Bihar Board Class 12 Chemistry Set A 2026

Question Paper with Solutions

Conducted by the Bihar School Examination Board (BSEB)

Time Allowed: 3 hrs 15 min **Maximum Marks: 70**

General Instructions

(i) This question booklet is divided into two sections: **Section A** and **Section B**. The paper has **96 questions** (70 + 20 + 6) and carries **70 marks**.

(ii) In **Section A**, there are 70 objective type questions, out of which **any 35 questions** are to be answered, each carrying **1 mark**. If more than 35 questions are answered, only the first 35 answers are evaluated. The answers are marked on the OMR answer sheet.

(iii) In **Section B**, there are 20 short answer type questions, out of which **any 10 questions** are to be answered, each carrying **2 marks**.

(iv) Apart from these, Section B has 6 long answer type questions, out of which **any 3 questions** are to be answered, each carrying **5 marks**.

(v) Candidates must enter the 10-digit Question Booklet Serial No. on the OMR answer sheet and should give their answers in their own words as far as practicable.

(vi) Figures in the right-hand margin indicate full marks. 15 minutes of extra time have been allotted to read the questions carefully.

Section A: Objective Type Questions (any 35 to be answered, 1 mark each)

1. The number of atoms present in a face centred cubic unit cell is [1 mark]

(A) 2

(B) 3

(C) 4

(D) 12

Correct Answer: (C) 4

Solution:

Concept:

- A unit cell is the smallest repeating block of a crystal.
- Atoms at its corners, faces and body centre are shared with neighbouring unit cells, so only a fraction of each such atom belongs to one unit cell.

Step 1: Key approach Contribution of an atom depends on where it sits:
Corner atom: shared by 8 cells, so contributes $\frac{1}{8}$.
Face-centre atom: shared by 2 cells, so contributes $\frac{1}{2}$.
Body-centre atom: not shared, contributes 1.

Step 2: Count for the face-centred cubic (fcc) cell An fcc cell has 8 atoms at the 8 corners and 1 atom at the centre of each of the 6 faces.

$$Z = 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4$$

So one fcc unit cell holds 4 atoms.

Step 3: Why the other options are wrong (A) 2 is the number for a body-centred cubic cell ($8 \times \frac{1}{8} + 1 = 2$).
(B) 3 does not match any of the three cubic cells.
(D) 12 is the coordination number of an atom in fcc, not the number of atoms per cell.

Step 4: Conclusion An fcc unit cell contains 4 atoms, which is option (C).

Quick Tip to Solve: Add the share of corner atoms (each one-eighth) and face-centre atoms (each one-half).

2. The packing fraction for body-centred cubic cell is [1 mark]

(A) 0.42

(B) 0.53

(C) 0.68

(D) 0.82

Correct Answer: (C) 0.68

Solution:

Concept:

- Packing fraction (packing efficiency) is the fraction of the volume of the unit cell that is actually filled by the atoms, treated as hard spheres:

Step 1: Find Z and the relation between r and a for bcc A body-centred cubic cell has $Z = 8\times\frac{1}{8}+1 = 2$ atoms. The atoms touch along the body diagonal. The body diagonal of a cube of edge a is $\sqrt{3}\,a$, and it carries 4 radii (one full atom in the middle and a radius from each corner atom):

$$\sqrt{3}\,a = 4r \quad \Rightarrow \quad r = \frac{\sqrt{3}}{4}a$$

Step 2: Put the values in

$$\text{PF} = \frac{2 \times \frac{4}{3}\pi\left(\frac{\sqrt{3}a}{4}\right)^3}{a^3} = \frac{2 \times \frac{4}{3}\pi \times 3\sqrt{3}}{64} = \frac{\sqrt{3}\,\pi}{8}$$

$$\text{PF} = \frac{1.732 \times 3.1416}{8} \approx 0.68$$

So 68 percent of the cell volume is filled and 32 percent is empty.

Step 3: Why the other options are wrong 0.52 is the packing fraction of the simple cubic cell $(\pi/6)$ and 0.74 is that of fcc and hcp $(\pi/3\sqrt{2})$. The printed values 0.42, 0.53 and 0.82 do not belong to any cubic cell, so (A), (B) and (D) are wrong.

Step 4: Conclusion The packing fraction of a body-centred cubic cell is about 0.68, option (C).

Quick Tip to Solve: In bcc the atoms touch along the body diagonal, so $\sqrt{3}a = 4r$ and $Z = 2$. Put these in the packing fraction formula.

3. Which of the following is ferromagnetic substance ? [1 mark]

(A) Fe

(B) Cu

(C) NaCl

(D) MnO

Correct Answer: (A) Fe

Solution:

Concept:

- A ferromagnetic substance has many unpaired electrons whose magnetic moments line up in the same direction inside small regions called domains, even without a magnetic field.
- Such a substance is strongly attracted by a magnet and can be magnetised permanently.
- Examples are iron, cobalt, nickel and CrO_2.

Step 1: Check option (A), Fe Iron has unpaired 3d electrons and its domains stay aligned in the same direction. It is strongly attracted by a magnet, so Fe is ferromagnetic. (A) is correct.

Step 2: Check option (B), Cu In metallic copper the 3d subshell is full and the electrons of the metal are paired, so the substance is weakly repelled by a magnetic field. Cu is diamagnetic, so (B) is wrong.

Step 3: Check option (C), NaCl Both Na^+ and Cl^- have completely filled shells, so there are no unpaired electrons. NaCl is diamagnetic, so (C) is wrong.

Step 4: Check option (D), MnO Mn^{2+} has 5 unpaired electrons, but in solid MnO the moments of neighbouring ions point in opposite directions and cancel. This arrangement is called antiferromagnetism. It does not give the strong aligned magnetism of a ferromagnet, so (D) is wrong.

Step 5: Conclusion Among the given substances only iron is ferromagnetic, which is option (A).

Quick Tip to Solve: Ferromagnetic substances such as iron, cobalt and nickel keep their unpaired electron moments aligned in domains.

4. Which of the following has Frenkel defect ? [1 mark]

(A) Sodium chloride

(B) Graphite

(C) Silver chloride

(D) Diamond

Correct Answer: (C) Silver chloride

Solution:

Concept:

- A Frenkel defect is a point defect in an ionic crystal in which a smaller ion (usually the cation) leaves its normal lattice site and sits in an interstitial site, the gap between ions.
- The ion is displaced, not lost, so the density of the crystal does not change.

Step 1: When does it occur The defect is common in crystals where the cation is much smaller than the anion and the coordination number is low. Typical examples are ZnS, $AgCl$, $AgBr$ and AgI. The Ag^+ ion is small, so it can move into an interstitial position.

Step 2: Check option (A), sodium chloride In NaCl the cation and the anion are of nearly equal size and the coordination number is 6. Here the Schottky defect is found (both ions missing in equal number). So (A) is wrong.

Step 3: Check option (B), graphite Graphite is a covalent (network) solid and has no ions that could move into voids. Frenkel defect is an ionic crystal defect. So (B) is wrong.

Step 4: Check option (C), silver chloride $AgCl$ has a small Ag^+ cation and a large Cl^- anion, and shows the Frenkel defect. So (C) is correct.

Step 5: Check option (D), diamond Diamond is also a covalent network solid, so it has no ionic defect of this type. So (D) is wrong.

Step 6: Conclusion Silver chloride shows the Frenkel defect, which is option (C).

Quick Tip to Solve: Frenkel defect needs an ionic crystal in which the cation is much smaller than the anion, so it can move to an interstitial site.

5. An aqueous solution of which of the following compounds shows abnormal osmotic pressure? [1 mark]

(A) Urea

(B) Common salt

(C) Glucose

(D) Sucrose

Correct Answer: (B) Common salt

Solution:

Concept:

- Osmotic pressure is the pressure exerted by a solution to prevent the flow of solvent into it through a semipermeable membrane.
- It depends on the concentration of solute particles in the solution.

Step 1: Analyze the compounds. - Urea, glucose, and sucrose are non-electrolytes. They do not dissociate into ions and therefore contribute only one particle each in the solution. - Common salt (NaCl) dissociates into two ions (Na^+ and Cl^-), so it contributes two particles per formula unit, which leads to a higher osmotic pressure than the non-electrolytes.

Step 2: Apply to the options. Since common salt dissociates into two ions, it will show abnormal osmotic pressure compared to the other non-electrolytes.

Step 3: Conclusion

Quick Tip to Solve: Electrolytes like NaCl dissociate into multiple ions, leading to higher osmotic pressure compared to non-electrolytes like urea, glucose, and sucrose.

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6. The elevation in boiling point produced by one molal solution of a solute in a solvent is called [1 mark]

(A) Ebullioscopic constant

(B) Vapour pressure constant

(C) Cryoscopic constant

(D) None of these

Correct Answer: (A) Ebullioscopic constant

Solution:

Concept:

- A solute added to a solvent raises the boiling point.
- The rise is called the elevation in boiling point, written ΔT_b.
- For dilute solutions it is directly proportional to the molality m of the solute.

Step 1: Key Formula or Approach

$$\Delta T_b = K_b\, m$$

Here K_b is a constant that depends only on the solvent. If we put $m = 1$ molal, then $\Delta T_b = K_b$. So K_b is the elevation in boiling point for a one molal solution.

Step 2: Name the constant The constant K_b is called the molal elevation constant or the ebullioscopic constant. The word comes from the Latin “ebullire”, which means to boil. So the elevation in boiling point produced by a one molal solution is the ebullioscopic constant. This is option (A).

Step 3: Why the other options are wrong Option (B), vapour pressure constant, is not a standard constant. The vapour pressure is lowered by a solute, but that has nothing to do with a one molal boiling point rise.
Option (C), cryoscopic constant K_f, is the depression in freezing point for a one molal solution, so it is about freezing and not boiling.
Option (D) is wrong because option (A) is correct.

Step 4: Conclusion The elevation in boiling point for a one molal solution is the ebullioscopic constant K_b, which is option (A).

Quick Tip to Solve: Use $\Delta T_b = K_b m$ and put $m = 1$. The constant that remains is the answer.

7. Aqueous solution of which of the following will have lowest vapour pressure ? [1 mark]

(A) 0.1 M $BaCl_2$

(B) 0.1 M Urea

(C) 0.1 M Na_2SO_4

(D) 0.1 M Na_3PO_4

Correct Answer: (D) 0.1 M Na_3PO_4

Solution:

Concept:

- When a non-volatile solute dissolves in water, the vapour pressure of the solution falls below that of pure water.
- This is a colligative property, so the fall depends on the number of solute particles in solution and not on their kind.
- More particles means a bigger fall, so a lower vapour pressure.

Step 1: Key Formula or Approach Raoult's law gives the relative lowering of vapour pressure as

$$\frac{p^0 - p}{p^0} \approx i \times (\text{mole fraction of solute})$$

All four solutions have the same concentration, 0.1 M, so the one with the largest van't Hoff factor i (the number of particles one formula unit gives) has the lowest vapour pressure.

Step 2: Find the van't Hoff factor for each solution $BaCl_2 \rightarrow Ba^{2+} + 2Cl^-$, so $i = 3$ and particles = 0.3 M.
Urea does not ionise, so $i = 1$ and particles = 0.1 M.
$Na_2SO_4 \rightarrow 2Na^+ + SO_4^{2-}$, so $i = 3$ and particles = 0.3 M.
$Na_3PO_4 \rightarrow 3Na^+ + PO_4^{3-}$, so $i = 4$ and particles = 0.4 M.

Step 3: Compare The number of particles in solution follows $Na_3PO_4(0.4) > BaCl_2 = Na_2SO_4(0.3) >$ Urea(0.1).
The vapour pressure follows the opposite order, so Na_3PO_4 has the lowest vapour pressure.

Step 4: Why the other options are wrong Option (A) $BaCl_2$ and option (C) Na_2SO_4 give only 3 ions each, so their vapour pressure is higher than that of Na_3PO_4.
Option (B) urea gives just one particle per molecule, so it lowers the vapour pressure least and has the highest vapour pressure of the four.

Step 5: Conclusion The 0.1 M Na_3PO_4 solution gives the most particles (4 ions per unit), so it has the lowest vapour pressure. This is option (D).

Quick Tip to Solve: Equal molarity, so count the ions each solute gives. More particles means a lower vapour pressure.

8. 34.2 g of sugar is present in 234.2 g of its aqueous solution. Then its molal concentration is [1 mark]

(A) 0.1

(B) 0.5

(C) 5.5

(D) 55.0

Correct Answer: (B) 0.5

Solution:

Concept:

- Molality is the number of moles of solute dissolved in 1 kg of the solvent (not the solution).
- So we must separate the mass of the solvent from the mass of the solution.

Step 1: Key Formula or Approach

$$m = \frac{\text{moles of solute}}{\text{mass of solvent in kg}}$$

Molar mass of sugar (sucrose, $C_{12}H_{22}O_{11}$) $= 12(12) + 22(1) + 11(16) = 342$ g mol^{-1}.

Step 2: Moles of sugar Mass of sugar is 34.2 g.

$$n = \frac{34.2}{342} = 0.1 \text{ mol}$$

Step 3: Mass of solvent The 234.2 g is the mass of the whole solution, so the water is what is left after removing the sugar.

$$\text{mass of water} = 234.2 - 34.2 = 200 \text{ g} = 0.2 \text{ kg}$$

Step 4: Molality

$$m = \frac{0.1}{0.2} = 0.5 \text{ mol kg}^{-1}$$

Step 5: Why the other options are wrong Option (A) 0.1 is just the number of moles; it forgets to divide by the solvent mass. Option (C) 5.5 and option (D) 55.0 come from wrong powers of ten or from using the wrong mass. Dividing 0.1 mol by 234.2 g (the solution mass) would give about 0.43 mol per kg, which is also not an option, and it is wrong in principle.

Step 6: Conclusion The molality of the solution is 0.5, which is option (B).

Quick Tip to Solve: Molality uses the mass of solvent only. Subtract the sugar mass from the solution mass to get 200 g of water, then divide 0.1 mol by 0.2 kg.

9. Which of the following equations represents the Faraday's first law of electrolysis ? [1 mark]

(A) $mz = c \cdot t$

(B) $m = c \cdot z \cdot t$

(C) $mc = z \cdot t$

(D) $c = m \cdot z \cdot t$

Correct Answer: (B) $m = c \cdot z \cdot t$

Solution:

Concept:

- Faraday's first law of electrolysis says that the mass of a substance deposited or liberated at an electrode is directly proportional to the quantity of charge passed through the electrolyte.

Step 1: Key Formula or Approach Charge is current times time, $Q = c \cdot t$, where c is the current in amperes and t is the time in seconds. The mass m is proportional to Q, and the constant of proportionality is the electrochemical equivalent z. So

$$m = z \cdot Q = z \cdot c \cdot t$$

Step 2: Compare the options Option (A) $mz = c \cdot t$ puts m and z as a product on one side. That would make mass smaller when z is larger, which is the opposite of the law. So (A) is wrong.
Option (B) $m = c \cdot z \cdot t$ is exactly the law, so (B) is right.
Option (C) $mc = z \cdot t$ makes mass inversely proportional to current, which is wrong.
Option (D) $c = m \cdot z \cdot t$ makes current depend on mass and time, which has no meaning here.

Step 3: Conclusion The mass deposited is the product of current, time and the electrochemical equivalent, so option (B) is correct.

Quick Tip to Solve: Mass deposited is proportional to charge, and charge is current times time, so $m = z \cdot c \cdot t$.

10. On increasing dilution, the specific conductance of an electrolyte [1 mark]

(A) increases

(B) decreases

(C) remains constant

(D) none of these

Correct Answer: (B) decreases

Solution:

Concept:

- Specific conductance (conductivity, κ) is the conductance of a solution kept between two electrodes of area 1 cm^2 that are 1 cm apart.
- In other words, it is the conductance of 1 cm^3 of the solution.

Step 1: Key Formula or Approach κ depends on how many ions are present in each unit volume of the solution.
Diluting a solution adds solvent, so the number of ions per cm^3 falls.

Step 2: Detailed Explanation On dilution, the degree of ionisation (for weak electrolytes) increases a little, and the ions move more freely. But the number of ions in 1 cm^3 drops far more because the same amount of electrolyte now fills a larger volume.
So fewer ions are present between the two faces of the 1 cm^3 cube, and the specific conductance decreases.
Molar conductivity $\Lambda_m = \dfrac{\kappa \times 1000}{M}$ is different: it increases on dilution, because M falls faster than κ. Do not mix up the two.

Step 3: Check the options (A) increases: wrong, that is true for molar conductivity, not specific

conductance.
(B) decreases: right, as explained above.
(C) remains constant: wrong, the ion count per unit volume changes.
(D) none of these: wrong, because (B) is correct.

Step 4: Conclusion Specific conductance falls on dilution, so option (B) is correct.

Quick Tip to Solve: Specific conductance is the conductance of 1 cm^3 of solution. Dilution leaves fewer ions in that volume.

11. The standard electrode potentials of metals A, B, C and D are $-3.05\,V$, $-1.66\,V$, $-0.40\,V$ and $+0.8\,V$ respectively. Which of the following would have the highest reducing power? [1 mark]

(A) A

(B) B

(C) C

(D) D

Correct Answer: (A) A

Solution:

Step 1: Recall rule. **More negative** standard reduction potential (E°) $\Rightarrow$ **stronger reducing agent** (greater tendency to be oxidized).

Step 2: Compare values. $E^\circ(\text{A}) = -3.05\ \text{V} < E^\circ(\text{B}) = -1.66\ \text{V} < E^\circ(\text{C}) = -0.40\ \text{V} < E^\circ(\text{D}) = +0.8\ \text{V}$.
Thus, A is the most negative and hence the strongest reducing agent.

Step 3: Conclusion. Metal **A** has the highest reducing power.

Quick Tip to Solve: Remember: Most negative E° = strongest \textbf{reducing} agent; most positive E° = strongest \textbf{oxidizing} agent.

12. Which of the following is a secondary cell ? [1 mark]

(A) Leclanche cell

(B) Lead storage battery

(C) Concentration cell

(D) All of these

Correct Answer: (B) Lead storage battery

Solution:

Concept:

- A primary cell works only once.
- Its cell reaction cannot be reversed by passing current, so it cannot be recharged.
- A secondary cell has a reversible cell reaction, so it can be recharged by passing current in the opposite direction and used again and again.

Step 1: Check option (A) Leclanche cell The Leclanche cell (dry cell) has a zinc container and a carbon rod in a paste of NH_4Cl and MnO_2. Its products pile up and the reaction is not reversible in

practice. It is a primary cell, so (A) is wrong.

Step 2: Check option (B) Lead storage battery The lead storage battery has a lead anode and a lead dioxide cathode in dilute H_2SO_4. On discharge:

$$Pb + PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$$

When current is passed from outside, this reaction runs backward and the plates are restored. So it is a secondary cell, and (B) is right.

Step 3: Check options (C) and (D) A concentration cell has two identical electrodes in solutions of different concentration. It runs only until the two concentrations become equal and is not used as a rechargeable battery, so (C) is wrong. Option (D) says all of these, which fails because (A) and (C) are not secondary cells.

Step 4: Conclusion Only the lead storage battery is a secondary cell, which is option (B).

Quick Tip to Solve: A secondary cell is rechargeable. The lead storage battery is the standard example.

13. Which of the following represents the effect of temperature on reaction rate ? [1 mark]

(A) Nernst's equation

(B) Gibbs-Helmholtz equation

(C) Arrhenius equation

(D) Van't Hoff equation

Correct Answer: (C) Arrhenius equation

Solution:

Concept:

- The question asks for the equation that links the rate of a reaction with temperature.
- The rate of a reaction is measured through its rate constant k, so we need the equation that shows how k changes when T changes.

Step 1: Recall the relation Svante Arrhenius gave the relation between the rate constant and temperature:

$$k = A\, e^{-E_a/RT}$$

Here A is the frequency factor, E_a is the activation energy, R is the gas constant and T is the absolute temperature. When T rises, $e^{-E_a/RT}$ rises, so k and the rate both increase. The logarithmic form is $\ln k = \ln A - \dfrac{E_a}{RT}$.

Step 2: Check option (A), Nernst equation The Nernst equation, $E = E^\circ - \dfrac{RT}{nF}\ln Q$, gives the electrode or cell potential for given concentrations. It does not deal with reaction rate. So (A) is wrong.

Step 3: Check option (B), Gibbs-Helmholtz equation This equation connects the free energy change ΔG with the enthalpy change ΔH and the temperature. It tells us about the spontaneity and energetics of a reaction, not how fast it goes. So (B) is wrong.

Step 4: Check option (C), Arrhenius equation This is exactly the relation between rate constant and temperature written above. So (C) is correct.

Step 5: Check option (D), Van't Hoff equation The Van't Hoff equation shows how the equilibrium constant K changes with temperature. It describes the position of equilibrium, not the speed at which equilibrium is reached. So (D) is wrong.

Step 6: Conclusion The effect of temperature on the rate constant, and so on the reaction rate, is given by the Arrhenius equation. This is option (C).

Quick Tip to Solve: The rate constant depends on temperature through the equation $k = Ae^{-E_a/RT}$. Find the option named after the scientist who gave it.

14. Which of the following is not a first order reaction ? [1 mark]

(A) $CH_3COOC_2H_5 + H_2O \xrightarrow{H^+} CH_3COOH + C_2H_5OH$

(B) $CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$

(C) $2H_2O_2 \rightarrow 2H_2O + O_2$

(D) $2N_2O_5 \rightarrow 4NO_2 + O_2$

Correct Answer: (B) $CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$

Solution:

Concept:

- The order of a reaction is the sum of the powers of the concentration terms in the experimental rate law. It must be found from experiment, not from the balanced equation.
- A reaction can look bimolecular and still follow a first order rate law when one reactant is present in large excess. That is called a pseudo first order reaction.

Step 1: Key Approach Write the experimental rate law for each reaction and add the powers.
A reaction counts as first order if the rate depends on one concentration term to the power 1 (true or pseudo).

Step 2: Option (A): acid hydrolysis of ethyl acetate. The rate law is rate $= k[CH_3COOC_2H_5]$. Water is the solvent and is present in large excess, so its concentration is almost constant, and H^+ is only a catalyst.
So the reaction is pseudo first order.

Step 3: Option (B): hydrolysis with NaOH. The rate law is rate $= k[CH_3COOC_2H_5][NaOH]$. Both the ester and the hydroxide ion are present in comparable amounts and both change with time.
The order is $1 + 1 = 2$, so this is a second order reaction. It is not first order.

Step 4: Option (C): decomposition of hydrogen peroxide. The experimental rate law is rate $= k[H_2O_2]$, so the order is 1, even though the equation shows 2 molecules of H_2O_2.

Step 5: Option (D): decomposition of dinitrogen pentoxide. The experimental rate law is rate $= k[N_2O_5]$, so the order is 1, although the equation has the coefficient 2.

Step 6: Conclusion Reactions (A), (C) and (D) follow a first order rate law. The alkaline hydrolysis in (B) is second order, so (B) is not first order.

Quick Tip to Solve: Write the rate law of each reaction. In which one do two reactants, neither in large excess, appear in the rate expression?

15. For a reaction, $aA + bB \rightarrow$ products, $\frac{-d[A]}{dt}$ is equal to [1 mark]

(A) $\frac{-d[B]}{dt}$

(B) $\frac{-b}{d}\frac{d[B]}{dt}$

(C) $\frac{-a}{b}\frac{d[B]}{dt}$

(D) $\frac{-b}{a}\frac{d[B]}{dt}$

Correct Answer: (C) $\frac{-a}{b}\frac{d[B]}{dt}$

Solution:

Concept:

- The rate of a reaction is the same whichever substance we follow, but the rate of change of each concentration differs when the coefficients differ.
- We divide each concentration change by its stoichiometric coefficient to get the same rate.

Step 1: Key Formula or Approach For $aA + bB \rightarrow$ products, the rate of reaction is

$$\text{Rate} = -\frac{1}{a}\frac{d[A]}{dt} = -\frac{1}{b}\frac{d[B]}{dt}$$

A minus sign is used because reactants are used up and their concentration falls.

Step 2: Detailed Explanation Start from the equality of the two rate expressions:

$$-\frac{1}{a}\frac{d[A]}{dt} = -\frac{1}{b}\frac{d[B]}{dt}$$

Multiply both sides by a:

$$-\frac{d[A]}{dt} = -\frac{a}{b}\frac{d[B]}{dt}$$

This matches option (C). As a check, take $a = 2$ and $b = 1$. Then A is used up twice as fast as B, and the formula gives $-d[A]/dt = 2\,(-d[B]/dt)$, which is correct.

Step 3: Why the other options are wrong Option (A) says A and B are used up at equal speed, which is true only when $a = b$.
Option (B) has the factor b/d, but d is not a coefficient in this reaction, so it has no meaning here.
Option (D) has the factor b/a, which is the inverse of the right ratio. It would give $-d[A]/dt$ smaller than $-d[B]/dt$ when $a > b$, the opposite of what happens.

Step 4: Conclusion Dividing by the coefficients gives the same rate, so the correct relation is option (C).

Quick Tip to Solve: The rate of reaction is the same for every species once each concentration change is divided by its coefficient: $-\frac{1}{a}\frac{d[A]}{dt} = -\frac{1}{b}\frac{d[B]}{dt}$.

16. Radioactive decay is a [1 mark]

(A) Zero order reaction

(B) First order reaction

(C) Second order reaction

(D) Third order reaction

Correct Answer: (B) First order reaction

Solution:

Concept:

- The order of a reaction is the sum of the powers of concentration terms in its rate law.
- A first order reaction has a rate proportional to the first power of one concentration.

Step 1: Key Formula or Approach For radioactive decay, the rate of decay (activity) is proportional to the number of radioactive nuclei present:

$$-\frac{dN}{dt} = \lambda N$$

Here λ is the decay constant, which plays the role of the rate constant.

Step 2: Detailed Explanation The rate law has N raised to the power 1, so the order is 1. Integrating it gives

$$N = N_0 e^{-\lambda t}$$

which is the same form as the integrated first order rate law $[A] = [A]_0 e^{-kt}$.
The half life is $t_{1/2} = \frac{0.693}{\lambda}$, independent of the starting amount, which is another sign of first order kinetics. The decay of one nucleus does not depend on any other nucleus or on temperature and pressure, so it is a simple unimolecular process.

Step 3: Why the other options are wrong A zero order reaction has a constant rate that does not depend on concentration, but the activity of a sample falls as nuclei decay, so (A) is wrong.
A second order reaction needs rate proportional to the square of concentration, and a third order one to the cube, which is not seen in decay. So (C) and (D) are wrong.

Step 4: Conclusion Radioactive decay obeys $-dN/dt = \lambda N$, so it is a first order reaction, option (B).

Quick Tip to Solve: The decay rate is proportional to the number of nuclei present, $-dN/dt = \lambda N$. Which order has the rate proportional to the first power of concentration?

17. The volumes of gases H_2, CH_4, CO_2 and NH_3 adsorbed by 1 g of charcoal at 288 K are in the order [1 mark]

(A) $H_2 > CH_4 > CO_2 > NH_3$

(B) $CH_4 > CO_2 > NH_3 > H_2$

(C) $CO_2 > NH_3 > H_2 > CH_4$

(D) $NH_3 > CO_2 > CH_4 > H_2$

Correct Answer: (D) $NH_3 > CO_2 > CH_4 > H_2$

Solution:

Concept:

- Gases stick to the surface of a solid like charcoal by physical adsorption.
- The amount adsorbed depends mainly on how easily the gas can be liquefied.
- Gases that liquefy easily are held more strongly by the weak van der Waals forces on the surface.

Step 1: Key Formula or Approach A gas with a higher critical temperature T_c and stronger intermolecular forces is easier to liquefy. So the volume adsorbed per gram of charcoal rises with T_c.

Step 2: Compare the gases Approximate critical temperatures:

NH_3: 406 K
CO_2: 304 K
CH_4: 191 K
H_2: 33 K
At 288 K, ammonia is already close to its liquid state, so it is adsorbed the most. Hydrogen is far above its critical temperature and is adsorbed the least. The order is:

$$NH_3 > CO_2 > CH_4 > H_2$$

Step 3: Check option (A) This is the exact reverse of the real order. Hydrogen cannot be adsorbed the most, because it has the weakest van der Waals forces. So (A) is wrong.

Step 4: Check options (B) and (C) In (B), hydrogen is placed last but ammonia is placed third, although ammonia is the most easily liquefied gas. In (C), hydrogen is placed above methane, which contradicts their critical temperatures. So (B) and (C) are wrong.

Step 5: Check option (D) The order follows the critical temperatures of 406 K, 304 K, 191 K and 33 K exactly. So (D) is correct.

Step 6: Conclusion Ammonia is adsorbed the most and hydrogen the least, so the correct order is option (D).

Quick Tip to Solve: Easily liquefied gases (higher critical temperature) are adsorbed more on charcoal.
Compare the critical temperatures of the four gases.

18. The correct expression for Langmuir's adsorption isotherm is [1 mark]

(A) $\frac{x}{m} = \frac{1+aP}{b}$

(B) $\frac{x}{m} = \frac{aP}{1+bP}$

(C) $\frac{x}{m} = \frac{1+aP}{1+bP}$

(D) $\frac{x}{m} = \frac{1}{a} + \frac{bP}{a}$

Correct Answer: (B) $\frac{x}{m} = \frac{aP}{1+bP}$

Solution:

Concept:

- Langmuir assumed that a solid surface has a fixed number of identical sites, and each site holds only one gas molecule (a single layer).
- Adsorption stops being possible once all the sites are filled.

Step 1: Key Formula or Approach Let θ be the fraction of surface covered. At equilibrium, the rate of adsorption equals the rate of desorption:

$$k_a P(1-\theta) = k_d \theta$$

Step 2: Derive the isotherm Solve for θ:

$$\theta = \frac{k_a P}{k_d + k_a P} = \frac{bP}{1 + bP}, \quad b = \frac{k_a}{k_d}$$

The amount adsorbed per gram, x/m, is proportional to θ. Writing $x/m = (a/b)\,\theta$ and simplifying gives

$$\frac{x}{m} = \frac{aP}{1 + bP}$$

Step 3: Check the limits At low pressure, $bP \ll 1$, so $x/m \approx aP$, which is linear in P. At high pressure, $bP \gg 1$, so $x/m \to a/b$, a constant. This is the saturation of a monolayer, as Langmuir predicted.

Step 4: Check the options (A) grows without limit as P rises and gives a nonzero value at $P = 0$, which is impossible.
(C) gives $x/m = 1$ at $P = 0$, so something is adsorbed with no gas present, which is wrong.
(D) gives $x/m = 1/a$ at $P = 0$, which is not zero, and it also rises without limit.
Only (B) has $x/m = 0$ at $P = 0$ and a finite saturation value.

Step 5: Conclusion The Langmuir isotherm is option (B).

Quick Tip to Solve: Langmuir gives a single layer, so the adsorbed amount is zero at $P = 0$ and reaches a constant value at high pressure.
Only one option has both features.

19. The size of colloidal particle is [1 mark]

(A) 1 nm - 10 nm

(B) 10 nm - 100 nm

(C) 1 nm - 100 nm

(D) 10 nm - 1000 nm

Correct Answer: (C) 1 nm - 100 nm

Solution:

Concept:

- A colloid sits between a true solution and a suspension.
- The size of the dispersed particles decides which one it is.

Step 1: Key Formula or Approach True solution: particles smaller than 1 nm.
Colloid: particles between 1 nm and 100 nm in diameter (the standard Class XII range).
Suspension: particles larger than 100 nm (some books say 1000 nm).

Step 2: Compare with the options Option (C), 1 nm - 100 nm, is exactly the colloidal range.
Option (A) covers only the lower part of it, so it leaves out many colloids.
Option (B) leaves out the small colloidal particles between 1 nm and 10 nm.
Option (D) goes up to 1000 nm and starts at 10 nm, so it is not the usual range given for a colloid.

Step 3: Conclusion Colloidal particles have a size of 1 nm - 100 nm, which is option (C).

Quick Tip to Solve: A colloid lies between a true solution and a suspension.
Recall the standard particle-size range for a colloid in nanometres.

20. Smoke is a colloidal state in which [1 mark]

(A) a gas is dispersed in solid

(B) a solid is dispersed in gas

(C) a gas is dispersed in gas

(D) a liquid is dispersed in gas

Correct Answer: (B) a solid is dispersed in gas

Solution:

Concept:

- A colloid has two parts: the dispersed phase (the tiny particles) and the dispersion medium (what they are spread in).
- Colloids are named from these two phases.

Step 1: Key Formula or Approach Smoke contains fine particles of carbon and ash floating in air. Carbon and ash are solids, and air is a mixture of gases.

Step 2: Identify the phases Dispersed phase = solid.
Dispersion medium = gas.
A solid dispersed in a gas is called an aerosol (a solid aerosol). Fog and clouds are liquid aerosols, but smoke is a solid aerosol.

Step 3: Check the options (A) gas in solid is a solid foam such as pumice, not smoke.
(B) solid in gas is smoke and dust, so (B) is correct.
(C) gas in gas is a homogeneous gas mixture, not a colloid at all.
(D) liquid in gas is fog, mist or cloud.

Step 4: Conclusion Smoke is a solid dispersed in a gas, which is option (B).

Quick Tip to Solve: Smoke is fine soot or ash particles floating in air.
Decide which phase is dispersed and which is the medium.

21. Butter is an example of [1 mark]

(A) Gel

(B) Emulsion

(C) Sol

(D) Foam

Correct Answer: (A) Gel

Solution:

Concept:

- Colloids are classified by the physical state of the dispersed phase and the medium.
- The four types in the options are: gel (liquid in solid), emulsion (liquid in liquid), sol (solid in liquid) and foam (gas in liquid or solid).

Step 1: Key Formula or Approach Butter is a semi-solid. It holds tiny droplets of water spread inside solid fat. So it is a liquid dispersed in a solid.

Step 2: Identify the type Dispersed phase = liquid (water droplets).
Dispersion medium = solid (fat).
A liquid dispersed in a solid is a gel. Cheese and jelly are other examples.

Step 3: Check the options (A) Gel is correct, as shown above.
(B) Emulsion needs both phases to be liquid, as in milk. Butter is not a liquid, so (B) is wrong.
(C) Sol has a solid dispersed in a liquid, such as paint or starch in water. This does not fit butter.
(D) Foam has a gas dispersed in a liquid or solid, such as whipped cream. Butter is not a gas dispersion.

Step 4: Conclusion Butter is a gel, which is option (A).

Quick Tip to Solve: Butter is water droplets spread inside solid fat.
Name the colloid type for a liquid dispersed in a solid.

22. Which one of the following substances acts as an emulsifier ? [1 mark]

(A) Common salt

(B) Urea

(C) Soap

(D) Oil

Correct Answer: (C) Soap

Solution:

Concept:

- An emulsion is a colloid in which tiny drops of one liquid are spread through another liquid that does not mix with it, for example oil in water. Such a mixture separates on standing.
- An emulsifier (emulsifying agent) is a substance added to keep the drops from joining together, so that the emulsion stays stable.

Step 1: Key Approach A good emulsifier has a polar head that likes water and a long non-polar tail that likes oil. It collects on the surface of each drop and stops the drops from coalescing.

Step 2: Detailed Explanation Soap is a sodium salt of a long chain fatty acid, for example $C_{17}H_{35}COONa$. The $-COO^-$ head is hydrophilic and the $C_{17}H_{35}$ tail is hydrophobic.
In an oil in water emulsion the tails dip into the oil drop and the heads point into water, so each drop gets a charged layer and the drops repel each other.
So soap is an emulsifier.

Step 3: Why the other options are wrong. Common salt is an electrolyte. It has no oily part and it coagulates colloids rather than stabilising them.
Urea is a small polar molecule with no hydrophobic tail, so it cannot form a layer around drops.
Oil is the dispersed phase itself. It is the substance being emulsified, not the agent that does it.

Step 4: Conclusion Soap acts as the emulsifier, option (3).

Quick Tip to Solve: An emulsifier needs a water-loving end and an oil-loving end. Which listed substance has both?

23. Which of the following is a biological catalyst ? [1 mark]

(A) Carbohydrate

(B) Enzyme

(C) Amino acid

(D) Nitrogenous base

Correct Answer: (B) Enzyme

Solution:

Concept:

- A catalyst is a substance that speeds up a chemical reaction without being used up.
- A biological catalyst is one that works inside living cells to speed up the reactions of life.
- We have to pick which of the four given substances does that job.

Step 1: Recall the concept Enzymes are protein molecules made by living cells. They catalyse almost every biochemical reaction in the body, such as digestion of starch by amylase and breakdown of urea by urease. They work at body temperature and are highly specific, so they are called biocatalysts.

Step 2: Check option (1), Carbohydrate Carbohydrates such as glucose and starch are sources of energy and structural material. They do not catalyse reactions. So (1) is wrong.

Step 3: Check option (2), Enzyme Enzymes are exactly the biological catalysts described above. So (2) is correct.

Step 4: Check options (3) and (4) Amino acids are the building blocks of proteins. They are the small units, not the catalyst. So (3) is wrong.
Nitrogenous bases (adenine, guanine, cytosine, thymine, uracil) are parts of nucleotides in DNA and RNA and store genetic information. So (4) is wrong.

Step 5: Conclusion Enzymes act as biological catalysts, so the correct option is (2).

Quick Tip to Solve: A biological catalyst is a protein made in living cells that speeds up a specific reaction. Pick the option that names it.

24. Which of the following is a shape selective catalyst ? [1 mark]

(A) V_2O_5

(B) Cr_2O_3

(C) MnO_2

(D) ZSM-5

Correct Answer: (D) ZSM-5

Solution:

Concept:

- A shape selective catalyst is a porous catalyst whose pores have a fixed size. Only reactant molecules small enough to enter the pores can react, and only product molecules that fit through the pore openings can leave. So the catalyst selects the reaction by the shape and size of the molecules, not by chemistry alone.
- Zeolites are the standard examples of such catalysts.

Step 1: Key Formula or Approach We need to find the option that is a zeolite (a porous aluminosilicate with a honeycomb-like structure). The other options are ordinary solid catalysts used in specific industrial reactions. We match each one with its known use.

Step 2: Check option (1): vanadium pentoxide V_2O_5 is the catalyst of the contact process, where SO_2 is oxidised to SO_3. It is a solid with no pore network that sorts molecules by size. So it is not shape selective.

Step 3: Check option (2): chromium(III) oxide Cr_2O_3 is a metal oxide used as a promoter, for example with zinc oxide in methanol synthesis. It works through its surface chemistry, not through pores of

fixed size. So it is not shape selective.

Step 4: Check option (3): manganese dioxide MnO_2 speeds up the decomposition of $KClO_3$ and H_2O_2. It is an ordinary heterogeneous catalyst with no shape-sorting pores. So it is not shape selective.

Step 5: Check option (4): ZSM-5 ZSM-5 is a zeolite, an aluminosilicate with channels of a fixed diameter. In the petroleum industry it converts alcohols into gasoline range hydrocarbons, and only molecules that fit the channels react or come out. So ZSM-5 is a shape selective catalyst, and option (4) is correct.

Step 6: Conclusion ZSM-5 is a zeolite whose pore size decides which molecules can react, so it is the shape selective catalyst. This is option (4).

Quick Tip to Solve: A shape selective catalyst has pores of fixed size, so only molecules of the right size and shape can react. Zeolites are the standard example.

25. In thermite process, reducing agent is [1 mark]

(A) C

(B) Zn

(C) Na

(D) Al

Correct Answer: (D) Al

Solution:

Concept:

- The thermite process (aluminothermy) reduces a metal oxide with powdered aluminium.
- It is used to get molten iron for welding rails and to prepare metals like chromium from their oxides.
- A reducing agent must have a stronger attraction for oxygen than the metal it is reducing.

Step 1: Key Formula or Approach The reaction is:

$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$$

The oxide of aluminium has a very large negative free energy of formation, so the reaction gives out a lot of heat. The iron produced is molten.

Step 2: Identify the reducing agent In the equation Al goes from oxidation state 0 to +3. It loses electrons and is oxidised, so aluminium is the reducing agent. Iron goes from +3 to 0 and is reduced.

Step 3: Why the other options are wrong Carbon (option 1) is the reducing agent in the blast furnace, not in the thermite process. Zinc (option 2) is a weaker reducing agent than aluminium, so it cannot reduce oxides like Cr_2O_3 in this way. Sodium (option 3) is too reactive and costly, and it reacts violently with air and water. So only Al fits.

Step 4: Conclusion Aluminium is the reducing agent in the thermite process. This is option (4).

Quick Tip to Solve: In thermite, a metal oxide such as iron(III) oxide is heated with a powder that has a very strong attraction for oxygen.

26. Which of the following metals is extracted by leaching the ore with dilute cyanide solution ? [1 mark]

(A) Silver

(B) Titanium

(C) Vanadium

(D) Zinc

Correct Answer: (A) Silver

Solution:

Concept:

- Leaching is a method of concentrating an ore by dissolving the metal (or its compound) in a suitable chemical solution.
- For ores of noble metals, a dilute cyanide solution is used because the metal forms a soluble cyanide complex, while the rock impurities stay undissolved.

Step 1: Key Formula or Approach The cyanide process is used for silver and gold. For silver ore (argentite) the reaction is, in the presence of air:

$$Ag_2S + 4NaCN \rightleftharpoons 2Na[Ag(CN)_2] + Na_2S$$

The sodium sulphide is oxidised by air so the reaction goes forward.

Step 2: Recover the metal Silver is then obtained from the solution by displacement with zinc dust:

$$2[Ag(CN)_2]^- + Zn \rightarrow [Zn(CN)_4]^{2-} + 2Ag$$

So silver is extracted by leaching with dilute cyanide solution.

Step 3: Check the other options Titanium is obtained by the Kroll process, where $TiCl_4$ is reduced with magnesium. Vanadium is obtained by reducing V_2O_5 with calcium or aluminium. Zinc is obtained by roasting the sulphide ore to zinc oxide and reducing it with carbon. None of these use cyanide leaching, though zinc is itself the metal used to precipitate silver. So option (1) is correct.

Step 4: Conclusion Silver is extracted by leaching its ore with dilute sodium cyanide solution. This is option (1).

Quick Tip to Solve: Cyanide leaching (the MacArthur-Forrest process) is used for the noble metals that form soluble cyanide complexes, silver and gold.

27. The main constituent of bones is [1 mark]

(A) $CaCO_3$

(B) $Ca_3(PO_4)_2$

(C) $CaSO_4$

(D) CaF_2

Correct Answer: (B) $Ca_3(PO_4)_2$

Solution:

Concept:

- Bones are the hard framework of the body.
- Their mineral part is a calcium phosphate compound, which gives them strength.
- About 60 to 70 percent of bone by mass is this inorganic part, and calcium and phosphorus are the

main elements in it.

Step 1: Key Formula or Approach We compare the four calcium compounds with where they occur in nature or the body. The one that is a phosphate and forms the hard part of bones is the answer.

Step 2: Check each option $CaCO_3$ is calcium carbonate. It is the main part of limestone, marble, chalk and egg shells, so it is not the main constituent of bones.
$Ca_3(PO_4)_2$ is calcium phosphate. Bones and teeth are made mostly of it (as hydroxyapatite), so this is the main constituent of bones.
$CaSO_4$ is calcium sulphate, found as gypsum and used as plaster of Paris, not in bones.
CaF_2 is calcium fluoride (fluorspar), a mineral. Only a trace of fluoride is present in bones and teeth.

Step 3: Conclusion The main constituent of bones is calcium phosphate. This is option (2).

Quick Tip to Solve: Bones and teeth are built from a calcium phosphate mineral, and bone ash is mostly the same compound.

28. Which of the following metals is not obtained by electrolysis? [1 mark]

(A) Na

(B) Mg

(C) Al

(D) Fe

Correct Answer: (D) Fe

Solution:

Concept:

- Electrolysis is the process of using electricity to break down compounds into their components.
- It is commonly used for extracting metals from their ores.

Step 1: Analyze each option. - Sodium (Na) and Magnesium (Mg) are both extracted using electrolysis. - Aluminum (Al) is also extracted by electrolysis in the Bayer process. - Iron (Fe) is typically extracted by reduction using carbon, not by electrolysis.

Step 2: Apply to the options. Iron (Fe) is the metal that is not obtained by electrolysis, making option (D) correct.

Step 3: Conclusion

Quick Tip to Solve: Electrolysis is used to extract highly reactive metals like sodium and magnesium, while less reactive metals like iron are extracted using reduction methods.

29. The extensive use of P_4O_{10} is done as [1 mark]

(A) Reducing agent

(B) Preservative

(C) Oxidising agent

(D) Dehydrating agent

Correct Answer: (D) Dehydrating agent

Solution:

Concept:

- Phosphorus(V) oxide, P_4O_{10}, is the anhydride of phosphoric acid.
- It is a white powder that takes up water very strongly from its surroundings.

Step 1: Key Formula or Approach Its reaction with water is

$$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$$

Because this reaction is so vigorous and complete, the oxide pulls water out of other materials. A substance that removes water like this is a dehydrating agent.

Step 2: Use of P_4O_{10} It dries gases and organic liquids in the laboratory and in desiccators. It can even remove the elements of water from compounds, for example:

$$2HNO_3 \xrightarrow{P_4O_{10}} N_2O_5 + H_2O$$

$$RCONH_2 \xrightarrow{P_4O_{10}} RCN + H_2O$$

So the main use of P_4O_{10} is as a dehydrating agent.

Step 3: Why the other options are wrong Option (A): phosphorus is already in its highest oxidation state, +5, so it cannot act as a reducing agent.
Option (B): it is not used to preserve food, as it reacts violently with moisture and forms an acid.
Option (C): it is not an oxidising agent in its normal use, because its reactions with water and with compounds do not involve any change in oxidation state.

Step 4: Conclusion P_4O_{10} is used extensively as a dehydrating agent, which is option (D).

Quick Tip to Solve: P_4O_{10} grabs water very strongly to form phosphoric acid. Think of what that makes it good for.

30. Which of the following oxides is the most acidic ? [1 mark]

(A) P_2O_5

(B) N_2O_5

(C) Sb_2O_5

(D) As_2O_5

Correct Answer: (B) N_2O_5

Solution:

Concept:

- The acidic nature of an oxide depends on how electronegative and how small the central element is.
- Non-metallic, small, highly electronegative elements give strongly acidic oxides.
- Larger and more metallic elements give weakly acidic or amphoteric oxides.

Step 1: Key Formula or Approach All four oxides have the same formula type, M_2O_5, and the same oxidation state +5 for the group 15 element. So we compare only the elements N, P, As and Sb.
Going down group 15, electronegativity and non-metallic character decrease, so the acidic character

of the +5 oxides also decreases.

Step 2: Rank the oxides

$$N_2O_5 > P_2O_5 > As_2O_5 > Sb_2O_5$$

Nitrogen is at the top of the group and is the smallest and most electronegative. Its pentoxide N_2O_5 reacts with water to form the strong acid HNO_3. P_2O_5 gives the weaker H_3PO_4. As_2O_5 is weakly acidic, and Sb_2O_5 is nearly amphoteric.

Step 3: Why the other options are wrong Option (A) P_2O_5 is acidic but less than N_2O_5.
Option (C) Sb_2O_5 is the least acidic of the four, because antimony is the most metallic.
Option (D) As_2O_5 lies between P_2O_5 and Sb_2O_5.

Step 4: Conclusion N_2O_5 is the most acidic oxide, which is option (B).

Quick Tip to Solve: All are +5 oxides of group 15. Acidic character falls on going down the group, so look at the top element.

31. Which of the following has the highest bond energy? [1 mark]

(A) O - O

(B) S - S

(C) Se - Se

(D) Te - Te

Correct Answer: (B) S - S

Solution:

Concept:

- Bond energy refers to the energy required to break a bond between two atoms.
- As the atomic size increases, the bond energy typically decreases because the bonding atoms are farther apart.

Step 1: Analysis of options. **(A) O - O:** The oxygen-oxygen bond in O_2 is relatively weak, but it has the highest bond energy among the options listed.
(B) S - S: The sulfur-sulfur bond in S_2 is weaker than the oxygen-oxygen bond.
(C) Se - Se: Selenium-selenium bonds are weaker than sulfur-sulfur bonds.
(D) Te - Te: The tellurium-tellurium bond is the weakest of all the listed bonds.

Step 2: Conclusion. The correct answer is **(A)** because the oxygen-oxygen bond has the highest bond energy among these elements.

Quick Tip to Solve: In general, as atomic size increases (from oxygen to tellurium), bond energy decreases due to longer bond lengths.

32. Sulphur molecule is [1 mark]

(A) Diatomic

(B) Tetratomic

(C) Triatomic

(D) Octatomic

Correct Answer: (D) Octatomic

Solution:

Concept:

- Sulphur exists in several allotropic forms.
- The common ones, rhombic (alpha) and monoclinic (beta) sulphur, are both made of the same kind of molecule.
- The question asks how many atoms that molecule has.

Step 1: Key Formula or Approach The molecular formula of the stable forms of sulphur is S_8. The molecule is a puckered eight-membered ring, often called a crown shape.
Each sulphur atom is bonded to two neighbouring sulphur atoms by single bonds.

Step 2: Count the atoms The ring contains 8 sulphur atoms, so the molecule is octatomic. The molar mass supports this, because a molecule of formula S_8 has mass $8 \times 32 = 256$ g/mol.

Step 3: Why the other options are wrong Option (A), diatomic S_2, exists only in the vapour state at very high temperature.
Options (B) and (C), tetratomic and triatomic, are not the form of ordinary sulphur. (Triatomic S_3 is a minor species in vapour.)
So only the eight-atom ring fits normal sulphur.

Step 4: Conclusion A sulphur molecule is S_8, so it is octatomic. This is option (D).

Quick Tip to Solve: Ordinary rhombic and monoclinic sulphur are made of ring molecules. Count the atoms in the ring.

33. Which of the following is the strongest base ? [1 mark]

(A) ClO_4^-

(B) ClO_3^-

(C) ClO_2^-

(D) ClO^-

Correct Answer: (D) ClO^-

Solution:

Concept:

- A base is a species that accepts a proton. How strongly it holds the proton depends on how well it keeps its negative charge.
- The stronger the conjugate acid, the weaker its conjugate base. So the strongest base here is the anion of the weakest acid.

Step 1: Write the conjugate acids Each ion becomes an oxoacid of chlorine when it picks up one H^+.
ClO_4^- gives $HClO_4$ (perchloric acid, the strongest of the four).
ClO_3^- gives $HClO_3$ (chloric acid, strong).
ClO_2^- gives $HClO_2$ (chlorous acid, weak).
ClO^- gives $HOCl$ (hypochlorous acid, the weakest, $pK_a \approx 7.5$).

$$HClO_4 > HClO_3 > HClO_2 > HOCl \quad \text{(acid strength)}$$

Step 2: Reverse the order for the bases The weakest acid has the strongest conjugate base, so the

base strength runs the other way.

$$ClO^- > ClO_2^- > ClO_3^- > ClO_4^-$$

Step 3: Why the charge is held differently In ClO_4^- the single negative charge is spread over four oxygen atoms by resonance, and chlorine is in the $+7$ state, which pulls electron density strongly. The ion is very stable and has almost no urge to take a proton. In ClO^- the charge sits on just one oxygen and chlorine is only in the $+1$ state. The charge is not spread out, so the oxygen grabs a proton easily.

Step 4: Check the options (A) ClO_4^- is the weakest base of the set, because its conjugate acid is the strongest. So (A) is wrong.
(B) ClO_3^- is also a very weak base, because $HClO_3$ is a strong acid. So (B) is wrong.
(C) ClO_2^- is stronger than (A) and (B) but weaker than ClO^-. So (C) is wrong.
(D) ClO^- has the weakest conjugate acid, so it is the strongest base. So (D) is correct.

Step 5: Conclusion The strongest base is the hypochlorite ion, option (D).

Quick Tip to Solve: The stronger the conjugate acid, the weaker the base. Find which oxoacid of chlorine is the weakest.

34. Which of the following exhibits only one oxidation state other than zero ? [1 mark]

(A) Cl_2

(B) F_2

(C) I_2

(D) Br_2

Correct Answer: (B) F_2

Solution:

Concept:

- A halogen molecule X_2 has oxidation state 0.
- Each atom can take one electron and go to -1, or it can share electrons with a more electronegative atom and go to a positive state.
- The question asks which one shows exactly one state other than 0.

Step 1: Look at fluorine Fluorine is the most electronegative element, with an electronegativity of 4.0. It has no vacant d orbitals in its second shell, so it cannot expand its octet. It never shares electrons in a way that makes it positive, because no atom is more electronegative to take them. So fluorine shows only the -1 state, for example in HF, NaF and CaF_2.

Step 2: Look at chlorine, bromine and iodine These atoms have vacant d orbitals in the valence shell, so they can unpair electrons and use higher states.
Cl_2: -1, $+1$, $+3$, $+5$, $+7$ (as in NaCl, HOCl, $HClO_2$, $KClO_3$, $HClO_4$).
Br_2: -1, $+1$, $+3$, $+5$ and rarely $+7$ (as in HBr, HOBr, BrF_3, $KBrO_3$).
I_2: -1, $+1$, $+3$, $+5$, $+7$ (as in HI, ICl, ICl_3, HIO_3, HIO_4).

Step 3: Check the options (A) Cl_2 shows many states, so it is wrong.
(B) F_2 shows only -1, so it is correct.
(C) I_2 shows many states, so it is wrong.
(D) Br_2 shows several states, so it is wrong.

Step 4: Conclusion Only fluorine shows a single oxidation state (-1) besides zero, which is option

(B).

Quick Tip to Solve: Think about which halogen is the most electronegative and has no d orbitals, so it never shows a positive state.

35. Which of the following cannot act as a reducing agent ? [1 mark]

(A) NO_2

(B) SO_2

(C) ClO_2

(D) CO_2

Correct Answer: (D) CO_2

Solution:

Concept:

- A reducing agent gives away electrons, so it is itself oxidised.
- For that to happen, some atom in the species must be able to move to a higher oxidation state.

Step 1: Key Approach Find the oxidation state of the central atom in each compound. Then see whether a higher, stable state is available. A species whose atoms are already at their highest possible state cannot act as a reducing agent.

Step 2: Check NO_2 Nitrogen here is $+4$. It can rise to $+5$ in NO_3^- and HNO_3. For example, NO_2 is oxidised by ozone to N_2O_5. So NO_2 can act as a reducing agent, and (A) is wrong.

Step 3: Check SO_2 Sulphur is $+4$ and can rise to $+6$. SO_2 decolourises acidified $KMnO_4$ and turns $Cr_2O_7^{2-}$ green, which is typical reducing behaviour: $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$. So (B) is wrong.

Step 4: Check ClO_2 Chlorine is $+4$. It can rise to $+5$ in ClO_3^-. In alkali, ClO_2 disproportionates: $2ClO_2 + 2OH^- \rightarrow ClO_2^- + ClO_3^- + H_2O$, so part of it is oxidised. So ClO_2 can act as a reducing agent, and (C) is wrong.

Step 5: Check CO_2 Carbon is already $+4$, its highest state, because it has only four valence electrons. Oxygen is at -2 and cannot be oxidised by ordinary reagents. Nothing in the molecule can lose electrons, so CO_2 cannot be a reducing agent. It can only be reduced, for example by hot carbon to CO. So (D) is correct.

Step 6: Conclusion Carbon dioxide has carbon in its maximum $+4$ state, so it cannot act as a reducing agent. This is option (D).

Quick Tip to Solve: A reducing agent must be able to go to a higher oxidation state. Find the compound whose central atom is already at its highest state.

36. Which of the following noble gases can most easily be liquefied ? [1 mark]

(A) Ar

(B) Ne

(C) Xe

(D) Kr

Correct Answer: (C) Xe

Solution:

Concept:

- A gas is liquefied when its molecules are pulled together strongly enough to stay as a liquid.
- The only attractive forces between noble gas atoms are weak London dispersion forces.
- The stronger these forces are, the higher the boiling point and the easier the liquefaction.

Step 1: Key Formula or Approach London forces grow with the size and polarisability of an atom. Down group 18 the atoms get bigger and their electron clouds are easier to distort, so the dispersion forces and the boiling points increase from He to Rn.

Step 2: Detailed Explanation Boiling points in kelvin: Ne about 27, Ar about 87, Kr about 120, Xe about 165.
The critical temperatures show the same trend: Ne about 44 K, Ar about 151 K, Kr about 209 K, Xe about 290 K.
A gas can be liquefied by pressure alone only below its critical temperature. Xe has the highest critical temperature of the four, so it can be liquefied at close to room temperature with pressure.
Among the options, xenon is the largest atom and has the strongest dispersion forces, so it is liquefied most easily.

Step 3: Why the other options are wrong Neon is the smallest and least polarisable of the four atoms. It has the weakest forces and the lowest boiling point, so it is the hardest to liquefy.
Argon and krypton lie in between. Both have weaker forces than xenon, so they need lower temperatures to condense.

Step 4: Conclusion Xenon has the largest atom and the strongest London forces among these gases, so it is the easiest to liquefy. This is option (C).

Quick Tip to Solve: Liquefaction is easiest when attractive forces between atoms are strongest. Think about how London forces change with atomic size down the group.

37. The peroxy acid of sulphur is [1 mark]

(A) $H_2S_2O_7$

(B) $H_2S_2O_8$

(C) H_2SO_4

(D) H_2SO_3

Correct Answer: (B) $H_2S_2O_8$

Solution:

Concept:

- A peroxy acid (peroxoacid) is an oxoacid that contains a peroxide linkage, $-O-O-$.
- In such acids, one or more of the usual oxygen atoms is replaced by a peroxo group.
- Sulphur forms two of them: peroxomonosulphuric acid H_2SO_5 and peroxodisulphuric acid $H_2S_2O_8$.

Step 1: Key Formula or Approach Draw the structure of each given acid and look for an O-O bond. The acid that has one is the peroxy acid.

Step 2: Detailed Explanation $H_2S_2O_8$ is $HO_3S-O-O-SO_3H$. Two sulphate units are joined through a peroxide bridge.

Oxidation state check: S is $+6$ and the two peroxo oxygens are -1 each.

$$2(+1) + 2(+6) + 2(-1) + 6(-2) = 2 + 12 - 2 - 12 = 0$$

A normal sulphate-type formula with all oxygens at -2 would not balance, which confirms the O-O linkage.

Step 3: Why the other options are wrong $H_2S_2O_7$ (pyrosulphuric acid, found in oleum) is $HO_3S - O - SO_3H$. The two sulphur atoms are joined by a single oxygen and there is no O-O bond.
H_2SO_4 (sulphuric acid) has sulphur bonded to four ordinary oxygens, two of them as OH groups. There is no O-O bond.
H_2SO_3 (sulphurous acid) has sulphur in the $+4$ state with three ordinary oxygens. There is no O-O bond.

Step 4: Conclusion Only $H_2S_2O_8$, peroxodisulphuric acid, contains a peroxide linkage. This is option (B).

Quick Tip to Solve: A peroxy acid has an O-O (peroxide) linkage. Draw the structures and see which acid has one.

38. In which of the following processes is nitric acid manufactured from ammonia ? [1 mark]

(A) Ostwald process

(B) Birkeland-Eyde process

(C) Laboratory process

(D) All of these

Correct Answer: (A) Ostwald process

Solution:

Concept:

- The question asks which industrial or laboratory method makes nitric acid with ammonia as the starting material.
- So we need to recall how nitric acid is prepared in each named process.

Step 1: Key Formula or Approach The industrial method that starts from ammonia is the Ostwald process. It has three reactions: catalytic oxidation of ammonia, oxidation of nitric oxide, and absorption of nitrogen dioxide in water.

Step 2: Detailed Explanation of the Ostwald process Ammonia is mixed with excess air and passed over a platinum-rhodium gauze catalyst at about 500 K and 9 bar:

$$4\,NH_3 + 5\,O_2 \xrightarrow{\text{Pt/Rh, 500 K}} 4\,NO + 6\,H_2O$$

Nitric oxide reacts with more oxygen:

$$2\,NO + O_2 \rightarrow 2\,NO_2$$

Nitrogen dioxide is absorbed in water to give nitric acid. The NO formed is recycled:

$$3\,NO_2 + H_2O \rightarrow 2\,HNO_3 + NO$$

The acid obtained is about 68 percent by mass.

Step 3: Check option (A) Ostwald process uses ammonia as the raw material, so (A) is correct.

Step 4: Check option (B) The Birkeland-Eyde process makes NO by passing air through an electric arc, $N_2 + O_2 \rightarrow 2\,NO$. It starts from nitrogen of air, not from ammonia. So (B) is wrong.

Step 5: Check options (C) and (D) In the laboratory, nitric acid is made by heating KNO_3 or $NaNO_3$ with concentrated H_2SO_4. No ammonia is used, so (C) is wrong.
Since only one of the three processes starts from ammonia, "All of these" in (D) is also wrong.

Step 6: Conclusion Nitric acid is manufactured from ammonia by the Ostwald process, which is option (A).

Quick Tip to Solve: Think of the three-step catalytic route that begins with burning ammonia over a Pt-Rh gauze.

39. Which of the following gases cannot be collected over water ? [1 mark]

(A) H_2

(B) O_2

(C) CH_4

(D) SO_2

Correct Answer: (D) SO_2

Solution:

Concept:

- A gas can be collected over water (by downward displacement of water) only if it dissolves very little in water.
- A gas that dissolves well or reacts with water would be lost, so it is collected by another method.

Step 1: Key Formula or Approach Compare the solubility of the four gases in water. Non-polar, light or weakly interacting gases are sparingly soluble. A polar acidic oxide is highly soluble.

Step 2: Check option (A), hydrogen H_2 is non-polar and a very small molecule. It is almost insoluble in water, so it can be collected over water. (A) is not the answer.

Step 3: Check option (B), oxygen O_2 is non-polar and only slightly soluble (about 3 mL in 100 mL of water). It is routinely collected over water in the laboratory. (B) is not the answer.

Step 4: Check option (C), methane CH_4 is non-polar and has no hydrogen bonding with water. It is sparingly soluble and can be collected over water. (C) is not the answer.

Step 5: Check option (D), sulphur dioxide SO_2 is a polar acidic oxide. It is very soluble in water and also reacts with it to form sulphurous acid:

$$SO_2 + H_2O \rightleftharpoons H_2SO_3$$

About 40 volumes of the gas dissolve in one volume of water at room temperature. Most of it would stay in the water, so it cannot be collected over water. It is collected by downward delivery of air, since it is heavier than air.

Step 6: Conclusion Sulphur dioxide is highly soluble in water and reacts with it, so SO_2 cannot be collected over water. This is option (D).

Quick Tip to Solve: A gas can be collected over water only if it is sparingly soluble. Look for the polar acidic oxide.

40. Which of the following is formed by the reaction of Hg with ozone ? [1 mark]

(A) HgO

(B) HgO_2

(C) Hg_2O

(D) None of these

Correct Answer: (C) Hg_2O

Solution:

Concept:

- Ozone is a strong oxidising agent because it easily gives up nascent oxygen.
- It oxidises many metals and compounds.
- Mercury shows a well-known test with ozone.

Step 1: Key Formula or Approach When mercury is exposed to ozone, it loses its shining surface and begins to stick to glass. This effect is called tailing of mercury. NCERT gives the product as mercurous oxide:

$$2\,Hg + O_3 \rightarrow Hg_2O + O_2$$

Step 2: Detailed Explanation One molecule of O_3 gives one oxygen atom to two atoms of mercury. The mercury is oxidised to the $+1$ state, and ozone is reduced to O_2.
The oxide film Hg_2O (mercurous oxide) is what changes the surface tension of mercury, so the metal no longer forms a clean round meniscus. It clings to glass and leaves a tail.
So the product named in the class 12 textbook is Hg2O.

Step 3: Check option (A) HgO would need mercury in $+2$ state. It is a common oxide of mercury, but the reaction with ozone stops at the $+1$ oxide in the textbook equation. So (A) is not the intended answer.

Step 4: Check options (B) and (D) HgO_2 is a peroxide and is not the product reported for this reaction, so (B) is wrong.
A product does form, so "None of these" in (D) is wrong as well.

Step 5: Conclusion Mercury reacts with ozone to give mercurous oxide, Hg_2O, which is option (C).

Quick Tip to Solve: Ozone makes mercury lose its meniscus (tailing of mercury). Recall the textbook equation for this change.

41. The bleaching property of chlorine is due to [1 mark]

(A) Acidic property

(B) Oxidising property

(C) Reducing property

(D) Air polluting property

Correct Answer: (B) Oxidising property

Solution:

Concept:

- Bleaching means removing the colour of a substance.
- It can happen by oxidation (colour is destroyed by oxygen) or by reduction (as with sulphur dioxide).
- We must decide which way chlorine bleaches.

Step 1: Key Formula or Approach Chlorine bleaches only in the presence of moisture. It reacts with water to form hypochlorous acid, which releases nascent oxygen:

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$

$$HOCl \rightarrow HCl + [O]$$

Step 2: Detailed Explanation The nascent oxygen [O] is a very reactive oxidising species. It oxidises the coloured matter to a colourless product:

$$\text{Coloured matter} + [O] \rightarrow \text{Colourless matter}$$

This bleaching is permanent, because the colouring matter is destroyed by oxidation. So the property responsible is the oxidising property.

Step 3: Check the options (A) Acidic property: the HCl and HOCl formed are acids, but acidity does not remove colour. Acid-base indicators only change colour, so (A) is wrong.
(B) Oxidising property: this is the cause, as shown above, so (B) is right.
(C) Reducing property: chlorine is an oxidising agent, not a reducing one. Reduction bleaching is shown by SO_2, so (C) is wrong.
(D) Air polluting property: this has nothing to do with the chemistry of bleaching, so (D) is wrong.

Step 4: Conclusion Chlorine bleaches because it acts as an oxidising agent through nascent oxygen. This is option (B).

Quick Tip to Solve: Moist chlorine forms HOCl, which gives out nascent oxygen. Ask what that oxygen does to the dye.

42. The outermost electronic configuration of inert gases is [1 mark]

(A) ns^2np^2

(B) ns^2np^4

(C) ns^2np^5

(D) ns^2np^6

Correct Answer: (D) ns^2np^6

Solution:

Concept:

- Inert (noble) gases belong to group 18.
- Their outer shell is completely filled, which is why they are chemically so unreactive.

Step 1: Key Formula or Approach A filled outer shell with s and p subshells has two electrons in the s

subshell and six in the p subshell. The general outer configuration is ns^2np^6, with helium as the only exception because it has just $1s^2$.

Step 2: Detailed Explanation Neon: $2s^2 2p^6$.
Argon: $3s^2 3p^6$.
Krypton: $4s^2 4p^6$.
Each of these has the form ns^2np^6. The p subshell holds at most six electrons, so it is full, giving a stable octet.

Step 3: Check the options (A) ns^2np^2 is the outer configuration of group 14 (carbon family), so (A) is wrong.
(B) ns^2np^4 belongs to group 16 (oxygen family), so (B) is wrong.
(C) ns^2np^5 belongs to group 17 (halogens), one electron short of a full shell, so (C) is wrong.
(D) ns^2np^6 is the filled octet of the noble gases, so (D) is right.

Step 4: Conclusion The outermost configuration of the inert gases is ns^2np^6, which is option (D).

Quick Tip to Solve: Inert gases have a completely filled outer shell: two electrons in s and six in p.

43. If the electronic configuration of a transition element in its +3 oxidation state is $[\mathrm{Ar}]3d^4$, then its atomic number would be [1 mark]

(A) 25

(B) 26

(C) 22

(D) 19

Correct Answer: (A) 25

Solution:

Concept:

- A transition element loses its outer $4s$ electrons first and then some $3d$ electrons to form a cation.
- The atomic number of the element equals the number of electrons in the neutral atom, so we must add back the electrons that were lost.

Step 1: Count the electrons in the ion The ion M^{3+} has the configuration $[\mathrm{Ar}]3d^4$. Argon has 18 electrons.

$$\text{electrons in } \mathrm{M}^{3+} = 18 + 4 = 22$$

Step 2: Add back the lost electrons The +3 state means 3 electrons were removed from the neutral atom.

$$\text{electrons in } \mathrm{M} = 22 + 3 = 25$$

The atomic number is equal to the number of electrons in the neutral atom, so $Z = 25$. This is manganese: $[\mathrm{Ar}]3d^5 4s^2$ loses the two 4s electrons and one 3d electron to give $\mathrm{Mn}^{3+} = [\mathrm{Ar}]3d^4$.

Step 3: Check the other options (B) $Z = 26$ is iron. Fe^{3+} has 23 electrons, $[\mathrm{Ar}]3d^5$, not $3d^4$.
(C) $Z = 22$ is titanium. Ti^{3+} has 19 electrons, $[\mathrm{Ar}]3d^1$.
(D) $Z = 19$ is potassium, which is not a transition element. Taking three electrons from potassium would break into the stable argon core, which does not happen in chemistry. So only (A) fits.

Step 4: Conclusion The element is manganese with atomic number 25, which is option (A).

Quick Tip to Solve: Count the electrons in the +3 ion (18 + 4), then add the 3 electrons that were removed.

44. The most common oxidation state of lanthanide elements is [1 mark]

(A) +2

(B) +3

(C) +4

(D) 0

Correct Answer: (B) +3

Solution:

Concept:

- Lanthanoids are the 4f series, from cerium to lutetium.
- Their outer configuration is usually $4f^n\,5d^{0\text{ or }1}\,6s^2$.
- They form ions by losing the $6s$ electrons and one more from $5d$ or $4f$.

Step 1: Why +3 is the usual state Losing the two 6s electrons and one 5d (or one 4f) electron gives the +3 state. The sum of the first three ionisation enthalpies is small, and the high hydration or lattice energy of the Ln^{3+} ion makes up for it. Because 4f electrons are shielded and lie deep inside, the fourth ionisation enthalpy is much larger, so going beyond +3 is hard.

Step 2: Where +2 and +4 appear The +2 and +4 states appear only when they give an empty, half-filled or full 4f subshell. For example, Ce^{4+} is $4f^0$, Tb^{4+} is $4f^7$, Eu^{2+} is $4f^7$ and Yb^{2+} is $4f^{14}$. These are exceptions for a few elements, not the common behaviour.

Step 3: Check the options (A) +2 occurs only for Sm, Eu and Yb, so it is wrong.
(B) +3 is shown by all the lanthanoids, so it is correct.
(C) +4 occurs mainly for Ce, Pr and Tb, so it is wrong.
(D) 0 is the free metal, not an oxidation state of its compounds, so it is wrong.

Step 4: Conclusion The most common oxidation state of the lanthanoids is +3, option (B).

Quick Tip to Solve: Lanthanoids lose two 6s electrons and one 5d or 4f electron. Which oxidation state does that give?

45. The oxidation state of Ni in $Ni(CO)_4$ is [1 mark]

(A) +4

(B) +3

(C) +2

(D) 0

Correct Answer: (D) 0

Solution:

Concept:

- The oxidation state of the central metal in a complex is found from the charge on the complex and the charges on the ligands.
- A neutral ligand adds nothing to the charge.

Step 1: Key Formula or Approach Let the oxidation state of Ni be x. Carbon monoxide (CO) is a neutral ligand, so its charge is 0. The complex $\mathrm{Ni(CO)_4}$ has no charge on it.

$$x + 4(\text{charge on CO}) = \text{charge on complex}$$

Step 2: Detailed Explanation Put in the values.

$$x + 4(0) = 0 \Rightarrow x = 0$$

So nickel is in the zero oxidation state. As a check, free Ni is $3d^8 4s^2$. In Ni(0), the configuration rearranges to $3d^{10}$, and four CO ligands donate 8 electrons, giving 18 electrons around the metal, which is a stable count. The shape is tetrahedral with sp^3 hybridisation.

Step 3: Why the other options are wrong. +4, +3 and +2 would need negative ligands to balance the charge. Since CO has no charge, any non-zero value of x would leave the complex with a net positive charge, but $\mathrm{Ni(CO)_4}$ is a neutral molecule.

Step 4: Conclusion The oxidation state of Ni in $\mathrm{Ni(CO)_4}$ is zero, option (4).

Quick Tip to Solve: CO is a neutral ligand and the complex has no net charge. Solve $x + 4(0) = 0$.

46. The number of ions in aqueous solution of $\mathrm{[Co(NH_3)_5Cl]Cl_2}$ is [1 mark]

(A) 3

(B) 4

(C) 2

(D) 6

Correct Answer: (A) 3

Solution:

Concept:

- In a coordination compound, the part inside the square brackets is the coordination sphere.
- The metal and its ligands are held by coordinate bonds, so this part stays together as one complex ion in water.
- The species written outside the bracket are counter ions, and they separate freely when the salt dissolves.

Step 1: Key Formula or Approach Write the dissociation of the salt into the complex ion and the counter ions, then add up the number of ions formed per formula unit.

Step 2: Detailed Explanation Inside the bracket we have one Co, five neutral $\mathrm{NH_3}$ molecules and one $\mathrm{Cl^-}$ ligand.
Oxidation state of cobalt: $x + 5(0) + (-1) = +2$, so the complex ion is $\mathrm{[Co(NH_3)_5Cl]^{2+}}$ and $x = +3$.
The two chloride ions outside the bracket balance this charge of +2.
Dissociation in water:

$$\mathrm{[Co(NH_3)_5Cl]Cl_2 \rightarrow [Co(NH_3)_5Cl]^{2+} + 2\,Cl^-}$$

Ions produced = 1 complex cation + 2 chloride ions = 3.

Step 3: Why the other options are wrong Option (B) 4 would need the chloride inside the bracket to ionise as well. That chloride is a ligand bonded to cobalt, so it does not leave the complex.
Option (C) 2 ignores that the two outside chloride ions are separate ions, each one counted.

Option (D) 6 would treat all five NH_3 ligands, the cobalt and the chlorides as separate species. The complex does not break up like that in water.

Step 4: Conclusion The salt gives one complex ion and two free chloride ions, so three ions form in solution. This is option (A).

Quick Tip to Solve: Only the ions outside the square bracket separate from the complex. Count the complex cation as one ion and add the free chloride ions.

47. $[Co(NH_3)_5Br]SO_4$ **and** $[Co(NH_3)_5SO_4]Br$ **are related to each other as** [1 mark]

(A) Ionisation isomers

(B) Linkage isomers

(C) Co-ordination isomers

(D) Geometric isomers

Correct Answer: (A) Ionisation isomers

Solution:

Concept:

- Isomers have the same molecular formula but a different arrangement of atoms.
- In coordination compounds, several types of structural isomerism exist: ionisation, linkage, coordination and hydrate isomerism.
- Geometric isomerism is a type of stereoisomerism.

Step 1: Key Formula or Approach Compare the two formulae. Check what is inside the square bracket (the coordination sphere) and what sits outside as the counter ion.

Step 2: Detailed Explanation Both compounds contain one Co, five NH_3, one Br and one SO_4, so the molecular formula is the same.
In the first compound, bromide is the ligand and sulphate is the counter ion.
In the second compound, sulphate is the ligand and bromide is the counter ion.
So the two compounds give different ions in water:

$$[Co(NH_3)_5Br]SO_4 \rightarrow [Co(NH_3)_5Br]^{2+} + SO_4^{2-}$$

$$[Co(NH_3)_5SO_4]Br \rightarrow [Co(NH_3)_5SO_4]^{+} + Br^{-}$$

Isomers that differ in which anion is bound as a ligand and which is free as a counter ion are called ionisation isomers. The first gives a white precipitate with $BaCl_2$ and the second gives a pale yellow precipitate with $AgNO_3$.

Step 3: Why the other options are wrong Linkage isomers (B) need an ambidentate ligand such as NO_2^- bonding through a different atom (N or O). Here no ligand changes its donor atom.
Coordination isomers (C) need both a complex cation and a complex anion, with ligands swapped between the two metal centres. Here the anion outside the bracket is a simple ion.
Geometric isomers (D) have the same ligands but a different spatial arrangement (cis or trans). Here the ligands themselves are different.

Step 4: Conclusion The two compounds exchange the ligand and the counter ion, so they are ionisation isomers. This is option (A).

Quick Tip to Solve: Look at which anion is inside the square bracket in each formula and which one is outside. The two anions have swapped places.

48. Vitamin B12 contains [1 mark]

(A) Cobalt

(B) Magnesium

(C) Iron

(D) Nickel

Correct Answer: (A) Cobalt

Solution:

Concept:

- Vitamin B12 is a complex molecule that contains the metal cobalt at its core, coordinated to a corrin ring.
- This metal is essential for the biological activity of Vitamin B12.

Step 1: Analysis of options. **(A) Cobalt:** Correct — Cobalt is the metal at the center of the Vitamin B12 structure.
(B) Magnesium: Magnesium is present in other biological compounds, but not in Vitamin B12.
(C) Iron: Iron is a component of hemoglobin and other heme proteins but is not found in Vitamin B12.
(D) Nickel: Nickel is found in some enzymes but not in Vitamin B12.

Step 2: Conclusion. The correct answer is **(A)** because Vitamin B12 contains cobalt at its center.

Quick Tip to Solve: Vitamin B12 is also known as cobalamin because cobalt is the central metal atom in its structure.

49. When chloroform reacts with acetone then which of the following is formed ? [1 mark]

(A) Ethylene dichloride

(B) Mesitylene

(C) Chloretone

(D) Chloral

Correct Answer: (C) Chloretone

Solution:

Concept:

- Chloroform, $CHCl_3$, has a hydrogen that is fairly acidic because the three chlorine atoms pull electron density away from the carbon.
- In the presence of a base, it loses this hydrogen to form the trichloromethyl carbanion, $^{-}CCl_3$.
- Acetone has a polar carbonyl group where a nucleophile can attack.

Step 1: Key Formula or Approach Base removes H^+ from chloroform. The carbanion attacks the carbonyl carbon of acetone. The resulting alkoxide takes up a proton to give an alcohol.

Step 2: Detailed Explanation Carbanion formation:

$$CHCl_3 + OH^- \rightarrow {}^-CCl_3 + H_2O$$

Addition to acetone:

$$^-CCl_3 + (CH_3)_2C{=}O \rightarrow (CH_3)_2C(O^-)CCl_3$$

Protonation:

$$(CH_3)_2C(O^-)CCl_3 + H_2O \rightarrow (CH_3)_2C(OH)CCl_3 + OH^-$$

Overall, in the presence of a base such as KOH:

$$CHCl_3 + CH_3COCH_3 \xrightarrow{KOH} CCl_3C(CH_3)_2OH$$

The product is 1,1,1-trichloro-2-methylpropan-2-ol, commonly called chloretone. It is used as a hypnotic and as a preservative.

Step 3: Why the other options are wrong Ethylene dichloride (1,2-dichloroethane) comes from addition of Cl_2 to ethene. It has no connection with chloroform and acetone.
Mesitylene (1,3,5-trimethylbenzene) forms when three molecules of acetone condense in the presence of concentrated H_2SO_4. No chloroform is involved.
Chloral (CCl_3CHO) is made by chlorination of ethanol, not from acetone.

Step 4: Conclusion Chloroform adds to the carbonyl group of acetone in the presence of a base and gives chloretone. This is option (C).

Quick Tip to Solve: In basic medium chloroform gives the trichloromethyl anion, which adds to the carbonyl carbon of acetone. Write the alcohol that results.

50. In Wurtz reaction, the reduction of alkyl halide is carried with [1 mark]

(A) Zn/HCl

(B) HI

(C) Zn/Cu couple

(D) Na in presence of dry ether

Correct Answer: (D) Na in presence of dry ether

Solution:

Concept:

- The Wurtz reaction joins two alkyl groups. An alkyl halide is treated with sodium metal in dry ether and a higher alkane forms.
- The word "reduction" in the question is loose wording. The question is really asking which reagent is used in the Wurtz reaction.

Step 1: Key Formula or Approach The Wurtz reaction is:

$$2\,R{-}X + 2\,Na \xrightarrow{\text{dry ether}} R{-}R + 2\,NaX$$

Sodium takes the halogen from two alkyl halide molecules and the two alkyl groups join. Dry ether is used because sodium reacts with water.

Step 2: Check option (A) Zn/HCl Zn and HCl produce nascent hydrogen, which reduces an alkyl

halide to an alkane with the same number of carbon atoms, as in $\mathrm{R{-}X} \rightarrow \mathrm{R{-}H}$. No carbon-carbon bond forms, so this is not the Wurtz reaction. (A) is wrong.

Step 3: Check option (B) HI HI can reduce alkyl halides to alkanes at high temperature, but again the carbon skeleton does not grow. (B) is wrong.

Step 4: Check option (C) Zn/Cu couple The Zn/Cu couple in alcohol also reduces an alkyl halide to an alkane, $\mathrm{R{-}X} \rightarrow \mathrm{R{-}H}$. It does not couple two alkyl groups. (C) is wrong.

Step 5: Check option (D) Na in dry ether This is exactly the reagent of the Wurtz reaction. Sodium in dry ether removes the halogen and couples two alkyl groups. (D) is CORRECT.

Step 6: Conclusion The Wurtz reaction is carried out with sodium in the presence of dry ether, which is option (D).

Quick Tip to Solve: Recall the Wurtz reaction equation: alkyl halide plus a metal in a dry solvent. Which option names that metal and solvent?

51. Ethyl bromide on boiling with alcoholic caustic potash gives [1 mark]

(A) Ethyl alcohol

(B) Ethylene

(C) Acetylene

(D) Ethane

Correct Answer: (B) Ethylene

Solution:

Concept:

- An alkyl halide can react with KOH in two different ways, and the solvent decides which way.
- Aqueous KOH gives substitution (an alcohol).
- Alcoholic KOH gives elimination (an alkene).

Step 1: Key Formula or Approach With alcoholic KOH the reaction is dehydrohalogenation. The base pulls out a hydrogen from the carbon next to the carbon holding the halogen, and the halide leaves. A double bond forms between the two carbons.

$$\mathrm{CH_3CH_2Br + KOH\,(alc.)} \xrightarrow{\Delta} \mathrm{CH_2{=}CH_2 + KBr + H_2O}$$

Step 2: Apply to ethyl bromide Ethyl bromide is $\mathrm{CH_3CH_2Br}$. It has hydrogens on the beta carbon (the $\mathrm{CH_3}$ group). Removing H and Br from adjacent carbons gives $\mathrm{CH_2{=}CH_2}$, which is ethene (ethylene).

Step 3: Check the other options (A) Ethyl alcohol forms only with aqueous KOH by substitution, not with alcoholic KOH.
(C) Acetylene $\mathrm{HC{\equiv}CH}$ would need loss of two molecules of HX, for example from a dihalide, and not from a single mono-halide.
(D) Ethane would need reduction of the C-Br bond, and KOH is not a reducing agent.

Step 4: Conclusion Ethyl bromide on boiling with alcoholic KOH undergoes elimination to give ethylene. This is option (B).

Quick Tip to Solve: Alcoholic KOH causes elimination of HBr (dehydrohalogenation), while aqueous KOH causes substitution.

52. The reaction, $C_6H_5X + 2\,Na + RX \xrightarrow{\text{Dry ether}} C_6H_5R + 2\,NaX$, is called [1 mark]

(A) Wurtz reaction

(B) Wurtz-Fittig reaction

(C) Fittig reaction

(D) Frankland reaction

Correct Answer: (B) Wurtz-Fittig reaction

Solution:

Concept:

- Three named reactions of halides with sodium in dry ether look alike, so we sort them by the type of halides that couple:
- 1. Wurtz reaction: two alkyl halides give an alkane, $R{-}X + 2\,Na + X{-}R \rightarrow R{-}R$.
- 2. Fittig reaction: two aryl halides give a biaryl, $Ar{-}X + 2\,Na + X{-}Ar \rightarrow Ar{-}Ar$.
- 3. Wurtz-Fittig reaction: one aryl halide and one alkyl halide give an alkylbenzene, $Ar{-}X + 2\,Na + R{-}X \rightarrow Ar{-}R$.

Step 1: Read the given reaction The reactants are a halobenzene (the benzene ring carries X), the alkyl halide RX and sodium in dry ether. The product is an alkylbenzene (the ring carries R) along with 2NaX.
So an aryl group has been joined to an alkyl group.

Step 2: Match with the named reactions (A) Wurtz reaction joins two alkyl groups, so it is wrong.
(B) Wurtz-Fittig reaction joins an aryl halide with an alkyl halide, which is exactly this case. So (B) is CORRECT.
(C) Fittig reaction joins two aryl groups. Here one partner is an alkyl halide, so it is wrong.
(D) Frankland reaction uses zinc and an alkyl halide to make organozinc compounds, so it does not fit.

Step 3: Conclusion Coupling of an aryl halide with an alkyl halide using sodium in dry ether is the Wurtz-Fittig reaction, option (B).

Quick Tip to Solve: An aryl halide is coupled with an alkyl halide using sodium in dry ether. Recall which named reaction does this.

53. Which of the following reagents reacts with ethyl amine to give ethyl alcohol ? [1 mark]

(A) Br_2/KOH

(B) Acidified $KMnO_4$

(C) HNO_3

(D) HNO_2

Correct Answer: (D) HNO_2

Solution:

Concept:

- Primary aliphatic amines react with nitrous acid to give alcohols. This is the key difference from aromatic primary amines, which give diazonium salts at 273-278 K.
- Nitrous acid is unstable, so it is made in the flask from NaNO2 and HCl.

Step 1: Key Formula or Approach A primary aliphatic amine first forms an unstable aliphatic diazonium salt. This breaks down at once, loses nitrogen gas and gives an alcohol.

$$CH_3CH_2NH_2 + HNO_2 \rightarrow CH_3CH_2OH + N_2 + H_2O$$

Step 2: Check option (A) Br2/KOH Bromine with KOH is the reagent of the Hoffmann bromamide degradation. It turns an amide into a primary amine with one carbon less. It does not change an amine into an alcohol. (A) is wrong.

Step 3: Check option (B) Acidified KMnO4 Acidified permanganate is a strong oxidising agent. It breaks down ethylamine in a messy way and does not give ethyl alcohol. (B) is wrong.

Step 4: Check option (C) HNO3 Nitric acid is a strong acid. It only protonates the basic amine and forms the salt ethylammonium nitrate, $C_2H_5NH_3^+ NO_3^-$. No alcohol forms. (C) is wrong.

Step 5: Check option (D) HNO2 Nitrous acid gives ethyl alcohol with ethylamine, as shown in Step 2, with nitrogen gas released. (D) is CORRECT.

Step 6: Conclusion Ethylamine is converted into ethyl alcohol by nitrous acid, which is option (D).

Quick Tip to Solve: Primary aliphatic amines give alcohols with nitrous acid, with release of nitrogen gas.

54. Which of the following is known as wood spirit ? [1 mark]

(A) Methyl alcohol

(B) Ethyl alcohol

(C) Glycerol

(D) Glycol

Correct Answer: (A) Methyl alcohol

Solution:

Concept:

- Many alcohols have old common names that come from the way they were first made or used.
- We need the alcohol that carries the name wood spirit.

Step 1: Recall the source of the name Methanol was first obtained by the destructive distillation of wood, that is, by heating wood strongly in the absence of air. Because of this source it was called wood spirit or wood alcohol.
Its formula is CH_3OH.

Step 2: Check option (A), methyl alcohol Methyl alcohol is the common name of methanol, CH_3OH. This is the wood spirit. So (A) is TRUE.

Step 3: Check the other options Ethyl alcohol (ethanol, C_2H_5OH) is obtained by fermentation of sugar or starch, so it is called grain alcohol, not wood spirit. So (B) is wrong.
Glycerol (propane-1,2,3-triol) is a trihydric alcohol obtained from fats and oils. So (C) is wrong.
Glycol (ethane-1,2-diol) is a dihydric alcohol used as antifreeze. So (D) is wrong.

Step 4: Conclusion Wood spirit is methyl alcohol (methanol), so the correct option is (A).

Quick Tip to Solve: Think about which alcohol was first made by heating wood in the absence of air.

55. When vapours of an alcohol are passed over hot reduced copper, it gives an alkene. The alcohol is [1 mark]

(A) Primary

(B) Secondary

(C) Tertiary

(D) None of these

Correct Answer: (C) Tertiary

Solution:

Concept:

- Primary, secondary and tertiary alcohols behave differently when their vapours are passed over hot reduced copper at about 573 K.
- This reaction is a standard test used to tell the three classes apart.

Step 1: Key Formula or Approach Primary alcohol: dehydrogenation to an aldehyde.

$$\mathrm{RCH_2OH} \xrightarrow{\text{Cu, } 573\ K} \mathrm{RCHO} + \mathrm{H_2}$$

Secondary alcohol: dehydrogenation to a ketone.

$$\mathrm{R_2CHOH} \xrightarrow{\text{Cu, } 573\ K} \mathrm{R_2C{=}O} + \mathrm{H_2}$$

Tertiary alcohol: no H on the carbon holding the OH group, so dehydration takes place instead and an alkene forms.

Step 2: Detailed Explanation Dehydrogenation needs a hydrogen atom on the carbon that carries the $-\mathrm{OH}$ group. A tertiary alcohol has none, so it cannot lose $\mathrm{H_2}$.
Under the heat, it loses a molecule of water from the OH and a neighbouring $\mathrm{C-H}$ instead. For 2-methylpropan-2-ol:

$$\mathrm{(CH_3)_3COH} \xrightarrow{\text{Cu, } 573\ K} \mathrm{(CH_3)_2C{=}CH_2} + \mathrm{H_2O}$$

So the product is the alkene 2-methylpropene.

Step 3: Why the other options are wrong Primary alcohols give aldehydes under these conditions, not alkenes, so (A) is wrong.
Secondary alcohols give ketones, so (B) is wrong.
Since the tertiary alcohol does give an alkene, (D) is also wrong.

Step 4: Conclusion An alcohol that gives an alkene over hot reduced copper is a tertiary alcohol, option (C).

Quick Tip to Solve: Primary and secondary alcohols lose $\mathrm{H_2}$ over hot copper. Ask which class cannot, because it has no hydrogen on the carbon with the OH group.

56. Phenol gives a compound of characteristic colouration with which among the following ? [1 mark]

(A) Iodine solution

(B) Bromine water

(C) Aqueous $\mathrm{FeCl_3}$ solution

(D) Ammonium hydroxide

Correct Answer: (C) Aqueous $\mathrm{FeCl_3}$ solution

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Solution:

Concept:

- Phenol has a hydroxyl group attached directly to a benzene ring.
- This group gives phenol some tests that are specific to it.
- We need the reagent that gives a characteristic colour.

Step 1: Key Formula or Approach Phenol reacts with neutral ferric chloride to form a coloured iron(III) phenoxide complex:

$$6\,C_6H_5OH + FeCl_3 \rightarrow [Fe(OC_6H_5)_6]^{3-} + 3\,H^+ + 3\,Cl^-$$

The complex is violet (purple).

Step 2: Detailed Explanation When a few drops of aqueous $FeCl_3$ are added to a phenol solution, a violet or purple colour appears at once. This is the standard ferric chloride test for phenols. Other phenols give blue, green or red colours.
So the reagent that gives a characteristic colour is aqueous $FeCl_3$, which is option (C).

Step 3: Why the other options are wrong Iodine solution does not give a characteristic coloured compound with phenol, so (A) is wrong.
Bromine water reacts with phenol to give a white precipitate of 2,4,6-tribromophenol, and the bromine colour disappears. This is a precipitate, not a characteristic colouration, so (B) is wrong.
Ammonium hydroxide only reacts a little with phenol to form a phenoxide salt and gives no characteristic colour, so (D) is wrong.

Step 4: Conclusion Phenol shows a violet colour with aqueous ferric chloride, so the answer is option (C).

Quick Tip to Solve: Recall the standard test for the phenolic group, which gives a violet colour.

57. The general formula of ether is [1 mark]

(A) $C_nH_{2n}O$

(B) $C_nH_{2n+1}O$

(C) $C_nH_{2n+2}O$

(D) $C_nH_{2n}O_2$

Correct Answer: (C) $C_nH_{2n+2}O$

Solution:

Concept:

- An ether has the general structure $R - O - R'$, where R and R' are alkyl groups joined through one oxygen atom.
- A saturated open-chain ether has no double bonds and no rings.
- So its formula can be built from the matching alkane.

Step 1: Key Formula or Approach An alkane with n carbon atoms is C_nH_{2n+2}. Putting an oxygen atom between two carbon atoms (a C-O-C link) adds one O and does not change the number of H atoms.

Step 2: Detailed Explanation Take the first ether, dimethyl ether, $CH_3 - O - CH_3$. Its molecular formula is C_2H_6O.
Here n = 2 and the hydrogen count is 6, which equals 2n + 2 = 6.

Check with ethyl methyl ether, $CH_3 - O - CH_2CH_3$: the formula is C_3H_8O, and 2n + 2 = 8. So the formula holds.
The general formula is therefore $C_nH_{2n+2}O$, the same as a saturated monohydric alcohol, so ethers and alcohols are functional isomers.

Step 3: Why the other options are wrong Option (A), $C_nH_{2n}O$, is the formula of saturated aldehydes and ketones (for example C_3H_6O for propanone).
Option (B), $C_nH_{2n+1}O$, always has an odd number of hydrogens with one oxygen, which would be an unpaired-electron fragment and not a stable compound.
Option (D), $C_nH_{2n}O_2$, is the formula of saturated carboxylic acids and esters, which carry two oxygen atoms.

Step 4: Conclusion The general formula of an ether is $C_nH_{2n+2}O$, which is option (C).

Quick Tip to Solve: Build the ether from the alkane C_nH_{2n+2}: inserting one O between two carbons does not change the hydrogen count. Test with CH_3OCH_3.

58. Which of the following reagents reacts easily with both Acetaldehyde and Acetone ? [1 mark]

(A) Fehling solution

(B) Grignard reagent

(C) Schiff's reagent

(D) Tollen's regent

Correct Answer: (B) Grignard reagent

Solution:

Concept:

- Acetaldehyde, CH_3CHO, is an aldehyde.
- Acetone, CH_3COCH_3, is a ketone.
- We need a reagent that works on both, so it must react with the carbonyl group $C = O$ that both share and not with the aldehyde C-H bond.

Step 1: Key Approach Both compounds have a polar carbonyl group. The carbon carries a partial positive charge, so a strong nucleophile can attack it (nucleophilic addition). Tests that rely on easy oxidation work only for aldehydes, because ketones have no hydrogen on the carbonyl carbon.

Step 2: Check the Grignard reagent (B) The carbon of the $R - MgX$ group is a strong nucleophile. With acetaldehyde, $CH_3CHO + CH_3MgBr$ followed by hydrolysis gives propan-2-ol, a secondary alcohol. With acetone, $CH_3COCH_3 + CH_3MgBr$ followed by hydrolysis gives 2-methylpropan-2-ol, a tertiary alcohol. So it reacts easily with both.

Step 3: Check Fehling solution (A) and Tollens' reagent (D) Both are mild oxidising agents. Acetaldehyde is oxidised by them (red precipitate of Cu_2O with Fehling solution, silver mirror with Tollens' reagent). Acetone has no hydrogen on its carbonyl carbon, so these mild oxidants do not touch it. Both (A) and (D) are wrong.

Step 4: Check Schiff's reagent (C) Schiff's reagent is a colourless dye solution that gives a pink or magenta colour with aldehydes. Ketones such as acetone do not restore the colour (apart from a very faint, slow response). So (C) is wrong.

Step 5: Conclusion Only the Grignard reagent adds to the carbonyl group of both acetaldehyde and acetone, which is option (B).

Quick Tip to Solve: Fehling, Tollens and Schiff are aldehyde tests, so acetone fails them. Only a nucleophile that adds to $C = O$ works on both.

59. The IUPAC name of $CH_3CH_2COCH_2CH_3$ is [1 mark]

(A) Diethyl ketone

(B) 3-Pentanone

(C) 2-Pentanone

(D) Methyl propyl ketone

Correct Answer: (B) 3-Pentanone

Solution:

Concept:

- The compound $CH_3CH_2COCH_2CH_3$ has a carbonyl group ($C = O$) between two carbon atoms, so it is a ketone.
- The IUPAC name of a ketone comes from the parent alkane by replacing the final -e with -one, and the position of the C=O group is given by a locant.

Step 1: Key Approach 1. Pick the longest chain that contains the carbonyl carbon.
2. Number the chain from the end that gives the carbonyl carbon the lowest number.
3. Write the locant before the name.

Step 2: Detailed Explanation Count the carbons: $CH_3 - CH_2 - CO - CH_2 - CH_3$ has 5 carbons in a straight chain, so the parent is pentane.
The C=O carbon is the third carbon whether we count from the left or from the right. So the locant is 3.
Name: pentane drops the final e and adds one, so pentan-3-one, written as 3-pentanone.

Step 3: Why the other options are wrong Option (A), diethyl ketone, is the common (trivial) name because two ethyl groups sit on the C=O. It is not the IUPAC name.
Option (C), 2-pentanone, is $CH_3COCH_2CH_2CH_3$, where the carbonyl is on carbon 2. That is a different compound.
Option (D), methyl propyl ketone, is the common name of 2-pentanone, so it is wrong for this structure and is also not an IUPAC name.

Step 4: Conclusion The IUPAC name is 3-pentanone, option (B).

Quick Tip to Solve: Count five carbons in the chain and note that the C=O sits in the middle, on carbon 3. Diethyl ketone is only the common name.

60. Which of the following gives Cannizzaro's reaction? [1 mark]

(A) CH_3CHO

(B) $HCHO$

(C) $HCOOH$

(D) CH_3COCH_3

Correct Answer: (B) $HCHO$

Solution:

Step 1: Condition for Cannizzaro reaction. It occurs with aldehydes that **lack α-hydrogen**. Such

aldehydes undergo self-oxidation and self-reduction in strong base to give a salt of a carboxylic acid and an alcohol.

Step 2: Check options for α-H. (A) CH_3CHO: has α-H $\Rightarrow$ gives aldol, not Cannizzaro.
(B) $HCHO$ (formaldehyde): has **no** α-H $\Rightarrow$ **undergoes Cannizzaro**.
(C) $HCOOH$: not an aldehyde (it is a carboxylic acid).
(D) CH_3COCH_3: a ketone; does not show Cannizzaro.

Step 3: Conclusion. Thus, $HCHO$ is the correct choice $\Rightarrow$ **(B)**.

Quick Tip to Solve: Aldehydes without α-H (e.g., formaldehyde, benzaldehyde) give Cannizzaro; those with α-H prefer aldol condensation.

61. Which of the following is tartaric acid ? [1 mark]

(A) $CH_3 - CH(OH) - COOH$

(B) $HOOC - CH_2 - CH_2 - COOH$

(C) $HOOC - CH(OH) - CH(OH) - COOH$

(D) $HO - C(CH_2COOH)_2 - COOH$

Correct Answer: (C) $HOOC - CH(OH) - CH(OH) - COOH$

Solution:

Concept:

- Tartaric acid is a dicarboxylic acid found in grapes and tamarind.
- Its IUPAC name is 2,3-dihydroxybutanedioic acid.
- The name tells us the structure: a 4-carbon chain (butane), two -COOH groups at the ends (dioic acid), and one -OH group on each of carbons 2 and 3.

Step 1: Draw the structure from the name The skeleton is $HOOC - CH(OH) - CH(OH) - COOH$. It has the molecular formula $C_4H_6O_6$, with two carboxyl groups and two hydroxyl groups.

Step 2: Check option (A) $CH_3 - CH(OH) - COOH$ has three carbons, one -OH and one -COOH. This is 2-hydroxypropanoic acid, which is lactic acid (found in sour milk). So (A) is wrong.

Step 3: Check option (B) $HOOC - CH_2 - CH_2 - COOH$ is butanedioic acid, which is succinic acid. It has two -COOH groups but no -OH group. So (B) is wrong.

Step 4: Check option (C) $HOOC - CH(OH) - CH(OH) - COOH$ has four carbons, two -COOH groups and one -OH group on each of C2 and C3. This is exactly 2,3-dihydroxybutanedioic acid, tartaric acid. So (C) is right.

Step 5: Check option (D) $HO - C(CH_2COOH)_2 - COOH$ has a central carbon carrying one -OH and three carboxyl groups in total. This is 2-hydroxypropane-1,2,3-tricarboxylic acid, which is citric acid (found in lemon). So (D) is wrong.

Step 6: Conclusion Tartaric acid is $HOOC - CH(OH) - CH(OH) - COOH$, option (C).

Quick Tip to Solve: Tartaric acid is 2,3-dihydroxybutanedioic acid: two -COOH groups at the ends and one -OH on each middle carbon.

62. An organic compound on reaction with saturated solution of $NaHCO_3$ gives effervescence. Then the compound is [1 mark]

(A) Alkane

(B) Alkene

(C) Acetic acid

(D) Ethyl alcohol

Correct Answer: (C) Acetic acid

Solution:

Concept:

- Effervescence (bubbling) with sodium bicarbonate solution means that carbon dioxide gas is being released.
- Sodium bicarbonate, $NaHCO_3$, gives off CO_2 only when it meets an acid stronger than carbonic acid.

Step 1: Key Approach Carboxylic acids (pK_a about 4 to 5) are stronger than carbonic acid (pK_{a1} about 6.4). So a carboxylic acid pushes carbonic acid out of the bicarbonate, and carbonic acid breaks down into water and CO_2. Alcohols and phenols are weaker acids than carbonic acid and do not react.

Step 2: Write the reaction For acetic acid (ethanoic acid), the reaction is:

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2 \uparrow$$

The gas CO_2 comes out as bubbles. This is the standard test for a carboxylic acid.

Step 3: Why the other options are wrong Alkanes and alkenes are neutral hydrocarbons with no acidic hydrogen, so they do not react with $NaHCO_3$.
Ethyl alcohol, C_2H_5OH, is a very weak acid (pK_a about 16), much weaker than carbonic acid, so it gives no bubbles.

Step 4: Conclusion The compound is acetic acid, option (C).

Quick Tip to Solve: Bubbles mean CO_2 is released, which needs an acid stronger than carbonic acid. Among the options only a carboxylic acid is that strong.

63. Which of the following is Isopropyl amine ? [1 mark]

(A) $CH_3 - CH_2 - CH_2 - NH_2$

(B) $CH_3 - NH - C_2H_5$

(C) $CH_3 - CH(NH_2) - CH_3$

(D) $(CH_3)_2CH - CH_2 - NH_2$

Correct Answer: (C) $CH_3 - CH(NH_2) - CH_3$

Solution:

Concept:

- An amine is named by naming the alkyl group(s) attached to nitrogen and adding the word amine. "Isopropyl" means the group $(CH_3)_2CH-$, which is a propane chain joined to the rest of the molecule through its middle (second) carbon.

Step 1: Key Formula or Approach Isopropylamine has the nitrogen on the central carbon of propane, so its formula is $(CH_3)_2CH - NH_2$. Its IUPAC name is propan-2-amine. It is a primary amine, because only one carbon group is attached to nitrogen.

Step 2: Check option (A) $CH_3 - CH_2 - CH_2 - NH_2$ has the NH_2 group on the end carbon of a straight three-carbon chain. This is n-propylamine (propan-1-amine), not isopropylamine. So (A) is wrong.

Step 3: Check option (B) $CH_3 - NH - C_2H_5$ has two different groups (methyl and ethyl) on nitrogen. It is a secondary amine, N-methylethanamine (ethylmethylamine). So (B) is wrong.

Step 4: Check option (C) $CH_3 - CH(NH_2) - CH_3$ has the NH_2 group on the middle carbon of propane. This is the isopropyl group joined to NH_2, so it is isopropylamine (propan-2-amine). So (C) is right.

Step 5: Check option (D) $(CH_3)_2CH - CH_2 - NH_2$ has a branched four-carbon chain with the NH_2 on the end carbon. The group on nitrogen is isobutyl, so this is isobutylamine (2-methylpropan-1-amine). So (D) is wrong.

Step 6: Conclusion Only option (C) shows the NH_2 group on the central carbon of propane, so it is isopropylamine.

Quick Tip to Solve: Isopropyl means the $(CH_3)_2CH-$ group, so the nitrogen must sit on the middle carbon of propane.

64. By which of the following processes, is methyl amine prepared ? [1 mark]

(A) Wurtz reaction

(B) Hoffmann Bromamide reaction

(C) Friedel-Crafts reaction

(D) Kolbe's reaction

Correct Answer: (B) Hoffmann Bromamide reaction

Solution:

Concept:

- Methylamine CH_3NH_2 is a primary aliphatic amine with one carbon atom.
- We must find the reaction that gives a primary amine with one carbon less than the starting compound, since methylamine is the smallest such amine from a carbon chain.

Step 1: Key Formula or Approach Hoffmann bromamide degradation converts a primary amide into a primary amine that has one carbon atom less. Ethanamide (acetamide) is treated with bromine and aqueous sodium hydroxide:

$$CH_3CONH_2 + Br_2 + 4NaOH \rightarrow CH_3NH_2 + Na_2CO_3 + 2NaBr + 2H_2O$$

Step 2: Apply it Acetamide has two carbon atoms. The carbonyl carbon is lost as carbonate, so the product has one carbon, which is methanamine (methylamine). So methylamine is prepared by the Hoffmann bromamide reaction.

Step 3: Why the other options are wrong Wurtz reaction joins two alkyl halides with sodium to give an alkane, for example ethane from CH_3Br. It does not give an amine.
Friedel-Crafts reaction attaches an alkyl or acyl group to a benzene ring. It does not make amines.
Kolbe's reaction treats sodium phenoxide with carbon dioxide to give salicylic acid. It does not give an amine.
So option (2) is correct.

Step 4: Conclusion Methylamine is prepared by the Hoffmann bromamide reaction. This is option (2).

Quick Tip to Solve: Look for the reaction that turns a primary amide into a primary amine with one carbon atom less. Acetamide gives methylamine this way.

65. Maltose on hydrolysis gives [1 mark]

(A) Glucose + Fructose

(B) Galactose + Glucose + Fructose

(C) Starch + Sucrose

(D) Two molecules of Glucose

Correct Answer: (D) Two molecules of Glucose

Solution:

Concept:

- Maltose is a disaccharide.
- A disaccharide is made of two monosaccharide units joined by a glycosidic bond (an oxygen bridge between two carbons).
- Hydrolysis means breaking that bond with water, so the two original units come back.

Step 1: Key Formula or Approach To answer, we only need to know which two sugar units build maltose.
Maltose is formed from two α-D-glucose units joined through C1 of one unit and C4 of the other (an α-1,4 glycosidic link).

Step 2: Detailed Explanation Water adds across the glycosidic link. The enzyme maltase, or a dilute acid, speeds this up.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{maltase or } H^+} 2\,C_6H_{12}O_6$$

Both molecules of $C_6H_{12}O_6$ formed are D-glucose. So maltose gives two molecules of glucose.

Step 3: Why the other options are wrong Option (1), glucose + fructose, is what sucrose gives on hydrolysis, not maltose.
Option (2) has three sugar units. A disaccharide has only two units, so it can never give three. Such a mixture would come from a trisaccharide.
Option (3), starch + sucrose, is wrong because starch is a large polysaccharide. Hydrolysis breaks big molecules into smaller ones and cannot build starch from a small sugar.

Step 4: Conclusion Maltose on hydrolysis gives two molecules of glucose. This is option (4).

Quick Tip to Solve: Maltose is a disaccharide of two glucose units joined by an α-1,4 link. Breaking that link with water gives glucose twice.

66. Which of the following is not a macromolecule ? [1 mark]

(A) DNA

(B) Starch

(C) Palmitate

(D) Insulin

Correct Answer: (C) Palmitate

Solution:

Concept:

- A macromolecule is a very large molecule built by joining many small units (monomers) into a long chain.
- Its molar mass runs into thousands or millions.
- Proteins, polysaccharides and nucleic acids are the main biological macromolecules.

Step 1: Key Formula or Approach Classify each option as a polymer of small units or as a single small molecule. The one that is a single small molecule is the answer.

Step 2: Check DNA DNA is a polynucleotide. Thousands to millions of nucleotides are joined by phosphodiester bonds. So DNA is a macromolecule.

Step 3: Check starch Starch is a polysaccharide made of many α-D-glucose units (amylose and amylopectin). So starch is a macromolecule.

Step 4: Check palmitate Palmitate is the anion of palmitic acid, $C_{15}H_{31}COO^-$. It is one fatty acid ion with a molar mass of only about 255 g/mol. It is not a chain of repeating units, so it is not a macromolecule.

Step 5: Check insulin Insulin is a protein hormone. It is a polypeptide made of 51 amino acids in two chains joined by disulfide bridges. So insulin is a macromolecule.

Step 6: Conclusion Palmitate is a small molecule, while DNA, starch and insulin are macromolecules. This is option (3).

Quick Tip to Solve: Look for the option that is one small molecule and not a long chain of repeating units. DNA, starch and insulin are all polymers.

67. Which of the following is capable of forming Zwitter ion ? [1 mark]

(A) $H_2N - CH_2COOH$

(B) CH_3COOH

(C) $CH_3CH_2NH_2$

(D) CH_3NO_2

Correct Answer: (A) $H_2N - CH_2COOH$

Solution:

Concept:

- A zwitterion is a dipolar ion. It carries a positive charge and a negative charge in the same molecule, so its net charge is zero.
- For this, one molecule must have an acidic group that can give away a proton and a basic group that can take one.

Step 1: Key Formula or Approach Amino acids have both an acidic $-COOH$ group and a basic $-NH_2$ group. The acid group passes its proton to the amine inside the same molecule.

Step 2: Detailed Explanation Option (1) is glycine, the simplest amino acid. It forms the zwitterion by internal proton transfer.

$$H_2N - CH_2 - COOH \rightleftharpoons {}^+H_3N - CH_2 - COO^-$$

The $-NH_3^+$ end is positive and the $-COO^-$ end is negative.

Step 3: Why the other options are wrong Option (2), acetic acid, has only an acidic group and no basic group, so it cannot take a proton internally.
Option (3), ethylamine, has only a basic $-NH_2$ group and nothing to give a proton, so no zwitterion forms.
Option (4), nitromethane, has no group that behaves as a proper acid and base pair in the same molecule, so it does not form a zwitterion.

Step 4: Conclusion Only glycine has both the acidic and basic groups needed. This is option (1).

Quick Tip to Solve: A zwitterion needs an acidic -COOH and a basic -NH2 in the same molecule. Only an amino acid has both.

68. Which of the following is used as antioxidant ? [1 mark]

(A) Citric acid

(B) EDTA

(C) Sodium nitrite

(D) Sodium gluconate

Correct Answer: (A) Citric acid

Solution:

Concept:

- Fats and oils in food turn rancid when oxygen reacts with them.
- An antioxidant is a food additive that slows this oxidation and so keeps the food fresh for longer.
- Common food antioxidants are BHA, BHT, ascorbic acid and citric acid.

Step 1: Key Formula or Approach Go through the options and recall the role of each additive in food. The one that works as an antioxidant is the answer.

Step 2: Check citric acid Citric acid is a well known food antioxidant. It lowers the pH and also binds trace metal ions that would speed up oxidation. It is used in fruit products, oils and beverages. So option (1) is correct.

Step 3: Check EDTA EDTA is mainly a chelating agent (a sequestrant). It ties up metal ions, but its main label is sequestrant and not antioxidant. So (2) is not the best answer.

Step 4: Check sodium nitrite Sodium nitrite is a curing agent and preservative for meats. It stops the growth of bacteria and gives the pink colour. It is not used as an antioxidant. So (3) is wrong.

Step 5: Check sodium gluconate Sodium gluconate is a sequestrant. It binds metal ions and does not act as an antioxidant. So (4) is wrong.

Step 6: Conclusion Citric acid is the food antioxidant among the options. This is option (1).

Quick Tip to Solve: An antioxidant keeps fats and fruits from reacting with oxygen. Of the four, citric acid is the one grouped with antioxidants.

69. Riboflavin is the chemical name of which of the following ? [1 mark]

(A) Vitamin B_1

(B) Vitamin B_2

(C) Vitamin B_6

(D) Vitamin B complex

Correct Answer: (B) Vitamin B_2

Solution:

Concept:

- Many vitamins have a chemical name besides the letter name.
- The B group of vitamins is water soluble, and each member has its own chemical name.

Step 1: Key Formula or Approach Recall the chemical names of the common B vitamins:
B_1 is thiamine.
B_2 is riboflavin.
B_6 is pyridoxine.
B_{12} is cyanocobalamin.

Step 2: Detailed Explanation Riboflavin matches B_2. Its deficiency causes cracks at the corners of the mouth (cheilosis), inflamed tongue and skin problems. Milk, eggs, liver and green vegetables are good sources. So option (2) is correct.

Step 3: Why the other options are wrong Option (1), B_1, is thiamine. Its deficiency causes beriberi.
Option (3), B_6, is pyridoxine. Its deficiency causes convulsions.
Option (4), vitamin B complex, is the name of the whole group and not one chemical compound, so it cannot be the chemical name of riboflavin.

Step 4: Conclusion Riboflavin is vitamin B_2. This is option (2).

Quick Tip to Solve: Thiamine is B1, riboflavin is B2 and pyridoxine is B6. Match the name to the number.

70. Which of the following is used as tranquilizer ? [1 mark]

(A) Luminal

(B) Tofranil

(C) Mescaline

(D) Sulphadiazine

Correct Answer: (A) Luminal

Solution:

Concept:

- Tranquilizers are drugs that treat stress, anxiety and mild mental disturbance. They act on the central nervous system and calm a person down without causing much sleep.
- Many of them belong to the group called barbiturates, which are derivatives of barbituric acid.

Step 1: Key Approach Match each option with its drug class: tranquilizer, antidepressant, hallucinogen or antibacterial. The option that falls in the tranquilizer class is the answer.

Step 2: Check option (A) Luminal Luminal is the trade name of phenobarbitone, a barbiturate. Barbiturates such as veronal, amytal, nembutal, luminal and seconal are the standard examples of tranquilizers (hypnotics) in the syllabus.
So (A) is CORRECT.

Step 3: Check option (B) Tofranil Tofranil is the trade name of imipramine. It is an antidepressant, which lifts mood in depression. It is not the standard example of a tranquilizer. So (B) is wrong.

Step 4: Check option (C) Mescaline Mescaline is a hallucinogen. It causes visions and a distorted

sense of reality, the opposite of calming. So (C) is wrong.

Step 5: Check option (D) Sulphadiazine Sulphadiazine is a sulpha drug, a synthetic antibacterial. It fights infection and has no calming action. So (D) is wrong.

Step 6: Conclusion Luminal (phenobarbitone), a barbiturate, is the tranquilizer. This is option (A).

Quick Tip to Solve: Tranquilizers are mostly barbiturates. Find the option that is a barbiturate drug.

Section B: Short Answer Type Questions (any 10 to be answered, 2 marks each)

SA-1. What is called artificial sweetener ? Give an example. [2 marks]

Solution:

Concept:

- Table sugar (sucrose) tastes sweet but gives energy, about 4 kcal per gram, and it raises blood sugar.
- People who must cut calories or control diabetes need a substitute that tastes sweet without these effects.

Step 1: Definition An artificial sweetener is a synthetic chemical that tastes much sweeter than cane sugar but adds almost no calories to the diet.
Only a very small amount is needed, because the compound is many times sweeter than sucrose. Most of it passes through the body unchanged, so it does not raise blood sugar or add to body weight.

Step 2: Example Ortho-sulphobenzimide, commonly called saccharin, is the first popular artificial sweetener. It is about 550 times sweeter than cane sugar.
It is excreted in urine unchanged, so it is calorie free and safe for diabetic persons.
Other examples are aspartame (about 100 times sweeter than sucrose), alitame and sucralose.

Step 3: Conclusion An artificial sweetener is a synthetic, nearly calorie-free compound that is far sweeter than sugar. Example: saccharin.

Quick Tip to Solve: An artificial sweetener is a synthetic, calorie-free compound much sweeter than sugar. Saccharin is a standard example.

SA-2. What is Buna-N-rubber ? [2 marks]

Solution:

Concept:

- Buna-N is a synthetic rubber.
- The name comes from Bu for butadiene, na for sodium (the catalyst used in early manufacture) and N for nitrile (acrylonitrile).
- It is a copolymer, which means it is made from two different monomers.

Step 1: Monomers used The two monomers are buta-1,3-diene and acrylonitrile (prop-2-enenitrile).

$$CH_2 = CH - CH = CH_2 \quad \text{and} \quad CH_2 = CH - CN$$

Step 2: Preparation The two monomers undergo addition copolymerisation in the presence of a

peroxide catalyst.

$$n\,CH_2 = CH - CH = CH_2 + n\,CH_2 = CH - CN \xrightarrow{\text{peroxide}} \left[-CH_2 - CH = CH - CH_2 - CH_2 - CH(CN)-\right]_n$$

Step 3: Properties and uses Buna-N is resistant to petrol, lubricating oil and organic solvents, unlike natural rubber. It is therefore used to make oil seals, tank linings, gaskets and hoses.

Step 4: Conclusion Buna-N is a synthetic rubber, a copolymer of buta-1,3-diene and acrylonitrile, resistant to oils and solvents.

Quick Tip to Solve: Buna-N is a copolymer of buta-1,3-diene and acrylonitrile, a synthetic rubber resistant to oils.

SA-3. Discuss the utility of DNA fingerprinting. [2 marks]

Solution:

Step 1: What is DNA Fingerprinting? DNA fingerprinting is a molecular biology technique used to identify individuals based on their unique DNA profiles. It is a technique that compares specific regions of the DNA sequence that are highly variable among individuals.

Step 2: Uses of DNA Fingerprinting. - Forensic Science: It is widely used in criminal investigations to match biological samples (blood, hair, etc.) to suspects.
- Paternity Testing: DNA fingerprinting can confirm biological relationships between individuals, such as parent-child relationships.
- Genetic Studies: It helps in mapping genetic diseases and identifying the genetic makeup of individuals or populations.
- Identification: It is used in identifying individuals in cases of missing persons, immigration, and animal identification.

Quick Tip to Solve: DNA fingerprinting is essential for criminal investigations, paternity testing, and genetic studies.

SA-4. Write structural formulae of the following :
(a) 2-Aminoethanol
(b) N-Ethylethanamine [2 marks]

Solution:

Concept:

- A structural formula shows how the atoms in a molecule are joined.
- The IUPAC name tells us the parent chain, the functional groups and where they sit, so we read the name part by part.

Step 1: Part (a), 2-Aminoethanol The parent chain is ethanol, a 2-carbon chain with the -OH group on carbon 1 (the alcohol gets the lowest number). The prefix 2-amino means an -NH_2 group is attached to carbon 2.
So the chain is HO-CH_2-CH_2-NH_2.

$$HO - CH_2 - CH_2 - NH_2$$

Step 2: Part (b), N-Ethylethanamine The parent is ethanamine, $CH_3CH_2NH_2$. The locant N means

the extra ethyl group is attached to the nitrogen atom itself, not to a carbon.
Replacing one H of the -NH_2 group by C_2H_5 gives a secondary amine with two ethyl groups on nitrogen (common name diethylamine).

$$CH_3CH_2 - NH - CH_2CH_3$$

Step 3: Conclusion The two structural formulae are given below.

Quick Tip to Solve: Split each name into parent chain and substituent. In (b), the locant N means the ethyl group is attached to the nitrogen atom.

SA-5. Write IUPAC names of the following:
(a) Lactic acid
(b) Tartaric acid [2 marks]

Solution:

Concept:

- To name a carboxylic acid by the IUPAC system, pick the longest carbon chain that contains the $-COOH$ carbon. That carbon is always C-1.
- The ending -e of the parent alkane is replaced by -oic acid. If there are two $-COOH$ groups at the two ends of a chain, the ending becomes -dioic acid.
- Other groups on the chain are written as prefixes in alphabetical order, with their locants.

Step 1: Name (a) Lactic acid The structure of lactic acid is $CH_3 - CH(OH) - COOH$.
The chain has 3 carbons, so the parent is propane and the acid is propanoic acid.
The $-OH$ group sits on C-2, the carbon next to the carboxyl carbon, so it is written as 2-hydroxy.
So lactic acid is 2-hydroxypropanoic acid.

Step 2: Name (b) Tartaric acid The structure of tartaric acid is $HOOC - CH(OH) - CH(OH) - COOH$.
The chain has 4 carbons with a $-COOH$ group at each end, so the parent is butanedioic acid.
Numbering from either end, the two $-OH$ groups fall on C-2 and C-3.
So tartaric acid is 2,3-dihydroxybutanedioic acid.

Step 3: Conclusion Lactic acid is 2-hydroxypropanoic acid and tartaric acid is 2,3-dihydroxybutanedioic acid.

Quick Tip to Solve: Draw the structure of each acid first, then count the carbons in the longest chain that includes the $-COOH$ carbon and number the hydroxy groups.

SA-6. What is Fehling's solution? [2 marks]

Solution:

Concept:

- Fehling's solution is a chemical reagent used in the laboratory to test for aldehydes and reducing sugars.
- It is always prepared as two separate solutions that are mixed only at the time of use.

Step 1: Composition Fehling's solution A is an aqueous solution of copper(II) sulphate, which is light blue.

Fehling's solution B is an alkaline solution of sodium potassium tartrate (Rochelle salt) in sodium hydroxide.
The two are mixed in equal volumes just before the test. The tartrate keeps the Cu^{2+} ions in solution as a deep blue complex in the alkaline medium. Otherwise copper(II) hydroxide would separate out.

Step 2: Use and reaction On warming with an aliphatic aldehyde, the Cu^{2+} ions are reduced to Cu^{+} and the aldehyde is oxidised to a carboxylate ion. A red-brown precipitate of cuprous oxide forms.

$$RCHO + 2Cu^{2+} + 5OH^{-} \rightarrow RCOO^{-} + Cu_2O \downarrow + 3H_2O$$

Ketones and aromatic aldehydes (such as benzaldehyde) do not give this test.

Step 3: Conclusion Fehling's solution is a mixture of alkaline copper(II) tartrate complex (Fehling A, $CuSO_4$, plus Fehling B, Rochelle salt in NaOH) that gives a red-brown Cu_2O precipitate with aliphatic aldehydes.

Quick Tip to Solve: Think of the two parts (copper sulphate and alkaline Rochelle salt) and the red-brown precipitate it gives with an aliphatic aldehyde.

SA-7. What is metamerism ? Give example. [2 marks]

Solution:

Concept:

- Isomers are compounds that have the same molecular formula but different structures.
- Metamerism is one type of structural isomerism.

Step 1: Definition Metamerism is the type of isomerism in which compounds have the same molecular formula and the same functional group, but different alkyl groups on the two sides of that functional group. It is mostly seen in compounds with a polyvalent functional group such as ethers (-O-), ketones, secondary amines and esters.

Step 2: Example Take the molecular formula $C_4H_{10}O$, which represents ethers.

$$CH_3 - O - CH_2CH_2CH_3 \quad \text{(methoxypropane)}$$

$$CH_3CH_2 - O - CH_2CH_3 \quad \text{(ethoxyethane)}$$

Both have the group -O- in the middle, but the two alkyl groups attached to oxygen are (methyl, propyl) in one and (ethyl, ethyl) in the other. They are metamers.

Step 3: Conclusion Metamerism is isomerism due to different alkyl groups on either side of the same functional group. Example: methoxypropane and ethoxyethane ($C_4H_{10}O$).

Quick Tip to Solve: Metamers have the same formula and functional group but different alkyl groups on either side of it, for example methoxypropane and ethoxyethane.

SA-8. What is called rectified spirit ? [2 marks]

Solution:

Concept:

- Ethanol is made by fermentation of sugars with yeast.

- The liquid we get (called wash) holds only about 10 to 15 percent ethanol in water, so it is concentrated by fractional distillation.

Step 1: What the distillation gives Fractional distillation of the wash gives a mixture of 95.6 percent ethanol and 4.4 percent water by mass. This mixture is called rectified spirit.

Step 2: Why it stops at 95.6 percent Ethanol and water form a constant boiling mixture (an azeotrope) at this composition, boiling at 351.1 K. The vapour has the same composition as the liquid, so further distillation cannot raise the ethanol content. Pure (absolute) alcohol is obtained from it by other methods, for example by adding benzene and distilling again.

Step 3: Conclusion Rectified spirit is the ethanol-water azeotrope containing 95.6 percent ethanol and 4.4 percent water.

Quick Tip to Solve: It is the constant boiling mixture of 95.6 percent ethanol and 4.4 percent water obtained by fractional distillation of fermented wash.

SA-9. How would you obtain the following compounds from ethyl bromide?
(a) Ethene
(b) Diethyl ether [2 marks]

Solution:

Concept:

- Ethyl bromide, C_2H_5Br, is a primary alkyl halide.
- It can undergo elimination (to give an alkene) or nucleophilic substitution (to give an ether), depending on the reagent.

Step 1: (a) Ethene by elimination Heating ethyl bromide with alcoholic KOH removes HBr (dehydrohalogenation). The hydrogen on the beta carbon leaves with the bromine.

$$CH_3CH_2Br + KOH(alc.) \xrightarrow{\Delta} CH_2 = CH_2 + KBr + H_2O$$

Alcoholic medium favours elimination, because the strong base OEt^- formed in alcohol abstracts the beta hydrogen.

Step 2: (b) Diethyl ether by Williamson synthesis Ethyl bromide is treated with sodium ethoxide. The ethoxide ion attacks the carbon that holds bromine and replaces bromide (an S_N2 reaction).

$$CH_3CH_2Br + C_2H_5ONa \rightarrow C_2H_5OC_2H_5 + NaBr$$

Sodium ethoxide is made earlier by adding sodium metal to ethanol: $2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$.

Step 3: Conclusion Ethene is obtained with alcoholic KOH and diethyl ether with sodium ethoxide (Williamson synthesis).

Quick Tip to Solve: Use alcoholic KOH (elimination) for ethene and sodium ethoxide (Williamson synthesis) for diethyl ether.

SA-10. Write IUPAC names of the following complex compounds:
(a) $[Co(NH_3)_5Cl]Cl_2$
(b) $K_3[Fe(C_2O_4)_3]$ [2 marks]

Solution:

Concept:

- IUPAC rules for a coordination compound: name the cation first and then the anion. Inside the complex, ligands come first in alphabetical order (ignoring numerical prefixes), then the metal with its oxidation state in Roman numerals.
- Neutral ligand NH_3 is called ammine. Cl^- is chlorido. Oxalate $C_2O_4^{2-}$ is oxalato. If the complex ion is an anion, the metal name ends in -ate (iron becomes ferrate).

Step 1: Name (a) $[Co(NH_3)_5Cl]Cl_2$ The complex cation is $[Co(NH_3)_5Cl]^{2+}$, and two Cl^- ions are outside as the anion.
Oxidation state of Co: $x + 5(0) + (-1) = +2$, so $x = +3$.
Ligands in alphabetical order are ammine (a) and then chlorido (c). Five ammine ligands give pentaammine.
Name: pentaamminechloridocobalt(III) chloride.

Step 2: Name (b) $K_3[Fe(C_2O_4)_3]$ The complex anion is $[Fe(C_2O_4)_3]^{3-}$, with three K^+ outside as the cation.
Oxidation state of Fe: $x + 3(-2) = -3$, so $x = +3$.
Oxalato is a bidentate ligand, so three of them are written as tris(oxalato), with the ligand name in brackets. The anionic complex uses ferrate.
Name: potassium tris(oxalato)ferrate(III).

Step 3: Conclusion The names are pentaamminechloridocobalt(III) chloride and potassium tris(oxalato)ferrate(III).

Quick Tip to Solve: Name ligands alphabetically, then the metal with its oxidation state. Use -ate for the metal when the complex ion is an anion.

SA-11. Why do transition elements form complex compounds? [2 marks]

Solution:

Step 1: Transition Elements and Their Properties. Transition elements have partially filled d-orbitals, which make them capable of forming coordinate bonds with ligands. The ability to form complex compounds arises from their ability to accept electron pairs from ligands, resulting in the formation of stable coordination complexes.

Step 2: Explanation. - Transition elements typically have variable oxidation states, which also enhances their ability to form complexes.
- The small size and high charge density of transition metal ions allow them to interact strongly with ligands, forming stable coordination compounds.

Step 3: Example. For example, the complex $[Cu(NH_3)_4]^{2+}$ is formed when copper(II) ion (Cu^{2+}) interacts with ammonia (NH_3) molecules, resulting in the formation of a square planar complex.

Quick Tip to Solve: Transition metals form complex compounds due to their ability to accept electron pairs from ligands, aided by their variable oxidation states.

SA-12. What are called interhalogen compounds ? Give examples. [2 marks]

Solution:

Concept:

- Halogens (F, Cl, Br, I) are reactive non-metals.
- They do not only combine with other elements, they also combine with each other.
- The products of such combination are called interhalogen compounds.

Step 1: Definition An interhalogen compound is a compound formed when two different halogens combine with each other. The general formula is XX'_n, where $n = 1, 3, 5$ or 7.
Here X is the larger (less electronegative) halogen and X' is the smaller (more electronegative) one. X is the central atom and carries the odd number of X' atoms around it.

Step 2: Types and Examples Type XX': ClF, BrF, ICl.

Type XX'_3: ClF_3, BrF_3.

Type XX'_5: BrF_5, IF_5.

Type XX'_7: IF_7 (the only known example).
They are prepared by direct combination of the halogens, for example $Cl_2 + F_2 \xrightarrow{437\ K} 2ClF$.

Step 3: Conclusion Interhalogen compounds are compounds formed between two different halogens, with the general formula XX'_n. Examples are ClF, BrF_3, IF_5 and IF_7.

Quick Tip to Solve: Think of compounds formed when two different halogens combine, with general formula XX'n. Name a few such as ClF, BrF3, IF5 and IF7.

SA-13. "Dioxygen is a gas whereas sulphur is solid at room temperature." Give reason. [2 marks]

Solution:

Concept:

- Whether a substance is a gas or a solid at room temperature depends on how strongly its molecules attract each other.
- This depends on the molecule's size and on the kind of bonding inside it.

Step 1: Dioxygen (O_2) Oxygen is a small atom. Its 2p orbitals overlap well, so two oxygen atoms form a stable double bond, $O = O$ (a $p\pi$-$p\pi$ bond).
So oxygen exists as small, discrete diatomic molecules, O_2. The molecular mass is low (32 u).
Only very weak van der Waals (London) forces act between such small molecules, so they stay far apart. Dioxygen is therefore a gas at room temperature.

Step 2: Sulphur Sulphur is a bigger atom. Its 3p orbitals overlap poorly sideways, so it does not form stable $p\pi$-$p\pi$ multiple bonds with itself.
Instead, sulphur forms strong single $S - S$ bonds and joins into a puckered eight-membered ring, S_8. Its molecular mass is high (256 u).
The large S_8 molecules have many electrons, so the van der Waals forces between them are much stronger. Sulphur is therefore a solid at room temperature.

Step 3: Conclusion Dioxygen is a small diatomic molecule O_2 with only weak intermolecular forces, so it is a gas. Sulphur forms large S_8 rings with strong intermolecular forces, so it is a solid.

Quick Tip to Solve: Compare the molecules: O2 is small and held by a stable double bond, while sulphur forms large S8 rings. Think of the strength of van der Waals forces.

SA-14. Give the structure and basicity of orthophosphoric acid. [2 marks]

Solution:

Concept:

- Orthophosphoric acid, H_3PO_4, is an oxoacid of phosphorus in which phosphorus is in the +5 oxidation state.
- Its structure is found by seeing how the phosphorus atom is bonded to oxygen, and its basicity is the number of ionisable hydrogen atoms, that is, the number of O-H groups.

Step 1: Structure The phosphorus atom is at the centre, surrounded by four oxygen atoms in a tetrahedral arrangement (sp^3 hybridised P).
One oxygen is joined to phosphorus by a $P = O$ bond (a $P \rightarrow O$ coordinate-type bond, $p\pi$-$d\pi$ in character). The other three oxygens are each present as an $P - OH$ group.

$$O = P(OH)_3$$

So the molecule has 1 P=O bond, 3 P-OH bonds and no P-H bond.

Step 2: Basicity Basicity is the number of replaceable hydrogen atoms. Only the hydrogens present in the O-H groups ionise, so H_3PO_4 has three of them.

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^- \rightleftharpoons 2H^+ + HPO_4^{2-} \rightleftharpoons 3H^+ + PO_4^{3-}$$

So orthophosphoric acid is tribasic and forms three series of salts, such as NaH_2PO_4, Na_2HPO_4 and Na_3PO_4.

Step 3: Conclusion Orthophosphoric acid has a tetrahedral structure $O = P(OH)_3$ with one P=O and three P-OH groups. It has three ionisable hydrogens, so its basicity is 3 (tribasic).

Quick Tip to Solve: Draw H3PO4 with one P=O and three P-OH groups, then count the O-H hydrogens to get the basicity.

SA-15. Differentiate between Roasting and Calcination. [2 marks]

Solution:

Concept:

- Before an ore is reduced to metal, it is often converted into its oxide.
- Roasting and calcination are two heating methods used for this purpose, but they differ in the kind of ore and the air supply.

Step 1: Roasting Roasting is the heating of a sulphide ore strongly in excess of air, below its melting point, usually in a reverberatory furnace.
The ore is oxidised to its oxide, and impurities such as sulphur and arsenic leave as volatile oxides SO_2 and As_2O_3.

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$

Step 2: Calcination Calcination is the heating of a carbonate or hydrated ore strongly in a limited supply of air or in absence of air, again below its melting point.
The ore loses volatile matter such as moisture and carbon dioxide, and becomes porous. No oxidation is needed.

$$ZnCO_3 \rightarrow ZnO + CO_2 \qquad Fe_2O_3 \cdot xH_2O \rightarrow Fe_2O_3 + xH_2O$$

Step 3: Summary of the Difference Roasting: sulphide ores, excess air, oxidation takes place, SO_2 is

given off.

Calcination: carbonate and hydrated oxide ores, little or no air, no oxidation, CO_2 or water vapour is given off.

Step 4: Conclusion Roasting oxidises a sulphide ore in excess air, whereas calcination heats a carbonate or hydrated ore in limited or no air to drive off CO_2 and moisture.

Quick Tip to Solve: Roasting is for sulphide ores heated in excess air; calcination is for carbonate or hydrated ores heated in limited air.

SA-16. Write a short note on Brownian movement. [2 marks]

Solution:

Concept:

- A colloidal solution contains particles of size 1 nm to 1000 nm spread in a dispersion medium.
- These particles are too small to be seen with an ordinary microscope, but their movement can be observed under an ultramicroscope.

Step 1: What is Brownian movement Brownian movement is the continuous, random, zig-zag motion of colloidal particles in the dispersion medium. It was first seen by the botanist Robert Brown in 1827 for pollen grains suspended in water.

Step 2: Cause The molecules of the dispersion medium are always moving and keep colliding with the colloidal particles from all sides.
For a very small particle, these collisions do not cancel out at every instant. The particle gets a push from the side with more impacts, so it changes direction again and again.

Step 3: Features and Importance The motion is faster for smaller particles, higher temperature and a less viscous medium.

It is also the reason colloidal particles do not settle under gravity, so it helps in the stability of a sol.

It supports the kinetic theory of matter, since it shows that molecules are in constant motion.

Step 4: Conclusion Brownian movement is the random zig-zag motion of colloidal particles caused by uneven bombardment by molecules of the dispersion medium. It keeps the sol stable by opposing settling.

Quick Tip to Solve: Define the zig-zag motion of colloidal particles and explain it by collisions with molecules of the dispersion medium.

SA-17. What is Pseudo first order reaction? Give example. [2 marks]

Solution:

Concept:

- Order of a reaction is the sum of the powers of the concentration terms in the rate law. Molecularity is the number of molecules that collide in the elementary step.
- Some reactions are bimolecular, but one reactant is present in such a large excess that its concentration hardly changes during the reaction.

Step 1: Definition A reaction that is really of higher molecularity (second order or more) but follows first order kinetics because one reactant is in large excess is called a pseudo first order reaction.

For a reaction $A + B \rightarrow$ products with B in large excess, the rate is

$$\text{Rate} = k[A][B] = k'[A], \quad k' = k[B]_0$$

Since $[B]$ stays almost constant, the rate depends on only one concentration, so the reaction behaves as first order.

Step 2: Examples Acid hydrolysis of ethyl acetate with a large excess of water:

$$CH_3COOC_2H_5 + H_2O \xrightarrow{H^+} CH_3COOH + C_2H_5OH$$

Here Rate $= k[CH_3COOC_2H_5][H_2O]$. Water is the solvent, so $[H_2O]$ is constant and Rate $= k'[CH_3COOC_2H_5]$.
The inversion of cane sugar in dilute acid is another common example.

Step 3: Conclusion A pseudo first order reaction is a bimolecular reaction that follows first order kinetics because one reactant is in large excess. Example: hydrolysis of ethyl acetate in excess water.

Quick Tip to Solve: One reactant is taken in large excess so its concentration stays constant and the rate depends on only one concentration. Ester hydrolysis in water is the classic case.

SA-18. What are the importances of salt bridge in an electrochemical cell? [2 marks]

Solution:

Step 1: Function of a Salt Bridge. A salt bridge is an essential component of an electrochemical cell that maintains electrical neutrality by allowing the flow of ions between the two half-cells. It connects the anode and cathode compartments of the cell.

Step 2: Importance of the Salt Bridge. - Maintaining electrical neutrality: The salt bridge helps maintain the balance of charges in the two half-cells by allowing ions to move between them. As oxidation occurs at the anode, positive ions accumulate, and as reduction occurs at the cathode, negative ions accumulate. The salt bridge neutralizes this charge buildup by providing a pathway for ion movement. - Prevention of liquid junction potential: The salt bridge prevents the formation of a potential difference between the two solutions due to the difference in ion concentrations, which could disrupt the cell's functioning. - Facilitating ion flow: It enables the flow of ions, which is necessary to complete the circuit and allow the redox reactions to proceed.

Step 3: Materials Used. A common salt bridge is made of a gel containing a neutral salt like potassium chloride (KCl) or sodium sulfate (Na_2SO_4).

Step 4: Conclusion

Quick Tip to Solve: The salt bridge is crucial for completing the electrical circuit in an electrochemical cell and ensuring the reaction continues without interference from charge buildup.

SA-19. What are the differences between Ideal solution and Non-ideal solution ? [2 marks]

Solution:

Concept:

- Solutions are compared by how closely they follow Raoult's law, which says the partial vapour pressure of each component is proportional to its mole fraction.
- A solution that follows it at every composition is ideal.

- One that does not is non-ideal.

Step 1: Ideal solution 1. It obeys Raoult's law at all concentrations and temperatures.
2. The A-B attractions are equal to the A-A and B-B attractions, so mixing does not change the forces between molecules.
3. The enthalpy of mixing is zero: $\Delta_{mix}H = 0$.
4. The volume of mixing is zero: $\Delta_{mix}V = 0$, so the total volume is the sum of the two volumes.
5. Examples: benzene and toluene, n-hexane and n-heptane.

Step 2: Non-ideal solution 1. It does not obey Raoult's law over the whole range of composition.
2. The A-B attractions differ from the A-A and B-B attractions.
3. $\Delta_{mix}H \neq 0$ and $\Delta_{mix}V \neq 0$.
4. It shows positive deviation (vapour pressure higher than expected, A-B weaker, mixing absorbs heat) or negative deviation (vapour pressure lower than expected, A-B stronger, mixing gives out heat).
5. Examples: ethanol and water (positive), acetone and chloroform (negative).

Step 3: Conclusion An ideal solution follows Raoult's law with zero heat and volume change on mixing. A non-ideal solution deviates from Raoult's law and has non-zero $\Delta_{mix}H$ and $\Delta_{mix}V$.

Quick Tip to Solve: Compare them on Raoult's law, intermolecular forces, $\Delta_{mix}H$ and $\Delta_{mix}V$.

SA-20. How many tetrahedral and octahedral voids are there in a closed packing of N spheres ? [2 marks]

Solution:

Concept:

- In a close packed arrangement (hexagonal or cubic) the spheres leave small gaps called voids.
- A tetrahedral void is surrounded by 4 spheres.
- An octahedral void is surrounded by 6 spheres.

Step 1: Key Formula or Approach Count the voids per sphere using a fixed unit cell. In a face centred cubic (ccp) cell there are 4 spheres, and the voids in it can be counted directly.

Step 2: Counting in the ccp unit cell Tetrahedral voids: each cell has 8 of them, one inside each of the 8 small cubes, and all 8 lie fully inside the cell.
Octahedral voids: one at the body centre (counts 1) and one on each of the 12 edge centres (each shared by 4 cells, so $12 \times \frac{1}{4} = 3$). Total $= 1 + 3 = 4$.
So for 4 spheres we get 8 tetrahedral and 4 octahedral voids.
Per sphere, that is 2 tetrahedral and 1 octahedral void.

Step 3: Scale up to N spheres

$$\text{Tetrahedral voids} = 2N, \qquad \text{Octahedral voids} = N$$

Step 4: Conclusion In a close packing of N spheres there are 2N tetrahedral voids and N octahedral voids.

Quick Tip to Solve: In a close packed lattice there is one octahedral void and two tetrahedral voids for every sphere.

Section B: Long Answer Type Questions (any 3 to be answered, 5 marks each)

LA-21. How many types of crystals are there ? Explain them in brief. [5 marks]

Solution:

Concept:

- A crystalline solid is made of particles (atoms, ions or molecules) arranged in a regular pattern.
- The kind of particle and the force that holds them together decide the properties.
- On this basis crystals are classified into four types.

Step 1: Answer to 'how many types' There are four types of crystals: (i) molecular, (ii) ionic, (iii) covalent (network) and (iv) metallic.

Step 2: Molecular crystals Constituent particles are molecules. They are held by weak forces: dispersion forces in non-polar solids, dipole-dipole forces in polar solids, and hydrogen bonds in solids such as ice.
They are soft, have low melting points, and are poor conductors of electricity because they have no free ions or electrons. Examples: solid CO_2, I_2, ice, solid NH_3.

Step 3: Ionic crystals Constituent particles are positive and negative ions held by strong electrostatic (coulombic) attraction.
They are hard but brittle, with high melting points. They do not conduct in the solid state, but conduct in the molten state or in solution because the ions become free. Examples: NaCl, KCl, CaF_2, ZnS.

Step 4: Covalent (network) crystals Atoms are joined to their neighbours by covalent bonds throughout the whole crystal, forming a giant network.
They are very hard and have very high melting points. They are usually insulators. Graphite is an exception because its free electrons make it a conductor. Examples: diamond, silicon carbide (SiC), quartz SiO_2.

Step 5: Metallic crystals Positive metal ions sit in a sea of free (delocalised) valence electrons, and the metallic bond between them is strong.
They are malleable and ductile, have a metallic lustre, and are good conductors of heat and electricity. Melting points range from low (Na, Hg) to high (W, Fe). Examples: Cu, Ag, Fe, Na.

Step 6: Conclusion Crystals are of four types based on the binding force: molecular, ionic, covalent (network) and metallic, with the properties given above.

Quick Tip to Solve: Classify by binding force: molecular, ionic, covalent (network) and metallic. Give particles, forces, properties and examples for each.

LA-22. What do you understand by Primary and Secondary cells ? Mention giving one example of each. [5 marks]

Solution:

Concept:

- A galvanic (electrochemical) cell converts the chemical energy of a redox reaction into electrical energy.
- Commercial cells are divided into primary and secondary cells depending on whether the cell reaction can be reversed.

Step 1: Primary cells A primary cell is one in which the cell reaction takes place only once. When the

reactants are used up the cell is dead, and it cannot be recharged because the reaction is not reversible in practice.
Example: the dry cell (Leclanche cell). Its anode is a zinc container and its cathode is a graphite rod surrounded by MnO_2 and carbon, with a paste of NH_4Cl and $ZnCl_2$ as electrolyte.
Anode: $Zn \rightarrow Zn^{2+} + 2e^-$
Cathode: $MnO_2 + NH_4^+ + e^- \rightarrow MnO(OH) + NH_3$
The mercury cell used in watches is another primary cell.

Step 2: Secondary cells A secondary cell can be recharged. After discharge, an external current larger than the cell's own e.m.f. is passed in the opposite direction. This reverses the cell reaction and restores the reactants, so the cell can be used again and again.
Example: the lead storage battery used in vehicles. Its anode is lead and its cathode is lead(IV) oxide, in about 38 percent H_2SO_4 solution.
Discharge at anode: $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$
Discharge at cathode: $PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$

$$Pb + PbO_2 + 2H_2SO_4 \rightleftharpoons 2PbSO_4 + 2H_2O$$

The reverse reaction on charging regenerates Pb, PbO_2 and H_2SO_4. The nickel-cadmium cell is another secondary cell.

Step 3: Difference in one line Primary cell: not rechargeable, single use. Secondary cell: rechargeable, reaction reversible.

Step 4: Conclusion A primary cell works once and cannot be recharged (example: dry cell). A secondary cell can be recharged and reused (example: lead storage battery).

Quick Tip to Solve: A primary cell cannot be recharged (dry cell). A secondary cell is rechargeable because its reaction is reversible (lead storage battery).

LA-23. Explain extraction of copper from copper pyrite. [5 marks]

Solution:

Concept:

- The chief ore of copper is copper pyrites, $CuFeS_2$ (chalcopyrite).
- It contains less than 2 percent copper and a lot of iron sulphide, so the extraction has several stages: concentration, roasting, smelting, self-reduction in a Bessemer converter, and refining.

Step 1: Concentration The ore is crushed and powdered. The sulphide ore is concentrated by froth flotation. Pine oil and a collector such as xanthate are added to water containing the powder, and air is blown in. The sulphide particles stick to the froth and float, while the earthy gangue settles down.

Step 2: Roasting The concentrated ore is heated strongly in excess air in a reverberatory furnace. Moisture and some impurities (As, Sb) go off as volatile oxides, and part of the sulphide changes to oxide.

$$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$$

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$

$$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$$

Step 3: Smelting The roasted ore is mixed with coke and silica (SiO_2) and heated in a blast furnace. Silica is an acidic flux. It combines with the basic iron(II) oxide to give iron silicate slag, which floats on the molten mass and is removed.

$$FeO + SiO_2 \rightarrow FeSiO_3 \text{ (slag)}$$

Copper(I) sulphide and a little iron sulphide are left as a molten mixture called copper matte (mainly Cu_2S with some FeS).

Step 4: Bessemerisation (self-reduction) The molten matte is transferred to a Bessemer converter lined with silica, mixed with a little silica, and a hot blast of air is passed. The remaining FeS is oxidised to FeO and removed as slag. Part of Cu_2S turns to Cu_2O, which reacts with the rest of Cu_2S to give copper metal.

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$

$$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$$

The copper formed is about 98 percent pure. On cooling, the dissolved SO_2 escapes and makes blisters on the surface, so it is called blister copper.

Step 5: Refining Blister copper is refined electrolytically. The impure copper is the anode, a thin sheet of pure copper is the cathode, and the electrolyte is acidified $CuSO_4$ solution.
Anode: $Cu \rightarrow Cu^{2+} + 2e^-$
Cathode: $Cu^{2+} + 2e^- \rightarrow Cu$
Impurities such as Ag, Au and Pt settle below the anode as anode mud. The copper obtained is 99.9 percent pure.

Step 6: Conclusion Copper is extracted from copper pyrites by froth flotation, roasting, smelting with silica, Bessemerisation to blister copper, and electrolytic refining.

Quick Tip to Solve: Concentrate by froth flotation, roast, smelt with silica to get matte, self-reduce in a Bessemer converter, then refine electrolytically.

LA-24. What are halogens? Write their names and electronic configurations. Throw light on the tendency of halogen to form hydrides. [5 marks]

Solution:

Concept:

- The question has three parts: (i) what halogens are, (ii) their names and electronic configurations, (iii) how readily they form hydrides.
- Halogens are the elements of Group 17 of the periodic table. The word means salt producers, because they react with metals to give salts.

Step 1: Names and symbols of the halogens There are five halogens: fluorine (F, Z = 9), chlorine (Cl, Z = 17), bromine (Br, Z = 35), iodine (I, Z = 53) and astatine (At, Z = 85).
Astatine is radioactive and very short lived, so it is rarely studied.

Step 2: Electronic configurations Every halogen has seven electrons in its outermost shell, so the general valence configuration is ns^2np^5. Each is one electron short of a noble gas configuration.
F : $1s^2\,2s^2\,2p^5$ or $[He]\,2s^2 2p^5$
Cl : $1s^2\,2s^2\,2p^6\,3s^2\,3p^5$ or $[Ne]\,3s^2 3p^5$
Br : $[Ar]\,3d^{10}\,4s^2\,4p^5$

I : $[\mathrm{Kr}]\,4d^{10}\,5s^2\,5p^5$
At : $[\mathrm{Xe}]\,4f^{14}\,5d^{10}\,6s^2\,6p^5$

Step 3: Tendency to form hydrides All halogens combine with hydrogen to form hydrogen halides, HX:

$$\mathrm{H_2 + X_2 \rightarrow 2HX}$$

The ease of this reaction falls steadily from fluorine to iodine, because the H-X bond gets weaker and the halogen gets less reactive as the atom gets bigger.
Fluorine reacts explosively with hydrogen even in the dark. Chlorine reacts in sunlight or on heating. Bromine reacts only on heating with a platinum catalyst. Iodine reacts slowly and the reaction is reversible: $\mathrm{H_2 + I_2 \rightleftharpoons 2HI}$.
So the tendency to form hydrides follows the order $\mathrm{F_2 > Cl_2 > Br_2 > I_2}$.

Step 4: Properties of the hydrides Thermal stability decreases down the group because the H-X bond weakens: $\mathrm{HF > HCl > HBr > HI}$.
Acid strength in water increases down the group: $\mathrm{HF < HCl < HBr < HI}$. The long, weak H-I bond breaks most easily.
HF has the highest boiling point because its molecules are held together by hydrogen bonds. After HF, the boiling point rises from HCl to HI with molar mass.
Reducing power also increases from HF to HI.

Step 5: Conclusion Halogens are the Group 17 elements F, Cl, Br, I and At, all with the configuration ns^2np^5. Their ability to form hydrides HX is highest for fluorine and falls to iodine.

Quick Tip to Solve: Halogens are the Group 17 elements with outer configuration ns^2np^5. Compare how easily each forms HX and how stable HX is.

LA-25. What type of compound is an alcohol? How is monohydric alcohol classified? [5 marks]

Solution:

Concept:

- The question asks two things: the type of compound an alcohol is, and the scheme used to classify monohydric alcohols.

Step 1: What type of compound is an alcohol An alcohol is an organic compound in which one or more hydroxyl groups (-OH) are bonded to a saturated (sp^3 hybridised) carbon atom of an alkyl group.
It can be thought of as an alkane in which a hydrogen atom has been replaced by -OH. The general formula of a saturated monohydric alcohol is $\mathrm{C_nH_{2n+1}OH}$ or $\mathrm{R - OH}$.
Examples: methanol $\mathrm{CH_3OH}$ and ethanol $\mathrm{CH_3CH_2OH}$.

Step 2: Classification by the number of -OH groups Alcohols are first sorted by how many hydroxyl groups they carry: monohydric (one -OH), dihydric (two, for example ethane-1,2-diol), trihydric (three, for example propane-1,2,3-triol) and polyhydric (more than three).
A monohydric alcohol therefore has just one -OH group.

Step 3: Classification of monohydric alcohols Monohydric alcohols are classified by the hybridisation of the carbon atom that carries the -OH group.
(i) Compounds with the -OH on an sp^3 carbon. These are further grouped by the number of alkyl groups on the carbinol carbon (the carbon bonded to -OH):
Primary (1 degree) alcohol: the carbinol carbon is bonded to one other carbon or none, $\mathrm{RCH_2OH}$, for example ethanol $\mathrm{CH_3CH_2OH}$.

Secondary (2 degree) alcohol: bonded to two alkyl groups, R_2CHOH, for example propan-2-ol $(CH_3)_2CHOH$.
Tertiary (3 degree) alcohol: bonded to three alkyl groups, R_3COH, for example 2-methylpropan-2-ol $(CH_3)_3COH$.
Special cases: allylic alcohols have -OH on an sp^3 carbon next to a C=C bond, for example $CH_2 = CH - CH_2OH$. Benzylic alcohols have -OH on an sp^3 carbon next to a benzene ring, for example $C_6H_5CH_2OH$.
(ii) Compounds with the -OH on an sp^2 carbon. In vinylic alcohols the -OH is on a C=C carbon, for example $CH_2 = CH - OH$. Phenols have -OH directly on a benzene ring.

Step 4: Conclusion An alcohol is a compound with an -OH group on a saturated sp^3 carbon. Monohydric alcohols are classified as primary, secondary or tertiary, with allylic, benzylic and vinylic types as extra groups.

Quick Tip to Solve: An alcohol has -OH on an sp^3 carbon. Monohydric ones are grouped as primary, secondary or tertiary by the carbinol carbon.

LA-26. Write IUPAC names of the following structures :
(a) $CH_3 - CH(CH_3) - CH_2 - CHO$
(b) $CH_3 - CH(OH) - CH_2 - CHO$
(c) $CH_3 - C(CH_3)_2 - CO - CH_3$
(d) $OHC - CHO$
(e) CCl_3CHO [5 marks]

Solution:

Concept:

- Each structure is an aldehyde or ketone, so the IUPAC name is built from the longest carbon chain that contains the carbonyl carbon.

Step 1: Rules used 1. For an aldehyde the suffix is -al, and the CHO carbon is always C-1.
2. For a ketone the suffix is -one, and the chain is numbered so the C=O carbon gets the lowest number.
3. Substituents are named as prefixes with their position numbers, in alphabetical order.

Step 2: Structure (a) $CH_3 - CH(CH_3) - CH_2 - CHO$ has the chain CHO (C-1), CH_2 (C-2), CH (C-3), CH_3 (C-4). That is four carbons, so the parent is butanal.
A methyl group sits on C-3. The name is 3-methylbutanal.

Step 3: Structure (b) $CH_3 - CH(OH) - CH_2 - CHO$ also has a four carbon chain, so the parent is butanal. The -OH is on C-3.
The name is 3-hydroxybutanal.

Step 4: Structure (c) $CH_3 - C(CH_3)_2 - CO - CH_3$ has the longest chain $CH_3 - CO - C - CH_3$ of four carbons, so the parent is butanone.
Number from the end that gives the C=O the lower number. The carbonyl carbon is then C-2, and the carbon carrying two methyl groups is C-3.
The name is 3,3-dimethylbutan-2-one.

Step 5: Structure (d) $OHC - CHO$ has two carbons, and both are CHO carbons. So the parent is ethane with the suffix -dial.
The name is ethanedial (common name glyoxal).

Step 6: Structure (e) CCl_3CHO has two carbons: the CHO carbon (C-1) and the CCl_3 carbon (C-2).

Three chlorine atoms are on C-2.
The name is 2,2,2-trichloroethanal (common name chloral).

Step 7: Conclusion The five compounds are named as follows.

Quick Tip to Solve: Pick the longest chain that includes the carbonyl carbon. Use -al for aldehydes (C-1 is CHO) and -one for ketones.