GUJARAT TECHNOLOGICAL UNIVERSITY
BE- SEMESTER–1 PAPER SOLUTION – SUMMER 2025

Subject Name & Code:
Chemistry- B01000031

MARKS

Q.1 **(a)** What do you understand by biodegradable polymer? **03**

Answer:
Biodegradable polymers are polymers that can be broken down into simpler substances such as carbon dioxide, water, and biomass by the action of natural microorganisms like bacteria, fungi, and algae. These polymers decompose in the environment through enzymatic or hydrolytic processes without leaving harmful residues.

They are often used in medical applications (e.g., surgical sutures), agricultural films, and packaging materials due to their eco-friendly nature. Examples of biodegradable polymers include polylactic acid (PLA), polyhydroxybutyrate (PHB), and starch-based plastics.

(b) Distinguish between chemical and electrochemical corrosion. **04**

Answer:
Distinguish between Chemical and Electrochemical Corrosion

Point of Difference	**Chemical Corrosion**	**Electrochemical Corrosion**
Definition	It is the direct reaction of a metal with dry gases (like O_2, Cl_2, SO_2).	It occurs due to redox reactions involving a metal and an electrolyte.
Medium Required	Usually occurs in dry environments (e.g., dry air or gas).	Requires the presence of an electrolyte (moisture or conducting liquid).
Mechanism	Involves uniform oxidation on the metal surface.	Involves formation of anodic and cathodic areas on the metal surface.
Example	Rusting of metal in dry Cl_2 gas.	Rusting of iron in presence of water and air (moisture).
Rate of Corrosion	Generally slow.	Faster than chemical corrosion due to electrochemical reactions.

(c) Describe with neat diagram of zeolite process and write its advantages and disadvantages. **07**

Answer:
Chemical Reactions Involved:
1. **Exchange of Ca^{2+} and Mg^{2+} with Na^+:**

$Ca^{2+} + Na_2Ze \rightarrow CaZe + 2Na^+$
$Mg^{2+} + Na_2Ze \rightarrow MgZe + 2Na^+$

2. **Regeneration of exhausted zeolite (with brine solution):**

$CaZe + 2NaCl \rightarrow Na_2Ze + CaCl_2$
$MgZe + 2NaCl \rightarrow Na_2Ze + MgCl_2$

Neat Diagram:

Advantages of Zeolite Process:
1. **Efficient and economical** method for water softening.
2. **No sludge** formation like lime-soda process.
3. **Compact equipment** and easy to operate.
4. **Continuous supply** of soft water.
5. Zeolite can be **regenerated** and reused multiple times.

Disadvantages of Zeolite Process:
1. Cannot remove **acidic ions**, turbidity, or **iron and manganese ions** effectively.
2. Requires **clear and non-turbid water**.
3. Treated water contains **high sodium content** — not suitable for boilers above 10.5 kg/cm² pressure.
4. **Regular regeneration** is required.

Q.2 **(a)** Write the short note on caustic embrittlement. **03**

Answer:
Caustic Embrittlement (Short Note)
Definition:
Caustic embrittlement is a **type of boiler corrosion** that occurs due to the **localized concentration of sodium hydroxide (NaOH)** in high-pressure boilers. It leads to the **brittleness (cracking)** of boiler material, especially at the **stressed parts** such as bends, rivets, and joints.

Cause:
It is mainly caused when **sodium carbonate (Na_2CO_3)** used in water softening undergoes hydrolysis to form **NaOH**:

$Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2\uparrow$
This **concentrated NaOH seeps into small cracks or joints**, and attacks the boiler metal by forming **sodium ferrite (Na_2FeO_2)**, weakening the metal.

Reaction:

$Fe + 2NaOH \rightarrow Na_2FeO_2 + H_2\uparrow$

Prevention:
1. Use **phosphate conditioning** instead of sodium carbonate.

2. Add **tannins** or **lignin** to block hairline cracks.
3. Proper **boiler design and maintenance**.

(b) Explain Top down and Bottom up approaches for synthesis of nanomaterial. **04**

Answer:
Top-Down and Bottom-Up Approaches for Synthesis of Nanomaterials
Nanomaterials can be synthesized by two main approaches: **Top-Down** and **Bottom-Up**.

---

1. Top-Down Approach:
- In this approach, **bulk material is broken down into smaller nanosized particles** using mechanical, chemical, or physical methods.
- This method **starts with a larger structure** and **reduces it to the nanoscale**.

Examples:
- Mechanical milling
- Lithography
- Laser ablation
- Etching techniques

Advantages:
- Suitable for mass production
- Easier to scale up

Limitations:
- May introduce **defects** in nanostructures
- Limited control over size and shape

---

2. Bottom-Up Approach:
- In this approach, **nanomaterials are built atom by atom or molecule by molecule**.
- This mimics natural processes like **self-assembly**.

Examples:
- Sol-gel method
- Chemical vapor deposition (CVD)
- Precipitation
- Biosynthesis using microorganisms

Advantages:
- Better **control over particle size, shape, and structure**
- Produces **high-purity nanomaterials**

Limitations:
- Difficult to scale up for industrial production
- May require **complex conditions**

Conclusion:
Both approaches are essential in nanotechnology. **Top-Down** is useful for bulk processing, while **Bottom-Up** is ideal for precision and structure control at atomic levels.

(c) Discuss about pitting corrosion with neat diagram and mechanism. **07**

Answer:
Pitting Corrosion
Definition:
Pitting corrosion is a **localized form of corrosion** that leads to the formation of **small holes or pits** on the metal surface. It is one of the most dangerous forms of corrosion because it is difficult to detect and can lead to sudden failure.

Diagram of Pitting Corrosion:

Mechanism of Pitting Corrosion:

1. **Initiation:**
   - Usually starts at **weak points** such as surface defects, scratches, or impurities.
   - The **protective oxide layer** (passive film) on the metal surface **breaks down** locally.
2. **Anodic Reaction (Inside the pit):**
   Metal gets oxidized:
   $$M \rightarrow Mn + +ne-$$
3. **Cathodic Reaction (Outside the pit):**
   Dissolved oxygen is reduced:
   $$O2+2H2O+4e- \rightarrow 4OH-$$
4. **Autocatalytic Growth:**
   - Inside the pit, metal ions (M^{n+}) hydrolyze to form acidic conditions:
     $$Mn++H2O \rightarrow MOH(n-1)++H+$$
   - The acidity accelerates corrosion.
   - Chloride ions (Cl^-) from the environment migrate into the pit and form **metal chlorides**, further lowering pH.
5. **Propagation:**
   - The pit deepens rapidly due to **localized acidic conditions**.
   - The surrounding surface remains passive, so the attack is highly **localized**.

Consequences of Pitting Corrosion:

- Loss of mechanical strength.
- Leakage in pipelines, tanks, or boilers.
- Often leads to **unexpected failures**.

Metals Susceptible to Pitting Corrosion:

- Stainless steel
- Aluminium
- Copper alloys

Prevention:

- Use of corrosion inhibitors.
- Proper material selection (e.g., more resistant alloys).
- Regular cleaning and inspection.
- Avoiding stagnant solutions and chlorides.

OR

(c) What is NMR spectroscopy? Explain with instrumentation and applications. **07**

Answer:
NMR Spectroscopy
Definition:
NMR (Nuclear Magnetic Resonance) spectroscopy is an analytical technique used to determine the **structure of organic compounds** by studying the **magnetic properties of certain nuclei**, typically **protons (^1H)** or **carbon-13 (^{13}C)**.

Basic Principle:

- Certain nuclei like ^1H and ^{13}C possess **nuclear spin** and behave like tiny magnets.
- When placed in a **strong magnetic field**, they can align either with or against the field.
- If **radiofrequency (RF) radiation** of the correct energy is applied, the nuclei **resonate**—they absorb this energy and flip their spin states.
- The energy absorbed is detected and converted into a spectrum.

Instrumentation of NMR Spectroscopy:

1. **Sample Holder:**
    - Sample is dissolved in a suitable solvent (usually deuterated solvents like $CDCl_3$ or D_2O) and placed in an NMR tube.
2. **Magnet:**
    - A **strong superconducting magnet** creates a uniform magnetic field to align nuclear spins.
3. **Radiofrequency (RF) Generator:**
    - Produces RF radiation that excites the nuclei to a higher energy state.
4. **Detector (Receiver Coil):**
    - Detects the emitted radiation when the nuclei return to their lower energy state.
5. **Computer System:**
    - Processes the signal and displays the **NMR spectrum**.

Diagram of NMR Instrument (Simple Block Diagram):

Applications of NMR Spectroscopy:

1. **Structural Elucidation:**
    - Used to determine the **structure and bonding** in organic compounds.
2. **Identification of Compounds:**
    - Helps in identifying **unknown substances** by comparing their spectra.
3. **Purity Check:**
    - Used to check the **purity** of organic compounds.
4. **Conformational Studies:**
    - Provides information about the **conformations** of molecules (e.g., cis-trans isomers).
5. **Medical Application:**
    - The principle of NMR is used in **MRI (Magnetic Resonance Imaging)** for medical diagnostics.

Conclusion:

NMR spectroscopy is a powerful and non-destructive analytical tool widely used in **chemical, pharmaceutical, and medical fields** for qualitative and quantitative analysis.

Q.3 **(a)** Write the applications of IR spectroscopy. **03**

Answer:
Applications of IR (Infrared) Spectroscopy:
Infrared spectroscopy is widely used for the identification and study of molecular structures by analyzing their **vibrational transitions**.

1. Identification of Functional Groups:
- IR spectroscopy helps to detect **functional groups** such as –OH, $–NH_2$, –COOH, –C=O, etc., based on their **characteristic absorption bands**.

2. Structure Elucidation:
- It provides information about **bond types and molecular structure**. For example, it can distinguish between alkanes, alkenes, and alkynes.

3. Purity of Compounds:
- A pure compound gives a **sharp and distinct IR spectrum**. Any impurity will show **extra peaks**.

4. Monitoring Reactions:
- It is used to observe the **progress of chemical reactions** by monitoring the disappearance or appearance of specific functional groups.

5. Polymer and Material Analysis:
- Widely used in studying polymers and materials to determine **chemical composition** and detect **defects or additives**.

Conclusion:
IR spectroscopy is a **non-destructive, fast, and reliable tool** for qualitative analysis in **organic chemistry, pharmaceuticals, polymers**, and **material science**.

(b) Explain properties and uses of copper, aluminum and nickel alloys. **04**

Answer:
Properties and Uses of Copper, Aluminium, and Nickel Alloys
1. Copper Alloys (e.g., Brass, Bronze)
Properties:
- Good electrical and thermal conductivity
- Excellent corrosion resistance
- Malleable and ductile
- Non-magnetic and antimicrobial

Uses:
- Electrical wiring and components (due to high conductivity)
- Plumbing and roofing
- Coins and musical instruments
- Bearings and marine hardware (in the form of bronze)

---

2. Aluminium Alloys (e.g., Duralumin, Magnalium)
Properties:
- Lightweight and low density
- High strength-to-weight ratio
- Good corrosion resistance due to oxide film

- Easily machinable and non-magnetic

Uses:
- Aerospace and aviation parts (aircraft body)
- Automobile engine components and body panels
- Packaging materials (cans and foils)
- Structural parts and kitchen utensils

---

3. Nickel Alloys (e.g., Monel, Inconel)
Properties:
- Excellent strength and toughness
- High resistance to heat and corrosion
- Oxidation and creep resistance
- Maintains properties at high temperatures

Uses:
- Turbine blades and jet engines
- Heat exchangers and chemical processing equipment
- Marine and nuclear applications
- Battery electrodes and coinage

Conclusion:
Alloys of copper, aluminium, and nickel are **essential materials** in engineering due to their **desirable mechanical, thermal, and corrosion-resistant properties**, making them suitable for a wide range of **industrial and technological applications**.

(c) Describe types of hybridization with suitable example of each type. **07**

Answer:
Types of Hybridization with Suitable Examples
Hybridization is the process of mixing atomic orbitals to form new hybrid orbitals with equivalent energy, suitable for the pairing of electrons to form chemical bonds in molecules.
There are several types of hybridization depending on the number and type of orbitals involved.

---

1. sp Hybridization (Linear Geometry)
- **Orbitals Involved:** 1 s + 1 p
- **Number of Hybrid Orbitals:** 2
- **Geometry:** Linear (180° bond angle)
- **Example: $BeCl_2$**
  - In $BeCl_2$, the central Be atom undergoes sp hybridization to form two sp hybrid orbitals that form sigma bonds with two Cl atoms.

---

2. sp^2 Hybridization (Trigonal Planar Geometry)
- **Orbitals Involved:** 1 s + 2 p
- **Number of Hybrid Orbitals:** 3
- **Geometry:** Trigonal planar (120° bond angle)
- **Example: BF_3**
  - In BF_3, the B atom forms three sp^2 hybrid orbitals which make sigma bonds with three fluorine atoms.

---

3. sp^3 Hybridization (Tetrahedral Geometry)
- **Orbitals Involved:** 1 s + 3 p
- **Number of Hybrid Orbitals:** 4

- **Geometry:** Tetrahedral (109.5° bond angle)
- **Example: CH_4 (Methane)**
    - The carbon atom in methane uses four sp^3 hybrid orbitals to form four sigma bonds with hydrogen atoms.

---

4. sp^3d Hybridization (Trigonal Bipyramidal Geometry)

- **Orbitals Involved:** 1 s + 3 p + 1 d
- **Number of Hybrid Orbitals:** 5
- **Geometry:** Trigonal bipyramidal (bond angles 90° and 120°)
- **Example: PCl_5**
    - Phosphorus uses five sp^3d orbitals to form five sigma bonds with chlorine atoms.

---

5. sp^3d^2 Hybridization (Octahedral Geometry)

- **Orbitals Involved:** 1 s + 3 p + 2 d
- **Number of Hybrid Orbitals:** 6
- **Geometry:** Octahedral (90° bond angles)
- **Example: SF_6**
    - Sulphur forms six sp^3d^2 hybrid orbitals to bond with six fluorine atoms.

Conclusion:
Hybridization helps in understanding the shape and bonding of molecules. The type of hybridization depends on the number of sigma bonds and lone pairs around the central atom.

OR

Q.3 **(a)** What do you meant by biomass briquettes? **03**

Answer:
Biomass briquettes are a type of renewable and eco-friendly solid fuel made from **agricultural waste, forestry residues, and other organic materials** such as sawdust, groundnut shells, rice husk, and bagasse. These materials are compressed under high pressure without using any binder to form solid blocks or cylindrical shapes called **briquettes**.

Key Features:

- Biomass briquettes are used as a substitute for **coal, wood, and other fossil fuels**.
- They are produced using **briquetting machines** which compress the raw material into a dense, combustible form.
- Briquettes have **high calorific value**, low moisture content, and produce less smoke.

Advantages:

- Eco-friendly and carbon-neutral fuel.
- Utilizes agricultural waste, reducing disposal problems.
- Reduces dependency on non-renewable energy sources.

Example:

- Briquettes made from **sawdust** are commonly used in industrial boilers and domestic stoves.

(b) State Lambert and Beer's law and deduce its mathematical expression. **04**

Answer:
Lambert's Law and Beer's Law
Lambert's Law:
Lambert's law states that *"the intensity of monochromatic light decreases exponentially as it passes through an absorbing medium, and the rate of decrease in intensity is directly proportional to the thickness (path length) of the medium."*
Mathematically:

$$\frac{dI}{dx} = -kI$$

Where:

- I= intensity of light
- x = thickness of absorbing medium
- k = absorption coefficient

Beer's Law:
Beer's law states that *"the absorbance of light by a solution is directly proportional to the concentration of the absorbing species present in the solution."*
Mathematically:

$$A \propto C$$

Where:

- A = absorbance
- C = concentration

Combined Lambert-Beer's Law:
When combined, the laws are expressed as:

$$A = \varepsilon \cdot C \cdot l$$

Where:

- A = absorbance (unitless)
- ε = molar absorptivity ($L\ mol^{-1}\ cm^{-1}$)
- C = concentration of solution (mol/L)
- l = path length (cm)

Conclusion:
Lambert-Beer's law is the basis of many spectrophotometric methods used to determine the concentration of solutions in analytical chemistry.

(c) What is ferrous alloy? Explain heat treatments and applications of steel alloy. **07**

Answer:
What is Ferrous Alloy?
A **ferrous alloy** is a metallic material that contains **iron (Fe) as its main constituent**. These alloys usually include small amounts of **carbon**, and sometimes other elements like **chromium, nickel, manganese, vanadium, etc.**, to enhance properties such as strength, hardness, and corrosion resistance.
Examples:

- Carbon steel
- Stainless steel
- Cast iron

- Tool steel

Heat Treatment of Steel Alloys:
Heat treatment is a process involving heating and cooling of metals in a controlled manner to alter their **physical and mechanical properties** without changing the chemical composition.
Common Heat Treatment Processes:

1. **Annealing:**
    - *Process:* Steel is heated to a specified temperature and then cooled slowly.
    - *Purpose:* Increases ductility, reduces hardness, removes internal stresses.
2. **Normalizing:**
    - *Process:* Steel is heated above its critical temperature and then cooled in air.
    - *Purpose:* Refines grain structure, improves toughness.
3. **Hardening:**
    - *Process:* Steel is heated above the critical temperature and then rapidly cooled (quenched) in water or oil.
    - *Purpose:* Increases hardness and strength.
4. **Tempering:**
    - *Process:* Performed after hardening; steel is reheated to a lower temperature and cooled.
    - *Purpose:* Reduces brittleness, improves toughness.
5. **Case Hardening / Surface Hardening:**
    - *Process:* Only the surface of the steel is hardened while the core remains soft.
    - *Purpose:* Gives a hard surface with a tough inner core (useful for gears, shafts).

Applications of Steel Alloys:

1. **Carbon Steel:**
    - Used in construction (beams, bridges), automotive parts, pipelines.
2. **Alloy Steel:**
    - Used in tools, high-strength machine parts, and pressure vessels.
3. **Stainless Steel:**
    - Due to its corrosion resistance, used in medical instruments, kitchenware, chemical plants.
4. **Tool Steel:**
    - Used in cutting tools, dies, and molds due to high hardness and wear resistance.

Conclusion:
Ferrous alloys, especially steel and its heat-treated forms, are vital in various industries due to their **versatile mechanical properties**. Heat treatment enhances the usability and durability of these materials in engineering applications.

Q.4 **(a)** Explain types of inhibitors with example. **03**

Answer:
Explain Types of Inhibitors with Example:
Inhibitors are chemical substances that **decrease the rate of corrosion** by

forming a protective layer on the metal surface or interfering with the corrosion process.
Inhibitors are classified into the following **types**:

---

1. Anodic Inhibitors:

- These inhibitors reduce the rate of anodic (oxidation) reaction.
- They form a **passive oxide layer** on the metal surface.
- *Example:* **Chromates**, **phosphates**, and **molybdates**.

---

2. Cathodic Inhibitors:

- These decrease the rate of **cathodic (reduction) reaction**, usually by precipitation or blocking the cathodic sites.
- *Example:* **Zinc salts**, **arsenates**, and **antimonates**.

---

3. Mixed Inhibitors:

- These inhibitors **affect both anodic and cathodic reactions**.
- They form a protective film over the entire metal surface.
- *Example:* **Sodium silicate**, **polyphosphates**, and **benzoates**.

---

4. Vapor Phase Inhibitors (Volatile Inhibitors):

- These are **volatile chemicals** that **sublime** and form a protective layer in enclosed systems (e.g., in storage).
- *Example:* **Dicyclohexylammonium nitrite (DICHAN)** and **benzotriazole**.

Conclusion:
Inhibitors are an effective and economical method for **preventing corrosion** in industries, and their selection depends on the type of environment and the metal to be protected.

(b) Define and write Schrodinger's wave equation. **04**

Answer:
Definition:
Schrödinger's wave equation is a fundamental equation in quantum mechanics that **describes the behavior of an electron** (or any microscopic particle) in terms of a **wave function (ψ)**. It helps to determine the **energy levels** and **probability distribution** of electrons in atoms and molecules.
The wave function **ψ (psi)** contains all the information about the system. The square of the wave function, $|\psi|^2$, gives the **probability density** of finding a particle in a given region of space.

Schrödinger's Time-Independent Wave Equation (for one particle in 3D space):

$$-\frac{h^2}{8\pi^2 m}\nabla^2\psi + V\psi = E\psi$$

Or,

$$\left(-\frac{\hbar^2}{2m}\nabla^2 + V\right)\psi = E\psi$$

Where:
- $\nabla 2$ = Laplacian operator (second derivative with respect to space),
- h = Planck's constant,
- $\hbar$=h2/π = reduced Planck's constant,
- m = mass of the particle,
- ψ = wave function,
- V = potential energy,
- E = total energy of the system.

Explanation:
- The **left side** of the equation represents the **total energy operator** (kinetic + potential energy).
- The **right side** gives the **actual energy (E)** of the particle when operating on the wave function.

Conclusion:
Schrödinger's equation is the **foundation of quantum mechanics** and is used to predict **energy levels** and **electron distribution** in atoms and molecules.

(c) Describe with neat diagram of fractional distillation of crude petroleum. **07**

Answer:
Introduction:
Crude petroleum is a complex mixture of hydrocarbons which cannot be used directly. It is separated into useful fractions by a **physical separation process** known as **fractional distillation**.

Fractional Distillation:
Fractional distillation is a process of **separating components of crude petroleum** based on their **boiling points**. It is carried out in a **fractionating column**, which operates on the principle that **different hydrocarbon fractions condense at different heights** in the column due to their specific boiling ranges.

Process:
1. **Heating:**
   Crude petroleum is first heated in a **furnace** to about **400–600°C**, converting it into a **vapour-liquid mixture**.
2. **Entry into Fractionating Column:**
   The hot mixture is then fed into the **fractionating column** from near the bottom.
3. **Fractionating Column:**
   The column is a **tall tower** fitted with **horizontal trays** or **bubble caps** at regular intervals. It has **temperature decreasing from bottom to top**.
4. **Separation of Fractions:**
   - Vapors rise through the column.
   - Heavier hydrocarbons with **high boiling points** condense **lower** in the column.
   - Lighter hydrocarbons with **low boiling points** condense **higher** in the column.
   - Each tray collects a different **fraction** based on boiling range.

Diagram:

Main Fractions and Their Uses:

Fraction	Boiling Range	Uses
Petroleum gas	< 40°C	LPG for cooking, fuel
Petrol (Gasoline)	40–120°C	Motor fuel
Naphtha	120–180°C	Chemical industry (solvents)
Kerosene	180–250°C	Jet fuel, domestic lighting
Diesel oil	250–320°C	Diesel engines
Lubricating oil	320–400°C	Lubrication of machinery
Fuel oil	>400°C	Industrial heating
Bitumen/residue	Leftover	Road surfacing, waterproofing

Conclusion:
Fractional distillation is a **crucial refining process** that separates crude petroleum into **economically valuable products** used in **transportation, heating, and chemical industries**.

OR

Q.4 (a) Write the properties and applications of fullerenes. **03**

Answer:
Properties and Applications of Fullerenes
Properties of Fullerenes:

1. **Molecular Structure:**
   - Fullerenes are allotropes of carbon, composed entirely of carbon atoms arranged in **closed hollow spheres**, **ellipsoids**, or **tubes**.
   - The most common fullerene is **C_{60}**, shaped like a **soccer ball** (truncated icosahedron).
2. **Solubility:**
   - Unlike other carbon allotropes (like graphite and diamond), fullerenes are **soluble in organic solvents** such as toluene and benzene.
3. **Electrical Properties:**
   - Fullerenes act as **semiconductors** and can **accept electrons**, making them useful in electronic applications.
4. **Thermal Stability:**
   - They are **thermally stable** and can withstand high temperatures without decomposition.
5. **Chemical Reactivity:**
   - Fullerenes can undergo **addition reactions** and can form a wide variety of **derivatives** with different properties.

Applications of Fullerenes:

1. **Medicine:**
   - Used in **drug delivery systems**, **antioxidants**, and potential **anti-cancer treatments**.
2. **Electronics:**
   - Employed in **organic solar cells**, **field-effect transistors (FETs)**, and **superconductors**.
3. **Lubricants:**
   - Due to their spherical shape, fullerenes are used as **molecular ball bearings** in **lubrication systems**.
4. **Materials Science:**
   - Used in developing **high-strength materials**, **coatings**, and **composites**.
5. **Environmental:**
   - Investigated for **hydrogen storage** and **pollutant removal** from water and air.

Conclusion:
Fullerenes exhibit unique structural, chemical, and physical properties, making them highly valuable in **advanced scientific and industrial applications**.

(b) Distinguish between sludge and scale formation with examples. **04**

Answer:
Distinguish between Sludge and Scale Formation (With Examples)

Sr. No.	**Sludge**	**Scale**
1	Sludge is a **soft, loose, and slimy precipitate** formed inside the boiler.	Scale is a **hard, adherent, and dense deposit** formed on the inner walls of the boiler.
2	It forms in areas of **low temperature** (e.g., cooler parts of the boiler like bends and joints).	It forms in areas of **high temperature** (e.g., near the heating surface of the boiler).
3	Sludge can be **easily removed** by **blow down operation**.	Scale is **hard and tightly adhered**, and requires **mechanical or chemical removal**.
4	Sludge is formed due to **magnesium chloride ($MgCl_2$), magnesium sulphate ($MgSO_4$), calcium bicarbonate ($Ca(HCO_3)_2$)**, etc.	Scale is formed due to **calcium sulphate ($CaSO_4$), calcium carbonate ($CaCO_3$), and silica (SiO_2)**.
5	Sludge does **not hinder heat transfer** significantly.	Scale acts as an **insulator** and **reduces heat transfer efficiency**, causing overheating.

Conclusion:
Sludge and scale are both undesirable in boiler operation. While **sludge** is relatively easy to remove and forms in low-temperature areas, **scale** is hard

and forms in high-temperature zones, leading to **reduced efficiency and damage** to the boiler.

(c) What is chromatography? Explain principle and instrumentation of gas chromatography. **07**

Answer:
Chromatography
Definition:
Chromatography is a **separation technique** used to separate and analyze the components of a mixture based on their **differential distribution between a stationary phase and a mobile phase**.

Gas Chromatography (GC)
Principle:
Gas chromatography works on the principle of **partitioning**. The components of a vaporized sample are distributed between a **stationary phase (usually a liquid or solid on a solid support)** and a **mobile phase (an inert gas like helium or nitrogen)**. Each component travels through the column at a different rate depending on its **boiling point, polarity**, and **interaction with the stationary phase**, allowing for their separation and analysis.

Instrumentation of Gas Chromatography:
A typical gas chromatograph consists of the following major components:
1. Carrier Gas System:
- Inert gases like **helium, nitrogen, or argon** are used as the **mobile phase**.
- They help to carry the sample through the column.

2. Sample Injection Port:
- A small amount of liquid or gaseous sample is injected using a micro-syringe.
- The sample is **immediately vaporized** in the heated zone.

3. Column:
- Made of stainless steel or glass and **coiled** inside an oven.
- Filled with **stationary phase** (a solid or liquid coated on a solid support).
- It is housed in a **temperature-controlled oven**.

4. Column Oven:
- Maintains the **optimum temperature** required for the separation.
- Can be programmed to vary temperature for better resolution.

5. Detector:
- Detects the separated components as they exit the column.
- Common detectors include **Flame Ionization Detector (FID)** and **Thermal Conductivity Detector (TCD)**.

6. Recorder / Data System:
- Records a **chromatogram** showing peaks corresponding to each component.
- Peak **retention time** is used to identify substances, and peak area is used to measure quantity.

Diagram of Gas Chromatography Setup:

Applications of Gas Chromatography:
- Analysis of **petroleum products**, **alcohols**, and **hydrocarbons**.
- Detection of **pollutants** in air or water.

- Quality control in **pharmaceutical** and **food** industries.
- Forensic science (e.g., alcohol detection in blood).

Q.5 (a) Define and write Heisenberg's Uncertainity principle. **03**

Answer:
Heisenberg's Uncertainty Principle
Definition:
Heisenberg's Uncertainty Principle states that:
"It is impossible to determine simultaneously and precisely both the position and momentum (or velocity) of a microscopic particle, such as an electron."
This principle arises due to the dual nature of matter, particularly for particles like electrons which exhibit both wave and particle characteristics.

Mathematical Expression:

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

Where:

- Δx = uncertainty in position
- Δp = uncertainty in momentum (= mass × velocity)
- h = Planck's constant (6.626×10^{-34} Js)

Explanation:
This principle implies that **the more precisely the position of a particle is known, the less precisely its momentum can be known**, and vice versa. This limitation is not due to experimental errors but is a **fundamental property of quantum systems**.

(b) Differentiate between proximate and ultimate analysis of coal. **04**

Answer:
Difference Between Proximate and Ultimate Analysis of Coal

Sr. No.	Proximate Analysis	Ultimate Analysis
1	Proximate analysis determines the **physical constituents** of coal.	Ultimate analysis determines the **elemental composition** of coal.
2	It gives the percentage of **moisture**, **volatile matter**, **ash**, and **fixed carbon**.	It gives the percentage of **carbon (C)**, **hydrogen (H)**, **nitrogen (N)**, **sulphur (S)**, and **oxygen (O)**.
3	It is used to assess the **quality and grade** of coal.	It is used to understand the **chemical composition** and **combustion properties** of coal.
4	This analysis is **simpler and quicker** to perform.	This analysis is **more detailed and complex**.
5	It is useful for **practical uses** like boiler operation and fuel classification.	It is useful for **calculating calorific value** and air requirement for combustion.

Conclusion:

Both analyses are essential for evaluating the suitability of coal for various industrial purposes, such as power generation and metallurgy.

(c) Describe with suitable diagram to determination of calorific value by bomb calorimeter. **07**

Answer:
Determination of Calorific Value by Bomb Calorimeter
Definition:
The **calorific value** of a fuel is the amount of heat released when a unit mass of fuel is completely burned in oxygen. It is expressed in **kJ/kg** or **kcal/kg**.

Bomb Calorimeter – Construction & Diagram:
Diagram:

Working Principle:
The bomb calorimeter works on the principle of **conservation of energy**. The heat produced by combustion of the fuel is absorbed by a known mass of water, and the temperature rise is measured.

Procedure:
1. A known mass of **air-dried fuel sample** is taken in a crucible inside the steel bomb.
2. The bomb is filled with **pure oxygen** (25-30 atm).
3. The bomb is placed in the **calorimeter vessel** containing a known mass of water.
4. Initial **temperature** of water is recorded.
5. The fuel is ignited by an **electric ignition coil**.
6. After complete combustion, the **final temperature** of water is noted.
7. The heat released by fuel = heat absorbed by water + calorimeter.

Formula to Calculate Calorific Value:

$$\text{Gross Calorific Value (GCV)} = \frac{(W + w)(T_2 - T_1) + C_c}{m}$$

Where:
- W = mass of water (kg)
- w= water equivalent of calorimeter (kg)
- T1 = initial temperature (°C)
- T2 = final temperature (°C)
- Cc = heat correction for fuse wire, acid formation, etc. (kJ)
- m = mass of fuel sample (kg)

Net Calorific Value (NCV):

$$\text{NCV} = \text{GCV} - \left(\frac{m \times 9 \times L}{100}\right)$$

Where **L** is the latent heat of steam (approx. 587 kcal/kg or 2.45 MJ/kg).

Conclusion:
Bomb calorimetry gives **accurate calorific values** for solid and liquid fuels and is widely used in fuel testing laboratories.

OR

Q.5 **(a)** Write the uses of carbon nanotubes and nanowires. **03**

Answer:
Uses of Carbon Nanotubes and Nanowires
1. Carbon Nanotubes (CNTs):
Carbon nanotubes are cylindrical nanostructures made of carbon atoms. They exhibit exceptional mechanical, electrical, and thermal properties.
Uses of Carbon Nanotubes:

- **Electronics:** Used in field-effect transistors (FETs) and nano-circuits due to their excellent electrical conductivity.
- **Composites:** Reinforce polymers and metals to enhance strength and reduce weight in aerospace and automotive components.
- **Sensors:** Used in chemical and biosensors because of high surface area and sensitivity.
- **Drug Delivery:** Serve as carriers for targeted drug delivery in biomedical applications.
- **Energy Devices:** Used in supercapacitors, fuel cells, and batteries.

---

2. Nanowires:
Nanowires are ultra-thin wires with diameters in the nanometer range, made from materials like metals (e.g., gold, silver), semiconductors (e.g., silicon), or oxides.
Uses of Nanowires:

- **Nanoelectronics:** Act as conducting pathways in nano-scale electronic devices.
- **Photovoltaics:** Used in solar cells to enhance light absorption and efficiency.
- **Sensors:** Employed in gas and biosensors due to high sensitivity and surface-to-volume ratio.
- **Optoelectronics:** Used in LEDs and photodetectors.
- **Energy Storage:** Play a role in next-generation battery and supercapacitor development.

(b) Explain the fermentation process for preparation of acetic acid. **04**

Answer:
Fermentation Process for Preparation of Acetic Acid
Acetic acid (CH_3COOH) is commercially prepared by the **aerobic fermentation** of ethyl alcohol (ethanol) using specific microorganisms.

Process:

- **Raw Material:** Dilute ethyl alcohol (10–15%) solution.
- **Microorganism Used:** *Acetobacter aceti* (also known as vinegar bacteria).
- **Type of Fermentation:** Aerobic fermentation (requires oxygen).

Chemical Reaction:

$$C_2H_5OH\ (ethanol) + O_2 \xrightarrow{\text{Acetobacter aceti}} CH_3COOH\ (acetic\ acid) + H_2O$$

Steps in the Process:

1. **Preparation of Medium:**
    - A dilute solution of ethanol is taken as the substrate.
2. **Inoculation:**
    - The solution is inoculated with *Acetobacter aceti*.
3. **Aeration:**
    - The fermentation is carried out in a shallow tray or tank known as a **fermenter** or **acetator**.
    - Continuous supply of air (oxygen) is provided to support aerobic conditions.
4. **Fermentation Time:**
    - The process continues for **2 to 3 days** at around **30°C**.
5. **Product Formation:**
    - Ethanol is oxidized to acetic acid by the bacteria.

Diagram: ***(Draw a simple fermenter setup with ethanol + bacteria + air inlet and collection outlet for acetic acid.)***

(c) Discuss about construction, working and uses of lithium batteries. **07**

Answer:
Construction, Working, and Uses of Lithium Batteries

---

1. Introduction:
Lithium batteries are a type of **primary or secondary electrochemical cell** that use **lithium metal or lithium compounds** as an anode material. Due to lithium's high electrochemical potential, these batteries offer **high energy density and long shelf life**.

---

2. Construction:
A **lithium battery** typically consists of the following components:

- **Anode (Negative Electrode):** Lithium metal or lithium compound (e.g., lithium cobalt oxide).
- **Cathode (Positive Electrode):** A metal oxide such as manganese dioxide (MnO_2), cobalt oxide (CoO_2), or iron disulfide (FeS_2).
- **Electrolyte:** A non-aqueous electrolyte like a lithium salt ($LiPF_6$, $LiBF_4$) dissolved in an organic solvent (e.g., ethylene carbonate).
- **Separator:** A porous membrane that prevents direct contact between anode and cathode while allowing ion flow.
- **Container:** Airtight and corrosion-resistant housing to prevent moisture ingress.

---

3. Working Principle:

- When the battery discharges:
    - **Lithium atoms from the anode** lose electrons (oxidation) and form **Li^+ ions**.
    - The **Li^+ ions migrate through the electrolyte** to the cathode.
    - At the cathode, these ions **combine with electrons** (reduction) and get embedded into the cathode material.

During charging (in rechargeable lithium-ion batteries), the reverse process takes place.

Electrochemical Reactions (in lithium-ion cell):

- **At Anode:**

$Li \rightarrow Li^{+} + e^{-}$

- **At Cathode:**
  $Li^{+} + e^{-} + CoO_2 \rightarrow LiCoO_2$

---

4. Diagram:

5. Uses of Lithium Batteries:

- **Portable Electronics:** Mobile phones, laptops, cameras.
- **Medical Devices:** Pacemakers, hearing aids.
- **Electric Vehicles (EVs):** Power source for modern EVs and hybrid vehicles.
- **Aerospace:** Satellites and space applications due to lightweight and high energy.
- **Backup Systems:** UPS and emergency lighting systems.
- **Power Tools:** Cordless drills and other rechargeable tools.

---

6. Advantages:

- High energy density
- Long shelf life
- Lightweight
- Low self-discharge rate
- Rechargeable types available (Li-ion)

Conclusion:
Lithium batteries are widely used due to their superior performance, compactness, and long cycle life. Their applications are rapidly expanding in modern technology and sustainable energy systems.