



NOTES OF LESSON – INDEX PAGE

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SUBJECT&SUBJECT CODE:	40014 &ENGINEERING CHEMISTRY-I

UNIT: 1 BASIC CONCEPTS IN CHEMISTRY

S.N O	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	1.1 ATOMIC STRUCTURE & CHEMICAL BONDING Fundamental particles-proton-electron-neutron-atomic number-mass number.	Chemistry – Higher Secondary – 1 st and 2nd year, Vol. I & II, Tamil Nadu TextBook Corporation, 2018.	https://www.youtube.com/watch?v=tNaqCtxzZYw&list=PL1b9Ht9ISqIFsliqREfRjehR2WAs3qCW4	1. ATOMIC STRUCTURE 2. CHEMICAL BONDING	
	Extra nuclear part-filling up of electrons-Aufbau principle-s-p-d-f orbitals-electronic configuration .				
	Octet rule-Electrovalent bond-sodium chloride formation.				
	Covalent bond-Formation of ammonia.				
2	1.2 PERIODIC TABLE Modern periodic law	Basic inorganic chemistry by Arun Bahl and B. S. Bahl	https://youtu.be/gipOu5jeiqQ	PERIODIC TABLE	
	Periodic classification of elements.				
	Features of modern periodic table				
	Properties of s-p-d-f block elements				
3	1.3 ACIDS AND BASES Properties of acids and bases-Lewis concept of acids and bases-advantages	Chemistry – Higher Secondary – 1 st and 2nd year, Vol. I & II, Tamil Nadu Text Book Corporation, 2018.	https://www.youtube.com/watch?v=eQWmobEbgf0&list=PL1b9Ht9ISqIFsliqREfRjehR2WAs3qCW4&index=4	THEORIES OF ACIDS AND BASES	
	pH-pOH-Definition-Numerical problems-Indicator-Definition				
	Buffer solution-Definition-Types of buffer solution with example-Application of pH in industries				

UNIT: 2. SURFACE CHEMISTRY

S.N O	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHE R
1	SURFACE CHEMISTRY 2.1 Colloids Colloids–Definition–True solution and Colloidal Differences – Types of colloids	1.Chemistry – Higher Secondary – 1 st and 2nd year, Vol. I & II, Tamil Nadu Text Book Corporation, 2018. 2.A Text Book of Engineering Chemistry – S.S. Dara – S. Chand Publication.	https://www.youtube.com/watch?v=W4KAbbVNMxc	PROPERTIES 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.				
2	2.2 Nanotechnology Nano particles–definition–properties	1.Chemistry – Higher Secondary – 1 st and 2nd year, Vol. I & II, Tamil Nadu Text Book Corporation, 2018 2.A Textbook of nanoscience and nanotechnology by B S MURTHY,P SHANKAR,BALDEV RAJ	https://youtu.be/dQhcg8YZo		
	Application of Nanotechnology – Engineering				
	Medicine – biomaterial.				
3	2.3 Catalysis Catalyst – Definition – Positive – Negative catalyst	Chemistry – Higher Secondary – 1 st and 2nd year, Vol. I & II, Tamil Nadu Text Book Corporation, 2018.	https://youtu.be/m_9bpZep1QM	CATALYSIS	
	Definition – Types of catalysis – Homogeneous and Heterogeneous				
	Promoter – Catalyst poison – active centre				
	Definition – Characteristics of a catalyst – Industrial applications of catalysts.				

UNIT: 3 MINERALS AND METALLURGY

S.N O	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHE R
1	MINERALS AND METALLURGY 3.1 Minerals and Metallurgy Mineral – Minerals of Tamilnadu – Sources and Uses (Basic concepts only)	A TEXTBOOK OF METALLURGICAL ANALYSIS BY BC AGARWAL,S.P JAIN	https://youtu.be/yEhrNelOACU		
	Extraction of iron – Blast furnace – cast iron				
	Steel manufacture – Bessemer				

	converter			
	Heat treatment of steel			
	Hardening – annealing – tempering.			
2	3.2 Metallurgy of Tungsten and Titanium Extraction and uses of Tungsten	A TEXTBOOK OF METALLURGICAL ANALYSIS BY BC AGARWAL,S.P JAIN	https://youtu.be/W-FNAQAyk80	
	Extraction and uses of Titanium			
3	3.3 Powder Metallurgy Definition – Powder metallurgical process	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE	https://www.youtube.com/watch?v=DqhL7d22uSc	
	Preparation of Metal Powder			
	Atomization – Reduction of Metal Oxide			
	blending – compacting – sintering – finishing			
	Applications of Powder Metallurgy			

UNIT: 4 INDUSTRIAL CHEMISTRY

S.NO	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	INDUSTRIAL CHEMISTRY 4.1 Nuclear Chemistry Nuclear reaction – Differences between nuclear reaction and ordinary chemical reaction	Basic inorganic chemistry by Arun Bahl and B. S. Bahl	https://youtu.be/KWAsz59F8gA		
	Radioactive decay – alpha emission – beta emission – gamma emission – half-life period – simple problems				
	Nuclear fission – nuclear fusion – chain reaction				
	components nuclear reactor, reactor core, nuclear reactor coolant, Control rods, neutron moderator				
	steam turbine – Application of radioactive isotopes.				
2	4.2 Cement and Ceramics Definition – Manufacture of Portland Cement – Wet Process – Setting of Cement (No equation)	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE	https://youtu.be/dyxL_BvkhJg	1.CEMENT 2.CERAMICS	
	Ceramics – White pottery – Definition – Manufacture of White pottery – Uses				
	Definition of glazing – purpose – Method – Salt glazing – liquid glazing.				
3	4.3 Refractories and Glass Definition – requirements of a good refractory – types with examples and uses	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE		1.REFRACTORIES	
	Uses of silica, fire clay and alumina. Composition of Glass				
	Manufacture of Glass – annealing of glass – varieties of glass – Optical glass				
	wind shield glass and Photo chromatic glass.				

UNIT: 5 CHEMISTRY OF ENGINEERING MATERIALS

S.NO	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	<p>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 – Thermoplasticsand Thermosetting plastics Differences –Mechanical properties of plastics – Polymers in Surgery Biomaterials – Definition Biomedical uses of Polyurethane, PVC, Polypropylene and Polyethylene.</p>	BASIC ORGANIC CHEMISTRY BY PURI & SHARMA	https://youtu.be/rQbr-s-QH7Y	1.POLYMER	
2	<p>5.2 Abrasives Definition – classification – hardness in Moh's scale Natural abrasives – Diamond, Corundum, Emery and Garnet. Synthetic abrasives – Carborundum – Boroncarbide manufacture – properties and uses.</p>	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE			
3	<p>5.3 Composite Materials Definition – examples – Classification of composites Advantages over metals and polymers – General application</p>	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE	https://youtu.be/S96zHUSxZc0		

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Submitted by IQAC on: 25.05.21	Checked and Approval by IQAC on:

coordinator

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UNIT I

BASIC CONCEPTS IN CHEMISTRY

ATOMIC STRUCTURE AND CHEMICAL BONDING

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 of 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.

- 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.
- 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.
- Each shell has sub energy level or sub shell, they are called s, p, d, f etc.
- 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

- 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

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

Atomic structure of Na atom
 At.no=11(11p,11e)
 Mass.no=23(11p,12n)

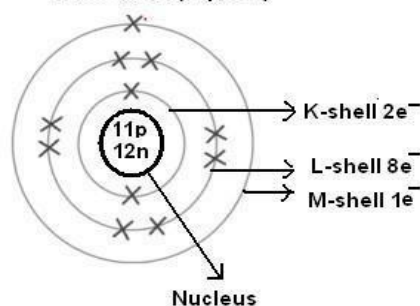
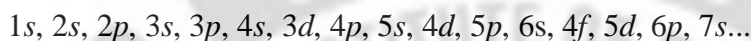


Fig.1.1.1. Structure of sodium atom

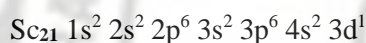
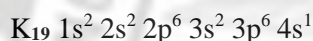
Aufbau principle states that in the ground state of an atom, the orbitals are filled in the increasing order of the energy.

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:



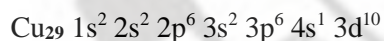
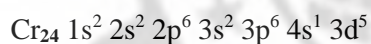
The orbitals s, p, d, f are called sub shells. The order may be remembered by using the method given in Fig. 1.1.2. Starting from the top, the direction of the arrows gives the order of filling of orbitals, that is starting from top right to bottom left.

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 3d and 4s orbitals and as predicted by this sequence, it is found in 4s orbital.



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



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

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Fig. 1.1.2 Order of filling of orbital

Atomic mass: Atomic mass of an element is the ratio of the mass an atom of that element to $1/12^{\text{th}}$ mass of an atom of carbon-12

Molecular mass: Molecular mass of an element is the mass of the molecule of that element to $1/12^{\text{th}}$ mass of an atom of carbon-12.

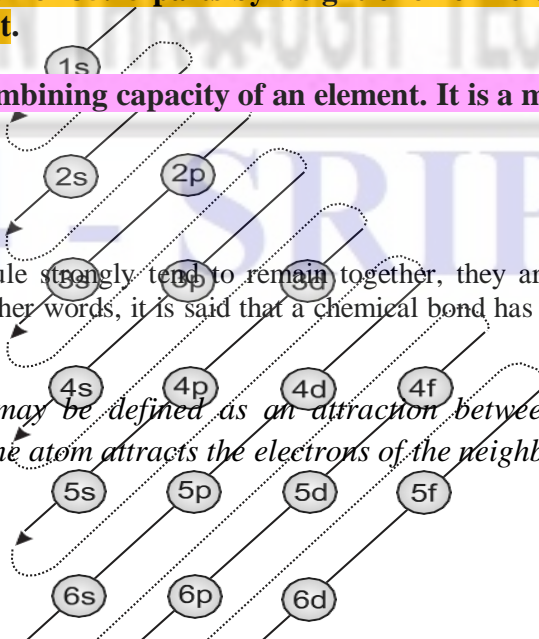
Equivalent mass: Equivalent mass of an element is the number of parts by weight of that element which can combine with or displaces 1.008 parts by weight of hydrogen or 8 parts by weight of oxygen or 35.45 parts by weight of chlorine or one equivalent mass of any other active element.

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.

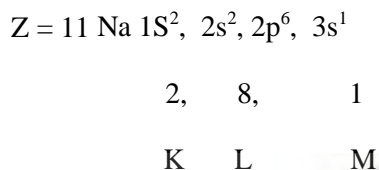
1. The complete transfer of valence electron(s) from one atom to another. This is called ionic bond (or) electrovalent bond.
2. The mutual sharing of (pair of) valence electrons between the combining atoms. The shared pair of electrons is given by both atoms. This is called as covalent bond.

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:

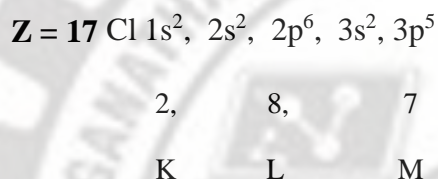
The atomic number of sodium is 11. It has 11 protons and 11 electrons i.e., 11 positive charges and 11 negative charges. Thus the electronic configuration is



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



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



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).

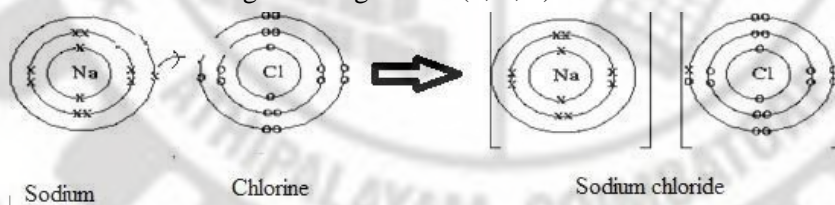


Fig.1.1.3. Formation of sodium chloride

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 argon (2,8,8). Thus sodium ion is more stable than sodium atom and chloride ion is more stable than chlorine atom.

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

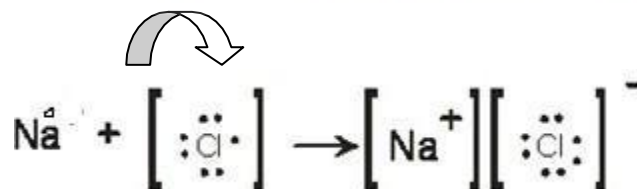


Fig.1.1.4. Formation of ionic bond

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 (NH₃):

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 1s², 2s², 2p³. There are 5 electrons in the outermost orbit. It can be shown as

2 5



Hydrogen has only one electron; the electronic configuration hydrogen is 1s¹.

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

PERIODIC TABLE

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* (ν) 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 bottom¹ of the periodic table.

¹ Inner transition elements

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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.
- 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.

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Representative elements		<i>d</i> -Transition elements										Representative elements					Noble gases
GROUP NUMBER		GROUP NUMBER										GROUP NUMBER					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IA	IIA	III A	IV A	V A	VIA	VII A	VIII	VIII	VIII	IB	II B	III B	IV B	V B	VI B	VII B	0
3 Li $2s^1$	4 Be $2s^2$											5 B $2s^2 2p^1$	6 C $2s^2 2p^2$	7 N $2s^2 2p^3$	8 O $2s^2 2p^4$	9 F $2s^2 2p^5$	10 Ne $2s^2 2p^6$
11 Na $3s^1$	12 Mg $3s^2$	21 Sc $3d^1 4s^2$	22 Ti $3d^2 4s^2$	23 V $3d^3 4s^2$	24 Cr $3d^4 4s^1$	25 Mn $3d^5 4s^2$	26 Fe $3d^6 4s^2$	27 Co $3d^7 4s^2$	28 Ni $3d^8 4s^2$	29 Cu $3d^9 4s^1$	30 Zn $3d^{10} 4s^2$	31 Ga $4s^2 4p^1$	32 Ge $4s^2 4p^2$	33 As $4s^2 4p^3$	34 Se $4s^2 4p^4$	35 Br $4s^2 4p^5$	36 Kr $4s^2 4p^6$
37 Rb $5s^1$	38 Sr $5s^2$	39 Y $4d^1 5s^2$	40 Zr $4d^2 5s^2$	41 Nb $4d^4 5s^1$	42 Mo $4d^5 5s^1$	43 Tc $4d^5 5s^2$	44 Ru $4d^7 5s^1$	45 Rh $4d^8 5s^1$	46 Pd $4d^{10}$	47 Ag $4d^9 5s^1$	48 Cd $4d^{10} 5s^2$	49 In $5s^2 5p^1$	50 Sn $5s^2 5p^2$	51 Sb $5s^2 5p^3$	52 Te $5s^2 5p^4$	53 I $5s^2 5p^5$	54 Xe $5s^2 5p^6$
55 Cs $6s^1$	56 Ba $6s^2$	57 La* $5d^1 6s^2$	72 Hf $4f^{14} 5d^2 6s^2$	73 Ta $5d^3 6s^2$	74 W $5d^4 6s^2$	75 Re $5d^5 6s^2$	76 Os $5d^6 6s^2$	77 Ir $5d^7 6s^2$	78 Pt $5d^9 6s^1$	79 Au $5d^{10} 6s^1$	80 Hg $5d^{10} 6s^2$	81 Tl $6s^2 6p^1$	82 Pb $6s^2 6p^2$	83 Bi $6s^2 6p^3$	84 Po $6s^2 6p^4$	85 At $6s^2 6p^5$	86 Rn $6s^2 6p^6$
87 Fr $7s^1$	88 Ra $7s^2$	89 Ac** $6d^1 7s^2$	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 $4f^2 5d^1 6s^2$	59 Pr $4f^3 5d^1 6s^2$	60 Nd $4f^4 5d^1 6s^2$	61 Pm $4f^5 5d^1 6s^2$	62 Sm $4f^6 5d^1 6s^2$	63 Eu $4f^7 5d^1 6s^2$	64 Gd $4f^7 5d^1 6s^2$	65 Tb $4f^9 5d^1 6s^2$	66 Dy $4f^{10} 5d^1 6s^2$	67 Ho $4f^{11} 5d^1 6s^2$	68 Er $4f^{12} 5d^1 6s^2$	69 Tm $4f^{13} 5d^1 6s^2$	70 Yb $4f^{14} 5d^1 6s^2$	71 Lu $4f^{14} 5d^1 6s^2$
90 Th $5f^6 6d^1 7s^2$	91 Pa $5f^7 6d^1 7s^2$	92 U $5f^6 6d^1 7s^2$	93 Np $5f^7 6d^1 7s^2$	94 Pu $5f^6 6d^1 7s^2$	95 Am $5f^7 6d^1 7s^2$	96 Cm $5f^7 6d^1 7s^2$	97 Bk $5f^9 6d^1 7s^2$	98 Cf $5f^{10} 6d^1 7s^2$	99 Es $5f^{11} 6d^1 7s^2$	100 Fm $5f^{12} 6d^1 7s^2$	101 Md $5f^{13} 6d^1 7s^2$	102 No $5f^{14} 6d^1 7s^2$	103 Lr $5f^{14} 6d^1 7s^2$

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 $n s^2(n-1)d^{0-1}(n-2)f^{1-14}$
- They are less abundant metals on earth crust 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

- Modern periodic law
- Periodic classification of elements
-
- Properties of s, p, d, f block

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.

764 - SRIPC

ACIDS AND BASES

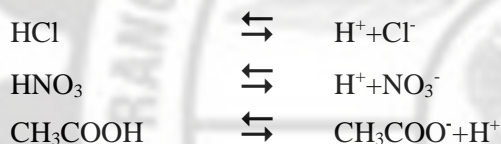
Introduction

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



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:



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

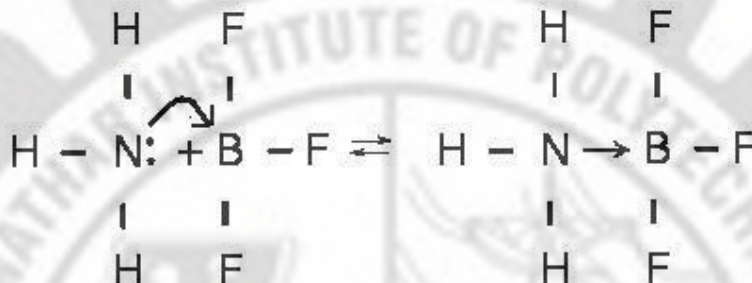
Lewis Base – Electron Donor

Illustration with Example:1

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

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 electrons over nitrogen available called a non-bonded pair or lone pair; Boron has a vacant orbital after the formation of BF_3 .

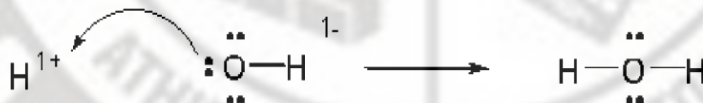


Ammonia donates a pair of electron to Boron trifluoride and is called as Lewis base. Hence, it is called as electron pair donor.

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

Example: 2

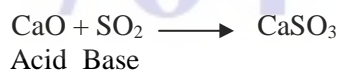
A **Lewis base** is an electron pair donor. This definition is more general than those we have seen to this point; any Arrhenius acid or base and any Bronsted-Lowry acid or base can also be viewed as a Lewis acid or base. The reaction of H^{1+} with OH^{1-} , for instance, involves donation and acceptance 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.



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 negative power of 10.

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

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

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

Definition pH and pOH

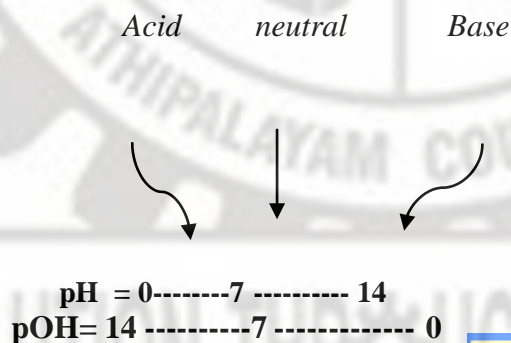
pH of a solution is defined as negative of logarithm to the base 10 of the hydrogen ion concentration [H⁺]

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

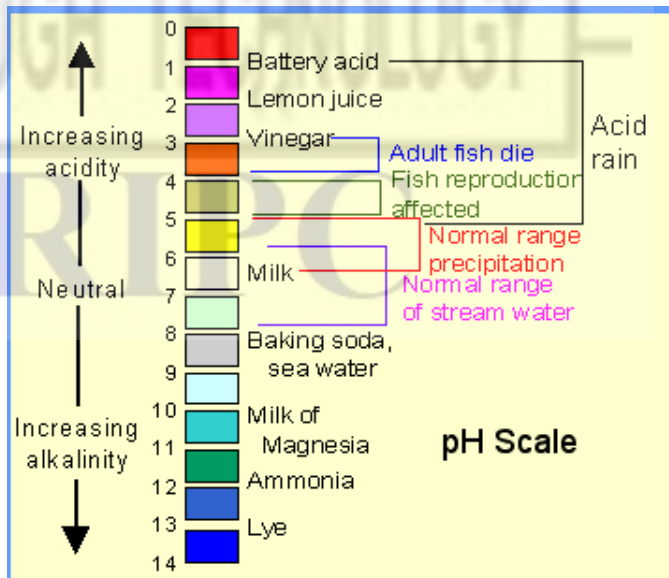
Similarly,

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

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



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

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

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

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

$$[H^+] = [OH^-] = [1 \times 10^{-7}] \text{ gm ions/litre. } [H^+]$$

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

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

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

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

Multiplying by (-1) on both sides

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

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

Problem.

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

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

$$5 + \text{pOH} = 14 \quad \text{pOH} = 14 - 5$$

$$\text{pOH} = 9$$

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. $\text{pH} + \text{pOH} = 14$.
3. Ionic product of water is 1×10^{-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.

$$\begin{aligned} \text{pH} &= -\log_{10} [\text{H}^+] \\ &= -\log_{10} [4.6 \times 10^{-4}] \\ &= -[\log_{10} 4.6] + [\log_{10} 10^{-4}] \\ &= -[0.6627 - 4] \\ &= -[-3.3373] \\ \text{pH} &= 3.3372 \end{aligned}$$

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

$$\begin{aligned} \text{pH} &= -\log_{10} [\text{H}^+] \\ &= -\log_{10} [1 \times 10^{-3}] \\ &= -\log_{10} [1] + \log_{10} [10^{-3}] \\ &= -(0-3) \text{ pH} \\ \text{pH} &= 2.5229 \end{aligned}$$

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

$$\begin{aligned} \text{pH} &= 4.45 \\ \text{pH} &= -\log_{10} [\text{H}^+] \\ = 4.45 &= -\log_{10} [\text{H}^+] \\ \log_{10} [\text{H}^+] &= -4.45 = (-4 - 1) + (-0.45) + 1 \\ &= -5 + 0.55 \\ [\text{H}^+] &= \text{Antilog of } 0.55 \times 10^{-5} \\ [\text{H}^+] &= 3.548 \times 10^{-5} \text{ g ions/litre.} \end{aligned}$$

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

$$\begin{aligned} \text{pH} &= 5.25 \\ \text{pH} &= -\log_{10} [\text{H}^+] \\ 5.25 &= -\log_{10} [\text{H}^+] \quad \log [\text{H}^+] = -5.25 = (-6 + 0.75) \end{aligned}$$

$$\begin{aligned}
 [H^+] &= \text{antilog } (0.75) \times 10^{-6} \\
 &= 5.623 \times 10^{-6} \text{ g ions/litre.}
 \end{aligned}$$

5. Calculate the pH of 0.1 m NaOH solution.

0.1 m NaOH means

$$= 0.1 \text{ g ions/litre.}$$

$$\begin{aligned}
 \text{pOH} &= -\log_{10} [OH^-] \\
 &= -\log_{10}[0.1] \\
 &= -\log_{10} [1 \times 10^{-1}] \\
 &= -[-1] \\
 &= 1.
 \end{aligned}$$

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

$$\text{pH} + 1 = 14$$

$$\text{pH} = 14 - 1 = 13$$

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-base titration, if certain pH is reached, indicator changes its colour.

<u>Indicator</u>	<u>Colour Change</u>	<u>pH Range</u>
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 solution is acidic. Methyl orange shows a yellow colour, when pH =

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	Methylorange / phenolphthalein	HCl/H ₂ SO ₄ - NaOH/KOH
Strong acid	Weak base	Only methyl orange	HCl/H ₂ SO ₄ - Na ₂ CO ₃ /NH ₄ OH
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.

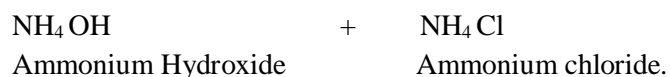
Example



Acetic acid sodium acetate

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

Example



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 dyeing 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.

UNIT II

SURFACE CHEMISTRY

2.1. COLLOIDS

INTRODUCTION

An aqueous solution of salt or sugar is homogeneous and it contains the solute particles as single molecules or ions. This is called a **true solution**.

In sugar solution, the sugar particles are not visible to the naked eye or under microscope. The diameter of the solute particle is less than 10^{-7} cm.

On the other hand when we mix sand and water, a heterogeneous mixture called coarse suspension is formed. The sand particles are visible because the diameter of the particle is greater than 10^{-5} cm. A heterogeneous mixture of dispersed particle in the dispersion medium falling in the range 10^{-7} to 10^{-5} cm is called as colloid.

The particles, which are larger than a molecule and smaller than a suspended particle, are said to be colloids and such solutions are called colloidal solutions or sols.

Molecular size < colloids < suspension

10^{-7} cm

10^{-7} to 10^{-5} cm (More than 10^{-5} cm)

Definition

A colloidal system is made up of two phases. The substance distributed as a colloidal particle is called the dispersed phase (analogous to solute) and the phase where the colloidal particles are dispersed is called the dispersion medium (analogous to solvent).

A heterogeneous mixture of a dispersed phase and dispersion medium is called as 'Colloid'.

A colloidal solution can form eight different types based upon the physical state (solid, liquid, gas) of dispersed phase and dispersion medium.

The common examples of colloids are milk, curd, cheese, clouds, paint etc.

Table -Differences between true solution and colloidal solutions

Sl. No.	Property	True Solution	Colloidal Solution
1.	Nature	Homogeneous system	Heterogeneous system
2.	Size	$1-10\text{\AA}$ (10^{-7} cm)	$10\text{\AA}-2000\text{\AA}$ (10^{-7} to 10^{-5} cm)
3.	Filtration	Cannot be filtered	can be filtered through animal or starch membrane
4.	Scattering of light	It does not scatter light	It scatters light
5.	Brownian movement	Does not exhibit	Does exhibit
6.	Electrophoresis	Does not show	Does show
7	Coagulation	Cannot be coagulated	Can be coagulated

The dispersed phase:

A substance which is dispersed into particles of colloidal size in a dispersion medium is called the dispersed phase.

The dispersion medium:

The continuous medium in which the colloidal particles are dispersed is called the dispersion medium.

For example, in colloidal starch solution, starch is the dispersed phase and water is the dispersion medium.

TYPES OF COLLOIDS

Based on the affinity between the dispersion medium and dispersed phase the colloid is classified into two types. They are

1. Lyophilic colloids

Colloidal solutions in which the dispersed phase has more affinity for the dispersion medium are called Lyophilic colloids [Lyo-solvent; philic-attract].
e.g. gelatin, protein, starch. The Lyophilic and Lyophobic colloids have different characteristics.

2. Lyophobic colloids

Colloidal solutions in which the dispersed phase has very little affinity for the dispersion medium are termed as lyophobic colloids [Lyo-solvent; phobic- hate]. E.g. colloidal solutions

of metals and sulphur in water.

Differences between Lyophilic and Lyophobic colloids

Sl. No.	Property	Lyophilic colloids	Lyophobic colloids
1.	Preparation	Can be easily prepared	Need some special methods to prepare
2.	Affinity towards solvent	Solvent attracting	Solvent hating
3.	Coagulation	Coagulation requires large quantity of electrolytes	A small quantity of electrolyte is sufficient
4.	Detection through ultra microscope	Cannot be easily detected	Can be easily detected
5.	Viscosity	Very much different from that of dispersion medium	Almost the same as that of dispersion medium
6.	Surface tension	Very much different from that of dispersion medium	Almost the same as that of dispersion medium
7.	Density	Very much different from that of dispersion medium	Almost the same as that of dispersion medium
8.	Electrophoresis	Particles migrate in either direction	Migrate in a particular direction
9.	Reversibility	The reaction is reversible	Irreversible
10.	Example	Starch solution, soap solution.	Colloidal gold, silver.

Property of colloids

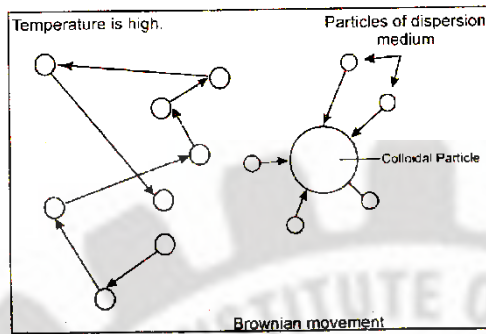
Colloids exhibit certain exclusive properties. They are:

- (i) Mechanical / kinetic property
- (ii) Optical property
- (iii) Electrical property
- (iv) Chemical property

(i) Mechanical / kinetic property (Brownian movement)

When the colloidal particles are seen through an ultra microscope, it is found that the colloidal particles are found to be in constant zig-zag, chaotic motion.

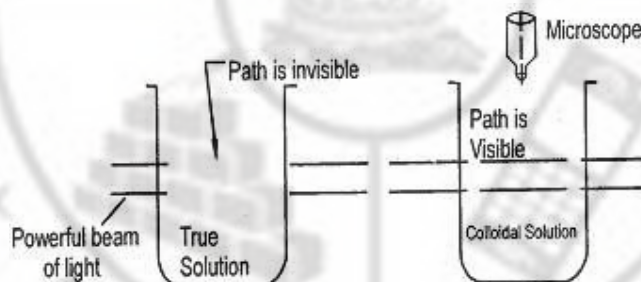
Fig- Brownian movement



This was first observed by Brown and so *this random movement of colloidal particles is called Brownian movement*. This movement is due to the unequal collisions of colloidal particles with the molecules of the dispersion medium. The motion becomes more rapid when the temperature of the dispersion medium is high and less viscous.

Optical property (Tyndall effect)

Fig.3.2. Tyndall effect



When the beam of light is passed through a true solution and if it is observed at right angles to the direction of the beam, the path of the light is not clear. At the same time, if the beam of light is passed through a colloidal solution, the path of the light is quite distinct due to scattering of light by the colloidal particles. *The phenomenon of scattering of light by the colloidal particles is known as "Tyndall effect"*.

Electrical property (Electrophoresis)

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.

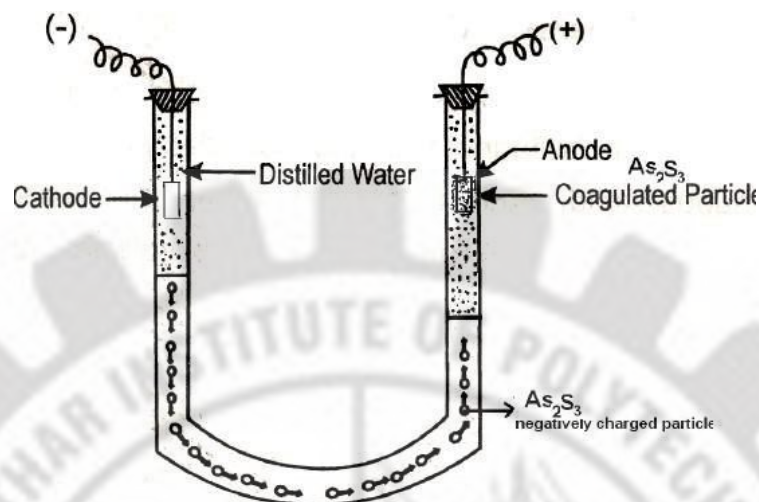


Fig. Electrophoresis

This phenomenon can be demonstrated by placing a layer of arsenic sulphide solution under two limbs of a U-tube. When current is passed through the limbs, it can be observed that the level of the colloidal solution drops out at one end of the limb and rises on the other end.

Coagulation of colloid :(Chemical property)

The entire colloidal particles are electrically charged. The particles are either positively charged or negatively charged. Therefore every colloidal particle repels each other and remains stable. In order to coagulate a colloid, first of all these charges have to be nullified. This can be done in three ways:

- (i) By adding a double salt (electrolyte)
- (ii) By introducing an electrode of opposite charge
- (iii) By introducing another colloid of opposite charge

After neutralizing the charges, the colloidal particles are brought together and they are large enough to settle down. **Thus the process of precipitating a colloidal solution is called coagulation.**

INDUSTRIAL APPLICATIONS OF COLLOIDS

Smoke precipitation

Smoke is a colloidal suspension of carbon particles in air. The smoke is first introduced into a chamber and subjected to a very high voltage. The particles are deposited in one of the electrodes and the hot air alone is let out through the chimney.

Purification of drinking water

The suspended impurities of the water cannot be filtered. So it is better to coagulate them. This is done by adding potash alum.

Cleansing action of soap

The dirt particles stick to the cloth or body by the greasy oily substance. It forms an emulsion with soap. The dirt particles get detached from the cloth / body and washed away along with soap with excess of water.

Tanning of leather

Animal hides are colloidal in nature. When a hide (positively charged particles) soaked in tannin (negatively charged particle) mutual coagulation takes place. This results in hardening of leather and the process is called tanning. Chromium salts are used as tannin.

Disposal of sewage

Sewage dirt particles are electrically charged. So the sewage is allowed to pass through disposal tanks. It is then subjected to high potential. The sewage particles lose the charges and coagulated. Clean water is recycled or used for gardening. Sludge is used as manure.

Summary: In this lessons the students have learnt about the true solution, colloid, types of colloids, difference the properties and application of colloids.

2.2 NANOTECHNOLOGY NANO PARTICLES

INTRODUCTION

Nano technology is the study of matter on an atomic and molecular scale. One nanometer is one billionth or 10^{-9} m. The carbon-carbon bond length is in the range of 0.12-0.15 nm, the DNA double helix has a diameter of 2nm, and that of bacteria will be around 200nm. **So particles of nanometer size are called Nano particles.**

DEFINITION

Nanoparticles are particle that have size ranging from 10to100 nanometer. $1\text{nm}=10^{-9}$ m. These are usually particles at the atomic or molecular size.

CHARACTERISATION

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). Therefore materials on nanoscale find wide applications in the field of medicine, electronics and in all fields of engineering.

Application of nanoparticle technology in medicine

The biological and medical research communities have exploited the properties of nano particles for various applications:

Integration of nano materials with biology led to the development of diagnostic devices and drug delivery vehicles.

- **Diagnostics:**

Gold nano particles tagged with DNA can be used for the detection of genetic sequence.

Manganese oxide nanoparticles have been used as contrast agent for magnetic resonance imaging (MRI).The results of an MRI scan can be used to help diagnose conditions, plan treatments and assess how effective previous treatment has been.

Nanoparticles are used for early and specific cancer detection and therapy.

- **Drug Delivery:** Drug can be delivered for specific cell using nano particles.

- **Tissue Engineering**

- 1.This may replace today's conventional treatment like organ transplants/artificial implants.

- 2.Advanced forms in tissue engineering may lead to life extension. 3.It can repair the targeted damaged tissue.

4. Lipid based nanoparticles are used in cosmetics and Creams.

5. The zinc oxide nanoparticles block the UV rays, hence it is used in Sunscreen lotion.

Application of nanotechnology in electronics

- (i) Today's solar cells utilize only 40% solar energy. Nanotechnology could help to increase the efficiency of *light conversion using nanostructures*.
- (ii) The efficiency of internal combustion engine is about 30-40%. Nano technology could *improve combustion by designing catalysts with maximized surface area*.
- (iii) The use of batteries with higher energy content is possible with nano materials.
- (iv) Nanotechnology has already introduced integrated circuits in nanoscale (50nm) in CPU's and DRAM devices.
- (v) Carbon nano-tubes based cross bar memory called Nano-RAM gives high density memory for computers has been developed.
- (vi) The data storage density of hard discs is increased by using the nanoparticle.

Biomaterials

- Problems in Food and bioprocessing industry for manufacturing high quality of safe food can be solved using nanotechnology.
- Bacteria identification and food quality monitoring using biosensors are examples of application of nano technology.
- A nano composite coating act as anti microbial agents.
- Natural bone surface is 100nm across. If the artificial bone implant is smooth, the body rejects it. So nano sized finishing of hip and knee would help the body to accept the implant.

SUMMARY: In this lesson the students have learnt about the nanoparticles, importance and applications in various fields.

2.3 CATALYSIS

INTRODUCTION

Catalyst plays an important role in chemical reaction. Catalytic reagents are better than ordinary reagents. Catalyst mainly used to prevents the environmental pollution. It helps us to achieve the goal of green chemistry.

DEFINITION

A catalyst is a substance which alters the speed of a chemical reaction without itself taking part in the chemical reaction. The process of using a catalyst to alter the speed of a chemical reaction is called as catalysis.

Example,



Decomposition of potassium chlorate is very slow under normal conditions. When a small amount of manganese dioxide is added the rate of decomposition of potassium chlorate increases. In the above reaction, MnO_2 acts as a catalyst. The reaction is called as catalysis.

TYPES OF CATALYST:

There are two types of catalysts

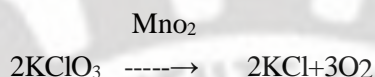
- (i) Positive catalyst

(ii) Negative catalyst

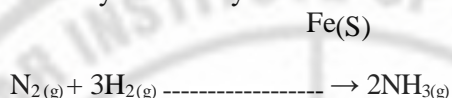
1. POSITIVE CATALYST

A catalyst which increases the speed of the reaction is called positive catalyst and the phenomenon is known as positive catalysis. Various examples are given below:

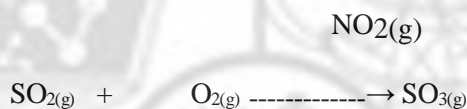
In Decomposition of KClO_3 , MnO_2 will act as a positive catalyst.



Iron is used as a positive catalyst in the synthesis of ammonia by Haber's process.



Nitric oxide is used as the catalyst in the lead chamber process



2. NEGATIVE CATALYST:

A catalyst which decreases the speed of the reaction is called negative catalyst and the phenomenon is known as negative catalysis.

The decomposition of hydrogen peroxide is decreases in the presence of glycerin.

Promoters: Glycerin

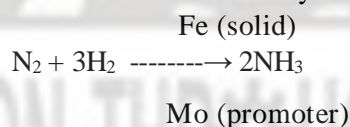


Promoter is a substance which increases the activity of the catalyst.

The activity of a catalyst can be increased by addition of a small quantity of a second material. These substances which, though itself not a catalyst, promotes the activity of a catalyst is called a promoter.

Some examples of the promoters are given below.

In the Haber's process for the synthesis of ammonia, traces of molybdenum increase the activity of finely divided iron which acts as a catalyst.

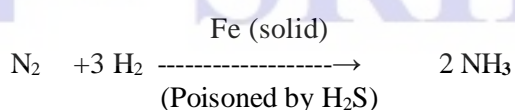


CATALYTIC POISONS:

Catalytic poison is a substance which lowers the activity of the catalyst.

A substance which destroys the activity of the catalyst is called a poison and the process is called catalytic poisoning. Some of the examples are:

The iron catalyst used in the synthesis of ammonia in Haber process is poisoned by H_2S .



Types of catalytic reactions

The process of using a catalyst to alter the speed of a chemical reaction is called as catalysis.

Catalytic reactions are classified into two broad types;

1. Homogeneous catalysis

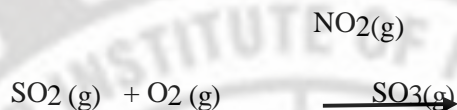
2. Heterogeneous catalysis

HOMOGENEOUS CATALYSIS:

If the catalyst and the reactants are in the same phase, then it is called as homogenous catalysis.

Example:

In the lead chamber process Oxidation of sulphur dioxide into sulphur trioxide with oxygen in the presence of nitric oxide is used as the catalyst



Hydrolysis of methyl acetate is catalyzed by H⁺ ions furnished by Hydrochloric acid.

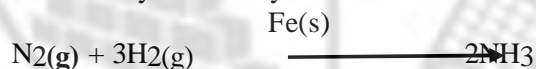


In above two reactions, the catalyst and the reactants are in same phase, hence these reactions are called as homogenous catalysis reactions.

HETEROGENEOUS CATALYSIS:

If the catalyst and the reactants are in the different phase, then it is called as heterogeneous catalysis. Some of the examples of heterogeneous catalysis are given below.

Iron is used as a positive catalyst in the synthesis of ammonia by Haber's process.



The reactants are in gaseous phase while the catalyst is in solid phase. Hence this reaction is called as heterogeneous catalysis reaction.

General characteristics of a catalyst:

The following characteristics are generally common to most of the catalytic reactions.

1. The catalyst remains unchanged in mass and in chemical composition at the end of the reaction. But it may undergo physical change.
2. Only a small quantity of catalyst is generally needed.
3. A catalyst cannot initiate a reaction.
4. The function of a catalyst is only to alter the speed of the reaction which is already occurring at a particular rate.
5. A catalyst does not alter the position of equilibrium in a reversible reaction.
6. The catalyst is generally specific in its action.
7. A catalyst cannot change the nature of the products obtained in a reaction.
8. A catalyst is efficient only at a particular temperature.

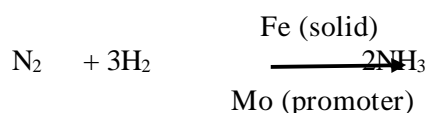
APPLICATIONS OF CATALYST:

In order to increase the yield of products and also to increase the rate of reaction, catalysts are employed for various applications in industries.

They are

- 1 In the Haber's process for the synthesis of ammonia, traces of molybdenum increase the

activity of finely divided iron which acts as a catalyst.



2. In the contact process of preparation of sulphuric acid, platinum is used as a catalyst.



3. In the manufacture of ethyl alcohol from sucrose, the enzyme Invertase and zymase are used as catalyst.



4. In the manufacture of hydrogen chloride from hydrogen and chloride, activated carbon is used as catalyst.



5. In the manufacture of methyl alcohol from CO and H₂, zinc oxide is used as Catalyst.



6. In the refining of petroleum, phosphoric acid is used as a catalyst.

7. In the cracking of petroleum fractions, silica is used as a catalyst.

8. In the hydrogenation of vegetable oil, nickel is used as a catalyst.

UNIT III

MINERALS AND METALLURGY









Introduction

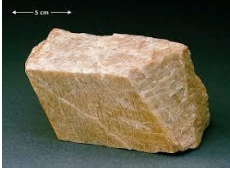






A mineral is a naturally occurring substance having a definite chemical composition, constant physical properties, and a characteristic crystalline form. Ores are a mixture of minerals: they are processed to yield an industrial mineral or treated chemically to yield a single or several metals. Ores that 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		<ol style="list-style-type: none"> Salem Namakkal Karur 	<ol style="list-style-type: none"> The refractory material. Magnesium cement. Catalyst and filler.
Dunite		<ol style="list-style-type: none"> Salem Namakkal Karur 	<ol style="list-style-type: none"> The refractory material. Catalyst and filler. Using as flux in the Iron & Steel industry.
Graphite		<ol style="list-style-type: none"> Sivaganga Madurai 	<ol style="list-style-type: none"> Insulator. Electrode. Atomic reactor Crucibles Carbon brushes.
Lignite		<ol style="list-style-type: none"> Cuddalore Ramana-thapuram 	<ol style="list-style-type: none"> Fuel. Power station.
Bauxite		<ol style="list-style-type: none"> Salem Namakkal 	<ol style="list-style-type: none"> Ore of Aluminium. Used as metal alloy for aircraft.
Iron Ore		<ol style="list-style-type: none"> Salem Tiruvannamalai 	<ol style="list-style-type: none"> Iron metal.
Limestone		<ol style="list-style-type: none"> Ariyalur Perambalur Tirunelveli Virudhunagar Madurai Salem Karur Dindigul 	<ol style="list-style-type: none"> Cement. Chemical Industries. Pharmaceuticals. Metal Industries.
Quartz		<ol style="list-style-type: none"> Salem Namakkal Karur Dharmapuri 	<ol style="list-style-type: none"> Silicon Chips. Glass Industries.

Feldspar		<ol style="list-style-type: none"> 1. Salem 2. Namakkal 3. Karur 4. Dharmapuri 	<ol style="list-style-type: none"> 1. Ceramic article. 2. Decorative tiles.
Garnet Sand		<ol style="list-style-type: none"> 1. Kanyakumari 2. Tirunelveli 3. Tuticorin 4. Trichy 	<ol style="list-style-type: none"> 1. Abrasives,. 2. Semiconductor. 3. Sand plastering.
Silica Sand		<ol style="list-style-type: none"> 1. Nagapattinam 	<ol style="list-style-type: none"> 1. Glass Industries. 2. Foundry moulding catalysts.
Fireclay		<ol style="list-style-type: none"> 1. Ariyalur 2. Cuddalore 	<ol style="list-style-type: none"> 1. Refractory. 2. Decorative tiles. 3. Ceramic article.
Molybdenum		<ol style="list-style-type: none"> 1. Dharmapuri 2. Krishnagiri 	<ol style="list-style-type: none"> 1. Electrical conductor. 2. Used in petroleum industries. 3. Heating Elements.
Gypsum		<ol style="list-style-type: none"> 1. Perambalur 2. Coimbatore 	<ol style="list-style-type: none"> 1. Plaster of Paris. 2. Cement. 3. Manure and Pesticides.
Calcite		<ol style="list-style-type: none"> 1. Salem 	<ol style="list-style-type: none"> 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 crust. Its 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 **haematite** on large scale using blast furnace. Haematite contains **iron** oxide. Iron is obtained

by reduction process.

Ores of iron :

Haemetite (Fe_2O_3) contains 70% iron

Magnetite(Fe_3O_4) contains 72% iron

Siderite- FeCO_3 contains 48 % Iron

raction 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.



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

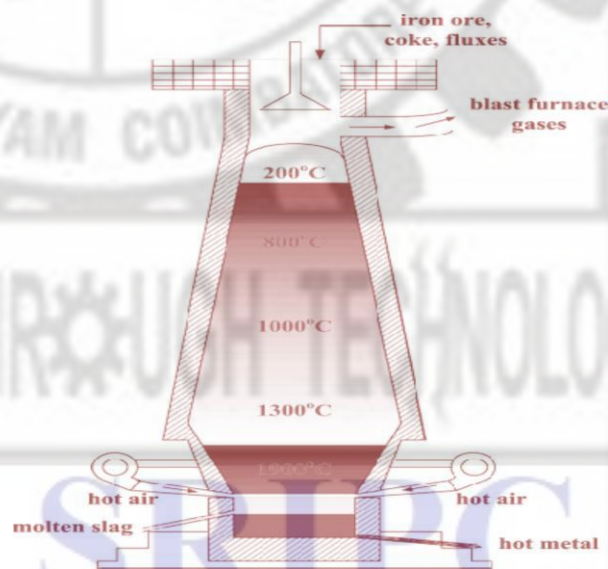
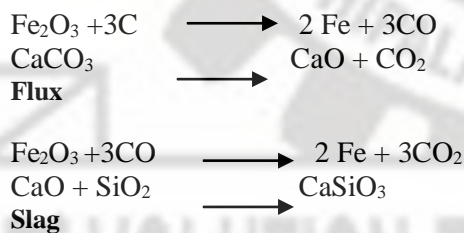
Smelting:

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°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:



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 converter. 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 converter 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.

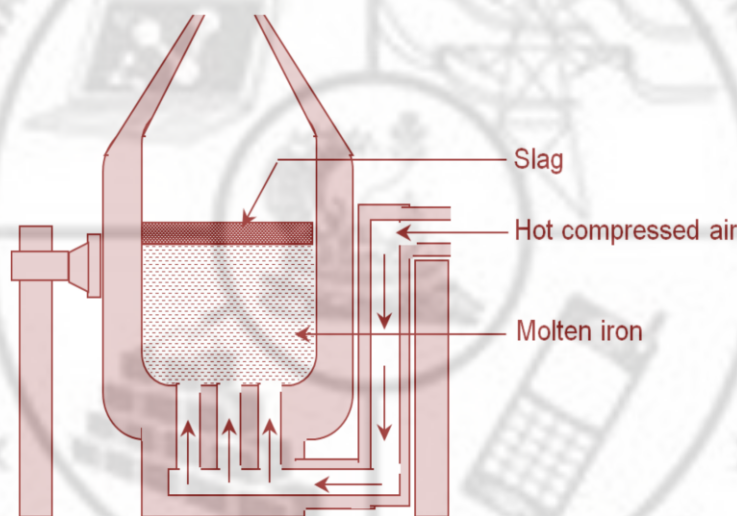


Fig. 3.1.3 Bessemer Converter

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

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) WO₄

Scheelite CaWO₄

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

Extraction

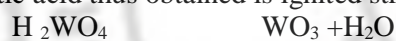
Concentrated ore is fused with a mixture of sodium carbonate and sodium nitrate. The fusion is done in an oxidizing atmosphere. The fused mass is extracted with water. Then the solution is acidified with HCl. Tungstic acid is precipitated.



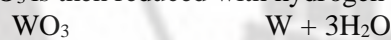
Sodium tungstate crystals are again dissolved in minimum quantity of water and acidified with HCl acid. Hydrated tungstic acid WO₃.H₂O (**H₂WO₄**) precipitates out.



Tungstic acid thus obtained is ignited strongly to remove water.



The WO₃ is then reduced with hydrogen to get tungsten.



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. WO₃ 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 crust, 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 –

TiO₂

Ilmenite – FeTiO₃

Extraction

Stage I: The ores of Titanium (Rutile or Ilmenite) is converted into titanium tetra chloride (TiCl₄) by heating them at 900°C with carbon in a current of Chlorine.



Stage II: The vapour of TiCl₄ is collected and condensed to get TiCl₄ liquid. TiCl₄ liquid, which boils at 136°C, is purified by distillation.

Stage III: TiCl₄ 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.



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.



Titanium tetra iodide is taken to a different chamber and passed over a heated tungsten wire at 140°C. TiI₄ decomposes to give pure Titanium.



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 compared to stainless steel. It is therefore used in aircrafts, gas turbine engines, marine equipments etc.
2. It is also used for hardening steel.
3. TiO₂ is used as a semi-precious artificial gem.

occur while cooling, thereby repairing the defects and produce a refined microstructure. The annealing temperature varies 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.

POWDER METALLURGY

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) Atomisation: 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.

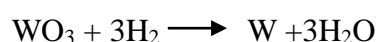
Metal powder can be obtained by passing reducing agent like carbon monoxide or hydrogen on heated metal oxides. The metal thus obtained is then crushed and ground to particle of desired size.

Example:

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

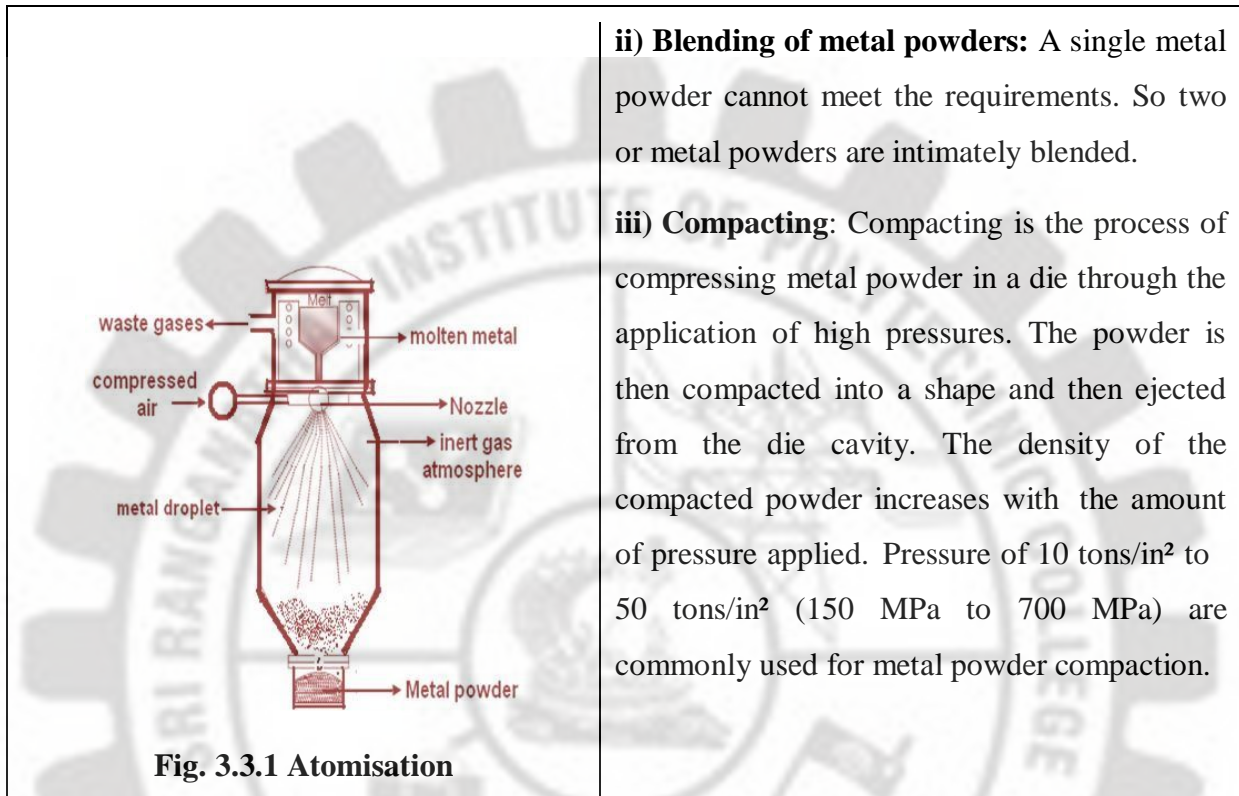


2. Tungsten powder is obtained by passing hydrogen over WO_3 .



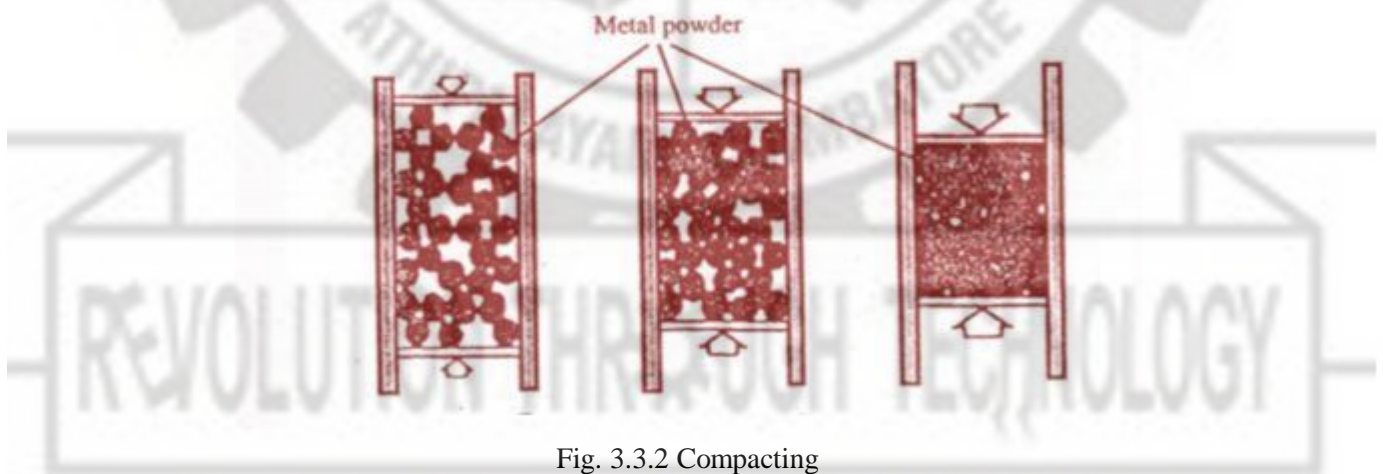
Advantages:

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



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.



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.

REVOLUTION THROUGH TECHNOLOGY

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UNIT IV

NUCLEAR CHEMISTRY

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.

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

- Examples:**
- i) ${}_{92}\text{U}^{235}$, ${}_{92}\text{U}^{236}$ and ${}_{92}\text{U}^{238}$ are the isotopes of Uranium.
 - ii) ${}_{90}\text{Th}^{228}$ and ${}_{90}\text{Th}^{232}$ are the isotopes of Thorium.
 - iii) ${}_{8}\text{O}^{16}$, ${}_{8}\text{O}^{17}$ and ${}_{8}\text{O}^{18}$ are the isotopes of Oxygen.

Isobars

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

- Examples:**
- i) ${}_{90}\text{Th}^{234}$ and ${}_{91}\text{Pa}^{234}$
 - ii) ${}_{88}\text{Ra}^{228}$ and ${}_{89}\text{Ac}^{228}$

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



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.



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



Emission of γ - particle

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



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, $\lambda = 0.03465/\text{yrs}$.

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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.

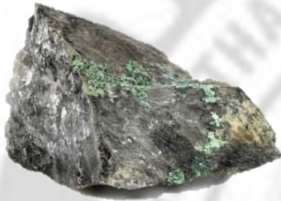


Image Uranium

For example, fission of U-235 by neutrons:

When U-235 is bombarded with accelerated neutrons, it splits into Ba¹⁴⁴ and Kr⁹⁰ releasing two neutrons and enormous amount of 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.

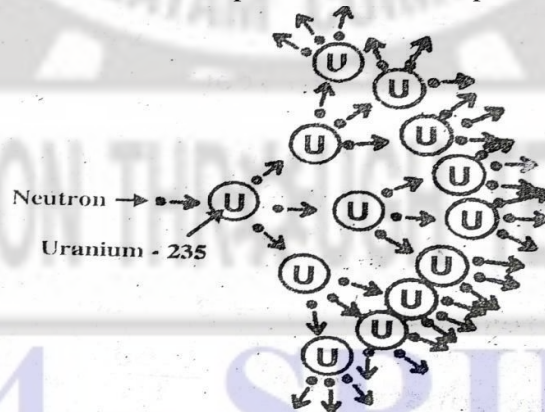


Fig. 4.1.1 Chain Reaction

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.

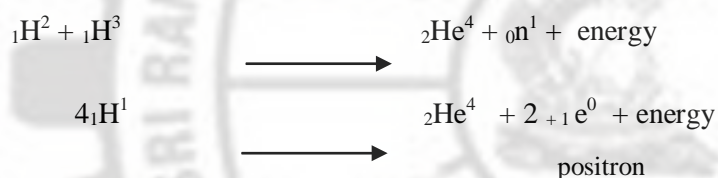
The chain reaction can be controlled and maintained steadily by absorbing a desired number of neutrons using materials like Cadmium, Boron, and Hafnium etc. Thus in average one neutron is made available for further fission reaction. Such reaction is called controlled chain reaction. This type of reaction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

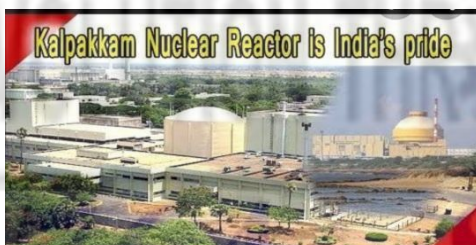
release of enormous amount of energy. For example fusion reactions taking place in Sun maybe given as follows.



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.



Kudankulam 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.

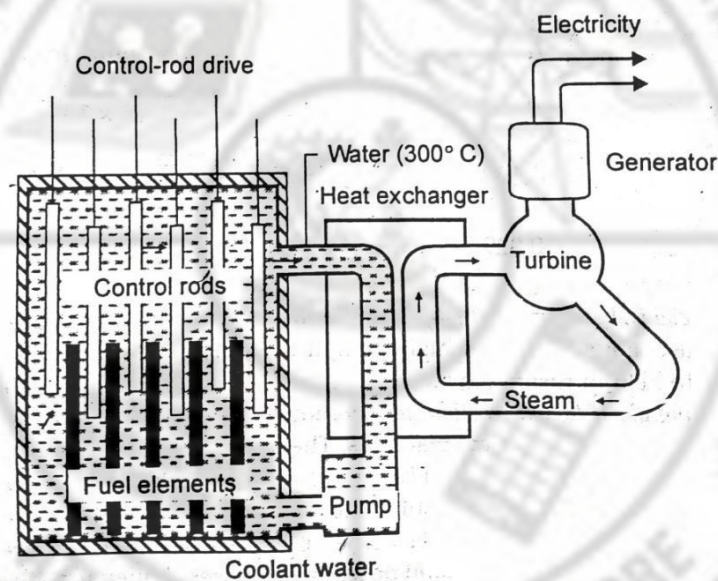


Fig. 4.1.2 Nuclear Reactor

- 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: H₂O, D₂O 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/cm². 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/cm² 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.



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

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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 valves.
- 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.

CEMENT AND CERAMICS

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 it 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 ($2\text{CaO} \cdot \text{SiO}_2$)-28% [C_2S]
2. Tricalcium silicates ($3\text{CaO} \cdot \text{SiO}_2$)-46% [C_3S]
3. Tricalcium aluminates ($3\text{CaO} \cdot \text{Al}_2\text{O}_3$)-10% [C_3A]
4. Tetra calcium aluminoferrite ($4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$)-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

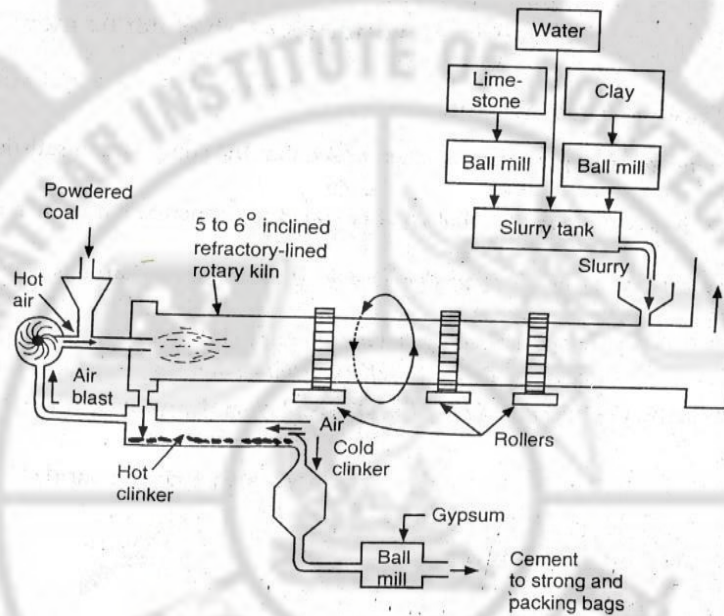
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Example: Limestone, chalk, marble

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°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 $900 - 1000^{\circ}\text{C}$, 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°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 aluminoferrite (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

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 $3300^{\circ}C$. 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.

REFRACTORIES AND GLASS

Introduction

Refractories find wide application in the linings of the furnace, tanks, converters, kilns, crucibles, ladles etc., employed for the manufacture of 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

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. Magnesite 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

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.

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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 $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$.
2. Potash lime Glass: $\text{K}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$.
3. Potash lead glass: $\text{K}_2\text{O} \cdot \text{PbO} \cdot 6\text{SiO}_2$.

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:

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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 (CO₂) bubbles. This is called fining. Na₂CO₃ 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, thereby 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.

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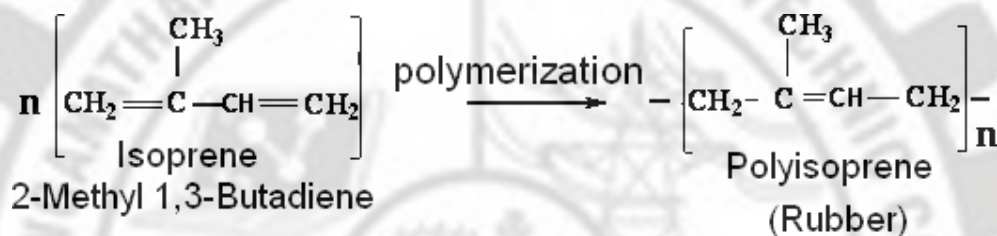
UNIT V

CHEMISTRY OF ENGINEERING MATERIALS

5.1 POLYMER

RUBBER

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



Preparation of natural rubber from Latex

1. Latex is the rubber milk containing about 30% to 45% rubber.
2. The rubber milk is diluted with water and allowed to stand for some time.
3. The clear liquid from the top is treated with **acetic acid or formic acid** to coagulate the rubber.
4. The coagulated rubber is thoroughly washed with water and then passed through rollers to get sheets of rubber.
5. Rubber sheets are finally dried either in air or in smoke. This rubber is called 'smoked rubber'.
6. During the coagulation of rubber milk with acetic or formic acid, retardants like sodium bisulphite (NaHSO_3) are added to prevent oxidation of rubber. This is called 'Creep rubber'. Thus natural rubber is obtained from 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. Vulcanization

Vulcanization is process of heating the natural rubber with sulphur at 140°C in CO₂ atmosphere. By vulcanization, the hardness of rubber is improved.

Example: sulphur.

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

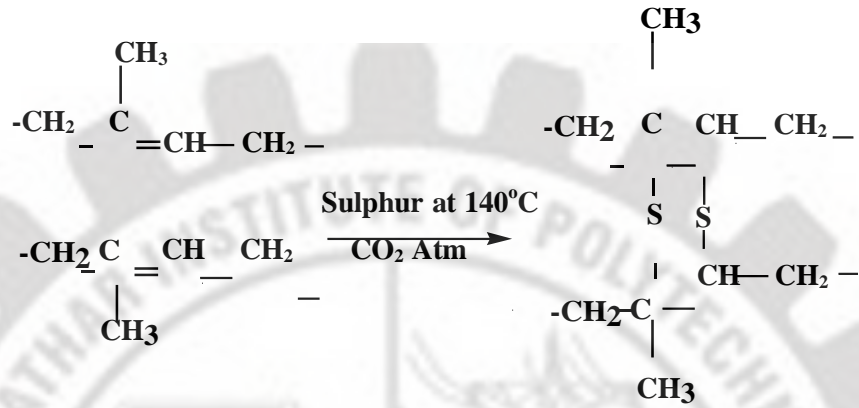
7. Fillers

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 process of heating the natural rubber with sulphur at 140°C in CO₂ atmosphere.
- The double bonds present in rubber chain 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



REVOLUTION THROUGH TECHNOLOGY

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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.

Reclaimed rubber

Rubber prepared from waste rubber articles such as worn out tyres, tubes, gaskets, hoses, foot wears and other rubber wastes is called reclaimed rubber.

The process of reclamation of rubber is carried out as follows.

1. The waste rubber is cut into small pieces and powdered by using a cracker.
2. Then iron impurities, if any present, is removed by using electromagnetic separator.
3. The purified waste rubber is digested with caustic soda solution at 200°C under pressure for 8 to 15 hours in 'steam jacked autoclaves'. This process hydrolyses the fibres present in the waste rubber.
4. After the removal of fibres, reclaiming agents like petroleum or coal tar based oils and softeners are added.
5. Sulphur gets removed as sodium sulphide and rubber gets devulcanized.
6. The rubber is thoroughly washed with water spray and dried in hot air driers.
7. Finally, the reclaimed rubber is mixed with small portions of reinforcing agents like clay, carbon black, etc.

Properties of reclaimed rubber

1. Reclaimed rubber has less tensile strength, low elasticity and possesses very low wear resistance when compared to natural rubber.
2. However, it is much cheaper and has uniform composition.
3. It has better ageing property.
4. It is quite easy for fabrication.

Uses of reclaimed rubber

1. It is used for the manufacture of tyres, tubes, etc.,
2. It is used for the manufacture of shoes, automobile floor mats, etc.,
3. It is used for the manufacture of hoses.
4. It is used for the manufacture of battery containers.

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 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 tissues 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.

ABRASIVES

5.2 ABRASIVES

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 a hard substance which is 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	1
Gypsum	2
Calcite	3
Fluorite	4
Appatite	5
Feldspar	6
Quartz	7
Topaz	8
Corundum	9
Diamond (C)	10

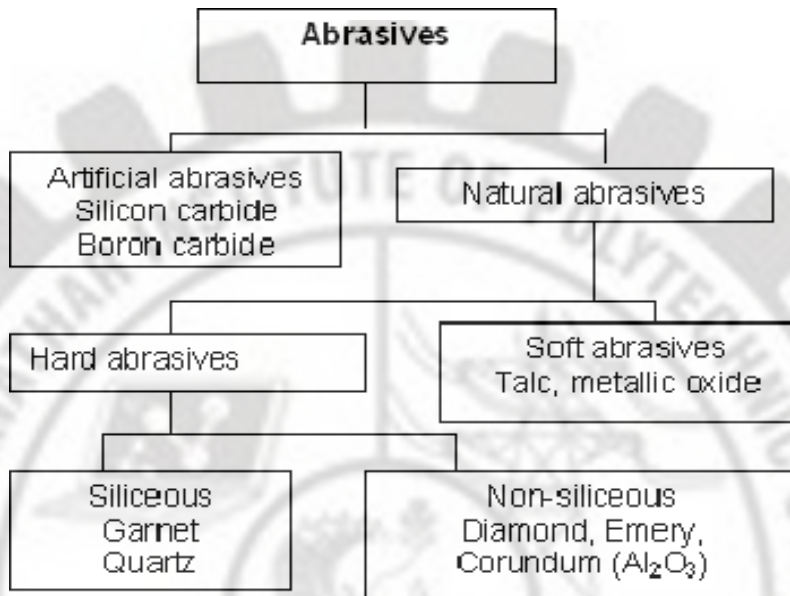
Generally, hardness of abrasives is measured by piercing a needle through it using some pressure. Hardness is measured in terms of the distance pierced by the needle in the abrasive material and comparing the same with a standard substance of known hardness.

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.

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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.

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.
- It consists of trisilicates of alumina, magnesia and ferrous oxide.
- 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.

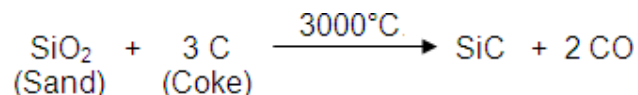
Important synthetic abrasives

1. Silicon carbide (SiC)-carborundum:

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

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 .



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

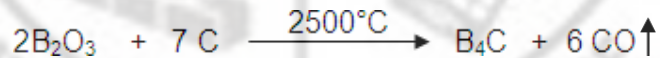
- It is used for making grinding wheels, cast iron and bronze.
- It is used for cutting and grinding glass.
- It is used for grinding granite.
- It is used for grinding carbides.

2. Boron carbide (B₄C)

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 (B₂O₃) 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.

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.

1.3 COMPOSITE MATERIALS

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.Dispered 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 collagen and brittle and hard material apatite)

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.

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, hulls and other ship parts.
6. In automobile industries, turbine engines,

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