Subject Name & Code:

CHEMISTRY- B01R00031

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Analytical Techniques

Q.1 Working Principle of UV-Visible, Infra-Red, and NMR Spectroscopy

Technique	Principle
UV-Visible	Measures absorption of UV/visible light (200–800 nm) due to electronic transitions in molecules ($\pi \rightarrow \pi$, $n \rightarrow \pi$). Follows Beer-Lambert law: $A = \varepsilon cl$.
Infra-Red	Measures absorption of IR radiation (4000–400 cm^{-1}) causing vibrational transitions (stretching, bending) in covalent bonds. Each functional group has a characteristic frequency.
NMR	Measures absorption of radio waves by atomic nuclei (e.g., ^{1}H, ^{13}C) in a strong magnetic field. Nuclei with spin $\neq 0$ align with/against field; resonance occurs when RF energy matches energy difference ($\Delta E = h\nu$).

Q.2 Applications of UV-Visible, Infra-Red, and NMR Spectroscopy

Technique	Applications
UV-Visible	Quantification of compounds (e.g., DNA, proteins), determination of unknown concentration, study of conjugated systems, kinetics of reactions.
Infra-Red	Identification of functional groups (e.g., –OH, C=O, N–H), detection of impurities, polymer analysis, quality control in pharmaceuticals.
NMR	Structure elucidation of organic compounds, study of dynamic processes (e.g., rotation), purity assessment, metabolomics, protein folding.

Q.3 Thin Layer Chromatography (TLC)

Principle: Separation based on differential adsorption of compounds on a stationary phase (silica gel or alumina coated on glass/plastic plate) and a mobile phase (organic solvent).

Steps:

1. **Preparation:** Spot sample near bottom of TLC plate.
2. **Development:** Place plate in solvent chamber; solvent rises by capillary action.
3. **Visualization:** Use UV lamp or iodine vapors to see spots.
4. **Calculation:**

$$R_f = \frac{\text{Distance traveled by solute}}{\text{Distance traveled by solvent front}}$$

Applications: Checking purity of compounds, monitoring reaction progress, identifying plant extracts.

Q.4 Gas Chromatography (GC)

Principle: Separation of volatile compounds based on partitioning between a mobile gas phase (carrier gas: He, N_2) and a stationary liquid phase coated on a column.

Key components:

- Injector (heated to vaporize sample)
- Column (packed or capillary) in an oven
- Detector (FID, TCD, ECD)

Workflow:
Sample injected → vaporized → carried through column by inert gas → separated based on boiling point & polarity → detected → chromatogram produced (retention time identifies compound, peak area quantifies).

Applications: Petroleum analysis, forensic science, environmental monitoring (pesticides, pollutants).

Q.5 Liquid Chromatography (HPLC)

Principle: Separation of dissolved compounds using high pressure to pump a liquid mobile phase through a column packed with solid stationary phase (C18, silica).

Modes:

- **Normal phase:** Polar stationary phase, non-polar mobile phase.
- **Reverse phase:** Non-polar stationary phase, polar mobile phase (most common).

Detection: UV-Vis, fluorescence, or mass spectrometer (LC-MS).

Applications: Pharmaceutical purity testing, protein separation, food additive analysis, clinical diagnostics.

Fermentation

Q.1 Manufacturing Process of Ethanol from Molasses

Raw material: Molasses (byproduct of sugar industry; contains ~50% sucrose).

Steps:

1. **Dilution:** Molasses diluted to 15–20% sugar concentration.
2. **Addition of nutrients:** $(NH_4)_2SO_4$, $MgSO_4$ for yeast growth.
3. **Sterilization:** Heating to kill unwanted microbes.
4. **Inoculation:** Add *Saccharomyces cerevisiae*.
5. **Fermentation:** Anaerobic, 30–35°C, pH 4–5, for 24–72 hours.

$$C_{12}H_{22}O_{11} + H_2O \rightarrow 4C_2H_5OH + 4CO_2$$

6. **Distillation:** Ethanol recovered (~95% purity).
7. **Dehydration:** Molecular sieves for anhydrous ethanol (99.5%).

Q.2 Manufacturing Process of Ethanol from Starches

Raw material: Corn, wheat, potatoes, rice.

Steps:

1. **Milling:** Grind starch source.
2. **Liquefaction:** α-Amylase at 90–100°C breaks starch into dextrins.
3. **Saccharification:** Glucoamylase at 60°C converts dextrins to glucose.
4. **Fermentation:** Yeast converts glucose to ethanol (similar to molasses process).
5. **Distillation & Dehydration:** Same as above.

Byproduct: DDGS (dried distiller's grains with solubles) – animal feed.

Q.6 Fermentation Process for Preparation of Acetic Acid

Method: Two-step fermentation (Orleans process / submerged fermentation).

Step 1 – Ethanol Production:
Yeast ferments sugar → ethanol + CO_2.

Step 2 – Acetic Acid Fermentation:
Acetobacter aceti oxidizes ethanol under aerobic conditions:

$$C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$$

Conditions: 25–30°C, pH 5–6, continuous aeration.

Product: 4–15% acetic acid (vinegar). Purified by distillation for glacial acetic acid.

Fuel and Combustion

Q.1 Refining of Petroleum

Process: Fractional distillation of crude oil based on boiling points.

Fraction	Boiling Range (°C)	Carbon atoms	Uses
Petroleum gas	<30	C1–C4	Fuel, LPG
Gasoline	40–180	C5–C10	Petrol
Kerosene	180–260	C11–C13	Jet fuel
Diesel	260–340	C14–C20	Diesel engines
Fuel oil	340–400	C21–C30	Ships, power plants
Lubricating oil	>400	C31–C40	Lubricants
Bitumen	Residue	>C40	Roads, roofing

Additional processes: Cracking (thermal/catalytic), reforming, alkylation to improve yield and octane number.

Q.2 Gross Calorific Value (GCV) / High Calorific Value (HCV)

Definition: Total heat released when 1 kg of fuel is completely burned and the products (including water vapor) are condensed to liquid water at 25°C.
Includes latent heat of vaporization of water.

Q.3 Net Calorific Value (NCV) / Low Calorific Value (LCV)

Definition: Heat released when 1 kg of fuel is burned and the products contain water vapor (not condensed).

$$LCV = GCV - 0.09H \times 587(\text{cal/g})$$

Where H = % hydrogen in fuel, 587 cal/g = latent heat of water.

Q.4 Dulong's Formula for Calculation of GCV and LCV

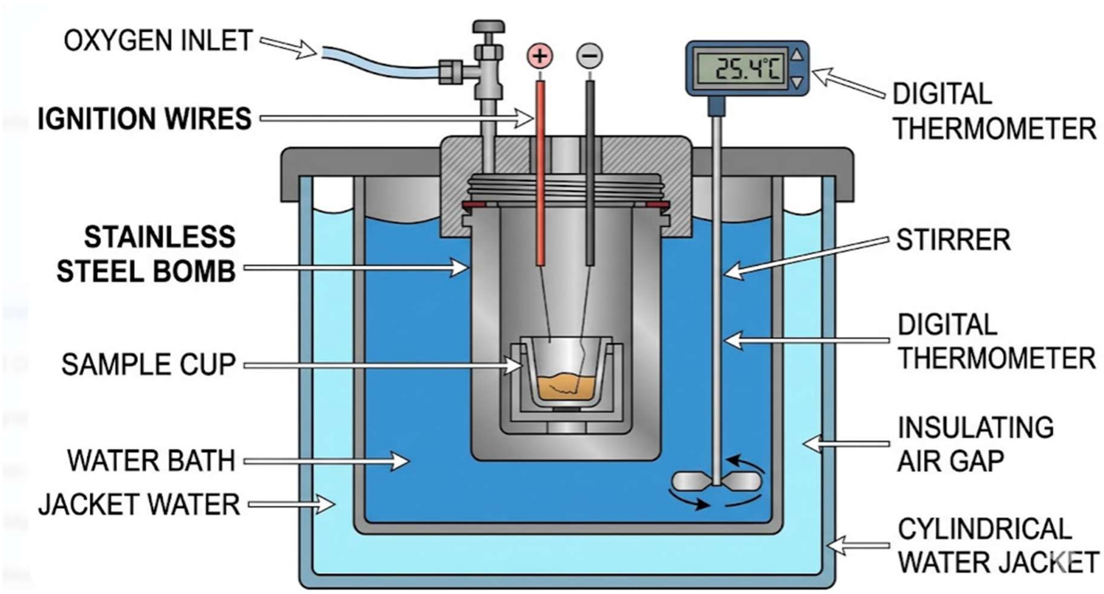
$$GCV\ (\text{kcal/kg}) = \frac{1}{100}\left(8080C + 34500\left(H - \frac{O}{8}\right) + 2240S\right)$$

Where C, H, O, S = % by mass of carbon, hydrogen, oxygen, sulfur.

$$LCV = GCV - 0.09H \times 587(\text{kcal/kg})$$

Q.5 Determination of Calorific Value by Bomb Calorimeter

Diagram: (Just for Reference)



Procedure:

1. Weigh fuel sample (≈1 g) in crucible.
2. Place in bomb with oxygen (25–30 atm).
3. Bomb submerged in known water mass in calorimeter.
4. Ignite electrically; heat released raises water temperature.
5. Calculate:

$$GCV = \frac{(M_w + W) \times \Delta T}{m}$$

Where M_w = water mass, W = water equivalent of calorimeter, ΔT = temp rise, m = fuel mass.

Q.6 Proximate Analysis of Coal

Component	Test Method	Significance
Moisture	Heat at 105°C (loss in weight)	Affects handling & combustion
Volatile Matter	Heat at 925°C (no air)	Indicates ignition ease
Ash	Burn completely at 750°C	Non-combustible residue
Fixed Carbon	100 – (M + VM + Ash)	Actual combustible carbon

Q.7 Ultimate Analysis of Coal

Determines elemental composition (mass %):

- Carbon (C)
- Hydrogen (H)
- Oxygen (O by difference)
- Nitrogen (N – Kjeldahl method)
- Sulfur (S – Eschka method)

Used for theoretical air requirement & Dulong's formula.

Q.8 Biofuels: Biodiesel and Biomass Briquettes

Biofuel	Production	Advantages
Biodiesel	Transesterification of vegetable oils/animal fats with methanol + NaOH → Fatty Acid Methyl Esters + glycerol	Renewable, lower emissions, biodegradable
Biomass Briquettes	Compressing agricultural waste (sawdust, husk, straw) without binder under high pressure	High energy density, cheap, reduces waste

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Q.14 Octane Number and Knocking

Knocking: Premature ignition of fuel in SI engine causing pinging sound, power loss, engine damage.

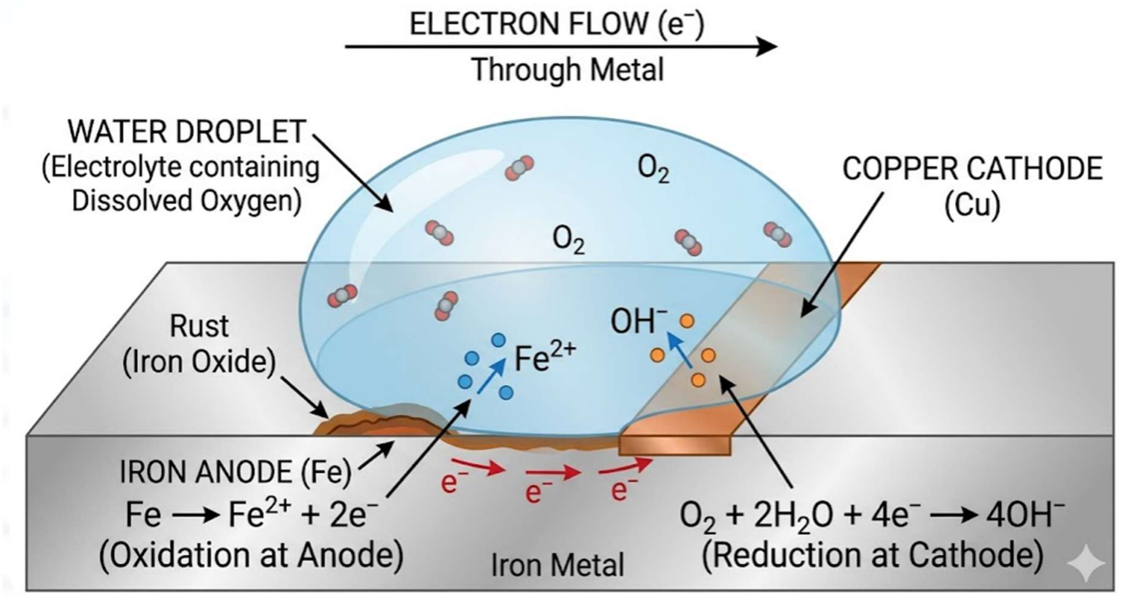
Octane Number (ON): Percentage of iso-octane (ON=100) in mixture with n-heptane (ON=0) that matches knocking tendency of test fuel.

Higher ON = better resistance to knocking.
RON (Research ON) used in petrol pumps.

Corrosion

Q.1 Electrochemical (Wet/Immersion) Theory of Corrosion

Diagram: (Just for Reference)



Process:

- **Anode (metal):** $M \rightarrow M^{n+} + ne^{-}$
- **Cathode (different area or impurity):** $O_2 + 2H_2O + 4e^{-} \rightarrow 4OH^{-}$ (neutral/alkaline)
- Rust forms when Fe^{2+} reacts with OH^{-} and O_2.

Q.2 Chemical (Dry) Theory of Corrosion

Occurs at high temperatures in absence of electrolyte.

Example: Oxidation of iron in air at 500°C:

$$2Fe + \frac{3}{2}O_2 \rightarrow Fe_2O_3$$

Follows parabolic law: weight gain ∝ √time.
Pilling-Bedworth rule: If oxide volume > metal volume, protective layer forms.

Q.3 Types of Corrosion

Type	Description
Uniform	Even metal loss (e.g., rust on steel)

Type	Description
Pitting	Localized holes (e.g., stainless steel in chlorides)
Crevice	In gaps/gaskets (oxygen concentration cell)
Intergranular	Along grain boundaries (e.g., weld decay in SS)
Stress Corrosion Cracking	Cracking under tensile stress + specific environment (e.g., brass in ammonia)

Q.4 Metallic and Nonmetallic Coating Methods

Coating Type	Methods	Examples
Metallic	Hot dipping, electroplating, metal spraying, vapor deposition	Galvanized iron, tinplate
Nonmetallic	Painting, powder coating, enameling, plastic coating	Painted steel, Teflon coating

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Q.5 Cathodic Protection Method

Principle: Make metal surface the cathode of an electrochemical cell.

Types:

1. **Sacrificial anode:** More active metal (Mg, Zn, Al) attached to steel – corrodes instead.
2. **Impressed current:** External DC power supply drives current from inert anode to protected structure.

Applications: Pipelines, ship hulls, underground tanks.

Q.6 Anodic Protection Method

Principle: Form a protective passive film by applying positive potential to metal (only for metals that **passivate**, e.g., stainless steel, titanium).

Working: Potential maintained in passive region (not transpassive). Requires continuous monitoring.

Applications: Chemical storage tanks, heat exchangers in sulfuric acid.

Q.7 Corrosion Inhibitors

Definition: Chemicals added in small concentrations to environment to reduce corrosion rate.

Types:

- **Anodic inhibitors:** Passivate metal (e.g., chromates, nitrites).
- **Cathodic inhibitors:** Slow cathodic reaction (e.g., polyphosphates).
- **Mixed inhibitors:** Both actions.
- **Vapor phase inhibitors:** For closed spaces (e.g., dicyclohexylamine nitrite).

Metals and Alloys

Q.1 Physical Properties of Metal

Property	Description
Luster	Shiny when polished (free electrons)
Conductivity	High electrical & thermal
Ductility	Can be drawn into wires
Malleability	Can be hammered into sheets
Density	Generally high (except Li, Na)
Melting point	Variable (very high for W, low for Hg)

Q.2 Heat Treatment Process

Stages: Heating → soaking → cooling at controlled rate.

Process	Procedure	Effect on steel
Annealing	Heat + slow cool (furnace)	Softens, relieves stress
Normalizing	Heat + air cool	Refines grain
Hardening	Heat + quench (water/oil)	Increases hardness (martensite)
Tempering	Reheat hardened steel (150–650°C) + cool	Reduces brittleness, improves toughness

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Q.3 Type and Applications of Alloys

Alloy Type	Base Metal	Examples	Applications
Ferrous alloys	Iron	Stainless steel, tool steel	Construction, tools

Alloy Type	Base Metal	Examples	Applications
Non-ferrous alloys	Cu, Al, Ni	Brass, Bronze, Duralumin	Electrical, marine, aircraft
High-temperature alloys	Ni, Co	Inconel, Hastelloy	Jet engines, turbines

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Q.4 Copper Alloys and Applications

Alloy	Composition	Applications
Brass	Cu + Zn (e.g., 70/30)	Valves, fittings, musical instruments
Bronze	Cu + Sn (plus P, Al, etc.)	Bearings, statues, ship propellers
Cupronickel	Cu + Ni (10–30%)	Heat exchangers, coins, seawater piping

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Q.5 Aluminium Alloys and Applications

Series	Main alloying element	Applications
1xxx	99% Al	Electrical conductors, chemical equipment
2xxx	Cu (e.g., 2024)	Aircraft structures (high strength)
6xxx	Mg + Si (e.g., 6061)	Bicycle frames, pipelines
7xxx	Zn (e.g., 7075)	Aerospace, rock climbing gear

Q.6 Nickel Alloys and Applications

Alloy	Composition	Applications
Monel	Ni 67%, Cu 30%	Marine equipment, valves

Alloy	Composition	Applications
Inconel	Ni 72%, Cr 16%, Fe 8%	Jet engine parts, nuclear reactors
Hastelloy	Ni + Mo, Cr	Chemical plants (acid resistance)

Battery

Q.1 Photolysis of Water

Definition: Splitting of water into hydrogen and oxygen using light energy, usually with a photocatalyst (e.g., TiO_2).

Reaction:

$$2H_2O + h\nu \rightarrow 2H_2 + O_2$$

Process:

1. Photocatalyst absorbs UV/visible light → electron-hole pair.
2. Electrons reduce $H^+ \rightarrow H_2$ (at cathode).
3. Holes oxidize $H_2O \rightarrow O_2$ (at anode).

Application: Green hydrogen production.

Q.2 Lithium Batteries

Principle: Electrochemical cell with Li^+ ions moving between anode (graphite) and cathode ($LiCoO_2$, $LiFePO_4$ etc.) through an organic electrolyte.

Reactions (discharge):
Anode: $Li_xC_6 \rightarrow C_6 + xLi^+ + xe^-$
Cathode: $Li_{1-x}CoO_2 + xLi^+ + xe^- \rightarrow LiCoO_2$

Advantages: High energy density, low self-discharge, no memory effect.

Applications: Smartphones, laptops, EVs, medical implants.

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