

Code: 23BS1204

**I B.Tech - II Semester – Regular / Supplementary Examinations  
MAY 2025**

**ENGINEERING CHEMISTRY  
(Common for CE, ME)**

Duration: 3 hours

Max. Marks: 70

- Note: 1. This question paper contains two Parts A and B.  
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.  
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.  
4. All parts of Question paper must be answered in one place.
- BL – Blooms Level CO – Course Outcome

**PART – A**

		BL	CO
1.a)	Identify various units of hardness and the relationship between them.	L2	CO1
1.b)	Predict which salts are responsible for temporary and permanent hardness of water?	L2	CO1
1.c)	Describe Pilling Bedworth ratio.	L2	CO1
1.d)	List the applications of lithium ion battery.	L1	CO1
1.e)	Define functionality of monomers.	L1	CO1
1.f)	Describe the significance of bio fuel.	L2	CO1
1.g)	Classify composites.	L2	CO1
1.h)	Describe how thermal conductivity of a refractory related to its porosity?	L2	CO1
1.i)	Define the term adsorption.	L1	CO1
1.j)	Identify the advantages of using neem leaf extract for the synthesis of gold nanoparticles.	L2	CO1

	b)	Discuss the characteristics of good lubricants and give their significance.	L3	CO3	5 M
<b>OR</b>					
9	a)	Explain flash and fire point of a lubricant.	L4	CO5	5 M
	b)	Describe the chemical composition of ordinary Portland cement and its functions.	L3	CO3	5 M
<b>UNIT-V</b>					
10	a)	Discuss the advantages and limitations of the Braggs method for synthesizing colloidal particles.	L3	CO3	5 M
	b)	Explain BET equation. Mention the application of the BET equation in the characterization of nanoporous materials.	L4	CO5	5 M
<b>OR</b>					
11	a)	How does the Freundlich isotherm differ from the Langmuir isotherm in terms of adsorption behavior?	L3	CO3	5 M
	b)	List out the steps involved in synthesis of nanoparticles by using sol-gel method.	L4	CO5	5 M

**PART – B**

			BL	CO	Max. Marks
<b>UNIT-I</b>					
2	a)	Illustrate the causes, consequences and preventive methods for caustic Embrittlement in boiler feed water.	L3	CO2	5 M
	b)	Explain the principle involved in Reverse osmosis. Discuss the desalination of Brackish water by Reverse Osmosis method.	L4	CO4	5 M
<b>OR</b>					
3	a)	Analyze and calculate the temporary, permanent and total hardness of water sample containing following impurities: $Mg(HCO_3)_2 = 16.8$ mg/L, $MgSO_4 = 24.0$ mg/L and $NaCl = 58.5$ mg/L	L4	CO4	5 M
	b)	Discuss about priming and foaming. Mention their prevention methods.	L3	CO2	5 M
<b>UNIT-II</b>					
4	a)	Define fuel cell. Analyze the working principle of hydrogen – oxygen fuel cell with reactions. Write the advantages of fuel cells.	L4	CO4	5 M
	b)	Discuss the factors affecting rate of corrosion by metal.	L3	CO2	5 M
<b>OR</b>					

5	a)	Analyze the following cell, $Ni/Ni^{+2}(0.01M)//Cu^{+2}(0.5M)/Cu$ The standard reduction potential of Ni and Cu are -0.25 & 0.34 V respectively. Write the electrode reactions and calculate the EMF of the cell at 298 K. $E^0 Ni^{+2} / Ni = -0.25$ V, $E^0 Cu^{+2} / Cu = 0.34$ V	L4	CO4	5 M
	b)	What is galvanic corrosion? Illustrate corrosion control methods.	L3	CO2	5 M
<b>UNIT-III</b>					
6	a)	Define octane number of gasoline. Discuss its significance and how is it measured? Why ethylene dibromide is added when TEL is used as an anti knock reagent?	L3	CO2	5 M
	b)	Explain proximate analysis of coal. How is it carried out?	L4	CO4	5 M
<b>OR</b>					
7	a)	Explain the significance of calorific value in fuel analysis.	L4	CO4	5 M
	b)	Discuss the mechanism of step growth polymerization of Bakelite.	L3	CO2	5 M
<b>UNIT-IV</b>					
8	a)	Distinguish the acidic, basic and neutral refractories with suitable examples.	L4	CO5	5 M

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## KEY AND SCHEME OF VALUATION

**PART-A**

- 1.a) Units of Hardness -2M
- 1.b) Temporary Hardness salts -1M , Permanent Hardness salts-1M
- 1.c) Pilling-Bedworth Ratio-2M
- 1.d) Any two applications of Li-ion Battery -2M
- 1.e) Functionality of monomer -2M
- 1.f) Significance of Bio-fuel-2M
- 1.g) Classification of Composites-2M
- 1.h) Thermal conductivity of refractory-2M
- 1.i) Adsorption def-2M
- 1.j) Two advantages of neem leaf extract for the synthesis of gold nanoparticles-2M

**PART-B****UNIT-I**

- 2.a) Caustic Embrittlement Causes-2M Consequences-1M Prevention methods-2M
- 2.b) Reverse Osmosis-Principle-1M Procedure-2M, Diagram-2M

OR

- 3a) Analyze and calculate the Temporary- 2M and permanent hardness-2M and total hardness of water -1M
- 3b) Priming and Foaming – 3M and Prevention methods-2M

**UNIT-II**

- 4a) Fuel cell- 1M , H<sub>2</sub>-O<sub>2</sub> Fuel cell diagram – 2M , Reactions -1M , advantages-1M
- 4b) Any four factors affecting rate of corrosion -5M

OR

- 5a) Electrode reactions- 2M Calculate the EMF of the cell – 3M
- 5b) Galvanic corrosion- 2M , Corrosion Control Methods-3M

**UNIT-III**

- 6a) Octane Number – 2M Significance and Measurement-2M anti knock reagent-1M
- 6b) Proximate analysis of coal-5M

OR

- 7a) Significance of calorific value in fuel analysis-5M
- 7b) Mechanism of step by growth polymerization with an example bakelite-5M

**UNIT-IV**

- 8a) Acidic refractories-2M Basic refractories -2M and Neutral refractories -1M
- 8b) Characteristics of good lubricants-4M and Significance-1M

OR

- 9a) Flash Point of lubricant-2.5M Fire Point of lubricant-2.5M
- 9b) Chemical Composition-3M functions-2M

**UNIT-V**

- 10a) Braggs method for synthesizing colloidal particles-3M , advantages -1M and Limitations-1M
- 10b) BET equation -2M Applications of BET equation-3M

OR

- 11a) Freundlich and Langmuir adsorption isotherm – 5M
- 11b) Steps involved in synthesis of nanoparticles by sol-gel method-5M

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KEY AND SCHEME OF VALUATION  
PART-A

1.a) Identify various Units of Hardness and the relationship between them.

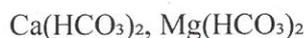
Ans: • ppm (parts per million) as  $\text{CaCO}_3$

- mg/L (milligrams per liter) as  $\text{CaCO}_3$
- $^\circ\text{Cl}$  (Clark's degree of hardness)
- $^\circ\text{Fr}$  (French degrees of hardness)

1ppm = 1mg/l = 0.07  $^\circ\text{Cl}$  = 0.10  $^\circ\text{Fr}$

1.b) Predict which salts are responsible for temporary and permanent hardness of water.

Ans: Temporary hardness is caused by bicarbonates of calcium and magnesium:



Permanent hardness is caused by chlorides and sulfates of calcium and magnesium:



1.c) Describe Pilling-Bedworth ratio.

Ans: The Pilling-Bedworth ratio relates the volume of oxide formed during metal oxidation to the volume of the metal consumed. It helps predict whether an oxide layer will be protective or non-protective. If the volume ratio is close to 1, the oxide layer is usually protective.

If the ratio = 1: **Protective oxide layer** forms.

If the ratio < 1: **Non-protective layer** .

1.d) List the applications of lithium ion battery.

Ans:

- Mobile phones and laptops
- Electric vehicles (EVs)
- Power backup systems
- Solar energy storage
- Digital cameras
- Medical devices

**1.e) Define functionality of monomer.**

The functionality of a monomer refers to the number of reactive sites or bonds in a monomer molecule that can participate in polymerization reactions, determining the type and structure of the resulting polymer.

**1.f) Describe the significance of bio fuel.**

1. Renewable and sustainable source of energy
2. Reduces greenhouse gas emissions
3. Decreases dependence on fossil fuels
4. Can be produced from agricultural waste and plants

**1.g) Classify composites?**

**Based on Reinforcement Type:**

Particle-Reinforced Composites: Composites where the matrix material is reinforced with small particles.

Fiber-Reinforced Composites: Composites where the reinforcement material is in the form of fibers. Fibers can be continuous or discontinuous.

**Based on Application:**

Structural Composites: Composites designed for load-bearing applications, offering high strength and stiffness.

Functional Composites: Composites designed for specialized functions like thermal insulation, electrical conductivity.

**1.h) Describe how thermal conductivity of a refractory related to its porosity?**

As porosity increases, thermal conductivity decreases. More pores mean more air gaps, which are poor conductors of heat. Therefore, high porosity = low thermal conductivity.

**1.i) Define the term adsorption.**

Adsorption is the process in which molecules from a gas or liquid accumulate on the surface of a solid or liquid. It is a surface phenomenon.

**1.j) Identify the advantages of using neem leaf extract for the synthesis of gold nanoparticles.**

1. Eco-friendly and green method
2. Acts as a natural reducing and stabilizing agent
3. Non-toxic and cost-effective
4. No need for harmful chemicals

**PART-II**  
**UNIT-I**

2.a) Illustrate the causes, consequences and preventive methods for caustic embrittlement in boiler feed water.

**CAUSTIC EMBRITTLEMENT**

The formation of brittle and in crystalline cracks in the boiler shell is called caustic embrittlement. The main reason for this is the presence of alkali-metal carbonates and bicarbonates in feed water. In lime-soda process, it is likely that, some residual  $\text{Na}_2\text{CO}_3$  is still present in the softened water. This  $\text{Na}_2\text{CO}_3$  decomposes to give  $\text{NaOH}$  and  $\text{CO}_2$ , due to which the boiler water becomes "Caustic Soda".



The  $\text{H}_2\text{O}$  evaporates, the concentration of  $\text{NaOH}$  increase progressively creating a concentration cell as given below thus dissolving the iron of the boiler as sodium ferrate ( $\text{Na}_2\text{FeO}_2$ ).

(-)Anode: 'Fe' at bents | Conc.NaOH || Dil.NaOH | 'Fe' at plane Surface: Cathode (+)

This causes embrittlement of boiler parts such as bends, joints, reverts etc, due to which the boiler gets fail. The iron at plane surfaces surrounded by dilute  $\text{NaOH}$  becomes cathodic while the iron at bends and joints surrounded by highly concentrated  $\text{NaOH}$  becomes anodic which consequently decayed or corroded.

**Caustic embrittlement can be prevented:**

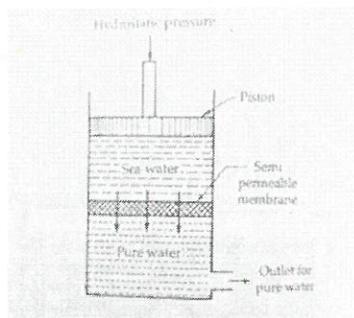
- a. By maintaining the pH value of water and neutralization of alkali.
- b. By using Sodium Phosphate as softening reagents, in the external treatment of boilers.
- c. Caustic embrittlement can also be prevented by adding Tannin or Lignin or Sodium sulphate which prevents the infiltration of caustic-soda solution blocking the hair-cracks.

2.b) Explain the principle involved in Reverse Osmosis. Discuss the desalination of Brackish water by Reverse osmosis method.

**Reverse Osmosis:**

**Principle:** Reverse osmosis is a water purification process where pressure forces water through a special membrane that blocks impurities and lets only clean water pass through.

Osmosis is the phenomenon, in which flow of solvent takes place from a region of low concentration to high concentration when two solutions of different concentrations are separated by a semi-permeable membrane.



**Reverse Osmosis**

If a hydrostatic pressure in excess of osmotic pressure is applied on concentrated side, the flow of solvent molecules forced to move from concentrated solution to dilute solution across the membrane. This is called reverse osmosis. This process is useful for removing salt from sea water. the process is known as super or hyper filtration. Semi permeable membrane based on thin films of cellulose acetate, poly acrylate and polyamide polymers are used.

**Advantages:**

1. Colloidal  $\text{SiO}_2$  can be removed by reverse osmosis.
2. It is simple and reliable process.
3. Cost is low.

The semi permeable membrane easily replaced within few minutes.

OR

3a) Analyze and calculate the temporary, permanent and total hardness of water sample containing following impurities:  $\text{Mg}(\text{HCO}_3)_2 = 16.8 \text{ mg/L}$ ,  $\text{MgSO}_4 = 24 \text{ mg/L}$  and  $\text{NaCl} = 58.5 \text{ mg/L}$ .

- $\text{Mg}(\text{HCO}_3)_2 = 16.8 \text{ mg/L}$  (contributes to temporary hardness)
- $\text{MgSO}_4 = 24 \text{ mg/L}$  (contributes to permanent hardness)
- $\text{NaCl} = 58.5 \text{ mg/L}$  (does not contribute to hardness)

#### Temporary Hardness:

Temporary hardness is caused by bicarbonates, particularly  $\text{Ca}(\text{HCO}_3)_2$  and  $\text{Mg}(\text{HCO}_3)_2$ . For  $\text{Mg}(\text{HCO}_3)_2$ , the hardness can be calculated using the equivalent weight of magnesium and the molecular weight of magnesium bicarbonate.

Formula for hardness contribution from  $\text{Mg}(\text{HCO}_3)_2$ :

The hardness contributed by  $\text{Mg}^{2+}$  is calculated as:

$$\text{Hardness (mg/L as CaCO}_3) = \frac{\text{mg/L of Mg}(\text{HCO}_3)_2 \times \text{Equivalent weight of CaCO}_3}{\text{Molecular weight of Mg}(\text{HCO}_3)_2}$$

- Molecular weight of  $\text{Mg}(\text{HCO}_3)_2 = 146.8 \text{ g/mol}$
- Equivalent weight of  $\text{CaCO}_3 = 50 \text{ g/mol}$  (used as a reference to express hardness)

Now, calculate the hardness for  $\text{Mg}(\text{HCO}_3)_2$ :

$$\text{Hardness (mg/L as CaCO}_3) = \frac{16.8 \text{ mg/L} \times 50}{146.8} = 5.72 \text{ mg/L as CaCO}_3$$

So, the temporary hardness contributed by  $\text{Mg}(\text{HCO}_3)_2$  is  $5.72 \text{ mg/L as CaCO}_3$ .

#### Permanent Hardness:

Permanent hardness is caused by salts like  $\text{MgSO}_4$ , which dissociate into ions that do not contribute to the formation of scale (not removed by boiling).

For  $\text{MgSO}_4$ , we calculate the hardness contributed by the  $\text{Mg}^{2+}$  ions.

Formula for hardness contribution from  $\text{MgSO}_4$ :

The hardness contributed by  $\text{Mg}^{2+}$  can be calculated similarly:

$$\text{Hardness (mg/L as CaCO}_3) = \frac{\text{mg/L of MgSO}_4 \times \text{Equivalent weight of CaCO}_3}{\text{Molecular weight of MgSO}_4}$$

- Molecular weight of  $\text{MgSO}_4 = 120.4 \text{ g/mol}$
- Equivalent weight of  $\text{CaCO}_3 = 50 \text{ g/mol}$

$$\text{Hardness (mg/L as CaCO}_3) = \frac{24 \text{ mg/L} \times 50}{120.4} = 9.99 \text{ mg/L as CaCO}_3$$

So, the permanent hardness contributed by  $\text{MgSO}_4$  is  $9.99 \text{ mg/L as CaCO}_3$ .

#### Total Hardness:

Total hardness is the sum of temporary and permanent hardness. Therefore:

$$\text{Total Hardness (mg/L as CaCO}_3) = \text{Temporary Hardness} + \text{Permanent Hardness}$$

$$\text{Total Hardness (mg/L as CaCO}_3) = 5.72 \text{ mg/L} + 9.99 \text{ mg/L} = 15.71 \text{ mg/L}$$

**3b) Discuss about priming and foaming. Mention their prevention methods.**

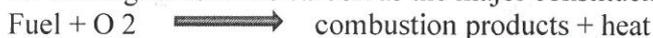
- **Priming:**
- Definition: Priming occurs when water droplets are carried over with steam from the boiler, contaminating the steam supply.
- Cause: High water levels in the boiler, excessive foaming, or improper boiler operation.
- Disadvantages:
  - Reduced steam quality
  - Water hammer
  - Equipment damage.
- **Prevention:**
  - Proper water level control: Ensuring that the boiler water level is maintained within the specified range to prevent carryover of water with steam.
  - Foaming control: Implementing effective chemical treatments and surface-active agents to minimize foaming in the boiler.
  - Steam separation: Installing steam separators or demisters to remove water droplets from the steam before it enters the steam distribution system.
- **Foaming:**
- Definition: Foaming is the formation of stable foam in the boiler, caused by the entrainment of air or gases in the water.
- Cause: High levels of dissolved or suspended solids in the water, chemical contamination, or improper boiler operation.
- Disadvantages: Reduced steam, quality Water Boiler instability.
- **Prevention:**
- Proper water treatment: Maintaining appropriate levels of dissolved solids and alkalinity in the boiler water to minimize foaming tendencies.
- Regular blow down: Removing suspended solids and impurities through scheduled blowdown operations to prevent foam formation.

Steam boiler design: Ensuring proper steam drum internals, such as baffles and steam separators, to promote efficient steam-water separation and minimize foaming.

## UNIT-II

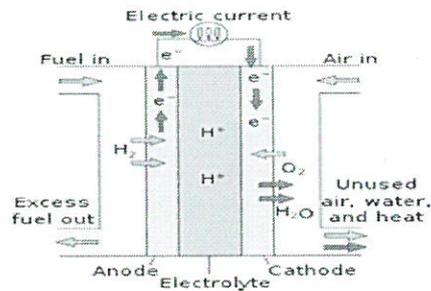
**4.a) Define fuel cell. Analyze the working principle of Hydrogen-Oxygen fuel cell with reactions. Write the advantages of fuel cells.**

Fuel is a combustible substance containing carbon as major constituent, which gives out heat energy on burning. It contains carbon as the major constituent.



**Construction and working of H<sub>2</sub>-O<sub>2</sub> fuel cell**

1. It has two electrodes where the reactions take place and an electrolyte i.e., molten KOH which carries the charged particles from one electrode to the other.
2.  $E^{\circ}_{\text{cell}}$  is positive, the cell reaction is spontaneous. The fuel cell produces power through redox reaction between hydrogen and oxygen.
3. At anode the hydrogen is oxidized through reaction with producing water and releasing two electrons.
4. The electrons flow through external circuit and returns to the cathode, reducing oxygen which consequently reacts with water to produce .
5. The fuel cell electrodes contain catalysts to speed up electrode reactions and the process is known electro catalysis. In the a mixture of Ni and NiO embedded in porous carbon electrodes which serves electro catalysts in the cell.

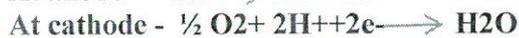


### Hydrogen- Oxygen fuel cell

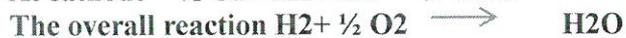
The corresponding reactions at anode cathode are;



$E_0 = 0\text{V}$



$E_0 = 1.2291 \text{ V}$



$E_0 = 1.2291 \text{ V}$

### 4b) Discuss the factors affecting rate of corrosion by metal.

Factors influencing rate of corrosion: The rate and extent to which a metal undergoes corrosion depend upon

1. The nature of the metal
2. The environmental factors.

#### 1. Nature of the metal

i) **Position of the metal in galvanic series:** The metal which occupies the higher position in galvanic series is more anodic and hence undergoes corrosion more easily than the metal which occupies lower position in the series. Hence when two metals make a cell, the metal higher in galvanic series suffers corrosion and other metal which is lower in galvanic series behaves as cathode. Further, greater the difference in electrode potentials of the two metals in the galvanic couple, the more will be the extent of corrosion of the anode.

ii) **Purity of metals:** Impure metals are more prone to corrosion than pure ones because in impure metals heterogeneity forms electro chemical cells where anodic parts get corroded.

iii) **Ratio of anodic area to Cathodic area:** The rate of corrosion increases with the decrease in the ratio of anodic area to cathodic area. The smaller the ratio the larger is the cathodic area and higher is its demand for electrons which can be met only by the rapid oxidation (corrosion) of the small anodic area. For example the small steel rivets in copper sheets are completely corroded because of their smaller size in contact with large cathodic area.

iv) **Nature of the metal oxide film:** Formation of stable protective oxide film reduces the corrosion rate of the metal where as the formation of volatile non porous and non protective oxide films prolong corrosion

v) **Physical state of the metal:** The rate of corrosion is also influenced by the physical state of the metal. Smaller the grain size of the metal, greater will be the extent of corrosion.

#### 2. Environmental factors

i) **Temperature:** Just as temperature increases the rate of reaction, it also increases the rate of corrosion.

ii) **Humidity of air:** Corrosion increases with the increase in humidity of air. This is due to the fact that moisture acts as a solvent for oxygen and other gases of the air and also salts to form an electrolyte necessary to set up a corrosion cell.

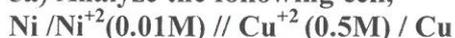
iii) **Presence of impurities in atmosphere:** Presence of impurities like  $\text{H}_2\text{S}$ ,  $\text{SO}_2$  and electrolytes like  $\text{NaCl}$  and  $(\text{NH}_4)_2\text{SO}_4$  caused by pollution increases corrosion.

iii) **Effect of pH:** In general acidic media are more corrosive than alkaline or neutral media. Thus low pH accelerates corrosion by supplying plenty of hydrogen ions.

iv) **Conductance of corroding medium:** It plays an important role in corrosion. For example dry sandy soils have lower conductance than clay and mineralised soils. Hence metallic parts submerged in clay and mineral soils undergo corrosion faster than those in dry and sandy soils.

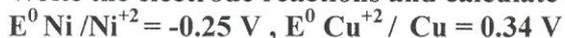
OR

5a) Analyze the following cell,



The standard reduction potential of Ni and Cu are -0.25 & 0.34 V respectively.

Write the electrode reactions and calculate the EMF of the cell at 298K.



The given electrochemical cell is:



Standard electrode potentials are:

- $E^{\circ}_{\text{Ni}^{2+}/\text{Ni}} = -0.25 \text{ V}$
- $E^{\circ}_{\text{Cu}^{2+}/\text{Cu}} = +0.34 \text{ V}$

Since  $\text{Cu}^{2+}/\text{Cu}$  has the higher reduction potential, Cu acts as the cathode, and Ni acts as the anode.

Electrode reactions:

- Anode (oxidation):  $\text{Ni} \rightarrow \text{Ni}^{2+} + 2e^{-}$
- Cathode (reduction):  $\text{Cu}^{2+} + 2e^{-} \rightarrow \text{Cu}$

The standard EMF of the cell is:

$$E^{\circ}_{\text{cell}} = E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}} = 0.34 - (-0.25) = 0.59 \text{ V}$$

To calculate the EMF under non-standard conditions, use the Nernst equation:

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{0.0591}{n} \log \left( \frac{[\text{Ni}^{2+}]}{[\text{Cu}^{2+}]} \right)$$

- $n = 2$  (number of electrons transferred)
- $[\text{Ni}^{2+}] = 0.01 \text{ M}$
- $[\text{Cu}^{2+}] = 0.5 \text{ M}$

$$E_{\text{cell}} = 0.59 - \frac{0.0591}{2} \log \left( \frac{0.01}{0.5} \right)$$

$$E_{\text{cell}} = 0.59 - 0.02955 \log(0.02)$$

$$\log(0.02) = \log(2 \times 10^{-2}) = \log 2 + \log 10^{-2} = 0.3010 - 2 = -1.6990$$

$$E_{\text{cell}} = 0.59 - (0.02955 \times -1.699) = 0.59 + 0.0502 = \boxed{0.640 \text{ V}}$$

**5b) What is galvanic corrosion? Illustrate corrosion control methods.**

Ans : Galvanic corrosion is an electrochemical process that occurs when two dissimilar metals are in electrical contact in the presence of an electrolyte (like water). One metal (more active or less noble) acts as the anode and corrodes, while the other (more noble) acts as the cathode and is protected.

Example:

When zinc and copper are connected in a saltwater environment, zinc (anode) corrodes while copper (cathode) remains protected.

**Corrosion control:** Though corrosion is an inevitable process, it can be minimized to some extent by adopting certain methods. Some of them are

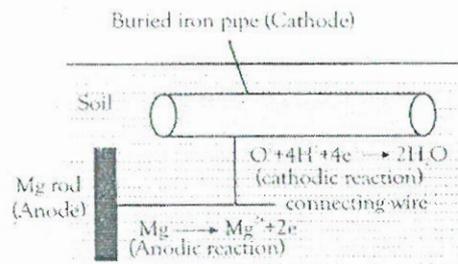
1. Proper selection and designing of materials
2. Cathodic protection
3. Use of corrosive inhibitors
4. Application of protective coatings

**1. Proper selection and designing of materials**

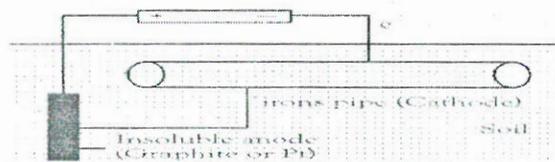
- Use metals that are similar in galvanic series to minimize potential difference.
- Choose corrosion-resistant materials (e.g., stainless steel, alloys).

**2. Cathodic protection:** In this method the metal to be protected is preferentially chosen as cathode and hence protected from undergoing corrosion. This can be achieved in two ways.

**a) Sacrificial anodic protection:** In this method the metal to be protected is selectively made as cathode by connecting it with a wire to a more anodic or reactive metal. Therefore the reactive metal undergoes corrosion and the selected metal is protected. The more active metal used as anode is known as sacrificial anode and it needs to be replaced from time to time. Some of the metals used as sacrificial anodes are zinc and magnesium



**b) Impressed current cathodic protection:** In this method the metallic object to be protected is made cathode by connecting it to the negative terminal of DC source. Where as its positive terminal is connected to an insoluble anode like graphite or platinum. Now electrons flow to the metallic object hence it acts as a cathode and is protected from corrosion.



However there are certain problems and limitations in applying cathodic protection method.

- The cathodic protection may increase the corrosion of an adjacent pipe line because of stray current (portion of the current that flows over a path other than the intended path and may cause electrochemical corrosion of metals in contact with electrolytes)
- Chemical reactions taking place on the surface of the protective structure may cause certain problems. For example if hydrogen is produced due to cathodic reactions, it may cause blistering on the surface of the cathode metal.

Though the metal is protected by the above methods underground structures may be effected by microbiological corrosion.

**3. Use of corrosive inhibitors:** Corrosive inhibitors are chemical substances which reduce the rate of corrosion when added in small quantities to a corrosive environment. They are of two types namely

A) Anodic inhibitors

B) Cathodic inhibitors.

A) **Anodic inhibitors:** These substances when added in small amounts form an insoluble and protective film on the surface of the anode and protect the anode.

Examples: Molybdates, chromates and phosphates of alkali and transition metals.

B) **Cathodic inhibitors:** These are substances when added in small amounts get adsorbed on to the cathodic surface and prevent the corrosion of the anode.

Organic inhibitors like amines, substituted urea, mercaptain etc get adsorbed on the surface of the cathode and restrict the diffusion of  $H^+$  ions to cathode.

As a result the cathodic reaction  $2H^+ + 2e^- \rightarrow H_2$  slows down, thus prevents the corrosion.

Cathodic reactions in neutral medium can be suppressed by removing  $O_2$  from the medium by addition of sodium sulphite.

**4. Application of protective coatings:** Corrosion can be prevented by coating the surface of a metal with a continuous, nonporous, and chemically inert material. The coating on the surface of the metal acts as a barrier and protects the metal from undergoing corrosion. Protective coatings are of two types. They are

**I. Metallic coating:** In metallic coatings the base metal to be protected from corrosion is coated with another metal which is anodic or cathodic in comparison with the base metal. The metallic coatings often used are Zn, Sn, Ni, Cu, Cr, Al, Pb etc. Metallic coatings are imparted by the following methods

A) **Anodic coating (sacrificial coating):** This method consists of coating a metal which is more anodic than the base metal. The coating provides complete protection to the underlying base metal as long as it is intact. However formation of cracks or pores on the protective layer sets up galvanic corrosion leading to complete destruction of base metal.

Example: Coating of zinc on iron. It is also known as galvanizing.

B) **Cathodic coating (noble coating):** This method consists of coating a metal which is cathodic in comparison with the base metal. This provides absolute protection to the underlying base metal irrespective of whether it is intact or not.

Example: Coating of tin on iron. It is also known as tinning.

### UNIT-III

6a) Define octane number of gasoline. Discuss its significance and how is it measured? Why ethylene di bromide is added when TEL is used as an anti-knock reagent?

Octane number is a measure of a fuel's **resistance to knocking** in a spark-ignition engine. It is based on a scale where:

- **Iso-octane** = 100 (no knocking)
- **n-Heptane** = 0 (knocks easily)

**Significance:**

- Higher octane number = better engine performance
- Prevents knocking and engine damage
- Allows use of higher compression ratios, improving efficiency

**Measurement:**

- Compared to standard mixtures of iso-octane and n-heptane in a test engine
- Two methods: RON (light load), MON (heavy load)

**Ethylene Di bromide is Added with TEL:**

- TEL increases octane number but leaves lead deposits
- Ethylene di bromide converts lead into volatile  $PbBr_2$

This is expelled with exhaust, voiding deposit build-up, Reducing lead residue in engine parts.

6b) Explain Proximate analysis of coal. How is it carried out?

(1) **Proximate Analysis:** It involves determination of moisture, volatile matter, ash content and fixed carbon in the coal sample. This analysis provides valuable information related to quality of coal.

(a) **Moisture content:** About 1 g of finely powdered air-dried coal sample is weighed in a crucible. The crucible is placed inside an electric hot air-oven maintained at 105-110 °C for about 1 hour. Then it is taken out, cooled in a desiccator and weighed. Loss in weight is reported as moisture on percentage scale. Moisture in coal evaporates during burning of coal and it takes some of the liberated heat in the form of latent heat of evaporation. Therefore, moisture lowers the effective calorific value of coal. Further, it quenches the fire in the furnace. Hence, lesser the moisture content, better the quality of coal as a fuel.

$$\text{Moisture (\%)} = \frac{\text{Loss in weight}}{\text{Weight of coal taken}} \times 100$$

(b) **Volatile matter:** The dried sample of coal left in the crucible after determination of moisture content is then covered with a lid and placed in an electric furnace (muffle furnace) maintained at  $925 \pm 20$  °C for about 7 minutes. Then it is taken out, cooled first in air, then in a desiccator and weighed. Loss in weight is reported as volatile matter on percentage scale. A high volatile matter content in a coal means that a high proportion of fuel will distill over as vapour, a large portion of which escapes unburnt. A coal sample may contain volatile matter as high as 50%, which includes combustible gases like methane, hydrogen, carbon monoxide, other Hydrocarbons as well as non-combustible gases like carbon dioxide, nitrogen, etc. Higher volatile content coal is undesirable. Lesser the

volatile matter, better the rank of the coal.

$$\text{Volatile matter (\%)} = \frac{\text{Loss in weight due to removal of volatile matter}}{\text{Weight of coal taken}} \times 100$$

**(c) Ash content:** The residual sample left in the crucible after determination of moisture content and volatile matter is heated without lid in a muffle furnace at  $700 \pm 50$  °C for half-an-hour. The crucible is then taken out, cooled first in air, then in desiccator and weighed. The process of heating, cooling and weighing is repeated till a constant weight is obtained. The residue is reported as ash content on percentage scale. Ash is a useless, non-combustible matter, which reduces the calorific value of a coal. Also, it causes the hindrance to the flow of air and heat. It often causes obstruction to the air supply required for combustion leading to irregular burning of coal. Hence, lower the ash content, better the quality of coal.

$$\text{Ash (\%)} = \frac{\text{Weight of ash left}}{\text{Weight of coal taken}} \times 100$$

**(d) Fixed carbon:** Percentage of fixed carbon is calculated using the following expression. Fixed carbon represents the quantity of carbon available for combustion. Higher the percentage of fixed carbon, greater is its calorific value and better the quality of coal. The information of percentage of fixed carbon in a coal helps in designing the furnace and fire-box, because it is the fixed carbon that burns in the solid state.

$$\text{Fixed carbon (\%)} = 100 - \% \text{ of (moisture + volatile matter + ash)}$$

OR

#### 7a) Explain the significance of calorific value in fuel analysis

Calorific value is the amount of heat energy produced by the complete combustion of a unit quantity of fuel.

#### Significance:

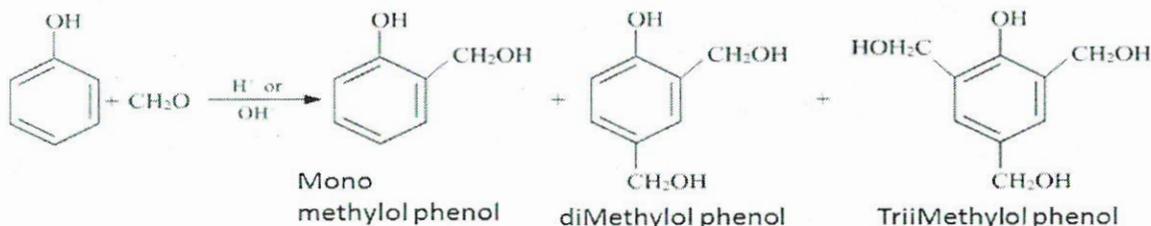
- Indicates fuel efficiency – higher value means more energy.
- Helps compare fuels (e.g., coal vs. diesel).
- Used in selecting fuels for engines, industries, power plants.
- Important for cost analysis and energy planning.
- Essential for designing combustion systems like boilers and furnaces.

7b) Discuss the mechanism of step growth polymerization of Bakelite

**STEP GROWTH POLYMERIZATION MECHANISM**

**Step-1**

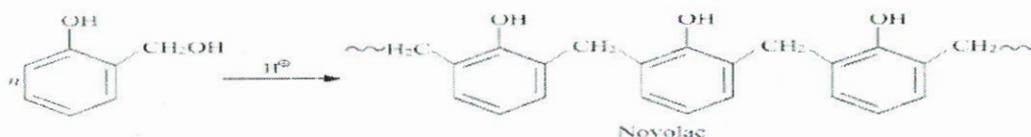
The first step is reaction between phenol and formaldehyde to form mono, di and tri-methylol phenols.



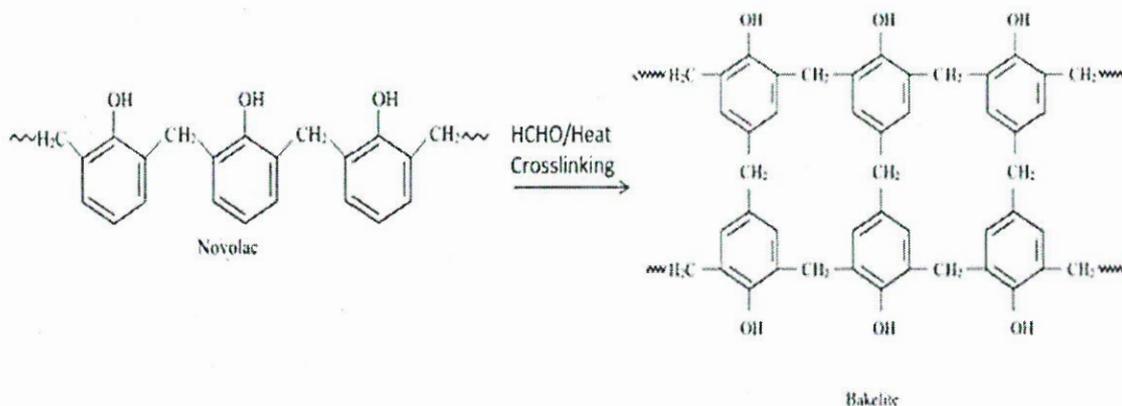
**Step-II**

When methylol phenols are heated with excess of phenol in presence of acid catalyst, the methylol phenols condense with phenol through methylene linkages to **form linear product novolac** with the elimination of water molecule.

**Step-III**



Further heating novolac and phenol in the presence of a catalyst (hexamethylenetetramine) leads to formation of hard, rigid, infusible cross linked polymer called Bakelite.



**UNIT-IV**

**8a) Distinguish the acidic, basic and neutral refractories with suitable examples.**

- **Acidic Refractories:** These refractories are resistant to acidic slag and are stable in acidic environments. Examples include silica (SiO<sub>2</sub>) refractories.
- **Basic Refractories:** These refractories are resistant to basic slag and are stable in basic environments. Examples include magnesia (MgO) and dolomite (CaO·MgO) refractories.
- **Neutral Refractories:** These refractories are resistant to both acidic and basic slags. Examples include alumina (Al<sub>2</sub>O<sub>3</sub>) and chromite (FeCr<sub>2</sub>O<sub>4</sub>) refractories.

**8b) Discuss the characteristics of good lubricants and give their significance.**

- **Characteristics of good lubricants :**
- Good lubricants have stable viscosity over temperatures.
- Lubricants resist breaking down when hot.
- Lubricants prevent oxidation and sludge buildup.
- Lubricants remain fluid in cold conditions.
- Lubricants have high flash points to avoid fire risk.
- Lubricants protect against rust and corrosion.
- Lubricants form a strong film to reduce friction.
- Lubricants keep machinery clean by suspending dirt.

**Significance:**

Lubricants protect machines, reduce wear, and improve efficiency.

**OR**

**9a) Explain flash and fire point of a lubricant.**

**○ Flash Point:**

- **Definition:** Flash Point is the lowest temperature at which the oil vaporizes to form a flammable mixture.
- **Applications:** Indicates the oil's safety during storage, handling, and operation. Oils with higher flash points are preferred in applications where fire hazards are a concern, such as in industrial machinery and power generation equipment.

**○ Fire Point:**

- **Definition:** Fire Point is the temperature at which the oil vapor sustains combustion.
- **Applications:** Indicates the oil's resistance to sustained burning. Oils with higher fire points are used in applications where exposure to high temperatures and fire hazards is common, such as in metallurgical processes and high-temperature industrial applications.

**9b) Describe the chemical composition of ordinary Portland cement and its functions**

Chemical Composition of Ordinary Portland Cement and Their Functions:

1. **Lime (CaO) – 61-67%**
  - Provides strength by forming compounds with silica and alumina.
2. **Silica (SiO<sub>2</sub>) – 19-23%**
  - Reacts with lime to form calcium silicates, which give strength.
3. **Alumina (Al<sub>2</sub>O<sub>3</sub>) – 2.5-6%**
  - Helps in setting and hardening by forming calcium aluminates.
4. **Iron Oxide (Fe<sub>2</sub>O<sub>3</sub>) – 0-6%**
  - Adds strength and imparts color to cement.
5. **Calcium Sulfate (CaSO<sub>4</sub>) Gypsum – 1.5-4.5%**
  - Controls the setting time by regulating the hydration of tri calcium aluminate.
6. **Magnesium Oxide (MgO) – up to 5%**
  - Small amounts can contribute to strength. Hardness and colour of the cement

## UNIT-V

### 10a) Discuss the advantages and limitations of the Braggs method for synthesizing colloidal particles.

The synthesis of colloids can be achieved through various methods, one of which is the Braggs method. The Braggs method involves the use of X-ray diffraction to produce colloidal particles. Here's a brief overview of the process:

1. **Preparation of Sol:** A sol is a colloidal suspension of solid particles in a liquid. In the Braggs method, a sol is typically prepared by dispersing a solid substance in a suitable liquid medium. This can be achieved through methods such as chemical reduction or precipitation.
2. **X-ray Diffraction:** Once the sol is prepared, it is subjected to X-ray diffraction. X-rays are directed at the sol, and the scattered X-rays are analyzed. The diffraction pattern produced provides information about the size, shape, and arrangement of the colloidal particles in the sol.
  - **Particle Characterization:** The diffraction pattern obtained from X-ray diffraction allows researchers to characterize the colloidal particles in the sol. By analyzing the pattern, information about the size distribution and crystalline structure of the particles can be obtained.
  - **Control of Colloidal Properties:** The parameters of the Braggs method can be adjusted to control the properties of the colloidal particles, such as their size and shape. This allows for the synthesis of colloids with specific characteristics tailored to various applications.
  - the Braggs method is a technique used for the synthesis of colloids by utilizing X-ray diffraction to characterize the particles in a colloidal sol. This method provides valuable information about the size, shape, and arrangement of colloidal particles, allowing for the controlled synthesis of colloids with desired properties.

#### **Advantages:**

1. It is easy and does not need expensive equipment.
2. It can make ordered patterns of particles, like crystals.
3. It is cheap and can be done on a large scale.
4. It uses simple materials like water .

#### **Limitations:**

1. It is hard to control the size and quality of the final product.
2. It only works well with round particles of the same size.
3. It takes a long time to finish.
4. Changes in temperature or humidity can affect the results.
5. It doesn't work for all types of particles or shapes.

10b) Explain BET equation. Mention the application of the BET equation in the characterization of Nano porous materials.

The Brunauer-Emmett-Teller (BET) equation is a fundamental model in surface science that describes the physical adsorption of gas molecules onto a solid surface, accounting for multilayer adsorption. This theory extends the Langmuir adsorption model, which is limited to monolayer adsorption, by allowing for the formation of multiple layers. The BET equation is expressed as:

$$\frac{P}{v(P_0 - P)} = \frac{1}{v_m C} + \frac{(C - 1)F}{v_m C P_0}$$

where:

- $P$  is the equilibrium pressure of the gas.
- $P_0$  is the saturation pressure of the gas.
- $v$  is the volume of gas adsorbed at pressure  $P$ .
- $v_m$  is the volume of gas required to form a monolayer on the adsorbent surface.
- $C$  is the BET constant, related to the heat of adsorption.

#### Applications in Nano-porous Materials:

- Important for nanomaterial's where surface area affects performance.
- Measures surface area of materials like zeolites and activated carbon.
- Helps analyse porosity and pore size.
- Used in designing catalysts, adsorbents, and sensors.

OR

11a) How does the Freundlich isotherm differ from the Langmuir isotherm in terms of adsorption behavior?

Langmuir Isotherm	Freundlich Isotherm
Assumes uniform (homogeneous) surface	Assumes non-uniform (heterogeneous) surface
Monolayer adsorption only	Multilayer adsorption possible
Has a fixed maximum adsorption capacity	No maximum limit (increases with pressure)
Equation: $\theta = \frac{K_p}{1 + K_p}$	Equation: $\frac{x}{m} = kP^{\frac{1}{n}}$
Best for ideal surfaces and low pressures	Best for real surfaces and wide pressure range

11b) List out the steps involved in synthesis of nanoparticles by using sol-gel method.

Steps involved in synthesis of nanoparticles by using sol-gel method.

1. Preparation of Homogeneous solution: Dissolve metal alkoxide or metal salt in water or alcohol.
2. 'Sol' formation by hydrolysis : Add water to form metal hydroxides and formation of colloidal particles (sol) due to hydrolysis reaction.
3. 'gel' formation by condensation : Hydroxides combine to form a gel (M–O–M bonds) by condensation reaction
4. Drying of gel :

**Xerogel:**

Formed by drying a gel at ambient temperature, causing significant shrinkage.

**Aerogel:**

Produced by supercritical drying, preserving the gel's porous structure with minimal shrinkage.

**Powder:**

powder formed by drying at 800°C and made by grinding dried gel into fine particles for use in various applications.

5. Reactions:

1) Hydrolysis



Metal alkoxide                  Metal Hydroxide

2) Condensation

