



MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)

Rasipuram - 637 408, Namakkal Dist., Tamil Nadu



LECTURE HANDOUTS

L 01

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: Characteristics of water

Introduction :

- ✓ Characteristics that decide the quality or purity of water, these characteristics are known as water quality parameters.
- ✓ These parameters also decide the nature and types of impurities present in water.
- ✓ Water quality parameters provide important information about the health of a water body.
- ✓ These parameters are used to find out if the quality of water is good enough for drinking, recreation, irrigation, and aquatic life.

Prerequisite knowledge for Complete understanding and learning of Topic:

The water quality parameters are as follows,

- ✓ Colour
- ✓ Turbidity
- ✓ Acidity
- ✓ Alkalinity
- ✓ Nitrogen
- ✓ Fluoride

i) Colour:

- ✓ Colour is a shade imparted by organic or inorganic material, which changes the appearance of the water.
- ✓ The colour producing substances are removed by coagulation, settling, adsorption and filtration.

Sources:

- ✓ Organic sources: Humus materials, tannin, algae, weeds, organic dyes, peat, etc.
- ✓ Inorganic sources: Metallic substances like salts of iron, manganese and copper, Chemicals and various inorganic dyes from industries.

ii) Turbidity:

- ✓ Turbidity is a measure of the cloudiness of water. The cloudiness of the water is greater, the turbidity also greater. (Or)
- ✓ Turbidity, on the other hand, is a measure of the amount of light scattered and adsorbed by water because of the suspended matter in the water.

Sources:

- ✓ Clay, silt, ferric hydroxide, silica, iron, manganese, vegetable or animal matter oils, fats, greases, micro-organisms etc.

iii) Acidity:

- ✓ The acidity of water is its capacity to neutralize hydroxide ions. Acidity may be caused by mineral acids such as sulfuric acid or hydrochloric acid or by dissolved carbon dioxide. Acidity is expressed in terms of pH.

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

- ✓ Acidity is generally measured by titration with sodium hydroxide to an accepted pH value. Phenolphthalein is an acid-base indicator which changes from colorless to a pink.

Sources:

- ✓ Surface water and ground water attain acidity from industrial wastes like acid, mine, drainage, pickling liquors, etc.

iv) Fluoride:

- ✓ Fluoride is a chemical that occurs naturally within many types of rock.
- ✓ Fluoridation is the addition of fluoride compounds into drinking water, to adjust
- ✓ concentrations to levels between 0.8 and 1.0 mg/L for the beneficial effect of tooth decay prevention.
- ✓ Studies have shown that children drinking fluoridated water can expect to have up to 35% less tooth decay than those drinking non-fluoridated water.

Sources:

- ✓ Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils.

v) Nitrogen:

- ✓ Nitrogen is present in water bodies in the form of nitrate, ammonia and other nitrogenous organic compounds.
- ✓ The concentrations are usually expressed in milligrams per liter of nitrogen. Many ground water contain small amounts of nitrate.
- ✓ Concentrations range from 0.1 mg/l to 3 or 4 mg/l in most areas.

Sources:

- ✓ Sources of nitrates include soil, sewage, and fertilizers.

vi) Alkalinity:

- ✓ Alkalinity is the measure of a water ability to neutralize hydrogen ions (its acid-neutralizing ability).

Sources:

- ✓ Alkalinity may be caused by dissolved strong bases such as sodium hydroxide or potassium hydroxide, dissolved carbonates bicarbonates, borates, and phosphates, silicates from various industries.

Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.1.2

Course Faculty

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LECTURE HANDOUTS

L 02

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

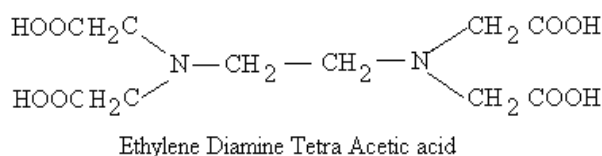
Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: Estimation of Hardness by EDTA method

Introduction :

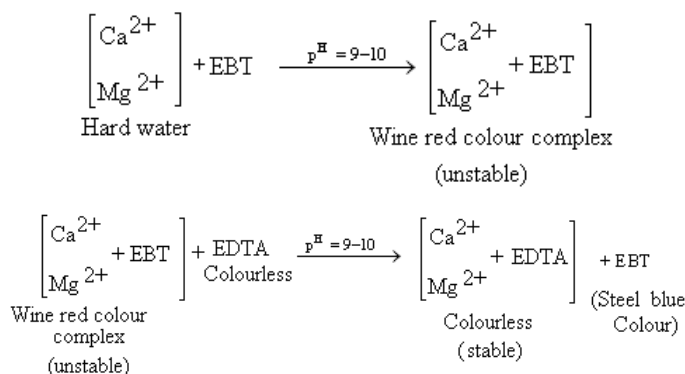
- ✓ Estimation of Hardness by EDTA method
 - Hardness can be estimated by using EDTA (Ethylene Diamine Tetra Acetic acid)
- ✓ STRUCTURE OF EDTA



Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Disodium salt of Ethylene Diamine Tetra Acetic acid (EDTA)
- ✓ When EDTA is added into the hard water, the metal ions form a stable metal complex.
- ✓ End point is wine red to steel blue colour
- ✓ Throughout reaction pH should be maintained in the range of 8-10.

Estimation of Hardness by EDTA Method



Preparation of solution:

a) Preparation of EDTA Solution:

EDTA solution is prepared by dissolving 4 gms of EDTA in 1000 ml of distilled water.

b) Standard Hard water:

1 gm of pure CaCO_3 is dissolved in minimum quantity of HCl and then made up to

1000ml using distilled water.

So, 1 ml of standard hard water = 1 mg of CaCO_3 equivalent hardness.

c) EBT indicator:

0.5 gms of EBT is dissolved in 100 ml of alcohol.

d) Buffer solution:

67.5 gms of NH_4Cl and 570 ml of NH_3 are dissolved and the solution is made up to 1000 ml using distilled water.

Experimental procedure:

i) Standardization of EDTA:

- ✓ 50 ml of standard hard water is pipetted out into a clean conical flask.
- ✓ 10 ml of buffer solution and 4-5 drops of EBT indicator are added and titrated against EDTA solution taken in the burette.
- ✓ The end point is the change of colour from wine red to steel blue.
- ✓ the volume of EDTA consumed be V_1 ml.

(ii) Estimation of total hardness of water sample

- ✓ 50 ml of the given hard water sample is pipetted out into a clean conical flask and titrated against EDTA as before.
- ✓ Let the volume of EDTA consumed be V_2 ml.

(iii) Estimation of permanent hardness of water sample

- ✓ 100 ml of the same hard water sample is taken in a 250 ml beaker.
- ✓ It is boiled for 15 minutes.
- ✓ During boiling temporary hardness gets removed.
- ✓ The solution is cooled and filtered and made up to 100 ml in a standard flask by adding distilled water.
- ✓ 50 ml of the made up solution is pipetted out into a clean conical flask and titrated against EDTA as before.
- ✓ Let the volume of EDTA consumed be V_3 ml.

Calculations:

i) Standardization of EDTA:

1 ml of Std. Hard water = 1 mg of CaCO_3

50 ml of Std. Hard water = 50 mg of CaCO_3

50 ml of Std. Hard water consumes = V_1 ml of EDTA

So, V_1 ml of EDTA = 50 mg of CaCO_3

equivalent hardness

Therefore, 1 ml of EDTA = $50 / V_1$ mgs of CaCO_3

equivalent hardness

(ii) Estimation of Total hardness of water sample:

50 ml of given hard water consumes = V_2 ml of EDTA

$$\begin{aligned} (\because 1 \text{ ml of EDTA} &= 50 / V_1 \text{ mgs of CaCO}_3) \\ &= V_2 \times 50 / V_1 \text{ mgs of CaCO}_3 \\ &\text{equivalent hardness} \end{aligned}$$

$$\begin{aligned} 1 \text{ ml of given hard water} &= V_2 / 50 \times 50 / V_1 \text{ mgs of CaCO}_3 \\ &\text{equivalent hardness} \end{aligned}$$

Therefore, 1000 ml of the given hard water sample

$$= 1000 \times V_2 / V_1 \text{ mgs of CaCO}_3 \text{ equivalent hardness}$$

$$\text{Total hardness} = 1000 \times V_2 / V_1 \text{ ppm}$$

(iii) Estimation of Permanent hardness of water sample:

50 ml of boiled and filtered

$$\begin{aligned} \text{hard water consumes} &= V_3 \text{ ml of EDTA} \\ &= V_3 \times 50 / V_1 \text{ mgs of CaCO}_3 \\ &\text{equivalent hardness} \end{aligned}$$

$$1 \text{ ml of boiled and filtered hard water} = V_3 / 50 \times 50 / V_1$$

Therefore, 1000 ml of the given hard water sample

$$= 1000 \times V_3 / V_1 \text{ mgs of CaCO}_3 \text{ equivalent hardness}$$

$$\text{Permanent hardness} = 1000 \times V_3 / V_1 \text{ ppm}$$

(iii) Estimation of Temporary hardness of water sample

$$\text{Temporary hardness} = \text{Total hardness} - \text{Permanent hardness}$$

$$= 1000 \times V_2 / V_1 - 1000 \times V_3 / V_1 \text{ ppm}$$

$$\text{Temporary hardness} = 1000 / V_1 \times [V_2 - V_3] \text{ ppm}$$

Hence, $\text{Total hardness} = 1000 \times V_2 / V_1 \text{ ppm}$

$$\text{Permanent hardness} = 1000 \times V_3 / V_1 \text{ ppm}$$

$$\text{Temporary hardness} = 1000 / V_1 \times [V_2 - V_3] \text{ ppm}$$

Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.1.6

Course Faculty

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LECTURE HANDOUTS

L 03

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: Determination of Alkalinity in given water sample

Introduction :

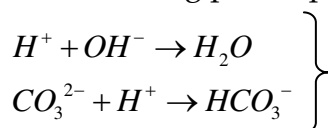
- ✓ Alkalinity is the measure of a water ability to neutralize hydrogen ions
- ✓ it is expressed in terms of mg of CaCO_3 although many substances may actually contribute to the alkalinity.
- ✓ Methyl orange, phenolphthalein used as indicator and end point is change from yellow to orange red.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Alkalinity is caused due to the presence of hydroxide, carbonate and bicarbonate. .
- ✓ Three different alkalinities can be estimated by this method
- ✓ Find out which type of alkalinity present it.

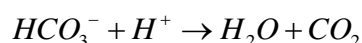
i) Phenolphthalein end point (P)

- ✓ Hydroxide alkalinity is completely neutralized and carbonate alkalinity is partially neutralized during phenolphthalein end point.



ii) Methyl Orange end point (M)

- ✓ Bicarbonate neutralization occurs during methyl orange end point



- ✓ From the two titer values the different alkalinities are calculated.

When,

$P=M \rightarrow$ Hydroxide alkalinity

$2P=M \rightarrow$ Carbonate alkalinity

$P=0 \rightarrow$ Bicarbonate alkalinity

$P < \frac{1}{2}M \rightarrow$ Carbonate and bicarbonate alkalinity

$P > \frac{1}{2}M \rightarrow$ Hydroxide and carbonate

- ✓ Alkalinity values are expressed in terms of milligram per litre in terms of equivalents calcium carbonate.

Procedure:

Titration I: (With Phenolphthalein indicator)

- ✓ 20 ml of water sample is pipetted out into a clean conical flask.
- ✓ A drop of Phenolphthalein indicator is added.
- ✓ The solution turns pink in colour and it is then titrated against acid taken in the burette. The end point is the disappearance of pink colour.
- ✓ The final reading in the burette is noted (V_1).
- ✓ The titration is repeated to get concordant values.
- ✓ This titer value corresponds to Phenolphthalein end point.

Titration II: (With Methyl orange indicator):

- ✓ Few drops of methyl orange indicator are added to the same solution after the Phenolphthalein end point.
- ✓ The titration is continued until the solution becomes red orange.
- ✓ The titer value is noted (V_2).
- ✓ This titer value corresponds to methyl orange end point.

Calculations:

Volume of acid consumed
using phenolphthalein indicator } = V_1 ml
Volume of acid consumed using
methyl orange indicator = V_2 ml

- ✓ Phenolphthalein alkalinity in terms of CaCO_3 equivalents

$$= \frac{V_1 \times \text{Strength of acid} \times \text{Equivalent weight of } \text{CaCO}_3}{\text{Volume of water sample taken}} \times 1000 \text{ ppm}$$

- ✓ Methyl orange alkalinity in terms of CaCO_3 equivalents

$$= \frac{(V_1 + V_2) \times \text{Strength of acid} \times \text{Equivalent weight of } \text{CaCO}_3}{\text{Volume of water sample taken}} \times 1000 \text{ ppm}$$

- ✓ The calculation of OH^- , CO_3^{2-} and HCO_3^- can be based on the following formulas given in the Table -I

Table -I Titer value and different alkalinities

S.No.	Result of titration of [P] and [M]	Hardness causing ions		
		OH^-	CO_3^{2-}	HCO_3^-
1.	[P]=0	0	0	[M]
2.	[P]=[M]	[P] = [M]	0	0
3.	$P = \frac{1}{2}M$	0	2[P] or M	0
4.	$P > \frac{1}{2}M$	2[P] - [M]	2[M] - [P]	0
5.	$P < \frac{1}{2}M$	0	2[P]	[M - 2[P]]

Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.1.5

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LECTURE HANDOUTS

L 04

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: BOD & COD, Boiler feed water

Introduction :

- ✓ The water fed into the boiler for the production of steam is called Boiler feed water.
- ✓ Any natural sources of water do not supply a perfectly suitable boiler feed water.
- ✓ Boiler feed water should be free from turbidity, oil, dissolved gases, alkali and hardness producing substances.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ If hard water obtained from natural sources is fed directly to the boilers, the following trouble may arise,
- ✓ Scale and sludge formation
- ✓ Priming and foaming
- ✓ Caustic embrittlement
- ✓ Boiler corrosion

Biological oxygen demand:

It is defined as the amount of oxygen required for the biological oxidation of organic matter under aerobic conditions at 25°C for the period of five days.

- ✓ BOD is a chemical procedure for determining how fast biological organisms use up oxygen in a body of water.
- ✓ It is used in water quality management and assessment, ecology and environmental science.
- ✓ BOD is not an accurate quantitative test, although it is considered as an indication of the quality of a water source.
- ✓ It is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C or 3 days of incubation at 27 °C.
- ✓ The BOD test must be inhibited to prevent oxidation of ammonia. If the inhibitor is not added, the BOD will be between 10% and 40% higher than can be accounted for by carbonaceous oxidation

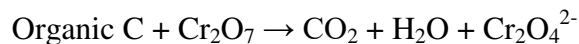
Chemical oxygen demand:

It is defined as the amount of oxygen required for the complete chemical oxidation of total oxidizable impurities present in water with strong oxidizing agents in acidic medium.

This test is carried out on the sewage to determine the extent of readily oxidizable organic matter, which is of two types:

- ✓ Organic matter which can be biologically oxidized is called biologically active
- ✓ Organic matter which cannot be oxidized biologically is called biologically inactive. COD gives the oxygen required for the complete oxidation of both biodegradable and non-biodegradable matter.
- ✓ COD is a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant.
- ✓ It is an indirect method to measure the amount of organic compounds in water.
- ✓ It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution

Analytical Procedure:

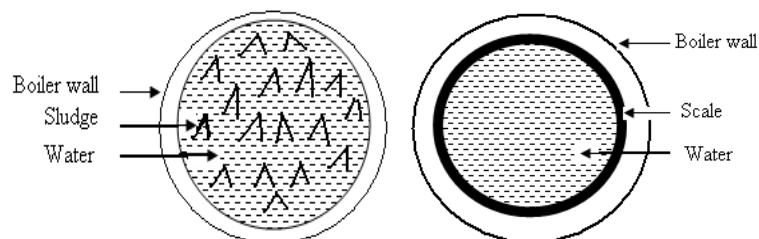


A sample is refluxed in strongly acidic solution with a known excess of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) for 2-3 h.

- ✓ After digestion, the remaining unreduced $\text{K}_2\text{Cr}_2\text{O}_7$ is titrated with ferrous ammonium sulphate to determine the amount of $\text{K}_2\text{Cr}_2\text{O}_7$ consumed.
- ✓ Then, the oxidizable matter is calculated in terms of oxygen equivalent.
- ✓ This procedure is applicable to COD values between 40 and 400 mg/L.

Scale and Sludge formation:

- ✓ When water is evaporated in boiler to produce the steam continuously, this results in the concentration of the dissolved salts in water increases progressively.
- ✓ When the concentrations of the salts reach their saturation point, they are thrown out in the form of precipitates either as scale or sludge on the inner walls of the boilers.



SludgeScale:

Sludge:

- ✓ During the production of steam, if the precipitate formed by the dissolved salts of

boiler feed water is loose and slimy, then that precipitate is called as sludge.

- ✓ Salts responsible for sludge formation are MgCl_2 , MgCO_3 , MgSO_4 and CaCl_2 .
- ✓ They have greater solubility in hot water than cold water.

Scale:

- ✓ During the production of steam, if the precipitate formed by the dissolved salts of boiler feed water, is hard and strongly adherent coating on the inner walls of the boiler, then that precipitate is called as Scale.
- ✓ Salts responsible for scale formation are $\text{Ca}(\text{HCO}_3)_2$, CaSO_4 and MgCl_2 .

Reason:

- ✓ Solubility product of salt must be exceeded the product of its constituent ions.
- ✓ The solubility of the salt decreases with rise in temperature.

Disadvantages of scale and sludge formation:

- ✓ Scales and Sludges act as a poor conductor of heat. It also decreases the efficiency of boiler.
- ✓ Scale may cause the formation of cracks inside the boiler due to uneven heating of boiler, sometimes excess heating may be lead to the explosion of boiler.
- ✓ Excessive scaling may cause clogging of tubes.
- ✓ Due to overheating of boiler may induce reaction between water and iron occurs at high temperature, causing additional thinning of the boiler wall.



Prevention of scale formation:

- ✓ Scales formation can be prevented by using acids like HCl , H_2SO_4 .
- ✓ Scales may be removed by giving thermal shocks (sudden heating & cooling).
- ✓ Loosely sticking scales can be removed by scrapping using wire brush, scrapers etc.
- ✓ Scales can be removed by treatment of boiler feed water like internal treatment and external treatment.

Prevention of Sludge formation:

- ✓ Sludge formation can be prevented by using softened water.
- ✓ Sludges can also be removed by Blow down operation.
- ✓ **Blow down operation** is a process of removal of a portion of concentrated water (salt water) by fresh water frequently from the boiler during steam production.

Priming and foaming:

- ✓ **Priming** is the process of the production of wet steam in the boiler during production of steam.
- ✓ Due to rapid boiling, some droplets of liquid water are carried along with steam.

Steam containing droplets of liquid water is called wet steam.

- ✓ These droplets of liquid water carry with some dissolved salts and suspended impurities. This phenomenon is called as **carry over**.
- ✓ This occurs during priming and foaming.

Priming is caused by:

- ✓ High steam velocity
- ✓ Sudden boiling of water Improper boiler design
- ✓ High level of water in boiler
- ✓ Sudden increase in steam production rate

Priming can be controlled by:

- ✓ Controlling the steam velocity.
- ✓ Maintaining medium water levels in boilers
- ✓ Good boiler design
- ✓ Using treated water

Foaming:

- ✓ Foaming is the production of persistent foam or bubbles on the surface of the water in boilers which do not break easily. These bubbles are carried over by the steam leading to excessive priming.
- ✓ Foaming is caused by presence of substances like oil, grease, finely divided particles and also certain dissolved salts present in water.

Foaming can be controlled by:

- ✓ Addition of coagulants like sodium aluminates, aluminum hydroxide.
- ✓ Addition of anti-foaming agents like synthetic polyamides.
- ✓ The efficiency of steam production in boiler is reduced, when the process of priming and foaming in boilers occur together.

Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.1.15

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LECTURE HANDOUTS

L 05

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: Caustic embrittlement & Boiler Corrosion

Introduction :

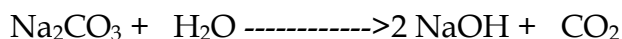
- ✓ Caustic embrittlement is the formation of irregular, intergranular cracks on the boiler metal, particularly at places of high local stress, such as riveted seams, bends and joints.
- ✓ It is caused by the high concentration of NaOH.
- ✓ The corrosion in boiler due to the chemical or electrochemical attack of its environment is known as boiler corrosion.

Prerequisite knowledge for Complete understanding and learning of Topic:

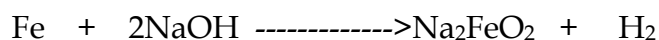
- ✓ The corrosion in boiler due to the chemical or electrochemical attack of its environment is known as boiler corrosion.
- ✓ Boiler corrosion is caused due to the presence of
 - ✓ i) Dissolved oxygen
 - ✓ ii) Dissolved carbon dioxide
 - ✓ iii) Dissolved salts

Detailed content of the Lecture:

- ✓ Boiler water usually contains a small proportion of Na_2CO_3 .
- ✓ These Na_2CO_3 present in the boiler undergoes hydrolysis at higher temperature and pressure, produces NaOH.



- ✓ This NaOH deposits in minute cracks inside the walls. When water evaporates the concentration of NaOH becomes more NaOH corrodes iron to form soluble sodium ferrate. This forms of corrosion in the boilers,

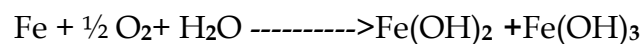


- ✓ The rate of caustic embrittlement increases with concentration of NaOH, temperature and increasing operating pressure.

Prevention of caustic embrittlement:

- ✓ Sodium phosphate can be used instead of sodium carbonate for water softening.

- ✓ By adding substances like tannin, lignin to water in boiler, blocks hair line cracks.
- ✓ By adding small amount of sodium sulphate to water in boilers, the hair line cracks at stressed area is blocked.
- ✓ pH of water present in boiler can be maintained between 8 and 9.
- ✓ **Dissolved oxygen:**
- ✓ Dissolved oxygen contributes major role in boiler corrosion at higher temperature.
- ✓ Oxygen is highly corrosive when present in hot water.
- ✓ Even small concentrations can cause serious problems: iron oxide generated by the corrosion can produce iron deposits in the boiler.
- ✓ Oxygen enters the boiler through raw make up water and also through infiltration of air into the boiler.
- ✓ When the water containing dissolved oxygen is heated in the boiler, the free gas is evolved which corrodes the metal parts of boiler.
- ✓ Oxygen attack can be described by the following reactions:

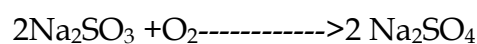


Removal of dissolved oxygen:

- ✓ Dissolved oxygen can be removed from water either by chemical or mechanical methods.

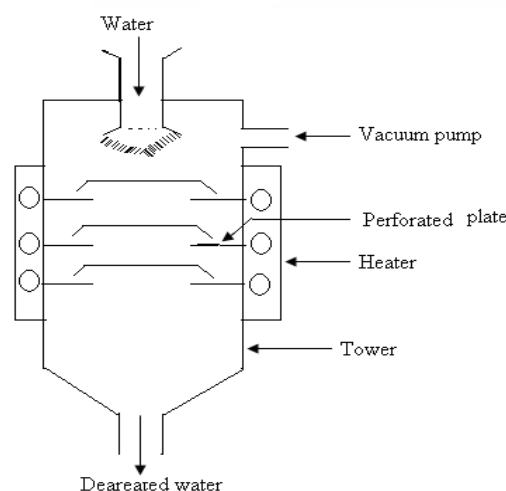
Chemical method:

- ✓ Dissolved oxygen can be removed from water by adding hydrazine, sodium sulphite etc.



- ✓ Out of these chemicals hydrazine is found to be the best compound, since it produces inert nitrogen gas and water, which is harmless.

ii) Mechanical de-aeration method:

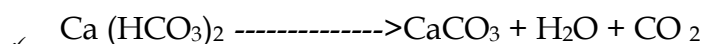


- ✓ Dissolved oxygen can also be removed from water by mechanical deaeration.

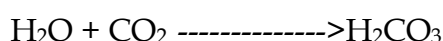
- ✓ In this method water is allowed to fall slowly on the perforated plates fitted inside the tower.
- ✓ The sides of the tower are heated ,and a vacuum pump is also attached to it.
- ✓ The high temperature and low pressure produced inside the tower reduce the dissolved oxygen content of the water.

ii) Dissolved carbon dioxide

- ✓ Dissolved carbon dioxide exists in water as free carbon dioxide and the decomposition of carbonate and bicarbonate ions which release the carbon dioxide on heating.



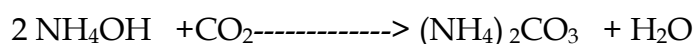
- ✓ Carbon dioxide gas will dissolve in water, producing corrosive carbonic acid, which is acidic and corrosive in nature corrosion.



- ✓ Dissolved Carbon dioxide along with oxygen can be removed from water by either by chemical or mechanical method (de-aeration method).

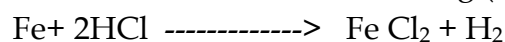
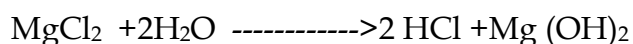
Chemical method:

- ✓ Dissolved Carbon dioxide along with oxygen can be removed from water by adding calculated amount of NH₄OH into water



iii) Dissolved Salts

- ✓ When water containing dissolved salts like magnesium chloride, CaCl₂ to produce the acids that induce the boiler corrosion.



Removal of acids:

- ✓ Acids can be removed from water by adding calculated amount of alkali like NaOH in water



Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No1.16,

Course Faculty

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LECTURE HANDOUTS

L 06

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: Internal Conditioning

Introduction :

Internal conditioning involves the removal of scale forming substance, which were not completely removed in the external treatment by adding chemicals directly into the boiler. The chemicals added to the boiler are called **boiler compounds**.

Prerequisite knowledge for Complete understanding and learning of Topic:

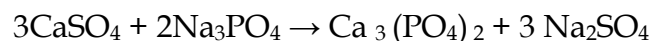
- ✓ Colloidal conditioning
- ✓ Carbvonnate conditioning
- ✓ Phosphate conditioning
- ✓ Calgon conditioning
- ✓ EDTA conditioning

i) Colloidal conditioning:

- ✓ In low pressure boilers scale formation can be avoided by adding colloidal conditioning agents like kerosene, agar-agar, gelatin, etc.
- ✓ These colloidal substances get coated over the scale forming particles and convert them into non-adherent, loose precipitate called sludge, which can be removed by blow down operation.

ii) Phosphate conditioning:

- ✓ In high pressure boilers, CaSO_4 scale whose solubility decreases with increase of temperature.
- ✓ Such scale can be converted into soft sludge by adding excess of soluble phosphates.



- ✓ There are three types of phosphates employed for this purpose

iii) Calgon conditioning:

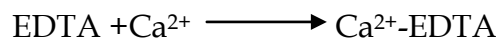
- ✓ Calgon is sodium hexa meta phosphate with a composition $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$. This calgon reacts with the calcium ions of soluble complex of scale forming substances like

CaSO₄, forming a highly soluble complex.

- ✓ Thus they prevent the precipitation of scale forming salt.
- ✓ The reaction is as follows:
- ✓ Since the complex is highly soluble there is no problem of sludge disposal.

iv) EDTA conditioning:

- ✓ Phosphate treatment fails to prevent the cuprous and ions depositions.
- ✓ EDTA forms soluble complexes with scale and sludge forming substances.



Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.5.2 to 5.5,

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LECTURE HANDOUTS

L 07

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: Zeolite process

Introduction :

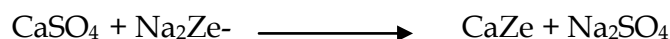
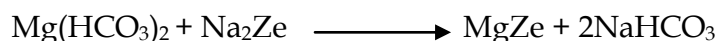
- ✓ Zeolite process is one of the external treatment process.
- ✓ Zeolites are naturally occurring hydrated sodium aluminosilicate.
- ✓ General formula for silicate is $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$. ($x=2-10, y=2-6$).

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Natural zeolites are green sand and non-porous.
- ✓ The synthetic form of zeolite is known as permutit
- ✓ Synthetic zeolite is represented by Na_2Ze .

- ✓ When hard water is passed through a bed of sodium zeolite (Na_2Ze), kept in a cylinder, it exchanges its sodium ions with Ca^{2+} and Mg^{2+} ions present in the hard water to form calcium and magnesium zeolites.

- ✓ The various reactions taking place during softening process are

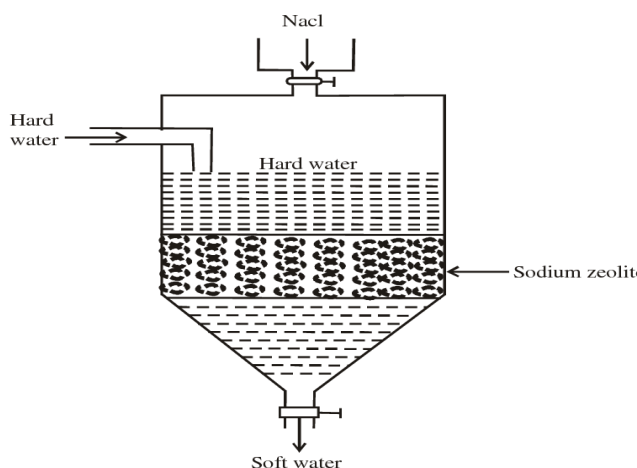
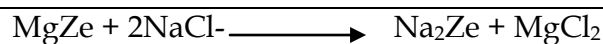


- ✓ The softened water is enriched with large amount of sodium salts, which do not cause any hardness, but cannot be used in boilers.

Regeneration:

- ✓ After some time zeolite gets exhausted.
- ✓ The exhausted zeolite is again regenerated by treating with 10% solution of NaCl.





Advantages of Zeolite process:

- ✓ Water obtained by this process will have only hardness of 1-2ppm.
- ✓ This method is cheap, because the regenerated zeolite can be used again.
- ✓ No sludge is formed during this process.
- ✓ The equipment used is compact and occupies a small space.
- ✓ Its operation is easy.

Disadvantages of Zeolite process:

- ✓ Turbid water cannot be treated, because it blocks the pores of the zeolite bed.
- ✓ Acidic water cannot be treated, because it decomposes the structure of zeolite.
- ✓ The softened water contains more dissolved sodium salts like NaHCO_3 , Na_2CO_3 , etc.
- ✓ When such water is boiled in boilers, CO_2 and NaOH is produced resulting in boiler corrosion and caustic embrittlement.
- ✓ Water containing Fe, Mn cannot be treated, because regeneration is very difficult.
- ✓ This process cannot be used for softening brackish water, because brackish water contains Na^+ ions. So the ion exchange reaction will not occur.

Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.2.6

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LECTURE HANDOUTS

L 08

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology Date of Lecture:

Topic of Lecture: External conditioning- Demineralization process

Introduction :

Demineralization of water is **the removal of essentially all inorganic salts by ion exchange**. In this process, strong acid cation resin in the hydrogen form converts dissolved salts into their corresponding acids, and strong base anion resin in the hydroxide form removes these acids

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ To learn about ion Exchanger process
- ✓ Study on cation and anion Exchanger
- ✓ Advantage and Disadvantage of ion Exchanger process

Demineralization process (or) Ion Exchange:

- ✓ Demineralization is the process in which removes almost all the ions (both cations and anions) present in the hard water can be removed.
- ✓ The soft water, produced by lime-soda and zeolite processes, does not contain hardness producing Ca^{2+} and Mg^{2+} ions, but it will contain other ions like Na^+ , k^+ , SO_4^{2-} , Cl^- , etc.
- ✓ But the demineralised water does not contain both anions and cations.
- ✓ Hence, it states that a soft water is not demineralised water whereas demineralised water is a soft water.
- ✓ In the demineralised process, the ions present in water are removed by ion exchangers.
- ✓ Ion exchangers are usually resins with long chain, cross linked, insoluble organic polymers with a micro porous structure.
- ✓ The functional groups attached to the chains are responsible for the ion exchanging properties.

- ✓ The ion exchangers should possess the following properties for effective demineralization process:
- ✓ It should be non-toxic It should possess a high ion-exchange capacity.
- ✓ It should be resistant to chemical attack.
- ✓ It should be cheap and commonly available.
- ✓ It should have a large surface area since ion exchange is surface phenomenon.
- ✓ Based on the acidity or basicity of the functional group, exchangers are classified as cation exchanger and anion exchanger.

Cation exchanger:

- ✓ Resins containing acidic functional (sulphonic, phenolic) groups are capable of exchanging their H⁺ ions with other cations of hard water.
- ✓ Cation exchange resin is represented as RH.

Example:

- ✓ Sulphonated coals
- ✓ Sulphonated polystyrene
- ✓ R-SO₃H; R-COOH.

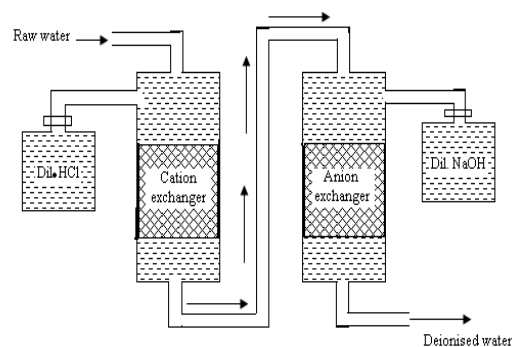
Anionic Exchanger:

- ✓ Resins containing basic functional groups are capable of exchanging their anions with other anions of hard water.
- ✓ Anion exchange resin is represented as R (OH).

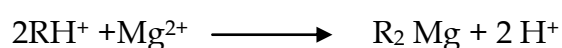
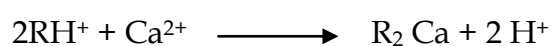
Example:

- ✓ Cross-linked quaternary ammonium salts
- ✓ Urea-formaldehyde resin
- ✓ R-OH; R-NR₃OH

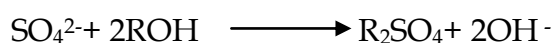
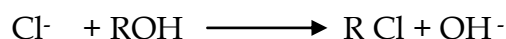
Process:



- ✓ The hard water first passing through cation exchanger column, which absorbs all the cations like Ca²⁺, Mg²⁺, Na⁺, etc present in hard water and release hydrogen ions.



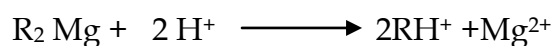
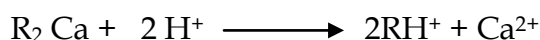
- ✓ Thus sulphates, chlorides and bicarbonates are converted into corresponding acids H_2SO_4 , HCl and H_2CO_3 .
- ✓ The cation free water is then passed through an anion exchanger column, which absorbs all the anions like Cl^- , SO_4^{2-} , HCO_3^- , etc. present in water and acids are converted into water.



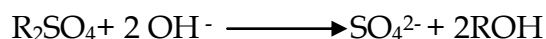
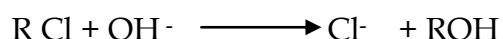
- ✓ The water coming out of the anion exchanger is completely free from cations and anions.
- ✓ This water is known as *Demineralised water or deionised water*.

Regeneration:

- ✓ When the cation exchange resins get exhausted, they are regenerated by passing a solution of dilute H_2SO_4 , or HCl .



- ✓ Similarly, when the anion exchange resin is exhausted, it can be regenerated by passing a solution of dilute NaOH .



Advantages:

- ✓ This process can be used to soften highly acidic or alkaline water.
- ✓ This process produces water of very low hardness (nearly 2 ppm).

Disadvantages:

- ✓ The equipment is costly and more expensive chemicals are needed.
- ✓ If water contains turbidity, then the output of the process is reduced.
- ✓ The turbidity must be below 10 ppm.
- ✓ If it is more, it has to be removed first by coagulation and filtration.

Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No 2.4

Course Faculty

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LECTURE HANDOUTS

L 09

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : I-Water Technology

Date of Lecture:

Topic of Lecture: Desalination and Reverse Osmosis

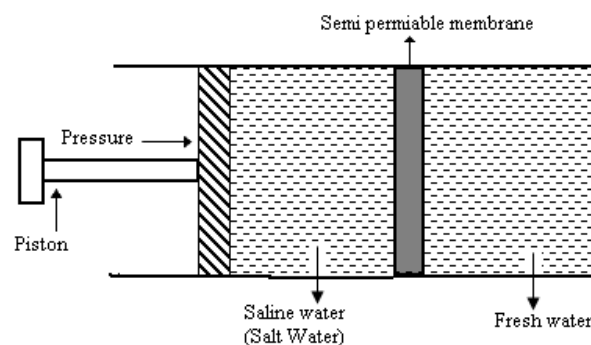
Introduction :

The key technology in the desalination process is Reverse Osmosis. In this process sea water is forced against semi-permeable membranes under pressure in a continuous flow condition. As the water permeates through the membrane most of the dissolved impurities removed and 99.5% of the total salt is removed

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Reverse osmosis
- ✓ Electrodialysis
- ✓ Distillation etc

Process:



- ✓ "When two solutions of different concentrations are separated by a semi-permeable membrane, solvent (water) flows from a region of lower concentration to a region of higher concentration. This process is called osmosis".
- ✓ The driving force or pressure involved in the process of osmosis is known as *osmotic*

pressure.

- ✓ This process can be reversed by applying a pressure higher than the osmotic pressure of the order 15 – 40 kg /cm² on the saturated solution side.
- ✓ If a hydrostatic pressure in excess of osmotic pressure is applied on the higher concentration side, the solvent flows from higher concentration side to lower concentration through the semi permeable membrane is called reverse osmosis.
- ✓ This process is also known as **super-filtration or hyper filtration**. Cellulose acetate, cellulose butyrate, polyamide and polyimide, polysulphone are the polymers used for the semi-permeable membrane.

Advantages:

- ✓ The water obtained by this process is used for high pressure boilers.
- ✓ Due to low capital and operating cost and high reliability and simplicity.
- ✓ The life time of the membrane is high and it can be replaced within a short time.
- ✓ It also removes ionic, non-ionic and colloidal impurities.

Video Content / Details of website for further learning (if any):

<http://nptel.ac.in/courses/105106119/>

Important Books/Journals for further learning including the page nos.:

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No. 2.8

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LECTURE HANDOUTS

L 10

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Introduction and types of corrosion

Introduction :

Corrosion is a general term used to describe various interactions between a material and its environment leading to degradation in the material properties. Interaction with ambient oxygen can cause the formation of oxide layers via diffusion controlled growth. These may passivate the material against further oxidation.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Corrosion
- ✓ Corrosion types
- ✓ Corrosive environment
- ✓ Consequence of corrosion

Introduction:

The continuous and gradual destruction of metals and alloys by the environment is known as corrosion.

Types of corrosion:

1) Uniform Corrosion:

Uniform corrosion is an idealized form of corrosion and causes less damage than other forms of corrosion. It leads to uniform thinning of the structures. The attack is measured in terms of penetration. The unit for measurement of this type of corrosion is mills per year or mm per year. Generally, a thickness tolerance limit (3-5 mm) is provided during the design phase of a structure in order to compensate the material loss because of this corrosion

2) Galvanic Corrosion

When dissimilar metals or alloys differing in their galvanic or corrosion potential are coupled and electrically shorted, it leads to this type of corrosion. The corrosion rate of the alloy with lower corrosion potential will be accelerated.

3) Crevice Corrosion:

Accelerated corrosion occurs if differential aeration exists due crevice, metal joining (lap joints, flanges etc.) or any deposits. Interestingly the location deficit of oxygen becomes anodic and the region having free access to oxygen becomes cathode.

4) Pitting Corrosion:

Alloys in presence of certain ions (such as halides) are prone to pitting corrosion. The rate of penetration within the pit can be as high as one million times as compared to the surroundings.

5) Selective Leaching (Dezincification):

When noble and active elements form an alloy it results in selective removal of the latter. As a consequence, the alloy loses its strength and fails prematurely. Cu-Zn alloys are well known where dezincification occurs if Zn content exceeds beyond 15 weight percentage. Similarly, we have de-nickelification, de-siliconation and de-cobaltification.

6) Intergranular Corrosion (IGC)

This type of corrosion occurs as a result of selective attack of the grain boundaries when either grain boundary becomes highly active or phases prone to selective attack are formed. Stainless steels, which are normally resistant to intergranular attack, when subjected to an heat treatment between 400-900°C become sensitive to intergranular corrosion.

7) Erosion Corrosion:

When there is a relative movement of the corrosive environment with respect to the alloy, it can lead to erosion corrosion. Pipelines and heat exchangers are subjected to such a kind of failure.

8) Cavitation Damage:

Some variation in erosion corrosion is termed as cavitation damage. Here there is damage due to bubble formation and collapse when there is hydrodynamic variation in pressure difference along the line.

9) Fretting Damage:

Moving or vibrating interfaces under load causes damage akin to wear called fretting damage. Here the relative movement is relatively small in angstroms. Typical failed surface under this process is brought out in.

10) Stress Corrosion Cracking (SCC):

When there is a combined action of stress and environment, SCC occurs. However, SCC is specific to environment. The alloys are susceptible to SCC, only when specific ions are present similar to pitting corrosion

Video Content / Details of website for further learning (if any)

<https://en.wikipedia.org/wiki/Corrosion>

Important Books/Journals for further learning including the page nos.: - Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.3.2

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LECTURE HANDOUTS

L 11

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Chemical corrosion & electrochemical corrosion

Introduction :

- ✓ Chemical corrosion is due to the attack of metal surfaces by the atmospheric gases such as oxygen, hydrogen sulfide, sulfur dioxide, nitrogen, etc.
- ✓ Electrochemical corrosion is caused when two dissimilar metals or alloys are in contact with each other in the presence of an aqueous solution or moisture.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Chemical corrosion
- ✓ Electrochemical corrosion
- ✓ Atmospheric gases
- ✓ Different metals

DRY OR CHEMICAL CORROSION:

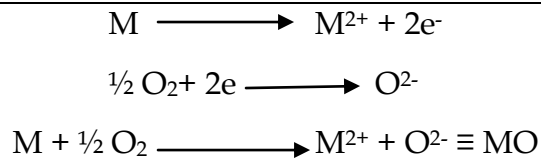
Dry corrosion is due to the attack of metal surfaces by the atmospheric gases such as oxygen, hydrogen sulfide, sulfur dioxide, nitrogen, etc.

There are three main types of dry corrosion:

1. Oxidation corrosion
2. Corrosion by hydrogen.
3. Liquid-metal corrosion.

1) Oxidation Corrosion (or) Corrosion by Oxygen:

- ✓ Oxidation corrosion is brought about by the direct attack of oxygen at low or high temperatures on metal surface in the absence of moisture. Alkali metals (Li, Na, K, etc.)
- ✓ Alkaline-earth metals (Mg, Ca, Sn, etc.) are rapidly oxidized at low temperature. At high temperature, almost all metals (except, Ag, Au and Pt) are oxidized.



Nature Of Oxide Film:

- ✓ Stable Oxide Layer
- ✓ Unstable Oxide Layer
- ✓ Volatile Oxide Layer
- ✓ Protective (or) Non-Protective oxide film (Pilling- Bed worth rule)

The ratio of the volume of the oxide formed to the volume of the metal consumed is called "Pilling-Bed worth ratio".

2) Corrosion by Hydrogen:

(a) Hydrogen embrittlement:

When metals contact to H₂S at ordinary temperature causes evolution of atomic H. This atomic hydrogen diffuses readily into the metal and collects in the voids, where it recombines to form molecular hydrogen.

(b) Decarburization:

Thus the process of decrease in carbon content in steel is termed as "decarburization" of steel.

3) Liquid - Metal Corrosion:

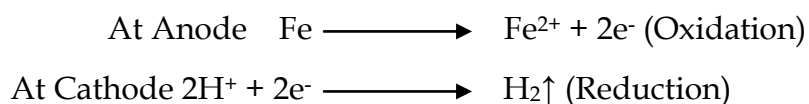
- ✓ Either dissolution of a solid metal by a liquid metal. (or)
- ✓ Liquid metal may penetrate into the solid metal.

WET OR ELECTROCHEMICAL CORROSION:

- ✓ When two dissimilar metals or alloys are in contact with each other in the presence of an aqueous solution or moisture.
- ✓ When a metal is exposed to varying concentration of oxygen or any electrolyte.

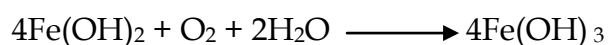
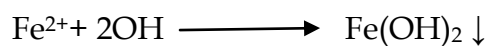
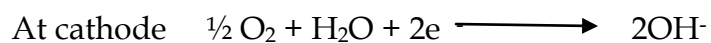
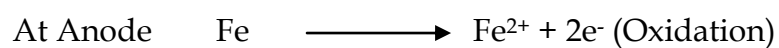
(a) Hydrogen Evolution Type Corrosion:

"All metals above hydrogen in the electrochemical series have a tendency to get dissolved in acidic solution with simultaneous evolution of hydrogen gas"



(b) Absorption of oxygen

The surface of iron is usually, coated with a thin film of iron oxide. However, if the oxide film develops, some crack will come and anodic areas are created on the surface while the remaining part acts as cathode



Video Content / Details of website for further learning (if any)

<https://www.youtube.com/watch?v=I3QLM11AK9Y>

Important Books/Journals for further learning including the page nos.: - Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No. 3.3

Course Faculty

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LECTURE HANDOUTS

L 12

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Types of wet corrosion (galvanic & differential aeration corrosion)

Introduction :

- ✓ Galvanic corrosion - When two different metals are in contact with each other in presence of an aqueous solution or moisture, galvanic corrosion occurs.
- ✓ Differential aeration corrosion - Metals partially immersed in water (or) conducting solution.

Prerequisite knowledge for Complete understanding and learning of Topic:

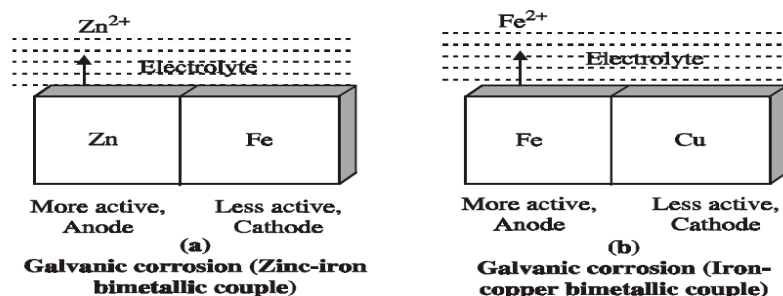
- ✓ Wet corrosion
- ✓ Corrosive environment behind wet corrosion
- ✓ Galvanic corrosion
- ✓ Differential aeration corrosion

Galvanic Corrosion:

When two different metals are in contact with each other in presence of an aqueous solution or moisture, galvanic corrosion occurs.

Examples for Galvanic Corrosion:

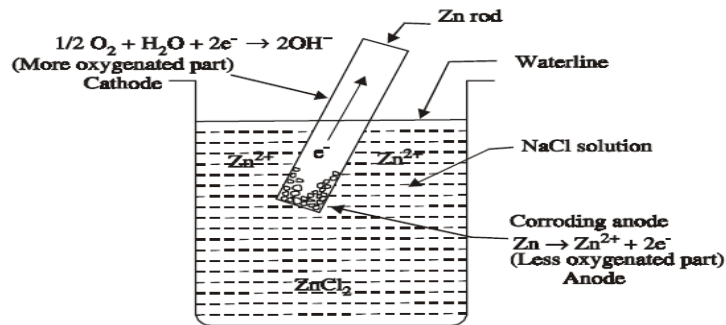
- ✓ Steel screw in a brass marine hardware corrodes
- ✓ ii) Bolt and Nut made of the same metal is preferred.



Galvanic Corrosion

Differential Aeration (or) Concentration Cell Corrosion:

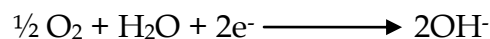
Metals partially immersed in water (or) conducting solution



At anode (less aerated) corrosion occurs

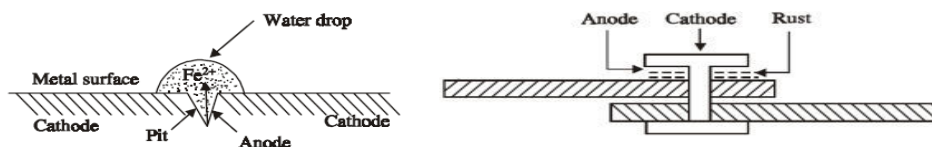


At cathode (more aerated part) OH^- ions produced



Ex for Differential Aeration Corrosion:

- ✓ Pitting or localized corrosion.
- ✓ Crevice corrosion.
- ✓ Pipeline corrosion.
- ✓ Corrosion on wire fence.



Pitting and crevice corrosion

Video Content/ Details of website for further learning (if any)

<https://www.youtube.com/watch?v=Bdk8P1WiXts>

Important Books/Journals for further learning including the page nos.: -

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.3.4

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LECTURE HANDOUTS

L 13

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Mechanism of dry & wet corrosion

Introduction :

- ✓ Dry corrosion is due to the attack of metal surfaces by the atmospheric gases such as oxygen, hydrogen sulfide, sulfur dioxide, nitrogen, etc.
- ✓ When two dissimilar metals or alloys are in contact with each other in the presence of an aqueous solution or moisture, wet corrosion occurs.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Dry corrosion
- ✓ Types of dry corrosion
- ✓ Wet corrosion
- ✓ Types of wet corrosion

DRY OR CHEMICAL CORROSION:

Dry corrosion is due to the attack of metal surfaces by the atmospheric gases such as oxygen, hydrogen sulfide, sulfur dioxide, nitrogen, etc.

There are three main types of dry corrosion:

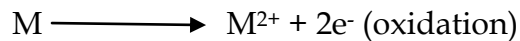
1. Oxidation corrosion
2. Corrosion by hydrogen.
3. Liquid-metal corrosion.

1) Oxidation Corrosion (or) Corrosion by Oxygen:

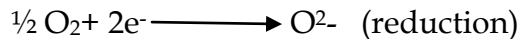
- ✓ Oxidation corrosion is brought about by the direct attack of oxygen at low or high temperatures on metal surface in the absence of moisture. Alkali metals (Li, Na, K, etc.)
- ✓ Alkaline-earth metals (Mg, Ca, Sn, etc.) are rapidly oxidized at low temperature. At high temperature, almost all metals (except, Ag, Au and Pt) are oxidized.

Mechanism of dry corrosion:

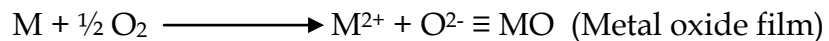
Oxidation takes place first at the surface of the metal, then the metal is oxidized to metal ions at anode



Then the oxygen is reduced to oxide ions at cathode due to transfer of electron from metal.



Oxide ion reacts with metal ion to form metal oxide film.



Once the metal surface is converted to a monolayer of metal - oxide(MO), the metal ion migrates outward through the metal - oxide barrier and oxide ions inward for further corrosion to occur.

Nature of oxide Film:

- ✓ Stable Oxide Layer
- ✓ Unstable Oxide Layer
- ✓ Volatile Oxide Layer
- ✓ Protective (or) Non-Protective oxide film (Pilling- Bed worth rule)

The ratio of the volume of the oxide formed to the volume of the metal consumed is called "Pilling-Bed worth ratio".

2) Corrosion by Hydrogen:

(a) Hydrogen embrittlement:

When metals contact to H₂S at ordinary temperature causes evolution of atomic H. This atomic hydrogen diffuses readily into the metal and collects in the voids, where it recombines to form molecular hydrogen.

(b) Decarburization:

Thus the process of decrease in carbon content in steel is termed as "decarburization" of steel.

3) Liquid - Metal Corrosion:

- ✓ Either dissolution of a solid metal by a liquid metal. (or)
- ✓ Liquid metal may penetrate into the solid metal.

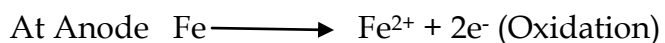
WET OR ELECTROCHEMICAL CORROSION

- ✓ When two dissimilar metals or alloys are in contact with each other in the presence of an aqueous solution or moisture.
- ✓ When a metal is exposed to varying concentration of oxygen or any electrolyte.

(a) Hydrogen Evolution Type Corrosion:

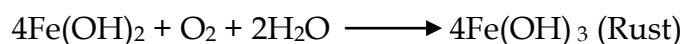
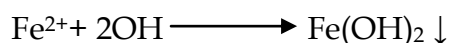
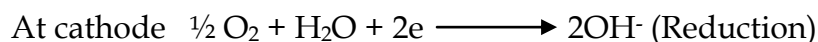
"All metals above hydrogen in the electrochemical series have a tendency to get dissolved in

acidic solution with simultaneous evolution of hydrogen gas”



(b) Absorption of oxygen:

The surface of iron is usually, coated with a thin film of iron oxide. However, if the oxide film develops, some crack will come and anodic areas are created on the surface while the remaining part acts as cathode.



Video Content / Details of website for further learning (if any)

<https://www.youtube.com/watch?v=uliSxGixs-c>

Important Books/Journals for further learning including the page nos.: -

Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.3.3

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LECTURE HANDOUTS

L 14

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Factors influencing rate of corrosion and its control

Introduction :

- ✓ The rate and extent of corrosion mainly depends on nature of the metal and nature of the environment.
- ✓ The rate of corrosion can be controlled by either modifying the metal or the environment.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ EMF series
- ✓ Nature of the metal
- ✓ Nature of the environment
- ✓ Idea about corrosion control

Factors influencing rate of corrosion:

1) Nature of the Metal:

(a) Position in EMF Series:

The extent of corrosion depends on the position of the metal in the emf series. Metals above the hydrogen in emf series get corroded vigorously. Lower the reduction potential, greater is the rate of corrosion.

(b) Relative Areas of the Anode and Cathode:

The rate of corrosion will be more, when the cathodic area is larger.

(c) Purity of the Metal:

The 100% pure metal will not undergo any type of corrosion. But, the presence of impurities occurs corrosion

(d) Over Voltage or Over Potential:

The over voltage of a metal in the corrosive environment is inversely proportional to corrosion rate.

(e) Nature of the surface film:

The nature of the oxide film formed on the metal surface decides the extent of corrosion which can be decided by Pilling-Bedworth rule

(f) Nature of the Corrosion Product:

If the corrosion product is soluble in the corroding medium, the corrosion rate will be faster. Similarly, if the corrosion product is volatile (like MoO_3 on Mo surface), the corrosion rate will be faster.

2) Nature of the Environment:

(a) Temperature: The rate of corrosion is directly proportional to temperature.

(b) Humidity

The rate of corrosion will be more, when the humidity in the environment is high. The moisture acts as a solvent for the oxygen

(c) Presence of Corrosive Gases

The acidic gases like, CO_2 , SO_2 , H_2S and fumes of HCl , H_2SO_4 , etc., produce electrolytes, which are acidic and increases the electrochemical corrosion

(d) Presence of Suspended Particles

Particles like, NaCl , $(\text{NH}_4)_2\text{SO}_4$ along with moisture act as powerful electrolytes and thus accelerate the electrochemical corrosion.

(e) Effect of pH

The possibility of corrosion with respect to pH of the electrolytic solution and the electrode potential of the metal.

Corrosion Control:

- ✓ By Cathodic Protection
- ✓ Sacrificial Anodic Protection Method

Control of Corrosion by Modifying the Environment:

- ✓ De-aeration
- ✓ Deactivation
- ✓ Dehumidification
- ✓ Alkaline Neutralization
- ✓ Using Corrosion Inhibitors

Video Content / Details of website for further learning (if any)

<https://www.youtube.com/watch?v=-Z-wXolzDjE>

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LECTURE HANDOUTS

L 15

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Sacrificial anodic & cathodic protection methods

Introduction :

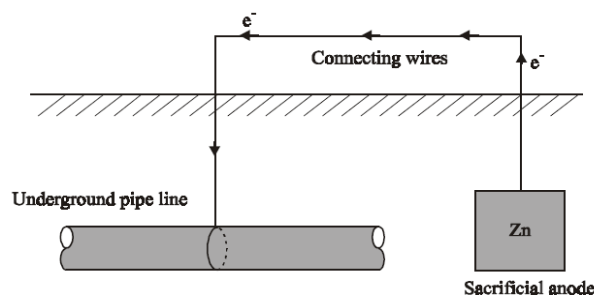
- ✓ In sacrificial anodic protection method, the metallic structure to be protected is made cathode by connecting it with more active metal.
- ✓ In impressed current cathodic protection method, an impressed current is applied in the opposite direction of the corrosion current to nullify it, and the corroding metal is converted from anode to cathode.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Cathode
- ✓ Anode
- ✓ Sacrificial anode
- ✓ Battery

Sacrificial Anodic Protection Method:

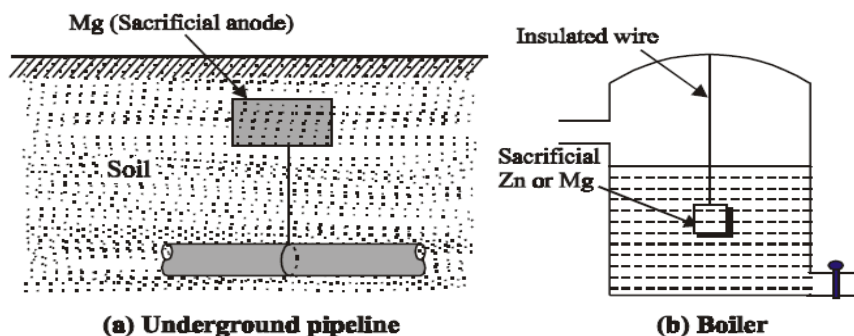
- ✓ The metallic structure to be protected is made cathode by connecting it with more active metal (anodic metal). So that all the corrosion will concentrate only on the active metal.



Sacrificial anodic protection method

- ✓ The artificially made anode thus gradually gets corroded protecting the original metallic

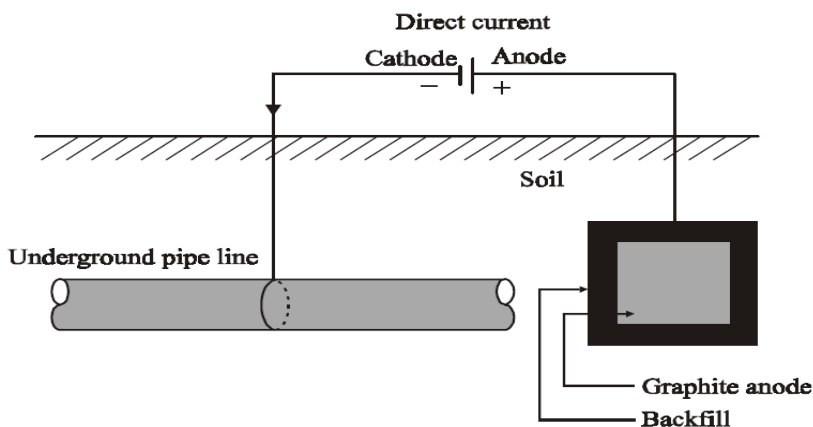
structure. Hence this process is known as sacrificial anodic protection. Al, Mg, Zn are used as sacrificial anodes.



Sacrificial anodic protection method

(ii) Impressed Current Cathodic Protection Method

- ✓ An impressed current is applied in the opposite direction of the corrosion current to nullify it, and the corroding metal is converted from anode to cathode.
- ✓ This can be done by connecting negative terminal of the battery to the metallic structure, to be protected, and positive terminal of the battery is connected to an inert anode.



Impressed Current Cathodic Protection Method

Video Content / Details of website for further learning (if any)

<https://www.youtube.com/watch?v=cZg4bfEnLcU>

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LECTURE HANDOUTS

L16

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Protective coatings –Metal coatings: Galvanization and Tinning

Introduction :

Corrosion of metal surfaces is a common phenomenon. To protect a metal surface from corrosion, the contact between the metal and the corrosive environment is to be cut off. This is done by coating the surface of the metal with a continuous, non-porous material. Such a coating is referred to as surface coating or protective coating.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ To prevent corrosion
- ✓ To enhance wear and scratch resistance
- ✓ To increase hardness
- ✓ To insulate electrically
- ✓ To insulate thermally

Metallic Coating:

Surfacing coatings made up of metals are known as metallic coatings. These coatings separate the base metal from the corrosive environment and also function as an effective barrier for the protection of base metals.

The metal which is coated upon is known as the base metal. The metal applied as coating is referred to as coat metal.

The different methods used for metal coating are.

- ✓ Hot dipping
 - (a) Galvanization (b) Tinning
- ✓ Metal spraying.
- ✓ Cladding.
- ✓ Cementation
 - (a) Sheardizing – Cementation with Zinc powder is called Shearding.
 - (b) Chromizing - Cementation with 55% Chromium powder & 45% Alumina is called

Chromizing.

(c) Calorizing – Cementation with Aluminium and Alumina powder is called Calorizing

✓ Electroplating or electrodeposition.

Hot dipping.

In the process of hot dipping, the metal to be coated is dipped in the molten bath of the coating metal. Such hot dip coatings are generally nonuniform. The common examples of hot dip coatings are galvanizing and tinning.

Galvanization:

The process of coating a layer of zinc over iron is called galvanization. The steel article is first pickled with dilute sulphuric acid to remove traces of rust, dust, etc. at 60-900 C for about 15 -20 minutes. Then this metal is dipped in a molten zinc bath maintained at 4300 C.

When zinc is coated over iron, zinc and iron forms a galvanic cell. The electropositive zinc forms the anode and undergoes corrosion. Hence iron is protected from corrosion by sacrificial protection method.

The surface of the bath is covered with ammonium chloride flux to prevent oxide formation on the surface of molten zinc. The coated base metal is then passed through rollers to correct the thickness of the film. It is used to protect roofing sheets, wires, pipes, tanks, nails, screws, etc

Tinning:

The coating of tin over iron is called tin plating or tinning. Tinning is done to protect iron, steel and copper from corrosion. It is also called tinplating. Since tin is non-toxic, it is mainly used in food industry for coating food containers. Tin-coated utensils are used for storing foodstuffs, pickles, oils, etc.

Tin is nobler metal (more cathodic) than iron. It is more resistant to atmospheric corrosion. Thus, uniform layer of tin protects iron from corrosion.

Tinning the base metal is first pickled with dilute sulphuric acid to remove surface impurities. Then it is passed through molten tin covered with zinc chloride flux. The tin coated article is passed through a series of rollers immersed in a palm oil bath to remove the excess tin. Galvanizing is preferred to tinning because tin is Cathodic to iron, whereas zinc is anodic to iron. So, if the protective layer of the tin coating has any cracks, iron will corrode. If the protective layer of the zinc coating has any cracks, iron being Cathodic and is not corroded. The corrosion products fill up the cracks, thus preventing corrosion.

Differences between Galvanizing and Tinning:

Galvanizing	Tinning
A process of covering iron or steel with a thin coat of 'Zinc' to prevent it from rusting	A process of covering iron or steel with a thin coat of 'Tin' to prevent it from corrosion.
Zinc protects the iron sacrificially.(Zinc undergo corrosion)	Tin protects the base metal without undergo any corrosion (non sacrificially)
Zinc continuously protects the base metal even if broken at some places	If any break, in coating causes rapid corrosion of base metal

Galvanized containers cannot be used for storing acidic food stuffs as Zinc becomes toxic in acidic medium.	Tin is non-toxic in nature of any medium.
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Video Content / Details of website for further learning (if any)

<https://www.youtube.com/watch?v=Eg5OpnUZ3v4>

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LECTURE HANDOUTS

L 17

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Inorganic coatings: Phosphating and Anodising

Introduction :

Inorganic coatings are generally chemical conversion coatings. A surface layer of the metal is converted into a compound, by chemical or electrochemical reactions, which forms a barrier between the underlying metal surface and the corrosion environment. There are two methods.

Prerequisite knowledge for Complete understanding and learning of Topic:

- (i) Anodizing and its Applications
- (ii) Phosphate coating and its Applications

Anodizing:

It is a process in which a protective passive metal oxide film is produced chemically or electrochemically on certain metals. Anodized coatings are generally produced on non-ferrous metals like Al, Zn, Mg and their alloys by anodic oxidation process using suitable electrolyte and electric current.

The process anodization of aluminium consists of following steps:

- ✓ The Al article to be anodized is first de-greased with organic solvents and polished to get clean surface. Then it is used as anode.
- ✓ It is then dipped in 5-10% chromic acid solution (even sulphuric acid and boric acid can be used).
- ✓ Pb is generally used as cathode.
- ✓ A current density of about 150 mA/cm^2 at 40V and temperature of about $35-40^\circ\text{C}$ is used.
- ✓ The aluminium oxide films of about 5-20nm thickness formed on aluminium. The oxide coating is slightly porous. The pores are sealed by dipping in boiling water.

- ✓ Al_2O_3 gets hydrated to $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ which occupies more volume and hence protects the metal from corrosion.

Application:

- ✓ Anodizing is used to produce articles such as window frames, household articles.
- ✓ Anodized Al is used in aircrafts.
- ✓ Anodization is used for aluminium pressure cookers and cooking pots.

Phosphate coating:

The coating of phosphates by the chemical reaction of base metal when it is immersed in an electrolyte solution of a phosphate and phosphoric acid is called phosphating.

The mechanism involves following steps.

- ✓ First dissolution of metals as metal ions.
- ✓ Metal ions reacting with phosphate ions to form insoluble metal phosphate.
- ✓ Deposition of the metal phosphate on the surface of the base metal.

The process involves following steps.

- ✓ The surface of the metal is first de-greased with organic solvents and polished to get clean surface.
- ✓ The article is immersed in a phosphating bath containing a mixture of phosphoric acid & Zn or Mn phosphate solution along with an accelerator like metal nitrites, hydrogen peroxide, etc to enhance the rate of deposition. Deposition is carried out at 35°C by maintaining the pH of 1.8-3.2.

Application:

- ✓ Phosphate coating is given before painting bodies of automobiles, refrigerators, washing machines.
- ✓ Phosphating is widely used for protection of metal parts which cannot be easily painted or plated. **Eg:** Nuts, bolts, moving parts of machinery.
- ✓ Galvanized iron (which is difficult to paint satisfactorily) is phosphated before painting..

Video Content / Details of website for further learning (if any)

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LECTURE HANDOUTS

L 18

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : II Corrosion and its control Date of Lecture:

Topic of Lecture: Electroplating of copper and electroless plating of nickel

Introduction :

- ✓ The process of coating of one metal over the another metal by the principle of electroplating is called electroplating.
- ✓ Electroless plating is a technique of depositing a noble metal on a catalytically active surface of the metal, to be protected, by using a suitable reducing agent without using electrical energy.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Electroplating
- ✓ Metals
- ✓ Non metals
- ✓ Electroless plating

Electroplating (or) Electro-Deposition:

The process of coating of one metal over the another metal by the principle of electroplating is called electroplating.

Objectives of Electroplating:

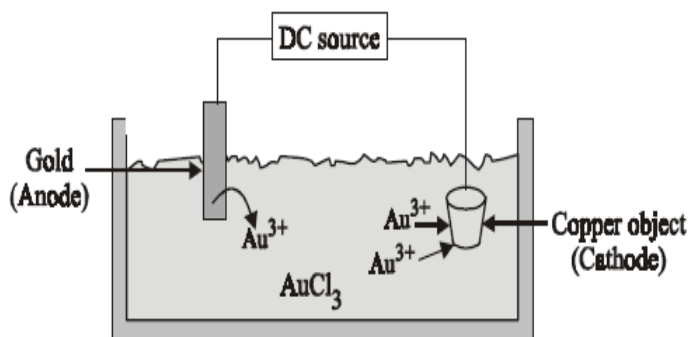
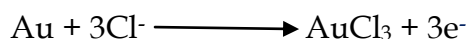
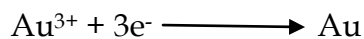
1. On metals:

- To increase the resistance to corrosion of the coated metal.
- To improve the hardness and physical appearance of the article.
- To increase the decorative and commercial values of the article.
- To increase resistance to chemical attack.

2. On non metals:

- To increase strength.

- To preserve and decorate the surfaces



Electroplating

Characteristics of Gold Plating:

- ✓ The deposits of gold are used for electrical and electronic applications.
- ✓ It is used for high quality decorations and high oxidation resistant coatings.

Electroless Plating:

Electroless plating is a technique of depositing a noble metal on a catalytically active surface of the metal, to be protected, by using a suitable reducing agent without using electrical energy.

Electroless Nickel Plating:

- ✓ Pretreatment and activation of the surface
- ✓ Preparation of Plating bath
- ✓ Procedure for Plating

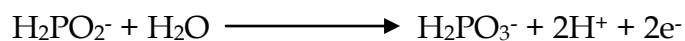
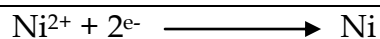
Electroless Nickel Plating Process:

In autocatalytic platings, the metal ion is reduced to metal only on a specific surface, which must have a catalyst present before the reaction can begin. The electroless plating involving a nickel sulphate bath has the reaction as

The electroless nickel solution consists of the following components:

- ✓ Nickel chloride NiCl_2 (20 g/l) which is the source for nickel.
- ✓ Sodium hypophosphite (20 g/l) which is the reducing agent.
- ✓ Sodium acetate buffer (10 g/l), sodium succinate which are the complexing agent and exhaulant, respectively.
- ✓ pH is maintained at about 4.5 and the temperature is about 93°C .

The electrode reactions are:



The advantages of this plating are as follows:

- The bath possesses excellent throwing power, hence method is suitable for plating the objects having intricate shapes.
- The deposits are free from pores, hence there is better corrosion resistance.
- The plating gives harder surface, hence it gives good wear resistance.
- Ni plating on Al enhances the solderability, also provides a non-magnetic underlay in magnetic components.

Applications

- Electroless Ni-plating is extensively used in electronic appliances.
- Electroless Ni-plating is used in domestic as well as automotive fields
- Electroless Ni-coated polymers are used in decorative and functional works.

Video Content / Details of website for further learning (if any)

<https://www.youtube.com/watch?v=T3ghqTVssoo>

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LECTURE HANDOUTS

L 19

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : III- Polymers Date of Lecture:

Topic of Lecture: Polymerization and its Types

Introduction :

A polymer is a large macromolecule of high to very high molecular weight which consists of many repeating units called monomers which are covalent bond to one another. In many cases, monomers are linked together in a row, like links in a chain. However branching and cross-linking between chains does occur.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ explain the terms - monomer, polymer and polymerization and their importance
- ✓ distinguish between various classes of polymers and different types of Polymerization processes
- ✓ Appreciate the importance of polymers in daily life.

Polymer:

Polymers are the substances consisting of giant or macromolecules made by linking a large number of smaller molecules (monomers). Polymer is a molecule formed by joining of thousands of smaller molecular units together by chemical bonds. A chemical process that leads to the formation of polymer is known as polymerization.

Degree of polymerization:

The number of repeat units (or) monomeric units available in the polymer is known as degree of polymerization.

Functionality:

Definition:

The number of bonding sites (or) reactive sites or functional groups present in the molecule.

Ex: The double bond in vinyl monomers ($\text{CH}_2 = \text{CHX}$) can be considered as a site for two free valencies. When the double bond is broken, two single bonds become available for combination.



- ✓ When the functionality of monomer is two bifunctional linear (or) straight chain polymer is formed.

(b) adipic acid (a) vinyl monomers (c) hexamethylene diamine (d) terephthalic acid

(e) ethylene glycol (f) amino acid

Example for polymer: HDPE (high density polythene)

- ✓ When the functionality of monomer is three (tri-functional), three dimensional net work polymer is formed.

Ex: phenol, glycerol

Examples for polymers : Urea formaldehyde, phenol formaldehyde.

Examples for bifunctional monomers:

- ✓ Vinyl monomers ($\text{HC}_2 = \text{P-CH}$) [where P = pendant group]

a) ethylene b) propylene c) vinyl chloride d) vinyl cyanide e) vinyl acetate f) styrene g) acrylic acid h) methyl methacrylate

- ✓ Dicarboxylic acids having general formula ($\text{HOOC} - \text{R} - \text{COOH}$)

a) succinic acid b) adipic acid c) terephthalic acid

- ✓ Amino acids with the general formula $\text{H}_2\text{N} - \text{R-CH} - \text{COOH}$

a) glycine b) alanine c) valine d) α - amino caproic acid

- ✓ Diols with the general formula $\text{HO} - \text{H}_2\text{C} - \text{R} - \text{CH}_2 - \text{OH}$

a) ethylene glycol

- ✓ Diamines with the general formula $\text{H}_2\text{N-CH}_2\text{-R-CH}_2\text{-NH}_2$

a) hexamethylene diamine

- ✓ when a trifunctional monomer is mixed in small amounts with a bifunctional monomer, a branched chain polymer is formed.

Ex: LDPE (LOW density polyethene)

Classification of Polymers:

Classification Based on Source:

There are several ways of classification of polymers based on some special considerations.

The following are some of the common classifications of polymers:

Under this type of classification, there are three sub categories.

- ✓ **Natural polymers**

These polymers are found in plants and animals. Examples are proteins, cellulose, starch, some resins and rubber.

- ✓ **Semi-synthetic polymers**

Cellulose derivatives as cellulose acetate (rayon) and cellulose nitrate, etc. are the usual examples of this sub category.

- ✓ **Synthetic polymers**

A variety of synthetic polymers as plastic (polythene), synthetic fibres (nylon 6,6) and synthetic rubbers (Buna - S) are examples of manmade polymers extensively used in daily life as well as

Classification Based on Structure of Polymers:

✓ **Homopolymer**

A polymer containing same type of monomer units.

Ex: polyethene, Polypropylene

✓ **Types of Homopolymer**

• **Linear polymers**

These polymers consist of long and straight chains. The examples are high density polythene, polyvinyl chloride, etc. These are represented as:



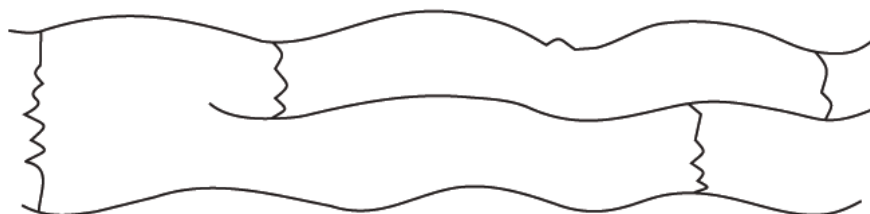
• **Branched chain polymers**

These polymers contain linear chains having some branches, *e.g.*, low density polythene. These are depicted as follows:



• **Cross linked or Network polymers**

These are usually formed from bi-functional and tri-functional monomers and contain strong covalent bonds between various linear polymer chains, *e.g.* bakelite, melamine, etc. These polymers are depicted as follows:



✓ **Heteropolymer or Copolymer:**

It is the joint polymerization in which two (or more) different monomers combine to give a co-polymer. Co-polymerization is mainly carried out to vary the properties of polymers such as hardness, strength, rigidity, heat resistance, etc.

The copolymer subdivided into three types as

• **Random Copolymer**

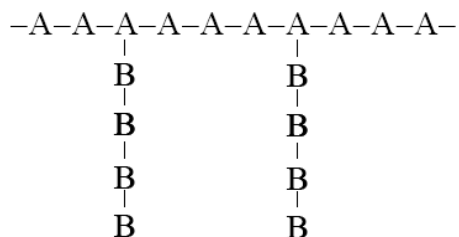
If different monomers are arranged randomly then its known as Random Copolymer
– A-A-A-A-B-A-B –

- **Block Copolymer**

If different monomers are arranged block wise then it's known as block Copolymer. $-A-A-A-A-A-A-A-B-B-B-B-B-B-B-$

- **Graft Copolymer**

If one of the different monomer act as a back bone and other monomers are arranged branch wise then it's known as Graft Copolymer.



- ✓ **Stereo specific polymer:**

The orientation of monomeric units in a polymer molecule can takes place in an orderly or disorderly fashion with respect to the main chain called as Stereo specific polymer

Video Content / Details of website for further learning (if any):

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

Important Books/Journals for further learning including the page nos.: - Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.5.2 to 5.5,

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MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)

Rasipuram - 637 408, Namakkal Dist., Tamil Nadu



LECTURE HANDOUTS

L 20

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : III - Polymers

Date of Lecture:

Topic of Lecture: Polymerization types and mechanism of polymerization

Introduction :

Polymerization is a process which allows simple low molecular weight compounds to combine and forms a complex high molecular weight compound. For this process, each molecule of the compound should have the capability to react at least with two other molecules of the same or some other Compound. In other words, they should have a functionality of at least two. The functionality of a compound depends on the number of its reactive sites. Due to the presence of the reactive functional groups, a compound assumes its functionality. These groups are such as -OH, -COOH, -NH₂, -SH, -NCO, etc. The number of these functional groups per molecule of the compound defines its functionality. As described earlier, the polymerization is effected by two processes, *i.e.*, addition and condensation polymerization. These terms were based on the conventional classification by *Carothers* (1929) and have since been modified by *H.F. Mark* (1950) as chain polymerization and step polymerization.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Importance of Polymerization
- ✓ To known about the Degree of polymerization
- ✓ Understand the various types polymerization
- ✓ Basic knowledge about polymer

Degree of polymerization

The number of repeating units (n) in a polymer chain is known as the degree of polymerization. It is represented by the following relationship,

$$\text{Degree of polymerization (n)} = \frac{\text{Molecular weight of the polymeric network}}{\text{Molecular weight of the repeating unit}}$$

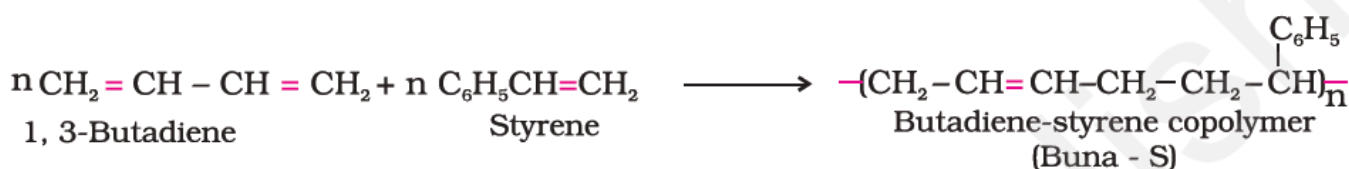
Types of Polymerization:

✓ Addition polymerization

- It is a reaction that yields polymer which is an exact multiple of the original monomer molecule.
- The monomer contains one or more double bonds.
- This reaction is initiated by the application of heat, light, pressure, or catalyst, for breaking down the double bonds of monomers.
- In addition polymerization there is no elimination of any molecule. (e.g) Polyethylene is produced from ethylene:



The polymers made by addition polymerisation from two different monomers are termed as **Copolymers**, e.g., Buna-S, Buna-N, etc.



Condensation (Step) Polymerisation:

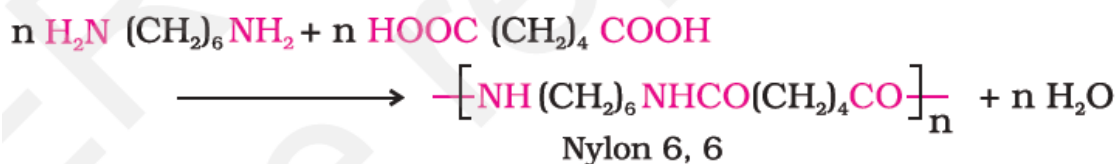
In condensation or step polymerization reaction, the reaction takes place in a step-wise manner and the polymer is formed through a reaction between functional groups of the monomers. Formation of polymer through step polymerization is a slow process, while in chain (addition) polymerization, chain growth is very fast. Step polymerization is a condensation reaction, where small molecules of water, methanol or ammonia etc., eliminate out. There are many known reactions which can be used in step polymerization, few of them are condensation, ring-opening, amidation, addition and ester-interchange reaction described as follows :

It is a reaction between simple polar groups containing monomers that yield polymers with the elimination of small molecules like H₂O, HCl, etc.

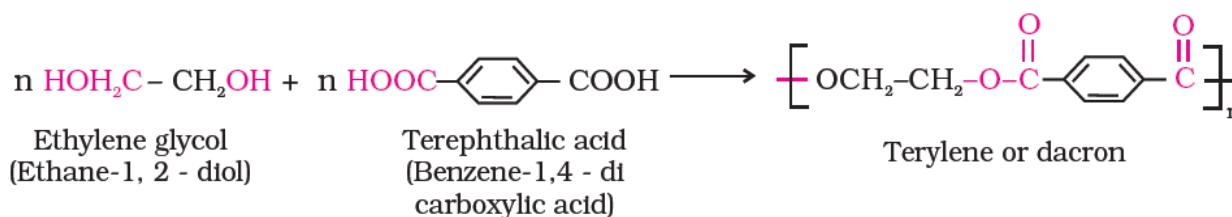
- ✓ To proceed the polymerisation, monomers should have two reactive functional groups.
- ✓ The polymerisation takes place by step-wise reaction between reactive functional groups.
- ✓ Only one type of reaction (e.g., condensation reaction in this case) between two functional groups is brought about in polymer formation.
- ✓ The polymer formed still consists of both the reactive functional groups at its chain end, this is 'active' and not 'dead', as in chain polymerisation. For example nylon 6,6 formed by the

condensation of hexamethylene diamine with adipic acid.

✓

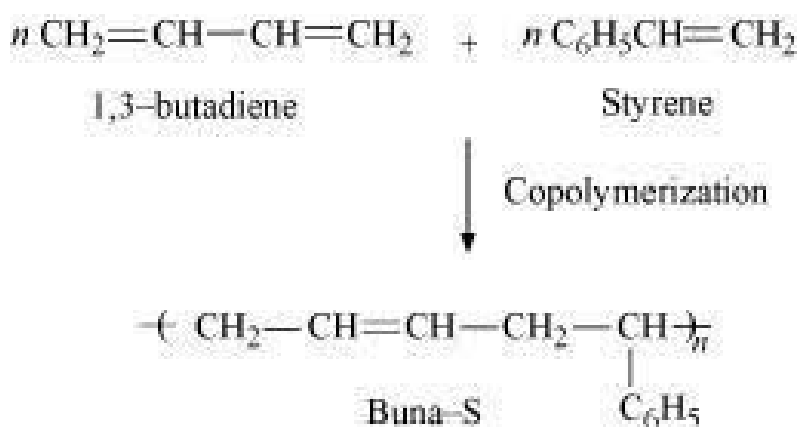


In these reactions, the product of each step is again a bi-functional species and the sequence of condensation goes on. Since, each step produces a distinct functionalised species and is independent of each other, this process is also called as step growth polymerisation. The formation of terylene or dacron by the interaction of ethylene glycol and terephthalic acid is an example of this type of polymerization.



Copolymerization:

It is the joint polymerization in which two (or more) different monomers combine to give a co-polymer. Co-polymerization is mainly carried out to vary the properties of polymers such as hardness, strength, rigidity, heat resistance, etc.



.No.	Addition Polymerization	Condensation Polymerization
1.	The monomer should have at least one multiple bond, e.g., $\text{CH}_2 = \text{CH}_2$ (ethylene)	The monomer should have at least two identical functional groups $\text{CH}_2 - \text{OH}$ (glycol) $\text{CH}_2 - \text{OH}$ $\text{H}_2\text{N}(\text{CH}_2)_6\text{COOH}$ (6-aminohexanoic acid)

2.	Monomer adds to give a polymer and no other by-product is formed.	Monomers condense to give a polymer and by-products such as H ₂ O, CH ₃ OH, are formed.
3.	Number of monomeric unit's decreases steadily throughout the reaction as there is steady growth of polymer chain.	Monomers disappear at the early stage of reaction as oligomers are formed first and then polymers are produced
4.	High molecular weight polymer is formed at once.	Molecular weight of the polymer rises steadily throughout the reaction.
5.	Usually thermoplastics are produced, e.g., polyethylene, PVC, etc.	Usually thermosetting plastics are produced, e.g., Bakelite, urea-formaldehyde.
6.	This follows a free radical mechanism.	This follows the mechanism of condensation reaction
7.	Homochain polymer is obtained.	Hetero-chain polymer is obtained.

Video Content / Details of website for further learning (if any):<https://www.youtube.com/watch?v=fMGHILcTjOw>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Sanathi and S. Elavarasan, P.No.5.6 to 5.10,

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LECTURE HANDOUTS

L 21

Chemistry

I/I

Course Name with Code : Engineering Chemistry /21BSS11

Course Faculty :

Unit : III - Polymers

Date of Lecture:

Topic of Lecture: Addition Free radical mechanism of polymerization

Introduction :

The functionality of a compound depends on the number of its reactive sites. Due to the presence of the reactive functional groups, a compound assumes its functionality. These groups are such as -OH, -COOH, -NH₂, -SH, -NCO, etc. The number of these functional groups per molecule of the compound defines its functionality.

As described earlier, the polymerization is effected by two processes, *i.e.*, addition and condensation polymerization. These terms were based on the conventional classification by *Carothers* (1929) and have since been modified by *H.F. Mark* (1950) as chain polymerization and step polymerization.

Prerequisite knowledge for Complete understanding and learning of Topic:

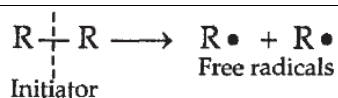
- ✓ Basic knowledge about polymerization
- ✓ To understand Mechanism of Free radical polymerization
- ✓ To Study about the Inhibitors

Addition Free radical mechanism of polymerization:

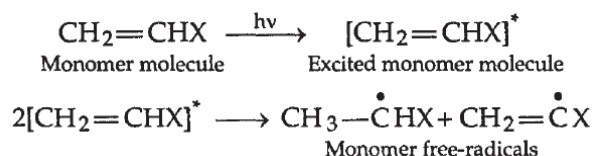
The polymer chain is initiated by free radicals produced by the decomposition of compounds called initiators:

Initiators :

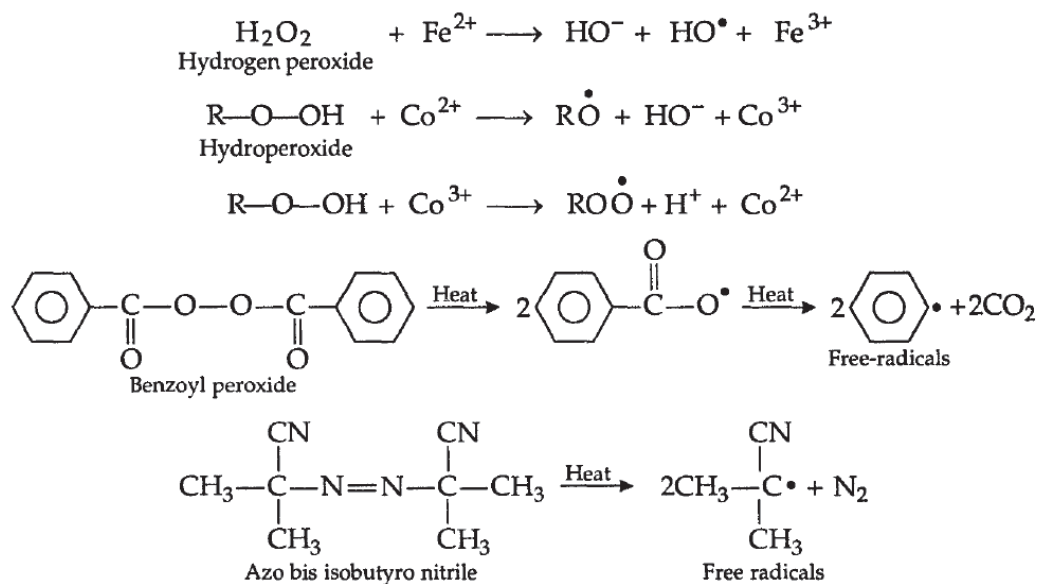
The initiators are thermally unstable compounds. When energy is supplied, they decompose into two identical fragments by 'homolytic decomposition'. Each fragment carries one unpaired (lone) electron with it; and called free radicals. If R-R is an initiator, it may split into two symmetrical components at its bond between the two R-R as :



The low molecular weight compounds mainly azo, peracids, peroxides, peresters, hydroperoxides are useful as initiators. Initiators can be decomposed and form free radicals, while induced by heat energy, light energy or catalysts. The initiators can also be decomposed by using ultraviolet light and form the same free radicals as those formed by its thermal decomposition. Free-radicals can be also produced by direct excitation of the monomer molecules in UV light as :

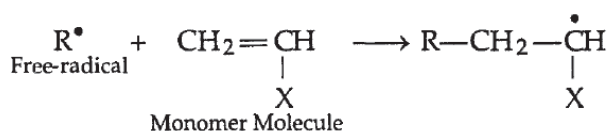


The polymerization reactions initiated by UV light are known as 'photoinitiated polymerization'. Free-radicals are also formed when initiators are induced by suitable catalysts. The decomposition of hydrogen peroxide by a ferrous ion and hydroperoxide by a cobaltous ion are the examples of initiators, decomposed by reduction-oxidation (redox) reaction. Polymerization reactions using these redox initiators are termed as 'redox polymerization' as shown below:



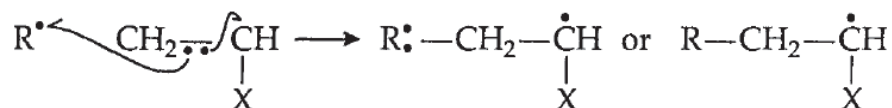
Initiation:

A free-radical contains an unpaired electron; which always search a lone electron to couple with and get stabilised itself. Free-radical is, therefore, highly reactive species which attacks the double bond in the monomer molecule in such a manner.



A double bond formed between two carbon atoms, C=C, one pair of electrons is called sigma electrons, while the other pair exists as (π) electrons. The n electrons are not very close to nucleus, therefore, they

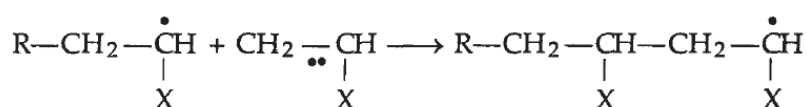
are susceptible to attack by other reactive species. By the homolytic decomposition of the initiator free-radicals are produced, which combine with one of the π electrons and forms a normal pair of electrons at the sigma level, and the other electron of the π pair is transferred to the other end of the molecule as given below:



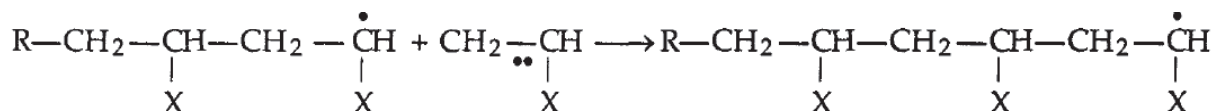
Thus, this whole sequence, in which one free-radical attacks a monomer molecule and adds with it, simultaneously transfers the free-radical site from itself to the monomer unit is called the *initiation step*

Propagation:

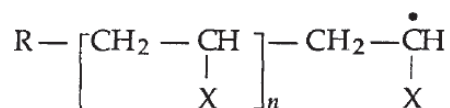
After initiation step, the propagation step gets started, where the free-radical site at the first monomer unit attacks the double bond of a fresh monomer unit.



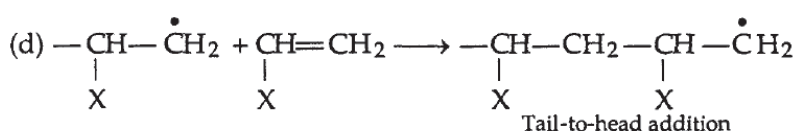
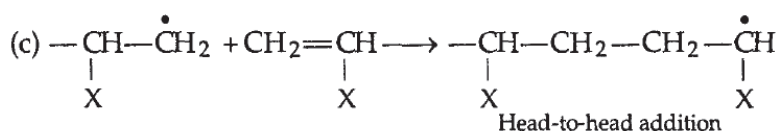
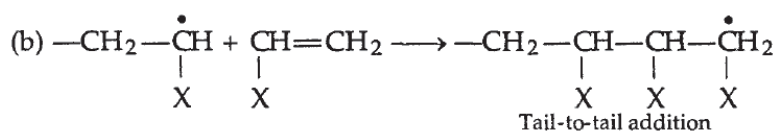
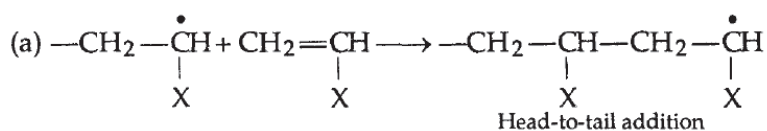
This chain again contains a radical site at its end carbon atom and can attack another monomer molecule with a transfer of the radical site to the new monomer molecule as follows:



This process continuing attack on new monomer molecules and adding to the growing chain to the one after another. The entire process is called *propagation* which can be shown as:



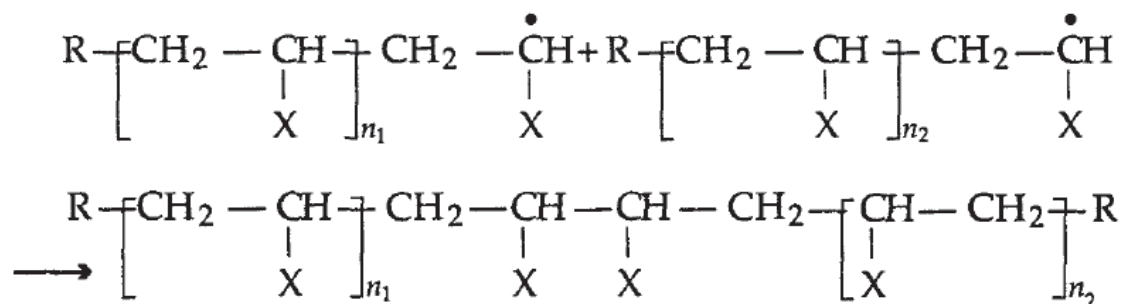
where n denotes the monomer molecules added in the chain growth. In the growing chain, the mode of the addition of monomer molecule can be of the head-to-tail, head-to-head, tail-to-head or tail-to-tail type. Suppose, the $-\text{CH}_2-$ is the head and $-\text{CHX}-$ is tail part of a monomer unit, the four types of propagation can be shown as:



Termination:

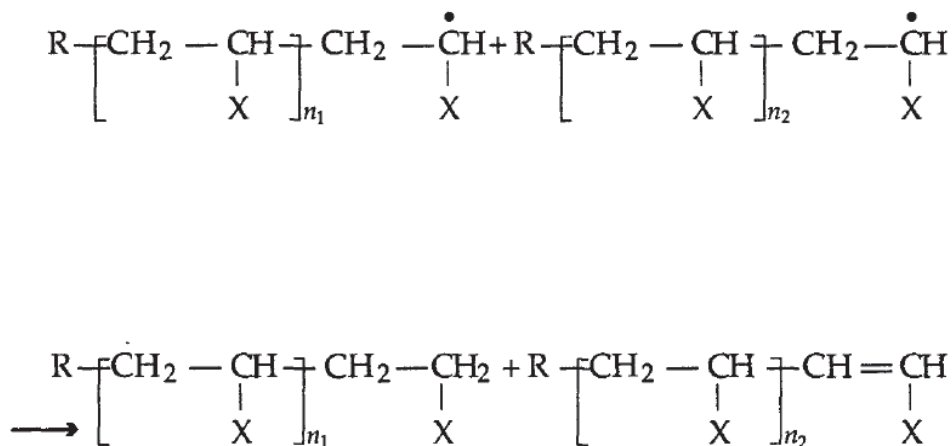
Termination by Coupling:

The two chains combine by the coupling of unpaired electrons and form a sigma bond. Such type of termination is called 'termination by coupling' because this process involves the coupling of the one lone pair of electrons.



Termination by disproportionation

One H-atom from one chain is abstracted by the other chain, and utilised unpaired electron, whereas the chain which has donated the H-atom, gets stabilized and form a double bond. In this reaction, two polymer molecules are formed. Both the molecules consist of shorter chain length as against a single molecule of a longer chain length. Such type of termination is known as 'termination by disproportionation'.



Video Content / Details of website for further learning (if any):<https://www.youtube.com/watch?v=Z8vpTL11Jkg>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Sanathi and S. Elavarasan, P.No.5.10 to 5.12,

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LECTURE HANDOUTS

L 22

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : III - Polymers

Date of Lecture:

Topic of Lecture: Plastics, classification and its type

Introduction :

Plastics are the high polymers that can be molded by the application of heat and pressure. During molding process, there is no chemical change. The plastics have linear structure. Examples: Polythene, polyvinyl chloride, polystyrene, nylons, polyesters

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Plastics
- ✓ Classification of plastics
- ✓ Thermosetting plastics
- ✓ Thermoplastic

Classification of Plastics:

The plastic are usually classified, depending on the type of resin used for its manufacture. Based on their thermal behaviour, resins are classified in to two types.

Thermoplastics:

Thermo plastics are the polymers that become soft on heating and hard on cooling and the process can be repeated for a number of times. They undergo reversible changes on heating. Examples: Polythene (PE), polypropylene (PP), polyvinyl- chloride (PVC), polytetrafluoroethylene (PTFE or Teflon), polystyrene (PS), plexiglass, nylons, polyesters, PMMA, PVA, HIDS.

Thermoplastics

- ✓ are formed by addition polymerisation
- ✓ consists of linear polymer chains with negligible cross-linking
- ✓ are soft and less brittle.
- ✓ are soluble in organic solvents.
- ✓ soften on heating and hence are amenable for moulding into any shape in the hot condition on

cooling, the resin becomes hard and rigid and retains the moulded shape.

- ✓ can be reheated and moulded into any other shape reversibly any number of times without any change in the chemical nature.

Thermosetting polymers or, Thermosets:

Thermosets are the polymers that undergo chemical changes and crosslinking on heating and become permanently hard, rigid and infusible. They will not soften on heating, Once they are set. Examples: Phenol-formaldehyde resin, urea-formaldehyde resin, epoxy resins (araldite), melamine, Bakelite

Thermosets (Thermosetting resins):

- ✓ Are mostly formed by condensation polymerisation.
- ✓ Are mostly branched polymer chains with potential to form a 3-dimensional structure.
- ✓ Become hard and rigid on heating during moulding process.
- ✓ are not soluble in common organic solvents.
- ✓ Exhibit their characteristic properties of non-softening and nonswelling nature, hardness and brittleness.
- ✓ Cannot be softened, reformed, reshaped once they are set.
- ✓ Cannot be reclaimed from wastes.

Difference between Thermoplastics and Thermosettings:

S.No.	Thermoplastics	Thermosettings
1.	Formed either by addition or by condensation polymerization reactions	Formed by condensation polymerisation reactions
2.	They have either linear or branched structures	They have 3-dimensional, crosslinked network structure
3.	Adjascent polymer chains are held together by either vanderwaals forces, or by dipole-dipole forces or by hydrogen bonds.	Adjascent polymer chains are held together by strong covalent bonds called crossed-links.
4.	They soften on heating and stiffen on cooling	They do not soften on heating
5.	Low molecular weight thermo plastics are soluble in their suitable solvents	They are insoluble in any solvent
6.	They can be remoulded, re-shaped and re-used.	They cannot be remoulded and hence cannot be used.
7.	They can be reclaimed from waste i.e., they can be recycled	They cannot be reclaimed from waste. They cannot be recycled
8.	There is no change in chemical composition and structure during moulding process	They undergo chemical changes such as further polymerisation and cross-linking during moulding process
9.	They undergo reversible changes,	They undergo irreversible changes

	on the application of heat.	on the application of heat.
10.	They are soft and flexible	They are hard, rigid and infusible.
11.	They swell or dissolve in organic Solvents.	They neither dissolve nor swell in Organic solvents.
12.	They are tough materials	They are brittle materials
13.	The moulded articles are to be cooled to room temperature before taking out from the moulds to avoid deformation.	The moulded articles can be taken out of the moulds even when they are still hot without any deformations
14.	Curing can be done by cooling	Curing can be done by applying heat and pressure
15.	Examples: Polyethylene(PE), Polypropylene(PP), Poly Vinyl Chloride(PVC), Polystyrene(PS), POLytetrafluoroethylene (PTFE or Teflon), Polymethyl methacrylate (PMMA - Lucite or plexiglass) nylons, Polyesters	Examples: Phenol-formaldehyde resin (PF), urea-formaldehyde resin (UF), Melamine - formaldehyde resin (MF), epoxy resins, XLPE, bakelite.

Video Content / Details of website for further learning (if any):<https://www.youtube.com/watch?v=ICKqN7Yw7Ew>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.6.1 to 6.2.

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LECTURE HANDOUTS

L 23

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : III - Polymers

Date of Lecture:

Topic of Lecture: Preparation, properties and uses of PVC, Teflon, Nylon 6, Nylon 6,6, Nylon 6,10 and PET

Introduction :

The word polymer is derived from two Greek words; *polos*: many and *merus*: parts (repeating units). Therefore, polymers can be defined as macromolecules (high molecular weight compounds) formed by linking large numbers of repeating units called monomers. For example, polythene is a polymer formed by linking together large number of ethene (C₂H₄) molecules. Ethene is a monomer of polythene (polyethylene). The molecular weight of polymers generally ranges from 5,000 to 200,000 Dalton. The reaction converting monomers to polymers is called polymerization. The number of repeating units (n) in a polymer is called degree of polymerization.

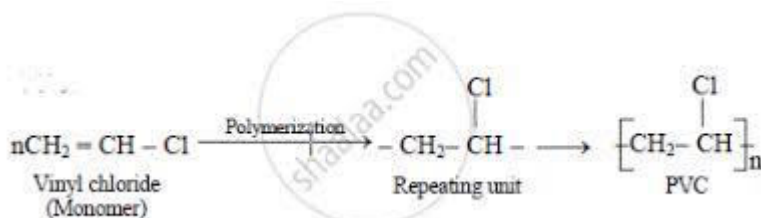
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Preparation properties of polymers
- ✓ PVC
- ✓ Teflon
- ✓ Nylon
- ✓ PET

Polyvinyl Chloride (PVC):

Preparation:

Polyvinyl chloride is obtained by heating a water emulsion of the vinyl chloride in an autoclave under pressure in the presence of benzoyl peroxide or hydrogen peroxide.



Properties:

- ✓ PVC is a colourless and adourless powder.

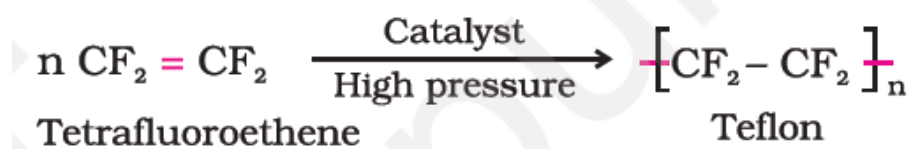
- ✓ It is chemically inert and non-inflammable and exhibits high resistance to light, atmospheric oxygen, acids and alkalis.
- ✓ 3) It is soluble in chlorinated hydrocarbons, tetrahydrofuran (THF) and cyclohexanone.
- ✓ 4) Pure resin possesses a high softening point (148°C) and a greater stiffness and rigidity compared to polyethylene, but is brittle.
- ✓ It is the most widely used synthetic plastic

Uses:

It is used for making sheets, that are employed for tank linings, light-fittings, safety helmets, refrigerator components, tyres, cycle and motor cycle mudguards.

Teflon:

Teflon is the trade name for polytetrafluoro ethylene. The linear structure of Teflon is $(CF_2 - CF_2)_n$.



Properties:

- ✓ It is a thermoplastic
- ✓ Chemical inertness over a wide range of temperature
- ✓ Excellent electrical insulation properties.
- ✓ Very-low coefficient of friction
- ✓ Excellent toughness and heat resistant.
- ✓

Applications: Teflon is used for

- ✓ Wire and cable insulation
- ✓ Laminates for printed circuitry
- ✓ Coatings of frying pans
- ✓ Non-lubricating bearings.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=HTh_5CWMSoQ

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.6.2 to 6.5.

Course Faculty

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LECTURE HANDOUTS

L 24

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 16SHB31

Course Faculty :

Unit : III - Polymers

Date of Lecture:

Topic of Lecture Preparation, properties and uses of Nylon 6,6 & PET

Introduction :

The orientation of monomeric units in a polymer molecule can take place in an orderly or disorderly fashion with respect to the main chain is called Tacticity. Nylon 66 (loosely written nylon 6-6, nylon 6/6, nylon 6,6, or nylon 6:6) is a type of polyamide or nylon. It, and nylon 6, are the two most common for textile and plastic industries. Nylon 66 is made of two monomers each containing 6 carbon atoms, hexamethylenediamine and adipic acid, which give nylon 66 its name

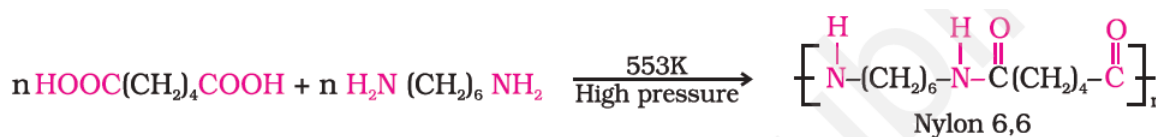
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ To learn about the synthesis of Nylon 6,6 and PET
- ✓ Properties of Nylon 6,6 and PET
- ✓ Application of Nylon 6,6 and PET

Preparation of nylons:

Nylon 6,6:

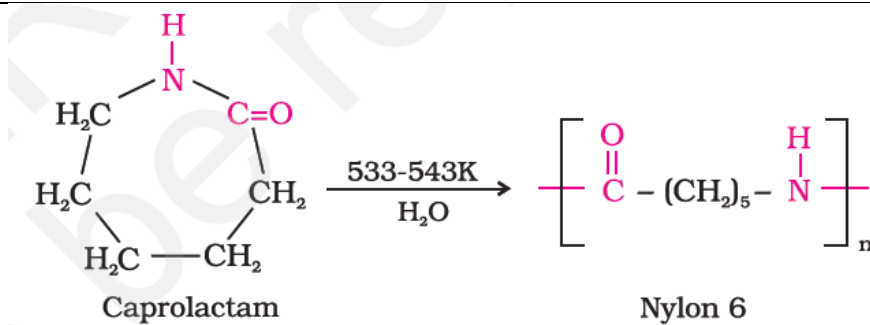
It is prepared by the condensation polymerization of hexamethylenediamine with adipic acid under high pressure and at high temperature



Nylon 6, 6 is used in making sheets, bristles for brushes and in textile industry.

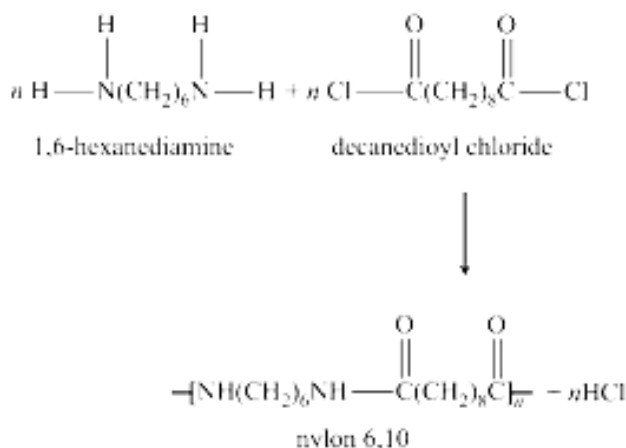
Nylon 6:

It is prepared by heating caprolactam with water at high temperature. It is used for the manufacture of tyre cords, fabrics and ropes.



Nylon6,10:

It is prepared by the condensation polymerization of hexamethylenediamine and sebacic acid.



Properties:

- ✓ The structure of nylons are linear that permits side-by-side alignment.
- ✓ The molecular chains are held together by hydrogen bonds.
- ✓ It is having toughness, abrasion resistance and retention of good mechanical properties upto 125oC.
- ✓ They are also sterilisable.
- ✓ They have good hydrocarbon resistance since nylons are polar polymers.
- ✓ Larger the number of carbon atoms, greater will be ease of processing and Hydrocarbon and moisture resistance.

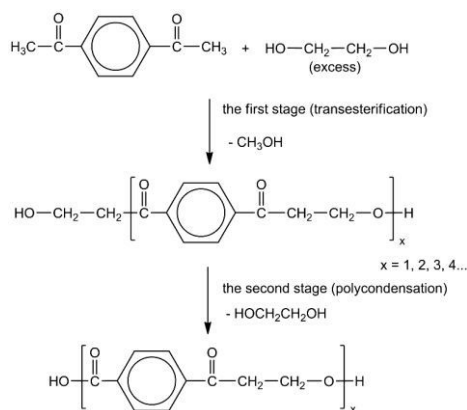
Uses:

- ✓ Mouldings have application in medicine and pharmacy because of sterilisability.
- ✓ Durable but costly hair combs.
- ✓ Nylon 6.10 is suitable for monofilaments that are used for bristles, brushes etc.,
- ✓ Glass reinforced Nylon plastics are used in housings and casings of domestic appliances, radiator parts of car and for relay coil formers.

Polyethylene terephthalate:

Polyethylene terephthalate (sometimes written poly (ethylene terephthalate)), commonly abbreviated **PET**, **PETE**, or the obsolete PETP or PET-P, is the most common thermoplastic polymer resin of the polyester family and is used in fibres for clothing, containers for liquids and

foods, thermoforming for manufacturing, and in combination with glass fibre for engineering resins.



Properties:

- ✓ PET in its natural state is a colorless, semi-crystalline resin
- ✓ PET can be semi-rigid to rigid, and it is very lightweight
- ✓ It makes a good gas and fair moisture barrier, as well as a good barrier to alcohol and solvents.
- ✓ It is strong and impact-resistant

Uses:

- ✓ Plastic bottles made from PET are widely used for soft drinks
- ✓ Non-oriented PET sheet can be thermoformed to make packaging trays and blister packs
- ✓ Color-conferring dyes can easily be formulated into PET sheet.
- ✓ PET is also used as a substrate in thin film solar cells.

Video Content / Details of website for further learning (if any):

<https://www.youtube.com/watch?v=hKMnnwICyT8>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.5.12 to 5.14.

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LECTURE HANDOUTS

L 25

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : III - Polymers

Date of Lecture:

Topic of Lecture: Rubbers, vulcanization of rubbers, Butyl rubber & SBR rubber

Natural rubber:

Natural rubber is found in several species of rubber trees grown in tropical countries of these *Hevea brasiliensis* is the most important source of natural rubber and the rubber obtained from this is known as "Hevea" rubber. Rubber is stored in the form of white fluid called 'latex' behind the bark of the rubber tree. Natural rubber is a high polymer of isoprene (2-methyl-1,3-butadiene). It is a hydrocarbon polymer having molecular formula $(C_5H_8)_n$.

Polysisoprene exists in two geometric isomers cis and trans. Natural rubber is soft and has cis-configuration while 'Guttapercha' or, 'Ballata' has trans configuration.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Role of information technology in environment
- ✓ To know the Remote sensing:
- ✓ To know where it's used Remote sensing application in environment
- ✓ To know the rights of the child.
- ✓ To get awareness about the IT

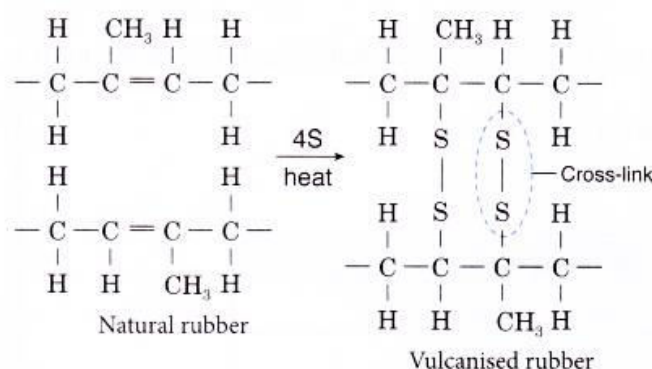
Deficiencies of natural rubber:

- ✓ Natural rubber as such has no practical utility value. It is because of many inherent deficiencies.
- ✓ It is hard and brittle at low temperature and soft and sticky at high temperature.
- ✓ It is soft and soluble in many hydrocarbon solvents and carbon disulphide (CS_2).
- ✓ It has high water absorption power.
- ✓ It is a sticky substance, rather difficult to handle
- ✓ It is readily attacked by acids and alkalis.

Vulcanization:

Vulcanization is a process of heating the raw rubber at 100 - 140°C with sulfur for 1 - 4 hours. The sulfur combines chemically at the double bonds of different rubber molecules and

provides cross-linking between the chains. The degree of vulcanization depends on the amount of sulfur used. Tyre industry uses 3 - 5% sulfur. If the amount of sulfur is increased to 30%, a hard and rigid rubber called "ebonite" is produced.



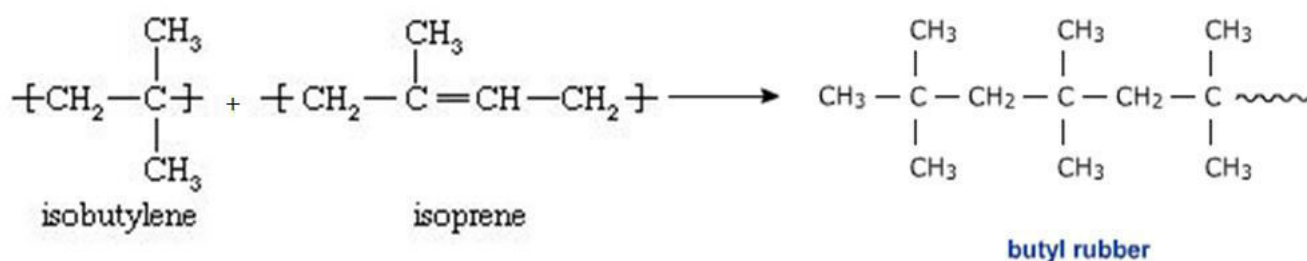
Advantages of vulcanization:

- ✓ The tensile strength of vulcanized rubber is very good. It is 10 times the tensile strength of raw rubber.
- ✓ It has excellent resilience i.e., articles made from it return to their original shape when the deforming load is removed.
- ✓ It has better resistance to moisture, oxidation, abrasion.
- ✓ It has much higher resistance to wear and tear compared to raw rubber.
- ✓ It has a broader useful temperature range (-40 to 100°C) compared to raw rubber's useful temperature range (10 - 60°C).
- ✓ It is a better electrical insulator Ex: Ebonite
- ✓ It is resistant to i) Organic solvents like petrol, benzene, CCl₄, ii) Fats and oils, but it swells in them.
- ✓ It has only slight tackiness.
- ✓ It has low elasticity. This property depends on the extent of vulcanization. Ebonite has practically no elasticity.
- ✓ It is very easy to manipulate the vulcanized rubber to produce the desired shapes.

Butyl rubber:

Preparation:

Butyl rubber is prepared by the aluminum chloride initiated cationic copolymerisation of isobutene with a small amount (1-5%) of isoprene.



Properties:

- ✓ Under normal conditions, it is amorphous but it crystallizes on stretching.
- ✓ It is quite resistant to oxidation due to low degree of unsaturation.
- ✓ Due to very low unsaturation, it can be vulcanized but it cannot be hardened much.
- ✓ It can be degraded by heat or light to sticky low-molecular weight products so stabilization is must.
- ✓ Being non-polar, it has good electrical insulation properties.
- ✓ Compared to natural rubber it possesses outstanding low permeability to air and other gases.
- ✓ It does not crystallize on cooling and hence remains flexible down to -50°C .
- ✓ Because of its hydrocarbon nature, butyl rubber is soluble in hydrocarbon solvents like benzene but has excellent resistance to polar solvents like alcohol, acetone and ageing chemicals (ex: HCl, HF, HNO₃, H₂SO₄ etc.)

Applications:

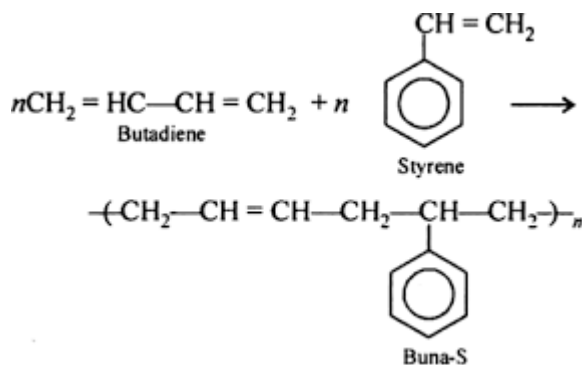
- ✓ It is used for insulation of high voltage wires and cables.
- ✓ Inner tubes of automobile tyres.
- ✓ Conveyor belts for food and other materials.
- ✓ Lining of tanks.
- ✓ Hoses

BuNa - S: [Styrene rubber or, SBR (Styrene - butadiene rubber)]

Preparation:

Buna - S is prepared by the copolymerization of butadiene (75%) and styrene (25%) in an emulsion system at 50°C in the presence of cumene hydroperoxide as catalyst.

If the emulsion polymerisation is carried out at low temperatures (-18 to 5°C) in the presence of redox catalyst like cumene hydroperoxide + dextrose in the presence of iron salt, the resultant SBR is known as cold SBR.



Vulcanization can be done either by sulfur or sulfur monochloride (S₂Cl₂). Less sulfur and more accelerators are required for vulcanization.

Properties:

- ✓ High abrasion resistance
- ✓ High load-bearing capacity

- ✓ It swells in oils and solvents.
- ✓ Low oxidation resistance, as it gets readily oxidized, especially in the presence of traces of ozone present in the atmosphere.
- ✓ Vulcanized and compounded cold rubber has a greater tensile strength and greater abrasion resistance than the SBR or natural rubbers.

Applications:

SBR is used in the following applications.

- ✓ Motor tyres
- ✓ Shoes soles
- ✓ Foot wear components
- ✓ Insulation of wire and cables

Video Content / Details of website for further learning (if any):

<https://www.youtube.com/watch?v=COAUwK4hZK4>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No. 6.5 to 6.9

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LECTURE HANDOUTS

L 26

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : III - Polymers Date of Lecture:

Topic of Lecture: Biodegradable Polymers – synthesis and properties of Poly lactic acid

Introduction :

Biodegradable polymers are a special class of polymer that breaks down after its intended purpose by bacterial decomposition process to result in natural byproducts such as gases (CO₂, N₂), water, biomass, and inorganic salts.^{[1][2]} These polymers are found both naturally and synthetically made, and largely consist of ester, amide, and ether functional groups. Their properties and breakdown mechanism are determined by their exact structure. These polymers are often synthesized by condensation reactions, ring opening polymerization, and metal catalysts

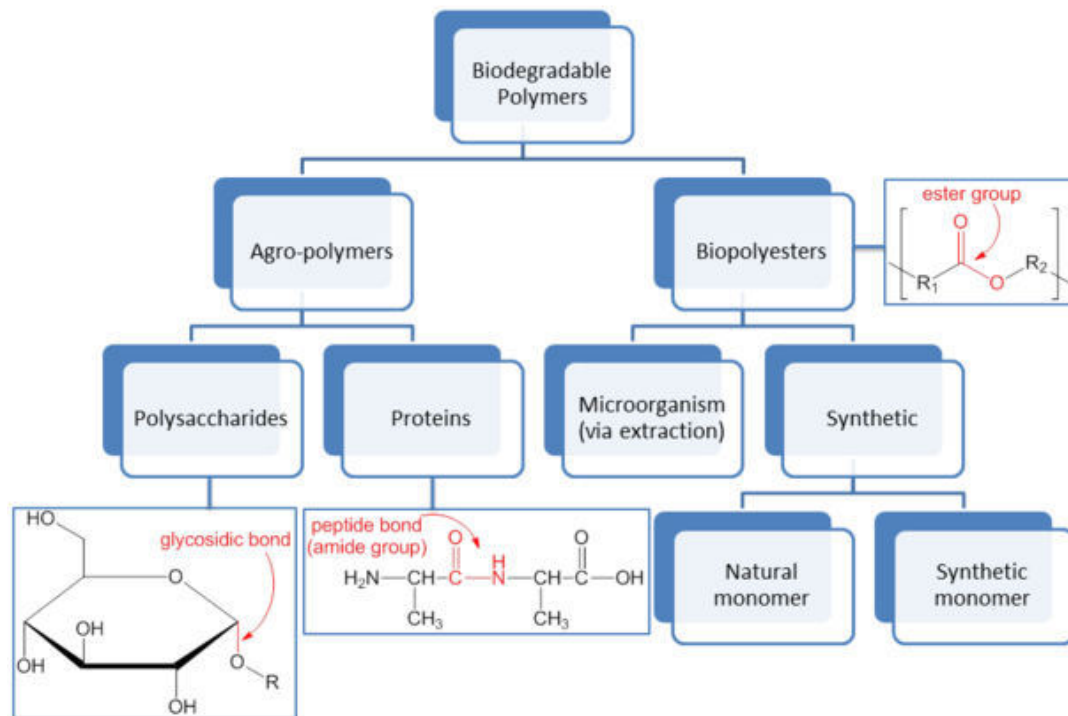
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Structure
- ✓ Properties
- ✓ Synthesis
- ✓ Mechanism of breakdown
- ✓ Uses

Structure and properties:

The structure of biodegradable polymers is instrumental in their properties. While there are innumerable biodegradable polymers, both synthetic and natural, there are a few commonalities among them.

Biodegradable polymers tend to consist of ester, amide, or ether bonds. In general, biodegradable polymers can be grouped into two large groups based on their structure and synthesis. One of these groups is agro-polymers, or those derived from biomass.^[1] The other consists of biopolyesters, which are those derived from microorganisms or synthetically made from either naturally or synthetic monomers.



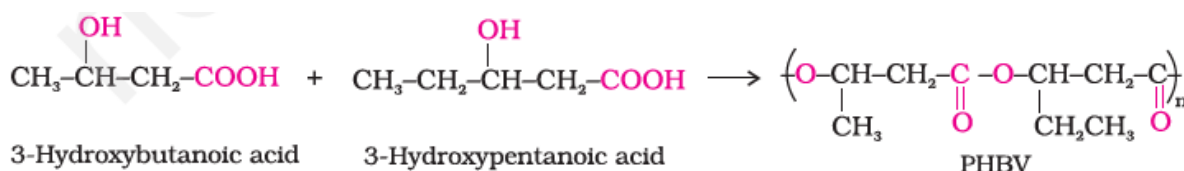
Properties:

- ✓ Biodegradable polymers should be stable and durable enough for use in their particular application.
- ✓ Its have extremely strong carbon backbones that are difficult to break.
- ✓ Crystallinity is often low as it also inhibits access to end groups
- ✓ non-toxic
- ✓ capable of maintaining good mechanical integrity until degraded
- ✓ capable of controlled rates of degradation

Synthesis:

Poly β -dihydroxybutyrate - co- β -hydroxy valerate (PHBV)

It is obtained by the copolymerization of 3-hydroxybutanoic acid and 3 - hydroxypentanoic acid. PHBV is used in specialty packaging, orthopaedic devices and in controlled release of drugs. PHBV undergoes bacterial degradation in the environment.



Mechanism of breakdown:

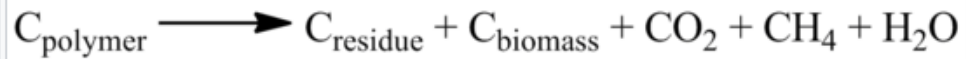
In general, biodegradable polymers break down to form gases, salts, and biomass. Complete biodegradation is said to occur when there are no oligomers or monomers left. The breakdown of these polymers depends on a variety of factors including the polymer and also, the environment the polymer is in.

There are two primary mechanisms through which biodegradation can occur. One is

through physical decomposition through reactions such as hydrolysis and photodegradation, which can lead to partial or complete degradation. The second mechanistic route is through biological processes which can be further broken down into aerobic and anaerobic processes. The first involves aerobic biodegradation, where oxygen is present and important. In this case, the general equation seen below where C_{residue} represents smaller fragments of the initial polymer such as oligomers.



The second mechanism of biodegradation is by anaerobic processes, where oxygen is not present.



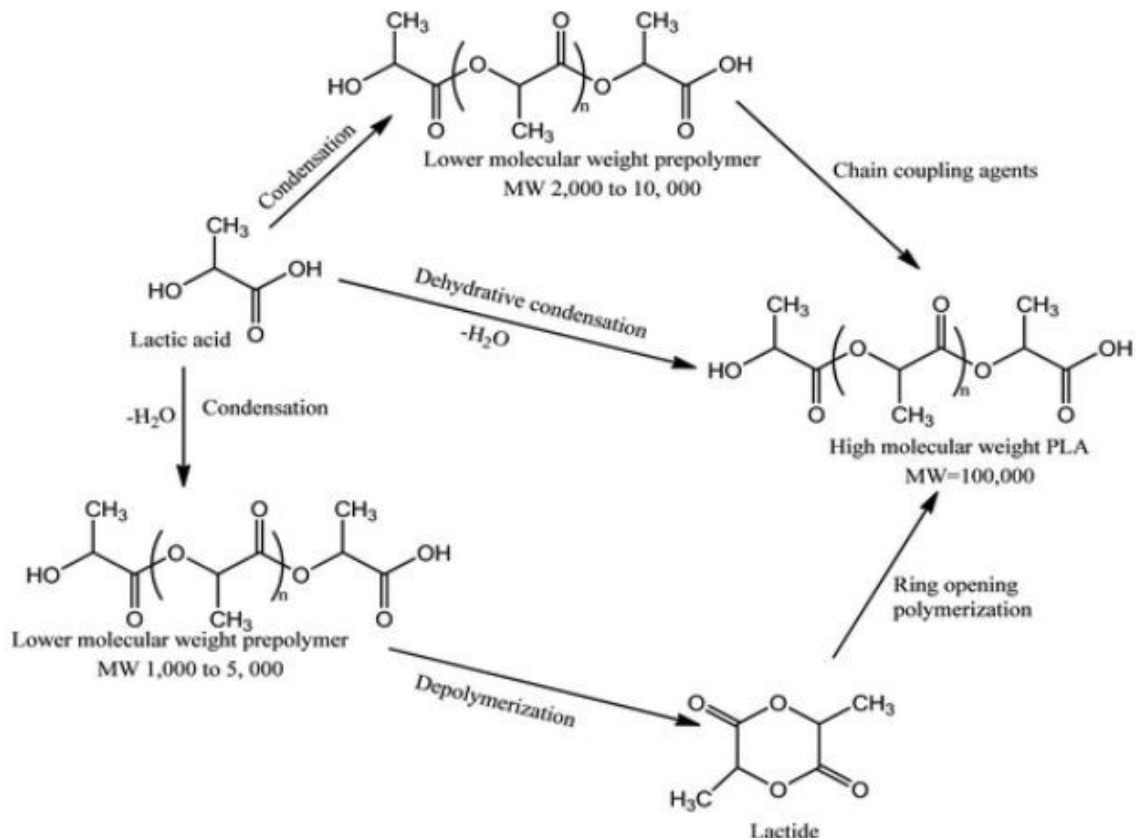
Applications and uses:

Biodegradable polymers have an innumerable uses in the

- ✓ Biomedical
- ✓ Tissue Engineering
- ✓ Drug delivery

Poly(lactic acid) (PLA):

Poly(lactic acid) (PLA) is obtained by polymerisation of the cyclic dimer of lactic acid or by microbiological synthesis of lactic acid followed by the polycondensation and removal of water by evaporation.



Applications:

It breaks down in the environment back to lactic acid which can be metabolized which has application in medical field such as sutures, drug delivery systems and wound clips. It has also agriculture applications such as time release coatings for fertilizers and pesticides

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=j2SqhnF_Eik

Important Books/Journals for further learning including the page nos.:

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

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LECTURE HANDOUTS

L 27

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 19BSS11

Course Faculty :

Unit : III - Polymers

Date of Lecture:

Topic of Lecture: Photo Conducting Polymers – Synthesis of Poly vinyl carbazole

Introduction :

Photoconductive polymers absorb electromagnetic radiation and produce an increase of electrical conductivity. Photoconductive polymers have been used in a wide variety of technical applications such as Xerography (electrophotography) and laser printing. Electrical conductivity is usually very small in organic compounds.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ To study about the photoconductivity
- ✓ Applications of photoconductivity
- ✓ Synthesis of polyvinylcarbazole
- ✓ Application of polyvinylcarbazole

The enhanced flow of current under the influence of an applied electric field that occurs when a semiconductor is exposed to visible light or other electromagnetic radiation is known as photoconduction.

There are two essential requirements for photoconductivity:

- ✓ The absorbed photons must induce the formation of charge carriers, and
- ✓ The charge carriers must be mobile, i.e. they must be able to move independently under the influence of an external electric field.

Photoconductivity was first detected in inorganic materials, for example in crystals of alkali metal halides containing colour centers (trapped electrons in anion vacancies) or in materials possessing atomic disorder such as amorphous silicon or selenium. As regards organic materials, dye crystals and, more recently, also various polymeric systems have been found to exhibit photoconductivity.

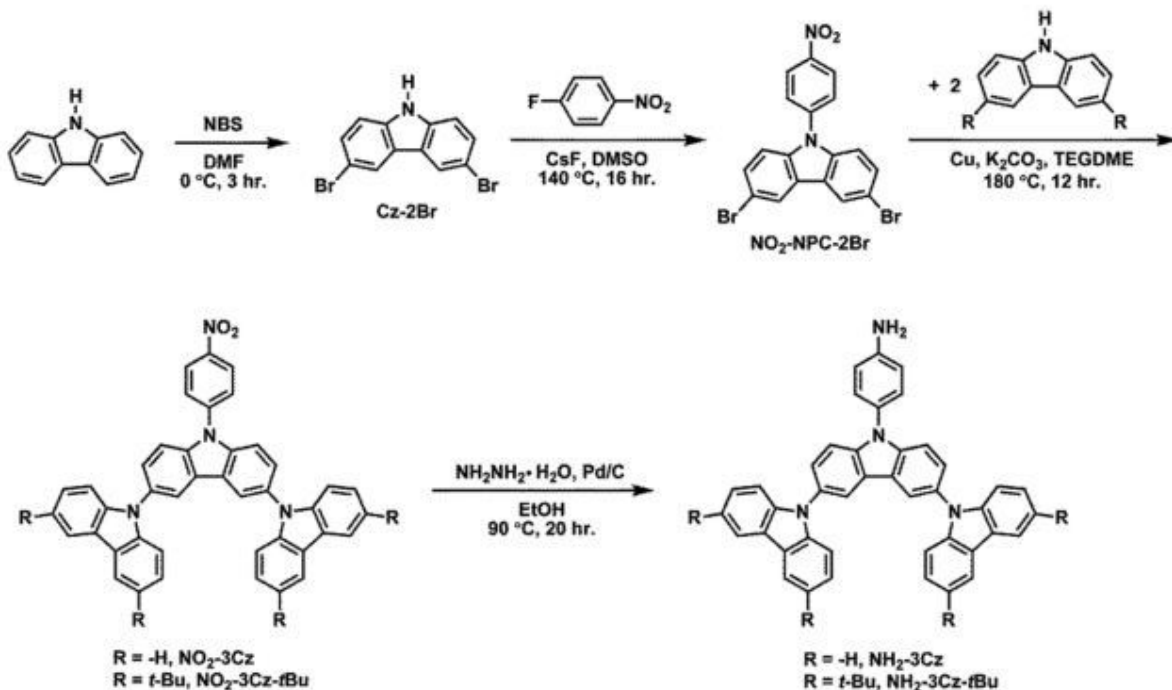
Two groups of photoconducting polymeric systems may be distinguished:

(a) solid solutions of active compounds of low molar mass in inert polymeric matrices, also denoted as molecularly doped polymers, and (b) polymers possessing active centers in the main chain or in pendant groups. Examples belonging to group (a) are polycarbonate and polystyrene molecularly doped with derivatives of triphenylamine, hydrazone, pyrazoline or certain dyes. Molecularly doped polymers are widely used as transport layers in the photoreceptor assemblies of photocopying machines.

Poly(N-vinyl carbazole) and various other vinyl derivatives of polynuclear aromatic compounds such as poly(2-vinyl carbazole) and poly(vinyl pyrene) have high photoconductive efficiencies, belong to the second group. The excellent photo conductivities of these polymers are believed to be due to their helical conformation with successive aromatic side chains lying parallel to each other in a stack along which electron transfer takes place relatively easily

Polyvinylcarbazole:

Polyvinyl carbazole has a high glass transition temperature (150°C), because it contains bulky side groups which hinder the freedom of motion



Poly(9-vinylcarbazole) (PVK) is a conductive polymer which is mainly used as a hole transporting medium at high efficiencies with low driving voltage. It can also be used as an anode for hole injection and can act as an effective charge transferring gate by co-doping it with organic dyes.

Physical properties:

PVK can be used at temperatures of up to 160 - 170 °C and is therefore a temperature-resistant thermoplastic. The electrical conductivity changes depending on the illumination. For this

reason, PVK is classified as a semiconductor or photoconductor. The polymer is extremely brittle, but the brittleness can be reduced by copolymerization with a little isoprene.

Chemical properties:

Polyvinylcarbazole is soluble in aromatic hydrocarbons, halogenated hydrocarbons and ketones.^[1] It is resistant to acids, alkalis, polar solvents and aliphatic hydrocarbons.^[2] The addition of PVC to other plastic masses increases their temperature resistance

Application:

Due to its high price and special properties, the use of PVK is limited to special areas.^[2] It is used in insulation technology,^[2] electrophotography (e.g. in copiers and laser printers),^[3] organic light-emitting diodes and photovoltaic devices.^[1] In addition, PVC is a well researched component in photorefractive polymers and therefore plays an important role in holography. Another application is the production of cooking-proof copolymers with styrene.

Video Content / Details of website for further learning (if any):

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

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.5.14 to 5.16.

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LECTURE HANDOUTS

L 28

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture: Introduction of non conventional energy sources & storage devices

Introduction :

- ✓ The process of breaking a heavy nucleus with a slow neutron into two lighter nuclei of almost equal size with the liberation of large amount of energy is called as nuclear fission or atomic fission.
$${}_{92}\text{U}^{235} + {}_0\text{n}^1 \rightarrow [{}_{92}\text{U}^{236}] \rightarrow {}_{56}\text{Ba}^{141} + {}_{36}\text{Kr}^{92} + 3{}_0\text{n}^1 + 200.5 \text{ MeV (Energy)}$$
- ✓ Nuclear fusion is the process in which two or more lighter nuclei combine to form one single heavier nucleus. Eg : The combination of various isotopes of hydrogen to form helium.
$${}_1\text{H}^2 + {}_1\text{H}^3 \rightarrow {}_2\text{He}^4 + {}_0\text{n}^1 + 17.6 \text{ MeV (Energy)}$$
- ✓ Storage cell - a cell that can be recharged. Secondary cell. Electric cell, cell - a device that delivers an electric current as the result of a chemical reaction. Storage battery, accumulator - a voltaic battery that stores electric charge.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Nuclear energy
- ✓ Nuclear Fission
- ✓ Nuclear Fusion
- ✓ Cell
- ✓ Battery

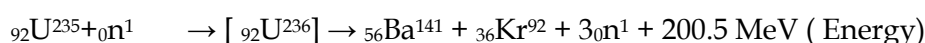
Nuclear Fission and Nuclear Fusion:

The process of breaking a heavy nucleus with a slow neutron into two lighter nuclei of almost equal size with the liberation of large amount of energy is called as nuclear fission or atomic fission.



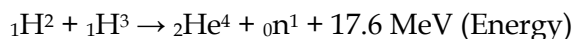
Mechanism of Nuclear Fission:

When U-235 is bombarded by slow moving neutron, unstable U-236 is formed. This nucleus disintegrates into two equal nuclei with the release of huge amount of energy and few neutrons.



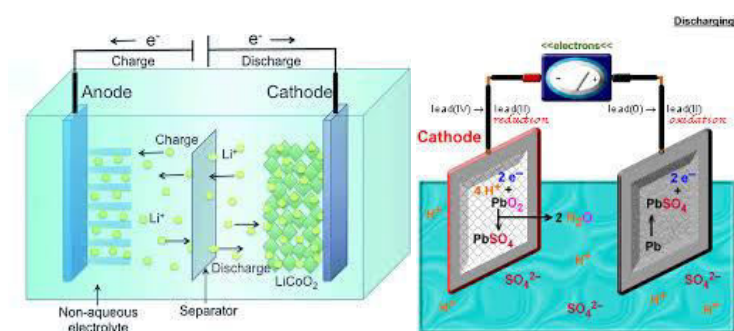
Nuclear Fusion:

The process of combination of lighter nuclei to form heavier nuclei, with simultaneous liberation of huge amount of energy is called as nuclear energy. Example: fusion reaction sun



Storage Devices:

- ✓ **Nickel Cadmium (NiCd)**: mature and well understood but relatively low in energy density. The NiCd is used where long life, high discharge rate and economical price are important. Main applications are two-way radios, biomedical equipment, professional video cameras and power tools. The NiCd contains toxic metals and is environmentally unfriendly.
- ✓ **Nickel-Metal Hydride (NiMH)** – has a higher energy density compared to the NiCd at the expense of reduced cycle life. NiMH contains no toxic metals. Applications include mobile phones and laptop computers.
- ✓ **Lead Acid** – most economical for larger power applications where weight is of little concern. The lead acid battery is the preferred choice for hospital equipment, wheelchairs, emergency lighting and UPS systems.
- ✓ **Lithium Ion (Li-ion)** – fastest growing battery system. Li-ion is used where high-energy density and lightweight is of prime importance. The technology is fragile and a protection circuit is required to assure safety. Applications include notebook computers and cellular phones.
- ✓ **Lithium Ion Polymer (Li-ion polymer)** – offers the attributes of the Li-ion in ultra-slim geometry and simplified packaging. Main applications are mobile phones.



Video Content / Details of website for further learning (if any): Can be added as link <https://www.youtube.com/watch?v=p8ecZ5oK7Fc>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.7.1 to 7.3.

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LECTURE HANDOUTS

L 29

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

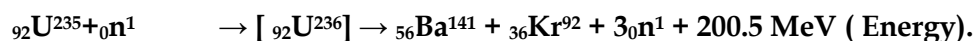
Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

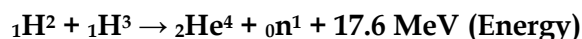
Topic of Lecture: Nuclear Fission and Nuclear Fusion

Introduction :

The process of breaking a heavy nucleus with a slow neutron into two lighter nuclei of almost equal size with the liberation of large amount of energy is called as nuclear fission or atomic fission.



Nuclear fusion is the process in which two or more lighter nuclei combine to form one single heavier nucleus. Eg : The combination of various isotopes of hydrogen to form helium.

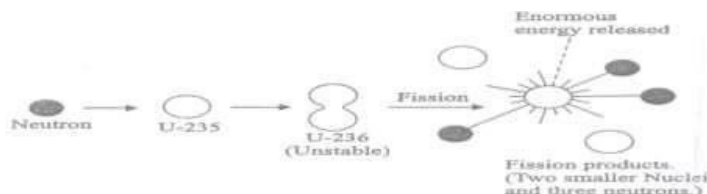
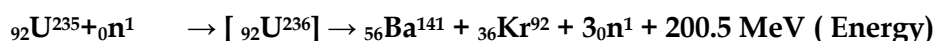


Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Nuclear energy
- ✓ Nuclear Fission
- ✓ Nuclear Fusion
- ✓ Disintegration
- ✓ Radiation

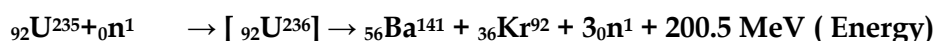
Nuclear Fission and Nuclear Fusion:

The process of breaking a heavy nucleus with a slow neutron into two lighter nuclei of almost equal size with the liberation of large amount of energy is called as nuclear fission or atomic fission.



Mechanism of Nuclear Fission:

When U-235 is bombarded by slow moving neutron, unstable U-236 is formed. This nucleus disintegrates into two equal nuclei with the release of huge amount of energy and few neutrons.

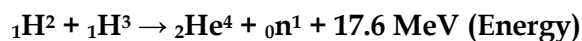


Characteristics of Nuclear Fission Reaction

- ✓ Heavy nucleus splits into two or more nuclei.
- ✓ Two or more neutrons are produced by fission of each nucleus.
- ✓ Large quantity of energy is produced during the nuclear fission reaction..
- ✓ All the fission fragments are radioactive in nature, giving off gamma radiations
- ✓ The atomic weights of nuclear fission product ranges from 70 to 160.
- ✓ All the fission reactions are self propagating chain reaction because one of the fission products is neutron.
- ✓ The nuclear reactions can be controlled by absorbing the neutrons using Cd, Boron.
- ✓ Every secondary neutron released in the fission reaction does not strike the nucleus. Some escape into air. Hence a chain reaction cannot be maintained.
- ✓ The number of neutrons resulting from a single fission is known as multiplication factor. When it is less than 1, nuclear chain reaction does not take place.

Nuclear Fusion

The process of combination of lighter nuclei to form heavier nuclei, with simultaneous liberation of huge amount of energy is called as nuclear energy. Example: fusion reaction in sun



Characteristics Of Nuclear Fusion Reaction:

- ✓ It is the combination of lighter nuclei.
- ✓ It does not emit radioactive rays.
- ✓ It takes place at very high temperature $4 \times 10^6 \text{K}$
- ✓ The mass number and atomic number of the fission product is higher than the starting elements.
- ✓ It does not give rise to chain reaction
- ✓ Positrons are emitted.
- ✓ It cannot be controlled.

Video Content / Details of website for further learning (if

any):<https://www.youtube.com/watch?v=6axVVhi62ac>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.7.2 to 7.5.

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LECTURE HANDOUTS

L 30

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture: Nuclear chain Reaction

Introduction :

Nuclear chain reaction is an autocatalytic reaction in which the number of neutrons keeps on multiplying rapidly till the whole of fissionable material is disintegrated.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Nuclear Energy
- ✓ Nuclear Fission
- ✓ Nuclear Fusion
- ✓ Chain reaction

Nuclear Energy:

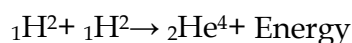
The enormous energy thus released during the Nuclear Fission & Fusion reaction is known as Nuclear Energy.

Nuclear fission:

It is the nuclear reaction in which heavy isotopes are split into lighter nuclei on bombardment by neutrons. Fission reaction of U^{235} is given below

Nuclear fusion:

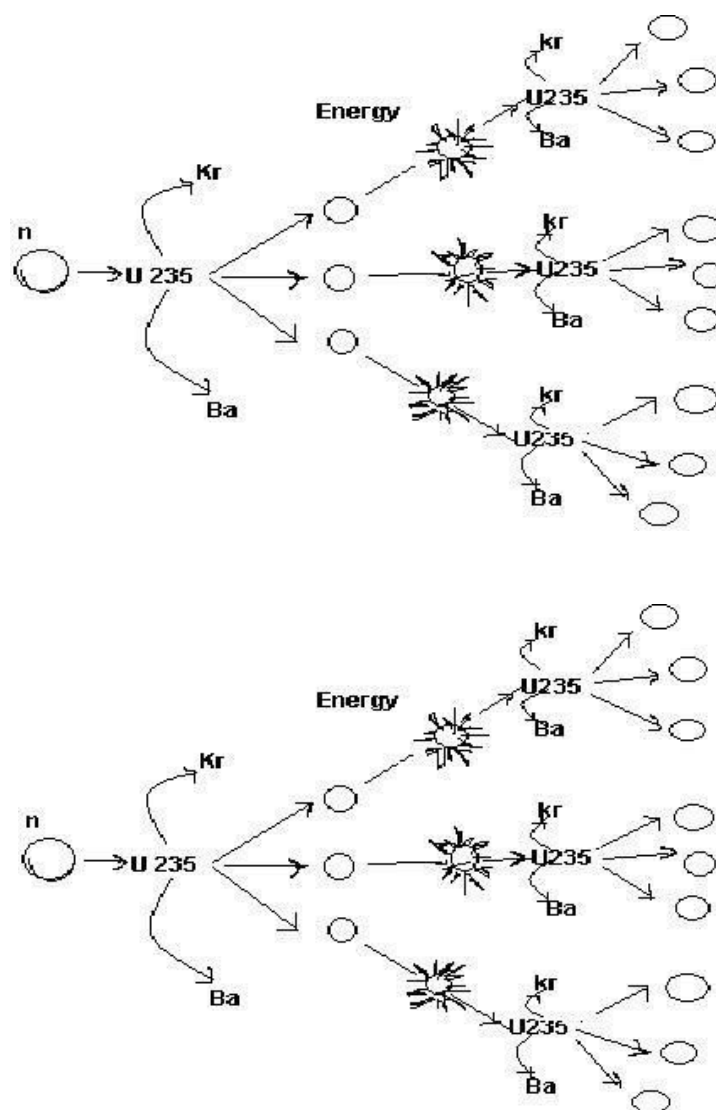
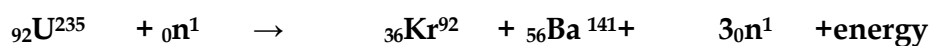
Process of combination of lighter nuclei into heavier nucleus with simultaneous liberation of large amount of energy. (e.g) solar system



Nuclear fusion reaction occurs in sun.

Nuclear chain reaction:

Nuclear chain reaction is an autocatalytic reaction in which the number of neutrons keeps on multiplying rapidly till the whole of fissionable material is disintegrated. Control rods are used control and regulate the number of neutrons that can cause fission.



Video Content / Details of website for further learning (if any): <https://www.youtube.com/watch?v=0Tgtv1CAfxI>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No. - 7.2 to 7.5

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LECTURE HANDOUTS

L 31

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

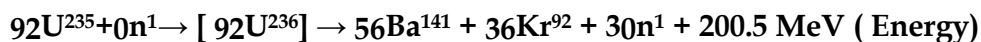
Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture: Light water nuclear reactor for power generation, Breeder reactor

Introduction :

The process of breaking a heavy nucleus with a slow neutron into two lighter nuclei of almost equal size with the liberation of large amount of energy is called as nuclear fission or atomic fission.



Nuclear fusion is the process in which two or more lighter nuclei combine to form one single heavier nucleus. Eg : The combination of various isotopes of hydrogen to form helium.



Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Nuclear Reaction
- ✓ Radioactive element
- ✓ Control rods
- ✓ Moderator

Components of a Light Water Nuclear Reactor

1. Fuel Rods
2. Moderator
3. Control rods
4. Coolant
5. Protective screen
6. Heat exchanger / pressure vessel
7. Turbine

FUELRODS:

The fissionable material used in the nuclear reactor is enriched U-235. It is used in the form of

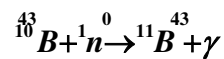
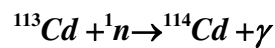
rods or strips. Example: U^{235} , Pu^{239}

Function: It produces heat energy and neutrons, that neutron starts nuclear chain reaction.

CONTROL RODS:

To control the rate of fission of U-235, movable rods made of Cd or B are suspended between fuel rods. These rods absorb the excess neutrons. So the fission reaction proceeds at steady rate. These rods are lowered and raised as of need.

If the rods are deeply inserted inside the reactor, they will absorb more neutrons and the reaction becomes very slow. If the rods are pushed outwards, they will absorb less neutrons and the reaction will be very fast.



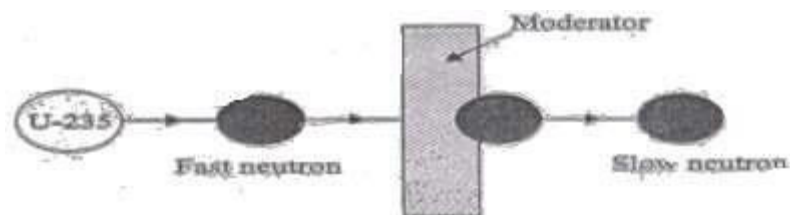
Example: Cadmium, Boron

Function: It controls the nuclear chain reaction and avoids the damage to the reactor.

Moderator:

The substances used to slow down the neutrons are called moderators.

Example: Ordinary water, Heavy water, graphite, beryllium.



Function: The kinetic energy of fast neutron (1meV) is reduced to slow neutrons (0.25 eV).

Coolant:

In order to absorb the heat produced during fission reaction, the coolant is circulated in the reactor core. It enters the base and leaves at the top. The heat carried by outgoing liquid is used to produce steam. Example: Water (act as coolant and moderator) Heavy water, liquid metal (Na or K) Function: It cools the fuel core.

Pressure Vessel:

It encloses the core and also provides the entrance and exit passages for coolant. Function: It withstands the pressure as high as 200atm.

Protective Shield:

The moderator, control rods and fuel element are enclosed in a chamber which has a thick

concrete shield(10m thick).

Function: The environment and the operating persons are protected from destruction in case of leakage of radiation.

Heat Exchanger:

It transfers the heat liberated from the reactor core to boil water and produce steam at about 400Kg/cm².

Turbine:

The steam generated in the heat exchanger is used to operate a steam turbine, which drives a generator to produce electricity.

Light Water Nuclear Power Plant:

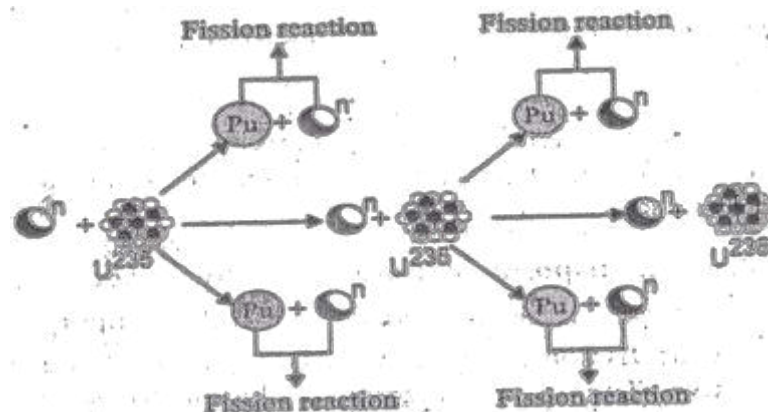
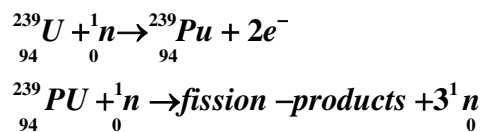
It is the one in which U-235 fuel rods are submerged in water. Here water acts as coolant and moderator.

Working

The fission reaction is controlled by inserting or removing the control rods of B¹⁰ automatically from the spaces in between the fuel rods. The heat emitted is absorbed by the coolant (light water) .The heated coolant then goes to the heat exchanger containing sea water, which is converted to steam. The steam drives the turbines, generating electricity.

Breeder reactor:

Breeder reactor is the one which converts non-fissionable material (U²³⁸ Th²³²) Into fissionable material(U²³⁵ , Pu²³⁹).



In breeder reactor, of the three neutrons emitted in the fission of U-235, only one is used in propagating the fission of U-235. The other two are allowed to react with U-238. Thus two fissionable atoms Pu-239 are reproduced for each atom of U-235 consumed. The breeder reactor produces more fissionable material than it uses.

In general

1. The fissionable nuclides such as U-235 and Pu-239 are called fissile nuclides.
2. The non-fissionable nuclides such as U-238 & Th-232 are called fertile nuclides.

Video Content / Details of website for further learning (if any):

<https://www.youtube.com/watch?v=1U6Nzcv9Vws>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.- 7.2 to 7.5

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LECTURE HANDOUTS

L 32

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture: Solar energy conversion – solar cells, wind energy

Introduction :

When solar rays fall on p-type semiconductor, the electrons from the valence band get promoted to the conduction band and cross the p-n junction into n-type semiconductor. Thereby potential difference is produced which causes flow of electrons and hence current is generated.

The strike of blowing wind on the blades of the wind mill makes it rotating continuously. The rotational motion of the blade drives a number of machines like water pump, flour mills and electric generators.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Solar Energy
- ✓ Cell
- ✓ Battery
- ✓ Semiconductor

Photo galvanic Cell:

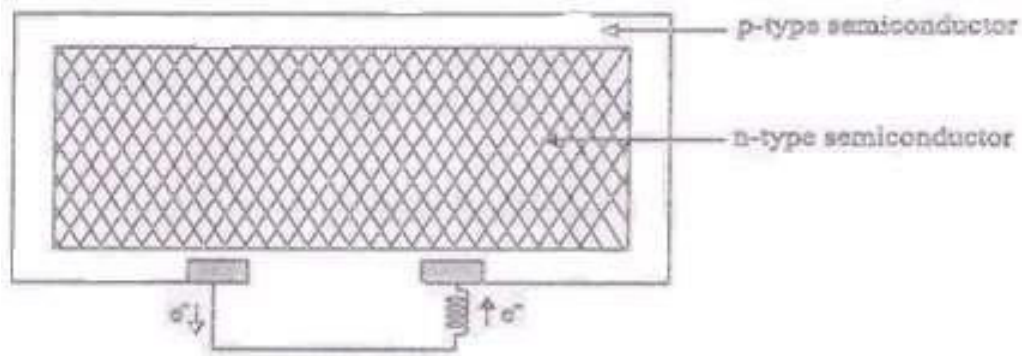
It is the one which converts the solar energy directly into electrical energy.

Principle:

The basic principle is based on the **photovoltaic effect**. When solar rays fall on a two layer of semiconductor devices, a potential difference between two layer is produced. This potential difference causes flow of electrons and produces electricity.

Construction:

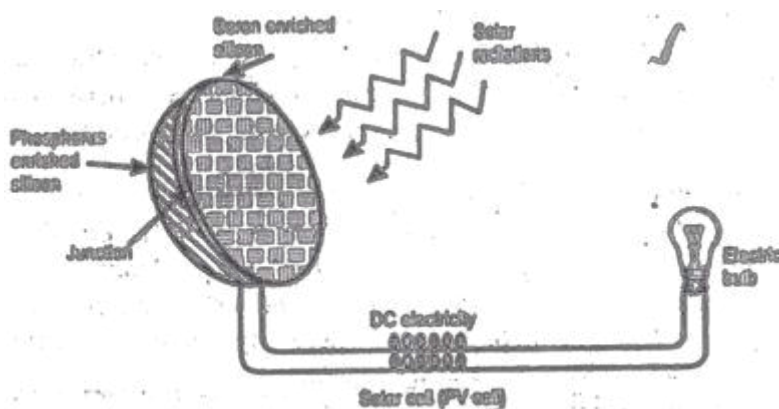
Solar cell consists of a p- type semiconductor (Si doped with B) and n-type semiconductor (Si doped with P). They are in close contact with each other.



Working:

When solar rays fall on p-type semiconductor, the electrons from the valence band get promoted to the conduction band and cross the p-n junction into n-type semiconductor. Thereby potential difference is produced which causes flow of electrons and hence current is generated.

Thus when this p and n layers are connected to an external circuit, electrons flow from n-layer to p-layer and hence current is generated



Applications of Solar Cells:

1. Lighting purpose.
2. Solar pumps can be run by solar battery.
3. Used in calculators, electronic watches, radios and TV.
4. Used to drive vehicles.
5. Used in space craft and satellites

Advantages:

Solar cells are nonpolluting and eco-friendly.

Wind Energy

- ✓ Energy recovered from the force of the wind is called wind energy.
- ✓ The wind energy is harnessed by making use of windmills.

Wind Mills:

The strike of blowing wind on the blades of the wind mill makes it rotating continuously. The rotational motion of the blade drives a number of machines like water pump, flour mills and

electric generators.

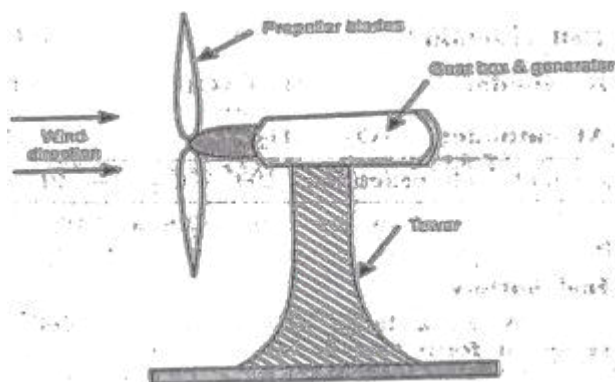
Nowadays windmill uses large sized propeller blades and connected to a generator through a shaft. Wind mills are capable of generating about 100kW electricity.

Wind Farms:

When a large number of wind mills are installed and joined together in a definite pattern it forms a wind farm. The wind farms produce a large amount of electricity.

Condition:

The minimum speed required for satisfactory working of a wind generator is 15Km/hr.



Advantages:

- (i) It does not cause any pollution.
- (ii) It is very cheap.
- (iii) It is renewable.

Disadvantages:

1. Public resists for locating the wind forms in populated areas due to noise generated by the machines.
2. Wind forms located on the migratory routes of birds will hazards.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=W_KNwGmuR2U

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. ElavarasanP.No-7.12 to 7.15

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LECTURE HANDOUTS

L 33

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture: Fuel cells – Hydrogen & Oxygen fuel cell

Introduction :

Fuel cell is an electrochemical or voltaic cell in which the chemical energy of the fuel is directly converted into electricity without combustion.

The essential process in a fuel is:



Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Fuel Cell
- ✓ Combustion
- ✓ Electrolyte
- ✓ Electrodes

Fuel Cell: It is a device in which the chemical energy of the fuel hydrogen is indirectly converted into electricity without combustion.

Anode	Hydrogen
Cathode	Oxygen (oxidizer)
Electrolyte	25% KOH or NaOH

Two porous electrodes – Made of compressed carbon containing a catalyst like pt / pd. It consists of two porous electrodes anode and cathode. In between two electrodes an electrolytic solution 25% KOH or NaOH filled.

When H₂ is bubbled through the anode compartment, where it is oxidized. The O₂ is bubbled at the cathode compartment where it is reduced.

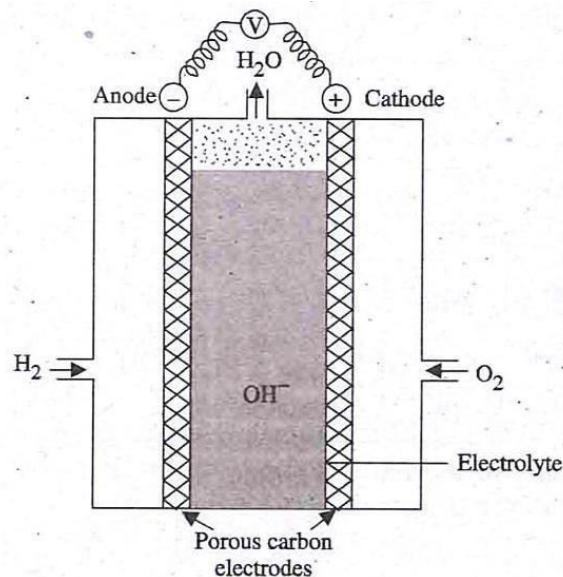


Fig. $\text{H}_2 - \text{O}_2$ Fuel cell

The emf of the cell = 0.8 to 1.0 V.

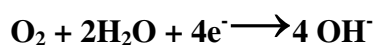
At anode

Hydrogen molecules are oxidized at the anode with the liberation of electrons which then combine with hydroxide ions to form water



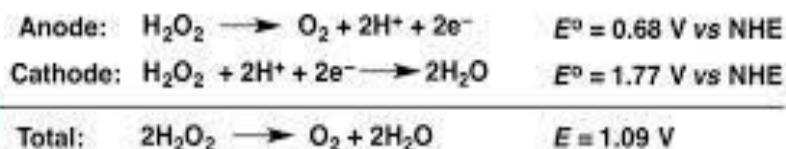
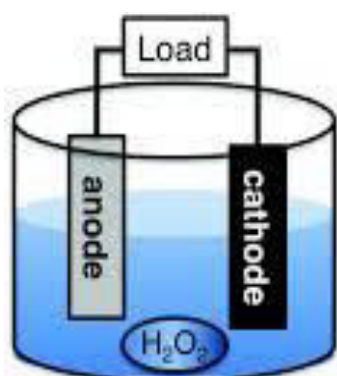
At Cathode

The electrons produced at the anode pass through the external wire to the cathode, where it is absorbed by oxygen and water to produce hydroxide ion :



Merits:

- i. High efficiency.
- ii. No unwanted noise and less maintenance
- iii. No Pollution
- iv. No need to change electrode often.



Uses:

- i. Used in military vehicles and space vehicles.
- ii. H₂ – O₂ fuel cell, the product is water, so no need of fuel because fuel is water

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=5_IDGna9MBM

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan P.No – 7.2 to 7.5

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LECTURE HANDOUTS

L 34

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture: Batteries – Alkaline and Lithium battery

Introduction :

A Battery is an arrangement of several electrochemical cells connected in series. It can be considered as store house for electrical energy on demand.

An electrochemical cell has only one anode and one cathode whereas a battery contains several anodes and cathodes.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Anode
- ✓ Cathode
- ✓ Electrolyte
- ✓ Battery

Types of Batteries

Secondary battery or secondary cells

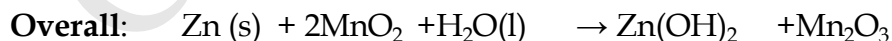
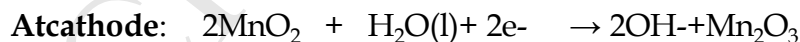
- ✓ In these cells, the electrode reactions can be reversed by passing an external energy.
- ✓ They can be recharged by passing electric current.
- ✓ They are called storage cells or accumulators.

Ex: Lead acid storage cell, Nickel- cadmium cell.

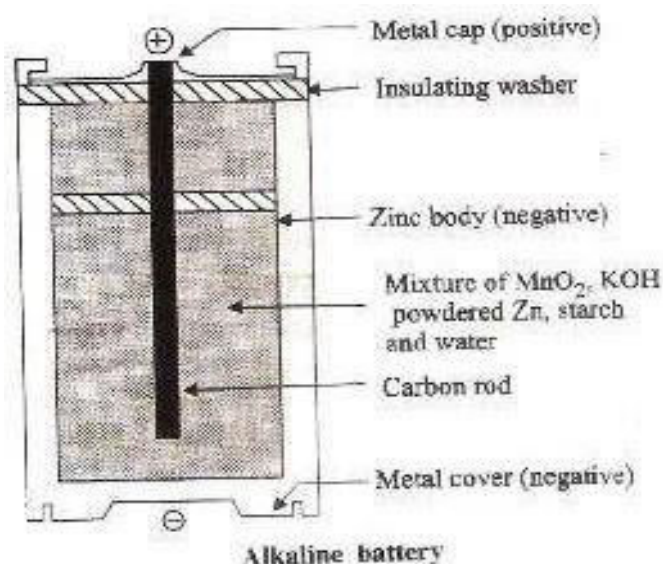
Alkaline Battery

Here the powdered zinc is mixed with KOH and MnO₂ to get a gel. A Carbon rod acts as cathode. It is immersed in KOH. The outside cylindrical body is made up of zinc.

Cell reactions



Uses: It is used in calculators, watches etc.,

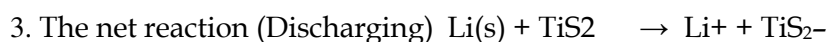


Lithium Battery

Description

- It consists of a lithium anode and a TiS₂ cathode.
- A solid electrolyte generally a polymer is packed in between the electrodes.
- The electrolyte permits the passage of ions but not electrons.

Cell reactions



2

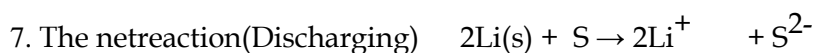
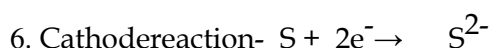
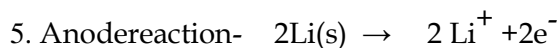
Lithium - Sulphur Battery

1. Anode - Lithium in molten state (Electron donor)

2. Cathode - Sulphur in molten state (Electron acceptor)

3. Electrolyte - Solid β alumina (NaAl₁₁O₁₇)

4. Cell representation- $\text{Li(s)} // \text{Solid } \beta \text{ alumina} // \text{S}$



8. Recharging: $2\text{Li}^+ + \text{S}^{2-} \rightarrow 2\text{Li(s)} + \text{S}$

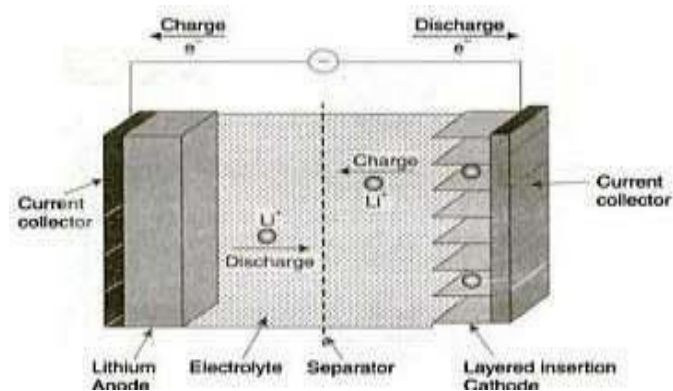
9. S^{2-} ions polymerized to give poly sulphide ions.



β - Alumina prevents direct contact between Li and S.

10. Capacity - 3.7V percell

11. Applications- It is used in power tools and electric vehicles.



Video Content / Details of website for further learning (if any):

<https://www.youtube.com/watch?v=PXNKkcB0pI4>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan P.No- 7.2 to 7.5

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LECTURE HANDOUTS

L 35

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture: Nickel – Cadmium and Lead acid battery

Introduction :

Batteries which can be recharged again by passing external electric current are called “secondary batteries” or reversible batteries.

Ex. Ni-Cd battery, lead-acid battery and lithium battery

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ To study about the basics of Battery
- ✓ Basic knowledge of Cadmium Battery
- ✓ Application of Battery
- ✓ Studied about the lead acid storage battery

1. Anode– Cadmium

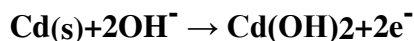
2. Cathode– A metal grid containing a paste of NiO_2 acting as acathode.

3. Electrolyte –KOH

4. Cell representation-



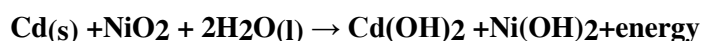
5. Anodereaction



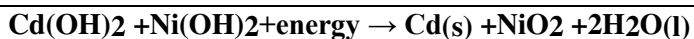
6. Cathodereaction



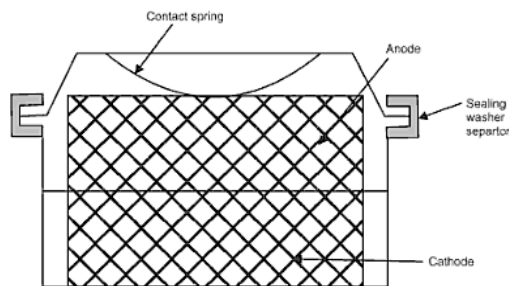
7. The net reaction (Discharging)is



8. Recharging:



Diagram



Advantages:

- It is lighter and smaller.
- It has longer life than lead storage cell.
- Like a dry cell, it can be packed in a sealed container.

Disadvantages:

It is more expensive than lead storage battery.

Uses:

It is used in calculators, Electronic flash units, transistors and cordless appliances.

LEAD ACID STORAGE BATTERY OR ACCUMULATOR

- It was invented by Gaston Plante in 1859.
- It acts both as voltaic cell and electrolytic cell. On supplying electrical energy, this acts as a voltaic cell. On recharging, the cell acts as an electrolytic cell.

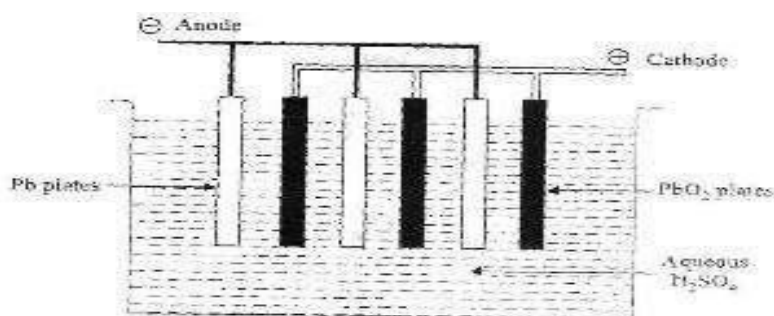


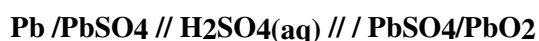
Fig. Lead storage cell

Description:

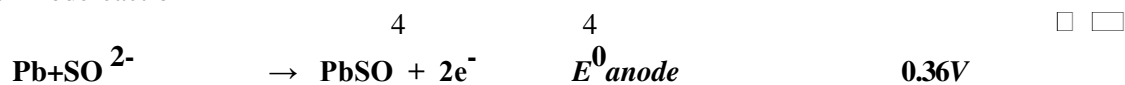
1. Anode –Lead
2. Cathode –PbO₂
3. Electrolyte - dil.H₂SO₄.

4. Insulator- rubber or glassfiber.

5. Cell representation-



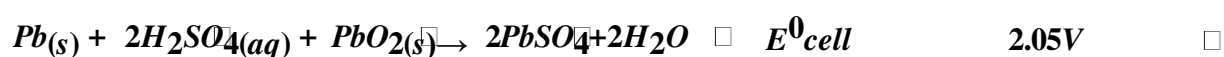
6. Anodereaction-



7. Cathode reaction –



8. The net reaction is



Uses:

1. It is used to supply current mainly in automobiles such as cars, Buses, trucks, etc
2. It is also used in gas engine ignition, telephone exchanges, hospitals, power stations

Video Content / Details of website for further learning (if any):

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

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan P.No T1 – 7.2 to 7.5

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LECTURE HANDOUTS

L 36

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : IV - Non Conventional Energy Storage Devices Date of Lecture:

Topic of Lecture:- Microbial Fuel Cell

Introduction :

A **microbial fuel cell (MFC)** is a device that converts chemical energy to electrical energy by the action of microorganisms. These electrochemical **cells** are constructed using either a bio anode and/or a bio cathode.

Prerequisite knowledge for Complete understanding and learning of Topic:

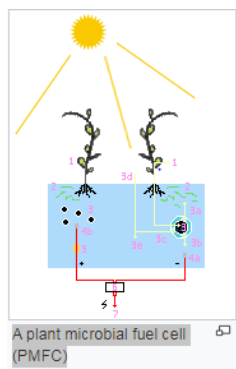
- ✓ Fuel Cell
- ✓ Anode
- ✓ Cathode
- ✓ Redox reaction

Microbial Fuel Cell (MFC)

A microbial fuel cell (MFC) is a device that converts chemical energy to electrical energy by the action of microorganisms. These electrochemical cells are constructed using either a bio anode and or a biocathode. Most MFCs contain a membrane to separate the compartments of the anode (where oxidation takes place) and the cathode (where reduction takes place). The electrons produced during oxidation are transferred directly to an electrode or, to a redox mediator species. The electron flux is moved to the cathode. The charge balance of the system is compensated by ionic movement inside the cell, usually across an ionic membrane.

Most MFCs use an organic electron donor that is oxidized to produce CO₂, protons, and electrons. Other electron donors have been reported, such as sulfur compounds or hydrogen. The cathode reaction uses a variety of electron acceptors that includes the reduction of oxygen as the most studied process. However, other electron acceptors have been studied, including metal recovery by reduction, water to hydrogen, nitrate reduction, and sulfate reduction.

Types Of MFCs



Mediator free- cell



Solid Based Cell

Applications

Power generation

MFCs are attractive for power generation applications that require only low power, but where replacing batteries may be impractical, such as wireless sensor networks. Wireless sensors, powered by microbial fuel cells can then for example be used for remote monitoring (conservation).

Bio-sensor

The current generated from a microbial fuel cell is directly proportional to the energy content of wastewater used as the fuel. MFCs can measure the solute concentration of wastewater (i.e., as a biosensor)

Waste Water Treatment

MFCs are used in water treatment to harvest energy utilizing anaerobic digestion. The process can also reduce pathogens. However, it requires temperatures upwards of 30 degrees C and requires an extra step in order to convert biogas to electricity. Spiral spacers may be used to increase electricity generation by creating a helical flow in the MFC. Scaling MFCs is a challenge because of the power output challenges of a larger surface area.

Video Content / Details of website for further learning (if any):

Can be added as link <https://www.youtube.com/watch?v=ZotwUJAb8R4>

Important Books/Journals for further learning including the page nos.:

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

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LECTURE HANDOUTS

L 37

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Refractories, Characteristics and its classification

Introduction :

Refractories are inorganic, nonmetallic, porous and heterogeneous materials composed of thermally stable mineral aggregates, a binder phase and additives. These materials have ability to retain its physical shape and chemical identity when subjected to high temperatures

Prerequisite knowledge for Complete understanding and learning of Topic:

The student should be expected to have primary knowledge about

- ✓ Acid , base, neutral
- ✓ corrosive action
- ✓ Hardness

Introduction of Refractories

Refractories are the materials that can withstand high temperature and load without softening, melting or deformation in its size and shape.

Refractories are chemically inert and hard materials used in the construction of lining of furnaces, kilns, crucibles etc. The main function of a refractories are to resist the loss of heat as well as to resist the abrasive and corrosive action of molten metal's, slag, flue gases etc. inside the furnaces at high temperatures without softening and deformation in its size and shape.

Characteristics of a refractory

A good refractory should possess the following characteristics.

- ✓ It should be infusible at the high temperature to which it is liable to be exposed.
- ✓ It should be chemically inert.
- ✓ It should withstand the load applied on it at the operating condition.
- ✓ It should expand and contract uniformly.
- ✓ It should resist the corrosive action of molten metal's, slag, flames etc.
- ✓ It should not crack at high temperature.

Classification of refractories

Refractories are classified into the following three main types on the basis of the chemical properties of their constituent substances.

i) Acid refractories:

They contain *acidic materials* and are not attacked by acidic materials. They are easily attacked by basic materials.

Examples:

Alumina, silica, fire clay refractories.

ii) Basic refractories:

These are *basic materials*. These are not attacked by basic materials. They are easily attacked by acidic materials.

Examples:

Magnesite, dolomite refractories.

iii) Neutral refractories:

They are made from weakly acidic/basic materials, but remain unaffected by acidic or basic environments.

Examples:

Graphite, Chromite, Zirconia and carborundum refractories.

Video Content / Details of website for further learning (if any):<https://www.youtube.com/watch?v=9gDSyEW-sww>,<https://www.youtube.com/watch?v=YH-00EOnfEE&v1=en>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.7 to 9.8

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LECTURE HANDOUTS

L38

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Properties of refractories

Introduction :

Properties of refractories include chemical composition, bulk density, apparent porosity, apparent specific gravity and strength at atmospheric temperatures. These properties are frequently among those which are used as 'control points' in the manufacturing and quality control process.

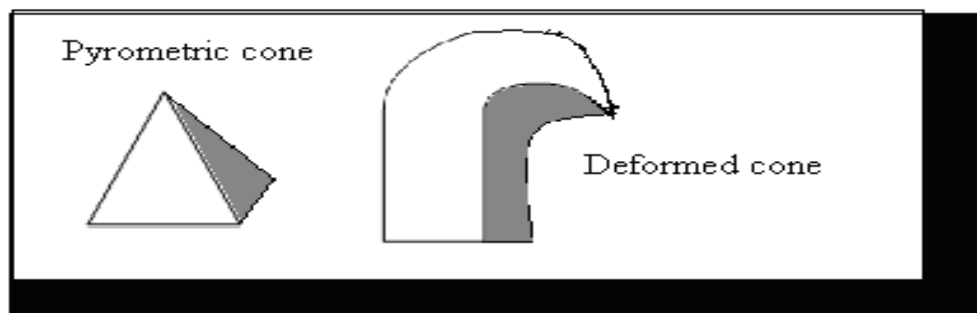
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Refractoriness
- ✓ Refractoriness under load
- ✓ Dimensional stability
- ✓ Porosity

Properties of refractories

1. Refractoriness

It is the property of a material by virtue of which it can withstand high temperatures without appreciable softening or deformation under working conditions.



Measurement of refractoriness

Measurement:

Refractoriness is determined in terms of pyrometric cone equivalent (PCE). In this method the softening behaviour of the cone to be tested is compared with a series of the seger cones of standard

dimensions. Pyrometric cones of same dimension (38mm height and 19mm sides) which are made of different mixtures of refractory materials that can soften at different temperatures are placed along the sample cone. The standard cones have particular number with known softening point. Sample cone along with standard cones are heated under standard conditions of 10° C per minute.

The pyrometric cone equivalent (PCE) value of the samples cone or test cone is taken as the number of the standard cone which softens along with the sample cone whose softening point is known. If the sample cones soften earlier than one standard cone but later than the next one, then the PCE value of the sample cone is taken as the average softening point values of the two standard cones. A good refractory should have high refractoriness.

Examples:

1. Silica bricks have PCE values ranging from 32–34 corresponding to softening temperature 1710–1750° C.
2. Magnesite bricks have PCE value 38 which corresponds to softening temperature 1850° C.

2. Refractoriness under load (R.U.L)

Refractories used in metallurgical operations and industries have to withstand varying loads. Hence refractories should have high mechanical strength under operating temperatures. The load bearing capacity of a refractory can be measured by means of R.U.L test.

R.U.L test

In R.U.L (Refractoriness under load) test a constant load (1.75 kg/cm or 3.5 kg/cm) is applied to the sample refractory specimen of rectangular shape (base 5 cm and height 75 cm) and heated at standard rate (approx

10⁰C/minute) in a furnace. The temperature at which atleast 10% of the specimen started get destroyed or deformed is taken as the R.U.L value. A good refractory should have high R.U.L value.

3. Dimensional stability:

The dimensional stability may be defined as the volume change of the refractory when subjected to high temperature. The shrinkage of a refractory can also be due to the transformation from one form to another form.

Types

1. Reversible dimensional changes

This may result due to the uniform expansion and contraction of a refractory material. So the dimensional changes of a refractory must be reversible.

2. Irreversible dimensional changes

This may result either in the contraction or expansion of a refractory.

Example - 1

Magnesite bricks shrink in service. Magnesite bricks (amorphous material) with specific gravity 3.05 are gradually converted to a more dense form of periclase (crystalline material) with specific gravity 3.54. Due to the increase in density of the material there will be shrinkage of the material.

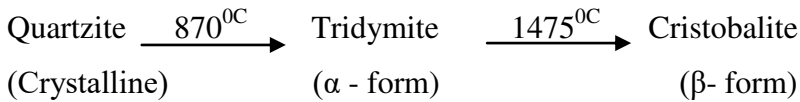
Magnesite -Periclase →

Amorphous
(Sp.gr = 3.05)

Crystalline
(Sp.gr = 3.54)

Example – 2

Silica bricks expand on heating due to the transformation of one form to another form. This is accompanied by a considerable increase in volume.



4. Porosity

All refractories contain pores. The pores may be open or closed. Porosity can be defined as the ratio of the pores volume to the bulk volume. It is calculated using the formula,

$$\text{Porosity (P)} = \frac{W - D}{W - A} \times 100$$

Where,

W = Weight of saturated specimen (with water) in air

D = Weight of dry specimen in air

A = Weight of saturated specimen (with water) in water

Advantages

1. High porosity lowers thermal conductivity due to the presence of more voids which acts as insulators and can be used for lining in furnaces, ovens, etc.

2. Lower porosity increases thermal conductivity owing to the absence of air voids and increases resistance to thermal spalling.

Disadvantages

1. Due to high porosity slags, gases etc. are likely to enter more easily to greater depth and also react with the refractory. Hence porosity reduces the strength, resistance to abrasion, resistance to corrosion etc.

5. Thermal Spalling

Thermal spalling is the property of breaking, cracking or peeling off a refractory material under high temperature. A good refractory must show a very good resistance to thermal spalling.

Causes

1. Rapid change in temperature

This causes uneven expansion and contraction within the mass of a refractory, thereby leading to development of uneven stresses and strains.

2. Slag penetration

This causes variation in the co-efficient of expansion.

3. Thermal spalling can be reduced by

- ✓ Using high porosity, low co-efficient of expansion and good thermal Conductivity refractory.

- ✓ Avoiding sudden temperature changes.
- ✓ 3. By modifying the furnace design

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=N_5ZT0hzx8o

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.8 to 9.12

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LECTURE HANDOUTS

L 39

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Manufacturing of Alumina, Magnesite

Introduction :

Alumina bricks are manufactured from *bauxite, ore of alumina*. The oxides of aluminium (alumina), silicon (silica) and magnesium (magnesia) are the most important materials used in the manufacturing of refractories.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Thermal expansion
- ✓ Porosity
- ✓ Thermal spelling
- ✓ Thermal shock

Detailed content of the Lecture:

1. ALUMINA BRICKS

Manufacture

Alumina bricks are manufactured from *bauxite, ore of alumina*. The bauxite ore is crushed to smaller size and then ground. The ground material is screened and purified. The pure raw bauxite material is then mixed with clay, a binding material normally used for the manufacture of alumina bricks. After mixing it is moulded by mechanical moulding process. After drying, the moulded bricks are fired at very high temperature.

Properties

They possess the following properties

1. High alumina bricks are acidic refractories. They are not attacked by acidic materials but attacked by basic materials.
2. Very low coefficient of thermal expansion.
3. High porosity.
4. Less prone to thermal spelling.
5. High temperature load bearing capacity (R.U.L is

1350⁰C).

6. Excellent wear resistance & resistance to slag.
7. Stability both in oxidizing and reducing conditioning.
8. Inertness to the action of gases like CO₂, H₂ and natural gas.

Uses

- In vertical shaft kilns for burning limes.
- In lining rotary kilns used for Portland cement manufacture.
- Used for lining of reverberatories for brass melting, alumina melting furnaces, etc.
- They are used for lining of blast furnaces, open hearths, ovens, crucible furnaces etc.
- They are used in foundaries, lime kilns, pottery kilns, glass furnaces, gas generators, boiler settings etc.

2.MAGNESITE BRICKS

Manufacture

These bricks are made from calcined magnesite (MgO) which is powdered to proper size, mixed with caustic magnesia, made into a paste with water and moulded into bricks. The bricks are then fired gradually upto 1500 C for about 8 hours in the kiln and cooled slowly.

Properties

1. Magnesite bricks are basic refractories. They are not attacked by basic materials, but are easily affected by acidic material.
2. Magnesite bricks can withstand very high temperature without softening or any deformation (up to 2000 C) without load.
3. It can withstand a load of 3.5 kg/cm² at a temperature of about 1500⁰C.
4. Thermal spalling and corrosion resistant capacity is also high.
5. Its refractoriness and dimensional stability are high.
6. The bricks have very little shrinking property.
7. It has a less tendency to react with neutral and basic slags.
8. The bricks are prone to thermal spalling and abrasive action of loads.

Uses

1. Magnesite bricks are largely used in steel industries in lining basic converters and open hearth furnaces.
2. They are also used in reverberatory furnaces, rotary kilns, refining furnaces for gold, silver, platinum etc.
- 1.

Video Content / Details of website for further learning (if any):

<https://www.youtube.com/watch?v=MFnijyVQT2E>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.13 to 9.16

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LECTURE HANDOUTS

L 40

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Manufacturing of Zirconia bricks

Introduction :

Alumina bricks are manufactured from *bauxite, ore of alumina*. The oxides of aluminium (alumina), silicon (silica) and magnesium (magnesia) are the most important materials used in the manufacturing of refractories

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Manufacture of Zirconia
- ✓ Properties of Zirconia
- ✓ Application of Zirconia

3. ZIRCONIA BRICKS

Manufacture

It is prepared by heating zirconium oxide (mineral of zirconia) in the form of colloidal zirconia and alumina as binding material at 1700⁰C. These types of bricks are stabilized by adding MgO or CaO.

Properties

1. They possess high resistance to acid slag.
2. Their resistance to thermal shock is high.
3. Their thermal expansion is low.
4. Their resistance to molten metal is high.
5. Their resistance to oxidizing atmosphere is low.
6. Their RUL is 1900 C under the load of 3.5 kg cm

7. They are very costly.

Uses

It is used in high frequency electric furnaces.

Video Content / Details of website for further learning (if any):
<https://www.youtube.com/watch?v=je8Jd9Vxt4g>

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.12

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LECTURE HANDOUTS

L 41

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Abrasives – Natural and Synthetic

Introduction :

Abrasives are used in a huge variety of applications throughout industry and in most manufacturing process, an **abrasive** will be employed at some point. ... The main uses remain grinding, cutting, sawing, honing, polishing, lapping, sanding, barrelling, drilling and blasting.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ **Hardness**
- ✓ **Toughness**
- ✓ **Abrasive power**

Detailed content of the Lecture:

ABRASIVES

Definition

Abrasives are hard substances, used for polishing, shaping, grinding operations. They are characterized by high melting point, high hardness and chemically inactive.

Properties of Abrasives

1. Hardness
2. Toughness
3. Abrasive power

1. Hardness

Hardness is one of the most important property of an abrasive. It is the ability of an abrasive to grind or scratch away other materials. The harder the abrasive, quicker will be its abrading action. Hardness of the abrasive is measured on Moh's scale or Vicker's scale.

Measurement of hardness using Moh's scale:

Moh's scale is a scale, in which natural or artificial abrasives (common) are arranged in the order of

increasing hardness.

The Moh's scale of hardness is given in the table I

Soft abrasives

Abrasives having their hardness 1 – 4 in Moh's scale are known as **soft abrasives**.

2. Toughness

It is the property of abrasives. Hard and brittleness of the abrasive is known as toughness. Abrasives are generally hard and brittle, which is otherwise known as toughness.

Table – Moh's scale

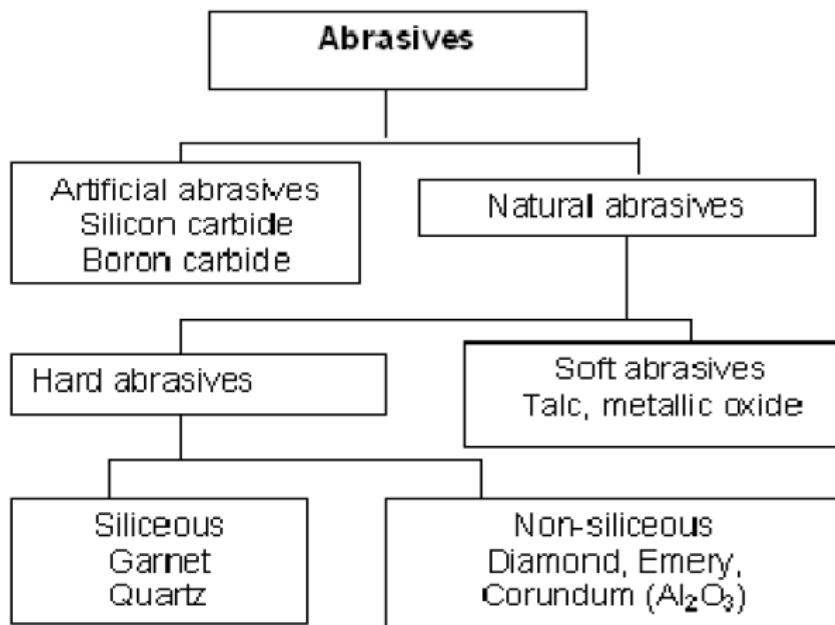
Name of the abrasives	Chemical formula	Moh's number
Talc	$3\text{MgO} \cdot 4\text{SiO}_2 \cdot \text{H}_2\text{O}$	1
Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	2
Calcite	CaCO_3	3
Fluorite	CaF_2	4
Apatite	$\text{CaF}_2 \cdot 3\text{Ca}_3(\text{PO}_4)_2$	5
Feldspar	$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$	6
Quartz	SiO_2	7
Topaz	$\text{AlF}_3 \cdot \text{SiO}_2$	8
Corundum	Al_2O_3	9
Diamond	C	10

3. Abrasive Power

It is also another important property of an abrasive. Abrasive power can be defined as the strength of an abrasive to grind away another material. It depends on hardness, toughness and refractoriness of abrasives.

Classification:

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



Important natural abrasives

1. Diamond

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

Uses

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

2. Corundum

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

Uses

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

3. Emery

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

Uses

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

Types of emery

Depending on the percentage of alumina, emery is classified into the following three types.

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

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=zu4MG_R8-KA

Important Books/Journals for further learning including the page nos.: -Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.2 ,9.5

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LECTURE HANDOUTS

L 43

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Manufacture, properties and use of Silicon carbide

Introduction :

Synthetic abrasives, on the other hand, are the product of considerable processing of raw materials or chemical precursors; they include silicon carbide, synthetic diamond, and alumina (a synthetic form of corundum).

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Basic knowledge about the abrasives
- ✓ Preparation of Silicon carbide
- ✓ Properties of abrasives
- ✓ Application of abrasives

Detailed content of the Lecture:

SYNTHETIC ABRASIVES

(a) Silicon carbide or carborundum (SiC)

Carborundum is the most important, hardest and synthetic abrasive. Its hardness on Moh's scale is 9.5.

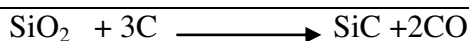
Manufacture

Silicon carbide is manufactured by heating sand (60%) and coke (40%) with some saw-dust and little salt in an electric furnace to about 1500⁰C

Saw-dust evolves gases during burning, which on circulation, increases the porosity of the charge.

Salt reacts with iron and other similar impurities, present in the raw materials, forming volatile chlorides. This also increases the porosity of the final product.

1500⁰C



The silicon carbide, removed from the furnace is then mixed with bonding agent (like clay, silicon nitride) and then shaped, dried and fired.

Properties

1. Silicon carbide possesses a high thermal conductivity, low thermal expansion and high resistance to abrasion and thermal spalling.
2. They are mechanically strong and withstand loads in furnaces upto 1650⁰C.
3. Heat conductivity of SiC is intermediate between metals and ceramic materials.
4. They are electrically intermediate between conductors and insulators.
5. The strength, density, abrasion-resistance, chemical resistance, softening temperature of the various bonded refractories will be in the following order.

Self – bonded product > silicon nitride bonded product > clay – bonded product.

Uses:

1. Silicon carbides are used as heating elements in furnaces in the form of rods and bars.
2. They are also used for partition wall of chamber kilns, coke ovens, muffle furnaces, and floors of heat-treatment furnaces.
3. SiC bonded with tar are excellent for making high conductivity crucibles.
4. It is used in cutting and grinding wheels.

(b) Alundum (Al₂O₃)

Next to carborundum, alundum is the most important synthetic abrasive. Its hardness on Mho's scale is 9.

Manufacture

It is prepared by heating a mixture of calcined bauxite, coke and iron in an electric furnace to about 4000⁰C. It is an artificial corundum. It is not as hard as carborundum but is less brittle and tougher. It is used in grinding of hard steels and other materials of high tensile-strength.

(c) Norbide or Boron carbide (B₄C)

It is prepared by heating a mixture of boron oxide (B₂O₃) and coke (carbon) in an electric furnace to about 2700⁰C.



Its hardness on Moh's scale is 9. It is used as hard materials for making grinding dies and for cutting and sharpening hard high-speed tools.

VideoContent/Detailsof website for furtherlearning(ifany);
<https://www.youtube.com/watch?v=j5ko-jBzWyo>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.3 to 9.4

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LECTURE HANDOUTS

L 43

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Manufacture, properties and use of Boron carbide

Introduction :

Synthetic abrasives, on the other hand, are the product of considerable processing of raw materials or chemical precursors; they include silicon carbide, synthetic diamond, and alumina (a synthetic form of corundum).

Prerequisite knowledge for Complete understanding and learning of Topic:

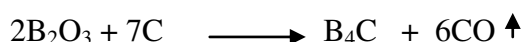
- ✓ Preparation of Boron carbide
- ✓ Properties of boron carbide
- ✓ Application of boron carbide

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.



Its hardness on Moh's scale is 9. It is used as hard materials for making grinding dies and for cutting and sharpening hard high-speed tools.

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

VideoContent/Detailsof website for furtherlearning(ifany);
<https://www.youtube.com/watch?v=j5ko-jBzWyo>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.3 to 9.4

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LECTURE HANDOUTS

L 44

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Applications of abrasives – paper, cloth & grinding wheels

Introduction :

Abrasives are used in a huge variety of applications throughout industry and in most manufacturing process, an abrasive will be employed at some point. The main uses remain grinding, cutting, sawing, honing, polishing, lapping, sanding, barrelling, drilling and blasting.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Application of Abrasives
- ✓ Manufacture of abrasive paper and cloth
- ✓ Manufacture of grinding wheel:

Applications of Abrasives:

Abrasives are used in three forms.

1. As loose powder

To clean the surface prior to coating abrasive powders are used.

Example:

Quartz and Garnet.

2. As abrasive paper or cloth

To prepare smooth wood, metal and plastic surfaces, abrasive paper or cloth is used.

Example:

Alumina and silicon carbide.

Manufacture of abrasive paper and cloth

The roll of paper or cloth is made to pass through a series of rollers, and a thin coating of glue is applied on its upper side. It is then passed under a hopper (fig. 5.2), from which the grit of abrasive is allowed to fall and spread evenly on the glued paper or cloth.

Then it is dried in warm drying room. Finally, it is allowed to age for few days, so that the glue sets firmly.

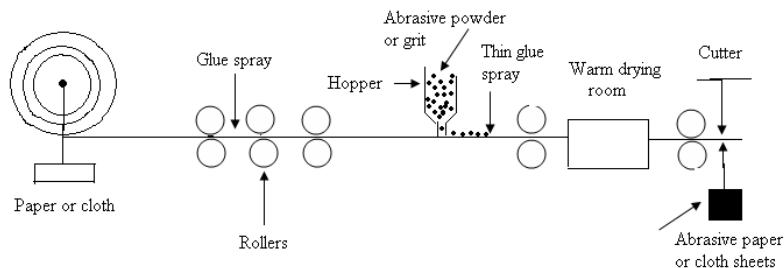


Fig :5.2 Manufacture of abrasives paper or cloth

3. As grinding wheels:

It is used for removal of scales from iron surfaces, cutting tool sharpening.

Manufacture of grinding wheel:

Grinding wheel is manufactured by using abrasive grains with binder. The mixture is moulded into desired shape, heated and cured. Generally, grinding wheels are manufactured by using artificial abrasive like silicon carbide and shellac resin, phenol formaldehyde resin, synthetic rubber materials etc.

Video Content / Details of website for further learning (if any);<https://www.youtube.com/watch?v=JX7YeQxk0j4>

Important Books/Journals for further learning including the page nos.: Engineering Chemistry by Dr.P.Santhi and S. Elavarasan, P.No.9.6 to 9.7

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LECTURE HANDOUTS

L 45

Chemistry

I/I

Course Name with Code : Engineering Chemistry / 21BSS11

Course Faculty :

Unit : V-Engineering Materials Date of Lecture:

Topic of Lecture: Glass manufacture, properties and uses

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.**

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ To be known about Composites of glass
- ✓ Study about the manufacture of glass
- ✓ Application of the glass

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

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

Raw material required for the manufacture of glass:

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

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

Manufacture of Glass:

Raw materials are:

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

Mixing:

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

Fusion:

The batch is then transferred to the tank or pot furnace. This batch is heated to 1400-1500o 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 bubbles. This is called fining.

Na_2CO_3 is often added to lower the viscosity of the molten glass. The impurities rise to the top as scum and it is removed. Cullet, oxidizing agents, reducing agents and other materials are also added to the molten glass according to the requirements.

Fabrication:

Coloring 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

- ✓ Cobalt oxides -Blue
- ✓ Cuprous salt -Red
- ✓ Chromium oxide -Green
- ✓ 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. 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 are lenses that 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 another plastic. Traditional photo chromic eyeglasses 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 gray or black

Windshield glass

A framed pane of usually curved glass 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 (polyvinyl 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 rocks, 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.

Video Content / Details of website for further learning (if

any);<https://www.youtube.com/watch?v=IkYimZBzguw>

Important Books/Journals for further learning including the page nos

Course Faculty

Verified by HOD