marks**

2. Answer any one of the subdivisions, either (a) or (b) from each question

21. (a) (i) Explain in detail about aufbau principle for filling of electrons in an atom with suitable example. (7)

(ii) Define valency of an element. Explain electrovalent bond with suitable example with a neat diagram (8)

(or)

(b) (i) Distinguish between s and d-block elements in the periodic table (7)

(ii) Define pH of a solution. Calculate the pH of 0.025 N sodium hydroxide solution(8)

22. (a) (i) Distinguish between lyophilic and lyophobic colloids. (7)

(ii) Define colloid. Describe any four industrial applications of colloids. (8)

(or)

(b) (i) List the industrial applications of catalyst. (7)

(ii) What is called nano technology? Illustrate the various applications of nanotechnology in various fields of Engineering. (8)

23. (a) (i) Describe the manufacture of steel by Bessemer process. (7)

(ii) What is meant by heat treatment of steel. Write notes on various heat treatment of steel. (8)

(or)

(b) (i) Explain the extraction of tungsten from its ore. (7)

(ii) Describe the process and applications of powder metallurgy. (8)

24. (a) (i) Distinguish between ordinary chemical reaction and nuclear reaction. (7)

(ii) Define half-life period. The decay constant of Co-60 is 0.132/yr. Calculate its half-life period. If the quantity of Co -60 is 2.5g, what will be the quantity that remain after 10.5 years. (8)

(or)

(b) (i) Describe the manufacture of Portland cement (7)

(ii) Define refractory. What are the requirements of a refractory. (8)

25. (a) (i) Explain vulcanization of rubber and give the properties of vulcanized rubber (7)

(ii) Write a note on advantage of composite materials over metals and polymers (8)

(or)

(b) (i) What are bio-materials? List biomedical uses of use following:

(a) Polyurethane (b) PVC (c) Polypropylene (d) Polyethylene (7)

(ii) Write a note on the following abrasives.

(a) Diamond (b) Corundum (c) Emery (d) Garnet (8)

ENGINEERING CHEMISTRY I
MODEL QUESTION PAPER-2

Part A

NB: 1. Answer all questions **5 x 1 = 5 Marks**

2. All questions carry equal marks

1. How many electrons are there in the ultimate orbital of any inert gas?
2. What is nanometer?
3. Name an ore of titanium?
4. Why gypsum is added to cement?
5. Name any two artificial abrasives.

Part B

NB: 1. Answer any 10 questions **10 x 2= 20 Marks**

2. All questions carry equal marks

6. State octet rule.
7. Write down the modern periodic law.
8. Name few Lewis acids and bases.
9. Define lyophilic and lyophobic colloids.
10. What are catalytic poisons?
11. Define biomaterial.
12. Mention the uses of stainless steel.
13. Mention the uses of tungsten.
14. Define atomization in powder metallurgy.
15. What is meant by half life period?
16. What is purpose glazing in ceramics.
17. What are the types of refractory.
18. What are the varieties of glass.
19. What is vulcanization?
20. How is norbide prepared?

Part C

NB: 1. Answer all questions **5 x 15= 75 Marks**

2. Answer any one of the subdivisions, either (a) or (b) from each question

21. (a) (i) What are the applications of pH? (7)

(ii) Define valency of an element. Explain covalent bond with suitable example with a neat diagram (8)

(or)

(b) (i) Write notes on d-block elements in the periodic table (7)

(ii) Define pH of a solution. Calculate the pOH of 0.02 N HCl solution (8)

22. (a) (i) Write notes on (i) Brownian movement(ii) Electrophoresis (7)

(ii) What is called nano technology? Illustrate the various applications of nanotechnology in medicine (8)

(or)

(b) (i) Write notes on types of catalyst with a neat diagram (7)

(ii) Define colloid. Describe any four industrial applications of colloids. (8)

23. (a) (i) Describe the extraction iron (7)

(ii) What is purpose of heat treatment of steel. Write notes on various heat treatment of steel. (8)

(or)

(b) (i) Explain the extraction of titanium from its ore. (7)

(ii) What are the applications of powder metallurgy. (8)

24. (a) (i) Define any five components of a nuclear rector. (7)

(ii) Define half life period. The decay constant of Co-60 is 0.132/yr. Calculate its half-life period. If the quantity of Co -60 is 2.5g, what will be the quantity that remain after 10.5 years. (8)

(or)

(b) (i) Describe the manufacture of white pottery (7)

(ii) Define refractory. What are the requirements of a refractory. (8)

25. (a) (i) List the differences between thermoplastics and thermosetting plastics. (7)

(ii) Mention the applications of composite materials. (8)

(or)

(b) (i) Explain the properties of plastics. (7)

(ii) What are abrasives? How are they classified? Give examples. (8)

SEMESTER – I

40007 ENGINEERING CHEMISTRY – I PRACTICAL
VOLUMETRIC ANALYSIS

The method is to determine the exact amount of a substance quantitatively in a given sample is termed as quantitative analysis. Volumetric analysis is a branch of quantitative analysis involving accurate measurement of volumes of reacting solutions. The volumetric analysis is very much useful due to simplicity, rapidity, accuracy and wide applicability.

The reacting substances are taken in the form of solutions and made to react. The concentration of one solution is determined using another suitable solution whose concentration is accurately known. A known volume of one solution is measured with a pipette and taken in a conical flask. The other solution is taken in a burette and run into the first solution till the chemical reaction is just complete. The volume of the second solution is read from the burette and the two volumes are compared.

Various terms used in volumetric analysis are given below:

Titration

The process of adding one solution from the burette to another in the conical flask in order to complete the chemical reaction is termed titration.

End point

It is the exact stage at which chemical reaction involved in the titration is just complete.

Indicator

It is a substance which will show the end point of the reaction by change of colour. For example, phenolphthalein and methyl orange are the indicators used in acid-alkali titrations. Potassium permanganate itself acts as an indicator in potassium permanganate titrations.

Acidimetry and alkalimetry Titration

Acidimetry refers to the titration of alkali with a standard acid and alkalimetry refers to the titration of an acid with a standard alkali.

Permanganometry Titration

The titration involving $KMnO_4$ is called permanganometric titration. In the presence of dilute H_2SO_4, $KMnO_4$ oxidises ferrous sulphate and ferrous ammonium sulphate to ferric sulphate and oxidises oxalic acid to CO_2 and H_2O.

Normality

The strength of a solution is expressed in terms of normality. Normality is the number of gram equivalents of a solute present in 1000 mL (1 litre) of a solution. It is represented by the symbol N.

Decinormal solution

A solution having the strength (Normality) of 0.1 N is called a decinormal solution.

Law of volumetric analysis

Whenever two substances react together, they react in the ratio of their equivalent mass. One litre of a normal solution of a substance will react exactly with the same volume of a normal solution of another substance. In other words, equal volume of equi-normal solutions will exactly interact with each other. This result is stated in the form of law of volumetric analysis.

If V_1 mL of a solution of strength N_1 is required for complete reaction by V_2 mL of the second solution of strength N_2, then

$$\mathbf{V_1 N_1 = V_2 N_2}$$

If any three factors (V_1, V_2 and N_1) are known, the fourth factor N_2 can be calculated.

The following formula is important, used in all volumetric estimations.

Mass of solute per litre of the solution = Equivalent mass × Normality

Equivalent mass of some important compounds

Name of the compound	Equivalent mass
Hydrochloric acid	36.5
Sulphuric acid	49
Oxalic acid	63
Sodium carbonate	53
Sodium hydroxide	40
Potassium hydroxide	56.1
Potassium permanganate	31.6
Ferrous sulphate	278
Ferrous ammonium sulphate	392
Potassium dichromate	49.04
Copper sulphate	249.54
EDTA (Disodium salt)	372
Iron	55.85
Sodium thiosulphate	158
$Na_2S_2O_3.5H_2O$	248

STATE BOARD OF TECHNICAL EDUCATION & TRAINING, TAMILNADU DIPLOMA IN ENGINEERING / TECHNOLOGY SYLLABUS N-SCHEME

(Implements from the Academic year 2020-21 onwards)

Course Name : **All Branches of Diploma in Engineering and Technology and Special Programmes except DMOP, HMCT and Film & TV**

Subject Code : **40007**

Semester : **I - Semester**

Subject Title **: ENGINEERING CHEMISTRY – I PRACTICAL**

TEACHING AND SCHEME OF EXAMINATION:

No. of Weeks per Semester: 16 Weeks

Instructions			Internal Assessment / Record	Board Examination
Subject	**Hours / Week**	**Hours / Semester**		
Engineering Chemistry – I Practical	2	32	15	53

OBJECTIVES:

1. At the end of the program the student will gain knowledge about volumetric analysis. They learn acidimetry, alkalimetry and permanganometry titration and their applications.
2. To get knowledge of estimation of total hardness, temporary and permanent hardness in a water sample.
3. To get knowledge about measurement of TDS, pH, and to calculate Hydrogen ion concentration in a solution.
4. To get knowledge of estimation of residual chlorine in a water sample.

ENGINEERING CHEMISTRY – I PRACTICAL

CONTENTS

Intellectual Skills

1. Carrying out Volumetric titrations and calculation of masses
2. Knowing units for Concentrations of solutions

Motor Skills

1. To measure quantities accurately
2. To observe chemical reactions
3. To handle the apparatus carefully

i) Acidimetry and Alkalimetry

1. Estimate the amount of sulphuric acid present in ………. mL of a given solution using standard solution of HCl of strength……………..N and an approximately decinormal solution of NaOH.
2. Estimate the amount of NaOH present in ……….mL the given solution using a standard solution of KOH of strength ………….N and an approximately decinormal solution of H_2SO_4
3. Compare of strength of two given hydrochloric acids and estimate the stronger/weaker solution present in ………….mL using a standard solution of sodium hydroxide of strength ………..N

ii) Permanganometry

4. Estimate of the amount of Mohr salt present in……….mL of the given solution using a standard solution of ferrous sulphate of strength ………..N and an approximately decinormal solution of $KMnO_4$.
5. Estimate of the amount of Fe2+ present in……….mL of the given solution using a standard solution of ferrous ammonium sulphate of strength ………..N and an approximately decinormal solution of $KMnO_4$.
6. Compare of strength of two given $KMnO_4$ solution and estimate the stronger/weaker solution present in ………….mL using a standard solution of ferrous ammonium sulphate of strength …………

iii) Water Analysis

7. Water analysis for residual chlorine
8. Estimation of total hardness of a sample using EDTA
9. Water quality testing, pH,(3 samples)
10. Water quality testing TDS(3 samples)

Determination of pH and TDS using a pH meter and TDS meter respectively and calculation of hydrogen ion Concentrations (For three given samples, one of the samples brought from home by each student)

(This question must be given to any two students per batch in the Board Examination).

A single experiment with different skill value may be given for a batch. The last two experiments (Determination of pH &) may be given to any two students per batch.

List of Apparatus to be provided for each student in Chemistry Laboratory during the Engineering Chemistry – I Practical Classes / Board Examination in addition to the required Solutions:

Sl. No.	Name of the Item	Quantity (Nos.)
1	Beaker (100 mL)	1
2	Burette (50 mL)	1
3	Burette Stand	1
4	Conical Flask (250 mL)	1
5	Funnel	1
6	Pipette (20 mL)	1
7	Porcelain Tile	1
8	Cleaning brush	1
9	Wash Bottle	1
10	pH meter	1
11	TDS meter	1

ACIDIMETRY AND ALKALIMETRY

1. ESTIMATION OF SULPHURIC ACID

Expt. No.: **Date:**

Aim

Estimate the amount of sulphuric acid present in 100 mL of a given solution supplied in bottle (A) using Standard solution of HCl of strength 0.1N provided in bottle (C) and an approximately decinormal solution of NaOH in bottle (B)[†]

Principle

The titration is based on the neutralisation reaction between hydrochloric acid and sodium hydroxide in titration – I and sulphuric acid and sodium hydroxide in titration –I I.

Procedure

Short Procedure

DESCRIPTION		TITRATION - I	TITRATION - II
Burette solution		Hydrochloric acid(C)	Sulphuric acid(A)
Pipette solution		Sodium hydroxide (B)	Sodium hydroxide(B)
Indicator		* Phenolphthalein	* Phenolphthalein
End point		Disappearance of pale pink colour	Disappearance of pale pink colour
	Equivalent mass of sulphuric acid = 49		

[†] **- For convenience solutions A and C may be common for all students, and the link solution can be with varying concentration .may be given for practice**

*-Methyl orange can also be used

Titration – I

Standardisation of sodium hydroxide solution

The burette is washed with water, rinsed with distilled water and then with the given hydrochloric acid solution. It is filled with same acid up to zero mark. The initial reading of the burette is noted. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given sodium hydroxide solution. 20 mL of sodium hydroxide solution is pipetted out into a clean conical flask. Two drops of phenolphthalein indicator is added into the flask. The solution turns to pale pink in colour. The solution is titrated against standard hydrochloric acid taken in the burette. The end point of the titration is the disappearance of pale pink colour to give colourless solution. The titration is repeated to get the concordant titre value. From the titre value, the normality of sodium hydroxide solution is calculated.

TITRATION – I

Hydrochloric acid Vs Sodium hydroxide

Sl. No	**Volume of Sodium hydroxide solution (V_2 mL)**	**Burette Reading**		**Volume of Hydrochloric acid solution (V_1) (V1 mL)**	**Indicator**
		Initial (mL)	**Final (mL)**		
1	20	0			Phenolphthalein
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation:

Volume of Hydrochloric acid solution (V_1) = mL

Normality of Hydrochloric acid solution (N_1) = 0.1 N

Volume of Sodium hydroxide solution (V_2) = 20 mL

Normality of Sodium hydroxide (N_2) = N

By the principle of Volumetric Analysis, $V_1N_1 = V_2N_2$

$$\text{Therefore, } N_2 = \frac{V_1\ N_1}{V_2} = \frac{\quad x\ 0.1}{20}$$

The normality of Sodium hydroxide solution (N_2) = N

Titration II

Estimation of sulphuric acid

The burette is washed with water, rinsed with distilled water and then with the given sulphuric acid solution. It is filled with same acid up to zero mark. The initial reading of the burette is noted. Since the pipette solution is the same, no need to wash the pipette again. 20 mL of sodium hydroxide solution is pipetted out into a clean conical flask. Two drops of phenolphthalein indicator is added into the flask. The solution turns to pale pink in colour. The solution is titrated against sulphuric acid taken in the burette. The end point of the titration is the disappearance of pale pink colour to give colourless solution. The titration is repeated to get the concordant titre value. From the titre value, the normality of sulphuric acid solution is calculated. From the normality the amount of sulphuric acid present in 100 mL of the solution is estimated.

TITRATION – II

Sulphuric acid Vs Sodiumhydroxide

Sl. No.	Volume of Sodium hydroxide solution (V_2 mL)	Burette Reading		Volume of Sulphuric acid solution (V_1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	20	0			Phenolphthalein
2	20	0			
3	20	0			
				Concordant titre value =mL	

Calculation:

Volume of sulphuric acid solution (V_1) = mL

Normality of sulphuric acid solution (N_1) = ?

Volume of Sodium hydroxide solution (V_2) = 20 mL

Normality of Sodium hydroxide solution (N_2) = N

By the principle of Volumetric Analysis, $V_1N_1 = V_2N_2$

$$\text{Therefore, } N_1 = \frac{V_2\ N_2}{V_1} = \frac{20 \text{ x}}{}$$

Amount of sulphuric acid present in one litre of the solution

= N_1 x equivalent mass of H_2SO_4

= N_1 x 49

= g

Amount of sulphuric acid present in 100mL of the solution

$$= \frac{\text{amount//L X 100}}{1000}$$

= g

Result

1. The normality of Sulphuric acid solution = N
2. The amount of Sulphuric acid present in 100mL of the given solution =

2. ESTIMATION OF SODIUM HYDROXIDE

Expt. No.: **Date:**

Aim

Estimate the amount of NaOH present in ……….mL the given solution supplied in **bottle(A)**using a standard solution of potassium hydroxide of strength ………….N provided in bottle **(C)** and approximately decinormal solution of H_2SO_4 in bottle(**B**)

Principle

The titration is based on the neutralisation reaction between sulphuric acid and potassium hydroxide in titration – I and sulphuric acid and sodium hydroxide in titration – II.

Procedure

Short Procedure

DESCRIPTION	TITRATION - I	TITRATION - II
Burette solution	Sulphuric acid (B)	Sulphuric acid (B)
Pipette solution	Potassium hydroxide(C)	Sodium hydroxide(A) solution(A)
Indicator	Methyl orange*	Methyl orange*
End point	Change of colour from straw yellow to permanent pale pink colour	Change of colour from straw yellow to permanent pale pink colour
Equivalent mass of sodium hydroxide = 40		

*-Phenolphthalein can also be used

Titration – I

Standardisation of Sulphuric acid solution

The burette is washed with water, rinsed with distilled water and then with the given sulphuric acid solution. It is filled with same acid up to zero mark. The initial reading of the burette is noted. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given potassium hydroxide solution. 20 mL of potassium hydroxide solution is pipetted out into a clean conical flask. Two drops of methyl orange indicator is added into the flask. The solution turns to straw yellow in colour. The solution is titrated against sulphuric acid solution taken in the burette. The end point of the titration is the change of colour from straw yellow to permanent pale pink colour. The titration is repeated to get the concordant titre value. From the titre value, the normality of sulphuric acid solution is calculated.

TITRATION – I

Sulphuric acid (B) Vs Potassium hydroxide(C)

Sl. No.	Volume of Potassium hydroxide (C) (V_2 mL)	Burette Reading		Volume of sulphuric acid (B) (V_1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	20	0			Methyl orange
2	20	0			
3	20	0			
				Concordant titre value =mL	

Calculation:

Volume of Sulphuric acid (A) solution (V_1) = mL

Normality of Sulphuric acid (A) solution (N_1) = ? N

Volume of Potassium hydroxide solution (V_2) = 20 mL

Normality of Potassium hydroxide solution (N_2) = N

By the principle of Volumetric Analysis, $V_1N_1 = V_2N_2$

$$\text{Therefore, } N_1 = \frac{V_2\ N_2}{V_1} = \frac{20 \text{ x}}{\quad}$$

The normality of sulphuric acid (A) solution = N

Titration II

Estimation of Sodium hydroxide

Since the burette solution is the same no need to wash the burette again.. It is filled with same acid up to zero mark. The initial reading of the burette is noted. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given sodium hydroxide solution. 20 mL of sodium hydroxide solution is pipetted out into a clean conical flask. Two drops of methyl orange indicator is added into the flask. The solution turns straw yellow in colour. The solution is titrated against sulphuric acid taken in the burette. The end point of the titration is the appearance of permanent pale pink colour solution. The titration is repeated to get the concordant titre value. From the titre value, the normality of sodium hydroxide solution is calculated. From the normality the amount of sodium hydroxide present in ……… mL is estimated

TITRATION – II

Sulphuric acid Vs Sodium hydroxide

Sl. No.	**Volume of Sodium hydroxide solution (V_2 mL)**	**Burette Reading**		**Volume of Sulphuric acid solution (V_1) (V1 mL)**	**Indicator**
		Initial (mL)	**Final (mL)**		
1	20	0			Methyl orange
2	20	0			
3	20	0			
				Concordant titre value =mL	

Calculation:

Volume of Sulphuric acid solution (V_1) = mL

Normality of Sulphuric acid solution (N_1) = N

Volume of Sodium hydroxide solution (V_2) = 20 mL

Normality of Sodium hydroxide solution (N_2) = ?

By the principle of Volumetric Analysis, $V_1N_1 = V_2N_2$

Therefore, $N_2 = \dfrac{V_1 N_1}{V_2} = \dfrac{x}{20}$

The normality of Sodium hydroxide solution = ... N

Amount of sodium hydroxide present in one litre of the solution

= N_2 x Equivalent mass of sodium hydroxide

= x 40

= g

Amount/L x

Amount of sodium hydroxide present in ……..mL = $\dfrac{\text{……………. x ……………..}}{1000}$

=

Result

1. The normality of Sodium hydroxide solution = N
2. The amount of Sodium hydroxide Present in ……..mL of the given solution = g

3. COMPARISON OF TWO HYDROCHLORIC ACID SOLUTIONS

Expt. No.: **Date:**

Aim: Compare of strength of two given hydrochloric acids supplied in bottle (A) and bottle (C) and estimate the stronger/weaker solution present in …………mL using a standard solution of sodium hydroxide of strength ……………. N in bottle (B).

Principle

The titration is based on the neutralisation reaction between hydrochloric acid (A) and sodium hydroxide in titration – I and hydrochloric acid (C) and sodium hydroxide in titration – II.

Procedure

Short Procedure

DESCRIPTION	TITRATION – I	TITRATION - II
Burette solution	Hydrochloric acid(A)	Hydrochloric acid(C)
Pipette solution	Sodium hydroxide (B)	Sodium hydroxide(B)
Indicator	Phenolphthalein	Phenolphthalein
End point	Disappearance of pale pink colour	Disappearance of pale pink colour
	Equivalent mass of hydrochloric acid = 36.5	

Titration – I

Standardisation of hydrochloric acid (A) solution

The burette is washed with water, rinsed with distilled water and then with the given hydrochloric acid (A) solution. It is filled with same acid up to zero mark The pipette is washed with water, rinsed with distilled water and then with the given sodium hydroxide solution. 20 mL of sodium hydroxide solution is pipetted out into a clean conical flask. Two drops of phenolphthalein is added to the conical flask. The solution turns to pale pink in colour. The initial reading of the burette is noted. The solution is titrated against hydrochloric acid taken in the burette. The end point of the titration is the disappearance of pale pink colour to give colourless solution. The titration is repeated to get the concordant titre value. From the titre value, the normality of hydrochloric acid (A) solution is calculated.

TITRATION – I

Hydrochloric acid (A)Vs Sodium hydroxide (B)

Sl. No	**Volume of Sodium hydroxide solution (V_2 mL)**	**Burette Reading**		**Volume of Hydrochloric acid solution (V_1) ($V1$ mL)**	**Indicator**
		Initial (mL)	**Final (mL)**		
1	20	0			Phenolphthalein
2	20	0			
3	20	0			
				Concordant titre value =mL	

Calculation:

Volume of Hydrochloric acid solution (V_1) = mL

Normality of Hydrochloric acid solution (N_1) = ?

Volume of Sodium hydroxide solution (V2) = 20 mL

Normality of Sodium hydroxide (N_2) = N

By the principle of Volumetric Analysis, $V_1N_1 = V_2N_2$

$$\text{Therefore, } N_1 = \frac{V_2\ N_2}{V_1} = \frac{20\ x}{\quad}$$

Titration – II

Standardisation of hydrochloric acid (C) solution

The burette is washed with water, rinsed with distilled water and then with the given hydrochloric acid (C) solution. It is filled with same acid up to zero mark. The pipette need not be washed since same sodium hydroxide solution is to be taken in the pipette. 20 mL of sodium hydroxide solution is pipetted out into a clean conical flask. Two drop of phenolphthalein is added to the conical flask. The solution turns to pale pink in colour. The initial reading of the burette is noted. The solution is titrated against hydrochloric acid taken in the burette. The end point of the titration is the disappearance of pale pink colour to give colourless solution. The titration is repeated to get the concordant titre value. From the titre value, the normality of hydrochloric acid (C) solution is calculated.

TITRATION – II

Hydrochloric acid (C) Vs Sodium hydroxide (B)

Sl. No	**Volume of Sodium hydroxide solution (V_2 mL)**	**Burette Reading**		**Volume of Hydrochloric acid solution (V_1) (V1 mL)**	**Indicator**
		Initial (mL)	**Final (mL)**		
1	20	0			Phenolphthalein
2	20	0			
3	20	0			
				Concordant titre value =mL	

Calculation:

Volume of Hydrochloric acid solution (V_1) = mL

Normality of Hydrochloric acid solution (N_1) = ?

Volume of Sodium hydroxide solution (V2) = 20 mL

Normality of Sodium hydroxide (N_2) = N

By the principle of Volumetric Analysis, $V_1N_1 = V_2N_2$

Therefore, $N_1 = \frac{V_2 \; N_2}{V_1} = \frac{x}{20}$

The hydrochloric acid present in bottle ( ) is stronger/weaker.

Amount of hydrochloric acid present in one litre of the solution

= N_1 x equivalent mass of HCl

= N_1 x 36.5

= g

Amount of hydrochloric acid present in…………mL of the solution

$= \frac{\text{amount/L X}}{1000}$

= g

Result

1. The normality of Hydrochloric acid solution supplied in bottle ( ) is stronger/weaker
2. The amount of stronger/weaker Hydrochloric acid present in__________mL of the given solution =

PERMANGANOMETRY

4. ESTIMATION OF MOHR'S SALT

Ex. No.: **Date:**

Aim

To estimate the amount of crystalline ferrous ammonium sulphate (Mohr's salt) present in …………mL of the given solution supplied in bottle (A) using a standard solution of ferrous sulphate of normality ………N provided in bottle (C) and an approximately decinormal solution of potassium permanganate in bottle (B).

Principle

The titration is based on the oxidation and reduction reaction. The oxidising agent, potassium permanganate oxidises the reducing agent, ferrous sulphate and ferrous ammonium sulphate in acidic medium to ferric sulphate.

Procedure

Short Procedure

DESCRIPTION	TITRATION – I	TITRATION - II
Burette solution	Potassium permanganate (B)	Potassium permanganate (B)
Pipette solution	Ferrous sulphate(C)	Ferrous ammonium sulphate (A)
Reagents added	20 mL of dilute sulphuric acid	20 mL of dilute sulphuric acid
Indicator	Self (KMnO4)	Self (KMnO4)
End point	Appearance of permanent pale pink colour	Appearance of permanent pale pink colour
Equivalent mass of ferrous ammonium sulphate = 392		

Titration – I

Standardisation of Potassium permanganate solution

The burette is washed with water, rinsed with distilled water and then with the given potassium permanganate solution. It is filled with same solution up to zero mark. The initial reading of the burette is noted. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given ferrous sulphate solution. 20 mL of ferrous sulphate solution is pipetted out into a clean conical flask. One test tube full of sulphuric acid (20 mL) is added into the flask. The solution is titrated against potassium permanganate solution taken in the burette. Potassium permanganate acts as the self-indicator. The end point of the titration is the appearance of permanent pale pink colour. The titration is repeated to get concordant titre value. From the titre value, the normality of potassium permanganate solution is calculated.

TITRATION – I

Potassium permanganate Vs Ferrous sulphate

Sl. No.	**Volume of Ferroussulphate solution (V_2 mL)**	**Burette Reading**		**Volume of Potassium permanganate solution (V_1)** (V_1 mL)	**Indicator**
		Initial (mL)	**Final (mL)**		
1	20	0			Self (KMnO4)
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation:

Volume of Potassium permanganate solution (V_1) = mL

Normality of Potassium permanganate solution (N_1) = ? N

Volume of Ferrous sulphate solution (V_2) = 20 mL

Normality of Ferrous sulphate solution (N_2) = N

By the principle of Volumetric Analysis,

$$V_1 N_1 = V_2 N_2$$

$$N_1 = \frac{V_2 N_2}{V_1}$$

$$= \frac{20 \quad x}{}$$

N_1 = ………………. N

The normality of Potassium permanganate solution = N

Titration –II

Estimation of Ferrous ammonium sulphate (Mohr's salt) solution

The burette is again filled with the same potassium permanganate solution. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given ferrous ammonium sulphate solution. 20 mL of ferrous ammonium sulphate solution is pipetted out into a clean conical flask. One test tube full of sulphuric acid (20 mL) is added into the flask. The solution is titrated against standardised potassium permanganate solution taken in the burette. Potassium permanganate acts as the self-indicator. The end point of the titration is the appearance of permanent pale pink colour. The titration is repeated to get concordant titre value. From the titre value, the normality of ferrous ammonium sulphate solution is calculated. From the normality of ferrous ammonium sulphate solution, the amount of ferrous ammonium sulphate present in ……..mL of the given solution is calculated.

TITRATION – II

Potassium permanganate Vs Ferrous ammonium sulphate

Sl. No.	Volume of Ferrous ammonium sulphate solution (V_2 mL)	Burette Reading		Volume of Potassium permanganate solution (V_1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	20	0			Self (KMnO4)
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation:

Volume of Potassium permanganate solution (V_1) = mL

Normality of Potassium permanganate solution (N_1) = N

Volume of Ferrous ammonium sulphate solution (V_2) = 20mL

Normality of Ferrous ammonium sulphate solution (N_2) = ?

By the principle of Volumetric Analysis,

$$V_1 N_1 = V_2 N_2$$

$$N_2 = \frac{V_1 N_1}{V_2}$$

$$N_2 = \frac{x}{20}$$

= ………………. N

The normality of Ferrous ammonium sulphate solution = N

Amount of ferrous ammonium sulphate present in one litre of the solution

= N_2 x Equivalent mass of ferrous ammonium sulphate

= x 392

= g

Amount of ferrous ammonium sulphate present -----------mL $= \dfrac{x}{1000}$

=

Result

1. The normality of Ferrous ammonium sulphate solution = N
2. The amount of Ferrous ammonium sulphate
   Present in ………..mL of the given solution = g

5. ESTIMATION OF IRON

Ex. No.: **Date:**

Aim

To estimate the amount of iron present in …………mL of the given ferrous sulphate solution supplied in bottle (A) using a standard solution of ferrous ammonium sulphate provided in bottle (C) of normality ………… N and an approximately decinormal solution of potassium permanganate in bottle (B)

Principle

The titration is based on the oxidation and reduction reaction. The oxidising agent, Potassium permanganate oxidises the reducing agent, ferrous sulphate and ferrous ammonium sulphate in acidic medium to ferric sulphate.

Procedure

Short Procedure

DESCRIPTION	TITRATION – I	TITRATION - II
Burette solution	Potassium permanganate (B)	Potassium permanganate(B
Pipette solution	Ferrous ammonium sulphate solution(C)	Ferrous sulphate solution(A)
Reagents added	20 mL of dilute sulphuric acid	20 mL of dilute sulphuric acid
Indicator	Self (KMnO4)	Self (KMnO4)
End point	Appearance of permanent pale pink colour	Appearance of permanent pale pink colour
Equivalent mass of iron = 55.85		

Titration – I

Standardisation of Potassium permanganate solution

The burette is washed with water, rinsed with distilled water and then with the given potassium permanganate solution. It is filled with same solution up to zero mark. The initial reading of the burette is noted. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given ferrous ammonium sulphate solution. 20 mL of ferrous ammonium sulphate solution is pipetted out into a clean conical flask. One test tube full of sulphuric acid (20 mL) is added into the flask. The solution is titrated against potassium permanganate solution taken in the burette. Potassium permanganate acts as the self-indicator. The end point of the titration is the appearance of pale permanent pink colour. The titration is repeated to get concordant titre value. From the titre value, the normality of potassium permanganate solution is calculated.

TITRATION – I

Potassium permanganate Vs Ferrous ammonium sulphate

Sl. No.	**Volume of Ferrous ammonium sulphate (C) (V_2 mL)**	**Burette Reading**		**Volume of Potassium permanganate (B) (V_1 mL)**	**Indicator**
		Initial (mL)	**Final (mL)**		
1	20	0			Self (KMnO4)
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation:

Volume of Potassium permanganate solution (V1) = mL

Normality of Potassium permanganate solution (N1) = ?

Volume of Ferrous ammonium sulphate solution (V2) = 20 mL

Normality of Ferrousammonium sulphate solution (N2) = N

By the principle of Volumetric Analysis,

$$V_1 N_1 = V_2 N_2$$

$$N_1 = \frac{V_2 N_2}{V_1}$$

$$= \frac{20 \ \ x}{\ }$$

N_1 = ………………. N

The normality of potassium permanganate solution = N

Titration – II

Estimation of Ferrous sulphate solution

The burette is again filled with the same potassium permanganate solution upto zero mark. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given ferrous sulphate solution. 20 mL of ferrous sulphate solution is pipetted out into a clean conical flask. One test tube of sulphuric acid (20 mL) is added into the flask. The solution is titrated against standardised potassium permanganate solution taken in the burette. Potassium permanganate acts as the self-indicator. The end point of the titration is the appearance of pale permanent pink colour. The titration is repeated to get concordant titre value. From the titre value, the normality of ferrous sulphate solution is calculated. From the normality of ferrous sulphate solution, the amount of iron present in whole of the given ferrous sulphate solution is calculated.

TITRATION – II

Potassium permanganate (A) Vs Ferrous sulphate

Sl. No.	Volume of Ferrous sulphate solution (A) (V2 mL)	Burette Reading		Volume of Potassium permanganate (B) solution (v_1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	20	0			Self (KMnO4)
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation:

Volume of Potassium permanganate (A) solution (V_1) = mL

Normality of Potassium permanganate (A) solution (N1) = N

Volume of Ferrous sulphate solution (V2) = 20 mL

Normality of Ferrous sulphate solution (N2) = N

By the principle of Volumetric Analysis,

$V_1 N_1 = V_2 N_2$

$$N_2 = \frac{V_1 N_1}{V_2}$$

$$N_2 = \frac{x}{20}$$

= ………………. N

The normality of Ferrous sulphate solution = N

Amount of ferrous ion present in one litre of the solution

= N_2 x Equivalent mass of ferrous ion

= x 55.85

= g

x

Amount of ferrous ion present = --------------------

-----------mL 1000

=

Result

1. The normality of Ferrous sulphate solution = N
2. The amount of iron present in ……….mL
   of the given Ferrous sulphate solution = g

6. COMPARISON OF STRENGTHS OF TWO POTASSIUM PERMANGANATE SOLUTIONS

Ex. No.: **Date:**

Aim

To compare the strengths of two potassium permanganate solutions in bottles (A) and (C) and estimate the amount of stronger /weaker potassium permanganate present in …………..mL of the given solution using a standard solution of ferrous sulphate of normality ……. N provided in bottle (B)

Principle

The titration is based on the oxidation and reduction reaction. The oxidising agent, Potassium permanganate oxidises the reducing agent, ferrous sulphate in acidic medium to ferric sulphate.

Procedure

DESCRIPTION	TITRATION - I	TITRATION - II
Burette solution	Potassium permanganate (A) solution	Potassium permanganate (C) solution
Pipette solution	Ferrous sulphate solution(B)	Ferrous sulphate solution(B)
Reagents added	20 mL of dilute sulphuric acid	20 mL of dilute sulphuric acid
Indicator	Self (KMnO4)	Self (KMnO4)
End point	Appearance of pale permanent pink colour	Appearance of pale permanent pink colour
Equivalent mass of potassium permanganate = 31.6		

Titration – I

Standardisation of Potassium permanganate (A) solution

The burette is washed with water, rinsed with distilled water and then with the given potassium permanganate (A) solution. It is filled with same solution up to zero mark. The initial reading of the burette is noted. A 20 mL pipette is washed with ferrous sulphate solution. 20 mL of ferrous sulphate solution is pipetted out into a clean conical flask. One test tube full of sulphuric acid (20 mL) is added into the flask. The solution is titrated against potassium permanganate (A) solution taken in the burette. Potassium permanganate (A) acts as the self-indicator. The end point of the titration is the appearance of pale permanent pink colour. The titration is repeated to get the concordant titre value. From the titre value, the normality of potassium permanganate (A) solution is calculated.

TITRATION – I

Potassium permanganate (B) Vs Ferrous sulphate

Sl. No.	Volume of Ferrous sulphate solution (B) (V_2 mL)	Burette Reading		Volume of Potassium permanganate (A) solution V_1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	20	0			Self (KMnO4)
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation

Volume of Potassium permanganate (B) solution (V_1) = mL

Normality of Potassium permanganate (B) solution (N_1) = ?

Volume of Ferrous sulphate solution (V_2) = 20 mL

Normality of Ferrous sulphate solution (N_2) = N

By the principle of Volumetric Analysis,

$$V_1 N_1 = V_2 N_2$$

$$N_1 = \frac{V_2 N_2}{V_1}$$

$$= \frac{20 \quad x}{\quad}$$

N_1 = ………………. N

Titration – II

Standardisation of Potassium permanganate (C) solution

The burette is washed with water, rinsed with distilled water and then with the given potassium permanganate (C) solution. It is filled with same solution up to zero mark. The initial reading of the burette is noted. 20 mL of ferrous sulphate solution is pipetted out into a clean conical flask. One test tube full of sulphuric acid (20 mL) is added into the flask. The solution is titrated against potassium permanganate (C) solution taken in the burette. Potassium permanganate (C) acts as the self-indicator. The end point of the titration is the appearance of pale permanent pink colour. The titration is repeated to get the concordant titre value. From the titre value, the normality of potassium permanganate (C) solution is calculated. The normalities of two potassium permanganate solutions are compared and then the amount of stronger/weaker potassium permanganate present in ………mL of the given solution is calculated.

TITRATION – II

Potassium permanganate (C) Vs Ferrous sulphate (B)

Sl. No.	**Volume of Ferrous sulphate (B) solution (V_2 mL)**	**Burette Reading**		**Volume of Potassium permanganate (A) solution (V_1 mL)**	**Indicator**
		Initial (mL)	**Final (mL)**		
1	20	0			Self (KMnO4)
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation

Volume of Potassium permanganate (C) solution (V_1) = mL

Normality of Potassium permanganate (C) solution (N_1) = ?

Volume of Ferrous sulphate solution (V_2) = 20 mL

Normality of Ferrous sulphate solution (N_2) = N

By the principle of Volumetric Analysis,

$$V_1 N_1 = V_2 N_2$$

$$N_1 = \frac{V_2 N_2}{V_1}$$

$$= \frac{20\ \ x}{}$$

N1 = ………………. N

The normality of Potassium permanganate (A) solution = N

The normality of Potassium permanganate (C) solution = N

Potassium permanganate ( ) solution is **……………** than

Potassium permanganate ( ) solution

Amount of ………………….potassium permanganate present in one litre of the solution

= N_1x Equivalent mass of $KMnO_4$

= x 31.6

= g

Amount ……………KMnO4 present = --------------------

-----------mL 1000

Result

1. Potassium permanganate ( ) solution is stronger/weaker
2. The amount of stronger/weaker Potassium permanganate = g
   Present in ……..mL of the given solution

WATER ANALYSIS

7. ESTIMATION OF RESIDUAL CHLORINE OF WATER

Ex. No.: **Date:**

AIM

To determine residual chlorine in the given water sample

INTRODUCTION

What is residual chlorine and why we need to measure residual chlorine. Let us first understand the importance of adding chlorine. Treated or filtered water is deemed to be fit for consumption only if it is devoid of disease producing microorganism. Chlorination is primarily adopted to destroy or deactivate disease-producing microorganisms in the public water supplies and polluted river. Chlorine is usually added to water in gaseous form or as sodium or calcium hypochlorite. **Bleaching powder can be added as 4mg/L and allowed stand for 30 minutes.** When chlorine is added to water, some of the chlorine reacts first with organic materials and metals in the water and is not available for disinfection (this is called the chlorine demand of the water). The remaining chlorine concentration after the chlorine demand is accounted for is called free chlorine. Total chlorine is thus divided into : 1) the amount of chlorine that has reacted with nitrates and is unavailable for disinfection which is called combined chlorine and, 2) the free chlorine, which is the chlorine available to inactivate disease - causing organisms, and thus a measure to determine the potability of water. The word "residual "means" remainder "or" that which is left", and as the name suggests the chlorine residual test is used to measure the amount of chlorine remaining in the water at the time the test is made. The chlorine residual is usually tested in finished water which is ready to be released into the distribution system, although operators must also ensure that there is adequate residual at the extreme ends of the distribution system. **It can be 0.2-0.5mg/L as per WHO standard.** Excess Chlorination may produce adverse effects. Potentially carcinogenic chloro organic compounds such as chloroform maybe formed.

PRECAUTIONS

The following precautions should be observed while performing the experiment:

- This experiment is a basic experiment and hence there will not be any major difficulties in performing the experiment. The entire procedure should be done in quick time without exposing the solutions to the ambient air.
- Do not expose the potassium iodide crystals in the air. If possible do the experiment in iodine flask instead of conical flask.
- Chlorine in water solutions is not stable. As a result, its concentration in samples decreases rapidly.

- Samples to be analyzed for chlorine cannot be stored or preserved. Tests must be started immediately after sampling. Therefore, samples taken for the chlorine residual test must be grab samples only and excessive agitation must be avoided.
- Exposure to sunlight or other strong light, air, or agitation will further reduce the quantity of chlorine present in solutions.

DESCRIPTION	TITRATION - I	TITRATION – II
Burette solution	Sodium thiosulphate (B)	Sodium thiosulphate (B)
Pipette solution	20 mL of $K_2Cr_2O_7$(C)	100 mL of water (Chlorinated water)
Reagents added	10mL of 10% H_2SO_4 + 10mL of KI	5 mL of Acetic acid + KI
Indicator	Starch	Starch
End point	Appearance of pale green colour	Disappearance of blue colour
Equivalent mass of chlorine = 35.45		

PREPARATION OF REAGENTS

Sodium Thiosulphate solution (~0.1N)

Weigh approximately 24.82 g of sodium thiosulphate $(Na_2S_2O_35H_2O)$

Transfer to the beaker and dissolve it in boiled distilled water. Transfer it to the standard flask and make it up to 1000 mL.

Potassium Dihromate Solution:

Weigh 4.903g of $K_2Cr_2O_7$ in 1000mL of water.(~0.1N)

10 % Potassium iodide

Weigh 10g KI in 100mL of water

10% H_2SO_4

11mL of Conc. H_2SO_4 in 89mL of water).

Standardisation of sodium thiosulphate

The burette is cleaned well and rinsed with sodium thiosulphate and filled with the same solution. 20 mL of potassium dichromate is pipette out into a well cleaned conical flask. 10mL of 10% H_2SO_4 and 10mL of potassium iodide is added to it. The solution is titrated against sodium thiosulphate until the colour changes from dark yellow to pale yellow. The titration is stopped and 1 mL of starch is added. Deep blue colour will be obtained. The titration is continued till the colour changes to pale green. The titration is repeated to get the concordant titre value. From the titre value, the normality of sodium thiosulphate is calculated.

TITRATION – I

Standardisation of sodium thiosulphate

Sodium thiosulphate Vs Potassium Dihromate

Sl. No.	Volume of $K_2Cr_2O_7$ (V_2 mL)	Burette Reading		Volume of sodium thiosulphate (A) (V_1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	20	0			Starch
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation:

Volume of sodium thiosulphate V_1 = mL

Normality of sodium thiosulphate N_1 = ?

Volume of $K_2Cr_2O_7$ V_2 = 20 mL

Normality of $K_2Cr_2O_7$ N_2 = 0.1 N

By volumetric principle $V_1N_1 = V_2\,N_2$

Normality of sodium thiosulphate $= \dfrac{V_2 \text{ X } N_2}{V_1} =$

$N_1 =$ ——

TESTING OF SAMPLE

The burette is filled with sodium thiosulphate solution (B). Fix the burette to the stand. Take 50 mL of a given sample in a conical flask. Add 5 mL Acetic acid. To acidify the sample. It is used to reduce the pH between 3 and 4 in the conical flask. Add about 1g Potassium Iodide (KI) measured using the spatula and dissolve it by thoroughly mixing it with stirring rod. Perform the titration quickly, since iodine liberate faster. Titrate the solution with standard $Na_2S_2O_3$ solution until the yellow color of liberated Iodine is almost faded out. (Pale yellow color) Add 1 mL of starch solution and continue the titration until the blue colour disappears.

In many cases residual chlorine is very low and starch needs to be added before starting up the titration. Note down the burette reading (to know the volume of sodium thiosulphate added.

TITRATION –II

Sodium thiosulphate Vs Cholorinated water

Sl. No.	Volume of Water sample (V2 mL)	Burette Reading		Volume of sodium thiosulphate (B) (V1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	50	0			Starch
2	50	0			
3	50	0			
				Concordant titre value = mL	

Calculation:

Volume of sodium thiosulphate V_1 = mL

Normality of sodium thiosulphate N_1 =

Volume of water sample V_2 = 50 mL

By volumetric principle $V_1 N_1 = V_2 N_2$

Normality of cholrine sample $= \dfrac{V_1 \text{ X } N_1}{V_2}$

=

Equivalent mass of chlorine = 35.45

Amount of residual chlorine in one litre of the solution= N_2 X 35.45 =

= ………..g

Amount of residual chorine in mg/l= amount in gram per litre X 1000

= mg/L

Result

Amount of residual chlorine present in the given sample = ……..mg/L

The residual chlorine is / is not within the limits of 0.2-0.5mg/L

8. ESTIMATION OF TOTAL HARDNESS OF WATER

Ex. No.: **Date:**

Aim

To estimate the total hardness of the given sample of water by EDTA titration using a standard solution of calcium chloride of strength 0.01M.

Principle

The total hardness of water can be determined by titrating a known volume of hard water against EDTA solution using Eriochrome Black – T indicator. The estimation is based on the complexometric titration.

Procedure

Short Procedure

DESCRIPTION	TITRATION - I	TITRATION - II
Burette solution	EDTA solution	EDTA solution
Pipette solution	Standard calcium chloride solution	Hard water
Reagents added	Ammonia buffer solution	Ammonia buffer solution
Indicator	Eriochrome Black – T	Eriochrome Black – T
End point	Change of colour from wine red to steel blue	Change of colour from wine red to steel blue

Titration – I

Standardisation of EDTA solution

The burette is washed with water, rinsed with distilled water and then with the given EDTA solution. It is filled with same solution up to zero mark. The initial reading of the burette is noted. A 20 mL pipette is washed with water, rinsed with distilled water and then with the given standard calcium chloride solution. 20 mL of standard calcium chloride solution is pipetted out into a clean conical flask. Half a test tube of ammonia buffer (10 mL) is added into the flask. A pinch of Eriochrome Black – T indicator is added into the flask. The solution turns to wine red in colour. The solution is titrated against EDTA solution taken in the burette. The end point of the titration is the change of colour from wine red to steel blue. The titration is repeated to get concordant titre value. From the titre value, the molarity of EDTA solution is calculated.

TITRATION – I

EDTA Vs Standard Calcium chloride solution

Sl. No .	Volume of Standard calcium chloride solution (V_2 mL)	Burette Reading		Volume of EDTA solution (V_1) (V1 mL)	Indicator
		Initial (mL)	Final (mL)		
1	20	0			EBT
2	20	0			
3	20	0			
				Concordant titre value = mL	

Calculation:

Volume of EDTA solution (V_1) = mL

Molarity of EDTA solution (M_1) = ? M

Volume of Standard calcium chloride solution (V_2) = 20 mL

Molarity of Standard calcium chloride solution (M_2) = 0.01 M

By the principle of Volumetric Analysis,

$$V_1 M_1 = V_2 M_2$$

$$M_1 = \frac{V_2 M_2}{V_1}$$

$$= \frac{x}{\quad}$$

= ………………. M

The molarity of EDTA solution (MEDTA) = M

Titration – II

Estimation of hard water

A 20 mL and a 10 mL pipette is washed with water, rinsed with distilled water and then with the given hard water sample. 50 mL of hard water sample is pipetted out into a clean conical flask. Half a test tube of ammonia buffer (10 mL) is added into the flask. A pinch of Eriochrome Black – T indicator is added into the flask. The solution turns to wine red in colour. The solution is titrated against EDTA solution taken in the burette. The end point of the titration is the change of colour from wine red to steel blue. The titration is repeated to get the concordant titre value. From the titre value, the hardness of the given sample of water is calculated in ppm.

TITRATION – II

EDTA Vs Hard water sample

Sl. No .	Volume of Hard water sample (V Hard water)	Burette Reading		Volume of EDTA solution (VEDTA)	Indicator
		Initial (mL)	Final (mL)		
1	50	0			EBT
2	50	0			
3	50	0			
				Concordant value = mL	

Calculation:

Volume of EDTA solution (V$_{EDTA}$) = mL

Molarity of EDTA solution (M$_{EDTA}$) = M

Volume of Hard water sample (V$_{Hard\ water}$) = 50 mL

$$\text{Total Hardness} = \frac{V_{EDTA} \times M_{EDTA}}{V_{HARD\ WATER}} \times 10^5$$

$$= \frac{\quad \times \quad}{\qquad} \times 10^5$$

$$= \qquad \text{ppm}$$

Result

The total hardness of the given sample of water = ppm

9. DETERMINATION OF pH AND TOTAL DISSOLVED SOLIDS (TDS)

Ex. No.: **Date:**

Aim

To find out

1. The pH of the given solution in bottles A, B, C
2. To calculate the hydrogen ion concentrations of the above solutions.
3. To find out the TDS of the samples A, B, C

Principle

(i) Determination of pH:

The pH of the solution can be directly measured using a pH meter. Acids give hydrogen ions in solution. The acidic nature of the solution depends on the hydrogen ion concentration which is expressed as grams ions per litre. The pH of the solution varies with the concentration of ions.

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

Procedure

Exactly 50 mL of the given three sample solutions are taken in three 150 mL beakers and labeled as A, B and C. One of the samples can be brought by the student from his/her home. The pH meter is standardized using a known buffer solution. The electrodes are then washed with distilled water and then immersed in the solution taken in the beaker. Similarly the pH reading is noted. The pH of the other solutions is determined. The electrodes are washed well with distilled water before the electrodes are immersed in next solution. The amount of hydrogen ions present in the solution is then calculated from the pH.

(ii) DETERMINATION OF TDS USING DIGITAL TDS METER

TDS in water

Total Dissolved solids (TDS) in water comprise inorganic salts like calcium, magnesium, potassium, sodium bicarbonates, chlorides and sulphates and some small amounts of organic matter that are dissolved in water. Total dissolved solids (TDS) is measured in milligrams per unit volume of water (mg/L) and also referred to as parts per million (ppm). For drinking water, the maximum concentration level set by Environmental Protection Agency (EPA) is 500 mg/L.

- The TDS less than 300 mg/L –Excellent
- Between 300 and 500 mg/L – Good
- The TDS greater than 1200 mg/L – Un acceptable

Procedure:

- Switch on the meter and press the temperature button, the temperature will be displayed in Celsius.
- Now press the temp button again to return to the TDS mode.
- Remove the protective cap and immerse the meter in to the water sample upto the level of 2 inches.

- Press the TDS meter and stir the meter to dislodge any air bubbles.
- Wait till the reading stabilizes(approximately 10 seconds)
- Press the hold button and take down the reading.
- After use shake off the excess water from the meter and replace the cap.

Note: If the meter displays " x 10 " symbol it means that the reading must be multiplied by 10.

DETERMINATION OF pH AND $[H^+]$

Sl. No.	Sample solution	TDS	pH	$[H^+]$ (g ions / litre)
1	A			
2	B			
3	C			

Calculations

Sample A

pH =

pH = – $\log_{10}[H^+]$

$[H^+]$ = Antilog (-pH)

= Antilog (-)

= g ions / litre

Sample B

pH =

pH = – $\log_{10}[H^+]$

$[H^+]$ = Antilog (-pH)

= Antilog (-)

= g ions / litre

Sample C

pH =

pH = – $\log_{10}[H^+]$

$[H^+]$ = Antilog (-pH)

= Antilog (-)

= g ions / litre

RESULT

DETERMINATION OF TDS, pH AND [H^+]

Sl. No.	Sample solution	TDS	pH	[H^+] (g ions / litre)
1	A			
2	B			
3	C			

References:

1. Introduction to Engineering Chemistry, Shradha Sinha , S S Dara & Sudha Jain, S. Chand Publishers, 2004.
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3. A Textbook of Engineering Chemistry, Dr. Uday Kumar, 2013.
4. Chemistry – Higher Secondary – 1st and 2nd year, Vol. I & II, Tamil Nadu Text Book Corporation, 2018.
5. Engineering Chemistry Fundamentals and Applications, Shikha Agarwal, Cambridge University Press, 2019.
6. Government of India, Geological Survey of India, Geology and Mineral Resources of The States of India Part VI – Tamil Nadu and Pondicherry
7. Indian Minerals Yearbook 2011, Government of India Ministry of Mines, Indian Bureau of Mines Indira Bhavan, Civil Lines, Nagpur – 440 004

ADDITIONAL USEFUL INFORMATION
(TEACHING & LEARNING PROCESS)

LINKS FOR SIMULATION

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

Build a molecule
https://phet.colorado.edu/en/simulation/legacy/build-a-molecule

All chemistry simulations
https://phet.colorado.edu/en/simulations/filter?subjects=chemistry&sort=alpha&view=grid

SECOND SEMESTER

ENGINEERING CHEMISTRY - II

UNIT 1

ELECTRO CHEMISTRY

1.1 ELECTROCHEMISTRY – I

Electrochemistry–electrolytes–non-electrolytes-Electronic concept of oxidation and reduction – Faraday's laws of electrolysis-simple problems – electrolysis – definition Mechanism – Industrial applications of Electrolysis – electroplating - chrome plating **- 5 Hours**

Introduction

Electrochemistry is a branch of chemistry which deals with the inter conversion of electrical and chemical energy. The common dry cell we use in our daily life is an example for the conversion of chemical energy to electrical energy. The electrical energy is converted to chemical energy during electroplating. We have studied in Physics about conductors which conduct electricity by the flow of electrons and hence they are called electronic conductors. They are different from electrolytes. Thus ***electrolytes are the substances which conduct electricity through ions either in a fused state or in a solution**, eg., fused sodium chloride, HCl solution etc. Non-Electrolytes are the substances which do not conduct electricity through ions either in fused state or in solution, eg. benzene, carbon tetra chloride etc.*

Electronic concept of oxidation and reduction:

During the above transformation, transfer of electron is always involved. When an atom loses an electron it undergoes oxidation.

$$\mathbf{Na \longrightarrow Na^{+} + e^{-}}$$

Thus oxidation is a process of removal of electron. Similarly reduction is a process of gaining electrons. When an atom gains an electron it undergoes reduction.

$$\mathbf{Cl + e^{-} \longrightarrow Cl^{-}}$$

Faraday's laws of electrolysis:

Faraday's laws of electrolysis are quantitative relationships based on the electrochemical research published by Michael Faraday in 1834. ***Faraday's First Law of Electrolysis states that the amount of chemical deposition or dissolution due to the flow of electric current through an electrolyte is directly proportional to the quantity of electricity passed through it.***

If the amount of deposition or dissolution is W and Q is the quantity of electricity passed, then

$$\mathbf{W \propto Q}$$

The quantity of electricity passed is equal to the current strength 'I' in amperes, and the time of deposition, 't' in seconds.

Thus, $\mathbf{Q = I \times \mathit{t}}$

Faraday's Second Law of Electrolysis

We have learned that the mass of the chemical deposited due to electrolysis is proportional to the quantity of electricity that passes through the electrolyte. The mass of the chemical deposited due to electrolysis is not only proportional to the quantity of electricity passed through the electrolyte, but it also depends upon some other factor. Every substance will have its own atomic weight. *Thus* ***when the same quantity of electricity is passed through different electrolytes the amount of deposition or dissolution is directly proportional to their respective equivalent masses.***

If W_1 and W_2 are the weight of metal –1 and metal -2 and their equivalent weights are E_1 and E_2 respectively, then according to Faradays 2nd law of electrolysis

$$W1/W2 = E1/E2$$

When both laws are combined together, the amount of deposition or dissolution in gram of the material is proportional to $I \times t \times e$, where I is the current strength in amperes, t is the time of deposition/ dissolution expressed in seconds and e is the equivalent *weight* of the material. Therefore,

$$w \ \alpha \ I \ t \ e$$

$$\text{Therefore, } w = \frac{I\times t\times e}{F} \ldots\ldots\ldots\ldots(1)$$

1/F is the proportionality constant, and F is the Faraday which is equivalent to 96500 coulombs.

The significance of this constant may be seen by taking the quantity I x t equal to F, the Faraday; then the weight 'w' of the substance deposited or dissolved is equal to 'e', the equivalent weight of the metal. In other words, F is the quantity of electricity which must be passed to deposit or dissolve one gram equivalent of any substance. Thus for one Faraday of electric charge, the amount of various metals that get deposited will be as follows:

Metal deposited or dissolved	Equivalent mass
Copper	31.75
Silver	108
Zinc	32.69
Tin	59.35
Nickel	29.35
Chromium	52

The charge of an electron is 1.6023×10^{-19} coulomb, and one mole of electron is

$$6.023 \times 10^{23} \times 1.6023 \times 10^{-19} \approx 96500 \text{ coulomb mol}^{-1}$$

Therefore one mole of electron would carry 96500 coulomb

The coulomb is the quantity of electricity passing through a conductor when one ampere flows for one second. Therefore, one coulomb will deposit 108/96500, ie. 0.0011 gram of silver which is the electrochemical equivalent of silver and that of copper is 0.000329.

Problem 1: A current of 0.2 ampere is passed through an aqueous solution of copper sulphate for 2 hours. Calculate the amount of deposition of copper at the cathode.

Given data:

The current strength, I = 0.2 A

Time of deposition is , t = 2 × 60 × 60s

Equivalent mass of copper = atomic mass / valency = 63.5 /2

Therefore, the amount of deposition,

$$w = \frac{0.2\times\ 2\times\ 60\times 60\times\ 63.5}{2\ \ \times 96500} = 0.4737\text{ g}$$

Problem 2: Calculate the equivalent mass of copper when a current of one ampere passes through a copper voltammeter for a hour and liberates 1.2g of copper.

Given data:

Weight of metal copper deposited, w = 1.2g

Current, I = 1A

Time of deposition, t = 60 x 60s

According to Faradays laws of electrolysis, the weight of metal deposited

= I x t x e/F

The equivalent mass = w x F/(I x t)

= 1.2 x 96500 / (1 x 60 x 60)

= 32.1

Electrolysis:

The dissociation of an electrolyte by the passage of' electricity is known as **electrolysis.** During the process, electrical energy is transformed into chemical energy. When electric current passes through an electrolyte, it is dissociated into positively and negatively charged ions. Positively charged ions are known as cations or basic radicals and negatively charged ions are known as anions or acid radicals. Cations move towards cathode or negative electrode. At the cathode reduction takes place. Anions move towards anode or positive electrode. At the anode oxidation takes place.

Electrolysis of Hydrochloric acid: As shown in the Fig. 4.1.1 dilute hydrochloric acid is taken in the Hofmann voltameter and two platinum electrodes are dipped in. The electrodes are then connected to a battery source through a key. When electric current passed through the solution the following reactions take place:

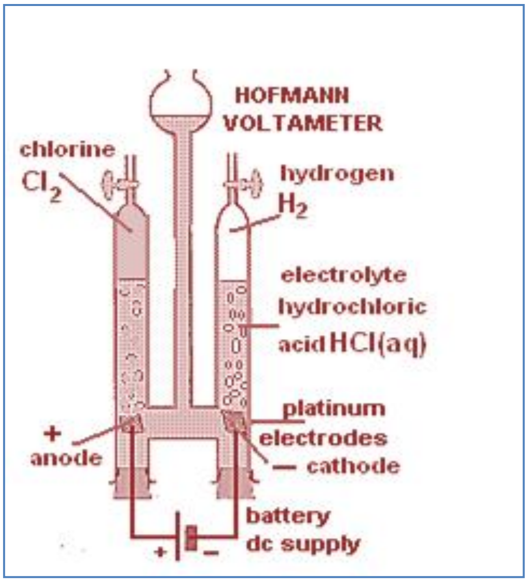


Fig. 1.1.1 Electrolysis of HCl

Step 1: Dissociation of HCl takes place

$$\mathbf{HCl \longrightarrow H^+ + Cl^- \ldots\ldots\ldots\ldots\ldots(1)}$$

Step 2: The ions will moves towards the oppositely charged electrode. **H^+ (hydrogen ion)** move towards the cathode and there by gains an electron and undergoes reduction

$$\mathbf{H^+ + e^- \longrightarrow H \quad \ldots\ldots\ldots\ldots\ldots(2)}$$

$$\mathbf{H + H \longrightarrow H_2 \quad \ldots\ldots\ldots\ldots\ldots(3)}$$

A single hydrogen is always not stable, so it combines with another hydrogen so as to form hydrogen gas which is evolved at the cathode. Since reactions (2) and (3) take place at the cathode, these reactions are called **cathodic reaction**.

Step 3: The **chloride ion (Cl^-)** move towards the anode and loses an electron there by undergoes oxidation and single chlorine is not stable and each chlorine atom combines with another chlorine to form chlorine gas at the anode and hence these reactions are called **anodic reaction**.

$$\mathbf{Cl^- \longrightarrow Cl + e^-}$$

$$\mathbf{Cl + Cl \longrightarrow Cl_2}$$

The hydrogen and chlorine gas can be obtained by opening the tap provided.

The Industrial applications of electrolysis:

The principle of electrolysis frequently employed in many industries:

i) Electrolytic extraction: In this method, the metal is taken in the form of electrolyte. When electric current is passed, metal gets deposited at the cathode. The anode is an insoluble conducting material. Metals like calcium, aluminium and sodium are extracted from their ores by this method.

ii) Electrolytic refining: This method is used for refining precious metals like gold, silver, etc. This is an electrolytic process. The impure metal is taken as anode. The cathode is usually a sheet of pure metal. On electrolysis, the pure metal is deposited at the cathode. Impurities either remain in solution or collect below the anode as **anode mud**.

iii) Electroless plating: Electroless plating, also known as chemical or auto–catalytic plating, is a non–galvanic type of plating method that involves several simultaneous reactions in an aqueous solution, which occur without the use of external electrical power

iv) Electrolytic decomposition of water: It helps to produce hydrogen and oxygen. Pure water is non–electrolyte and small amount of acid or alkali must be added. The oxy–hydrogen flame is used for lead welding.

v) Manufacture of chemicals by electrolysis: Sulphuric acid, hydrogen peroxide, nitrate salts can be manufactured by electrolysis.

vi) Electroplating: One of the major applications in modern trend is electroplating. In industries particularly in automobile industry, nickel plating, chrome plating are frequently employed. In jewel making, micro plating is very popular on large scale production.

Electroplating: It is the process of **coating one metal over another metal or non metal through electrolysis method.** The metal which is coated is known as coat metal. The metal on which coating is done is known as the base metal. Base metal is made as **cathode** and coat metal or some inert metal like **lead is made as anode. Salt solution of the coat metal acts as electrolyte.**

When electricity passes through the salt solution of the coat metal, it is dissociated into ions. The positive or cation move towards the base metal (cathode). It gets reduced at the **cathode** and forms a thin layer over the base metal. The factors given below, affect the quality as well as the quantity of coating.

i) Quantity of current passed (Faraday's I law)

ii) Concentration of the electrolyte

iii) Temperature

iv) Other ingredients added in the electrolyte, like H_2SO_4 etc.

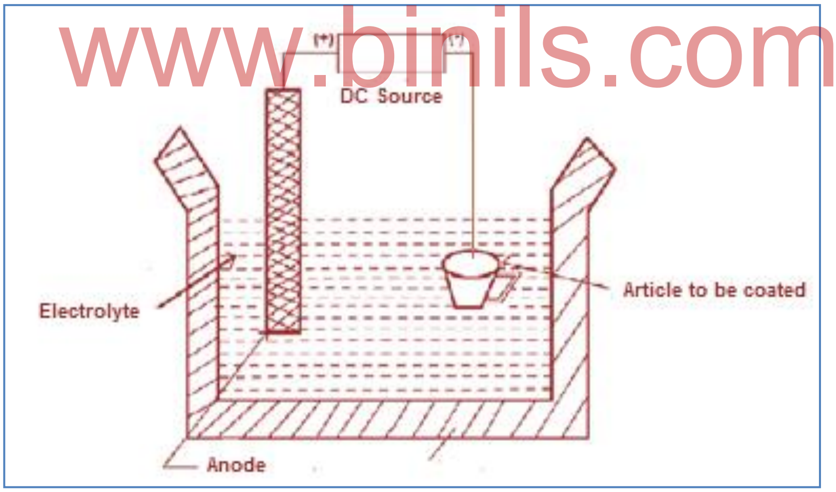


Fig. 1.1.2 Chrome plating

Chrome plating:

Chrome plating is most commonly used for decorative purpose. It is more durable and more resistant to chemical attack, abrasion and tarnish. Here the **article to be coated is made as cathode. Lead plate is used as the anode. A mixture of chromic acid and sulphuric acid in the ratio 100 : 1** is used as electrolyte. When electric current is passed, electrolysis takes place and chromium is deposited over the base metal

RECAP

We have learnt the following aspects of electrochemistry:

- Faradays laws of electrochemistry and its applications
- Few industrial applications of electrolysis
- Electroplating, chrome plating

ACTIVITY:

- Introduce a small zinc plate and copper plate in a lemon and try connect a small LED. Similarly try with tomatoes or potato. What do you understand?

EXERCISE FOR BETTER UNDERSTANDING

1. *Sodium chloride is a non-electrolyte-True/ False*
2. *One mole of electron would carry 9650 Coulomb- True/ False*
3. *Electroless plating can happen with external electrical power -True/ False*
4. *Faradays 2nd law states that quantity of deposition is inversely proportional to the equivalent mass-True/ False*
5. *Chromium is deposited over anode during chrome plating-True/ False*

Test paper 1

PART A

1. What is coulomb equivalent of 1 Faraday?
2. Give an example of an electrolyte.
3. What is the anode used in chrome plating?

PART B

1. Define an electrolyte.
2. What is meant by electrolysis?
3. What is Faradays first law of electrolysis?

PART C

1. Explain the process of electrolysis with suitable example.
2. Illustrate chrome plating with a neat diagram.
3. (a) Explain Faradays law of electrolysis.
   (b) When current is passed for an hour over a copper electrolyte, 0.453g was found to get deposited over the cathode. The equivalent mass of copper is 31.5. Calculate the current density.

Test paper 2

PART A

1. Write down the electronic concept of oxidation and reduction.
2. What is evolved at the anode when HCl is electrolised?
3. What is the electrolyte used in chrome plating?

PART B

1. Define Faradays 2nd law of electrolysis.
2. Define electroplating
3. What is meant by electrolytic refining?

PART C

1. a. What is called one Faraday?
   b. During electrolysis of electrolysis of silver nitrate, 4.029g of silver was found to get deposited over the cathode. How much time is required to get the deposition when 1 ampere current is passed?(equivalent weight for silver is 108)
2. a. Define electrolysis.
   b. What are the industrial applications of electrolysis

FACT STORE:

The story of electrochemistry begins with Alessandro Volta, who announced his invention of the voltaic pile, the first modern electrical battery, in 1800. Volta had built the voltaic pile to challenge Luigi Galvani’s claim to have demonstrated **that animals produce electricity**. According to Volta, Glavani’s results came from his use of two dissimilar metals connected by a moist conductor (a frog’s leg). Volta reproduced this configuration in his new invention, which consisted of pairs of zinc and silver disks connected by brine-soaked cardboard.

Broaden your understanding:

https://www.youtube.com/watch?v=zaOR7oo7qAg&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=14

1.2 ELECTRO CHEMISTRY-II

Electrochemical cell – Definition Galvanic cell – Formation of Daniel cell – Electrochemical series – Definition – significance **- 4 Hours**

ELECTROCHEMICAL CELL:

A system in which two electrodes are in contact with an electrolyte is called a cell. There are two types of cells, (i) Electrolytic Cell (ii) Electrochemical cell. Electrolytic cell is a device which produces chemical change when an electrical energy from outside source is supplied. Here, electrical energy is converted into chemical energy.

Electrochemical Cell:

Electrochemical cell is a device in which chemical energy is converted into electrical energy. This is also called Galvanic cell or Voltaic cell. ***eg.*** Daniel cell. The cell notation for Daniel cell is **Zn / $ZnSO_4$ // $CuSO_4$ / Cu**

Galvanic cell or Voltaic cell:

Two 250 ml beakers are taken. Beaker ‘A’ is filled with zinc sulphate solution. Beaker ‘B’ is filled with copper sulphate solutions. A zinc plate is dipped in the zinc sulphate solution. A copper plate is dipped in the copper sulphate solution. A salt bridge (using KCl) is used to connect the two solutions. The zinc plate and copper plate are connected through a voltmeter by means of a copper wire. Zinc will dissolve into zinc sulphate forming zinc ion and two electrons

$$Zn \longrightarrow Zn^{++} + 2e^{-}[\text{Oxidation}]$$

Thus zinc undergoes oxidation (removal of electrons) and act as anode. Copper plate will take up two electrons and undergoes reduction (Addition of electrons) and act as cathode.

$$Cu^{++} + 2e^{-} \longrightarrow Cu\ [\text{Reduction}]$$

They both constitute an electrochemical cell and flow of electrons will take place through the circuit. The cell based on the above chemical reactions is called Daniel cell.

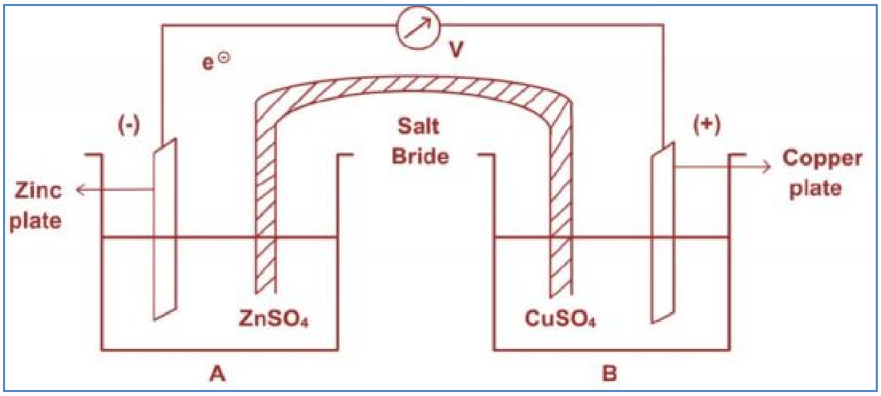


Fig. 1.2.1 Daniel Cell

The complete reaction will be

$$Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$$

Single electrode Potential:

An electro chemical cell consists of two half cell. The zinc and zinc sulphate forms a single electrode (half cell) and copper and its solutions forms another half cell. Thus an individual electrode develops a potential with respect to the solution, which is called single electrode potential, that constitutes a cell.

Zn / Zn^{++} (+ 0.763 V)

Cu^{++} / Cu (+ 0.337 V)

Total emf of the cell is **0.763 + 0.337 = 1.100V**

Electrochemical Series:

A series of single electrode in the increasing order of standard reduction potential is called electro chemical series. Conventionally, the single electrode potential is always given in reduction potential. When the sign of the potential is changed, it gives the oxidation potential. For example, the reduction potential of **Zn / Zn^{++} is – 0.763 V**. The oxidation potential is **+ 0.763**. The total emf is calculated by summing up the oxidation and reduction potential.

Electrochemical series

When various metals as electrodes are arranged in the order of their increasing values of standard reduction potential on the hydrogen scale, then the arrangement is called electrochemical series.

Significance and applications of electrochemical series:

i. Predicting spontaneity of redox reactions.

ii. Calculation of standard EMF of any cell can be made using this series.

iii. Relative ease of oxidation and reduction can be found. Higher the value of standard reduction potential (+ve value) greater is the tendency to undergo reduction. Thus, metals on the top having more negative (–ve) values are more easily oxidised.

iv. Displacement of one element by other. Metals which lie higher in the series can displace those elements which lie below them in the series.

v. Determination of equilibrium constant for the reaction. The equilibrium constant for the cell can be calculated from the standard electrode potential.

vi. Hydrogen displacement behavior. Metals having more negative potential in the series will displace hydrogen from acid solutions.

Table 4.1.1 Standard Electrode Reduction Potential

Nature	Reaction	Eo Volts
Li^+/Li	$Li^+ + e^- \longrightarrow Li$	–3.01
Mg^{2+}/Mg	$Mg^{2+} + 2e^- \longrightarrow Mg$	–2.37
Pb^{2+}/Pb	$Pb^{2+} + 2e^- \longrightarrow Pb$	–1.12

Nature	Reaction	Eo Volts
Zn^{2+}/Zn	$Zn^{2+} + 2e^- \longrightarrow Zn$	–0.76
Fe^{2+} / Fe	$Fe^{2+} + 2e^- \longrightarrow Fe$	–0.44
Sn^{2+} / Sn	$Sn^{2+} + 2e^- \longrightarrow Sn$	–0.13
H^+ / H	$H^+ + e^- \longrightarrow H$	0.00
Cu^{2+} / Cu	$Cu^{2+} + 2e^- \longrightarrow Cu$	+0.34
Ag^+ / Ag	$Ag^+ + e^- \longrightarrow Ag$	+0.80
Au^+/ Au	$Au^+ + e^- \longrightarrow Au$	+1.50

RECAP

We have learnt the following facts:

- Basic oxidation and reduction reactions in an electrochemical cell
- Electrochemical series
- Significance of electrochemical series.

ACTIVITY:

Construct an electrochemical cell using a beaker, zinc sulphate, copper sulphate, zinc plate and copper plate. Try to measure the voltage using a voltmeter. Compare it with the electrochemical series table

EXERCISE FOR BETTER UNDERSTANDING

1. Electrical energy is converted into chemical energy in an electrolytic cell-True/False
2. Daniel cell produces chemical energy from electrical energy-True/False
3. Oxidation occurs in an anode of an electrochemical cell-True/False
4. When the electrode iron and zinc are coupled zinc will act as cathode-True/False
5. The metal present higher in the series acts cathode when connected to a metal lower in the series-True/False

TEST PAPER 1

PART A

1. Define electrolysis.
2. What is meant by Galvanic cell?
3. Give two examples for electrochemical cell.

PART–B

1. How will you write the cell notation of Daniel cell?
2. Define electrochemical series.
3. Define single electrode potential

PART – C

1. Explain electrolysis with suitable example.
2. Explain electrochemical cell with example.
3. Explain the construction and working of Daniel cell

TEST PAPER 2

PART A

1. Write an example for a galvanic cell.
2. Mention the anode of the Daniel cell.
3. Which electrode will undergo reduction in an electrochemical cell.

PART B

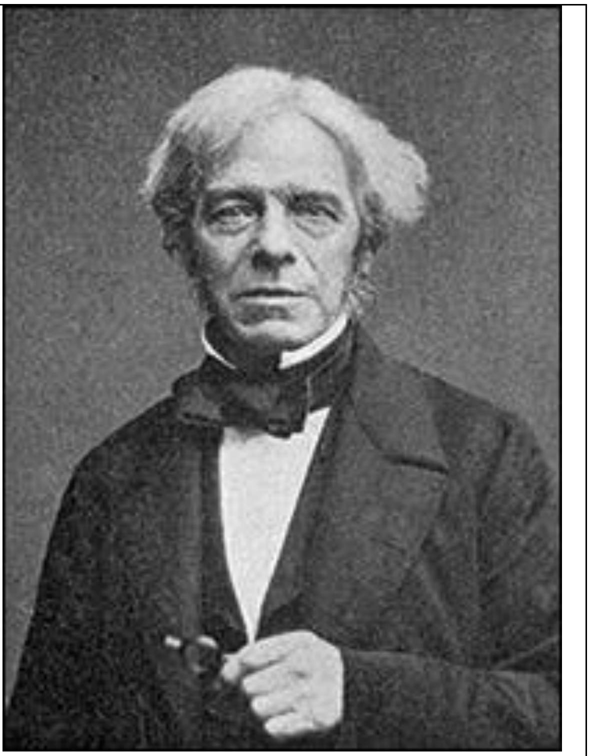
1. Write any three applications of electrochemical series.
2. Define half cell.
3. Write down the cell notations of Daniel cell.

PART C

1. Describe the galvanic cell with cell reactions
2. What are the significances of electrochemical series

FACT STORE:

Davy's student and successor, Michael Faraday, pursued the relationship between electricity and magnetism. In the course of his research he invented the first electric motor (in 1821) and the first dynamo (in 1831). Faraday's chief electrochemical achievement was to show that "magneto-electricity" had the same chemical effects as electricity generated in other ways. His two laws of electrochemistry, published in 1834, predict how much product results from passing a certain amount of current though a chemical compound or its solution, a process that he named "electrolysis." These laws are still fundamental to industrial electrolytic production of metals and other chemicals.



Broaden your understanding:

https://www.youtube.com/watch?v=ibFyc1aja24&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=15

https://www.youtube.com/watch?v=we5I4RDRD6o&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4iindex=16

1.3 ENERGY SOURCES

Primary Battery – Secondary Battery – Definition and example – cell – Construction, Working principle and Uses of Lead – acid Storage battery –Lithium ion-battery- Non – conventional Energy Sources – Solar Cell –Definition – working principle. **– 3 Hours**

A battery may be defined as an electrochemical cell or many electrochemical cells connected in series. This is used to store direct electric current at a constant voltage. The quality of a battery is determined by the following parameters:

i) Storage capacity – Coulombs/ kg

ii) Energy density – J / kg

iii) Power density – watts/kg

iv) Voltage efficiency – output voltage

v) Life time – Years

Batteries are classified as follows:

i) Primary battery

ii) Secondary battery

Primary battery:

A primary battery is a device in which the cell reaction is irreversible and it cannot be recharged. Eg : Dry cell, button cell etc.

Secondary battery:

A secondary battery is rechargeable battery and the reactions are reversible. Eg. Lead-acid battery.

Construction and working principle of Lead acid battery:

It consists of a polypropylene container containing six lead-acid electrochemical cells that are connected in series. Each cell gives an emf of 2.0V. Therefore, the total output of the battery will be 6 x 2.0 =12v. The cell is represented as

$$\mathbf{Pb(s) / PbSO_4 / H_2SO_4\,(aq) // PbSO_4\,(s), PbO_2\,(s) / Pb}$$

The anode is lead plate dipped in lead sulphate whereas cathode is lead plates covered with PbO_2. The electrolyte is $PbSO_4$ / H_2SO_4. All the anode and cathode are linked together. The overall reaction is

$$\mathbf{Pb + PbO_2 + 2H_2SO_4 \longrightarrow 2PbSO_4 + 2H_2O}$$

The reaction is in forward direction during discharge and in backward direction while charging. This is useful in motor vehicles.

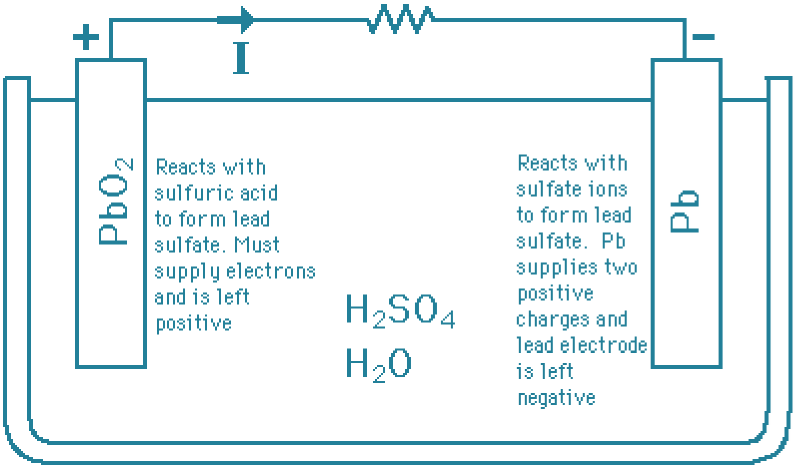


Fig.1.3.1 Lead Acid Battery

Reactions taking place while discharging:

At the negative pole oxidation of lead takes place at the anode.

$$Pb \longrightarrow Pb^{2+} + 2e^{-}[\text{oxidation}]$$

Then lead combines with sulphate ions to form lead sulphate

$$Pb^{2+} + [SO_4]^{2-} \longrightarrow Pb(SO_4)$$

At the positive pole, PbO_2 forms Pb^{2+} ions

$$\mathbf{PbO_2 + 4H^{+} + 2e^{-} \longrightarrow Pb^{2+} + 2H_2O}$$

$$\mathbf{Pb^{2+} + [SO_4]^{2-} \longrightarrow Pb(SO_4)}$$

Thus the total cell reaction is

$$\mathbf{Pb \longrightarrow Pb^{2+} + 2e^{-}\ [oxidation]}$$

$$\mathbf{Pb^{4+} + 2e^{-} \longrightarrow Pb^{2+}\ [reduction]}$$

$$\mathbf{Pb + Pb^{4+} \longrightarrow 2Pb^{2+}\ [Total\ reaction]}$$

During discharging the electrolyte concentration (H_2SO_4) is reduced. To maintain the level distilled water/rain water can be added and when the concentration becomes very low sufficient quantity of sulphuric acid is added and charged to elongate the life of the battery.

Charging:

Charging is done by connecting to a potential from an outside source. As long as the current is supplied, Pb^{2+}ions are reduced to lead metal at the lead electrode. Similarly at the PbO_2 electrode Pb^{2+}ions are oxidised to PbO_2. The reaction taking place during charging is:

$$\mathbf{2PbSO_4 + 2H_2O + Energy \longrightarrow Pb + PbO_2 + 2H_2SO_4}$$

The drawback of lead acid batteries :

i) It is much heavier.

ii) The H_2SO_4 becomes quite viscous which prevents the flow of ions.

iii) The batteries become self discharging, so when not in use, the connections can be disconnected.

iv) Rapid charging may result in evolution of H_2 which can tear PbO_2 coating.

LITHIUM ION BATTERY

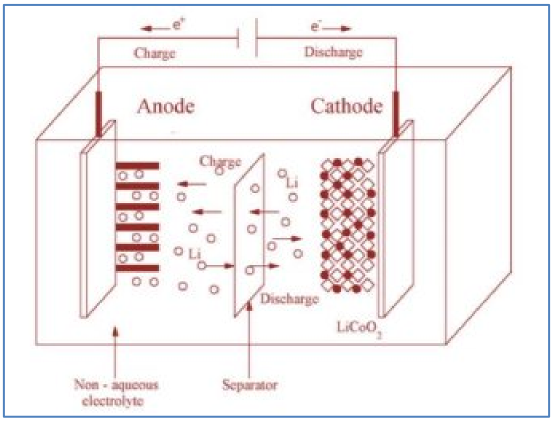


Fig. 1.3.2 Lithium cell

A lithium ion battery is a rechargeable battery.

They are commonly used in electronic devices, bikes and cars. Aerospace application is an extensive application of lithium ion battery. In 1991, Sony was the first company in the world to introduce lithium ion battery in the history of mobiles.

Construction:

Graphite acts as anode. Cobalt oxide coated lithium acts as cathode. Since lithium is highly reactive, non aqueous carbonate containing lithium ion complexes, are used as electrolytes.

Lithium undergoes oxidation in the anode.

$$\mathbf{LiC_6 \longrightarrow C_6 + Li^+ + e^-}$$

The half reaction of cathode is

$$\mathbf{CoO_2 + Li^+ + e^- \longrightarrow LiCoO_2}$$

The overall reaction will be

$$\mathbf{LiC_6 + CoO_2 \longrightarrow C_6 + LiCoO_2}$$

C_6 is grapheme, the output is 3.6 V.

Solar Cell

A **solar cell** (also called **photovoltaic cell** or **photoelectric cell**) is a solid state electrical device that converts the sunlight directly into electricity by the photovoltaic effect. It is the technology related to the practical application of photovoltaic cells in producing electricity from light.

Assemblies of cells used to make solar modules which are used to capture energy from sunlight, are known as solar panels. The energy generated from these solar modules, referred to as solar power, is an example of solar energy.

Solar cells are constructed by combining p– type and n–type semi conductor. The p–type means positive and n–type means negative. P–type is tetravalent silicon doped with trivalent boron. This leads to a positive hole, an acceptor. N–type semiconductor is silicon doped with pentavalent phosphorous. Therefore an excess electron is available. Thus when if we join (or fuse) these two semiconductor materials together they behave in a very different way by merging together and producing what is generally known as a “PN Junction”.

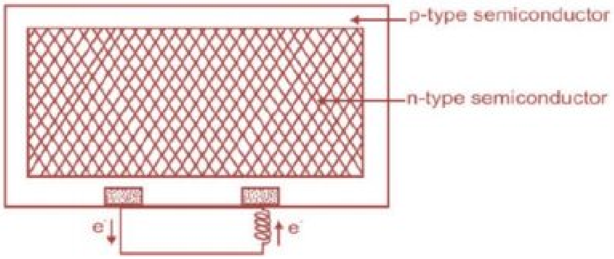


Fig. 1.3.3 Solar cell

When the solar rays fall on the top layer of p–type semiconductor, the electrons from the valence band get promoted to the conduction band and cross the p–n junction into n–type semiconductor. Thereby potential difference between two layers is created, which causes flow of electrons (i.e. electric current). The potential difference and hence current increases as more solar rays falls on the surface of the top layer. Thus, when this p– and n– layers are connected to an external circuit, electrons flow from n–layer to p–layer and hence current is generated.

Materials presently used for photovoltaic solar cells include mono crystalline silicon, Polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide / sulfide. Many currently available solar cells are made from bulk materials that are cut into wafers between 180 to 240 micrometers thick that are then processed like other semiconductors.

Most commercially available solar panels are capable of producing electricity for at least twenty years. The typical warranty given by panel manufacturers is over 90% of rated output for the first 10 years, and over 80% for the second 10 years. Panels are expected to function for a period of 30 – 35 years.

Uses of Solar Cells:

Solar cells are used in

1. Street lighting in villages.
2. Calculators and watches.
3. Eco – friendly vehicles.
4. Power generation in space crafts.
5. Power generation in remote places & forests.
6. Hot water preparation in hospitals and flats.

RECAP

We have learned about

- Few storage battery both conventional and non conventional
- Recent trends in storage battery like lithium cell and solar cell.

ACTIVITY:

- Try to identify the parts of a dry cell.
- List out few batteries and identify them as chargeable/rechargeable

Broaden your understanding:

https://www.youtube.com/watch?v=zcjNCwd3eig&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=17

EXERCISE FOR BETTER UNDERSTANDING

1. Primary can be recharged –True/False
2. Lead –lead oxide cells are connected in parallel in lead acid battery- True/False
3. Lead oxide coated lead is anode in lead-acid battery- True/False
4. During charging electrical energy is converted into chemical energy-True/False
5. P-type semiconductor is the one where silicon is doped with boron-True/False

TEST PAPER 1

PART - A

1. Define battery.
2. What is the difference between battery and a cell?
3. Give an example for a primary battery.

PART – B

1. Write the reactions taking place while discharging of lead acid battery.
2. Write the uses of solar cell
3. What are p–type semiconductors?

PART – C

1. Explain the construction and working principle of Lead acid battery / secondary battery.
2. Write notes on solar cell.

Test Paper 2

Part - A

1. Give an example for a secondary battery
2. What is meant by PN junction?
3. What are the electrodes used in a lithium cell

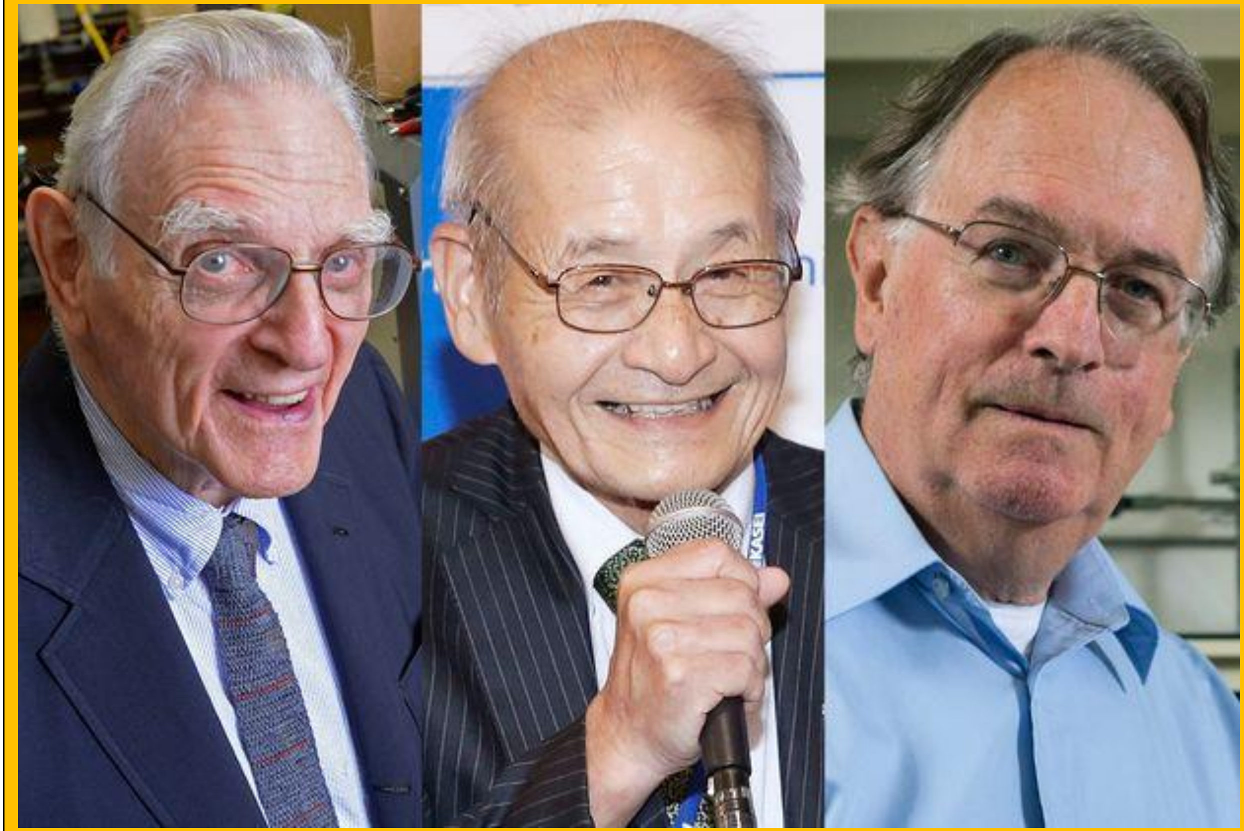
Part - B

1. Define solar cell.
2. What are n–type semiconductors?
3. What are the uses of solar cell?

Part - C

1. Write notes on lithium cell.
2. Write notes on storage devices.

FACT STORE



The Royal Swedish Academy of Sciences on Wednesday awarded the 2019 Nobel Prize in Chemistry to three scientists who developed lithium-ion batteries. John B. Good enough, M. Stanley Whittingham and Akira Yoshino were recognized for research that has "laid the foundation of a wireless, fossil fuel-free society."

Frequently Asked Questions

PART - A

1. What is coulomb equivalent of 1 Faraday?
2. Give an example of an electrolyte.
3. What is the anode used in chrome plating?
4. Write down the electronic concept of oxidation and reduction.
5. Define electrolysis.
6. Write down the electrolyte used for chrome plating?
7. What is meant by Galvanic cell?
8. Give two examples for electrochemical cell.
9. Write an example for a galvanic cell.
10. Define battery.
11. What is the difference between battery and a cell?
12. Give an example for a primary battery.
13. Give an example for a secondary battery.
14. Define solar cell

PART – B

1. Write the reactions taking place while discharging of lead acid battery.
2. Write the uses of solar cell
3. What are p–type semiconductors?
4. What are n–type semiconductors?
5. What is meant by p–n–Junction?
6. How will you write the cell notation of Daniel cell?
7. The standard reduction potential of zinc electrode is -/0.763v and that of copper electrode is 0.337v. calculate the total emf of the cell.
8. What are the drawbacks of lead acid battery?
9. Define single electrode potential
10. Define electrochemical series.
11. Write any three applications of electrochemical series.
12. Define an electrolyte.
13. What is meant by electrolysis?
14. What is Faradays first law of electrolysis?
15. Define Faradays 2nd law of electrolysis.
16. Define electroplating.

PART – C

1. Explain the construction and working principle of Lead acid battery / secondary
2. battery.
3. Write notes on solar cell.
4. Write notes on lithium cell.
5. Explain electrolysis with suitable example.
6. Explain electrochemical cell with example.
7. Explain the construction and working of Daniel cell.
8. Describe the galvanic cell with cell reactions.
9. What are the significances of electrochemical series?
10. Explain the process of electrolysis with suitable example.
11. Illustrate chrome plating.
12. (a) Explain Faradays law of electrolysis.
13. (b) When current is passed for an hour over a copper electrolyte, 0.453g was found to get deposited over the cathode. The equivalent mass of copper is 31.5. Calculate the current density.
14. (a) What is called one Faraday?
15. (b) During electrolysis of electrolysis of silver nitrate, 4.029g of silver was found to get deposited over the cathode. How much time is required to get the deposition when 1 ampere current is passed?(equivalent weight for silver is 108)

UNIT
2

CHEMISTRY OF CORROSION AND PREVENTION

2.1 CHEMISTRY OF CORROSION

Definition – types of corrosion – theories of corrosion – galvanic cell formation theory – differential aeration theory – factors influencing rate of corrosion. **– 4 Hours**

Introduction

Corrosion is a natural phenomenon in which the gases, moisture and other chemicals present in the atmosphere react chemically with metals to convert them into their salts, it results in huge loss of materials and money. Hence, corrosion is termed as ‘billion dollar thief’. We know very well that metals have a strong crystalline structure and when they are converted into their salts they lose the metallic nature resulting in the damage to tensile strength in which they are used. Thus corrosion causes damage to metals and thereby to the society. The estimate of loss due to corrosion is **approximately 2.5 billion dollars per annum** all over the world. Hence it is necessary to understand the mechanism of corrosion.

In this lesson, we are going to study about the causes and the mechanism of corrosion so that we can find ways to control this social enemy. **Corrosion is defined as the slow and continuous destruction of metal or alloy by the environment**. Due to corrosion the useful properties of metal like malleability, ductility, electrical conductivity and also the surface appearance are lost.

The most familiar example of corrosion is rusting of iron when exposed to atmospheric conditions. Another example is the formation of green film or basic carbonate [$CuCO_3$+$Cu(OH)_2$] on the surface of copper when exposed to moist air containing CO_2 and oxygen.

Corrosion is an oxidation process. Oxidation is a process which involves loss of electron. Oxidation takes place at the anode. Hence, the metal to be corroded will act as anode. It may be due to chemical or electrochemical reaction of the metals with the environment.

Example: Rusting of iron

Types of corrosion

Corrosion is of two types

1. Chemical Corrosion or Dry Corrosion
2. Electrochemical Corrosion or Wet Corrosion

1. Chemical Corrosion or Dry Corrosion

The direct chemical action of atmospheric gases like oxygen, halogens, H_2S etc., in a dry environment on metals is known as chemical Corrosion. Due to this, a dry layer of the Corrosion product is formed on the surface of the metal.

A solid film of the corrosion product is formed on the surface of the metal which protects the metal from further corrosion. If a soluble or volatile corrosion product is formed, then the metal is exposed to further attack.

For example, chlorine attack silver generating a protective film of silver halide on the surface which prevents further corrosion.

$$2Ag+Cl_2 \longrightarrow 2AgCl$$

2. Electro Chemical Corrosion or Wet Corrosion

Wet corrosion occurs due to the electrochemical action of moisture and oxygen on metals. Corrosion of iron takes place due to electrochemical attack.

There are two theories proposed to explain the rusting of iron

1. Galvanic cell formation theory
2. Differential aeration theory

1. Galvanic cell formation theory

1. When iron piece with impurity (copper, tin, dirt etc.) is exposed to atmosphere (moisture), a mini galvanic cell is formed.
2. Iron undergoes oxidation and acts as anode.
3. Impurity (copper, tin, dirt etc.) with atmosphere acts as cathode.
4. Moisture in the atmosphere acts as electrolyte.

Example: Rusting of iron

Electrolyte: The moisture (H_2O) dissociates to give H^+ and OH^- ions.

$$H_2O \longrightarrow H^+ + OH^-$$

Anodic reaction

The metal at the anode is oxidized into ferrous ions.

$$Fe \longrightarrow Fe^{2+} + 2e^- \quad \text{(oxidation – loss of electrons)}$$

$$Fe^{2+} + 2OH^- \longrightarrow Fe(OH)_2 \longrightarrow Fe(OH)_3 \longrightarrow Fe_2O_3$$

Fe^{2+} ions combine with **OH^-** in the environment forming ferrous hydroxide $Fe(OH)_2$, which undergoes further oxidation to give ferric hydroxide $Fe(OH)_3$. The ferric hydroxide undergoes decomposition to give ferric oxide Fe_2O_3(Rust).

Cathodic reaction

The electrons released at anode are taken up by the **H^+** ion in the environment.

(i) In acidic medium

$2\,H^+ + 2e^- \longrightarrow H_2(gas) \uparrow$ (reduction – gain of electrons)

(ii) In neutral solution with oxygen

$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

The ferric oxide formed (Fe_2O_3) over iron is called Rusting of iron.

Thus rust formed is explained based on the theory of formation of Galvanic cell.

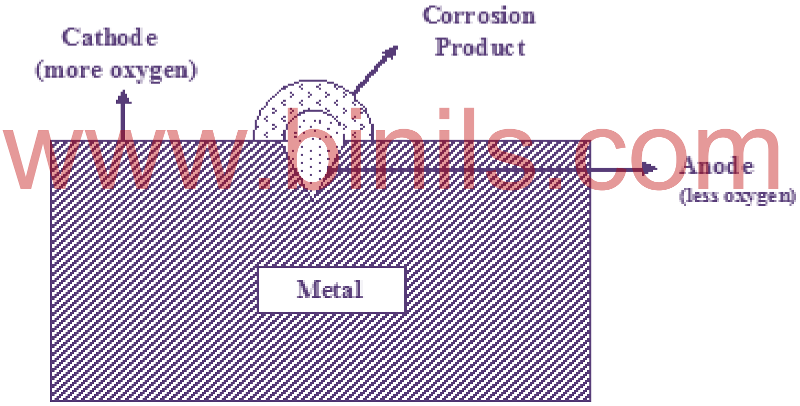
2. Differential Aeration theory or Concentration cell formation theory

According to this theory, when a metal is exposed to varying concentration of air (oxygen) or an electrolyte, concentration cell is formed.

The metallic area which is exposed to less amount of oxygen act as anode and undergoes corrosion.

The metallic area which is exposed to greater amount of oxygen act as cathode. Corrosion of metal occurs due to difference in concentration of air or electrolyte.

Hence this theory is called Differential Aeration theory or Concentration cell formation theory.



Example

1. **Corrosion under the crossing of wires in a wire fence.** In an iron fence the point where wire cross is exposed to oxygen and becomes anode. Therefore corrosion takes place at the point of contact where the wires cross each other.

2. Metal partially immersed in water, the immersed portion is less exposed to oxygen and becomes anode. Therefore corrosion takes place.

3. Metal area covered by drop of water, sand or dust.

The less oxygenated area acts as anode (gets corroded)

The more oxygenated area acts as Cathode (protected from corrosion)

Reaction at Anode

$$Fe \longrightarrow Fe^{2+} + 2e^- \quad \text{(oxidation)}$$

Reaction at Cathode

$$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^- \quad \text{(reduction)}$$

Therefore, $Fe^{2+} + 2OH^- \longrightarrow Fe(OH)_2$

$Fe(OH)_2$ is further oxidized to $Fe(OH)_3$. Since the anodic area is small and the cathodic area is large, corrosion is more concentrated at the anode. Moreover, the anodic area is still less exposed to oxygen and leading to continuous corrosion. Thus, a small hole is formed on the surface of the metal. This type of **intense localized corrosion is called pitting.**

Factors influencing the rate of corrosion

The factors that affect the rate of corrosion are

1) Nature of the metal and its surface
2) Nature of the atmosphere
3) Nature of the corrosion product

Factors connected with the metal

1) Position of the metal in the electrochemical series

The type of impurity present in it and its electropositive nature decides the corrosion of a metal. For example, when iron has impurities like copper, tin etc. iron corrodes, since iron is more electropositive than metals like copper and tin. On the other hand when iron is coupled with zinc, zinc corrodes since zinc is more electropositive than iron.

2) Purity of the metal

Generally pure metal does not corrode, as there is no cathode spot available to induce corrosion.

3) Surface of the metal

A rough surface corrodes readily as it collects more dirt and provides more cathode spot for corrosion. A polished surface does not corrode easily.

4) Stress corrosion

Stress in the metal surface is produced by mechanical workings such as quenching, pressing, bending and riveting improper heat treatment etc. The portion subjected to more stress acts as anode and other portion acts as cathode. This leads to the formation of stress corrosion. Stress corrosion is noted in fabricated articles of certain alloys like high zinc brasses and nickel brasses. Caustic embrittlement noted in boilers is a typical example for stress corrosion, which is due to the attack of alkali present in the water on stressed boiler metal.

5) Anode to cathode area ratio

When a bigger cathode area covers a smaller anode area, severe corrosion is noted in the anode spot. This is called erosion. It is frequently encountered in piping agitators, condenser tubes etc. where turbulent flow of gases and vapors remove the coated surface resulting in differential cells. Removal of surface coatings can also be caused by rubbing or striking activities of solids on the coated surfaces.

6) Physical state of a metal

The rate of corrosion is influenced by grain size, orientation of crystals, stress etc. The smaller grain sizes of the metal greater the rate of corrosion.

Factors connected with the nature of the atmosphere

1. Temperature

The rate of corrosion increases with increase of temperature

2. pH

Lower the pH greater is the corrosion.

3. Moisture

Increase of moisture in the environment increases the rate of corrosion.

4. Amount of oxygen

In some cases oxygen enhances the corrosion and in another it passivates the metal.

5. Chemical fumes

Chemical fumes like HCl, H_2SO_4 produce electrolytes which are acidic in nature and increases the rate of corrosion.

Examples

1. Buried pipelines and cables passing from one type of soil to another suffer corrosion due to differential aeration.
2. Lead pipelines passing through clay get corroded because it is less aerated than sand.

Factors connected with the corrosion product

In some cases the corroded product sticks to the surface and absorbs more moisture. This induces further corrosion. Examples:

1. In rusting of iron, as rust formed over iron absorbs more moisture, rate of rusting of iron increases.
2. In some cases the corroded product acts as the protective coating which prevents further corrosion.
3. Aluminium oxide formed over the surface of aluminium prevents further corrosion and act as a protective coating. This is the basic principle of Anodisation.
4. In some other cases the corroded product falls out of position exposing the fresh metal surface for further corrosion

Example: Magnesium oxide formed over the surface of Magnesium falls out of position exposing the fresh metal surface for further corrosion.

RECAP

In this chapter, the following topics are dealt with

- Types of corrosion
- Galvanic cell formation theory
- Differential Aeration theory or Concentration cell formation theory
- Factors influencing the rate of corrosion

ACTIVITY

- Collect some samples of corroded metal piece. Write down the reasons for corrosion. Try to summarise, review and demonstrate theories of corrosion and factors influence corrosion.
- Why corrosion often takes place under metal washers.
- Welded joints are better than riveted joints. Why?

EXERCISE FOR BETTER UNDERSTANDING

1. Chemical corrosion occurs due to presence of atmospheric gases – True/False
2. Wet corrosion occurs due to presence of moisture and oxygen – True/False
3. High temperature decreases the rate of corrosion – True/False
4. Low pH increases the rate of corrosion – True/False
5. Moisture decreases the rate of corrosion – True/False
6. Acidic nature increases the rate of corrosion – True/False

Test Paper 1

PART – A

1. What is corrosion?

2. What are the types of corrosion?

PART – B

1. What is corrosion? Give the types.

2. What type of reaction takes place in a metal when anode is small and cathode is large? Why?

PART – C

1. Explain the galvanic cell formation theory of corrosion.

Test Paper 2

PART – A

1. What is dry corrosion?

2. What is wet corrosion?

PART – B

1. What is corrosion? Give the types.

2. What types of reaction takes place in a metal when anode is small and cathode is large? Why?

PART – C

1. Explain the differential aeration theory of corrosion with suitable examples.

2. Explain the factors influencing the rate of corrosion.

FACT STORE

- The word corrosion is derived from the Latin term “Corrodere”
- The first formulation of the theory of electrolytic corrosion was made by Willis Rodney Whitney – The American Scientist in 1903.
- Losses due to corrosion could be around Rupees 2.0 lakh crores per annum in India.

Broaden your understanding

Click the following link or scan the QR code

https://www.youtube.com/watch?v=KcFUctIdM9I&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=18

2.2 METHODS OF PREVENTION OF CORROSION

Galvanization – tinning – anodisation – cathodic protection – sacrificial anode method and impressed voltage method. **– 4 Hours**

Introduction

In the previous chapters, we have studied electrochemical principles of corrosion. We have also understood the factors that influence the rate of corrosion. Based those factors, this chapter discusses about the methods of prevention of corrosion. It can be prevented by any one of the following methods:

1. Galvanization
2. Anodisation
3. Tinning
4. Cathodic protection

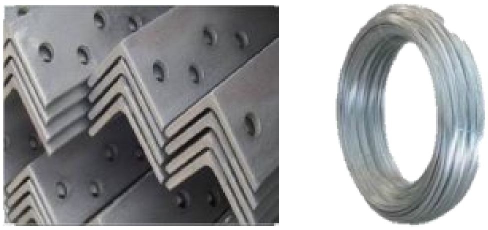


Fig. 2.2.1 Galvanized steel and wire

1. Galvanization

Galvanization is coating of zinc over iron.

Zinc acts as the sacrificial anode to save iron from corrosion. Zinc can be coated over iron by the following methods.

a. Hot dipping
b. Spraying
c. Cementing

a. Hot dipping

In this method, zinc can be coated over iron by dipping the iron article in molten zinc. In actual process iron or steel sheets are coated with zinc as follows.

The Iron sheet is first pickled with dilute sulphuric acid to remove traces of rust, dust etc. at 60^0C to 90^0C for about 15 to 20 minutes. Then this metal is dipped in a molten zinc bath maintained at 430^0C. The surface of the bath is covered with ammonium chloride flux to prevent oxide formation on the surface of molten zinc. The coated base metal is then passed through rollers to correct the thickness of the film.

b. Spraying

Molten zinc can be sprayed over iron using a spraying gun. Molten zinc is mixed with compressed air and sprayed over the iron article.

c. Cementing/sheardizing

In this method, iron article is packed with zinc powder and heated in vacuum condition in a rotating drum. The drum is rotated for 3 to 4 hours slowly and its temperature is kept at 350 to 370^0C. Zinc melts and forms a coating over iron.

Uses

It is used to protect roofing sheets, pipes, tanks, nails, screws etc.

2. Tinning

The coating of tin on iron is called tinning. In tinning, the base metal is first pickled with dilute sulphuric acid to remove surface impurities. Then it is passed through molten tin covered with zinc chloride flux. The tin coated article is passed through a serious of rollers immersed in a palm oil bath to remove the excess tin. Tin coated utensils are used for storing foodstuffs, pickles, oils etc.

3. Anodising

Anodising is the process of coating of aluminium oxide on the surface of aluminium or its alloys.

This type of coating is produced on non-ferrous metals like Al, Zn, Mg and their alloys, by anodic oxidation process, by passing direct electric current though a bath in which the metal is suspended from anode. Here the base metal aluminium or alloy of aluminium is connected to the anode. For anodizing 8% chromic acid is used as the electrolyte. Since it is a good oxidizing agent, it oxidizes aluminium (at the anode) to Al^{3+} · Oxygen is liberated at the anode, combines with aluminium ion forming aluminium oxide. The electrolytes are sulphuric, chromic, phosphoric, oxalic or boric acid.

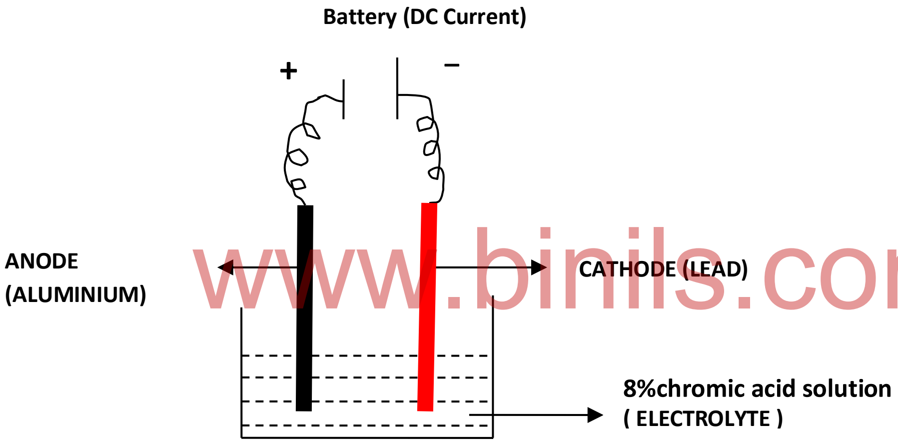


Fig. 2.2.2 Anodisation

Anodized coatings have more corrosive resistance due to thicker coating.

“Aluminium oxide coatings” are formed by the oxidation, taking place on the aluminium surface at moderate temperatures (35 to 40^{0}C) and moderate current densities. The formed oxide film is initially thin and gain thickness by the continuous oxidation of aluminium anode. The surface of oxide film contains pores which may cause corrosion. The pores can be sealed by exposing to boiling water, when oxide is converted to monohydrate ($Al_2O_3.H_2O$). This process is called sealing process.

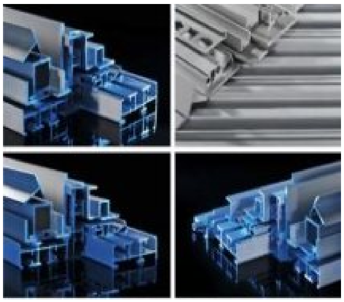


Fig. 2.2.3 Anodized aluminium

The anodized aluminium and its alloys are used in: 1. Aircrafts 2. Window frames 3. Machine parts 4. Fancy article and 5. Refrigerator etc.

4. Cathodic protection

The principle of transforming an anode into a cathode thereby protecting it is called cathodic protection. In cathodic protection we force a metal behave like cathode, because only the anode gets corroded. Since there will not be any anodic area on the metal, corrosion does not occur. There are two types of cathodic protection.

(a) Sacrificial anode method

(b) Impressed voltage method

(a) Sacrificial anode method

In this technique, a **more active metal is connected to the metal structure to be protected so that all corrosion is concentrated at the more active metal and thus saving the metal structure from corrosion**. The more active metal is the one which is higher in the electrochemical series above the metal that is corroded. This method is used for the protection of sea going vessels such as ships and boats. Sheets of zinc or magnesium are hung around the hull of ship. Zinc and magnesium being anodic to iron get corroded. Since they are sacrificed in the process of saving iron (anode), they are called sacrificial anode. The corroded sacrificial anode is replaced by a fresh one, when consumed completely. Important applications of sacrificial anodic protection are as follows.

i. Protection from soil corrosion of underground cables and pipelines.

ii. Magnesium sheets are inserted into domestic water boilers to prevent the formation of rust.

Fig. 2.2.4 Aluminium Sacrificial anode

(b) Impressed voltage method

We have seen that corrosion is an electrochemical process where a significant amount of voltage is developed. When we apply a higher voltage from an external source than the developed voltage the polarity is reversed. Thus in this method, **an impressed current is applied in an opposite direction to nullify the corrosion current and converting the corroding metal from anode to cathode.** This can be accomplished by applying sufficient amount of direct current from a battery to an anode buried in the soil and connected to the corroding metal structure which is to be protected.

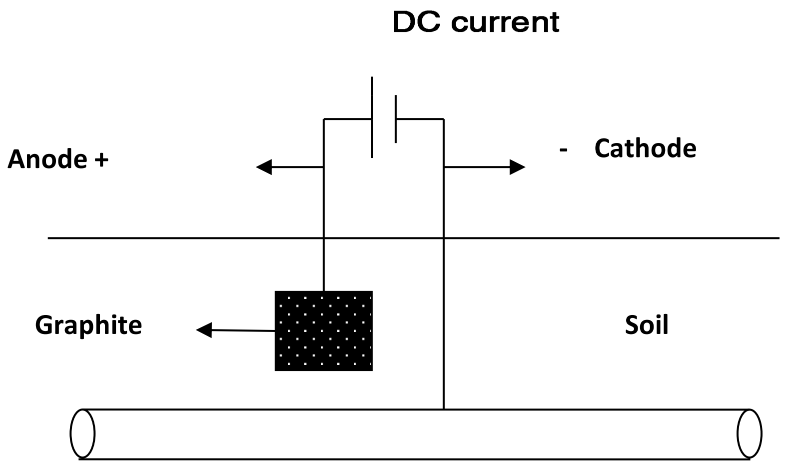


Fig. 2.2.5 Buried metal pipe

The anode is in a backfill (composed of gypsum) so as to increase the electrical contact with the soil. Since in this method current from an external source is impressed on the system, this is called impressed voltage method.

This type of protection is given in the case of buried structures such as tanks and pipelines.

RECAP

In this chapter, the following topics are dealt with

- Galvanization
- Anodization
- Tinning
- Cathodic protection

ACTIVITY

- Collect some samples of galvanized and anodized plate. Write down their uses. Try to note down the metals present in it.

EXERCISE FOR BETTER UNDERSTANDING

1. Galvanization is coating of zinc on iron – True/False

2. Coating of tin on iron is called tinning – True/False

3. Anodizing is the process of coating of aluminium oxide on aluminium– True/False

4. 8% chromic acid is used as the electrolyte in Anodizing – True/False

5. Zinc, Aluminium and Magnesium are used as Sacrificial anode in Cathodic protection method – True/False

Test Paper 1

PART – A

1. What is galvanization?

2. What is anodizing?

PART – B

1. What is galvanization? Give its uses.

2. What is anodizing? Give its uses.

PART – C

1. What is galvanization? Describe the methods of galvanization.

2. What is anodizing? How it is carried out? What are its applications?

Test Paper 2

PART - A

1. What is tinning?

PART – B

1. Write a note on tinning.

2. What is sacrificial anode method of prevention corrosion?

3. What is impressed voltage method of prevention corrosion?

PART – C

1. Write a note on cathodic protection.

Fact store

- In 1836, Sorel in France took out first of numerous patents for a process of coating steel by dipping it in molten zinc after first cleaning it. He provided the process with its name ‘galvanizing’.
- Anodizing was first used in 1923 to protect Duralumin sea plane parts from corrosion.
- Cathodic protection was first described by Sir HumphryDary in London in 1824

Broaden your understanding

Click the following link or scan the QR code

https://www.youtube.com/watch?v=1b6cBw9JFIl&list=PL1b9Ht9lSqIFsIiqREfRjehR2WAs3qCW4&index=19

https://www.youtube.com/watch?v=LZKLxUx_c2Q&list=PL1b9Ht9lSqIFsIiqREfRjehR2WAs3qCW4&index=20

2.3 ORGANIC COATINGS

Paint – definition – Components of paints – Varnish – definition –Preparation of oil varnish – differences between paint and varnish – Special Paints – Luminescent paint, fire retardant paint, Aluminum paint and distemper **- 3 Hours**

Introduction

Organic coating includes paints and varnishes. In this lesson, we are going to study about paint and its components. A little introduction to special paints used is also discussed. Further we are going to study about varnish its types and their preparation.

PAINTS

Definition

Paint is a dispersion of pigment in drying oil. Coating of paint is given to both metallic and wooden articles to protect them from corrosion and to give better surface appearance. Paint covers the manufacturing defects in the article.

When paint is applied to a metallic surface, the drying oil saves the surface from corrosion. The pigment saves the drying oil from the ultra violet light given by the sun.

Components of paint and their functions

The important constituents of paint are as follows.

1. Pigments
2. Drying oils or Vehicle or Medium
3. Thinners
4. Driers
5. Fillers or Extender
6. Plasticizers
7. Antiskinning agents

1. Pigments

A pigment is a solid and colour-producing chemical in the paint.

Example

White pigments – Titanium oxide, Zinc oxide

Black pigments – Graphite, Carbon black

Red pigments – Red lead (Pb_2O_3), Indian red (Fe_2O_3)

Functions

(a) It gives desired colour to paint.

(b) It gives strength to the film.

(c) It covers the manufacturing defects.

(d) It protects the film by reflecting the destructive ultra violet rays.

2. Drying oils or Vehicle or Medium

The liquid portion in which the pigment is dispersed is called drying oil.

Example

Linseed oil, dehydrated castor oil, soya bean oil and fish oil.

Functions

(a) Drying oils hold the pigment particles together on the metal surface.

(b) They form the protective film by evaporation or by oxidation and polymerization of the unsaturated constituents of the oil.

(c) They give better adhesion to the metal surface.

(d) They impart water repellency, durability and toughness to the film.

3. Thinner

Thinners are added to the paints to reduce the viscosity of the paints in order to make it easy to apply on the metal surface.

Example

Turpentine, kerosene and petroleum spirit.

Functions

(a) They reduce the viscosity of the paint to render it easy to handle and apply to the metal surface.

(b) They dissolve the oil, pigments etc., and produce a homogeneous mixture.

(c) They evaporate rapidly and help the drying of the film.

(d) They increase the elasticity of the film.

(e) They increase the penetrating power of the drying oil.

4. Driers

Driers are used to speed up the drying process and accelerate the drying of the oil film by oxidation, polymerization and condensation.

Example

Naphthanates and Resinates of lead, cobalt and manganese.

Function

Driers act as oxygen carrier catalysts which help the absorption of oxygen and catalyze the drying of the oil film by oxidation, polymerization and condensation.

5. Fillers or Extenders

Fillers are used to increase the volume of the paint and to reduce the cost. It increases the durability of the paint.

Example

Asbestos, talc, china clay, calcium sulphate and calcium carbonate.

Functions

(a) They serve to fill the voids in the film.

(b) They reduce the cracking of the paint.

(c) They increase the durability of the paint.

(d) They reduce the cost of the paint.

6. Plasticizers

Plasticizers are added to increase the elasticity of the film and prevent cracking of the film.

Example

Tertiary amyl alcohol, triphenyl phosphate, triglyceryl phosphate.

7. Antiskinning agents

They are added to paint to prevent skinning of the paint.

Example

Polyhydroxy phenols, guaiacol etc.

VARNISHES

Definition

Varnish is a homogeneous colloidal dispersion of natural or synthetic resin in oil or spirit medium.

It is used as a protective and decorative coating to the wooden surfaces. It provides a hard, transparent, glossy appearance and durable film to the coated surface.

They are two main types of varnishes

1. Oil varnish
2. Spirit varnish

1. Oil varnish

Oil varnish is a dispersion of resin in oil with thinners.

Preparation

Oil varnishes are more difficult to manufacture. Resins are natural occurring shellac or synthetic like phenolic or polyurethane high molecular weight substances are used in the preparation of oil varnishes. However, they are not easily soluble in oil.

The resin is taken in an aluminium kettle and heated over a fire pit or in a small furnace. When resin melts, the temperature is slowly increased to about 300^0C. This process is known as gum running. Some cracking or de-polymerization of the resin takes place and about 25% of the resin is lost in the form of fumes.

The required quantity (about 25% of the weight of the resin) of boiled oil or linseed oil along with driers is separately heated to 200 to 220^0C and is slowly added to the heated resin with constant stirring until thorough combination has taken place. This operation is known as cooking. Overheating must be avoided as it causes discoloration of varnish.

The kettle is removed from the furnace and allowed to cool, white spirit is then added (which is petroleum fraction, boiling between 150^0C and 200^0C). It is the most common thinner.

The varnish is stored in tanks for some days for maturing. Foreign matter and particles of resin, which is not dissolved, settle during this period. During maturing, the colour of the varnish also improves and it becomes more homogeneous. The varnish is filtered and packed for marketing.

2. SPIRIT VARNISH

Spirit varnish is a dispersion of resin in spirit.

Preparation

The resin and spirit are placed in a cylindrical drum. Plasticizer and other components are added. The resin is dissolved by agitating the mixture or by rotating the drum. It is then filtered and used. The final product is called spirit varnish.

Differences between paint and varnish

Sl. No	Paint	Varnish
1.	Paint has pigment	There is no pigment in the varnish
2.	It can be applied to both metals and wooden articles	It can be applied only to wooden articles
3.	It is opaque	It is transparent

Special Paints

In addition to the normal ingredients some special chemicals are incorporated to paints for some specific purposes. They are commonly known as special paints.

1. Luminous paints

Luminous paints are visible in the dark. Since it contains luminophor pigments (like CdS, ZnS) that are used for visibility in the dark. They absorb light radiations and emit them in the dark. The active components in the luminous paint are specially prepared phosphorescent materials like CdS, ZnS etc. For colour effect in luminous paints, certain chemicals like copper salts (green), silver salts (blue), cerium and uranium salts (yellow), etc. are added..

Uses

They find application in inks, advertising signboards, road marks, road traffic signs, number plates of the vehicles, watch dials, map, chart etc.

2. Fire retardant Paint

The paint which retards the fire is called fire-retardant paint.

This paint contains the chemicals PVC, Chlorinated rubber, urea formaldehyde and carbonate pigments which are fire-resistant in nature. They produce gases like CO_2, NH_3, HCl and HBr on heating which are themselves non-combustible and do not support combustion. Thus the fire is retarded.

Uses

Mainly used in defence, industrial, commercial, education and residential complexes.The most frequent source of a fire in any hotel, restaurant or residence. False ceiling, Lift, Equipment Rooms, Aircraft Safe deposit vaults, lockers, Computer Server rooms, Power plants, chemical plants, Storage Tanks, structures in Sugar Mills, Textile Mills and Floorings should be provided safety against fire. The walls, doors and even kitchen counters should be protected against the spread of fire.

3. Aluminium Paint

The base material in aluminium paint is a fine powder of aluminium. The finely ground powder of aluminium is suspended in either spirit varnish or an oil-varnish depending on the requirements. When the paints is applied, the thinner evaporates and oil, if any, undergoes oxidation and polymerization. A bright adhering film of aluminium is obtained on the painted surfaces.

Uses

1. Wooden and metallic article for interior and exterior decoration.
2. It retains the heat in hot water pipes and tanks.
3. It protects the surface from corrosion.

Advantages of aluminium Paint

1. It possesses a good covering power.
2. It imparts very attractive appearance to the surface.
3. It has fairly good heat-resistance.
4. It has very good electrical resistance.
5. The painted film is water proof.
6. The electrical surface is visible even darkness.
7. Corrosion protection for iron and steel surface is better than all other paints.

4. Distempers

Distempers are water paints. They contain chalk powder, glue and pigment dissolved in water. They are very cheap and can be easily applied on walls. They are durable and give pleasing finish to walls.

RECAP

In this chapter, the following topics are dealt with

- Paint
- Components of Paints and their functions
- Varnish
- Preparation of Oil Varnish and spirit varnish
- Differences between Paint and Varnish
- Special Paints (Luminescent Paints, Fire retardant Paints, Aluminium Paints and Distempers)

ACTIVITY

- Collect some samples of different colours of Paint. Try to note down the components present in it and their uses.
- Collect some samples of oil varnish and spirit varnish. Try to summarize their preparation and uses.

EXERCISE FOR BETTER UNDERSTANDING

1. Paint is a dispersion of pigment in thinners – True/False

2. Pigment gives desired colour to paint – True/False

3. Varnish is a colloidal dispersion of resin in oil or spirit – True/False

4. Oil varnish is a dispersion of resin in oil – True/False

5. Spirit varnish is a dispersion of resin in spirit – True/False

TEST PAPER 1

PART – A

1. Define paint
2. What is varnish?
3. What are the types of varnish?

PART- B

1. What are the differences between paint and varnish?
2. What is luminous paint?

PART – C

1. What are the components present in the paint? Explain their functions.

TEST PAPER 2

PART – A

1. How is spirit varnish prepared?
2. What is distemper?

PART- B

1. What is Aluminium paint?
2. What is Fire retardant paint?

PART – C

1. Explain the preparation of different types of varnish.
2. Explain briefly about special paints.

FACT STORE

- In 100,000 BC, Paint created by prehistoric man by mixing ground coloured rocks, earth and minerals with egg or animal fat.
- In 2,200 BC, Egyptian blue pigment created by mixing sand, lime and copper together.
- In 1700, the first modern synthetic pigment, Prussian blue, is discovered.
- In 1800, Traditional paint making methods replaced with industrially produced paints.
- 1900 onwards non-toxic paints developed, followed later by other types of paints.
- Varnish has been used throughout history for preservation and protection based upon natural materials such as resins, gums, linseed oils and glue.

FREQUENTLY ASKED QUESTIONS

UNIT – II

PART – A

1. What is corrosion?
2. What are the types of corrosion?
3. What is dry corrosion?
4. What is wet corrosion?
5. What is galvanization?
6. What is anodizing?
7. What is tinning?
8. Define: Paint
9. What is varnish?
10. What are the types of varnish?

PART – B

1. What is corrosion? Give the types.
2. What type of reaction takes place in a metal when anode is small and cathode is large? Why?
3. What is galvanization? Give its uses.
4. What is anodizing? Give its uses.
5. Write a note on tinning.
6. What is sacrificial anode method of prevention corrosion?
7. What is impressed voltage method of prevention corrosion?
8. What are the differences between paint and varnish?
9. How is spirit varnish prepared?
10. What is luminous paint?
11. What is Aluminium paint?
12. What is Fire retardant paint?
13. What is Distemper?

PART – C

1. Explain the galvanic cell formation theory of corrosion.
2. Explain the differential aeration theory of corrosion with suitable examples.
3. Explain the factors influencing the rate of corrosion.
4. What is galvanization? Describe the methods of galvanization.
5. What is anodizing? How it is carried out? What are its applications?
6. Write a note on cathodic protection.
7. What are the components present in the paint? Explain their functions.
8. Explain the preparation of oil varnish and spirit varnish.
9. Explain briefly about special paints.

UNIT

3

ENERGY CHEMISTRY

3.1 FUELS

Fuel – Definition – Calorific value – calorie – Liquid fuels – liquid hydrogen – power alcohol – uses – Refining of Petroleum – Fractional distillation – Cracking (Concept only) – Gaseous fuels – Preparation, composition and specific uses of Producer gas and Water gas – Composition and uses of CNG and LPG – advantages of gaseous fuels. **– 4 Hours**

Introduction

Fuels are energy giving substances that produce heat on combustion. Fuels are the materials used for burning, while combustion deals with the mechanism of burning. A fuel is a source of chemical energy. Generally every fuel is a source of carbon and it is a combustible substance, which on proper burning produces large amount of heat which can be used for domestic and industrial purpose.

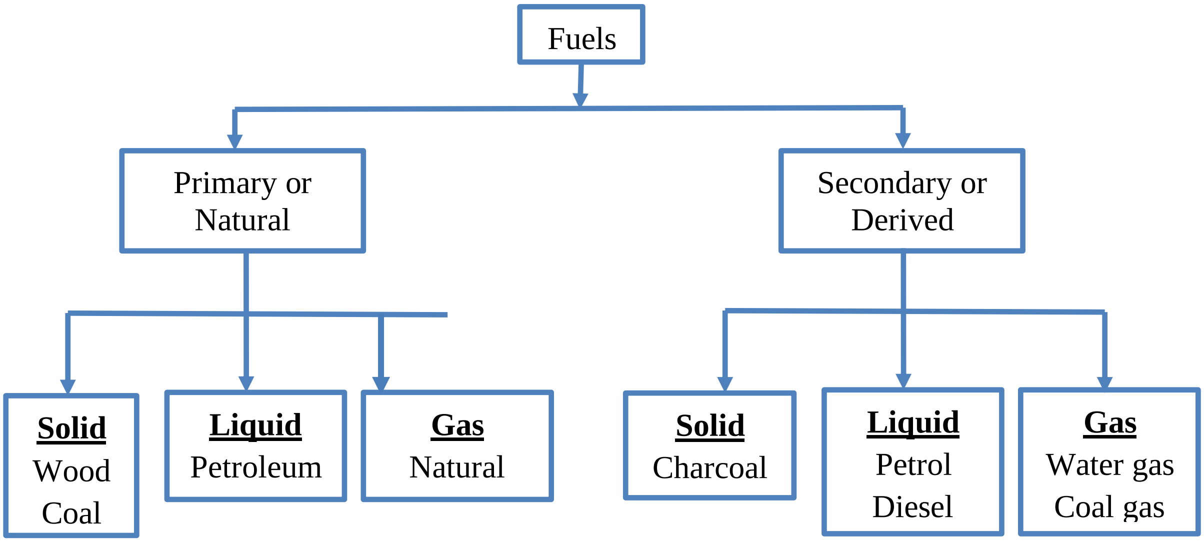
During the process of combustion of fuel containing atoms of carbon, hydrogen etc., combine with oxygen with a simultaneous liberation of heat.

$$\text{Fuel} + O_2 \longrightarrow \text{Products} + \text{Heat}$$

$$C + O_2 \longrightarrow CO_2 + \text{Energy (97.0 kcal)}$$

The fuel may be petrol or diesel used in a vehicle, or a firewood in a furnace or foodstuff in our body that undergo combustion or oxidation to give energy.

Classification of fuels



Calorific value

Calorific value of a fuel defined as "the total quantity of heat liberated, when an unit mass of a fuel is completely burnt".

Unit of heat - Calorie

Calorie is the amount of heat required to raise the temperature of one gram of water through 1°C (for eg. 15-16°C).

Liquid fuels

Liquid hydrogen

Liquid hydrogen is used as a fuel when hydrogen gas cooled below 33K under compression. The liquid H_2 density is very low compared to other common fuels.

Advantages of liquid H_2 as fuel

1. Liquid H_2 has high calorific value.
2. It is used as rocket and aircraft fuel.
3. When it burns with O_2 produces harmless water vapour, H_2O_2 and Ozone.
4. It is also used for power generation and used also as reducing agent in industries.

Power Alcohol

When ethyl alcohol is used as a fuel for internal combustion engine, it is called 'power alcohol'. Ethyl alcohol is not as a prime fuel but as an additive to motor fuel. Blends containing 25% of alcohol with petrol are used.

Advantages

1. Alcohol blended petrol possesses better anti-knock properties.
2. Alcohol-petrol blends have a lesser starting difficulties.
3. The great advantages of adding alcohol to petrol is the capacity of alcohol observing any traces of moisture present.

Petroleum

Petroleum or crude oil (Petra = rock; oleum = oil) is a greenish-brown oil found in deep earth crust. It is mainly composed of various hydrocarbons.

Refining of Petroleum

The process of removing impurities and separating the crude oil into various fractions is called refining of Petroleum, which involves the following steps.

1. Separation of water (Cottrell's process)

Crude oil is an emulsion of oil and salt water. It is allowed to flow between two highly charged electrodes water droplets combine to form large drops and separated out from oil.

2. Removal of sulphur compounds

Sulphur compounds are removed as copper sulphide by treating the crude oil with copper oxide.

3. Fractional distillation

Fractional distillation is the process of separation of a liquid mixture by repeated heating, cooling and condensing them into its components. The crude oil is then heated to 400°C in iron retort. The hot vapour is then passed into the bottom of a "fractionating column".

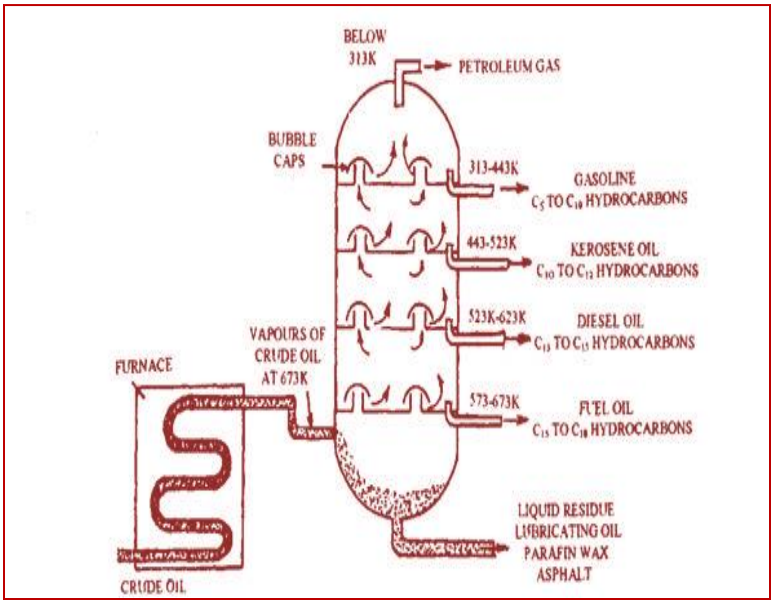


Fig. 3.1.1. Fractional Distillation

The fractional distillation column contains number of stainless steel trays with chimney. As the vapour goes up, they gradually get cooled and fractional condensation takes place at different heights of the column.

Various fractions obtained are given in the table

Sl.No.	Name of the Fraction	No. Of carbon	Boling Range °C	Uses
1	Uncondensed gases	$C_1 - C_4$	< 30	Fuel as LPG
2	Petroleum ether	$C_5 - C_8$	30 - 70	As a solvent
3	Gasoline (or) Petrol	$C_8 - C_9$	40 – 120	IC engines
4	Naphtha	$C_9 - C_{10}$	120 – 180	Solvent for paint and in dry cleaning
5	Kerosene	$C_{10} - C_{12}$	180 – 250	Domestic fuel
6	Diesel	$C_{12} - C_{16}$	250 – 320	Motor fuel
7	Heavy oil	$C_{17} - C_{30}$	320 - 400	Fuel for ship and to produce petrol

4. Cracking

Gasoline or petrol has the largest demand as a motor fuel; but only 20% of the crude oil can be converted into gasoline during fractional distillation. To overcome this demand, kerosene or heavy oil is subjected to get gasoline. Thus heavy hydrocarbon molecules of heavy oil or kerosene are broken into small molecules, forming gasoline. **Cracking is defined as "the decomposition of bigger hydrocarbon molecules into hydrocarbons of lower molecular weight".**

$$C_{10}H_{22} \longrightarrow C_5H_{12} + C_5H_{10}$$

Decane Pentane Pentene

Gaseous fuels

Producer gas

Producer gas is a mixture of carbon monoxide and nitrogen.

It is prepared by passing air mixed with a little steam over a red hot coke bed maintained at 1100°C in a reactor called 'gas producer'.

Gas producer is steel vessel of 3 m width and 4 m in height. It is lined inside with refractory bricks. It has a cup and cone arrangement at the top and then exit for producer gas.

The following reaction takes place at the combustion zone

$$C + O_2 \longrightarrow CO_2 + 97kCal$$

$$C + \frac{1}{2}O_2 \longrightarrow CO + 29.5kCal$$

In reaction zone

$$CO_2 + C \longrightarrow 2CO$$

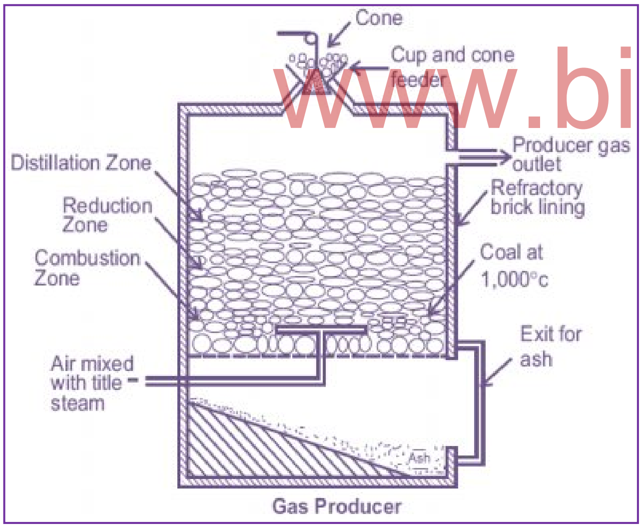


Fig. 3.1.2 Manufacture of Producer Gas

The composition of producer gas

CO	22 – 30 %
H_2	8 – 12 %
N_2	52 – 55 %
CO_2	3 %

Calorific Value = 1300kCal/m^3

Uses

Producer gas is used

1. for heating in steel and glass manufacture.
2. as a reducing agent in metallurgical operations

Water gas

Water gas is a mixture of carbon monoxide and hydrogen. It is made by passing steam and a little air through a bed of red hot coke at 900°C in a reactor.

Reactor consists of a steel vessel about 3m and 4m height. It is lined inside with refractory bricks. It has a cup and cone feeder to feed coke. At the top there is an outlet for the exit of water gas and at the bottom there are two inlet pipes for air and steam.

Reaction

$$C + O_2 \longrightarrow CO_2 + kCal$$

$$C + H_2O \longrightarrow CO + H_2 + kCal$$

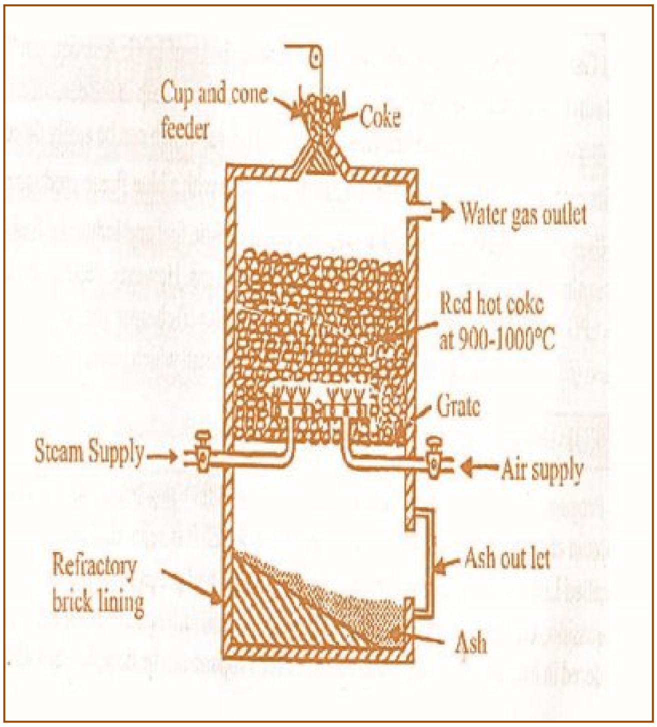


Fig. 3.1.3 Manufacture of Water Gas

The composition of water gas is

CO	41 %
H_2	51 %
N_2	4 %
CO_2	4 %

Calorific Value = 2800kCal/m^3

Uses

Water gas is used as

i) a source of hydrogen.

ii) an illuminating gas and

iii) a fuel gas

Compressed Natural Gas (CNG)

Natural gas is a mixture of hydrocarbon gases that occur naturally beneath the earth's surface and is used as a fuel primarily for cooking. When natural gas is compressed it is called as compressed natural gas (CNG). The main component present in CNG is Methane.

Composition

Methane	88.5%
Ethane	5.5%
Propane	3.7%
Butane	1.8%
Pentane	0.5%

Properties

i) CNG is the cheapest, clean and produce less CO and hydrocarbon emission.

ii) Less expensive than petrol and diesel.

iii) Ignition temperature of CNG is 540°C.

iv) It requires more air for ignition.

Uses

CNG is used as fuel for automobile just like LPG

Liquified Petroleum gas (LPG)

LPG is obtained during fractional distillation of crude petroleum oil below 30°C. LPG contains propane and butane. It can be liquefied under pressure, stored and transported in cylinders. In order to find leakage a small amount of mercaptan is added. During leakage it smells like onion or cooked cabbage.

Composition

n-butane	38.5%
Iso-butane	37%
Propane	24.5%

Its calorific value is about 2500 kcal/m^3

Uses:

i. it is used as a domestic and industrial fuel.
ii. it is used as a motor fuel.

Advantages of gaseous fuels over other fuels

1. It can be stored under pressure in least volume.
2. They can be easily transported through pipelines without manual labour
3. They can be lighted very easily
4. They give smokeless flame.
5. No ash smoke is produced.
6. They have high calorific value.
7. Complete combustion of the fuel is possible.
8. The supply of the gas to the burner can be easily controlled.
9. The oxidising and reducing flame can be easily got by regulating the air supply.
10. They can be directly used in IC engines.

RECAP

In this chapter following topics are dealt with

- Fractional distillation of petroleum
- Preparation, properties and uses of producer gas and water gas
- Advantages of gaseous fuels over other fuels

ACTIVITY

- Place a 500 ml beaker, fill 250g of water into it. Introduce a thermometer and note down the initial temperature. Place it over a wire gauze, and put on the flame. Watch the increase of temperature, and stop heating and note down the temperature. Calculate the heat consumed.
- The same experiment can be done with different sources of fuel and observe the calorific values of different fuels.

EXERCISE FOR BETTER UNDERSTANDING

1. Charcoal is a naturally occurring solid fuel :True/False
2. Calorific value is the amount of heat required to raise 1 gram of Water to 1˚C : True/False
3. Producer gas is a mixture of CO and N_2 :True /False
4. CNG Compressed Natural gas :True /False
5. LPG Contains methane :True/False

Test Paper - 1

Part-A

1. What are Fuels?
2. What are producer Gas?
3. What is CNG?

Part-B

4. What are fossil fuels?
5. Give the composition and uses of LPG?
6. Define calorific value?

Part-C

7. What are the fractions obtained from the fractional distillation of petroleum?
8. Explain the preparation, composition and uses of producer gas

Test Paper - 2

Part-A

1. Define calorie
2. What is water gas?
3. What is LPG?

Part-B

1. What is cracking?
2. Give the composition and uses of CNG?
3. Give the advantages of liquid H_2

Part-C

1. Explain the preparation, composition and uses of water gas
2. List out the advantages of gaseous fuel over the other fuels

FACT STORE

Bubbling Crude : There are some places on earth where oil is not trapped under

ground, but actually seeps out at the earth surface – “bubbling crude”. This is one of the largest natural petroleum seeps located at California. https://www.hartenergy.com/ exclusives/bubbling-crude-and-understanding-seeps-29154

The world petroleum comes from the Latin Petra, meaning “Rock” and oleum means „„„Oil”

Broaden your understanding:

Click the following link or scan the QR code

https://www.youtube.com/watch?v=OFRgfmdj01c&list=PL1b9Ht9lSqIEmoksyUA5Ab5WRuhWgB5V5&index=5

3.2 COMBUSTION

Definition – Combustion calculation by mass (for solid and liquid fuels) – Stoichiometric calculations – Volume of air required – Definition of Flue gas – Flue gas Analysis – Orsat Apparatus – Simple numerical problems. **– 4 Hours**

Introduction

Combustion is an exothermic chemical reaction, in which fuel burns in presence of oxygen with the evolution of heat and light.

The aim of combustion is to get maximum amount of heat from a combustible substance. Most of the combustible substances are enriched with carbon and hydrogen. During combustion they undergo decomposition with the evolution of heat.

$$C + O_2 \longrightarrow CO_2 + \text{heat} \uparrow (\text{exothermic})$$

$$H_2 + \tfrac{1}{2}O_2 \longrightarrow H_2O + \text{heat} \uparrow (\text{exothermic})$$

For proper combustion, the substance must be brought to its **kindling** or **ignition temperature** which may be defined as "the minimum temperature at which the substance ignites and burns without further addition of heat".

Minimum Mass of air required for the complete combustion of Fuels

For efficient combustion, it is essential that the fuel must be brought into contact with sufficient quantity of air. The combustible constituents present in the fuel are C, H, S and O.

The amount of Oxygen and air required for the complete combustion can be calculated by considering the following point.

Substances always combine indefinite proportions, which are determined by the molecular weights.

Table of atomic mass and molecular mass:

Name of the element / compound	Symbol	Atomic mass	Molecular mass
Hydrogen	H	1.008	2.016
Oxygen	O	16	32
Nitrogen	N	14	28
Carbon	C	12	12
Sulphur	S	32	32
Carbonmonoxide	CO	----------	28

Carbondioxide	CO_2	----------	44
Methane	CH_4	----------	16
Sulphurdioxide	SO_2	----------	64
Water	H_2O	----------	18

Combustion of carbon

$$\begin{array}{cccc} C & + \; O_2 & \longrightarrow & CO_2 \\ 12 & 32 & & 44 \end{array}$$

Divide by 12 on both sides

➢ $\frac{12}{12}$ $\quad \frac{32}{12}$ $\quad \frac{44}{12}$

➢ $\mathbf{\frac{1}{1}}$ $\quad \mathbf{\frac{8}{3}}$ $\quad \mathbf{\frac{11}{3}}$

1 kg of C needs $\mathbf{\frac{8}{3}}$ **kg ofoxygen** for complete combustion.

Combustion of Hydrogen

$$\begin{array}{cccc} 2H_2 & + \; O_2 & \longrightarrow & 2H_2O \\ 4 & 32 & & 36 \end{array}$$

Divide by 4 on both sides

➢ $\frac{4}{4}$ $\quad \frac{32}{4}$ $\quad \frac{36}{12}$

➢ **1** **8** **9**

1 kg of H_2 needs **8 kg of oxygen** for complete combustion.

Combustion of sulphur

$$\begin{array}{cccc} S & + \; O_2 & \longrightarrow & SO_2 \\ 32 & 32 & & 64 \end{array}$$

Divide by 32 on both sides

➢ $\frac{32}{32}$ $\quad \frac{32}{32}$ $\quad \frac{64}{32}$

➢ **1** **1** **2**

1 kg of sulphur needs 1 kg of oxygen for complete combustion.

On combining the equations

The theoretical oxygen required for combustion of 1 kg of fuel = $\mathbf{\frac{8}{3}C + 8H + S}$......(kg)

Minimum mass of oxygen required = Theoretical O_2 required – O_2 Present in Fuel

i.e., The total mass oxygen required per kg of fuel = $\left[\frac{8}{3}C + 8H + S\right]$- O_2

(O_2 = Mass of oxygen)

Mass percentage of oxygen

The mass percentage of oxygen in air = 23%

23% of oxygen is supplied by 100% mass of air. That is to supply 23kg of oxygen, 100kg of air is required.

Hence 1kg of oxygen is supplied by = $\frac{100}{23}$ kg of air.

$$\therefore \left.\begin{matrix}\text{Minimum mass of air required for}\\ \text{Combustion of 1kg of fuel}\end{matrix}\right\} = \frac{100}{23}\left[\frac{8}{3}C + 8H + S - O_2\right] \text{ kg}$$

Minimum volume of air required for the complete combustion of 1m^3 gaseous fuels (Derivation not required for examination)

The volume of air required for the combustion of gaseous fuels is calculated mainly based on balanced combustion equation.

Combustion of carbon monoxide

$$2CO + O_2 \longrightarrow 2CO_2$$

2 Vol **1** Vol **2** Vol

2m^3 of CO needs 1m^3 of oxygen

∴ 1m^3 of CO needs 0.5m^3 of O_2 for combustion.

Combustion of Hydrogen

$$2H_2 + O_2 \longrightarrow 2H_2O$$

2 Vol **1** Vol **2** Vol

2m^3 of Hydrogen needs 1m^3 of oxygen

∴ 1m^3 of H_2 needs 0.5m^3 of O_2 for combustion.

Combustion of Methane

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

1 Vol **2** Vol **1** Vol **2** Vol

∴ 1m^3 of CH_4 needs 2m^3 of O_2 for combustion.

Combustion of Ethylene

$$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$$

1 Vol **3** Vol **2** Vol **2** Vol

∴ 1m^3 of CO needs 3m^3 of O_2 for combustion.

Air contains 21% oxygen and 79% Nitrogen by volume, 21m^3 of oxygen present in 100m^3 of air.

$$\therefore \left.\begin{matrix}\text{Minimum volume of air required for}\\ \text{Combustion}\end{matrix}\right\} = \frac{100}{21}[0.5CO + 0.5H_2 + 2CH_4 + 3C_2H_4 - O_2]\text{m}^3$$

Flue gas

Flue gas is a mixture of gases produced from the products of combustion of fuel. Its major constitutions are CO, CO_2, O_2 and N_2.

Orsat apparatus for flue gas analysis

The mixture of gas like CO_2,O_2, CO, H_2O etc., coming out from the combustion chamber is called flue gas. The analysis of flue gas is done with the help of orsat apparatus.

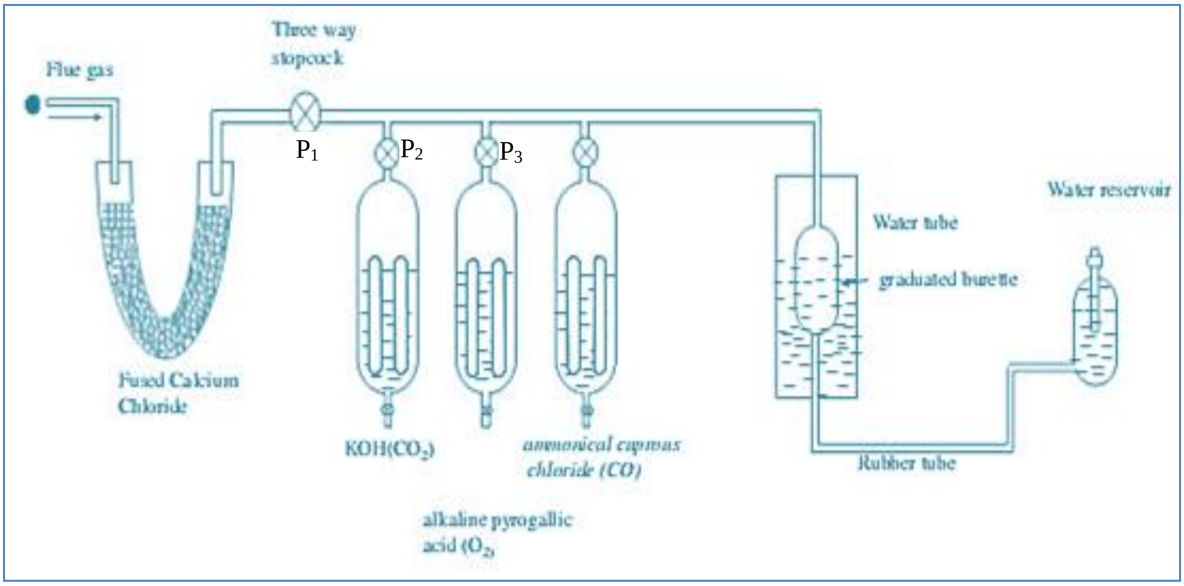


Fig. 3.2.1 Orsat apparatus for flue gas analysis

Description

It consists of a horizontal tube. One end of the tube is connected with graduated burette covered by a water jacket. Lower end of the burette connected with leveling bottle filled by NaCl.

The free end of horizontal tube is connected by U-tube through 3-way stopcock. The U-tube is packed with fused $CaCl_2$. The horizontal tube is also connected with the three absorption bulbs P_1, P_2 and P_3.

Working

The three way stopcock is opened on the flue gas is sucked into the burette and the volume of gas is adjusted to 100ml by raising or lowering the leveling bottle. Then the three way stopcock is closed.

Absorption of CO_2:

The stopper of bulb P_1 containing KOH solution is opened P_2 and P_3 are closed and the flue gas is passed into the bulb to ensure complete observation of CO_2.

The decrease in volume of flue gas in the burette indicates the volume of CO_2 in 100 ml.

Absorption of O_2:

The stopper of P_1 and P_3 are closed and stopper of bulb P_2 is opened. The oxygen present in a flue gas is completely absorbed by alkaline pyrogallol. The decrease in volume of gas indicates the volume of O_2 in 100ml.

Absorption of CO :

The stopper of P_1 and P_2 are closed and stopper of bulb P_3 is opened. The oxygen present in the flue gas is completely absorbed by $CuCl_2$ solution. The decrease in volume of flue gas indicates the volume of CO in 100 ml.

The remaining gas in the burette after the absorption of CO_2, O_2 and CO is taken as nitrogen.

Problems

1. A coal sample contains 80% C, 8% H, 1% S and 3% ash by mass. Find the amount of air required to burn 1 kg of coal.

Solution:

For 1 kg of coal

$$C = 88\% = \frac{88}{100} = 0.88\ \text{kg}$$

$$H_2 = 8\% = \frac{8}{100} = 0.08\ \text{kg}$$

$$S = 1\% = \frac{1}{100} = 0.01\ \text{kg}$$

$$\text{Ash} = 3\% = \frac{3}{100} = 0.03\ \text{kg}$$

Minimum mass of air required for the complete combustion

$$= \frac{100}{23}\left[\frac{8}{3}C + 8H + S - O_2\right]\text{kg}$$

$$= \frac{100}{23}\left[\left(\frac{8}{3}\text{x } 0.88\right) + (8\text{x}0.08) + (1\text{x}0.01) - 0\right]$$

$$= \frac{100}{23}[2.347 + 0.64 + 0.01]$$

$$= \frac{100}{23}[2.997]$$

$$= 13.03\ \text{kg}$$

2. Volumetric analysis of producer gas supplied to an engine is H_2= 20%, CH_4= 3%, CO 22%, CO_2 8% and N_2 47% . Estimate the volume of air required for combustion of 1 m^3 of gas.

Solution:

For $1m^3$ of gas

$$H_2 = 20\% = \frac{20}{100} = 0.2\ m^3$$

$$CH_4 = 3\% = \frac{3}{100} = 0.03\ m^3$$

$$CO = 22\% = \frac{22}{100} = 0.22\ m^3$$

$$CO_2 = 8\% = \frac{8}{100} = 0.08\ m^3$$

$$N_2 = 47\% = \frac{47}{100} = 0.47\ m^3$$

Minimum volume of air required for the complete combustion

$$= \frac{100}{21}[0.5CO+0.5H_2+2CH_4+3C_2H_4 - O_2]m^3$$

$$= \frac{100}{21}[(0.5x0.22) + (0.5x0.2) + (2x0.03) + (3x0)- 0]$$

$$= \frac{100}{21}[0.11+0.1+0.06]$$

$$= \frac{100}{21}[0.27]$$

$$= 1.286m^3$$

RECAP

In this chapter following topics are dealt with

- Theoretical volume of air required for the complete combustion of gaseous fuel
- Minimum mass of air required for the complete combustion of gaseous fuel
- Orsat apparatus for flue gas analysis

ACTIVITY

Different ways of putting a fire out

i. Putting water on a fire removes the heat
ii. Putting a blanket over fire removes the oxygen

Students to plan an experiment to test different fuels and compare the amount of heat given out.

EXERCISE FOR BETTER UNDERSTANDING

1. Combustion is an exothermic reaction : True / False
2. $C + O_2 \rightarrow CO_2$: True / False
3. $2H_2 + O_2 \rightarrow 2H_2O$: True / False
4. Flue gas is a mixture of CO and H_2 : True / False
5. Orsat apparatus used for flue gas analysis : True / False

Test Paper–1

Part-A

1. What is combustion?
2. What is ignition temperature?

Part-B

3. Write the complete equation for the combustion of methane
4. What are gases that can be analysed using Orsat apparatus?

Part-C

5. Calculate the minimum mass of air required for the complete combustion of fuel
6. Explain Orsat apparatus for flue gas analysis?

Test Paper – 2

Part-A

1. What are flue gases?
2. $C + O_2 \rightarrow$ ______

Part-B

3. Write the combustion equation of sulphur.
4. Name the reagents used for the absorption of CO_2, O_2 and CO in flue gas analysis

Part-C

5. A sample of coal was found to have the following composition C = 75%, H_2 =5.2%, O_2 = 12.1%, N_2 = 3.2% and ash 4.5% by mass calculate the amount of air required for the complete combustion of 1kg of fuel
6. Calculate the minimum volume of air required for the complete combustion of 1 M3 of gaseous fuel.

FACT STORE

- Black Carbon as an important climate change challenge Black carbon is a substance responsible for 40% of the effects of global warming.
- When this particulate matter gets deposited on the frozen surfaces such as in the arctic region in Himalayan glaciers and snow its high absorption of the sun's heat causes frozen material to melt and liquify.
- All In living system the principal substance used for the exchange of intracellular energy is adenosine triphosphate (ATP). Upon hydrolysis of one mole of ATP 7300 cal is liberated under normal condition. When the biological condition is changed even 13000 cal/mole is released. **We must be thankful to God for such a wonderful nature of human body.**

Broaden your understanding:

Click the following link or scan the QR code

https://www.youtube.com/watch?v=B1ZT84hycsE&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=6

https://www.youtube.com/watch?v=-o3GvVDW7R4&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=7

3.3 ROCKET PROPELLANTS

Definition – characteristics – Classification of propellants – brief idea of solid and liquid propellants. **– 3 Hours**

Introduction

We have studied a fuel requires oxygen to oxidise to give energy and we know well that when a rocket or space shuttle go out of this atmosphere the oxygen may not be available for oxidation. So a fuel has to be coupled with oxygen or oxygen giving substance called an oxidant must be used in rockets. Thus, rocket propellant is a mixture of fuel plus oxidant on combustion that produces very large volume of hot gases.

A propellant reacts quickly, producing a large volume of hot gases (at 3000°C and a pressure 300kg/Cm^2) which exit through a small opening at supersonic velocity. This act of pushing the gas backwards produces an equal and opposite reaction, which moves the rocket forward.

Characteristics of a good propellant

1. It should have a specific impulse (specific impulse = Thrust delivered / rate of propellant).
2. It should produce low molecular weight products during combustion (H_2, CO, CO_2 & N_2).
3. It should burn at slow and steady rate.
4. It should possess low ignition delay (Ignition delay is the time taken by the propellant to catch fire. It is expressed in milling seconds).
5. It should possess high density.
6. It should be stable over a wide range of temperatures.
7. It should be safe to handle and store.
8. It should be readily Ignitable.
9. It should be non-corrosive.
10. It should not leave solid residue after ignition.
11. It should not produce toxic emissions.

Classification of propellants

Rocket propellants are mainly classified into

1. Solid propellants
2. Liquid propellants

Solid propellants

Solid propellants having the following advantages

i. They can be easily handled and stored.

ii. They have controllable burning rates

iii. Cheap

Solid propellants further classified into

1. Homogeneous propellants
2. Heterogeneous propellants

1. Homogeneous propellants

When solid propellant or a mixture of a propellant is thoroughly mixed in a colloidal state, it is called homogeneous solid propellant.

Example:

i. Nitro cellulose mixed with nitro-glycerine (Ballistite).

ii. Nitro cellulose, nitro-glycerine and petroleum jelly (Cordite).

2. Heterogeneous propellants

When a oxidising agent is dispersed in a fuel mass, the solid propellant is called heterogeneous propellants.

The oxidants used are $KClO_4$, $NaNO_3$, NH_4ClO_4 etc.,

Example:

i. Potassium perchlorate 75% +Asphalt oil 25%

ii. Ammonium perchlorate 80% + Resin binder 20%

iii. Ammonium picrate 46% + Sodium nitrate 48% + Plastic resin 8%

Liquid propellants

Liquid propellants may be

i. Monopropellant (or)

ii. Bi propellant

Monopropellant

Monopropellants contain oxidised fuel and catalyst in the same system.

Example:

Hydrazine, H_2O_2, liquor Ammonia + aluminium nitrate etc.,

Bi-propellant

In bi propellant, the oxidiser and the fuel are stored in separate tanks and mixing takes place in the combustion chamber.

Example:

1. Liquid oxygen (oxidiser) + Ethanol (or) liquid H_2 or Kerosene(fuel)
2. Liquor fluorine(oxidiser) + Liquid H_2 (or)Liquid Ammonia (fuel)

Difference between solid propellant and liquid propellant

Solid Propellant	**Liquid Propellant**
1. They have low specific impulse	They have high specific impulse
2. They can easily stored and transported	They have storing, handling and transporting problems
3. The engines used for them are simple design	The engines used for them are more delicate
4. They are more economical	Comparatively less economical
5. It is difficult to calibrate the engines	Engine using them can be calibrated more easily

RECAP

In this chapter following topics are deal with

- Characteristics of rocket propellants
- Classification of rocket propellants
- Differences between solid and liquid propellants

ACTIVITY

Students can explore, rockets and rocket's motion, first they learn some basic facts about vehicles, rockets and why we use them, then they discover the motion of all objects including the flight of a rocket and movement of a can be described by Newton's three laws of motion.

EXERCISE FOR BETTER UNDERSTANDING

1. Rocket propellant is a mixture of fuel+ oxidant :True/False

2. Rocket propellant produce high molecular weight products during combustion :True/False

3. Rocket propellant mainly classified into solid and liquid propellants :True/False

4. Hydrazine is a example for nano propellant :True/False

5. Solid propellant have high specific impulse :True/False

Test Paper–1

Part-A

1. What is a propellant?
2. Give example for monopropellant?

Part-B

3. What is meant by homogeneous propellant?
4. What are the two types of liquid propellant?

Part-C

5. Explain the classification of rocket propellants.

Test Paper– 2

Part-A

1. What are the two types of propellants?
2. What is Bi-propellant?

Part-B

3. What is meant by heterogeneous propellant?
4. What is monopropellant?

Part-C

5. What are the characteristics of a good propellant?
6. Give the difference between solid and liquid propellant?

FACT STORE

- **Aryabhata** was India's first **satellite**, named after the famous Indian astronomer of the same name. It was launched on 19 April 1975 from Kapustin Yar, a Russian rocket launch and development site in Astrakhan Oblast using a Kosmos -3M launch vehicle. It was built by the ISRO.

- Chandrayaan -2 launched from the Satish Dhawan Space Center in Sriharikota, India, aboard a Geosynchronous Satellite Launch Vehicle (GSLV) rocket on July 22, 2019.

Frequently Asked Questions

UNIT III

QUESTIONS:

PART A

1. Define calorie.
2. What is the use of liquid hydrogen?
3. What is meant by power alcohol?
4. What is producer gas?
5. What is water gas?
6. What is CNG?
7. What is LPG?
8. What is ignition temperature?
9. What is the mass percentage of oxygen present in air.
10. What is the volume percentage of oxygen present in air.
11. What is the absorbent used in the Orsat apparatus to measure carbondioxide?
12. What is the absorbent used in the Orsat apparatus to measure carbonmonoxide?
13. What is the absorbent used in the Orsat apparatus to measure oxygen?
14. What are flue gases?
15. What are propellants?
16. What are the two types of propellants?
17. What is Bi-Propellant?

PART B

1. What are fuels?
2. What are fossil fuels?
3. Define calorific value.
4. What are the advantages of power alcohol?
5. Define fractional distillation.
6. What is cracking?
7. Give the composition and uses of CNG.
8. Give the composition and uses of LPG.
9. Give two advantages of liquid H_2.
10. Define combustion.
11. Write the complete equation for the combustion of the Methane present in a fuel.
12. Calculate the oxygen required for the combustion of 1 kg of hydrogen.
13. Calculate the oxygen required for the combustion of 1 kg of carbon.
14. Calculate the oxygen required for the combustion of 1 kg of sulphur.
15. Name the reagents used for the absorption of CO_2, O_2 and CO in flue gas analysis.
16. How is percentage of nitrogen present in the flue gas calculated?
17. What is Homogeneous propellant?
18. What is Heterogeneous propellant?
19. What is monopropellant?

PART C

1. What are the fractions obtained during the fractional distillation of petroleum?
2. Explain the preparation, composition and uses of producer gas.
3. Write a note on ‘water gas’.
4. What are the advantages of gaseous fuel over other fuels?
5. Explain the flue gas analysis by Orsat Apparatus
6. An example of coal was found to have the following composition

   C =75%, H_2= 5.2 %, O_2 12.1 %, N_2 3.2 % and ash 4.5% by mass

   Calculate the amount of air required for complete combustion of 1 kg of coal.
7. A fuel contains 45% $H_2$40% CO12% CH_4 and 3% O_2 by volume. Determine the volume of air required to burn 1 m^3 of the fuel.
8. What are the requirements of a good propellant.
9. Explain the classification of the propellant.
10. Give the differences between solid and liquid propellants.

UNIT
4

APPLIED CHEMISTRY

4.1 TECHNOLOGY OF WATER–I

Sources of water – depletion of underground water – Reasons – Rain water harvesting (Basic ideas) – advantages – Hard water and soft water – Hardness of water – Carbonate and Non – carbonate hardness – Methods of expressing hardness – mg/lit and ppm – Simple problems – Disadvantages of hard water – Estimation of total hardness by EDTA method – Problems involving Total, Carbonate and Non – carbonate hardness in ppm – Disadvantages of using hard water in boilers – Scale formation, Corrosion of boiler metal, Caustic Embrittlement – Priming and Foaming. **– 6 Hours**

Introduction:

There is one beautiful saying by biologists, "water is life". Water is the most essential compound for all living beings on earth. It plays an important role in human living, agriculture and industrial purposes. Ground water is a precious and mostly widely distributed resources of earth and unlike any other resource, it gets annual replenishment from meteoric precipitation. The world total water resources are estimated 1.37 x 10^6 million hm^3. Of this global water resource 97.2% is salt water, mainly present in oceans. Only 2.8% is available as fresh water on this planet earth. Out of this 2.8% about 2.2% is available as surface water in rivers, lakes and ponds and 0.6% as ground water. Out of this 0.6%, only 0.3% can economically be extracted from drilling technology and the remaining is situated below 800m.

Sources of water

The two important sources of water are (1) surface water and (2) underground water.

Surface water

The water available on the earth's surface is called as surface water. Surface water includes rainwater, river water, lake water and seawater.

Underground water

Underground water includes water present between the rocks in the earth crust, spring water, well water etc.

Reason for Depletion of underground water

The water available in lakes and ponds contributes only 0.01% of the total surface water (2.2%). Most of all these lakes were dug several years back, that too by the time the present day technology were quite unavailable. Agriculture is the greater use of water accounting for 80% consumption. The average annual rainfall of India is around 114 cm. Based on the total rainfall one third of it is lost by evaporation, 50% run off into ocean.

Formerly, the surface water from ponds, lakes and rivers were sufficient enough to meet our requirement. As the food requirement increased due to heavy population growth, tube wells were introduced. Slowly the surface water and percolation ponds were totally forgotten. The awareness came very recently and rain water harvesting is a must to meet our requirement.

The decrease in the quantum of underground water is depletion of water.

Depletion of water is mainly caused by,

1. Population growth, modernization and industrialization
2. Insignificant steps taken to preserve surface water and extraction using deep bore well to the core
3. Global warming causing excess evaporation of surface water
4. Deforestation
5. Decrease in rainfall caused by seasonal changes and
6. Effluents from the industries spoiling the ground water source.

To meet out this depletion of ground water sources, it is essential to find alternate plans using water management techniques to recharge the ground water sources. One of the techniques adopted is rainwater harvesting.

Rain Water Harvesting (RWH)

Rainwater harvesting is a technique of capturing and storing of rainwater (tanks, slums, lake) for useful purposes and recharging the excess water into the ground.

The methods employed are

1. Roof top harvesting
2. Open space harvesting

Roof top harvesting

Rainwater is directly used for recharging open wells and bore wells by directing them into it. It can also be stored in sumps or overhead tanks and used directly.

Open space Harvesting

Open spaces around the buildings are used for rainwater harvesting as follows:

1. With percolation/recharge pits
2. Recharge trenches
3. Recharge wells

The recharge method used depends on the soil condition.

Advantages of rain water harvesting

1. Rain water harvesting increases the ground water level.
2. It prevents the depletion of underground water.
3. Soil erosion is prevented.
4. It also prevents flooding in urban areas during rainy season.
5. It ensures the availability of water for our future generation.
6. The hardness or salty nature of the ground water is modified.

Types of water

Based on the sources of water, the taste, odour the quality of the water varies. This difference is due to the dissolved salts and minerals. Hence, water is classified as (i) soft water and (ii) hard water.

I. **Soft water** readily gives lather with soap.

II. **Hard water** does not give lather with soap.

Hardness of water

There are two types of hardness in water. They are:

Temporary Hardness: (Carbonate hardness)

It is due to the presence of calcium bicarbonate [$Ca(HCO_3)_2$] and magnesium bicarbonate [$Mg(HCO_3)_2$]. Temporary Hardness can be removed by mere boiling; soluble bicarbonates precipitate into insoluble carbonates.

$$Mg(HCO_3)_2 \longrightarrow MgCO_3 + H_2 \downarrow O + CO_2$$

Permanent Hardness: (Non-Carbonate hardness)

It is due to the presence of chloride and sulphate salts of calcium and Magnesium. ($CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$**).** Hence it is called permanent hardness water. This type of hardness cannot be removed by boiling.

Methods of expressing the Hardness.

The hardness of water can be expressed by any one of the following two methods. Units for measuring hardness

1. **mg/litre of $CaCO_3$**,It is the number of mg of $CaCO_3$ present in one litre of water or mg/lit
2. **Parts per million of $CaCO_3$**, It is the number of parts by weight of $CaCO_3$ present in million parts of water or ppm.

1mg / litre = 1 ppm

Usually, the hardness of water is expressed in terms of calcium carbonate equivalents.

The formula used to convert the mass of hardness producing salt to the mass of $CaCO_3$ equivalent is given below.

$$\text{Calcium Carbonate Equivalents} = \frac{\text{Mass of salt} \times \text{Molecular mass of } CaCO_3}{\text{Molecular mass of salt}}$$

To prove the relation between mg/litre and ppm

Let us consider a water sample whose hardness is ”x‟ mg/litre of $CaCO_3$.

Therefore, Mass of $CaCO_3$ present in 1000ml of water = **Y** mg

i.e. Mass of $CaCO_3$ present in 1000g of water = **$Y x 10^{-3}$g.**

Therefore, Mass of $CaCO_3$ present in 10^6g of water = **$Y \times 10^{-3}$g x 10^6/1000**

Hence hardness of water is = **Y ppm.**

Therefore, 1 mg / litre = 1 ppm. Hence it is proved.

Even though CaCO3 is not a hardness producing salt and is insoluble in water, it is used as the standard to express the hardness of water. Since the hardness producing salts are present in traces, mass of $CaCO_3$ equivalent to hardness producing salt is calculated to express the hardness of a water sample.

The formula used to convert the mass of hardness producing salt to mass of $CaCO_3$ is given as follows.

One molecular mass of ≡ one molecular mass of $CaCO_3$
Hardness producing salt

Note: Molecular masses of hardness producing salts are given below.

Hardness producing salt	Molecular Mass
$CaSO_4$	**136**
$MgSO_4$	**120**
$CaCl_2$	**111**
$MgCl_2$	**95**
$Ca\ (HCO_3)_2$	**162**
$Mg\ (HCO_3)_2$	**146**

Problem 1: **A** water sample contains 48 mg of $MgSO_4$ per 200ml of water. Calculate the hardness in terms of $CaCO_3$ equivalent in mg/litre of $CaCO_3$.

One molecular mass of $MgSO_4$ = one molecular mass of $CaCO_3$

i.e. 120 mass of Mg SO_4 = 100 mass of $CaCO_3$

Therefore mass of 48mg of $MgSO_4$ = $\frac{48 \times 100}{120}$

= 40mg of $CaCO_3$

Mass of $CaCO_3$ present in 200 ml of water = 40mg Therefore,

Mass of $CaCO_3$ present in 1000ml of water = 200mg

Hardness of water = 200mg / litre of $CaCO_3$

Disadvantages of a hard water sample

- Hard water cannot be used for drinking, as it does not quench thirst.
- Drinking Hard water causes bad effect on our digestive system. Moreover, the possibility of forming calcium oxalate (urinary stone) crystals in urinary tracks is increased.
- It cannot be used for cooking purposes.
- It cannot be used for bathing and washing purposes as it does not give lather with soap.
- Hard water cannot be used in laboratories as it gives unwanted chemical reactions.
- Hard water cannot be used in boilers for steam raising.
- It cannot be used in sugar and paper industries.
- Hard water cannot be used in textile and leather industries.

Estimation of hardness of water EDTA method

EDTA method is used to determine the hardness of a sample of water. EDTA refers to Ethylene-diamine tetra acetic acid. This method is also called Modern method.

Principle

This is a volumetric method based on the principle of formation of complexes. Ethylene diamine tetra acetic acid (E.D.T.A.) forms colourless complexes with Ca^{2+} and Mg^{2+} ions present in water. Similarly Eriochrome Black-T, another dye, also forms wine red coloured complexes with Ca^{2+} and Mg^{2+} ions. Pure Eriochrome Black-T is blue in colour. At the pH range of 9 to 10, the Eriochrome complexes are less stable when compared to E.D.T.A. complexes. Thus when E.D.T.A. solution is added to Eriochrome-Ca^{2+} or Mg^{2+} complexes it displaces pure Eriochrome to form E.D.T.A-Ca^{2+} or Mg^{2+} complexes. Thus at the end point E.D.T.A. frees the total Eriochrome Black-T to change the colour of the solution from wine red to steel blue.

Eriochrome-Ca^{2+} + E.D.T.A $\longrightarrow$ **E.D.T.A-Ca^{2+} + Eriochrome Black-T**

Wine Red ***Steel Blue***

PROCEDURE:

The burette is filled with the standard E.D.T.A. solution. A 50-ml pipette is washed with distilled water and rinsed with the sample of hard- water. Exactly 50 ml of hard-water is pipetted out into a conical flask and 5 ml of ammonia buffer (NH_4Cl - NH_4OH) solution is added. A pinch of Eriochrome Black-T indicator is added. The colour of the conical flask solution changes into wine red. The water sample is titrated against the E.D.T.A. Solution taken in the burette. The colour changes from wine red to steel blue. This is the end point of the titration. The burette reading is noted. Titrations are repeated until two consecutive values agree. From the volume of E.D.T.A. the hardness of the sample of water is calculated.

Note: In the estimation of hardness of water, a standard formula, already established is used. This gives a standard data relating the mass of $CaCO_3$ and volume of 0.01M EDTA solution.

1ml of 0.01M EDTA solution ≡ 1mg of $CaCO_3$

HARD WATER Vs EDTA

Sl. No.	Volume of Hard water	Burette Reading		Volume of EDTA (ml)	Indicator
		Initial	Final		
1	50	0			Eriochrome Black-T
2	50	0			
3	50	0			

Calculation:

Let V ml be the volume of E.D.T.A.

1 ml of 0.01 M E.D.T.A. ≡ 1 mg of $CaCO_3$

Therefore V ml of 0.01 M.E.D.T.A. = V mg of $CaCO_3$

50 ml of Hard water contains V mg of $CaCO_3$

Therefore, Weight of $CaCO_3$ present In 1000 ml of Hard water

$$\frac{V \times 1000}{50 \text{ mg}}$$

= 20 V mg

Hardness of water = 20V mg /litre of $CaCO_3$

(Note: In the estimation of hardness, 0.01M EDTA solution is prepared by dissolving 3.72 g of Disodium salt of EDTA in 1000 ml of distilled water. Ammonia buffer solution is prepared by dissolving 67.5 g of ammonium chloride (AR) in 200 ml of water and by adding 570 ml of Liquor ammonia (AR) and the total volume is made up to one litre.)

Problem 2: A sample of 100 ml of hard water consumes 25 ml of 0.01 M EDTA solution. Calculate the hardness of the sample of water.

1ml of 0.01 M EDTA solution ≡ 1 mg of CaCO3

Therefore, 25 ml of 0.01M EDTA solution ≡ 25 mg of CaCO3

By titration, 25 ml of 0.01 M EDTA solution ≡100 ml of hard water Therefore

Mass of $CaCO_3$ present in 100 ml of hard water = 25 mg

Therefore Mass of $CaCO_3$ present in 1000 ml of hard water = 250 mg

Hence hardness of water = 250mg/litre of $CaCO_3$

To convert into ppm

Mass of $CaCO_3$ present in 100 ml of hard water = 25 mg

Mass of $CaCO_3$ present in 100g of hard water = 25×10^{-3}g

Therefore, Mass of $CaCO_3$ present in 10^6g of hard water = $\frac{25\times10^{-3}\text{g}\times10^{6}}{100}$

= 250g

Hence, hardness of water = 250 ppm of $CaCO_3$

Problem 3: A sample of 100 ml of water consumed 12.5 ml of 0.01 M EDTA solution. In another titration 100 ml of the same sample, after boiling for half an hour consumed 8.2 ml of the same EDTA solution. Calculate the carbonate and non-carbonate hardness of the sample of water.

(NOTE: In the given problem, volume of EDTA consumed in the first titration is equivalent to total hardness of water which includes both carbonate and non- carbonate hardness. But the volume of EDTA consumed by the water after boiling is equivalent to non-carbonate hardness as carbonate hardness in water can be removed by boiling water.)

Total hardness

1ml of 0.01M EDTA solution≡ 1mg of $CaCO_3$

Therefore, 12.5ml of 0.01M EDTA solution ≡ 12.5 mg of $CaCO_3$

By titration, 12.5ml of 0.01M EDTA solution ≡100 ml of hard water

Therefore, Mass of $CaCO_3$ present in 100 ml of hard water = 12.5 mg

Therefore mass of $CaCO_3$ present in 1000ml of Hard water =125mg

Hence Total hardness of water = 125 mg/litre of $CaCO_3$

Non-carbonate Hardness

1ml of 0.01M EDTA solution ≡ 1mg of $CaCO_3$

Therefore, 8.2ml of 0.01M EDTA solution ≡ 8.2 mg of $CaCO_3$

By titration, 8.2ml of 0.01M EDTA solution ≡100 ml of hard water

Therefore, Mass of $CaCO_3$ present in 100 ml of hard water = 8.2 mg

Therefore, Mass of $CaCO_3$ present in 1000ml of hard water = 82 mg

Hence, Non-carbonate hardness of water =82 mg/litre of $CaCO_3$

Therefore, Carbonate Hardness = Total hardness – Non-carbonate hardness

= (125 – 82)

= 43 mg/litre of $CaCO_3$

Disadvantages of using hard water Boilers

1. The salt deposit formed is a poor conductor of heat. Therefore fuel is wasted in raising the temperature of the boiler.
2. Excess fuel spent also affects cost factor of the product.
3. Due to the increase in the temperature, the boiler tubes may weaken. This may lead to explosion of boiler.
4. At higher temperature, more oxygen may be absorbed by the boiler metal, which causes corrosion of boiler metal.

Boiler feed water

Water is used in boilers, steam engines etc., to raise steam. When a sample of hard water is used in boiler to prepare steam, the following problems will occur.

1. Scale formation
2. Corrosion of boiler metal
3. Caustic Embrittlement and
4. Priming and foaming.

Boiler Scale Formation:

When hard water is used in boilers to get steam, the impurities that are present in the hard water will settle down on the sides of the boiler. This residue in due course will adhere to the boiler vessel surface in the form of a sludge or scale. This is called boiler scale. The following calcium salts are responsible for the formation of boiler scale $CaSO_4$, $CaCO_3$,$Ca(OH)_2$, $Mg(OH)_2$ etc.

Methods employed to prevent scale formation are,

1. Internal conditioning method
2. External conditioning method.

1. Internal conditioning methods involve addition of complexing agents like Calgon to boiler feed water. Another method of internal conditioning is Phosphate conditioning. In this method, sodium phosphate is added to boiler feed water which forms non-sticky Calcium and Magnesium Phosphate Which can be removed by blow down operation.

2. In External conditioning methods water is purified either by Zeolite process or by ion-exchange method before being fed into boilers.

Corrosion of Boiler metal:

Water containing the following impurities is responsible for the corrosion of boiler metal. The impurities such as dissolved oxygen, dissolved Carbon dioxide, mineral acids, dissolved salts of calcium and magnesium, organic matter etc. are responsible for the corrosion of the boilers.

The dissolved matter undergoes hydrolysis and forms acids. The acid slowly attacks the inner part of the boiler. The dissolved oxygen attacks iron at high temperature. The CO_2 and H_2O form carbonic acid (H_2CO_3), which slowly attacks the metal.

Prevention of Boiler Corrosion:

1. By using proper water treatment procedures.
2. By degasification to remove the dissolved gases like oxygen, CO_2 etc.,
3. The dissolved CO_2 can be removed by the addition of limewater.
4. Adding calculated amount of base could neutralize the mineral acids.

Caustic embrittlement:

Caustic embrittlement is a type of boiler corrosion, caused by using highly alkaline water in the boiler. During softening process by lime soda process, free Na_2CO_3 is usually present which decompose to give sodium hydroxide and carbon dioxide.

$$Na_2CO_3 + H_2O \longrightarrow 2NaOH + CO_2$$

The sodium hydroxide containing water flows in to the hair- cracks of the boiler and causes embrittlement of boiler parts particularly stressed parts like bents, joints, rivets, etc.., Caustic embrittlement can be avoided

- By using sodium phosphate as softening reagent instead of sodium Carbonate.
- By adding tannin or lignin to boiler water which blocks the hair cracks, preventing infiltration of caustic soda.

Foaming and Priming

Foaming is nothing but the formation of foam. Bubbles of water will enter the surface of water inside the boilers and results in the formation of foam. Foam comes out of the boiler along with the steam. Hence the steam becomes wet and the heat content of the steam is reduced considerably. This type of wet steam spoils the machine parts where it is used. The main cause for foaming is the presence of dissolved salts in water. Hence soft water should be used in boilers to avoid foaming.

Priming

Priming is violent and rapid boiling of water inside the boiler. Due to priming, the water particles mix up with the steam when it comes out of the boiler. Like foaming, priming also reduces the heat content of the steam and reduces the efficiency of the steam.

Main reasons for Priming:

- Defective design of the boiler and improper handling of boiler.
- Presence of large quantities of dissolved salts, oily matter, alkaline and suspended matter.

Control

- Priming can be controlled by proper design of the boiler
- By uniformly heating the water in the boiler.
- By using a better sample of water.

RECAP

We have learnt about

- rain water harvesting,
- estimation of hardness using EDTA
- bad effects of hard water in boilers.

Key Terms

Hard water - Soft water - Temporary hardness- Permanent hardness - Rain water harvesting -Boiler scale- Caustic Embrittlement – Priming - Foaming.

ACTIVITY

- Find out between local tap water and potable mineral water, which is relatively harder?
- Collect the list of five countries that consume more water annually.

GET IT RIGHT

1. Drinking water flushes toxins from the body ---- Fact
2. Everyone should drink 8 glasses of water per day --- Myth
3. Men should drink 12 glasses of water/ fluid and women should drink 8 glasses of water/fluid per day---- Fact
4. Hard water is good for the digestive system ---- Myth
5. Prolonged use of hard water weakens the digestive system and may cause kidney stone – Fact

Test Paper 1

PART – A

1. How water is classified?
2. Why the carbonate hardness is called as Temporary hardness?
3. List the salts that cause permanent hardness in a water sample.
4. Which salt is responsible for the scale formation when hard water is used in the boiler?
5. What is the expansion of EDTA?

PART – B

1. List any three reasons which cause depletion of water.
2. How will you prove 1mg/litre=1 ppm?
3. Calculate the hardness in ppm of a sample of water containing 100mg of $caco_3$ in 100ml.
4. What is caustic embrittlement?
5. What is foaming?

PART – C

1. Explain rainwater harvesting method and also mention the advantages of rain water harvesting.
2. Explain EDTA method of estimating hardness of a sample of water.
3. What are the disadvantages of using hard water in boilers? Explain.

Test Paper 2

PART – A

1. Define hard water and soft water?
2. What are the types of hardness in water?
3. List the salts that cause temporary hardness in a water sample.
4. What is the relationship between mg/litre and ppm.
5. Name the indicator and buffer used for estimation of hardness of water by EDTA method.

PART – B

1. List the salts that cause temporary and permanent hardness in a water sample.
2. $CaCo_3$ is not a hardness producing salt but why it is used as the standard to express the hardness of water?
3. Give the formula used to convert the mass of hardness producing salt to the mass $CaCo_3$ equivalents.
4. Give any two problems caused by boiler scale.
5. How boiler metal gets corroded by hard water?
6. Mention the methods to prevent boiler corrosion.
7. What is priming?
8. What are the main reasons for priming and how it is controlled?

PART – C

1. Explain the types of hardness in water? Mention the method of expressing the hardness.
2. A sample of 100ml of hard water consumed 18ml of 0.01M EDTA solution. In another titration, 100ml of the same sample of hard water after boiling for half an hour consumed 12ml of the same EDTA solution. Calculate (i) Carbonate hardness and (ii) non-carbonate hardness.
3. What are boiler scales? List the problems caused by boiler scale. How will you overcome this problem?
4. Explain caustic embrittlement, priming and foaming in boilers during the production of steam.

Problems

1. 100 ml of a sample of water when titrated against standard EDTA of strength 0.01 M, it consumed 11.5 ml. The same sample after boiling, required only 8.2 ml of the same EDTA. Calculate carbonate and non-carbonate hardness and express them in ppm.

(Ans: 33 ppm, 82 ppm)

2. 50ml of a sample of water when titrated against standard EDTA of strength 0.02M, it consumed 6.5ml. Express the hardness of the sample both in mg/L and in ppm.

(Ans: 650 mg/L, 650 ppm)

3. A Sample of water contains 30mg of $CaCO_3$ in 100 ml of water. Express the hardness in mg/L and in ppm.

(Ans: 300mg/L, 300 ppm)

4. A sample of water has 18mg of $MgSO_4$ in 250ml. Express the hardness in calcium carbonate equivalent in ppm. (Ans:60 ppm)

Tech bytes

Indian scientists develop technology for harvesting water from dew.

FACT STORE

- 70% of the human brain is water.
- 1.7% of the world’s water is frozen and therefore unusable.
- Approximately 400 billion gallons of water are used in the United States per day.
- 500 sheets of paper require 1,321 gallons of water.

Broaden your understanding

Click the following link or scan the QR code

https://www.youtube.com/watch?v=f46iGCMIFBM&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=9

https://www.youtube.com/watch?v=-hKFNULAls4&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=10

4.2 TECHNOLOGY OF WATER – II

Softening of hard water–Ion – Exchange method and Reverse Osmosis method – Municipal supply – purification of drinking water–Quality of potable water (WHO standard)–parameters of potable water – pH–TDS – Residual Chlorine permissible limits – determination of ecoli (preliminary idea) **- 5 Hours**

SOFTENING OF HARD WATER

The method of converting the hard water into soft water is called softening of hard water. Two important methods of softening the hard water are 1. Ion- Exchange method 2. Reverse Osmosis method**.**

Ion Exchange method (Demineralization Method or de-ionization method)

In this method the hard water is first passed through an acidic resin column having replaceable hydrogen ion (RH) to remove the cations [Ca^{2+}, Mg^{2+}] and then it is passed through a basic resin column (ROH) having replaceable hydroxyl ion to remove the anion. Thus both types of ions are totally removed.

Acid resin is represented by RH. Base resin is represented by ROH.

Softening Process:

When the hard water sample is passed through the acid resin, calcium and magnesium ions are removed.

$$2RH + Ca^{2+} \longrightarrow R_2Ca + 2H^+$$

$$2RH + Mg^{2+} \longrightarrow R_2Mg + 2H^+$$

When this water is then passed through the basic resin, chloride, bicarbonate and sulphate ions are removed.

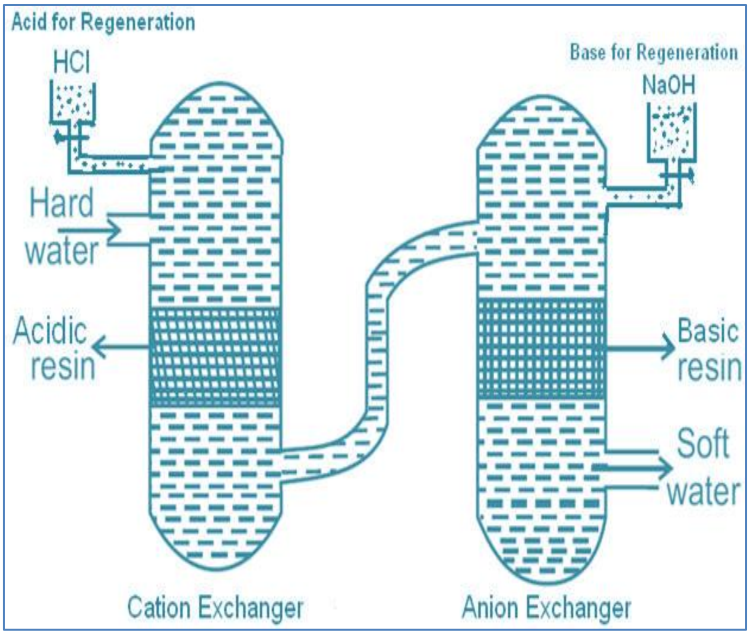


Fig. 4.2.1 Ion-Exchange Method

$$\mathbf{ROH + Cl^- \longrightarrow RCl + OH^-}$$

$$\mathbf{2ROH + SO_4^{2-} \longrightarrow R_2SO_4 + 2\,OH^-}$$

Thus both types of ions are removed from water. The H^+ and OH^- ions combine together to form water.

$$\mathbf{H^+ + OH^- \longrightarrow H_2O}$$

The quality of water obtained by this method is equivalent to distilled water.

Regeneration of Acidic Resin and Basic Resin:

After pronged usage of the columns, the acidic resin can be regenerated by washing it with strong solution of Hydrochloric acid.

$$\mathbf{R_2Ca + 2HCl \longrightarrow 2RH + CaCl_2}$$

The basic resin can be regenerated by washing it with a strong solution of NaOH.

$$\mathbf{RCl + NaOH \longrightarrow ROH + NaCl}$$

$$\mathbf{R_2SO_4 + 2NaOH \longrightarrow 2ROH + Na_2SO_4}$$

Advantages

1. In this method, both types of hardness are removed.
2. The quality of water obtained is equivalent to distilled water.
3. There is no wastage of water.

Reverse Osmosis Method

Osmosis

When two solutions of different concentrations are separated by a semi-permeable membrane, solvent molecules move from the region of low concentration side to the region of higher concentration side until the two concentrations become equal. This process is called osmosis. The pressure gradient produced due to osmosis is called osmotic pressure.

Reverse Osmosis

When a hydrostatic pressure greater than the osmotic pressure is applied on the high concentration region, solvent molecules move from higher concentration region to the lower concentration region across the semi permeable membrane. This is called reverse osmosis. This principle is used in Reverse Osmosis plants to soften hard water.

Method

In this method hard water and soft water are taken in two different chambers separated by semi permeable membrane. When a hydrostatic pressure greater than the osmotic pressure is applied on the hard waterside, the water molecules move from hard waterside to soft waterside leaving the impurities on the membrane due to reverse osmosis. Thus the hard water is converted to soft water by Super filtration or hyper filtration

Diagram

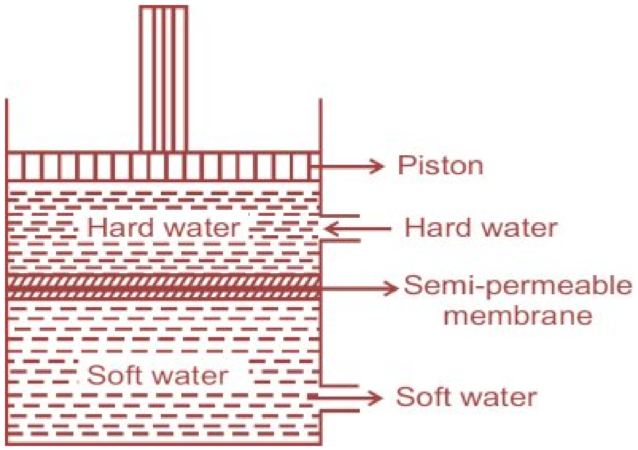


Fig. 4.2.2 Osmosis

The semi permeable membrane is made of polysulphone or cellulose acetate or polyamide.

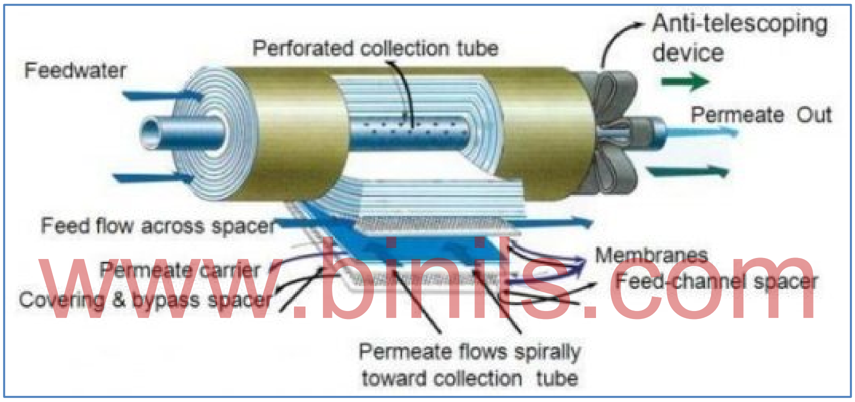


Fig. 4.2.3. Semipermeable Membrane

Advantages

- In this method ionic, non-ionic, colloidal, and organic particles are removed from water.
- The semipermeable membrane can be replaced and reused. However, one third of the salt water is wasted.

Municipal water supply- (potable water)

Water used for drinking should be colourless, odourless and free from

1. colloidal impurities
2. suspended impurities and
3. disease causing microorganisms and bacteria.

The three stages involved in purifying a water sample for drinking purpose are

- Sedimentation
- Filtration
- Sterilisation

Sedimentation

Water from river or lake is taken in the big tank called sedimentation tank. Here the insoluble matter settles down at the bottom of the tank as sediments. In this tank, the colloidal impurities are converted into precipitate by adding Alum. The clear water from the top layer is sent to the next tank called Filtration tank**.**

Filtration tank

In filtration tank, the suspended impurities and the micro organisms are removed. In all types of filtration, the filter bed used is constructed as follows. The filter bed consists of a layer of fine sand followed by the layer of coarse sand, which is then followed, by a layer of gravel. There is a drain at the bottom to remove the filtered water. The layer of fine sand acts as the filtering unit and the other two beds support the fine sand layer.

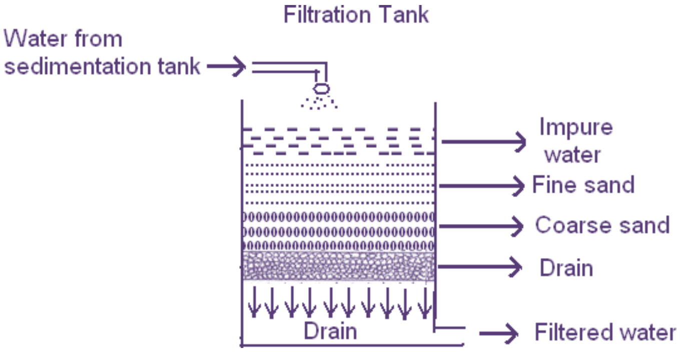


Fig. 4.2.4 Filtration

Generally filtration is done due to the gravitational force. The filtered water is then taken to the sterilization tank.

(Note: In drinking water supply schemes, generally gravity filters are used. However, in industrial areas where large amount of drinking water is required in short period, pressure filters are used in which water is sent through filter beds using external pressure. In gravity filtration, there are two types namely slow sand filtration and rapid sand filtration. The difference between these two methods is mainly in the recovery of filter beds used.)

Sterilisation

Sterilization is the process of killing the bacteria. It is done by physical or chemical method.

Physical method: Ultra-violet rays can be used for sterilizing purpose or exposed to sunlight or boiled.

Chemical method: Chlorination

Chlorination is addition of chlorine. Chlorine is added to water in the acidic pH range of 6.5 to 7. When chlorine is added to water, it forms HCl and HOCl. The hypochlorous acid molecule enters into the living cells of bacteria and kills them.

$$\mathbf{H_2O + Cl_2 \longrightarrow HCl + HOCl} \text{ (Hypochlorous acid)}$$

Other sterilizing agents used apart from chlorine are chloramines, bleaching powder etc. The advantage of using chloramines is that it does not evaporate out easily and can be carried over to a longer distance along with the water.

Quality of potable water pH, TDS, residual chlorine - permissible limits and determination of e-coli (preliminary idea)

Power of hydrogen ion concentration (pH)

p^H is an important factor in water analysis. Water having p^H value less than 4.5, contain carbonic acid.

The p^H of pure water is 7. In general, water with a p^H lower than 7, is considered to be acidic, and with a p^H greater than 7 is considered basic. The ideal p^H level of drinking water should lie, between 6 – 8.5.

TDS in water

Total Dissolved solids (TDS) in water comprise inorganic salts like calcium, magnesium, potassium, sodium bicarbonates, chlorides and sulphates and some small amounts of organic matter that are dissolved in water. Total dissolved solids (TDS) is measured in milligrams per unit volume of water (mg/L) and also referred to as parts per million (ppm). For drinking water, the maximum concentration level set by Environmental Protection Agency (EPA) is 500 mg/L.

- The TDS less than 300 mg/L –Excellent
- Between 300 and 500 mg/L – Good
- The TDS greater than 1200 mg/L – Un acceptable

Residual chlorine

Chlorination primarily adopted to destroy or deactivate disease-producing microorganisms in the public water supplies and polluted rivers. Chlorine is usually added to water in gaseous form or as sodium or calcium hypochlorite. Bleaching powder can be added as 4mg/L and allowed to stand for 30 minutes. When chlorine is added to water, some of the chlorine reacts first with organic materials and metals in the water and is not available for disinfection (this is called the chlorine demand of the water). The remaining chlorine concentration after the chlorine demand is accounted for is called total chlorine. Total chlorine is further divided into: 1) the amount of chlorine that has reacted with nitrates and is unavailable for disinfection which is called combined chlorine and, 2) the free chlorine, which is the chlorine available to inactivate disease-causing organisms, and thus a measure to determine the potability of water . The word "residual" means "remainder" or "that which is left", and as the name suggests the chlorine residual test is used to measure the amount of chlorine remaining in the water at the time the test is made. The chlorine residual is usually tested in finished water which is ready to be released into the distribution system, although operators must also ensure that there is adequate residual at the extreme ends of the distribution system. Excess Chlorination may produce adverse effects. Potentially carcinogenic chloro organic compounds such as chloroform may be formed. The quantity of free chlorine in treated water should not exceed 0.5 ppm.

Escherica coli (e-coli)

Water may contain bacteria which are very small organisms. Some bacteria are harmful and called pathogenic bacteria, while some others are harmless and are known as non – pathogenic bacteria. Cholera, typhoid, dysentery etc… are caused by pathogenic bacteria which are very difficult to isolate in the laboratory. Simple tests are performed to determine the possible presence of intestinal organisms, which are known as coliform group of bacteria.

Eschericha coli (E-coli) is the most common bacteria in the coliform group. These bacteria are harmless but their presence indicates that pathogenic bacteria may also be present. E-Coli germs are discharged in very large numbers with the faeces.

The sample to be tested is placed in sterile tubes and lactose is added. The tubes are placed in an incubator for 24 hours at 37° C. If gas is evolved, the test is positive and indicates the presence of bacteria. The water is unfit for drinking. If no gas is formed, the process is again examined at end of 48 hours. If still no gas is evolved, the test is negative.

The approximate number of E-coli present in 1ml of the sample of water is known as E-coli index. The index should be less than three in potable water.

Standards of drinking water : The water used for drinking purpose should have the following characteristics as prescribed by WHO, (World Health Organisation).

Contaminant	**Max. Limit**
Al^+	0.05 - 2 mg/L
Cl^-	250 mg/L
Copper	1.0 mg/L
F^-	2.0 mg
Iron	0.3 mg/L
Mn	0.05 mg/L
pH	6.5 - 8.5
Ag	0.10 mg
$SO4^{2-}$	250 mg/L
TDS	500 mg/L
Zn^{2+}	5.0 mg/L
E-coli index	**< 3**

RECAP

Students have learnt about

- softening of hard water methods,
- potable water and
- parameters of potable water like p^H – TDS –
- Residual chlorine permissible limits and
- determination of e-coli.

Key Terms

Softening - Reverse osmosis - Resin - Sedimentation - Sterilization – TDS - Dissolved chlorine - E- coli.

ACTIVITY

- Collect water from five different places and find out their pH and TDS.

GET IT RIGHT

- Desalination plants do not increase salinity of well water close to the shore ---- Fact
- Desalination plants kill fish and other marine life in that region --- Myth
- Desalination do not affect aquatic life -- Fact

Test Paper 1

PART – A

1. List any two methods of softening of hard water.
2. Name the membranes used in R.O. method of softening of hard water.
3. What is called sterilization of water?
4. Define TDS?
5. What is maximum permissible limit of free chlorine in drinking water?

PART – B

1. How acidic and basic resins are regenerated during Ion-Exchange method.
2. Write a short note on TDS.
3. How will you test the presence of e-coli.

PART – C

1. Explain Ion-Exchange method of softening of a hard water sample.
2. Describe the method used in water supply schemes to get potable water.
3. Write a notes on E-coli and residual chlorine.

Test Paper 2

PART – A

1. What is osmosis?
2. What is sedimentation?
3. What is the ideal p^H of drinking water?
4. Name the carcinogenic compounds formed by the presence of excess chlorine in drinking water.
5. What is meant by e-coli index?

PART – B

1. Mention the advantages of Ion-Exchange method.
2. What is meant by total chlorine?
3. Write a note on p^H for quality of potable water.

PART – C

1. Explain Reverse osmosis method of softening of hard water sample.
2. Write a note on drinking water standard.
3. Write a notes on residual chlorine, pH, TDS, e-coli index of potable water.

FACT STORE

- The Minjur Desalination Plant is a reverse osmosis, water desalination plant and it is the largest desalination plant in India.
- Some 80 percent of domestic water use in Israeli cities comes from desalinated water.
- The top three desalination countries are Saudi Arabia with 17 percent of global output, United Arab Emirates with 13.4 percent, and the United States with 13 percent.”

Broaden your understanding:

Click the following link or scan the QR code

https://www.youtube.com/watch?v=TKPPOTqgQyA&list=PL1b9Ht9ISqIFsIiqREfRjehR2WAs3qCW4&index=1

FREQUENTLY ASKED QUESTIONS - UNIT – IV

PART –A

1. What are the two important sources of water?
2. How is water classified?
3. Define hard water and soft water?
4. What are the types of hardness in water?
5. Why the carbonate hardness is called as Temporary hardness?
6. List the salts that cause temporary hardness in a water sample.
7. List the salts that cause permanent hardness in a water sample.
8. What is the relationship between mg/litre and ppm.
9. Name the indicator and buffer used for estimation of hardness of water by EDTA method.
10. Which salt is responsible for the scale formation when hard water is used in the boiler.
11. What is the expansion of EDTA?
12. List any two methods of softening of hard water.
13. What is osmosis?
14. Name the membranes used in R.O. method of softening of hard water.
15. What is sedimentation?
16. What is called sterilization of water?
17. What is the ideal p^H of drinking water?
18. Define TDS?
19. Name the Carcinogenic compounds formed by the presence of excess chlorine in drinking water.
20. What is maximum permissible limit of free chlorine in drinking water.
21. What is meant by e-coli index?

PART - B

1. List any three reasons which cause depletion of water.
2. List the salts that cause temporary and permanent hardness in a water sample.
3. The $CaCO_3$ is not a hardness producing salt but why it is used as the standard to express the hardness of water.
4. Give the formula used to convert the mass of hardness producing salt to the mass $CaCO_3$ equivalents.
5. How will you prove 1mg/litre=1ppm
6. Give the disadvantageous of hard water.
7. What are boiler scales?
8. What is caustic embrittlement?
9. What is foaming?
10. Give any two problems caused by boiler scale.

11. How is boiler metal corroded when hard water is used in the boiler?
12. Mention the prevention of boiler corrosion.
13. What is priming?
14. What are the main reasons for priming and how it is controlled?
15. Calculate the hardness in ppm of a sample of water containing 10.62 mg of calcium carbonate in 100ml.
16. How acidic and basic resins are regenerated during Ion-Exchange method.
17. Mention the advantages of Ion-Exchange method.
18. Write a short note on TDS.
19. What is meant by total chlorine.
20. How will you test the presence of e-coli.

PART – C

1. Explain rainwater harvesting method and also mention advantages of rain water harvesting.
2. Explain the types of hardness in water? Mention the method of expressing the hardness.
3. Explain EDTA method of estimating hardness of a sample of water.
4. What are the disadvantages of using hard water in boilers? Explain.
5. What are the boiler scales? List the problems caused by boiler scale. How it overcome this problem.
6. Explain caustic embrittlement, priming and foaming in boilers during the production of steam.
7. A sample of 100 ml of hard water consumed 18 ml of 0.01 M EDTA solution. In another titration, 100 ml of the same sample of hard water after boiling for half an hour consumed 12 ml of the same EDTA solution. Calculate (i) Carbonate hardness and (ii) non-carbonate hardness.
8. Explain Ion-Exchange method of softening of a hard water sample.
9. Explain Reverse osmosis method of softening of hard water sample.
10. Describe the method used in water supply schemes to get potable water.
11. Write a note on drinking water standard.
12. Write a note on E-coli.
13. Write a note on dissolved chlorine.

UNIT
5
ENVIRONMENTAL CHEMISTRY

5.1 AIR POLLUTION

Pollution and Air pollution – Definition – Air pollutants (SO_2, H_2S, HF, COand Dust) – Sources and Harmful effects –Smog and types - Formation of Acid Rain –Harmful effects – Green House Effect – Causes – Global warming –Harmful effects – Ozone Layer – Importance – Causes for Depletion of Ozone Layer (No equations) – Harmful effects of Ozone Layer Depletion– Control of Air Pollution **- 4 Hours**

Introduction

Population goes on increasing every year, and industrialisation becomes inevitable to cater the need of 700 crore population. Rapid industrialization throw too many garbages in excess into the living environment. Of course, nature has got the recycling capacity to convert these materials into useful material, in a new form, however when these materials are dumped on large scale in a shorter duration, nature is stumbling to regenerate them. Now a days, even noise pollution affects many people, but we do not bother much about them, because man becomes alert only when he is affected on his physical plane. When the effect is on the mental plane, we take it for granted that it is less significant.

In recent days, everyone speaks about pollution. We are all facing huge risks due to pollution. The air we breathe the water we drink and the place where we live may be full of toxic substances. The adverse effect of these pollutants, also affects future generation.

Pollution

Pollution may be defined as the excessive discharge or addition of unwanted and undesirable foreign matters into the environment that causes huge damage to the life and properties of human, plants and animal.

Environment includes air, water and land. The harmful substances that cause damage are called **pollutants**. They are discharged from various industries, automobiles, microorganism, volcanic eruptions, forests and strong winds.

Causes of pollution

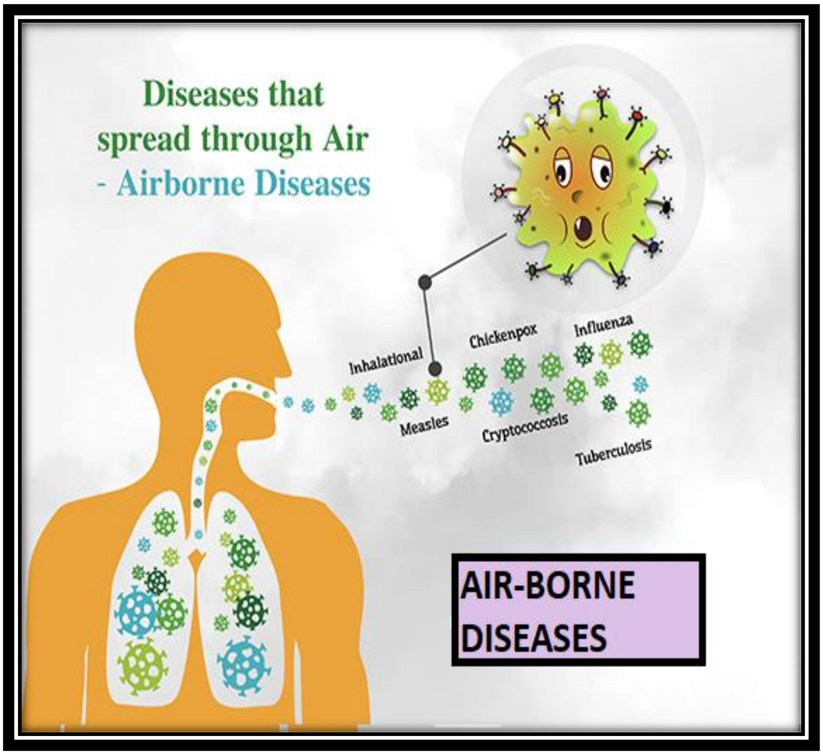
The following are the main causes of pollution.

1. Huge increase in population.
2. Rapid industrialization.
3. Rapid urbanization.
4. Uncontrolled exploitation of nature.
5. Radioactive substances.
6. Volcanic eruptions, etc.

Classification of pollution

To understand the magnitude of pollution problems, it may be classified into three types as follows.

1. Air pollution
2. Water pollution
3. Land pollution



Air pollution

Air Pollution may be defined as the excessive discharge or addition of unwanted and undesirable foreign matters into the atmosphere that causes huge damage to the life and properties of human, plants and animal.

Gaseous pollutants like sulphur dioxide, hydrogen sulphide, hydrogen fluoride, carbon monoxide and dust are the most important primary air pollutants.

Harmful effects of air pollutants

Sl. No.	Air pollutant	Source	Harmful effects
1	Sulphur dioxide (SO_2)	Petroleum industry, thermal power station, sulphuric acid manufacturing plants, etc.	Causes respiratory diseases, eye irritation, throat troubles, damage to agriculture, etc.
2	Hydrogen sulphide (H_2S)	Petroleum industries, paper industries, leather industries, etc.	Causes eye irritation, severe throat pain, headache, corrosion of metals, etc.
3	Hydrogen fluoride (HF)	Fertilizer industry, aluminum industry, etc.	Causes irritation, respiratory diseases, bone disorders, tooth disorders, etc.
4	Carbon monoxide (CO)	Automobile industry, oil refineries, cigarette smoke, etc.	Causes headache, visual difficulty, paralysis, etc.
5	Dust	Cement industry, mines, glass industry, ceramic industry, agricultural industry, etc.	Causes respiratory diseases, affects lungs, accelerates corrosion, etc.

Smog

The word smog is derived from smoke and fog. This is the most common example of air pollution that occurs in many cities throughout the world.

Types of smog:

a) **Classical Smog (London Smog)**

b) **Photochemical smog (Los Angeles Smog)**

(a) Classical smog occurs in cool humid climate. It is a mixture of smoke, fog and sulphur dioxide. Chemically it is a reducing mixture and so it is also called as **reducing smog**.

(b) Photochemical smog occurs in warm, dry and sunny climate. The main components of the photochemical smog result from the action of sunlight on unsaturated hydrocarbons and nitrogen oxides produced by automobiles and factories. Photochemical smog has high concentration of oxidising agents and is, therefore, called as **oxidising smog**.

Acid rain

The gases like SO_2 and NO_2 emitted from various industries react with moisture present in the atmosphere to form corresponding acids. It means that rain water becomes acidic and this is called acid rain. They slowly fall down on the earth as acid rain during snow fall or normal rainfall and the pH is generally less than 5.6.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$2Cl_2 + 2H_2O \longrightarrow 4HCl + O_2$$

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$4\,NO_2 + O_2 + 2\,H_2O \longrightarrow 4HNO_3$$

Harmful effects of acid rain

1. Acid rain makes the soil more acidic and thereby reduces the fertility of the soil.
2. It affects the growth of crops, plants, etc.
3. It affects the survival of fishes and reduces the population of aquatic species.
4. It badly damages to buildings, vehicles, structural materials, etc.
5. It affects human being's life system and organs like skin, lungs and hair.
6. It damages the memorable monuments, buildings, etc. The famous 'Taj Mahal' is being affected severely.
7. It causes corrosion in metal.
8. Acid rain damages automobiles coatings and oil based paints.

Green house effect

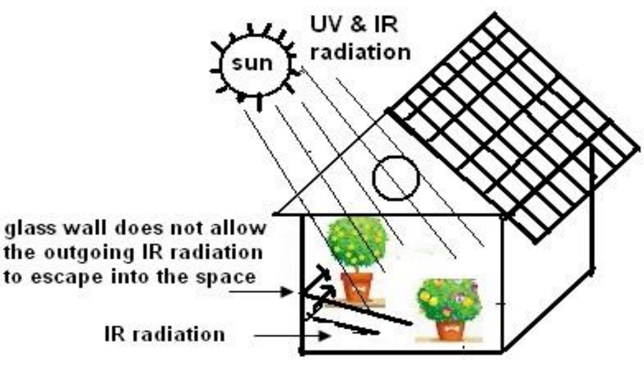
The earth surface gets warmed due to the blanketing effect of pollutants like CO_2 present in the atmosphere. It is known as greenhouse effect. Several radiations like UV, visible and infra-red rays from the sunlight reaches the earth surface and produce heat energy. Some of the heat that is absorbed by the earth's surface is radiated back into the space. The pollutants like CO_2 and other gases become dense and form a thick layer like blanket around the earth. This prevents the heat energy to escape from the surface of earth. Hence the earth gets warmed and this is called Green House Effect. It is similar to green glass houses where heat radiation cannot escape from them.

Gases that cause greenhouse effect are mainly CO_2, methane, water vapour and chlorofluoro carbons (CFC). These gases are called greenhouse gases.

Impacts of greenhouse effect:

Global warming

The warming up of the earth's surface due to greenhouse effect is termed as global warming. CO_2 and other greenhouse gases present in the atmosphere trap the infrared radiation from the sun and do not allow the radiations to escape. Hence the earth's surface is warming up more and more and the average temperature of the globe increases around 0.4° C year after year.



Green House effect

Harmful effects of global warming caused by Greenhouse effect:

1. Evaporation process of surface water is enhanced very much due the increase in temperature of earth's surface which leads to drastic seasonal change. Some region of the world would become dry.
2. Sea level is increased due to melting of glaciers. Hence, low lying land areas will be submerged under sea water.
3. Biological productivity also decreases due to global warming. Food chain is mainly affected and it leads to drought.
4. The tropical diseases like malarial fever, dengue fever and cholera will spread to the other parts of the world.
5. It causes drastic change in seasons. Hence, human beings and animals are mostly affected by climatic change.
6. Natural calamities like cyclones, hurricane, typhoons and tsunami may frequently and strongly occur.
7. Because of global warming, the normal weather pattern is disrupted. Some parts of the world will face severe water crisis while the other parts will suffer from flooding. Spring arrives earlier in many parts of the world. An early spring may disturb animal migration.

OZONE LAYER

One of the gifts given by nature is ozone layer. It is present about 20 km above the earth's surface in stratosphere. It forms a layer of about 3mm thickness called ozone layer. Oxygen is converted into ozone by photochemical change as follows.

$$3\,O_{2\,(g)} \xrightarrow{\text{Radiation}} 2\,O_{3\,(g)}$$

The region in which O_3 density high is called ozone layer.

Importance of Ozone layer

1. Ozone layer covers the earth's surface and prevents the entry of harmful UV radiation. It saves the lives of human beings and animals, otherwise no life can be found on earth.
2. If the ozone layer is not present in the atmosphere, the harmful UV radiations will enter the earth. This will change the global temperature, wind pattern, rain fall, climatic change, and ultimately destroy human and animal life.

Causes for depletion of ozone layer

Chlorine plays a vital role in the depletion of Ozone layer. Chlorofluoro Carbons (CFC) are released from the supersonic jets, air crafts and jet engines. They get accumulated at high altitude and undergo decomposition in the presence of ultraviolet radiations. Chlorine free radical is the main decomposition product. It reacts with the ozone and converts it into oxygen.

Free radical chlorine converts the ozone molecules into oxygen in the presence of UV radiation as follows.

$$.Cl + O_3 \longrightarrow ClO. + O_2$$

$$ClO. + O. \longrightarrow .Cl + O_2$$

It is noteworthy that one atom of chlorine may convert huge number of molecules of ozone into oxygen. **One atom of chlorine can convert about 10^6 molecules of ozone into oxygen**. The other gases which cause ozone layer depletion are NO and NO_2.

Harmful effects of ozone layer depletion

1. Due to ozone layer depletion, the harmful UV radiation may enter freely into the earth's surface and affect the lives on earth.
2. They affect human beings and cause skin cancer, skin aging, breast cancer, lung cancer, eye defects and visual defects.
3. They reduce the population of aquatic species.
4. They affect the growth of plants and vegetables.
5. They affect the eco-system very badly.
6. The sea food production also decreases due to the depletion of ozone layer.
7. Depletion of ozone layer causes the change in earth's climate, wind pattern, rainfall and global warming.

Control of air pollution

"Prevention is better than cure". Similarly, it is better to control the air pollutants at the source itself.

The following are the steps to be taken for controlling air pollution.

1. The exhaust gases from automobiles and vehicles should be minimized by the use of catalyst.
2. Tall chimneys may be used to reduce the concentration of pollutants at the ground level.
3. Smoke may be removed by Cottrell's electrostatic precipitator (Refer Application of Colloids).
4. Dust particles can be removed by the use of bag filters and dust separators.
5. The use of coal, wood and traditional fuels should be slowly reduced. Solar energy, tidal power, nuclear power and electricity should be used for domestic and industrial purpose.
6. Acid and chemical fumes are absorbed in water, concentrated and reduced.

7. Growing of trees reduces more pollution as well as the harmful carbon dioxide concentration in the atmosphere. Plants take carbon dioxide during photosynthesis and releases oxygen to environment. Hence, more trees should be planted.

RECAP

In this lesson,air pollution,

- acid rain, greenhouse effect,
- global warming, ozone layer depletion,
- harmful effects and methods to control the air pollution are discussed.

ACTIVITY

Ask the students to submit a report: Collecting air samples/data from various towns nearby area from District Environmental office. In their study, they may be reported the factors like causes, reasons and suggestions to control air pollution.

EXERCISE FOR BETTER UNDERSTANDING

ORAL TESTING

1. Classical smog is also called oxidizing smog. True/ False
2. CO_2 is a pollutant. True/ False
3. Green house effect is caused by Green trees. True/ False
4. The only health effect of ozone pollution is coughing. True /False
5. Automobiles contribute a lot to air pollution problems. True/ False

TEST PAPER-1

PART-A

1. Which air pollutant is a source from petroleum industries?
2. What is meant by classical smog?
3. Give one importance of ozone layer?

PART-B

1. Write the Harmful effects of acid rain.
2. Explain any two air pollutants and its harmful effects.

PART-C

1. Describe how to control air Pollution.
2. Write all the Harmful effects of Green House effect.

TEST PAPER-2

PART-A

1. What is Photochemical smog?
2. Which air pollutant is a source from cement industries?
3. What is Green House Effect?

PART-B

1. How ozone layer is depleted?
2. Write any two Harmful effects of acid rain.

PART-C

1. Describe the Harmful Effects of air pollutants.
2. Describe Global warming.

BROADEN YOUR UNDERSTANDING

https://www.youtube.com/watch?v=yGXlNHfUUzQ&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=1

TEST YOUR UNDERSTANDING

Discuss the various techniques employed for the control of air pollution.

FACT STORE (Beyond the scope of examination):

- What is cataract? The galactose accumulates in human body in brain, liver and eyes leads to the formation of cataract, an opacity of the optic lens.
- Diabetes is the result of the inability of the pancreas to provide adequate insulin which regulates glucose concentration in the blood
- Every year, environmental risks such as indoor and outdoor air pollution, second-hand smoke, and take the lives of 1.7 million children under 5 years – 26% of child deaths.
- Inhaling air pollution takes away at least 1-2 years of a typical human life.
- It has effects as small as burning eyes and itchy throat to as large as breathing problems and death.
- In November 2019, hundreds of Indians took to the streets in New Delhi to protest the levels of air pollution, after the city was blanketed in a dark yellow haze for several days.
- Four months later(March and April 2020), the skies are now clearing up- a potential vulnerability to the coronavirus pandemic -- a severe respiratory disease.
- Preventive measures of Corona virus – SMS (Sanitizer, Mask and Social distance)

5.2 WATER POLLUTION

Causes of Water Pollution – Sewage, Effluents, Algae and Microorganisms – Harmful effects – Definition – Sewage-sewerage Disposal – Industrial Effluents – Harmful effects of Effluents –Treatment of Effluents-Eutrophication-definition-harmful effects. **– 4 Hours**

INTRODUCTION

Water is more important for all living things. Water is essential for the plants to grow. If the water is contaminated with any foreign substance, it is harmful to human beings, plants, animals, etc.

Water Pollution

Water Pollution may be defined as the excessive discharge or addition of unwanted and undesirable foreign matters into the water that cause huge damage to the life and properties of human, plants and animal.

Causes of water pollution

The main sources of water pollution are

1. Sewage
2. Effluents
3. Algae and
4. Microorganisms

Sewage

Sewage is the liquid waste of the community which includes human wastes, kitchen wastes and street washings.

Harmful effects of sewage

1. Hydrogen sulphide gas is produced in the sewage due to the decomposition of organic impurities which gives a unpleasant smell.
2. Due to corrosive nature, it affects the pipelines.
3. It helps for the growth of harmful bacteria and viruses and may cause many diseases like cholera, jaundice, etc.
4. The enrichment of nutrients like nitrates and phosphates in sewage water which causes the growth of aquatic plants which releases the toxic chemicals .This affects the aquatic lives.
5. The solid waste in it reduce the flow of water and block pipe lines stagnant.
6. The aquatics like fish die due to lack of oxygen in sewage. The biological oxygen demand is increased.
7. It also affects the nature and fertility of the soil and affects the food production.

Sewerage (Treatment of sewage):

Removal of sewage by some treatment methods is called sewerage. It involves the following steps.

1. The floating impurities can be removed by mesh screens.

2. The suspended impurities can be removed by filtration and coagulation process using Alum.
3. Inflammable organic impurities can be removed by oxidation process.
4. By neutralization method, the corrosive acids and bases can be removed.
5. The bacterial impurities can be removed by chlorination.
6. The water left out from the sewage can be treated by suitable purification method and can be used for other purposes.
7. By passing oxygen the oxidisable matter is removed.
8. It is treated with lime to remove phosphorous as calcium phosphate.

Algae & Micro-Organism

Algae are a type of plant that can make food from sunlight by photosynthesis. They are unicellular.

Harmful effects of algae

1. Presence of algae in water produces foul odour and bad taste to water.
2. They block the pipelines and filters.
3. They affect the aquatic animals due to depletion of oxygen.

Treatment of algae

1. The growth of algae can be controlled by using algaecide like copper sulphate.
2. The algae can be destroyed by using chemicals like bleaching powder, activated carbon and lime.
3. The growth of algae can also be controlled by preventing the sunlight to fall on the surface of water.

Microorganisms

Unicellular or multicellular organisms which are microscopic, which means so small that people cannot see them with naked eye. Ex. Bacteria, virus and fungi.

Harmful effects and control of microorganisms (Bacteria and viruses)

1. They cause diseases like cholera, jaundice, typhoid, etc.
2. They are destroyed using disinfectants like bleaching powder and chlorine.

Effluents

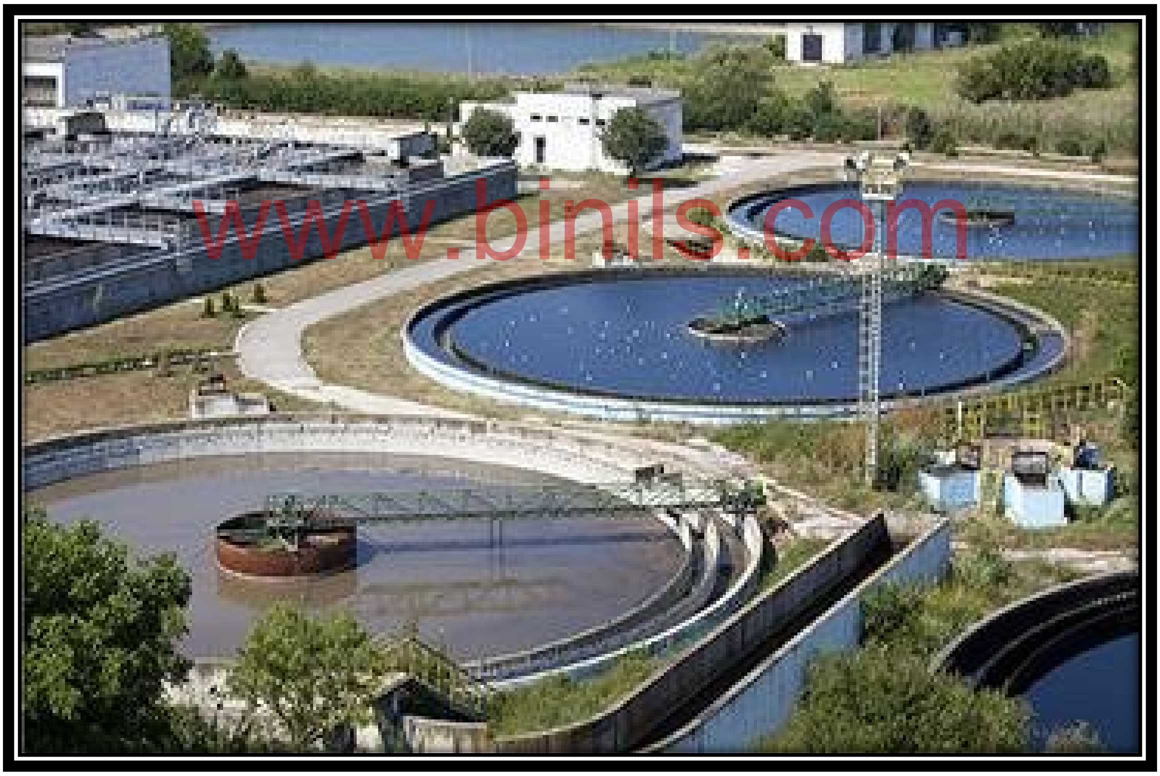
The waste water from various industries containing harmful chemicals. This Industrial waste water is known as effluent.

Harmful effects of effluents

1. It corrodes the pipelines due to acidic nature of effluents
2. The effluents may enrich the acidic nature of the soil and affect the fertility of the land and growth of plants
3. Inflammable substances like alcohol and ether may cause severe effects and fire accident

4. It may cause severe damage to aquatic animals
5. Inflammable substances like alcohol and ether may cause severe effects and fire accident.
6. The metals present in the effluent may seriously affect the human organs like kidney, brain, etc.
7. The effluents of chemical industries and nuclear power stations may affect the health of human beings and animals.
8. The phosphates and nitrates cause Eutrophication.
9. The metallic pollutants like Cu, Pb, Cd present in the effluents affects the health.
10. Accumulation of iron and manganese can cause paralysis. Mercury, when goes beyond 0.3 ppm damages nervous system. Zinc induces diarrhea, dizziness and vomiting. Copper destroys aquatics. Cadmium leads to renal failure when exceeds 0.01 ppm.
11. The organic impurities help the growth of disease causing microorganisms like bacteria, virus and protozoa and produces diseases like cholera, jaundice and typhoid.

A MODEL EFFLUENT TREATMENT PLANT



Treatment of effluents

1. Toxic nature of effluents may be removed by chemical methods.
2. The acidic nature and basic nature of the effluents may be removed by neutralization.
3. The radioactive effluents are carefully stored and buried under the ground.
4. The heavy metallic impurities may be removed by special chemical methods.
5. The toxic nature of metals can be removed by selective adsorbents.
6. The organic impurities may be removed by biochemical methods.

7. Mercury is removed by amalgamation using electrochemical method

$$2NaCl + 2Hg \longrightarrow Cl_2 + 2NaHg$$

Eutrophication:

It is a natural process. It is derived from Greek word "Eutrophos" which means well nourished (or) enriched. This enrichment leads to another slow process referred to as "natural aging of lakes". The agricultural waste water containing nutrients enrich the water bodies in ponds and lakes. Eutrophication is also due to the contamination of sewage water from agricultural land, domestic detergent wastes, containing nitrogen compounds and phosphates into lake water. It enhances the growth of algae. This leads to eutrophication. In brief **"Eutrophication means natural aging of lakes".**

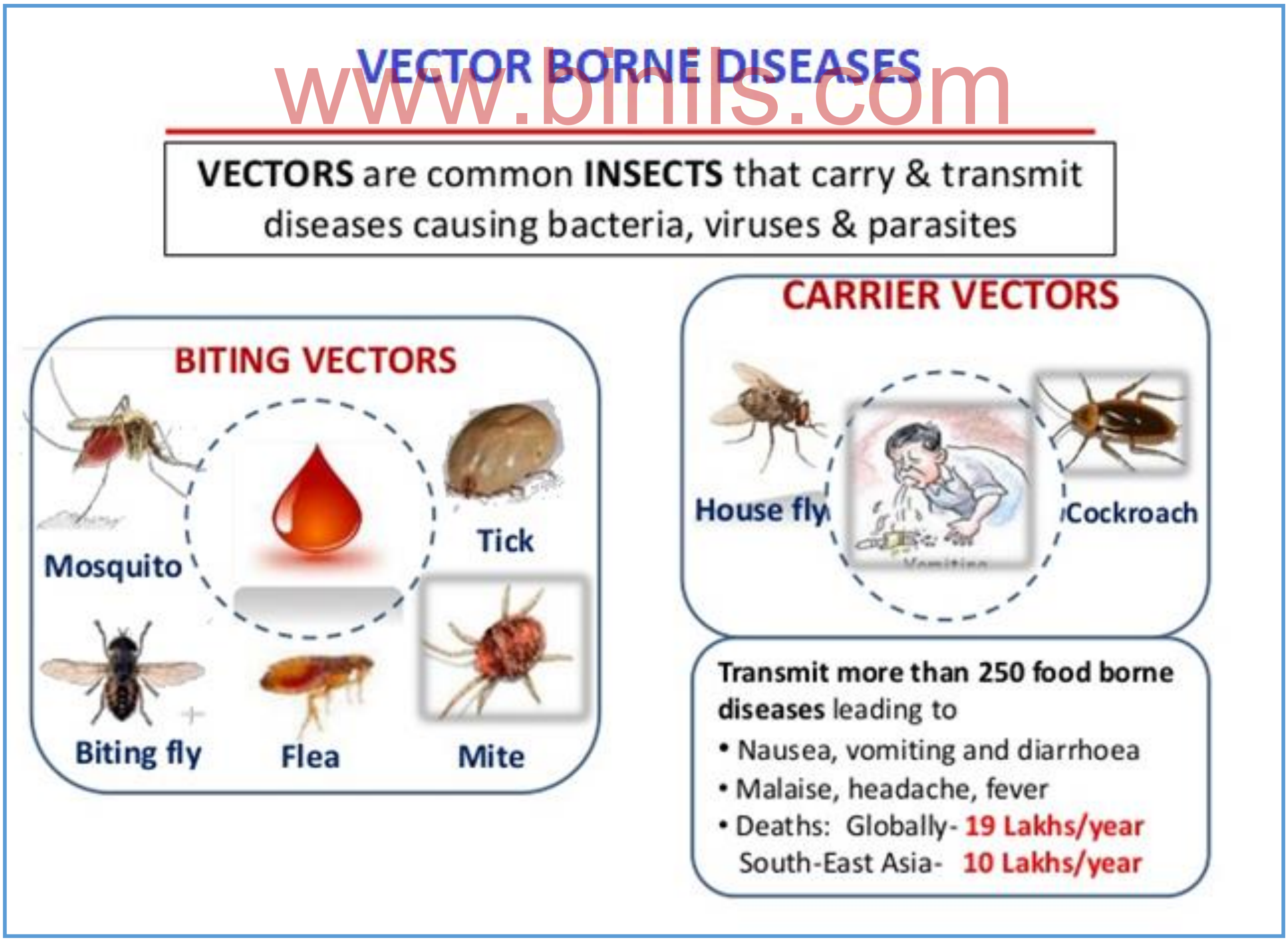
The ageing of lake and pond by the enrichment of nutrients is called eutrophication.

Harmful effects of eutrophication

1. It enhances the growth of algae in water which leads to depletion of oxygen in water. Algae release the toxic chemicals. It affects the aquatic animals badly.
2. When the oxygen level falls to zero, the sulphates are reduced to H_2S.
3. It produces bad taste and odour after it decays.
4. It blocks the pipelines and filters.
5. It admits the growth of bacteria and viruses. It may spread water borne disease like dysentery, cholera, Typhoid, yellow fever which affects human beings.
6. Phyto planktons are destroyed. It causes an imbalance in eco-system based on water resources.
7. Population of aquatic animals is reduced.
8. Algal toxin accumulated in shell fish are harmful to human system. They produce paralysis, diarrhea and stomach disorder.
9. Algae and other rooted weeds clog the water filters. They also cause damage to hydroelectric engine

WATER-BORNE DISEASES

Disease Caused by Drinking Polluted Water



VECTOR BORNE DISEASES

VECTORS are common **INSECTS** that carry & transmit diseases causing bacteria, viruses & parasites

BITING VECTORS

CARRIER VECTORS

Transmit more than 250 food borne diseases leading to

- Nausea, vomiting and diarrhoea
- Malaise, headache, fever
- Deaths: Globally- **19 Lakhs/year**
  South-East Asia- **10 Lakhs/year**

RECAP

In this lesson following topics are discussed:

- water pollutants like sewage
- effluents,
- eutrophication, their causes, problems and
- rectification methods.

ACTIVITY

Ask the students (3 or 4 in a group) to collect samples of effluents from industries nearby area. Report the metallic industrial effluent present in it and its harmful effects.

EXERCISE FOR BETTER UNDERSTANDING

ORAL TESTING

1. Humans can live without water (TRUE/FALSE).
2. Only a tiny fraction of the Earth's water is usable by humans (TRUE/FALSE).
3. There are mountains in the ocean (TRUE/FALSE).
4. 80% percent of the Earth's surface is covered with water(TRUE/FALSE)
5. Rainwater is made up of pure water (TRUE/FALSE).

TEST PAPER-1

PART-A

1. What is microorganism?
2. Which is called natural ageing of lakes?
3. Give any one harmful effects of algae?

PART-B

1. What are the causes of water pollution?
2. Explain briefly any two method of treatment of effluents

PART-C

1. Describe briefly about Sewerage.
2. Explain Harmful effects of sewage.

TEST PAPER-2

PART-A

1. Give any one source of water pollution
2. Write any one treatment method of sewage.
3. Give one Harmful effects of micro-organism

PART-B

1. Write the harmful effects of sewage
2. Give any two harmful effects of effluents

PART-C

1. How are effluents treated?
2. Write the Harmful effects of eutrophication.

FACT STORE

- Only 1% of our planet's water supply can be used. 97% is ocean water and 2% is frozen solid in the Artic, for now.
- When you throw plastic bags or other plastic material into the ocean, it kills as many as 1 million sea creatures annually.
- Fresh **water** on earth is only 2.5% of the total **water** when 70% of the earth's surface is covered by **water**.
- Around 70% of industrial waste is dumped to **water**.
- 80% of the **water pollution** is caused due to domestic sewage.
- More than 6 billion pounds of garbage, mainly plastic end up in the oceans every year.

TEST YOUR UNDERSTANDING

Discuss various methods of waste water treatment.

Broaden your understanding:

Click the following link into a browser or scan the QR code

https://www.youtube.com/watch?v=Uc3YsodLcco&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index

5.3 SOLID WASTE MANAGEMENT AND GREEN CHEMISTRY

Solid Waste – Definition – Problems – Types of Solid Waste – Methods of disposal – Land fill and Incineration – Recycling –Definition – Examples – Advantages of Recycling (Basic ideas**)** - Green Chemistry **-** Definition – Goals of Green Chemistry (Basic ideas). **– 4 Hours**

Introduction

Annual municipal waste in India is about 280 million tons per year and is creating huge problems for the country. Hence there is an urgent need to tackle this problem.

Solid waste

Any substance that is discarded is called waste. The waste may be solid, liquid of gaseous substances. The solid waste arises from human life style and animal activities.

Solid waste is a substance which is left of from industries, kitchen or other waste and thus thrown away. They can cause hazard to human health and environment. Hence, there is an urgent need for the management of solid waste.

Solid waste management is the collection of wastages, transporting, processing, recycling and monitoring of the waste materials to reduce their effect on health and environment.

Types of solid waste

Various types of solid wastes are

Sl. No.	Types	Examples
1	Commercial garbage	Bricks, cement, sand, etc.,
2	Agricultural waste	Herbicides, pesticides, crop residue, animal and poultry waste, etc.,
3	Rural waste	Bagasse, cow dung garbage, rice husk, etc.,
4	Plastic waste	Plastic toys, cosmetics, food packaging, etc.,
5	Medicinal waste	Cotton containing blood, dressing linen, syringes, waste medicines, etc.,
6	Domestic waste and e-waste	Food waste, plastics, computer, TV, broken bottle, ceramic materials, metallic containers, kitchen waste, etc.,
7	Municipal garbage	Food waste, plastics, metals, paper and paper board, etc.,
8	Industrial waste	Products of iron, cadmium, tin, lead, arsenic, mercury, radioactive materials, etc.,

Problems caused by solid waste

1. Air becomes unclean with foul smell.
2. The biomedical waste causes infectious disease and gives bad smell.
3. Human health is affected.
4. Pollutes the air, land and ground water.

5. Contaminate the environment.
6. Affects the climate.

Hence, there is an urgent need for the management of solid waste.

Solid waste management is not fully implemented because of

1. Lack of education and awareness
2. Lack of motivation
3. Resistance to change
4. Non co-operation from house holds
5. Lack of knowledge on benefits of segregation

Role of private sector organizations

The private sector can play an important role in construction, operation and maintenance of treatment and disposal facility. NGO's can also play an important role in,

i. Organizing rag-pickers/waste collectors for door-to-door collection and segregation of waste.

ii. Creating public awareness for storage of organic and recyclable waste separately at source and handing over the waste to waste collector.

Rag-pickers could be involved in door-to-door collection of municipal solid waste as well as recyclable waste, so that they could get a user fee for collecting waste from the doorstep and derive additional income from sale of recyclables.

Methods of disposal of solid waste

The waste management concepts includes 1. Reduce 2. Reuse 3. Recyle

The aim of waste management is to extract maximum benefit from the wastes and to reduce the amount of waste. The final disposal of solid wastes can be carried out by the following methods.

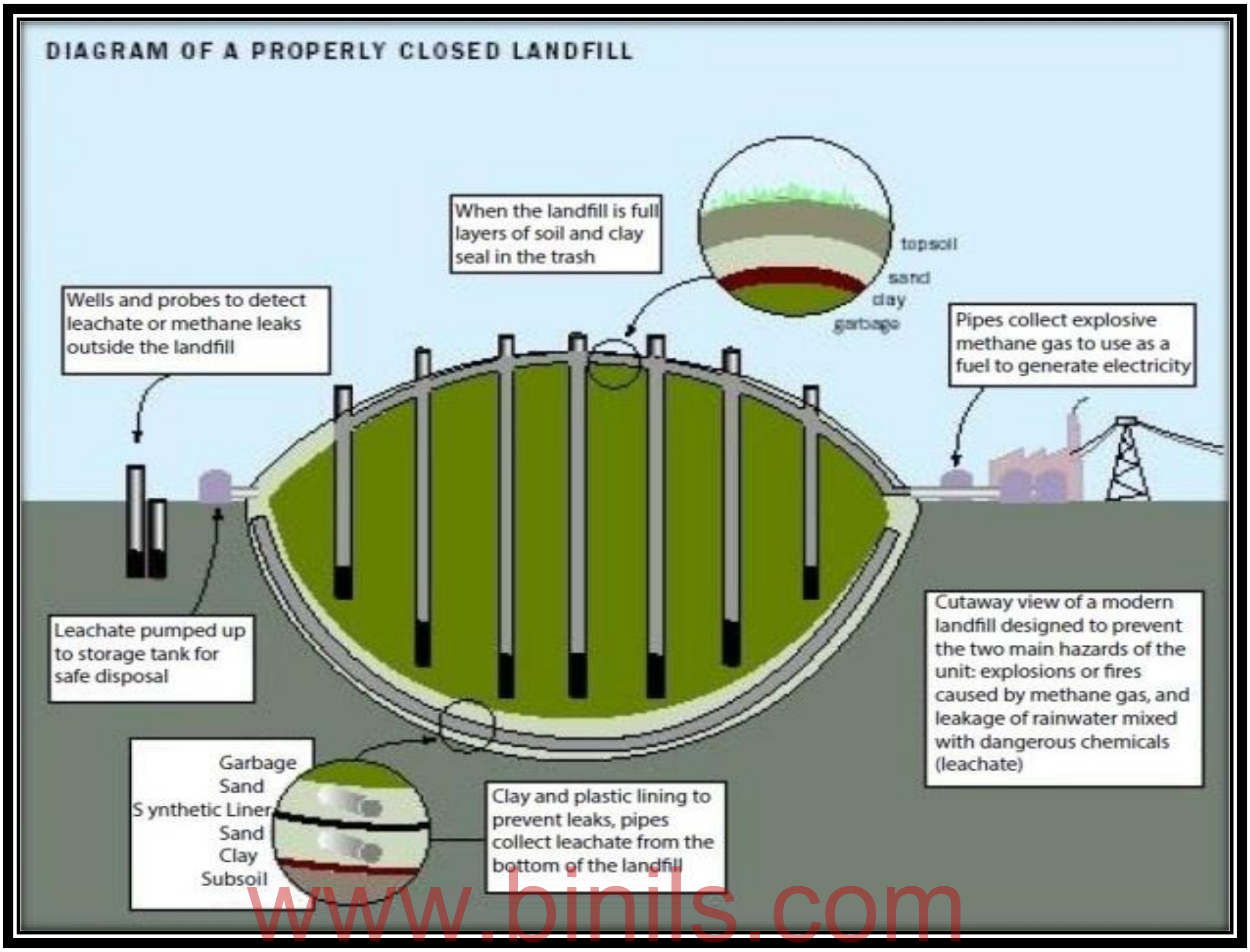
1. Land fill

This operation had been the practice in all villages to obtain natural compost. In this method, waste is buried underground and covered with soil. Landfills were often established in abandoned areas.

Modern land fill contain a series of three dimensional control cells. The wastes dumped in the appropriate cells can be covered by a layer of soil at the end of each day. Below the wastes dumped in the cell, a double liner system is provided to prevent the leachates from polluting the soil and ground water beneath the site. The upper liner must be a well flexible membrane lining made of plastic or rubber. The waste dumped transforms into natural manure and can be used for crop production.

A properly designed and well managed land fill can be a hygienic and relatively inexpensive method of disposing of waste materials.

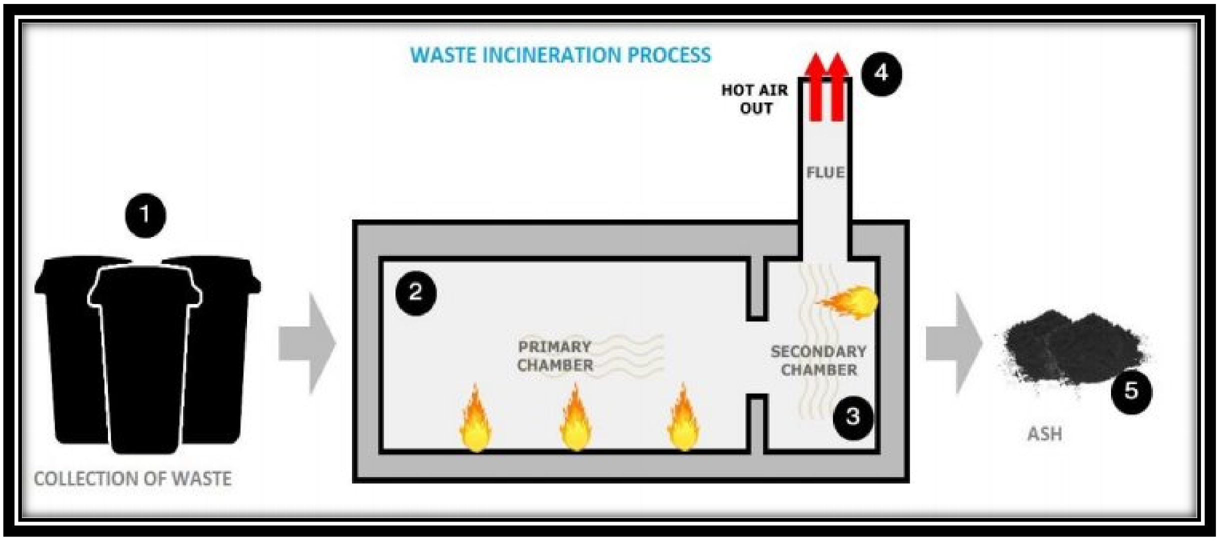
Poorly designed landfills can create a number of adverse environment impacts such as wind-blown litter. Harmful gases like methane are given off from land fill sites that cause air pollution and contribute to global warming.



2. Incineration

Incineration is a waste treatment process that involves the combustion of solid waste at 1000° C. Waste materials are converted into ash, flue gas and heat. The ash is mostly formed by the inorganic constituents of the waste and gases due to organic waste. The heat generated by incineration can be used to generate electricity.

This process reduces the volumes of solid wastes to 20-30 percent of original volume.



Incineration plant

The advantages of incineration

1. It reduces the waste to 75% by weight.
2. It destroys pathogenic micro organisms.
3. It also serves as an energy resource.
4. This converts waste into useful heat, gas, steam and ash

3. Recycling

Recycling is a process of converting used materials (waste) into new useful and valuable products. This process is carried out to,

1. prevent wastage of potentially useful materials
2. Reduce the consumption of fresh raw materials
3. Reduce energy usage
4. Reduce air pollution and water pollution

'4R' PRINCIPLES

Recycling reduces the need for "conventional" waste disposal methods and there by lower greenhouse gas emissions. Recycling is a key component of modern waste reduction and adopts **'4R' principle** as follows "Reduce, Reuse, Recycle and Recover" waste.

Recycling refers to the collection and reuse of waste materials. Materials for recycling may be collected from general waste and reprocessed into new products.

Examples of recycling

1. Used paper can be converted into new paper, like paper plate making.
2. Used foamed polystyrene can be converted into new polystyrene, for packaging.
3. Used aluminium containers can be converted into new containers.
4. Kitchen scraps can be used to make compost (Compost is an organic material that adds nutrients to soil).
5. Used glass containers can be converted into new glass containers.
6. Metal scraps can be converted into new materials.

Advantages of recycling

1. It helps in the conservation of natural resources.
2. It protects the environment of the area. The recycling is eco-friendly.
3. It protects our health.
4. It makes the air clean and free from foul smell.
5. It reduces the pollution of water bodies.
6. It saves lot of energy.
7. Forests are saved by recycling the waste paper. This minimizes the global warming.

8. Subsidy on products generated from recycling will encourage socio economic savings and bring awareness.
9. Recycling aims towards ‘zero waste’ movement in the society and protects environmental health.

GREEN CHEMISTRY

The chemical industries produce a large number of products that make invaluable contribution in our daily life. It improves the quality of lives and comforts. During the manufacture of such products, the chemical industry also releases enormous quantities of environmentally harmful wastes. It results in pollution. Hence, chemistry in particular, has lost some of its glamour in the public eye. The concept of green chemistry is the most innovative method for preventing pollution.

Green chemistry

Green chemistry is defined as the design of environment friendly products and process to minimize or remove hazardous substances. **The chemistry which is used to prevent pollution is called as Green chemistry.**

Natural processes are ‘green’ while synthetic processes are often ‘grey’. Cleaner process and cleaner synthesis will certainly contribute to better environmental protection.

Goals of green chemistry

Some guidelines may be given while choosing the reactants, products and designing the processes to achieve the goals of green chemistry.

$$A + B \xrightarrow{\text{Process}} C + D \text{ (waste or by product)}$$

Reactant (Resources) Product

Resources

1. To prevent the formation of waste material before it is formed.
2. To make use of renewable materials as raw materials rather than depleting during the process.
3. New methods should be developed to convert almost all the reactants used in the processes into the final product.

Process

4. To design synthetic methodologies that does not give toxic chemicals.
5. To perform the process in a safe and controlled way.
6. To reduce the quantity of highly hazardous chemicals during the process
7. To avoid the usage of auxiliary substances (solvents) wherever possible.
8. To ensure the conduction of synthetic methods at ambient temperature and pressure.
9. Using the non-conventional energy like solar and wind energy

Products

10. To reduce the formation of byproducts which are harmful..
11. The products should be recyclable.

RECAP

In this lesson,

- various types of solid wastes
- their problems and need for the management and
- methods of management
- recycling, examples of recycling and its advantages
- green chemistry, goals of green chemistry are discussed.

EXERCISE FOR BETTER UNDERSTANDING

ORAL TESTING

1. Landfills are de-facto choice for waste management and they cause lots of problem for the environment (TRUE/FALSE)
2. There is a high demand for compost in a market (TRUE/FALSE)
3. Understanding of social and legal aspects is not necessary in Solid waste management (TRUE/FALSE)
4. Waste is a material that has further value to his owner and is not thrown away(TRUE/FALSE)
5. Athens was the first city to an established system of waste removal(TRUE/FALSE)

TEST PAPER-1

PART-A

1. Define waste.
2. Define solid waste.

PART-B

1. Write briefly about any two types of solid waste.
2. What are the ‘4 R’s principle in solid waste management?

PART-C

1. Describe briefly about the advantages of recycling.
2. Explain the problems caused by solid waste.

TEST PAPER-2

PART-A

1. What the name of the method of disposal of solid waste is by buried and covered with soil?
2. Give one advantage of recycling?
3. Give one advantage of incineration method?

PART-B

1. Write short notes on a)industrial waste b) e-waste
2. What are the role of NGO's in solid waste management?

PART-C

1. Describe the role of private sector organisation in SWM?
2. Elaborate the goals of Green chemistry.

FACT STORE

Every year we dump a massive 2.12 billion tons of **waste.**

Zero Waste is a set of principles focused on **waste** prevention that encourages the redesign of resource **life** cycles so that all products are reused. The goal is for no trash to be sent to landfills, incinerators, or the ocean. ... **Zero waste** is more of a goal or ideal rather than a hard target.

Coloured bins for **different** waste:

Blue bin is for recyclable plastic and metal waste

Brown bin is for kitchen and garden waste.

Grey bin is for non-recyclable waste

Yellow bin must be **used** for the storage of soft **clinical waste** contaminated with infectious or potential infectious blood or bodily fluids.

Red Bin for disposal of bio hazardous **waste**

BROADEN YOUR UNDERRSTANDING

https://www.youtube.com/watch?v=sMeUGwpvLtk&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=3

https://www.youtube.com/watch?v=KHlOXta9Q4U&list=PL1b9Ht9ISqIEmoksyUA5Ab5WRuhWgB5V5&index=4

TEST YOUR UNDERSTANDING

1. Think of a project – How electricity can be produced from garbage?
2. Think of a project – How manure can be produced from garbage?

FREQUENTLY ASKED QUESTIONS

UNIT – V

Part –A

1. Give an example for air pollutants
2. Name any two examples for greenhouse gases.
3. Mention the name of the pollutants responsible for depletion of ozone layer?
4. Write any one causes of pollution.
5. Which gas is responsible for acid rain?
6. Give an example for gases causing acid rain.
7. Give one example for greenhouse gases.
8. What is global warming?
9. What is smog?
10. Mention one harmful effect of SO_2.
11. Mention one harmful effect of H_2S.
12. Which air pollutant comes out from petroleum industries?
13. What is meant by classical smog?
14. Give one importance of ozone layer?
15. What is Photochemical smog?
16. Which air pollutant is expelled out from cement industries?
17. Give an example for water pollutants.
18. What is Sewerage?
19. What is Sewage?
20. Name any one source which causes water pollution.
21. What is the name given for ageing of lake and pond by enrichment of nutrients.
22. What is eutrophication?
23. What is microorganism?
24. Which is called natural ageing of lakes?
25. Give any one harmful effects of algae?
26. Give any one source of water pollution
27. Write any one treatment method of sewage.

28. Give one Harmful effects of micro-organism
29. Give an example for rural waste?
30. Write any one example for e-waste?
31. Name any one method employed for disposal of solid waste?
32. What is Incineration?
33. Which chemistry is used to prevent pollution?
34. Define waste.
35. Define solid waste.
36. Why solid waste management is not fully implemented?
37. What the name of the method of disposal of solid waste is by buried and covered with soil?
38. Give one advantage of recycling?
39. Give one advantage of incineration method?

Part – B

1. What is acid rain?
2. Mention the harmful effects of acid rain.
3. What is greenhouse effect?
4. Mention the harmful effects of global warming.
5. What is the importance of ozone layer?
6. Mention the harmful effects of ozone layer depletion.
7. How is ozone layer depleted?
8. What are the causes of water pollution?
9. Explain briefly any two method of treatment of effluents
10. Write the harmful effects of sewage
11. Write a note on sewage disposal.
12. Mention the harmful effects of effluents.
13. Mention the harmful effects of algae. How is it controlled?
14. Mention the harmful effects of microorganisms. How is it controlled?
15. Mention any three harmful effects of eutrophication
16. Write briefly about any two types of solid waste.
17. Write short notes on a)industrial waste b) e-waste
18. What are the role of NGO’s in solid waste management?
19. What are the 4 R’s principle in solid waste management?
20. Write a note on landfill.
21. Write a note on incineration.
22. Write the advantages of recycling.

Part - C

1. What are the major air pollutants? Give their source and harmful effects.
2. What is acid rain? Mention its harmful effects.
3. Write a note on greenhouse effect.
4. What is global warming? List its harmful effects.
5. What are the causes of ozone layer depletion? List the problems caused by ozone layer depletion.
6. Write a note on control of air pollution.
7. Describe the Harmful Effects of air pollutants.
8. Describe Global warming.
9. Describe how to control air Pollution.
10. Write all the Harmful effects of Green House effect.
11. What are the major water pollutants? Give their harmful effects.
12. What is sewage? What are its harmful effects? How is it disposed?
13. What are effluents? Explain the problems and treatment of effluents.
14. Define eutrophication. Mention its harmful effects.
15. Describe briefly about Sewerage.
16. Explain Harmful effects of sewage.
17. How effluents are treated?
18. Write the Harmful effects of eutrophication
19. List the different types of solid wastes. Explain their origination.
20. Mention the problems caused by solid waste.
21. Explain the two methods of disposal of solid waste.
22. Define Green chemistry. What are the goals of green chemistry?
23. Describe briefly about the advantages of recycling.
24. Explain the problems caused by solid waste.
25. Describe the role of private sector organisation in Solid Waste Management
26. Elaborate the goals of Green chemistry.

ENGINEERING CHEMISTRY II
MODEL QUESTION PAPER-1

Part A

NB: 1. Answer all questions **5 X 1= 5 Marks**

2. All questions carry equal marks

1. What is one Faraday?
2. What is called Galvanisation?
3. What is meant by producer gas?
4. Define e-coli?
5. What is meant by smog?

Part B

NB: 1. Answer any 10 questions **10 X 2= 20 Marks**

2. All questions carry equal marks

6. Define Faraday's I law of electrolysis.
7. Mention the anode and cathode of Lithium ion battery.
8. Write down the cell notation of Daniel cell.
9. Define corrosion.
10. What is meant by galvanizsation?
11. What are luminescent paints?
12. Mention the composition of LPG.
13. Write down the equation for the calculation of finding theoretical quantity of oxygen required for the combustion of 1kg of a fuel containing carbon, hydrogen, sulphur and moisture?
14. What are rocket propellants?
15. What is called a bio material?
16. What is harness of water?
17. How will you remove temporary hardness of water?

18. What are green house gases?

19. Define eutrophication.

20. Define green chemistry.

PART C

NB: 1. Answer all questions **5 X 15= 75 Marks**

2. Answer any one of the subdivisions either (a) or (b) from each question

21. (a) (i) What are the industrial applications of electrolysis. (7)

(ii) What is a secondary battery? Explain the working principle of lead acid battery. (8)

(or)

(b) (i) Explain the cell reactions in Daniel cell. (7)

(ii) What is Fardays's second law of electrolysis. During electrolysis of silver nitrate, 4.029g of silver was found to get deposited over the cathode. How much time is required to get the deposition when 1 ampere current is passed? (equivalent weight or silver is 108) (8)

22. (a) (i) Explain differential aeration theory of corrosion with suitable example. (7)

(ii) Distinguish between paint and varnish. Explain the preparation of oil and sprit varnish. (8)

(or)

(b) (i) Write notes on cathodic protection. (7)

(ii) What are the types of corrosion. Mention the factors that influences the rate of corrosion. (8)

23. (a) (i) Write notes of refining of petroleum. (7)

(ii) Explain flue gas analysis using Orsat apparatus with a neat diagram (8)

(or)

(b) (i) What are the characteristics of rocket propellants. (7)

(ii) A coal sample contains 80% C, 8% H, 1% S and 3% ash by mass. Find the amount of air required to burn 1 kg of coal (8)

24. (a) (i) Write notes on rain water harvesting. (7)

(ii) When 250 ml of sample of hard water is titrated against standard EDTA of strength 0.01M, it consumed 12.5ml. The same sample after boiling required only 8.5ml of the same EDTA. Calculate the carbonate and non carbonate hardness of the sample in mg/L (8)

(or)

(b) (i) Explain ion exchange process of removing hardness. (7)

(ii) Write a note on dissolved chlorine. (8)

25. (a) (i) What are the harmful effects of global warming? (7)

(ii) What is meant by depletion of ozone layer? Mention their harmful effects. (8)

(or)

(b) (i) Explain land fill operation and recycling of solid waste management. (7)

(ii) Mention the harmful effects of sewage and ways to treat them (8)

ENGINEERING CHEMISTRY II

MODEL QUESTION PAPER-2

Part A

NB: 1. Answer all questions **5 X 1= 5 Marks**

2. All questions carry equal marks

1. What is the cathode of lead acid battery?
2. What is called tinning?
3. What is meant by water gas?
4. What is the maximum limit of TDS in drinking water?
5. Name few green house gases?

Part B

NB: 1. Answer any 10 questions **10 X 2= 20 Marks**

2. All questions carry equal marks

6. Define Faraday's II law of electrolysis.
7. Define electrochemical series.
8. Write down the cell notation of lead acid battery
9. Define corrosion.
10. What is meant by cathodic protection?
11. What are fire retardant paints?
12. Mention the composition of producer gas.
13. Write down the equation for the calculation of finding theoretical quantity of oxygen required for the combustion of 1 kg of a fuel containing carbon, hydrogen, sulphur and moisture?
14. Name few solid propellants.
15. What is caustic embrittlement?
16. What are the main reasons for priming and how it is controlled?

17. Mention the advantages of Ion-Exchange method.

18. What are green house effect?

19. Define global warming.

20. Define green chemistry.

PART C

NB: 1. Answer all questions **5 X 15= 75 Marks**

2. Answer any one of the subdivisions either (a) or (b) from each question

21. (a) (i) Explain electrolysis. (7)

(ii) What is secondary battery? Explain the working principle of lithium cell (8)

(or)

(b) (i) Explain the cell reactions in Daniel cell. (7)

(ii) What is Fardays's second law of electrolysis. During electrolysis of silver nitrate, 4.029g of silver was found to get deposited over the cathode. How much time is required to get the deposition when 1 ampere current is passed? (equivalent weight or silver is 108) (8)

22. (a) (i) Explain rusting of iron and the formation of galvanic cell. (7)

(ii) Distinguish between paint and varnish. Explain components of paint and their function. (8)

(or)

(b) (i) Write notes on special paints. (7)

(ii) Define corrosion. Explain differential aeration theory with example (8)

23. (a) (i) Write notes of refining of petroleum. (7)

(ii) Explain flue gas analysis using Orsat apparatus with a neat diagram (8)

(or)

(b) (i) What are the characteristics of rocket propellants. (7)

(ii) A coal sample contains 80% C, 8% H, 1% S and 3% ash by mass. Find the amount of air required to burn 1 kg of coal (8)

24. (a) (i) Write notes on reverse osmosis process. (7)

(ii) When 250ml of sample of hard water is titrated against standard EDTA of strength 0.02M, it consumed 6.5ml. The same sample after boiling required only 4.5ml of the same EDTA. Calculate the carbonate and non carbonate hardness of the sample and express them in ppm (8)

(or)

(b) (i) Explain the problems caused by hard water in boilers. (7)

(ii) Write a note on drinking water standard. (8)

25. (a) (i) What are the harmful effects of acid rain? (7)

(ii) What is the cause of depletion of ozone layer? Mention their harmful effects. (8)

(or)

(b) (i) Explain land fill operation and incineration of solid waste management. (7)

(ii) Write notes on eutrophication (8)

SEMESTER - II

40007 - ENGINEERING CHEMISTRY – II PRACTICAL

CONTENTS

Intellectual Skills

1. Studying the effect of heating on substances and reagents
2. Study of the reactions of the following radicals leading to qualitative analysis of the given Inorganic simple salt soluble in water or dilute acids
3. Studying the harmful effects of effluents

Acid Radicals : Carbonate, Chloride, Nitrate and Sulphate

Basic Radicals: Lead, Copper, Ferrous, Aluminium, Zinc, Barium, Calcium, Magnesium and Ammonium

Effluent analysis: Effluent containing Lead, copper and Zinc

Motor Skills

1. Handling the apparatus carefully
2. Awareness on Industrial safety

I. Analysis of inorganic simple salt (qualitative analysis)

Analysis of nine inorganic simple salts containing any one acid radical and basic radical without omitting any of the above mentioned radicals.

II. Analysis of effluent containing Lead, Copper and Zinc metal ions (effluent analysis)

Analysis of three effluents, each containing the above mentioned metal ions. Report on the metallic pollutant with procedure (Basic Radical Analysis Procedure) and their harmful effects.

SYSTEMATIC ANALYSIS OF THE GIVEN INORGANIC SIMPLE SALT

Sl. No.	EXPERIMENT	OBSERVATION	INFERENCE
1.	**COLOUR** The colour of the given salt is noted.	a. Blue or bluish green b. White	May be Copper or iron Absence of Copper and iron
2.	**APPEARANCE** Appearance of the given salt is noted.	a. Amorphous b. Crystalline	May be Carbonate Absence of Carbonate

Sl. No.	EXPERIMENT	OBSERVATION	INFERENCE
3.	**SOLUBILITY**		
a	**In dilute HCl acid** A little of the given salt is dissolved in dilute hydrochloric acid in a test tube.	a. Soluble	Absence of Lead
		b. Insoluble	May be Lead
b	**In water** A little of the given salt is dissolved in distilled water in a test tube.	a. Insoluble	May be Carbonate
		b. Soluble	Absence of Carbonate
4.	**ACTION OF HEAT** A little of the given salt is strongly heated in a dry test tube.	a) A white sublimate is formed	May be Ammonium
		b) Yellow when hot and white and when cold	May be Zinc
		c) Orange red when hot and yellow when cold	May be Lead
		d) Reddish brown vapour is evolved	May be Nitrate
		e) Blue changes to white	May be Copper
		f) No characteristic change	Absence of Ammonium, Zinc, Lead, Nitrate and Copper
5.	**FLAME TEST** The paste of the given salt with concentrated hydrochloric acid is introduced into a non-luminous part of the flame and the colour is noted.	a. Bluish green coloured flame	May be Copper
		b. Brick red coloured flame	May be Calcium
		c. Pale green coloured flame	May be Barium
		d. No characteristic coloured flame	Absence of Copper, Calcium and Barium
	B. WET REACTIONS		
6.	**ACTION OF dil. HCl** To a pinch of the salt taken in a test tube dilute hydrochloric acid is added.	a. A colourless gas with brisk effervescence turning lime water milky is evolved	Presence of Carbonate is confirmed
		b. No characteristic gas	Absence of Carbonate

Sl. No.	EXPERIMENT	OBSERVATION	INFERENCE
7.	**ACTION OF Conc. H2SO4** To a little of the salt taken in a test tube few drops of concentrated sulphuric acid is added and warmed.	a. A colourless pungent smelling gas giving dense white fumes with a glass rod dipped in ammonium hydroxide is evolved b. Brown vapour is evolved c. No characteristic reaction	May be Chloride May be Nitrate Absence of Chloride and Nitrate
8.	**ACTION OF Conc. H_2SO_4 AND COPPER TURNINGS** To a small amount of the given salt a bit of copper turnings and a few drops of concentrated sulphuric acid are added and heated.	a. Copious evolution of brown vapours b. No characteristic gas is evolved	May be Nitrate Absence of Nitrate
9.	**ACTION OF Conc. H_2SO_4 AND MnO_2** To a small amount of the given salt a pinch of manganese dioxide and a few drops of concentrated sulphuric acid are added and warmed.	a. A greenish yellow gas is evolved b. No characteristic gas	May be Chloride Absence of Chloride
10.	**CHROMYL CHLORIDE TEST** To a small amount of the given salt few crystals of potassium dichromate and few drops of concentrated sulphuric acid are added and warmed.	a. Reddish brown vapour giving yellow precipitate with a glass rod dipped in lead acetate solution are evolved. b. No reddish brown vapour	May be Chloride Absence of Chloride

C. REACTIONS USING SODIUM CARBONATE EXTRACT

Preparation of Sodium Carbonate Extract

A mixture of one part of the given salt and three parts of solid sodium carbonate is boiled with distilled water for 10 minutes. Cooled and filtered. The filtrate is called sodium carbonate extract.

Sl. No.	EXPERIMENT	OBSERVATION	INFERENCE
11.	**SILVER NITRATE TEST** To a little of the extract dilute nitric acid is added till the effervescence ceases and then silver nitrate solution is added.	a. A curdy white precipitate soluble in ammonium hydroxide is obtained b. No characteristic precipitate is obtained	Presence of Chloride is confirmed Absence of Chloride
12.	**BARIUM CHLORIDE TEST** To a little of the extract dilute hydrochloric acid is added till the effervescence ceases and then barium chloride solution is added.	a. A white precipitate insoluble in concentrated hydrochloric acid is obtained b. No characteristic precipitate is obtained	Presence of Sulphate is confirmed Absence of Sulphate
13.	**LEAD ACETATE TEST** To a little of the extract dilute acetic acid is added till the effervescence ceases and then lead acetate solution is added.	a. A white precipitate is obtained b. No characteristic precipitate is obtained	Presence of Sulphate is confirmed Absence of Sulphate
14.	**BROWN RING TEST** To a little of the extract dilute sulphuric acid is added till the effervescence ceases. To this freshly prepared ferrous sulphate solution is added and then concentrated sulphuric acid is added through the sides of the test tube.	a. Brown ring is formed at the junction of two liquids b. No brown ring	Presence of Nitrate is confirmed Absence of Nitrate

D. IDENTIFICATION OF BASIC RADICALS

Preparation of original solution

The original solution is prepared by dissolving the given salt in distilled water/hot water/dilute hydrochloric acid/dilute nitric acid.

GROUP SEPARATION

1.	To a little of the original solution dilute hydrochloric acid is added.	a. A white precipitate is obtained b. No characteristic precipitate is obtained	Presence of I Group Radical (Lead) Absence of I Group Radical
2.	To a little of the original solution dilute hydrochloric acid and yellow ammonium sulphide are added.	a. A black or brown precipitate is obtained b. No characteristic precipitate is obtained	Presence of II Group Radical (Copper) Absence of II Group Radical
3.	To a little of the original solution ammonium chloride and ammonium hydroxide solutions are added.	a. A gelatinous white precipitate is obtained. b. A green precipitate is obtained c. No characteristic precipitate is obtained	Presence of III Group Radical (Aluminium) Presence of III Group Radical (Iron II) Absence of III Group Radical
4.	To a little of the original solution ammonium chloride and ammonium hydroxide solutions are added. Then hydrogen sulphide gas is passed through the solution.	a. A white precipitate is obtained b. No characteristic precipitate is obtained	Presence of IV Group Radical (Zinc) Absence of IV Group Radical
5.	To a little of the original solution ammonium chloride, ammonium hydroxide and ammonium carbonate solutions are added.	a. A white precipitate is obtained b. No characteristic precipitate is obtained	Presence of V Group Radical (Barium or Calcium) Absence of V Group Radical
6.	To a little of the original solution ammonium chloride, ammonium hydroxide and disodium hydrogen phosphate solutions are added.	a. A white precipitate is obtained b. No characteristic precipitate is obtained	Presence of VI Group Radical (Magnesium) Absence of VI Group Radical
7.	To a small amount of the salt sodium hydroxide solution is added and heated.	A colourless gas giving dense white fumes with a glass rod dipped in concentrated hydrochloric acid is evolved	Presence of Zero Group Radical (Ammonium)

	CONFIRMATORY TESTS FOR BASIC RADICALS		
	LEAD – GROUP I		
1.	To a little of the original solution potassium chromate solution is added.	A yellow precipitate is obtained	Presence of Lead is confirmed
2.	Toa little of the original solution potassium iodide solution is added.	A yellow precipitate is obtained	Presence of Lead is confirmed
3.	The above yellow precipitate is dissolved in hot water and cooled under tap water.	Golden yellow spangles are obtained	Presence of Lead is confirmed
	COPPER – GROUP II		
1.	To a little of the original solution ammonium hydroxide solution is added.	A pale blue precipitate is obtained	Presence of Copper is confirmed
2.	To the pale blue precipitate excess of ammonium hydroxide solution is added.	The precipitate dissolves in excess of ammonium hydroxide and forms a deep blue solution	Presence of Copper is confirmed
3.	To a little of the original solution potassium ferrocyanide solution is added.	A chocolate brown precipitate is obtained	Presence of Copper is confirmed
	ALUMINIUM – GROUP III		
1.	**Ash Test** To a little of the original solution (fairlyconc. solution) few drops of dilute nitric acid and cobalt nitrate solutions are added. A filter paper is soaked in this solution and burnt in a blue flame.	Blue ash is obtained	Presence of aluminium is confirmed

2.	To a little of the original solution potassium ferricyanide is added. To a portion of original solution potassium thiocyanate solution is added	A blue precipitate is obtained A pale red colour is obtained	Presence of Iron II is confirmed. **Presence of Iron II is confirmed**
ZINC – GROUP IV			
1.	To a little of the original solution potassium ferrocyanide solution is added.	A white precipitate is obtained	Presence of Zinc is confirmed
2.	**Green ash Test** To a little of the original solution (fairlyconc. solution) few drops of dilute nitric acid and cobalt nitrate solutions are added. A filter paper is soaked in this solution and burnt in blue flame.	Green ash is obtained	Presence of Zinc is confirmed
BARIUM – GROUP V			
1	To a little of the original solution acetic acid and potassium chromate solutions are added.	A yellow precipitate is obtained	Presence of barium is confirmed
		No yellow precipitate is obtained	Presence of calcium
3.	To a little of the original solution dilute sulphuric acid is added.	A white precipitate is obtained	Presence of Barium is confirmed
4.	To a little of the original solution ammonium chloride, ammonium hydroxide and ammonium oxalate solutions are added.	A white precipitate is obtained	Presence of Calcium is confirmed

MAGNESIUM – GROUP VI			
1.	To a little of the original solution sodium hydroxide is added (drop by drop to excess).	A white precipitate insoluble in excess of sodium hydroxide is obtained.	Presence of is Magnesium confirmed.
	Ash test To a little of the original solution (fairlyconc. solution) few drops of dilute nitric acid and cobalt nitrate solutions are added. A filter paper is soaked in this solution and burnt in a blue flame.	Pink ash is obtained	Presence of magnesium is confirmed
AMMONIUM – GROUP ZERO			
1.	To a little of the original solution Nessler's reagent is added.	A brown precipitate is obtained	Presence of is Ammonium confirmed

MODEL ANALYSIS – AMMONIUM SULPHATE

Sl. No.	EXPERIMENT	OBSERVATION	INFERENCE
A. PRELIMINARY DRY REACTIONS			
1.	**COLOUR** The colour of the given salt is noted.	White	Absence of Copper
2.	**APPEARANCE** Appearance of the given salt is noted	Crystalline	Absence of Carbonate
3.	**SOLUBILITY** **a.** In dilute hydrochloric acid. A little of the given salt is dissolved in dilute hydrochloric acid in a test tube. **b.** In water, a little of the given salt is dissolved in distilled water in a test tube.	Soluble Soluble	Absence of Lead Absence of Carbonate

Sl. No.	EXPERIMENT	OBSERVATION	INFERENCE
4.	**ACTION OF HEAT** A little of the given salt is strongly heated in a dry test tube.	A white sublimate is formed	May be Ammonium
	B. WET REACTIONS		
5.	**ACTION OF dil. HCl** To a pinch of the salt taken in a test tube dilute hydrochloric acid is added.	No characteristic gas	Absence of Carbonate
6.	**ACTION OF Conc. H_2SO_4** To a little of the salt taken in a test tube few drops of concentrated sulphuric acid is added and warmed.	No characteristic reaction	Absence of Chloride and Nitrate
7.	**ACTION OF Conc. H_2SO_4 AND COPPER TURNINGS** To a small amount of the given salt a bit of copper turnings and a few drops of concentrated acid are added and heated.	No brown vapours	Absence of Nitrate
8.	**ACTION OF Conc. H_2SO_4 AND MnO_2** To a small amount of the given salt a pinch of manganese dioxide and a few drops of concentrated sulphuric acid are added and warmed.	No characteristic gas	Absence of Chloride
9.	**CHROMYL CHLORIDE TEST** To a small amount of the given salt few crystals of potassium dichromate and few drops of concentrated sulphuric acid are added and warmed.	No reddish brown vapour	Absence of Chloride

C. REACTIONS USING SODIUM CARBONATE EXTRACT

Preparation of Sodium Carbonate Extract

A mixture of one part of the given salt and three parts of solid sodium carbonate is boiled with distilled water for 10 minutes. Cooled and filtered. The filtrate is called sodium carbonate extract.

10	**LEAD ACETATE TEST** To a little of the extract dilute acetic acid is added till the effervescence ceases and then lead acetate solution is added.	A white precipitate is obtained	Presence of Sulphate is confirmed
11.	**SILVER NITRATE TEST** To a little of the extract dilute nitric acid is added till the effervescence ceases and then silver nitrate solution is added.	No white precipitate	Absence of Chloride
12.	**BROWN RING TEST** To a little of the extract dilute sulphuric acid is added till the effervescence ceases. To this freshly prepared ferrous sulphate solution is added and then concentrated sulphuric acid is added through the sides of the test tube.	No brown ring	Absence of Nitrate

D. IDENTIFICATION OF BASIC RADICALS

Preparation of original solution

The original solution is prepared by dissolving the given salt in distilled water.

GROUP SEPARATION

1.	To a little of the original solution dilute hydrochloric acid is added.	No white precipitate	Absence of I Group Radical
2.	To a little of the original solution dilute hydro-chloric acid and yellow ammonium sulphide are added.	No characteristic precipitate	Absence of II Group Radical

3.	To a little of the original solution ammonium chloride and ammonium hydroxide solutions are added.	No white precipitate	Absence of III Group Radical
4.	To a little of the original solution ammonium chloride and ammonium hydroxide solutions are added. Then hydrogen sulphide gas is passed through the solution.	No white precipitate	Absence of IV Group Radical
5.	To a little of the original solution ammonium chloride, ammonium hydroxide and ammonium carbonate solutions are added.	No white precipitate	Absence of V Group Radical
6.	To a little of the original solution ammonium chloride, ammonium hydroxide and disodium hydrogen phosphate solutions are added.	No white precipitate	Absence of VI Group Radical
7.	To a small amount of the salt sodium hydroxide solution is added and heated.	A colourless gas giving dense white fumes with a glass rod dipped in concentrated hydrochloric acid is evolved	Presence of Zero Group Radical (Ammonium)

E. CONFIRMATORY TEST FOR ACID RADICAL - SULPHATE			
1.	**BARIUM CHLORIDE TEST** To a little of the extract dilute hydrochloric acid is added till the effervescence ceases and then barium chloride solution is added.	A white precipitate in soluble in concentrated hydrochloric acid is obtained	Presence confirmed of Sulphate
F. CONFIRMATORY TEST FOR BASIC RADICAL - AMMONIUM			
1.	To a little of the original solution Nessler’s reagent is added.	A brown precipitate is obtained	Presence of Ammonium is confirmed

RESULT

1. Acid Radical: Sulphate

2. Basic Radical: Ammonium

3. The given salt is Ammonium sulphate

ANALYSIS OF EFFLUENTS CONTAINING METALLIC POLLUTANTS (LEAD, COPPER AND ZINC)

IDENTIFICATION OF BASIC RADICAL IN EFFLUENT

Sl. No	EXPERIMENT	OBSERVATION	INFERENCE
01	To a little of the effluent dilute hydrochloric acid is added.	a. A white precipitate is obtained b. No white precipitate	Presence of Lead Absence of Lead
02	To a little of the effluent dilute hydrochloric acid is added. Then hydrogen sulphide gas is passed through the solution.	a. A black precipitate is obtained. b. No characteristic precipitate	Presence of Copper Absence of Copper
03	To a little of the effluent ammonium chloride and ammonium hydroxide solutions are added. Then hydrogen sulphide gas is passed through the solution.	a. A white precipitate is obtained. b. No white precipitate	Presence of Zinc Absence of Zinc
CONFIRMATORY TESTS FOR METALLIC POLLUTANTS			
LEAD			
01	To a little of the effluent potassium chromate solution is added.	A yellow precipitate is obtained	Presence of Lead is confirmed
02	To a little of the effluent potassium iodide solution is added.	A yellow precipitate is obtained	Presence of Lead is confirmed

Sl. No	EXPERIMENT	OBSERVATION	INFERENCE
03	The above yellow precipitate is dissolved in hot water and cooled under tap water.	Golden yellow spangles are obtained	Presence of Lead is confirmed
	COPPER		
01	To a little of the effluent ammonium hydroxide solution is added.	A pale blue precipitate is obtained	Presence of Copper is confirmed
02	To the pale blue precipitate excess of ammonium hydroxide solution is added.	The precipitate dissolves in excess of ammonium hydroxide and forms a deep blue solution	Presence of Copper is confirmed
03	To a little of the effluent potassium ferrocyanide solution is added.	A chocolate brown precipitate is obtained	Presence of Copper is confirmed
	ZINC		
01	To a little of the effluent potassium ferrocyanide solution is added.	A white precipitate is obtained	Presence of Zinc is confirmed
02	**Green ash Test** To a little of the effluent (fairly concentrated) few drops of dilute nitric acid and cobalt nitrate solutions are added. A filter paper is soaked in this solution and burnt in a blue flame.	Green ash is obtained	Presence of Zinc is confirmed

HARMFUL EFFECTS OF METALLIC POLLUTANTS

Harmful effects of Lead

1. Affects liver and kidney
2. Causes nervous disorder
3. Produce mental retardation in children
4. Produce gastro-intestinal damage
5. Causes loss of appetite

Harmful effects of Copper

1. Severely affect the digestive system
2. Causes vomiting and diarrhea
3. Affects blood, bone and teeth
4. It is toxic to aquatic life
5. Causes cancer and tuberculosis

Harmful effects of Zinc

1. Affects skin
2. Causes vomiting and diarrhea
3. Causes irritation
4. Causes dizziness and itching
5. Causes nausea

Broaden your understanding:

Click the following link or scan the QR code

https://youtu.be/vQgJp6HIKRs

https://youtu.be/0mB7_bBZ7So

MODEL QUESTION PAPER

1. Analyse the given Inorganic simple salt and report the acid radical and basic radical present in it.
2. Analyse the given sample of effluent and report the metallic pollutant present in it with procedure and its harmful effects.

I. MODEL ANALYSIS OF AN EFFLUENT

Sl. No	EXPERIMENT	OBSERVATION	INFERENCE
1	To a little of the effluent dilute hydrochloric acid is added.	A white precipitate is obtained	Presence of Lead
2	To a little of the effluent dilute hydrochloric acid is added. Then hydrogen sulphide gas is passed through the solution.	No characteristic precipitate	Absence of Copper
3	Toa little of the effluent ammonium chloride and ammonium hydroxide solutions are added. Then hydrogen sulphide gas is passed through the solution.	No white precipitate	Absence of Zinc
CONFIRMATORY TESTS FOR LEAD – GROUP I			
1	To a little of the effluent potassium chromate solution is added.	Yellow precipitate is obtained	Presence of Lead is confirmed
2	To a little of the effluent potassium iodide solution is added.	Yellow precipitate is obtained	Presence of Lead is confirmed
3	The above yellow precipitate is dissolved in hot water and cooled under tap water.	Golden yellow spangles are obtained	Presence of Lead is confirmed

REPORT

The metallic pollutant present in the given Effluent is Lead.

Harmful effects of Lead

1. Affects liver and kidney
2. Causes nervous disorder
3. Produce mental retardation in children
4. Produce gastro-intestinal damage
5. Causes loss of appetite

II. MODEL ANALYSIS OF AN EFFLUENT

Sl. No.	EXPERIMENT	OBSERVATION	INFERENCE
01	To a little of the effluent dilute hydrochloric acid is added.	No white precipitate	Absence of Lead
02	To a little of the effluent dilute hydrochloric acid is added. Then hydrogen sulphide gas is passed through the solution.	A black precipitate is obtained.	Presence of Copper
03	To a little of the effluent ammonium chloride and ammonium hydroxide solutions are added. Then hydrogen sulphide gas is passed through the solution.	No white precipitate	Absence of Zinc
CONFIRMATORY TESTS FOR METALLIC POLLUTANTS			
COPPER			
01	To a little of the effluent ammonium hydroxide solution is added.	A pale blue precipitate is obtained	Presence of Copper is confirmed
02	To the pale blue precipitate excess of ammonium hydroxide solution is added.	The precipitate dissolves in excess of ammonium hydroxide and forms a deep blue solution	Presence of Copper is confirmed
03	To a little of the effluent potassium ferro cyanide solution is added.	A chocolate brown precipitate is obtained	Presence of Copper is confirmed

REPORT

The metallic pollutant present in the given Effluent is **Copper**.

Harmful effects of Copper

1. Severely affect the digestive system
2. Causes vomiting and diarrhea
3. Affects blood, bone and teeth
4. It is toxic to aquatic life
5. Causes cancer and tuberculosis

** FIRST AID FOR ACCIDENTS IN CHEMISTRY LABORATORIES

(First aid to be given by trained/certified experts/taken to medical supervision)

ACCIDENT		FIRST AID TREATMENT
1. FIRE (a) Inflammable gases, liquids on fire.	I	Pour water carefully. Except when sodium, potassium, oil, spirit is on fire
	ii	Throw large quantities of sand if sodium, etc. is on fire.
	iii	Throw a mixture of sand and sodium bicarbonate if oil or spirit is on fire.
	iv	If any liquid or flask has caught fire, cover the mouth of the vessel with a damp cloth or duster
	v	Cover with a piece of blanket or thick cloth or card- board.
(b) Burning of clothes.	i	Lay the person on the floor, burning parts of cloth upwards and cover with a blanket. Never throw water on the person; otherwise it will cause serious boils on the body.
2. Cuts		Remove the visible glass pieces, etc. if any from the affected part. Stop bleeding by one of the following methods i. By applying pressure at the place of injury. ii. By washing with alum or $FeCl_3$ solution. iii. By applying a little spirit or Dettol on the skin and cover with a piece of leucoplast
3. BURNS (a) By dry heat (i.e., flame, steam, hot object, etc.)	1	i. Avoid handling the affected area as far as possible. Do not break the blisters. For minor burns apply burnol and sarson oil (mustard oil). ii. Cover the affected part with lint or linen saturated with carron oil (a mixture of linseed oil and lime water in equal amounts) or with cold cream, etc. and bandage tightly
(b) By corrosive acids.	1	i. If conc. H_2SO_4 falls on skin, wipe it with cotton. ii. Wash with plenty of cold water, then with dilute $NaHCO_3$ solution and again with water. If burning persists wipe the skin with cotton wool and apply burnol and sarson oil.
(c) By corrosive alkalis.		Wash immediately with excess of water, then with dilute acetic acid or lemon juice and apply burnol or sarson oil dressing
(d) By bromine.	i	Wash with petrol or alcohol and then rub glyerine. Finally smear with burnol.
	ii	Wash with dil. Na_2CO_3 solution (1:10); then with alcohol and picric acid and apply oil dressing

ACCIDENT		FIRST AID TREATMENT
4. EYE INJURIES a) By acid.		Wash with excess of water, then with 3% $NaHCO_3$ and then with excess of water, forcibly opening the eyes. If necessary, drop castor oil (mobile oil) into the eyes, cover with cotton wool and bandage lightly
(b) By alkalis.		Wash well with 2% boric acid solution; the fest as in (a).
(c) By bromine or chlorine vapour.		Wash with dil. $NaHCO_3$ solution and then bring near the eyes a cloth or sponge soaked in alcohol or alcohol + ether mixture. Do not allow the liquid to enter the eyes
(d) By foreign particles.		Wash it by sprinkling water into the eyes. Open the eye carefully and remove the particle by means of cotton wool or clean handkerchief. Wash again with water. Then put a drop olive or castor oil in the eyes and keep closed
5. DAMAGE TO CLOTHES **(a) By acids.**	1	Apply $(NH_4)_2$CO3 solution or dilute ammonia and wash well with water
(b) By alkalis.	2	Apply lemon juice or dil. acetic acid, wash well with plenty of water
6. POISONING (a) Strong acids.	1	Give plenty of water. Then give 2 tablespoons of lime water or milk of magnesia.
(b) Caustic alkalis.	2	Give plenty of water. Then give orange or lemon juice.
(c) Salts of heavy metal or copper sulphate.	3	Give milk or white of an egg.
(d) Mercury salts.	4	Immediately give a tablespoon of common salt or zinc sulphate in a tumbler of warm water
e) Arsenic or antimony salt.	5	(i) Drink plenty of warm water and make vomiting. (ii) Give large quantities of freshly precipitated ferric hydroxide (mix equal vols. of $FeCl_3$ and NH_4OH) or magnesium hydroxide or castor oil mixed with milk and white of egg. (iii) Keep the feet and abdomen warm by hot waters bottles and blankets.
7. **INHALATION** (a) Bromine or chlorine.		Inhale alcohol or ammonia vapour.
(b) Carbon monoxide.		Fresh air; inhale dilute oxygen.
(c) Nitrous fumes.		Plenty of fresh air; inhale steam

ACCIDENT		FIRST AID TREATMENT
(d) Chloroform.		Fresh air; artificial respiration: apply hot and cold
(e) H_2S.		Artificial respiration; inhalation of ammonia. Apply warm and cold douches to head.

ENGINEERING CHEMISTRY LABORATORY(DO'S & DON'T'S)

DO'S

1. ENTER THE LAB WITH PROPER UNIFORM.
2. WEAR SHOES INSIDE THE LAB.
3. BRING WASTE CLOTH TO THE LAB.
4. KEEP YOUR WORK TABLE CLEAN.
5. HANDLE CHEMICALS CAREFULLY.
6. WASH ALL YOUR APPARATUS BEFORE AND AFTER THE USE.
7. SWITCH OFF THE LAMP, WHEN NOT IN USE.
8. THROW ALL THE WASTAGES INTO THE DUST BIN.
9. USE BLUE FLAME FOR HEATING.
10. USE TEST TUBE HOLDER FOR HEATING.
11. POUR RUNNING WATER TO THE WOUNDS CAUSED BY HEAT OR ACIDS.
12. MEMORISE THE PROCEDURE THOROUGHLY.
13. ANALYSE THE SALT SYSTEMATICALLY.
14. RECORD THE FINDING THEN AND THERE.
15. USE TONGS FOR HANDLING CHINA DISH WHILE HEATING.
16. BE DISCIPLINED INSIDE THE LAB.
17. COMPLETE THE EXPERIMENT WITHIN THE SPECIFIED HOURS.
18. DO THE EXPERIMENT AS PER THE PROCEDURE. NEVER ATTEMPT THE ADDITION OF UNNECESSARY CHEMICALS.
19. **THEN AND THERE GET THE SIGNATURE IN THE OBSERVATION AND RECORD NOTE.**

DONT'S

1. DON'T CONSULT OTHERS INSIDE THE LAB.
2. DON'T THROW THE SALT WITH RAW HAND, USE SPATULA.
3. DON'T THROW THE WASTE MATERIALS IN AND AROUND YOUR PLACE.
4. DON'T HANDLE THE CHEMICALS NOT CONCERNING YOU.
5. DON'T WASH THE APPARATUS WHEN IT IS HOT.

STATE BOARD OF TECHNICAL EDUCATION & TRAINING, TAMILNADU
DIPLOMA IN ENGINEERING / TECHNOLOGY SYLLABUS
N-SCHEME
(Implements from the Academic year 2020-21 onwards)

Course Name: **All Branches of Diploma in Engineering and Technology and Special Programmes except DMOP, HMCT and Film & TV**

Subject Code: **40007**

Semester: **I - Semester**

Subject Title**: ENGINEERING CHEMISTRY – PRACTICAL (Annual Pattern)**

TEACHING AND SCHEME OF EXAMINATION:

No. of Weeks per Semester: 16 Weeks

Subject	Instructions		Internal Assessment / Record	Board Examination
	Hours / Week	Hours / Semester		
Engineering Chemistry – I Practical	2	32	15	53

OBJECTIVES:

1. At the end of the program the student will have knowledge about volumetric analysis in acidimetric, alkalimetric and permanganometric titration and their applications.
2. To get knowledge of estimation of total hardness, temporary and permanent hardness in the hard water sample.
3. To get knowledge about measurement of TDS, pH and to calculate Hydrogen ion concentration in a solution.
4. To get knowledge of estimation of dissolved chlorine in a water sample.

ENGINEERING CHEMISTRY – I PRACTICAL

CONTENTS

Intellectual Skills

1. Carrying out Volumetric titrations and calculation of masses
2. Knowing units for Concentrations of solutions

Motor Skills

1. Measure quantities accurately
2. Observe chemical reactions
3. Handle the apparatus carefully

i) Acidimetry and Alkalimetry

1. Estimate the amount of sulphuric acid present in ………. ml of a given solution using Standard solution of HCl of strength……………..N and an approximately decinormal solution of NaOH.
2. Estimate the amount of NaOH present in ……….ml the given solution using a standard solution of KOH of strength …………N and approximately decinormal solution of H_2SO_4
3. Compare of strength of two given hydrochloric acids and estimate the stronger / weaker solution present in …………ml using a standard solution of sodium hydroxide of strength …………N

ii) Permanganometry

4. Estimate of the amount of Mohr salt present in……….ml of the given solution using a standard solution of ferrous sulphate of strength …………N and an approximately decinormal solution of $KMnO_4$.
5. Estimate of the amount of Fe^{2+} present in……….ml of the given solution using a standard solution of ferrous ammonium sulphate of strength …………N and an approximately decinormal solution of $KMnO_4$.
6. Compare of strength of two given KMnO4 solution and estimate the stronger/weaker solution present in …………ml using a standard solution of ferrous ammonium sulphate of strength …………N

iii) Water Analysis

7. Water analysis **for residual** chlorine?
8. Estimation of total hardness of a sample using EDTA?
9. Water quality testing, pH (3 sample)?
10. Water quality testing TDS(3 sample)?

List of Apparatus to be provided for each student in Chemistry Laboratory during the Engineering Chemistry – I Practical Classes/Board Examination in addition to the required Solutions:

Sl. No.	Name of the Item	Quantity (Nos.)
1	Beaker (100 ml)	1
2	Burette (50 ml)	1
3	Burette Stand	1
4	Conical Flask (250 ml)	1
5	Funnel	1

6	Pipette (20 ml)	1
7	Porcelain Tile	1
8	Standard Flask (100 ml)	1
9	Wash Bottle	1
10	pH meter	2
11	TDS meter	2

Semester : **II - Semester**

Subject Title : **ENGINEERING CHEMISTRY – II PRACTICAL**

Subject	**Instructions**		**Internal Assessment / Record**	**Board Examination**
	Hours / Week	**Hours / Semester**		
Engineering Chemistry - II Practical	2	32	10	42

Intellectual Skills

1. Studying the effect of heating on substances and reagents
2. Study of the reactions of the following radicals leading to qualitative analysis of the given Inorganic simple salt soluble in water or dilute acids
3. Studying the harmful effects of effluents

Acid Radicals : Carbonate, Chloride, Nitrate and Sulphate

Basic Radicals : Lead, Copper, ferrous, Aluminium, Zinc, Barium, Calcium, Magnesium and Ammonium

Motor Skills

1. Handling the apparatus carefully
2. Awareness on Industrial safety

I. Analysis of Inorganic simple salt (QUALITATIVE ANALYSIS)

- Analysis of nine inorganic simple salts containing any one acid radical and basic radical without omitting any of the above mentioned radicals.

II. Analysis of Effluent containing Lead, Copper and Zinc metal ions (EFFLUENT ANALYSIS)

- Analysis of three effluents, each containing the above mentioned metal ions. Report on the metallic pollutant with procedure (Basic Radical Analysis Procedure) and their harmful effects.

Engineering Chemistry I &II Practical, Annual pattern, Scheme of Examination

Subject	Hours / Week	Hours / Semester	Internal Assessment / Record	Board Examination	Duration of examination
Engineering Chemistry - I Practical	2	32	15	53	**3h**
Engineering Chemistry - II Practical	2	32	10	42	
Viva voce				5	
Total	**-**	**64 h**	**25**	**100**	

MODEL QUESTION PAPER

MODEL 1: **3 Hours**

1. Estimate the mass of Iron present in whole of the given ferrous sulphate solution using a standard solution of ferrous ammonium sulphate of strength 0.1N and an approximately decinormal solution of potassium permanganate. (53 marks)
2. Analyse the given Inorganic simple salt and report the acid radical and basic radical present in it. (42 marks)
3. Viva voce (05 marks)

MODEL 2: **3 Hours**

1. Calculate the total hardness of the given sample of water using a standard hard water solution of molarity 0.01M and an approximately decimolar solution of EDTA. (53 marks)
2. Analyse the given samples (two samples) of effluent and report the metallic pollutant present in it with procedure and its harmful effects. (42) marks)
3. Viva voce (05 marks)

MODEL 3: **3 Hours**

1. Determine the pH of three given samples using pH meter and calculate the hydrogen ion concentration of the samples determine the TDS of the same sample. (Any two students per batch). (53 marks)
2. Analyse the given Inorganic simple salt and report the acid radical and basic radical present in it. (42 marks)
3. Viva voce (05 marks)

MODEL 4: 3 Hours

1. Estimate the amount of sulphuric acid present in the whole of the given sulphuric acid using a standard solution of hydrochloric acid of strength 0.1N and an approximately decinormal solution of sodium hydroxide. (53 marks)
2. Analyse the given Inorganic simple salt and report the acid radical and basic radical present in it. (42 marks)
3. Viva voce (05 marks)

Determination of pH using a pH meter and calculation of hydrogen ion Concentrations in the solutions and TDS using TDS meter (For three given samples)

(This question may be given to any two students per batch).

A single experiment with different skill value may be given for a batch. The two experiment (Determination of pH) TDS may be given to any two students per batch.

INTERNAL ASSESSMENT/RECORD : 25 Marks

BOARD EXAMINATION : 100 Marks

SCHEME OF EVALUATION	
Engineering Chemistry I- (Volumetric analysis or Determination pH and TDS)	**53 marks**
Engineering Chemistry II (Salt analysis or effluent analysis)	**42 marks**
Viva voce	**05 marks**
Total	**100 marks**

ENGINEERING CHEMISTRY – I PRACTICAL

Volumetric Analysis-Distribution of marks:

FOR	MARKS ALLOTTED
Short Procedure	05
Titration – I	18
Titration – II	18
Calculations (3 x 4)	12
Total	**53**

Volumetric Analysis:

Titration value accuracy for Titration – I and II

ACCURACY	MARKS
± 0.2 ml	18
above ± 0.2 ml to ± 0.4 ml	15
above ± 0.4 ml to ± 0.6 ml	12
above ± 0.6 ml	5

Determination of pH:-Distribution of marks

FOR	MARKS ALLOTTED
Answer for Short Questions On pH & TDS	05
Determination of pH of three samples (3x7)	21
Calculation of [H+](3X2)	06
Determination of TDS-three samples (3x7)	21
Total	53

Accuracy per pH value

ACCURACY	MARKS
± 0.2	7
above ± 0.2 to ± 0.4	5
above ± 0.4	2

TDS value Accuracy:

ACCURACY	MARKS
± 2%	7
above ± 2 % to ± 4%	5
ABOVE 6%	2

Note: All the students are the given same question and each batch of student is given different inorganic simple salt and effluent. (nine salt and three effluents).

Qualitative Analysis:

FOR	MARKS
Identification of Acid Radical with Systematic procedure	21
Identification of Basic Radical with Systematic procedure	21

Without systematic procedure	
Identification of Acid Radical with confirmatory test only	**13**
Identification of Basic Radical with confirmatory test only	**13**
Mere Spotting of Acid Radical and Basic Radical (3+3)	**06**

EFFLUENT ANALYSIS:

FOR	MARKS
Identification of metallic pollutant procedure with systematic procedure Effluent sample I	**16**
Harmful effects of metallic pollutant	**05**
Identification of metallic pollutant procedure with systematic procedure Effluent sample II	**16**
Harmful effects of metallic pollutant	**05**
Without systematic procedure	
Group Identification Tests of metallic pollutant	**13**
Confirmatory Test of metallic pollutant	**13**
Mere Spotting of the pollutant(3+3)	**06**

List of Apparatus to be provided for each student in Chemistry Laboratory during the Engineering Chemistry – II Practical Classes/Board Examination in addition to the required Reagents:

Sl. No.	Name of the Item	Quantity (Nos.)
1	Funnel	1
2	Glass Rod	1
3	Test Tubes (15 x 1.5 mm)	4
4	Test Tubes (15 x 1.5 mm)	1
5	Test Tube cleaning Brush	1
6	Test Tube Holder	1
7	Test Tube Stand	1
8	Wash Bottle	1

LIST OF EQUIPMENTS

List of Equipments Required for a Batch of 30 Students
Non-Consumable Items

Sl. No.	Name of the Item	Quantity (Nos.)
1	LPG Connection	
2	Exhaust Fan (High Capacity)	Sufficient Nos.
3	Fire Extinguisher	1
4	First Aid Box (Full Set)	2
5	Safety Chart	1
6	Chemical Balance	1
7	Fractional Weight Box	1
8	pH Meter	5
9	Working Table with all accessories	8

Glassware and Other Items

Sl. No.	Name of the Item	Quantity (Nos.)
1	Burette (50 ml)	35
2	Burette Stand	35
3	Pipette (20 ml) (With safety Bulb)	35
4	Pipette (10 ml)	5
5	Conical Flask (250 ml)	35
6	Funnel (3”)	50
7	Porcelain Tile	35
8	Measuring Cylinder (10 ml)	5
9	Measuring Cylinder (1000 ml)	2
10	Reagent Bottle (White) (250 ml)	60
11	Reagent Bottle (White) (125 ml)	100
12	Reagent Bottle (Amber) (250 ml)	80
13	Test Tube (15 mm x 1.5 mm)	1000
14	Test Tube (15 mm x 2.5 mm)	500
15	Test Tube Stand	35
16	Test Tube Holder	35
17	Test Tube cleaning brush	35
18	Glass Trough	5
19	Beaker (100 ml)	35
20	Glass Rod (15 cm)	100
21	Watch Glass (3”)	35
22	Wash Bottle (Polythene)	35
23	Nickel Spatula	35
24	Bunsen Burner for Gas connection	35
25	Plastic Bucket (15 L)	10
26	Filter Papers (Round)	Sufficient Nos.
27	Pipette bulb/filling devices	35

References:

1. Introduction to Engineering Chemistry, Shradha Sinha , S S Dara & Sudha Jain, S. Chand Publishers, 2004.
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3. A Textbook of Engineering Chemistry, Dr. Uday Kumar, 2013.
4. Chemistry – Higher Secondary – 1st and 2nd year, Vol. I & II, Tamil Nadu Text Book Corporation, 2018.
5. Engineering Chemistry Fundamentals and Applications, Shikha Agarwal, Cambridge University Press, 2019.
6. Government of India, Geological Survey of India, Geology and Mineral Resources of The States of India Part VI – Tamil Nadu and Pondicherry
7. Indian Minerals Yearbook 2011, Government of India Ministry of Mines, Indian Bureau of Mines Indira Bhavan, Civil Lines, Nagpur – 440 004

ADDITIONAL USEFUL INFORMATION (TEACHING & LEARNING PROCESS)

LINKS FOR SIMULATION

Build an atom

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

Build a molecule

https://phet.colorado.edu/en/simulation/legacy/build-a-molecule

All chemistry simulations

https://phet.colorado.edu/en/simulations/filter?subjects=chemistry&sort=alpha&view=grid