Total No. of Questions : 9]

SEAT No. :

P6487

[Total No. of Pages : 4

[5868]-103

F.E. (Semester - I & II)

ENGINEERING CHEMISTRY

(2019 Pattern) (Paper - II) (107009)

Time : 2½ Hours] *[Max. Marks : 70*

Instructions to the candidates:

1) *Questions No. 1 is compulsory. Solve Q.No. 2 or Q.No. 3, Q.No. 4 or Q.No. 5, Q.No. 6 or Q.No. 7 and Q.No. 8 or Q.No. 9.*
2) *Neat diagrams must be drawn wherever necessary.*
3) *Figures to the right indicates full marks.*
4) *Use of logarithmic tables slide rule, Mollier charts, electronic pocket calculator and steam tables is allowed.*
5) *Assume suitable data if necessary.*

Q1) Multiple choice questions -

i) PPV shows ______ fluorescence on application of electric field and can be used in ______ **[2]**

A) blue, sutures B) yellow-green, organic LEDs

C) red, eye-wear lenses D) violet, drug - delivery

ii) C atoms in graphene show ______ hybridisation. **[1]**

A) sp^3 B) sp

C) sp^2 D) sp^3d^2

iii) Power alcohol is advantageous because it ______. **[1]**

A) decreases octane number B) burns clean

C) increases calorific value D) increases cetane number

iv) Units of calorific value are ______. **[1]**

A) Cal/g B) Cal/m

C) Joules D) Kg/m^3

v) CO_2 is _________ and shows _________ fundamental modes of vibration. **[2]**

A) linear, 3 B) non-linear, 3

C) linear, 4 D) non-linear, 4

vi) Electromagnetic radiations with wavelength 10-400 nm are called ______ radiations. **[1]**

A) Visible B) Microwave

C) IR D) Ultra violet

vii) Tinning is coating of ______. **[1]**

A) Fe on Sn B) Zn on Fe

C) Sn on Fe D) Fe on Zn

viii) Rate of corrosion _______ with increase in purity of the metal. **[1]**

A) decreases

B) increases

C) remains same

D) initially increases and then remains constant

Q2) a) What are biodegradable polymers? Explain three factors responsible for biodegradation. Give two properties and two uses of biodegradable polymer. **[6]**

b) What are nanomaterials? Discuss in brief two properties and applications of nanomaterials. **[5]**

c) Give the structure and three properties and applications each of polycarbonate. **[4]**

OR

Q3) a) What are carbon nano-tubes? Discuss the different types of carbon nanotubes with respect to their structure. **[6]**

b) Explain the structure of graphene with the help of diagram and mention its two properties and two applications. **[5]**

c) What are conducting polymers? State the structural requirements for a polymer to be conducting and give any three applications of conducting polymers. **[4]**

Q4) a) What is proximate analysis of coal? Give the procedure and formula for determination of each constituent. **[6]**

b) Explain the production of hydrogen by steam reforming of coke and methane with reaction conditions. **[5]**

c) The following data was obtained in a Boy's gas

Calorimeter experiment -

Volume of gas burnt at STP = $0.1 m^3$

Mass of cooling water = 30 kg

Rise in temperature of cooling water = 8.1°C

Mass of steam condensed = 0.08 kg

Calculate GCV and NCV of the fuel **[4]**

OR

Q5) a) Give the principle and explain the process of fractional distillation of crude oil with labelled diagram. Give the composition and boiling range of any one fraction obtained during refining. **[6]**

b) Give the preparation reaction of biodiesel. State four advantages and two limitations of biodiesel. **[5]**

c) 1.0g of coal sample on complete combustion increased the weight of U-tube containing $CaCl_2$ by 0.5g and tube containing KOH by 2.4g. Calculate % of C and H in the given coal sample. **[4]**

Q6) a) Draw block diagram of IR spectrophotometer. Explain its any four components and give their function. **[6]**

b) Explain the possible transitions which occur on absorption of UV-Vis radiations by an organic molecule. **[5]**

c) Explain any four applications of IR spectroscopy. **[4]**

OR

Q7) a) Draw block diagram of single beam UV-vis spectrophotometer. Explain its four components and give their function. **[6]**

b) Give the principle of IR spectroscopy. Explain fundamental modes of bending vibrations. **[5]**

c) Define the following terms - **[4]**

i) Chromophore

ii) Hypsochromic shift

iii) Auxochrome

iv) Hypochromic shift

Q8) a) Explain hydrogen evolution and oxygen absorption mechanism of wet corrosion. **[6]**

b) What is electroplating? Explain the process with diagram and reactions. Give applications of electroplating. **[5]**

c) What are anodic and cathodic coatings? Which are better and why? **[4]**

OR

Q9) a) State Pilling Bedworth ratio and give its significance. Give the different types of oxide films with suitable example formed during the oxidation corrosion of metals. **[6]**

b) Explain any five factors affecting the rate of corrosion. **[5]**

c) What is the principle of cathodic protection? Explain any one method of cathodic protection. **[4]**

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First Year Engineering (FE SEM I/II)

ENGINEERING CHEMISTRY

(2019 Pattern)

<u>Solution With Appropriate Answers</u>

Instruction to the candidate

1) Answer Q.1 or Q.2, Q.3 or Q.4, Q.5 or Q.6, Q.7 or Q.8.

2) Neat diagrams must be drawn wherever necessary.

3) Figures to the right indicate full marks.

Tips to Remember You Start Writing Answer Sheet

1) Read the question carefully.

2) Plan your answer before writing.

3) Start with a strong introduction.

4) Organize your thoughts in a logical manner.

5) Support your arguments with evidence and examples.

6) Use clear and concise language.

7) Be specific and precise in your responses.

8) Address all parts of the question.

9) Manage your time effectively.

10) Review and revise your answers.

These points should help you structure and write your answers effectively during the exam. Good luck!

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Q. 1

→ i) B) yellow-green, organic LEDs

→ ii) C) sp2

→ iii) B) burns clean

→ iv) A) Cal/g

→ v) C) linear, 4

→ vi) D) Ultra violet

→ vii) C) Sn on Fe

→ viii) A) decreases

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Q. 2

➔ a) **Biodegradable polymers :**

- Biodegradable polymers are a type of polymers that can be broken down into simpler compounds by biological processes, such as the action of enzymes or microorganisms, over a period of time.
- They are designed to degrade and return to the environment without leaving behind harmful residues.

Factors responsible for biodegradation:

Chemical Structure:

- The chemical structure of a biodegradable polymer plays a crucial role in its biodegradation. Certain chemical groups, such as ester, amide, or ether linkages, are more susceptible to enzymatic attack and microbial degradation.
- Polymers with these susceptible linkages can be easily broken down by biological processes.

Molecular Weight:

- The molecular weight of a biodegradable polymer affects its biodegradation rate. Generally, polymers with lower molecular weights tend to degrade faster than those with higher molecular weights.
- Smaller polymer chains provide more accessible sites for microbial colonization and enzyme attack, leading to quicker degradation.

Environmental Conditions:

- The environment in which biodegradable polymers are present significantly influences their degradation rate. Factors like temperature, humidity, pH, and the presence of microorganisms can impact the rate and extent of biodegradation.
- For example, high temperatures and the presence of suitable microorganisms can accelerate the degradation process.

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Q. 2

Properties of biodegradable polymers:

Environmental Compatibility:

Biodegradable polymers are environmentally friendly materials as they break down naturally into harmless substances.

- They do not persist in the environment like conventional non-biodegradable plastics, reducing the accumulation of waste and potential ecological damage.

Versatility:

- Biodegradable polymers can be designed with a wide range of properties, such as mechanical strength, flexibility, and degradation rate.
- This versatility allows for the development of customized materials suitable for various applications and industries.

Uses of biodegradable polymers:

Packaging Materials:

- Biodegradable polymers find applications in the production of packaging materials, such as bags, films, and containers.
- These materials can be used for food packaging or other single-use applications where their biodegradability helps reduce environmental pollution.

Medical Applications:

- Biodegradable polymers are extensively used in the medical field. They are used in the production of sutures, drug delivery systems, tissue engineering scaffolds, and biodegradable implants.
- These polymers degrade within the body, eliminating the need for surgical removal and minimizing potential complications.

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Q. 2

→ b) **Nanomaterials :**

- Nanomaterials are materials that have unique properties and structures at the nanoscale level, typically between 1 and 100 nanometers.
- These materials exhibit novel characteristics different from their bulk counterparts due to their small size and increased surface area-to-volume ratio.

Two properties of nanomaterials:

Size-dependent Properties:

- Nanomaterials display size-dependent properties, meaning their behavior and characteristics change as their size decreases.
- For example, nanoparticles may have enhanced optical, magnetic, or catalytic properties compared to larger particles of the same material.

High Surface Area:

- Nanomaterials have a significantly higher surface area compared to their volume.
- This large surface area enables efficient interaction with other substances, making them highly reactive and suitable for applications such as adsorption, catalysis, and sensing.

Two applications of nanomaterials:

Nanomaterials in Electronics/Optoelectronics:

- Nanomaterials are used in electronics and optics for their unique properties.
- For instance, nanoparticles or nanowires can be utilized in the development of smaller, faster, and more efficient electronic devices.
- Nanomaterials are also employed in the production of high-resolution displays, solar cells, and sensors.

Nanomaterials in Biomedical Applications:

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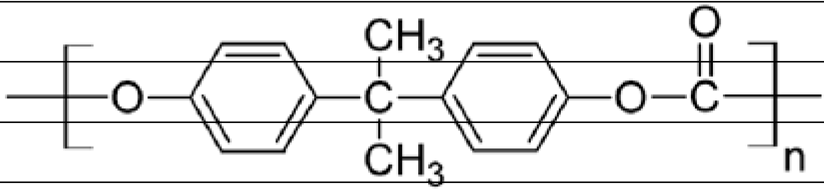
Q. 2

- Nanomaterials have revolutionized the field of medicine and healthcare.
- They can be engineered for targeted drug delivery, imaging, and diagnostic purposes.
- Nanoparticles can carry and release drugs at specific sites in the body, enhancing therapeutic efficacy and minimizing side effects.

➔ c) **structure of polycarbonate:**



Properties of Polycarbonate:

High Impact Resistance:
- Polycarbonate exhibits excellent impact resistance, making it highly durable and able to withstand significant forces without breaking or shattering.
- This property makes it ideal for applications requiring impact resistance, such as safety goggles, bulletproof glass, and protective equipment.

Transparency:
- Polycarbonate has high optical clarity and transparency, allowing light to pass through with minimal distortion.
- This property makes it suitable for applications where visibility or light transmission is crucial, including eyeglass lenses, windows, and transparent protective barriers.

Heat Resistance:
- Polycarbonate possesses good heat resistance, with a glass transition temperature

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temperature around 147°C (297°F).

- It can withstand high temperatures without deforming or melting, making it suitable for applications that require exposure to heat, such as electrical components, automotive parts, and cookware handles.

Applications of Polycarbonate:

Electrical and Electronics:

- Polycarbonate is widely used in electrical and electronic applications due to its excellent electrical insulation properties, impact resistance, and transparency.
- It is used in electrical connectors, switches, insulators, LED light diffusers, and optical discs.

Automotive Industry:

- Polycarbonate finds extensive use in the automotive sector due to its impact resistance, lightweight nature, and transparency.
- It is used for headlamp lenses, interior trim components, instrument panels, sunroofs, and exterior mirrors.

Construction and Architecture:

- Polycarbonate's combination of strength, transparency, and weather resistance makes it suitable for construction applications.
- It is used for roofing panels, skylights, safety glazing, sound barriers, and architectural features where both aesthetic appeal and durability are essential.

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Q. 3

➔ a) **Carbon nanotubes :**

Carbon nanotubes are cylindrical structures composed of carbon atoms arranged in a hexagonal lattice.

They have unique mechanical, electrical, and thermal properties, making them of great interest in various fields such as electronics, materials science, and nanotechnology.

There are different types of carbon nanotubes based on their structure, including:

Single-Walled Carbon Nanotubes (SWCNTs):

Structure of Single-Walled Carbon Nanotubes

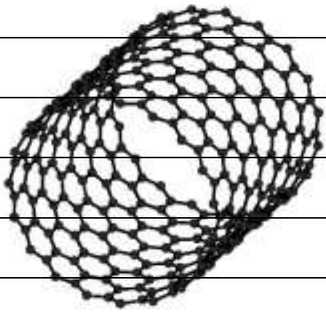

figure :Structure of Single-Walled Carbon Nanotubes

- SWCNTs consist of a single cylindrical graphene sheet rolled into a seamless tube.

Properties:

- They can have varying diameters and lengths, with aspect ratios reaching up to thousands.
- SWCNTs can exhibit metallic or semiconducting behavior depending on their chirality, which is the arrangement of carbon atoms in the tube.

Applications:

SWCNTs find applications in electronics, energy storage, nanocomposites, and

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Q. 3

biomedical fields due to their excellent electrical conductivity and mechanical properties.

Multi-Walled Carbon Nanotubes (MWCNTs):

Structure of multi- walled carbon nanotubes :

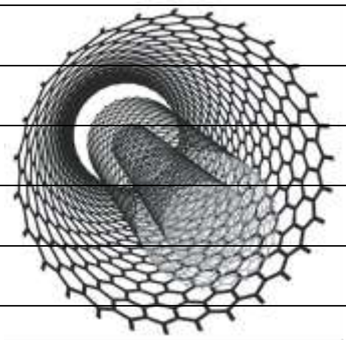

figure :Structure of multi-Walled Carbon Nanotubes

- MWCNTs consist of several concentric graphene layers arranged like nested cylinders, forming a tube within a tube structure.

Properties:

- MWCNTs have larger diameters than SWCNTs and can possess multiple walls.
- The number of walls can vary, resulting in different interlayer spacing and properties.
- The outermost layer can exhibit properties similar to SWCNTs.

Applications:

- MWCNTs are used in a wide range of applications, including reinforced composites, catalyst supports, thermal management materials, and sensors.

3. Double-Walled Carbon Nanotubes (DWCNTs):

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Structure of Double-Walled Carbon Nanotubes:

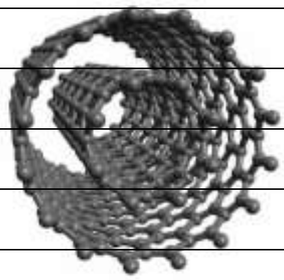

figure :Structure of Double-Walled Carbon Nanotubes

- DWCNTs are composed of two concentric graphene layers forming a tube within a tube structure, similar to MWCNTs but with only two walls.

Properties:

- DWCNTs combine some properties of SWCNTs and MWCNTs.
- The inner and outer tubes can have different chiralities, leading to tunable electronic properties.

Applications:

- DWCNTs have potential applications in nanoelectronics, energy storage, and as catalyst supports due to their unique structure and properties

→ b) **Graphene :**

- Graphene is a two-dimensional allotrope of carbon arranged in a hexagonal lattice structure.
- Each carbon atom in graphene is bonded to three neighboring carbon atoms, forming a flat sheet with exceptional properties.

Structure of Graphene :

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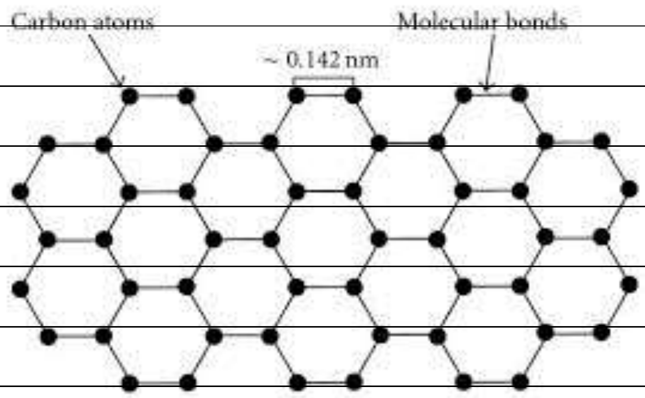

figure : structure of Graphene

- Graphene consists of a single layer of carbon atoms arranged in a honeycomb lattice. The carbon atoms are sp^2 hybridized, forming strong sigma bonds between them.
- The hexagonal lattice structure of graphene resembles a chicken wire fence, where each vertex represents a carbon atom and each line represents a carbon-carbon bond.
- Due to its unique structure, graphene exhibits extraordinary strength and is considered one of the strongest materials known.

Properties of graphene:

- Graphene is incredibly strong. Despite being only one atom thick, it is considered one of the strongest materials known. Its carbon bonds give it exceptional structural integrity.
- Graphene is an excellent conductor of electricity. Its unique structure allows electrons to move rapidly through its lattice, making it ideal for electronic applications.
- Graphene also possesses excellent thermal conductivity. It can efficiently conduct heat, making it valuable for applications that require efficient heat dissipation.

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Application of graphene :

Electronics and Photonics:

- Transistors, flexible displays, touchscreens, photodetectors, and sensors.
- Enables faster, smaller, and more efficient electronic devices.

Energy Storage:

- Improving batteries and supercapacitors.
- Potential applications in electric vehicles and renewable energy storage.

Composite Materials:

- Enhances properties of composites.
- Improved mechanical strength, electrical conductivity, and thermal properties.
- Applications in aerospace, automotive, and construction industries.

→ c) **Definition of Conducting Polymers:**

- Conducting polymers are a type of polymer that can conduct electricity due to their unique chemical structure and electronic properties.

Structural Requirements for Conductivity:

π-Conjugation:

- Conducting polymers must have a conjugated backbone containing alternating single and double bonds or aromatic rings.
- This allows for the delocalization of π-electrons, enabling the transport of charge carriers.

Doping:

- Conducting polymers require the presence of dopants or charge carriers to enhance

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enhance their electrical conductivity.

- These dopants can be added during synthesis or through electrochemical processes.

Applications of Conducting Polymers:

1. Organic Electronics:
    - Organic light-emitting diodes (OLEDs)
    - Organic photovoltaic cells (OPVs)
    - Organic field-effect transistors (OFETs)

2. Energy Storage:
    - Supercapacitors
    - Batteries

3. Sensors:
    - Biosensors
    - Gas sensors
    - Chemical sensors

4. Antistatic Coatings:
    - Coatings to prevent electrostatic discharge (ESD)
    - Protect sensitive electronic components or materials

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Q. 4

→ a)

Proximate analysis

- Proximate analysis is a laboratory technique used to determine the major constituents or components of coal.
- It provides valuable information about the coal's quality, combustion characteristics, and potential applications.
- The four main constituents analyzed in proximate analysis are moisture, volatile matter, fixed carbon, and ash

procedure and formulas for the determination of each constituent:

1. Moisture:

Procedure:

- Weigh a representative coal sample and place it in a drying oven at a specified temperature (typically 105°C to 110°C).
- Dry the sample until it reaches a constant weight.
- Calculate the percentage of moisture as the difference between the initial and final weights of the sample.

Formula:

$$\text{Moisture content (\%)} = \left[\frac{\text{(Initial weight – Final weight)}}{\text{Initial weight}}\right] \text{x } 100$$

2. Volatile Matter:

Procedure:

- Take a weighed coal sample and place it in a covered crucible.
- Heat the crucible in a furnace or muffle furnace at a specific temperature (typically 900°C) for a specified duration.
- Remove the crucible and allow it to cool in a desiccator.
- Weigh the crucible with the remaining residue.
- Calculate the percentage of volatile matter as the difference between the initial weight and the weight of the residue.

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Formula:

$$\text{Volatile matter (\%)} = \left[\frac{\text{(Initial weight – Residue weight)}}{\text{Initial weight}}\right] \text{x } 100$$

3. Fixed Carbon:

Procedure:

- Calculate fixed carbon by subtracting the sum of moisture, volatile matter, and ash percentages from 100%.

Formula:

Fixed carbon (%) = 100 - (Moisture content + Volatile matter + Ash content)

4. Ash:

Procedure:

- Take the previously dried coal sample from the moisture determination.
- Heat the sample in a muffle furnace at a specific temperature (typically 575°C to 625°C) until the sample is completely burned.
- Allow the sample to cool in a desiccator and weigh it.
- Calculate the percentage of ash based on the weight of the sample.

Formula:

$$\text{Ash content (\%)} = \left(\frac{\text{Ash weight}}{\text{Initial weight}}\right) \text{x } 100$$

➔ b) **Hydrogen production through steam reforming :**

- it involves the reaction of a hydrocarbon, such as coke or methane, with steam (water vapor) at elevated temperatures in the presence of a catalyst.

explanation of the production of hydrogen by steam reforming of coke and methane, along with the reaction conditions :

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1. Steam Reforming of Coke:

- Coke, a carbon-rich material derived from coal or petroleum, can undergo steam reforming to produce hydrogen.
- Reaction: $C + H_2O \rightarrow CO + H_2$
- Carbon reacts with steam to produce carbon monoxide (CO) and hydrogen gas (H2).

2. Steam Reforming of Methane (Natural Gas):

- Methane (CH_4), the primary component of natural gas, can be steam-reformed to produce hydrogen.
- Reaction: $CH_4 + H_2O \rightarrow CO + 3H_2$
- Methane reacts with steam to produce carbon monoxide (CO) and three molecules of hydrogen gas (H2).

Reaction Conditions:

- Temperature: Steam reforming reactions typically occur at high temperatures, typically ranging from 700°C to 1000°C.
- Higher temperatures favor the reaction kinetics but may increase the risk of catalyst deactivation.

Catalyst:

- A catalyst is used to enhance the reaction rate and promote the desired reactions.
- Common catalysts include nickel-based catalysts, which are effective for steam reforming.

Steam-to-Carbon Ratio:

- The steam-to-carbon ratio (S/C ratio) refers to the molar ratio of steam to carbon-containing feedstock.
- An S/C ratio greater than 2 is typically maintained to ensure sufficient steam for complete reaction and prevent the formation of carbon deposits (carbon fouling).

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Pressure:

- Steam reforming is typically conducted at elevated pressures, often ranging from 10 to 30 bar, to promote better conversion rates and increase the yield of hydrogen.

Reactor Design:

- Steam reforming can be carried out in fixed-bed, fluidized-bed, or tubular reactor systems, depending on the scale and specific requirements of the process.
- The steam reforming process is widely used for large-scale industrial hydrogen production due to its efficiency and ability to utilize various feedstocks.
- It is an important method in the production of hydrogen for various applications, including fuel cells, ammonia synthesis, and other chemical processes.

→ c) Given data:

- Volume of gas burnt at STP = 0.1 m^3
- Mass of cooling water = 30 kg
- Rise in temperature of cooling water = 8.1°C
- Mass of steam condensed = 0.08 kg
- Specific Heat Capacity of water = 4.186 J/g°C
- Latent Heat of vaporization of water = 2260 kJ/kg

Step 1: Calculate the heat gained by the water:

Heat gained by water = Mass of water x Specific Heat Capacity of water x Rise in temperature

Heat gained by water = 30 kg x 4.186 J/g°C x 8.1°C = 1019.423 J

Step 2: Calculate the heat gained by the steam:

Heat gained by steam = Mass of steam x Latent Heat of vaporization of water

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Heat gained by steam = 0.08 kg x 2260 kJ/kg = 180.8 kJ = 180800 J

Step 3: Calculate the Gross Calorific Value (GCV):

GCV = (Heat gained by water + Heat gained by steam) / Volume of gas burnt

GCV = (1019.423 J + 180800 J) / 0.1 m^3 = 1818832.3 J/m^3 = 1.8188323 MJ/m^3

Step 4: Calculate the Net Calorific Value (NCV):

NCV = GCV - [(Mass of water x Specific Heat Capacity of water) + (Mass of steam x Latent Heat of vaporization of water)] / Volume of gas burnt

NCV = GCV - [(30 kg x 4.186 J/g°C x 8.1°C) + (0.08 kg x 2260 kJ/kg)] / 0.1 m^3

= 1.8188323 MJ/m^3 - (1019.423 J + 180800 J) / 0.1 m^3

= 1.8188323 MJ/m^3 - 1818192.3 J / 0.1 m^3

= 1.8188323 MJ/m^3 - 18181923 J/m^3

= -16.0011707 MJ/m^3

The Gross Calorific Value (GCV) of the fuel is approximately 1.8188323 MJ/m^3, and the Net Calorific Value (NCV) is approximately -16.0011707 MJ/m^3.

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→ a) **Principle of Fractional distillation :**

Fractional distillation is based on the principle that different components of a mixture, such as crude oil, have different boiling points.

By gradually heating the mixture and condensing the vapors at different temperatures, the components can be separated based on their boiling points and collected as distinct fractions.

diagram illustrating the fractional distillation of crude oil:

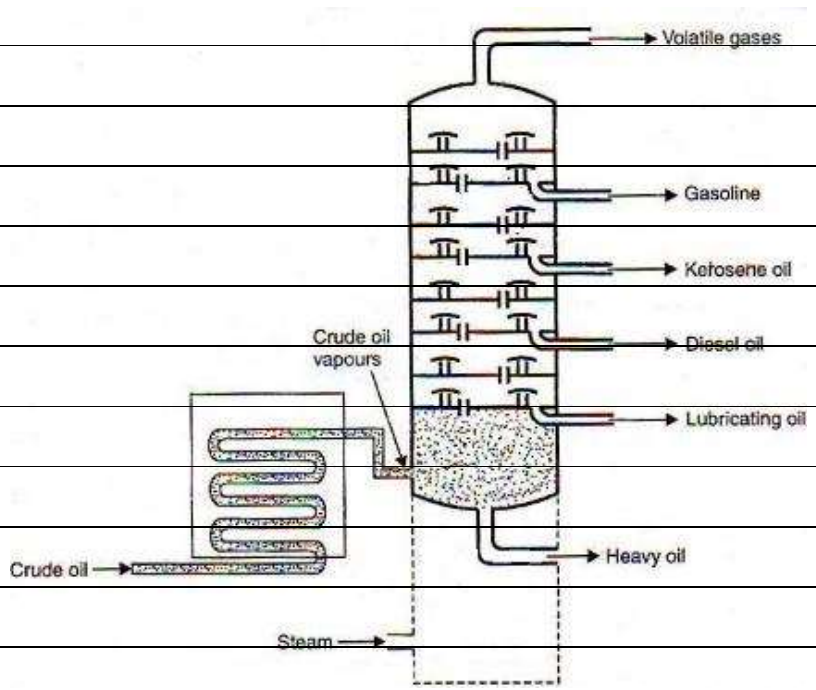

Figure : fractional distillation of crude oil

Process of Fractional Distillation of Crude Oil:

Heating:

- The crude oil is heated in a furnace or heat exchanger to vaporize the mixture.
- The temperature is carefully controlled to ensure the desired components evaporate without decomposition.

Fractionating Column:

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- The vaporized crude oil enters a tall fractionating column, which is packed with a series of horizontal trays or plates.
- These trays help in achieving better separation of the components.

Temperature Gradient:
- The column is hotter at the bottom and cooler at the top.
- As the vapors rise, they encounter temperature variations along the column.

Separation:
- Each component in the mixture has a specific boiling point. When the vapors rise, they reach a height in the column where the temperature matches their boiling point.
- At this point, the component condenses into a liquid state and is collected on the corresponding tray.

Collection of Fractions:
- The condensed fractions are collected at different levels of the fractionating column.
- The lower boiling point components condense at higher levels (near the top of the column), while the higher boiling point components condense at lower levels (closer to the bottom of the column).

Condenser:
- As the fractions condense, they are collected in different receivers or condensers.
- These receivers are designed to collect and separate the different fractions obtained during the distillation process.

Composition and Boiling Range of a Fraction:
- One fraction obtained during refining is gasoline or petrol.
- Its composition typically consists of hydrocarbons with 5 to 12 carbon atoms.

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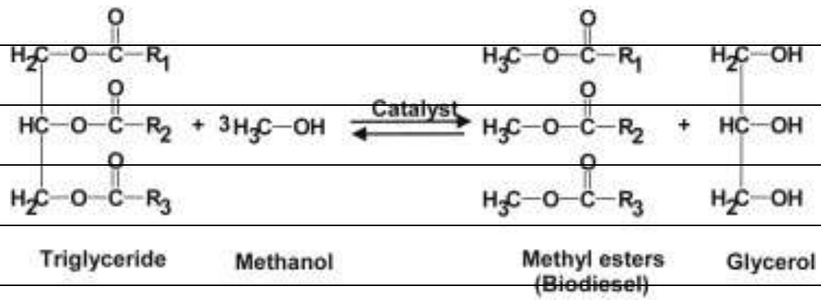
- The boiling range of gasoline is approximately 30°C to 200°C.
- Gasoline is commonly used as a fuel for internal combustion engines in automobiles.

➔ b) **Preparation reaction of biodiesel:**

- Biodiesel, also known as fatty acid methyl ester (FAME), is typically prepared through a process called transesterification.
- The reaction involves the conversion of vegetable oils or animal fats into their corresponding esters (biodiesel) and glycerol.

The basic transesterification reaction is as follows:



Vegetable oil (triglyceride) + Alcohol (typically methanol) → Biodiesel (FAME) + Glycerol

Advantages of Biodiesel:

- Biodiesel is derived from renewable sources such as vegetable oils and animal fats.
- It reduces dependence on fossil fuels and contributes to sustainable energy production.

- Biodiesel has lower carbon dioxide (CO2) emissions compared to fossil diesel.
- It helps mitigate climate change and reduces air pollution, improving air quality.

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biodiesel is readily biodegradable, which means it breaks down more easily in the environment than petroleum-based diesel, reducing the environmental impact in case of spills or leaks.

- Biodiesel can be used in existing diesel engines and fuel distribution systems without major modifications, making it a viable alternative fuel option.

Limitations of Biodiesel:

- Biodiesel production can be more expensive compared to conventional diesel due to the higher cost of feedstock, processing, and quality control.

- Biodiesel tends to have poorer low-temperature properties, such as higher cloud and pour points, which can affect its flow and performance in cold climates.

➔ c) Given data:

- Mass increase in $CaCl_2$ U-tube = 0.5g (due to absorption of CO2)
- Mass increase in KOH U-tube = 2.4g (due to absorption of H2O)
- Mass of coal sample used = 1.0g

Step 1: Calculate the mass of carbon in the coal sample:

Mass of carbon = Mass increase in $CaCl_2$ U-tube = 0.5g

Step 2: Calculate the mass of hydrogen in the coal sample:

Mass of hydrogen = Mass increase in KOH U-tube = 2.4g

Step 3: Calculate the percentage of carbon and hydrogen in the coal sample:

Percentage of carbon = (Mass of carbon / Mass of coal sample) x 100

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$= (0.5g / 1.0g) \times 100$

$= 50\%$

Percentage of hydrogen = (Mass of hydrogen / Mass of coal sample) x 100

$= (2.4g / 1.0g) \times 100$

$= 240\%$

The percentage of hydrogen obtained is 240%, which is unusually high and suggests an error in the given data.

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➔ a) **block diagram of IR spectrophotometer :**

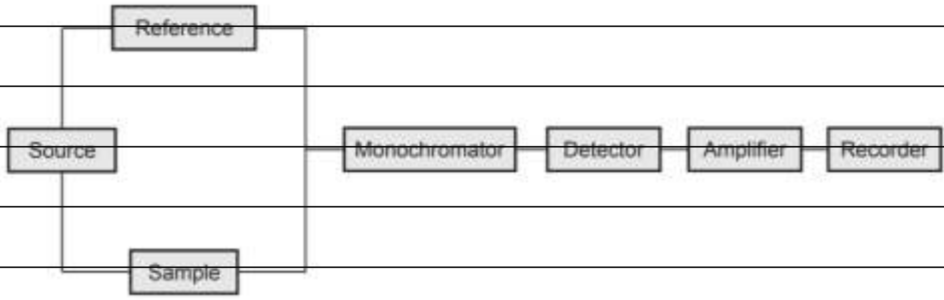

figure : block diagram of IR spectrophotometer

in the above figure,

- reference source is Provides a known and stable source of IR radiation for calibration and baseline correction.

- using sample The substance being analyzed, which interacts with the IR radiation to either absorb or transmit specific wavelengths based on its composition.

-monochromator Separates the different wavelengths of IR radiation emitted by the source and allows only a specific range of wavelengths to pass through to the sample for analysis.

- detector is used for Measures the intensity of the IR radiation transmitted or absorbed by the sample, converting it into an electrical signal for further processing.

- after that amplifier Amplifies the electrical signal from the detector to a suitable level for accurate data processing, improving sensitivity and signal-to-noise ratio.

- recorder is used for Captures and records the processed signals, typically in the form of an IR spectrum, providing a visual representation of the sample's IR absorption or transmission.

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Components and their Functions:

Light Source:

- The light source emits IR radiation, usually a broad spectrum of wavelengths. It provides the energy necessary for the analysis of the sample.

Monochromator:

- The monochromator separates the different wavelengths of IR light, allowing only a specific range (selected by the user) to pass through to the sample.
- It ensures that only the desired wavelengths are used for analysis, increasing accuracy.

Detector:

- The detector measures the intensity of the transmitted or absorbed IR light after it interacts with the sample.
- It converts the light signals into electrical signals that can be processed and analyzed.

Signal Processor:

- The signal processor receives the electrical signals from the detector and processes them.
- It may perform functions such as amplification, filtering, and data conversion. It prepares the signals for further analysis and interpretation.

These components work together to measure the absorption or transmission of IR radiation by the sample, generating an IR spectrum. The spectrum provides valuable information about the chemical composition, functional groups, and molecular structure of the sample.

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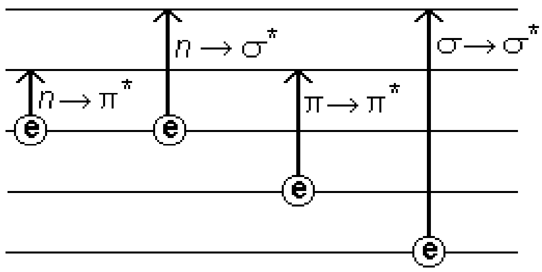
→ b)

possible transitions which occur on absorption of UVVis radiations by an organic molecule :

- When an organic molecule absorbs UV-Vis radiation, it undergoes electronic transitions, resulting in the excitation of electrons from the ground state to higher energy levels.
- The specific transitions that occur depend on the molecular structure and the energy of the absorbed photons.



the above figure consist of the following transition :

1. $\pi \rightarrow \pi^*$ Transition:

- This transition involves the excitation of an electron from a π orbital (typically a non-bonding or antibonding π orbital) to a higher-energy π^* antibonding orbital.
- This transition is commonly observed in molecules with conjugated systems, such as double bonds or aromatic rings.

2. $n \rightarrow \pi^*$ Transition:

- In this transition, an electron from a non-bonding (n) orbital is excited to a higher-energy π^* antibonding orbital.
- This transition is common in molecules with lone pair electrons, such as amines, ethers, and carbonyl compounds.

3. $\sigma \rightarrow \sigma^*$ Transition:

- This transition involves the excitation of an electron from a bonding σ orbital to a higher-energy σ^* antibonding orbital.

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- It typically occurs in saturated organic compounds and is less common in UV-Vis spectroscopy.

4. $n \rightarrow \sigma^*$ Transition:

- it occurs when there is a transfer of electron density from one molecular entity to another.
- This can happen between two atoms or groups with different electron egativities.
- this transitions are often observed in molecules containing electron donor and acceptor groups, such as metal complexes or dyes.

➔ c) **applications of IR spectroscopy as follow :**

analysis of chemical compounds:

- IR spectroscopy is used for qualitative and quantitative analysis of chemical compounds.
- It helps identify functional groups present in a molecule, aiding in compound characterization and verification.
- It is widely employed in fields such as pharmaceuticals, forensics, and environmental analysis.

Material Characterization:

- IR spectroscopy is utilized to study and analyze the composition of various materials.
- It is used in polymer science to determine the type and structure of polymers.
- It helps identify and differentiate different types of fibers, coatings, adhesives, and films.
- It is also employed in the analysis of minerals, ceramics, and other solid-state materials.

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Pharmaceuticals and Drug Development:

- IR spectroscopy plays a crucial role in drug development and quality control.
- It helps identify active pharmaceutical ingredients (APIs) and analyze drug formulations.
- It assesses the stability of drug molecules and detects impurities.
- It is employed to monitor chemical reactions during synthesis and assess drug-drug interactions.

Environmental and Forensic Analysis:

- IR spectroscopy aids in environmental monitoring and forensic investigations.
- It identifies and quantifies pollutants in air, water, and soil samples.
- It helps analyze volatile organic compounds (VOCs) and detect hazardous substances.
- It assesses the quality of food and beverages and aids in trace evidence analysis in forensics.

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➔ a)	**block diagram of single beam UV-Vies Spectrophotometer :**

figure : block diagram of single beam UV-Vies Spectrophotometer

In the above figure,

- Source provide UV-Vis radiation used for analysis.
- Monochromator used for Selects a specific wavelength of radiation for measurement.
- Sample Holder are used to Holds the sample in position for analysis.
- Detector: detector Measures the intensity of radiation after it passes through the sample.
- Amplifies the electrical signal from the detector for improved sensitivity and signal quality.
- recorder are used for Captures and records the signal, often in the form of a spectrum, for analysis and interpretation.

functions of component in a single beam UV-Vis spectrophotometer:

Light Source:

- Emits UV-Vis radiation used for analysis
- Provides a stable and controllable source of UV-Vis radiation.
- Ensures consistent and reliable light input for accurate measurements.

Monochromator:

- Selects a specific wavelength of radiation for measurement.
- Separates the incoming radiation into its component wavelengths.
- Allows only the desired wavelength to pass through to the sample.
- Ensures accurate selection and control of the wavelength for analysis.

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Sample Holder:

- Holds the sample in position for analysis.
- Provides a stable and reproducible position for the sample.
- Ensures the sample is correctly positioned in the optical path for accurate measurements.
- Allows the light to interact with the sample uniformly.

Detector:

- Measures the intensity of radiation after it passes through the sample.
- Converts the light signals into an electrical signal.
- Measures the intensity of the transmitted or absorbed light.
- Provides a quantitative measure of the sample's interaction with the radiation.

Amplifier:

- Amplifies the electrical signal from the detector for improved sensitivity and signal quality.
- Increases the amplitude of the electrical signal.
- Enhances the signal-to-noise ratio, improving the detection limit and accuracy of measurements.
- Enables precise and reliable quantification of the absorbed or transmitted light.

Recorder:

- Captures and records the signal, often in the form of a spectrum, for analysis and interpretation.
- Captures the amplified signal for further analysis.
- Records the signal as a function of wavelength, creating an absorption or transmission spectrum.
- Provides a visual representation of the sample's interaction with the radiation.

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→ b)

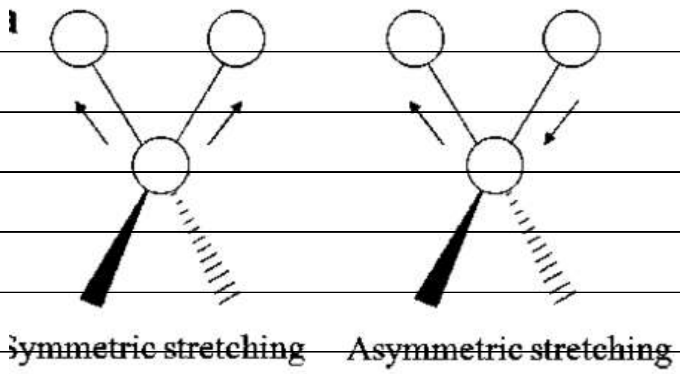
Principle of IR Spectroscopy:

- IR spectroscopy is based on the principle that molecules absorb infrared radiation at specific frequencies that correspond to the vibrational energies of the chemical bonds within the molecule.
- When infrared light is passed through a sample, the molecules present absorb energy at characteristic frequencies, resulting in the absorption of specific wavelengths of light.
- By analyzing the absorbed wavelengths, valuable information about the molecular structure, functional groups, and chemical bonds can be obtained.

fundamental modes of bending vibrations include:

1. symmetric and asymmetric stretching :

Scissoring vibrations in IR spectroscopy refer to the bending motion of atoms, typically hydrogen atoms, towards and away from a central atom. There are two main types of scissoring vibrations:



Symmetric Scissoring:
- Involves the simultaneous inward and outward bending motion of two identical atoms with respect to a central atom.
- Example: Water (H2O).

Asymmetric Scissoring:
- Involves the bending motion of two different atoms with respect to a central

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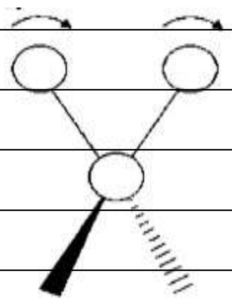
Example: Methyl chloride (CH3Cl).

2. Rocking (ρ)

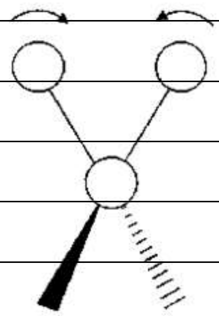
- Rocking vibrations involve a periodic motion where atoms move back and forth like the motion of a rocking chair.
- It occurs in molecules with groups of atoms that are connected by flexible bonds.
- An example is the rocking motion of methyl (CH3) groups in organic compounds.



in-plane rocking

3. Scissoring (ν):

- Scissoring vibrations involve the periodic bending of atoms towards and away from each other in a scissor-like motion.
- It occurs in molecules with two hydrogen atoms bonded to a central atom, such as water (H2O).
- The scissoring mode is characterized by a bending motion of the hydrogen atoms towards and away from the oxygen atom.



in-plane scissoring

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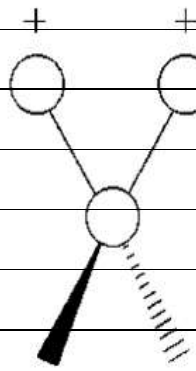
4. Wagging (δ):

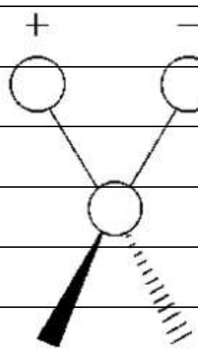
- Wagging vibrations involve an in-plane bending motion where atoms move side to side, like the wagging of a dog's tail.
- It occurs in molecules with groups of atoms connected by flexible bonds.
- An example is the wagging motion of hydrogen atoms in ethane (C2H6).



out-of-plane wagging

5. Twisting (τ):

- Twisting vibrations involve the rotation or torsion of groups of atoms around a central bond axis.
- It occurs in molecules with flexible bonds that allow rotation.
- An example is the twisting motion of the methyl groups in butane (C_4H_{10}).



out-of-plane twisting

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➔ c) **definition of the terms:**

i) Chromophore:

- A chromophore is a specific group or moiety within a molecule responsible for its color or light absorption.
- It is often a conjugated system of double bonds or a functional group with delocalized electrons.
- Chromophores absorb specific wavelengths of light, resulting in the observed color of compounds.

ii) Hypsochromic shift:

- A hypsochromic shift refers to a shift in the absorption wavelength towards the shorter wavelength (higher energy) region in a spectrum.
- It occurs when a compound absorbs light at shorter wavelengths compared to a reference compound or under different conditions.
- This shift can result from changes in molecular structure, electronic environment, or intermolecular interactions.

iii) Auxochrome:

- An auxochrome is a functional group or substituent in a molecule that modifies the absorption properties of a chromophore.
- It does not directly absorb light but influences the wavelength or intensity of absorption by altering the electronic structure or polarity of the molecule.
- Auxochromes typically enhance the color or absorption characteristics of a chromophore.

iv) Hypochromic shift:

- A hypochromic shift refers to a shift in the absorption wavelength towards the longer wavelength (lower energy) region in a spectrum.
- It occurs when a compound absorbs light at longer wavelengths compared to a

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reference compound or under different conditions.

- This shift can be caused by changes in molecular structure, electronic environment, or intermolecular interactions.

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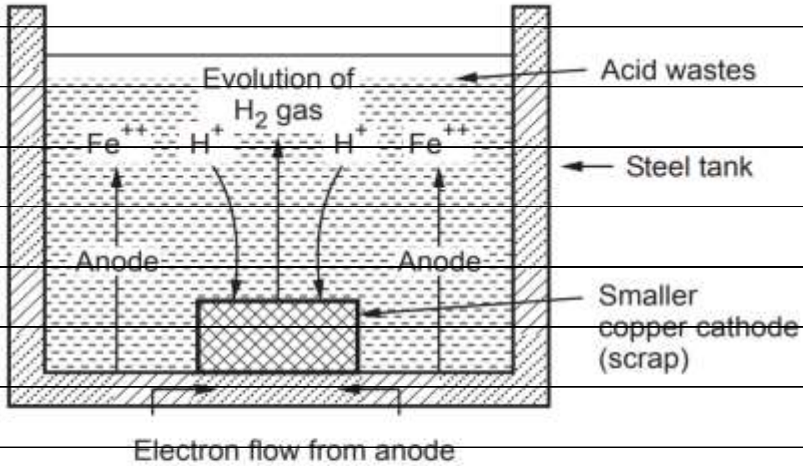
➔ a) **Hydrogen Evolution Mechanism :**

- Consider a situation where a piece of copper and a steel tank are in contact with each other in the presence of an acid electrolyte as shown in below figure.



- This setup forms an electrochemical cell, with the steel tank acting as the anode and the copper acting as the cathode.
- Due to the difference in their electrochemical potentials, the steel tank undergoes oxidation at the anode, and the copper acts as the site for reduction at the cathode.
- At the anode (steel tank), iron (Fe) from the steel reacts with the acid electrolyte, dissociating into Fe^{+2} ions and releasing electrons.
- The released electrons flow through the metal surface and reach the cathode (copper), where hydrogen ions (H^+) from the acid electrolyte combine with the electrons to form hydrogen gas (H_2).
- The hydrogen gas is liberated as bubbles at the cathode and can accumulate on the metal surface.
- The overall net reaction is $Fe + 2H^+ \longrightarrow Fe^{+2} + H_2$, representing the corrosion of the steel tank through the process of hydrogen evolution.

Oxygen Absorption Mechanism :

- Consider a steel plate lying on the ground and exposed to the atmosphere develops an oxide layer on its surface. It shown in below figure.

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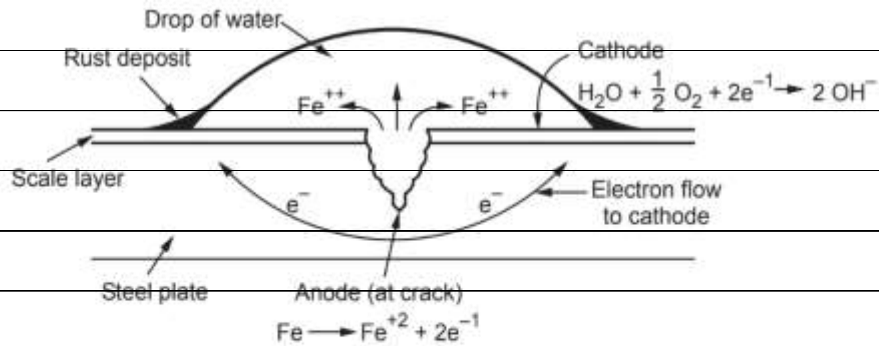

- Water droplets may collect over a small crack on the oxide film.
- Water acts as the electrolyte, steel plate as the anode, and oxide scale as the cathode.
- Iron (Fe) in the steel plate undergoes oxidation at the anode, forming ferrous ions (Fe^{+2}).
- Oxygen molecules (O2) from the atmosphere dissolve in water and participate in reduction at the cathode.
- Electrons flow from the anode to the cathode, and oxygen accepts electrons to form hydroxyl ions (OH^-).
- Ferrous ions and hydroxyl ions combine to form ferrous hydroxide ($Fe(OH)_2$).
- Depending on oxygen availability, ferrous hydroxide can be further oxidized to ferric hydroxide ($Fe(OH)_3$) or black anhydrous Fe_3O_4 (iron(II,III) oxide).
- Corrosion primarily occurs at the anode (steel plate), while rust deposition or corrosion product formation occurs at the cathode (oxide scale).

→ b) **Electroplating :**

- Electroplating is a process in which a metal coating is deposited onto the surface of an object using electrolysis.
- It involves the application of a thin layer of metal onto a substrate to enhance its appearance, protect it from corrosion, improve conductivity, or provide other desirable properties.

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Diagram of Electroplate:

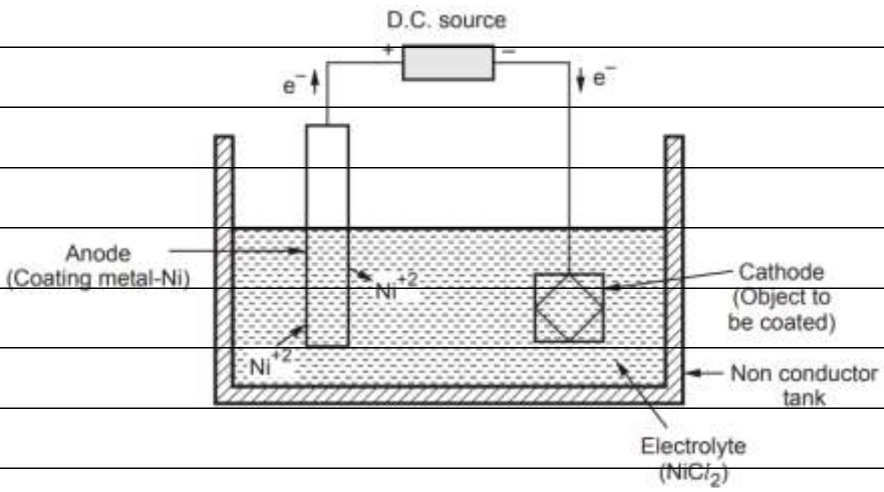

figure : diagram of Electroplate

Process of Electroplating:

- The base metal article to be coated is cleaned to remove oils, greases, oxides, scales etc.

Electroplating is carried out in electroplating bath. The metal article to be plated is made cathode. Coating metal is made anode.

- Number of cathodes and anodes can be and suspended alternately for getting uniform deposition over the entire surface.
- Cathode and anode are dipped in the electrolyte (normally a salt solution of coating metal), containing suitable concentration of mineral acid.
- Mineral acids increase the electrical conductivity and suppress the hydrolysis of salt. pH of electrolyte is adjusted and suitable current density is chosen for electrolysis.
- As the electrolysis proceeds, the anode metal gets oxidized and enters the electrolytic solution.
- Themetal ions get reduced and deposited on cathodeto give uniform coating on the surface of basemetal article.
- The metal ions getting reduced and deposited at cathode are reformed by anode metal oxidation. Thus, there is no change in salt concentration of electrolyte.

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Reactions :

	Reaction at anode	Reaction at cathode	Salts for electrolyte
For nickel plating	$Ni \rightarrow Ni^{+2} + 2e^-$	$Ni^{+2} + 2e^- \rightarrow Ni$	$NiCl_4$, $NiSO_4$
For copper plating	$Cu \rightarrow Cu^{+2} + 2e^-$	$Cu^{+2} + 2e^- \rightarrow Cu$	$CuSO_4$
For silver plating	$Ag \rightarrow Ag^+ + e^-$	$Ag^+ + e^- \rightarrow Ag$	AgCN

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Applications of Electroplating:

1. Decorative Purposes: Plating gold, silver, or chrome onto jewelry, watches, and automotive parts.
2. Corrosion Protection: Plating metals like zinc, nickel, or chromium onto iron or steel surfaces.
3. Electrical Conductivity: Enhancing electrical conductivity of connectors, printed circuit boards, and contacts.
4. Mechanical Properties: Improving wear resistance, hardness, and lubricity of components.
5. Restoration and Preservation: Restoring and preserving antique items, artworks, and artifacts.

➔ c) **Anodic and cathodic coatings are two types of protective coatings used in various applications.**

1. Anodic Coatings:

- Anodic coatings are formed by anodizing a metal surface, typically aluminum or its alloys.

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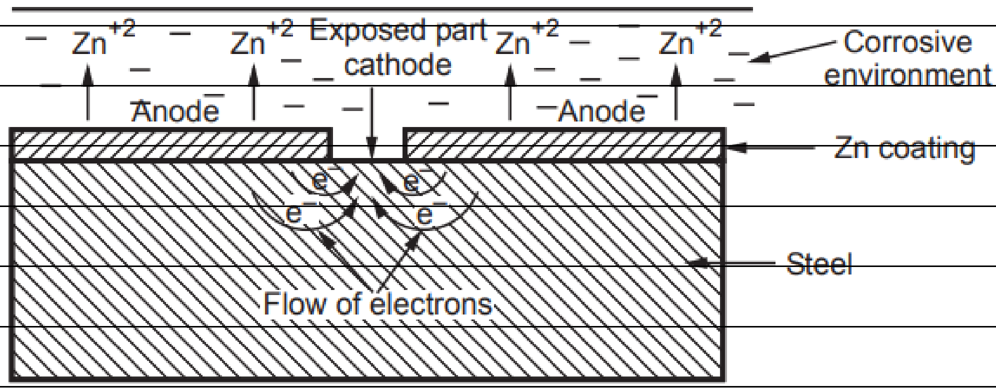
- Anodizing involves creating an oxide layer on the metal surface through an electrolytic process.
- Anodic coatings provide excellent corrosion resistance, hardness, and wear resistance.
- They offer good adhesion to the substrate and can be dyed or colored for aesthetic purposes.
- Anodic coatings can be porous or non-porous, depending on the specific application requirements.
- Examples of anodic coatings include anodized aluminum used in architectural, automotive, and electronic industries.

functioning diagram of anodic coatings:



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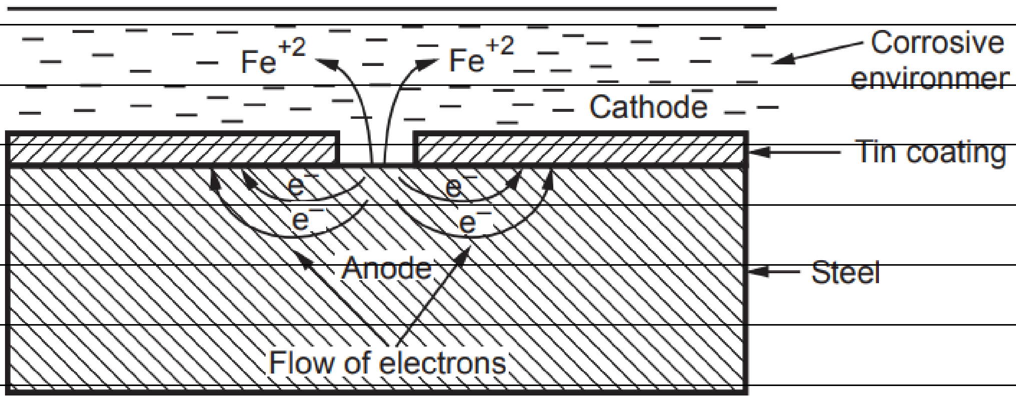
2. Cathodic Coatings:

- Cathodic coatings are typically achieved through cathodic electrodeposition, also known as electrocoating or electrophoretic deposition.
- Cathodic coatings involve immersing the object to be coated (cathode) in a bath containing paint or coating material and applying a direct current.
- Cathodic coatings provide excellent corrosion protection and adhesion to the substrate.
- Cathodic coatings can be applied to various materials, including metals, plastics, and composites.

- Examples of cathodic coatings include cathodic epoxy coatings used in automotive, aerospace, and industrial applications.

Functioning diagram of cathodic coating :



Which is better and why?

the selection of the better coating depends on factors such as the base material, desired properties, cost considerations, and the specific environmental conditions and performance requirements of the application.

Both types offer unique advantages

- Anodic coatings, such as anodized aluminum, provide superior corrosion resistance, hardness, and wear resistance.

They are particularly suitable for aluminum and its alloys in applications where durability and aesthetic appeal are important.

- Cathodic coatings, achieved through electrodeposition, offer excellent corrosion protection and adhesion to various substrates, including metals, plastics, and composites.

They are advantageous for achieving uniform film thickness on complex-shaped objects

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→ a) **Pilling-Bedworth Ratio:**

- The Pilling-Bedworth ratio is a concept used in corrosion science to determine the stability and protective nature of oxide films formed on metal surfaces during oxidation.
- It is the ratio of the volume change during oxide formation to the volume of the original metal.

Significance:

- The Pilling-Bedworth ratio is significant because it helps assess whether the oxide film formed during oxidation will provide effective corrosion protection.

The following scenarios can be observed:

1. Pilling-Bedworth Ratio < 1:

- In this case, the oxide film formed has a smaller volume than the original metal.
- This can lead to cracks and voids in the oxide film, exposing the metal to further corrosion. - The film may be ineffective in preventing corrosion.

2. Pilling-Bedworth Ratio = 1:

- When the Pilling-Bedworth ratio is equal to 1, the volume of the oxide film matches the volume of the original metal.
- This suggests that the oxide film will be continuous and tightly adherent to the metal surface, providing effective corrosion protection.

3. Pilling-Bedworth Ratio > 1:

- If the Pilling-Bedworth ratio is greater than 1, the oxide film has a larger volume than the original metal.
- This can lead to the formation of tensile stresses within the film, causing it to crack and delaminate.

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- The corrosion protection provided by the oxide film may be compromised.

Different Types of Oxide Films Formed during Oxidation Corrosion of Metals:

1. Protective Oxide Films:

- Certain metals, such as aluminum and stainless steel, form protective oxide films that adhere tightly to the metal surface.
- Examples include aluminum oxide (Al_2O_3) and chromium oxide (Cr_2O_3). These films act as barriers against further oxidation and corrosion.

2. Non-Protective Oxide Films:

- Some metals form oxide films that are not protective and do not provide effective corrosion resistance.
- For example, iron (Fe) forms rust, which is a porous and loosely adherent oxide film primarily composed of hydrated iron(III) oxide ($Fe_2O_3 \cdot nH_2O$).
- Rust is prone to flaking and does not offer long-term corrosion protection.

3. Passivation Films:

- Certain metals, such as stainless steel, can form passivation films when exposed to oxygen.
- These films are thin and self-repairing, providing an additional layer of protection against corrosion.
- An example is the chromium-rich oxide layer that forms on stainless steel, known as the passive layer.

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➔ b) **Factors Affecting the Rate of Corrosion:**

1. Environmental Conditions:

- Humidity, temperature, presence of corrosive gases, and pH of the surrounding medium affect corrosion.
- Aggressive environments with high moisture, elevated temperatures, and acidic conditions accelerate corrosion.

2. Metal Composition:

- The composition of the metal determines its susceptibility to corrosion.
- Some metals, like stainless steel and aluminum, form passive oxide layers that protect against corrosion.
- Alloying elements can enhance or decrease corrosion resistance.

3. Presence of Dissolved Oxygen:

- Availability of dissolved oxygen influences corrosion rates.
- Oxygen acts as an oxidizing agent, facilitating metal oxidation reactions and accelerating
corrosion.

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4. Electrolyte Conductivity:

- Presence of an electrolyte, such as an ion-containing solution, affects corrosion rates.
- Higher electrolyte conductivity enables more efficient electrochemical reactions, increasing corrosion rates.

5. Surface Area:

- The exposed surface area of the metal impacts corrosion rates.
- Greater surface area allows for more contact with the corrosive medium, leading to increased corrosion rates.
- Irregular osurfaces can promote localized corrosion with higher corrosion rates.

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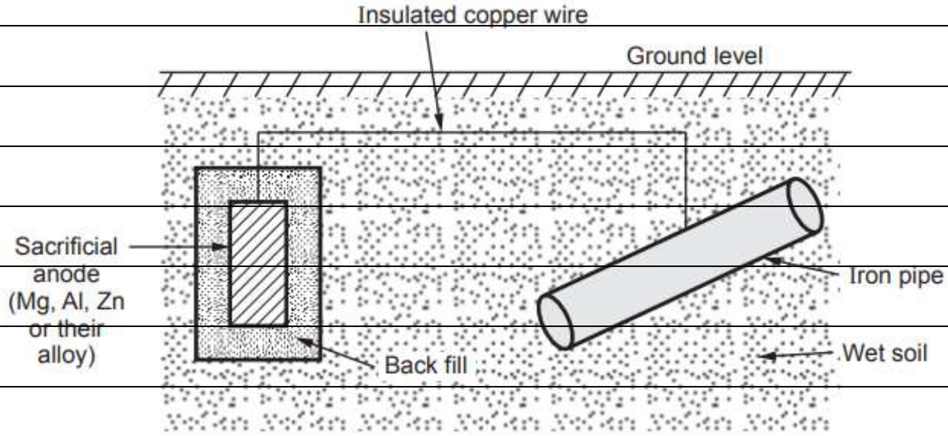
→ c)

Principle of Cathodic Protection:

- The principle of cathodic protection is based on the concept of creating a protective environment for a metal structure by making it the cathode of an electrochemical cell.
- By applying a direct current to the metal structure, the potential of the metal is shifted to a more negative value, effectively reducing or eliminating the corrosion reaction.

Diagram of Sacrificial Anode Cathodic Protection :



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- In sacrificial anode cathodic protection, a more reactive metal is connected to the metal structure to be protected.
- The sacrificial anode, usually made of a metal like zinc or magnesium, undergoes corrosion sacrificially instead of the protected structure.

how the sacrificial anode cathodic protection method works:

1. Selection of Sacrificial Anode:

- A suitable sacrificial anode material is chosen based on its position in the galvanic series and its ability to provide sufficient protection to the metal structure.
- The sacrificial anode material should have a more negative electrochemical potential compared to the protected structure.

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2. Connection of Sacrificial Anode:

- The sacrificial anode is connected to the metal structure to be protected, creating a direct electrical connection.
- This connection can be achieved through a metallic conductor or by direct contact.

3. Electrochemical Reaction:

- The sacrificial anode, being more reactive, undergoes corrosion instead of the protected metal structure.
- As a result, the sacrificial anode material is consumed over time.

4. Cathodic Protection:

- The corrosion process at the sacrificial anode generates electrons, which flow through the electrical connection to the protected metal structure.
- This flow of electrons causes the potential of the protected structure to become more negative, creating a cathodic protection effect.

5. Protection of Metal Structure:

- The more negative potential of the metal structure inhibits the corrosion reaction, preventing or significantly reducing the corrosion of the protected structure.
- The metal structure functions as the cathode in the electrochemical cell, effectively protected from corrosion.