CBSE EXAMINATION PAPER-2022

CHEMISTRY

(Solved)

Time allowed : 3 hours | Maximum Marks : 43

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **17 questions.** All questions are **compulsory.**

ii. This question paper is divided into **3 sections.**

iii. **Section A** – questions number **1 to 2** are case based questions

iv. **Section B** – questions number **3 to 4** are short answer

v. **Section C** – questions number **5 to 17** are long answer

vi. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.

vii. Use of calculator is NOT allowed.

Section A

Question 1. The rate law for a chemical reaction relates the reaction rate with the concentrations or partial pressures of the reactants. For a general reaction aA + bB → C with no intermediate steps in its reaction mechanism, meaning that it is an elementary reaction, the rate law is given by r = k[A]^x[B]^y, where [A] and [B] express the concentrations of A and B in moles per litre. Exponents x and y vary for each reaction and are determined experimentally. The value of k varies with conditions that affect reaction rate, such as temperature, pressure, surface area, etc. The sum of these exponents is known as overall reaction order. A zero order reaction has a constant rate that is independent of the concentration of the reactants. A first order reaction depends on the concentration of only one reactant. A reaction is said to be second order when the overall order is two. Once we have determined the order of the reaction, we can go back and plug in one set of our initial values and solve for k.

Question 2.

Read the passage given below and answer the questions that follow :

The rate law for a chemical reaction relates the reaction rate with the concentrations or partial pressures of the reactants. For a general reaction aA + bB→ C with no intermediate steps in its reaction mechanism, meaning that it is an elementary reaction, the rate law is given by r = k[A]X [B] y , where [A] and [B] express the concentrations of A and B in moles per litre. Exponents x and y vary for each reaction and are determined experimentally. The value of k varies with conditions that affect reaction rate, such as temperature, pressure, surface area, etc. The sum of these exponents is known as overall reaction order. A zero order reaction has a constant rate that is independent of the concentration of the reactants. A first order reaction depends on the concentration of only one reactant. A reaction is said to be second order when the overall order is two. Once we have determined the order of the reaction, we can go back and plug in one set of our initial values and solve for k.

(1)

Calculate the overall order of a reaction which has the following rate expression : Rate = k[A] $^{1/2}$ [B] $^{3/2}$

[1 Marks]

Answer: Step 1: Find the order with respect to A which is 1/2 from the given rate expression Rate = k$[A]^{1/2}$ $[B]^{3/2}$.
Step 2: Find the order with respect to B which is 3/2.
Step 3: Add both exponents to find overall order = 1/2 + 3/2 = 2.
Therefore, the overall order of the reaction is 2, which means it is a second order reaction as explained in the passage.

Key Points: Order with respect to A is 1/2 - Order with respect to B is 3/2 - Overall order is sum of individual orders which equals 2

(2)

What is the effect of temperature on rate of reaction ?

[1 Marks]

Answer: Effect of temperature on rate of reaction:
The rate constant k varies with temperature according to the passage. As temperature increases, the rate constant k increases, which makes the reaction rate faster. Therefore, higher temperature increases the rate of reaction by increasing k, as stated in the passage.

Key Points: Rate constant k depends on temperature - Increase in temperature increases rate constant - Higher temperature increases rate of reaction

(3)

A first order reaction has a rate constant 1x 10 $^{-3}$ per sec. How long will 5 g of this reactant take to reduce to 3 g ? (log 3 = 0·4771; log 5 = 0·6990)

[1 Marks]

Answer: For a first order reaction, time t = (1/k) * log(initial amount / final amount). Given k = 1 * 10^{-3} sec^{-1}, initial amount = 5 g, final amount = 3 g. So, t = (1 / 0.001) * (log 5 - log 3) = 1000 * (0.6990 - 0.4771) = 221.9 seconds. Hence, it will take 221.9 seconds to reduce 5 g to 3 g.

Key Points: Rate law relates rate and concentration - First order reaction means rate depends on one reactant concentration - Time formula t = (1/k) * log(initial/final) for first order reaction

(4)

A first order reaction takes 77·78 minutes for 50% completion. Calculate the time required for 30% completion of this reaction. (log 10 = 1, log 7 = 0·8450)

[1 Marks]

Answer: For a first order reaction, the time taken for 50% completion ($t_{1/2}$) is 77.78 minutes.

We use the first order kinetics formula: log (100/(100 - x)) = kt/2.303, where x is percentage completion.

For 30% completion, log (100/70) = k*t/2.303.

Log (100/70) = log 10 - log 7 = 1 - 0.8450 = 0.155.

Since k = 0.693 / 77.78, solving gives t = (2.303 * 0.155) / k = 47.6 minutes approximately.

So, time required for 30% reaction completion is about 47.6 minutes as per the rate law given in the passage.

Key Points: First order reaction relation - Use of log formula for completion time - Calculation steps for 30 percent completion

(5)

What is meant by rate of a reaction ?

[1 Marks]

Answer: Rate of a reaction is the speed at which reactants change into products. It shows how fast the concentration of reactants or products changes with time. According to the passage, it depends on the concentrations of reactants and factors like temperature and pressure.

Key Points: rate of reaction means speed of reactants turning into products - depends on concentrations of reactants - affected by conditions like temperature and pressure

Section B

Question 3.

In a plot of ∧m against the square root of concentration (C1/2) for strong and weak electrolyte, the value of limiting molar conductivity of a weak electrolyte cannot be obtained graphically. Suggest a

way to obtain this value. Also state the related law, if any.

[2 Marks]

Answer: The limiting molar conductivity (∧°m) of a weak electrolyte can be obtained using Kohlrausch's law of independent migration of ions. According to this law, the limiting molar conductivity of an electrolyte is the sum of the contributions of its constituent ions. For example, for sodium chloride, if λ°Na+ is the limiting molar conductivity of sodium ions and λ°Cl– for chloride ions, then ∧°m for NaCl can be calculated as ∧°m = λ°Na+ + λ°Cl–. Therefore, by knowing the individual contributions of the ions, we can determine the limiting molar conductivity of weak electrolytes even if it cannot be measured graphically.

Key Points: Kohlrausch's law; Limiting molar conductivity; Contributions of anions and cations; Calculation of ∧°m

Question 4.

Write reasons for the following statements :

(i) Benzoic acid does not undergo Friedel-Crafts reaction.(1)

(ii)Oxidation of aldehydes is easier than that of ketones. (1)

[2 Marks]

Answer: (i) Benzoic acid does not undergo Friedel-Crafts reaction because the -COOH group is strongly deactivating and electron withdrawing. It decreases the electron density on the benzene ring, making it less reactive towards electrophilic substitution. Also, the -COOH group reacts with the Friedel-Crafts catalyst ($AlCl_3$) forming a complex, which inhibits the reaction.

(ii) Oxidation of aldehydes is easier than ketones because aldehydes have a hydrogen atom attached to the carbonyl carbon, which can be easily removed in oxidation. Ketones have alkyl groups on both sides of the carbonyl group, making them more stable and resistant to oxidation. Hence, aldehydes are easily oxidised to carboxylic acids, while ketones are not easily oxidised under normal conditions.

Key Points: Benzoic acid is strongly deactivating due to -COOH group - -COOH forms complex with AlCl3 inhibiting Friedel-Crafts reaction - Aldehydes have a hydrogen attached to the carbonyl carbon making oxidation easier - Ketones have no such hydrogen and are more stable - Aldehydes oxidise to carboxylic acids readily

---

Section C

Question 5.

Write reasons for the following :

(i) Ethylamine is soluble in water whereas aniline is insoluble.(1)

(ii) Amino group is o- and p-directing in aromatic electrophilic substitution reactions, but aniline on nitration gives a substantial amount of m-nitroaniline. (1)

(iii) Amines behave as nucleophiles.(1)

[3 Marks]

Answer: (i) Ethylamine is soluble in water because it is an aliphatic amine where the amino group can form hydrogen bonds with water molecules easily. On the other hand, aniline is less soluble because the lone pair on the nitrogen is delocalized into the benzene ring through resonance, reducing its ability to form hydrogen bonds with water.
(ii) The amino group ($-NH_2$) is an o- and p-directing activating group because it donates electron density into the benzene ring, favoring substitution at ortho and para positions. However, during nitration, the reaction conditions are strongly acidic, which protonates the amino group to form anilinium ion ($-NH_3^+$). This protonated group is a meta-directing deactivating group, causing the formation of substantial m-nitroaniline.
(iii) Amines behave as nucleophiles because the nitrogen atom has a lone pair of electrons that can be donated to electron-deficient species (electrophiles) to form a new bond. This lone pair makes amines reactive in nucleophilic substitution and addition reactions.

> **Key Points: Ethylamine hydrogen bonds with water - Aniline's nitrogen lone pair delocalized by resonance - Amino group protonation changes directing effects - Amines have lone pair making them nucleophiles**

Question 6.

How will you carry out the following conversions :

(i) Ethanenitrile to Ethanamine. (1)

(ii) Ethanamide to Methanamine. (1)

(iii) Nitrobenzene to Aniline. (1)

[3 Marks]

Answer: (i) Ethanenitrile to Ethanamine: Reduce ethanenitrile (CH_3CN) using hydrogen (H_2) in presence of a catalyst like nickel (Ni) or platinum (Pt) under high pressure and temperature to get ethanamine ($CH_3CH_2NH_2$).
(ii) Ethanamide to Methanamine: First convert ethanamide (CH_3CONH_2) into an intermediate by

Hofmann bromamide reaction, using bromine (Br_2) and sodium hydroxide (NaOH) which removes one carbon atom to form methanamine (CH_3NH_2).
(iii) Nitrobenzene to Aniline: Reduce nitrobenzene ($C_6H_5NO_2$) using tin (Sn) and concentrated hydrochloric acid (HCl), or catalytic hydrogenation using H_2 and a metal catalyst to get aniline ($C_6H_5NH_2$).

> **Key Points: Reduction of ethanenitrile to ethanamine using H2 and catalyst - Hofmann bromamide reaction converts ethanamide to methanamine - Reduction of nitrobenzene to aniline using Sn and HCl or catalytic hydrogenation**

Question 7.

(i) Write the electronic configuration of d5 on the basis of crystal field splitting theory if *Δ*o < P. (1)

(ii) $[Fe(CN)_6]^{3-}$ is weakly paramagnetic whereas $[Fe(CN)_6]^{4-}$ is diamagnetic. Give reason to support this statement. [Atomic no. : Fe = 26].(1)

(iii) Write the number of ions produced from the complex $[Co(NH_3)_6]Cl_2$ in solution.(1)

[3 Marks]

Answer: (a) For d5 configuration with \u0394o < P (weak field ligands), the complex is high spin octahedral. Electronic configuration: t2g3 eg2 with 5 unpaired electrons.
(b) In [Fe(CN)6]3-, Fe is in +3 oxidation state (d5). CN- is a strong field ligand causing pairing, but here pairing is only partial resulting in one unpaired electron hence it is weakly paramagnetic. In [Fe(CN)6]4-, Fe is +2 (d6) and all electrons pair up in the lower energy t2g orbitals with no unpaired electrons. Therefore it is diamagnetic.
(c) [Co(NH3)6]Cl2 dissociates in solution into one complex cation [Co(NH3)6]2+ and two Cl- ions. Total ions produced = 3.

> **Key Points: High spin d5 configuration - reason for paramagnetic and diamagnetic behavior of Fe complexes - number of ions from complex salt**

Question 8.

(b) (i) Calculate the spin only magnetic moment of the complex $[CoF_6]^{3-}$ (Atomic no. of Co = 27).(1)

(ii) Write the IUPAC name of the given complex : $[CrCl_2(H_2O)_4]Cl$. (1)

(iii) Which out of the two complexes is more stable and why ? $[Fe(H_2O)_6]3+$, $[Fe(C_2O_4)_3]^{3-}$. (1)

[3 Marks]

Answer: (i) The complex $[CoF_6]^{3-}$ is an outer orbital complex with electronic configuration of Co^{3+} as d^6. Since fluoride ion is a weak field ligand, it does not cause pairing; number of unpaired electrons = 4.
Spin only magnetic moment, μ = sqrt(n(n+2)) Bohr magneton = sqrt(4(4+2)) = sqrt(24) = 4.9 BM.
(ii) The IUPAC name of $[CrCl_2(H_2O)_4]Cl$ is Tetraaquadichloridochromium(III) chloride.
(iii) $[Fe(C_2O_4)_3]^{3-}$ is more stable than $[Fe(H_2O)_6]^{3+}$, because oxalate ion $C_2O_4^{2-}$ is a bidentate ligand that forms chelate rings with Fe^{3+}. Chelate complexes are more stable due to chelate effect compared to complexes with monodentate ligands like H_2O. Therefore, $[Fe(C_2O_4)_3]^{3-}$ is more stable.

Key Points: Spin only magnetic moment calculation - IUPAC naming of coordination compound - Chelate effect and stability of complexes

Question 9.

(i) Which ion amongst the following is colourless and why ? Ti^{4+}, Cr^{3+}, V^{3+} (Atomic number of Ti = 22, Cr = 24, V = 23). (1)

(ii) Why is Mn^{2+} much more resistant than Fe^{2+} towards oxidation ?(1)

(iii) Highest oxidation state of a metal is shown in its oxide or fluoride only. Justify the statement. (1)

[3 Marks]

Answer: (a) Among Ti^{4+}, Cr^{+}, and V^{+}, Ti^{4+} is colourless because it has an electronic configuration of $3d^0$ $4s^0$, meaning d-orbitals are empty. Colour in transition metal ions arises due to d-d electronic transitions which require partially filled d orbitals. Since Ti^{4+} has no d-electrons, it does not show colour.

(b) Mn^{+} is more resistant to oxidation than Fe^{+} because Mn^{+} has a half-filled d^5 configuration ($3d^5$), which is more stable due to exchange energy and symmetry. Therefore, it is less easily oxidized compared to Fe^{+} which has a $3d^6$ configuration and is less stable.

(c) The highest oxidation states of metals are usually observed in their oxides or fluorides because oxygen and fluorine are highly electronegative elements and can stabilize high positive charges on the metal atoms. These compounds have strong covalent character that helps stabilize high oxidation states which are often not possible in other types of compounds due to instability and lack of suitable electronegative ligands.

Key Points: Ti4+ is colourless due to empty d-orbitals - Mn2+ resists oxidation due to stable half-filled d5 configuration - Highest oxidation state stabilized by highly

electronegative O and F in oxides and fluorides

Question 10.

A compound 'A' (C_2H_4O) on oxidation gives 'B' ($C_2H_4O_2$). 'A' undergoes Iodoform reaction to give yellow precipitate and reacts with HCN to form the compound 'C'. 'C' on hydrolysis gives 2-hydroxypropanoic acid. Identify the compounds 'A', 'B' and 'C'. Write down equations for the reactions involved.

[3 Marks]

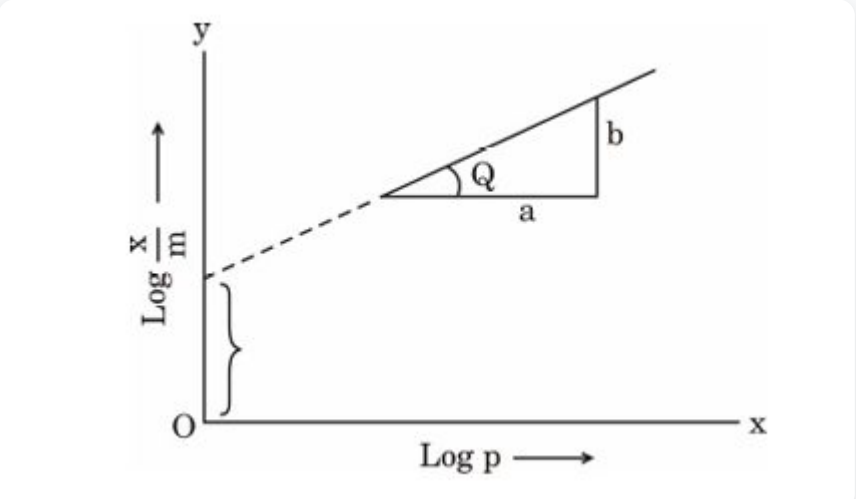
Answer: The compound 'A' is ethanol (C_2H_5OH), which upon oxidation yields 'B', ethanoic acid ($C_2H_4O_2$). The iodoform reaction confirms that 'A' has a methyl group adjacent to the hydroxyl group, leading to a yellow precipitate of iodoform (CHI_3). When ethanol reacts with HCN, it forms a cyanohydrin, which is 'C', specifically 2-hydroxypropionitrile (C_2H_5OH). Upon hydrolysis, this compound forms 2-hydroxypropanoic acid ($C_3H_6O_3$). The relevant reactions can be summarized as follows: 1. $C_2H_5OH + [O] \rightarrow CH_3COOH + H_2O$ 2. $C_2H_5OH + I_2 + NaOH \rightarrow CHI_3 + NaOH + H_2O$ (iodoform reaction) 3. $C_2H_5OH + HCN \rightarrow C_2H_5(OH)CN$; and 4. $C_2H_5(OH)CN + H_2O \rightarrow C_3H_6O_3$.

Key Points: 1. Compound 'A' is ethanol (C_2H_5OH) 2. Compound 'B' is ethanoic acid ($C_2H_4O_2$) 3. Compound 'C' is 2-hydroxypropionitrile 4. Iodoform reaction produces yellow precipitate 5. Hydrolysis of 'C' forms 2-hydroxypropanoic acid 6. Relevant chemical equations included

Question 11.

Observe the given figure and answer the following questions :(i) (a) Write the expression for adsorption of gases on solids in the form of an equation. (ii)What is the slope of the graph ? (iii)What does the intercept of the line represent ?

[3 Marks]



Answer: The expression for the adsorption of gases on solids can be represented by the equation: $AP_1 = P_{10} - P_1$, which relates the pressure of the gas to its adsorption on a solid surface. In this equation, AP_1 represents the change in pressure, P_{10} is the initial pressure, and P_1 is the equilibrium pressure after adsorption. The slope of the graph indicates the extent of adsorption, reflecting how the quantity of gas adsorbed changes with pressure. The intercept of the graph represents the theoretical maximum amount adsorbed when pressure is zero, demonstrating how adsorption initially occurs even under low pressure conditions.

> **Key Points: Expression for adsorption: $AP_1 = P_{10} - P_1$; Slope shows extent of adsorption; Intercept indicates maximum adsorption at zero pressure**

Question 12.

Write equations involved in the following reactions :

(i) Ethanamine reacts with acetyl chloride.(1)

(ii) Aniline reacts with bromine water at room temperature.(1)

(iii) Aniline reacts with chloroform and ethanolic potassium hydroxide.(1)

[3 Marks]

Answer: (i) Reaction of Ethanamine with Acetyl Chloride:

$C_2H_5NH_2 + CH_3COCl \rightarrow CH_3CONHCH_2C_2H_5 + HCl$

Explanation: Ethanamine reacts with acetyl chloride to form N-ethylacetamide and hydrogen chloride.

(ii) Reaction of Aniline with Bromine Water at Room Temperature:

$C_6H_5NH_2 + 3Br_2 \rightarrow C_6H_2Br_3NH_2 + 3HBr$

Explanation: Aniline reacts with bromine water to give 2,4,6-tribromoaniline as a white precipitate and hydrobromic acid.

(iii) Reaction of Aniline with Chloroform and Ethanolic Potassium Hydroxide (Reimer-Tiemann Reaction):

$C_6H_5NH_2 + CHCl_3 + 4KOH \rightarrow C_6H_4NH_2CHO + 3KCl + 3H_2O$

Explanation: Aniline reacts with chloroform and ethanolic KOH to form salicylaldehyde (an aldehyde derivative) via Reimer-Tiemann reaction along with potassium chloride and water.

> **Key Points: Ethanamine reacts with acetyl chloride to form N-ethylacetamide - Aniline reacts with bromine water to form 2,4,6-tribromoaniline - Aniline reacts with chloroform and ethanolic KOH (Reimer-Tiemann) to form salicylaldehyde**

Question 13.

(i)Write the IUPAC name for the following organic compound :

$(CH_3CH_2)_2NCH_3$ (1)

(ii) Write the equations for the following : (1)

(I) Gabriel phthalimide synthesis (II) Hoffmann bromamide degradation. (1)

[3 Marks]

Answer: (i) The compound $(CH_3CH_2)_2NCH_3$ contains two ethyl groups (CH_3CH_2-) and one methyl group (-CH_3) attached to a nitrogen atom. Such a compound is named as an N-substituted amine. The longest alkyl chain is ethyl, and since there are two ethyl groups attached to nitrogen along with one methyl group, the correct IUPAC name is N-methylethanamine or more commonly N-methyldiethylamine.

(ii) (I) Gabriel phthalimide synthesis: This reaction is used to prepare primary amines. It involves the reaction of potassium phthalimide with an alkyl halide followed by hydrolysis.
$C_6H_4COCONH + KOH + R–X \rightarrow C_6H_4COCONHR$ (alkyl phthalimide)
$C_6H_4COCONHR + 2H_2O + KOH \rightarrow R–NH_2$ + phthalic acid salt

(II) Hoffmann bromamide degradation: This reaction converts an amide to a primary amine with one less carbon atom using bromine and alkali.
$RCONH_2 + Br_2 + 4KOH \rightarrow R–NH_2 + K_2CO_3 + 2KBr + 2H_2O$

Thus, (i) the IUPAC name is N-methyldiethylamine, (ii) the two reaction equations are as given above.

> **Key Points: IUPAC naming of amines-N-methyldiethylamine - Gabriel phthalimide synthesis reaction equation - Hoffmann bromamide degradation reaction equation**

Question 14.

Write the Nernst equation and calculate emf of the following cell at 298 K :

$Cr|Cr^{3+}$ (0·1 M)$||Fe^{2+}$ (0·01 M)$|Fe$

Given : $E^\Theta Cr^{3+}/Cr$ =- 0·75 V $E^\Theta Fe^{2+}/Fe$ =- 0·45 V (log 10 = 1)

[3 Marks]

Answer: Step 1: Write the Nernst equation.
The Nernst equation for a cell is given by:
$E = E^\nabla - (RT / nF) * \ln Q$

Where, E is the emf of the cell at non-standard conditions,
E∇ is the standard emf of the cell,
R is the gas constant = 8.314 J/mol K,
T is the temperature in Kelvin = 298 K,
n is the number of moles of electrons transferred,
F is Faraday constant = 96485 C/mol,
Q is the reaction quotient.

Step 2: Determine the cell reaction and E∇ cell.
Given half reactions:
$Cr^{3+} + 3e^- \rightarrow Cr$, E∇ = -0.75 V
$Fe^{2+} + 2e^- \rightarrow Fe$, E∇ = -0.45 V

The anode (oxidation) will be $Cr \rightarrow Cr^{3+} + 3e^-$ (oxidation potential = +0.75 V)
The cathode (reduction) will be $Fe^{2+} + 2e^- \rightarrow Fe$ (reduction potential = -0.45 V)

Since electrons must balance, multiply Fe reaction by 3 and Cr reaction by 2:
Anode: $2\ Cr \rightarrow 2\ Cr^{3+} + 6e^-$
Cathode: $3\ Fe^{2+} + 6e^- \rightarrow 3\ Fe$

Overall reaction: $2\ Cr + 3\ Fe^{2+} \rightarrow 2\ Cr^{3+} + 3\ Fe$

Calculate standard emf:
E∇ cell = E∇ cathode - E∇ anode = (-0.45 V) - (-0.75 V) = +0.30 V

Step 3: Calculate reaction quotient Q.
$Q = [Cr^{3+}]^2 / [Fe^{2+}]^3 = (0.1)^2 / (0.01)^3 = 0.01 / 0.000001 = 10000$

Step 4: Calculate emf using Nernst equation.
Use the simplified Nernst equation at 298 K:
E = E∇ - (0.0592 / n) * log Q
Number of electrons transferred n = 6

E = 0.30 V - (0.0592 / 6) * log (10000)
log 10000 = 4

E = 0.30 V - (0.00987) * 4 = 0.30 V - 0.0395 V = 0.2605 V

Answer: The emf of the cell at 298 K is approximately 0.261 V.

Key Points: Nernst equation expression - Calculation of standard emf of the cell - Use of reaction quotient Q and log values to find emf at given concentrations

Question 15.

(a) (i) Silver atom has completely filled d-orbitals in its ground state, it is still considered to be a transition element. Justify the statement. (1)

(ii) Why areEΘ M^{2+}/ M values of Mn and Zn more negative than expected ? (1)

(iii) Why do transition metals form alloys ?

[3 Marks]

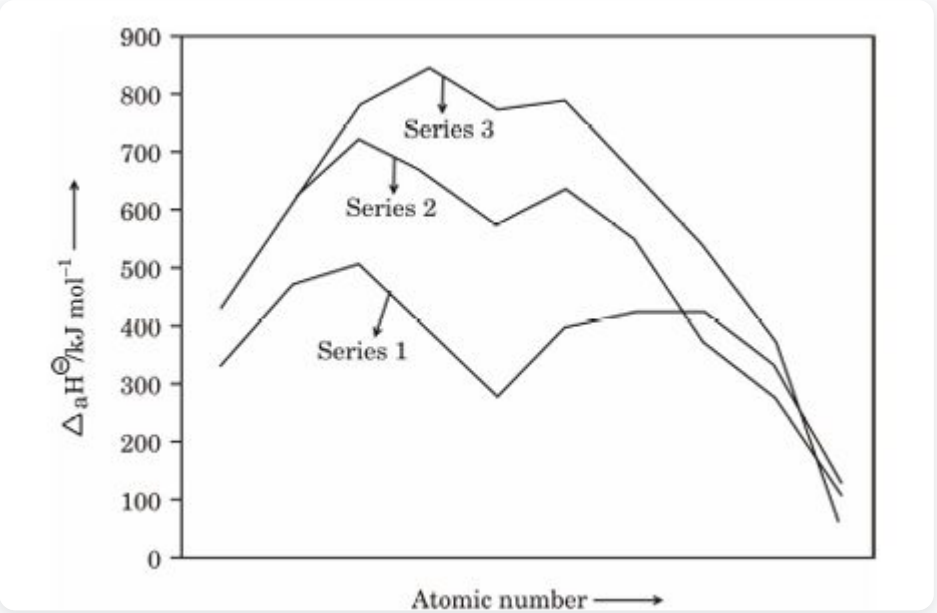
Answer: (a) (i) Silver atom has electronic configuration [Kr] $4d^{10}$ $5s^1$. Although its 4d orbitals are completely filled, silver is considered a transition element because it forms ions like Ag^+ by losing the 5s electron, and the 4d electrons also participate in bonding and influence its chemical behaviour.
(ii) The standard electrode potentials (EΘ) of Mn^{2+}/Mn and Zn^{2+}/Zn are more negative than expected because of their stable half-filled (Mn: $3d^5$) and completely filled (Zn: $3d^{10}$) d-subshells which make these elements more stable in the metallic state. Thus, more energy is required to remove electrons and form ions, resulting in more negative EΘ values.
(iii) Transition metals form alloys easily because they have similar atomic sizes and their atoms can replace each other in the crystal lattice. Their incomplete d orbitals and metallic bonding allow for the formation of solid solutions with varied properties, enhancing hardness, strength and resistance to corrosion.

Key Points: Silver has fully filled 4d orbitals but loses 5s electron in ion formation - Mn and Zn have stable half-filled or filled d-subshells making EΘ values more negative - Transition metals have similar sizes and bonding allowing alloy formation

Question 16.

Answer the following questions on the basis of the figure given below :(i) Which element in 3d series has lowest enthalpy of atomisation ?(ii) Why do metals of the second and third series have greater enthalpies of atomisation ? (iii) Why are enthalpies of atomisation of transition metals quite high ?

[3 Marks]



Answer: In the 3d series, the element with the lowest enthalpy of atomisation is Scandium (Sc). This is primarily because it has fewer d-electrons contributing to its metallic bonding compared to its counterparts. Furthermore, metals in the second and third transition series exhibit greater enthalpies of atomisation due to the increased number of d-electrons that allow for stronger metallic bonds. The presence of multiple oxidation states, as well as greater interactions among d-orbitals, enhances the strength of metal-metal bonding. Hence, transition metals display higher enthalpies of atomisation compared to non-transition metals, due to their more complex electronic configurations and stronger inter-atomic metallic bonding.

Key Points: Scandium has the lowest enthalpy of atomisation. Greater number of d-electrons in second/third series leads to stronger bonds. Transition metals have higher enthalpies due to complex electronic configurations and stronger metallic bonding.

Question 17.

Arrange the following compounds in the increasing order of their property indicated :

(i) Acetaldehyde, Benzaldehyde, Acetophenone, Acetone (Reactivity towards HCN).(1)

(ii) $(CH_3)_2CHCOOH$, $CH_3CH_2CH(Br)COOH$, $CH_3CH(Br)CH_2COOH$ (Acidic strength)

(iii) CH_3CH_2OH, CH_3CHO, CH_3COOH (Boiling point)

[3 Marks]

Answer: (i) Reactivity towards HCN:
Reactivity towards HCN depends on the electrophilicity of the carbonyl carbon. Aldehydes are more reactive than ketones due to less steric hindrance and less electron donating alkyl groups.
- Acetaldehyde (an aldehyde) is more reactive than acetone (a ketone).

- Benzaldehyde is less reactive than acetaldehyde because the phenyl group withdraws electron density by resonance, reducing electrophilicity.
- Acetophenone has a phenyl group attached to the carbonyl carbon and is less reactive than acetone due to resonance stabilization.
Increasing order of reactivity: Acetophenone < Benzaldehyde < Acetone < Acetaldehyde.

(ii) Acidic strength of carboxylic acids with halogen substituents:
Acid strength increases with electronegative groups that stabilize the carboxylate ion by withdrawing electron density.
- $(CH_3)_2CHCOOH$ (Isobutyric acid) has no halogen and thus lowest acidity.
- $CH_3CH_2CH(Br)COOH$ has Br on the third carbon from COOH, showing weaker inductive effect.
- $CH_3CH(Br)CH_2COOH$ has Br closer on the second carbon, stronger inductive effect, thus more acidic.
Increasing order of acidic strength: $(CH_3)_2CHCOOH < CH_3CH_2CH(Br)COOH < CH_3CH(Br)CH_2COOH$.

(iii) Boiling point order of CH_3CH_2OH (ethanol), CH_3CHO (acetaldehyde), CH_3COOH (acetic acid):
Boiling points depend on inter molecular forces.
- Alcohols and acids have hydrogen bonding, higher boiling points.
- Acetic acid has stronger hydrogen bonding (dimer formation), highest boiling point.
- Ethanol also hydrogen bonds but less strongly than acetic acid.
- Acetaldehyde has only dipole-dipole interactions, lowest boiling point.
Increasing boiling point: $CH_3CHO < CH_3CH_2OH < CH_3COOH$.

> **Key Points:** Reactivity of carbonyl compounds depends on electrophilicity - Electron withdrawing groups increase acidity by stabilizing carboxylate ion - Hydrogen bonding increases boiling point