

THE UNITED REPUBLIC OF TANZANIA
NATIONAL EXAMINATIONS COUNCIL
ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/2

CHEMISTRY 2

Time: 3 Hours

ANSWERS

Mwaka: 2021

Instructions

1. This paper consists of a total of six questions
2. Answer five questions.

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1 (a) (i) Distinguish between an electrolytic cell and a galvanic cell.

An electrolytic cell uses electrical energy to drive a non-spontaneous chemical reaction, while a galvanic cell produces electrical energy from a spontaneous chemical reaction.

(ii) Lead rods are placed in each of the following solutions: AgNO_3 , CuSO_4 , FeSO_4 , ZnSO_4 . In which solution would you expect a coating of one metal on lead rod? Give a reason.

Lead will get coated by the metal which has a higher reduction potential than Pb^{2+}/Pb ($E^\circ = -0.13 \text{ V}$).

Given E° values:

$\text{Ag}^+/\text{Ag} = +0.81 \text{ V} \rightarrow \text{Ag}$ will be deposited on Pb

$\text{Cu}^{2+}/\text{Cu} = +0.34 \text{ V} \rightarrow \text{Cu}$ will be deposited on Pb

$\text{Fe}^{2+}/\text{Fe} = -0.44 \text{ V} \rightarrow \text{No deposition}$

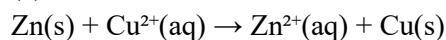
$\text{Zn}^{2+}/\text{Zn} = -0.76 \text{ V} \rightarrow \text{No deposition}$

Hence, deposition is expected in AgNO_3 and CuSO_4 solutions.

(b) Why the Kohlrausch's law of independent migration of ions applies at infinite dilution of electrolytes? Briefly explain.

At infinite dilution, interionic interactions are negligible. Each ion migrates independently, and the total conductivity is the sum of individual ionic conductivities. This independence justifies Kohlrausch's law.

(c) Show that for the cell reaction:



with different cell concentrations and at 298 K, the cell potential is given by:

$$E = E^\circ_{\text{cell}} - 0.0295 \log \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]}$$

This is derived from the Nernst Equation:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (0.0591/n) \log Q$$

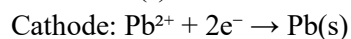
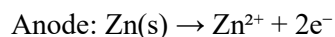
For this reaction, $n = 2$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (0.0591/2) \log ([\text{Zn}^{2+}]/[\text{Cu}^{2+}])$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - 0.0295 \log ([\text{Zn}^{2+}]/[\text{Cu}^{2+}])$$

(d) A galvanic cell consists of metallic zinc and lead plates immersed in 0.1 M $\text{Zn}(\text{NO}_3)_2$ and 0.02 M $\text{Pb}(\text{NO}_3)_2$ solution.

(i) Write the chemical equations for the electrode reactions.



(ii) Write the cell notation for the reaction.



(iii) Calculate the e.m.f. of the cell.

$$E^{\circ}_{\text{cell}} = E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}} = (-0.13) - (-0.76) = 0.63 \text{ V}$$

Use Nernst Equation:

$$\begin{aligned} E_{\text{cell}} &= 0.63 - 0.0295 \log\left(\frac{[\text{Zn}^{2+}]}{[\text{Pb}^{2+}]}\right) \\ &= 0.63 - 0.0295 \log(0.1 / 0.02) = 0.63 - 0.0295 \log(5) \\ &= 0.63 - 0.0295 \times 0.699 = 0.609 \text{ V} \end{aligned}$$

2 (a) Write a mathematical expression for distribution law.

$$C_1/C_2 = K_d$$

Where C_1 and C_2 are concentrations in two solvents and K_d is the distribution coefficient.

(b) Compound P has a partition coefficient of 4.00 between ethoxyethane and water. Given that 2.0 g of P is obtained in solution, in 50 cm³ of water, calculate the mass of P that can be extracted:

(i) By 50 cm³ of ethoxyethane.

K_d = amount in ether / amount in water

$$4 = x / (2 - x) \rightarrow 4(2 - x) = x$$

$$8 - 4x = x \rightarrow 5x = 8 \rightarrow x = 1.6 \text{ g}$$

(ii) Two successive extractions of 25 cm³ each of ethoxyethane.

Let x = amount left after first extraction

$K_d = y/x$, where y = amount extracted

$$4 = y / (2 - y) \rightarrow y = 1.6 \text{ g after first extraction}$$

Remaining = 0.4 g

Repeat for 0.4 g:

$$4 = z / (0.4 - z) \rightarrow 4(0.4 - z) = z \rightarrow z = 0.32 \text{ g}$$

$$\text{Total extracted} = 1.6 + 0.32 = 1.92 \text{ g}$$

(c) Comment on the variation of the amount extracted in (b) (i) and (ii)

Two successive extractions yield a higher total mass than one single extraction of equal volume. This is due to better partitioning when extraction is done in smaller portions.

(d) When 500 cm³ of aqueous solution containing 4 g of solute G per litre was shaken with 100 cm³ of pentan-1-ol, 1.5 g of the solute G was extracted.

(i) The partition coefficient of G between pentan-1-ol and water.

Partition coefficient = amount in organic / amount in aqueous

G in 100 cm³ pentan-1-ol = 1.5 g

Remaining in aqueous = 4 – 1.5 = 2.5 g

$K_d = 1.5 / 2.5 = 0.6$

(ii) Mass of solute G which will remain in aqueous solution after further shaking with 100 cm³ pentan-1-ol.

Let x = remaining mass in aqueous

$K_d = (2.5 - x)/x \rightarrow 0.6 = (2.5 - x)/x \rightarrow 0.6x = 2.5 - x$

$1.6x = 2.5 \rightarrow x = 1.56 \text{ g}$

3 (a) To a solution containing 0.1 M Cl⁻ and 0.01 M CrO₄²⁻, a solution of AgNO₃ is added slowly.

(i) Which salt will precipitate first between AgCl and Ag₂CrO₄?

Use K_{sp} comparison:

$K_{sp}(\text{AgCl}) = 2.72 \times 10^{-10}$

$K_{sp}(\text{Ag}_2\text{CrO}_4) = 2.4 \times 10^{-12}$

Since Ag₂CrO₄ has lower K_{sp}, it should precipitate first, but CrO₄²⁻ concentration is 0.01 M while Cl⁻ is 0.1 M.

AgCl starts precipitating when $[\text{Ag}^+] = K_{sp} / [\text{Cl}^-] = 2.72 \times 10^{-10} / 0.1 = 2.72 \times 10^{-9} \text{ M}$

Ag₂CrO₄ starts when $[\text{Ag}^+]^2 = K_{sp} / [\text{CrO}_4^{2-}] = 2.4 \times 10^{-12} / 0.01 = 2.4 \times 10^{-10}$

$[\text{Ag}^+] = \sqrt{2.4 \times 10^{-10}} = 1.55 \times 10^{-5} \text{ M}$

Since $2.72 \times 10^{-9} < 1.55 \times 10^{-5}$, AgCl will precipitate first.

(ii) Find the concentration of the ion that will precipitate first at the time the second ion will start precipitating.

When Ag₂CrO₄ starts precipitating, $[\text{Ag}^+] = 1.55 \times 10^{-5} \text{ M}$

Cl⁻ concentration needed for AgCl at this Ag⁺ concentration:

$[\text{Cl}^-] = K_{sp} / [\text{Ag}^+] = 2.72 \times 10^{-10} / 1.55 \times 10^{-5} = 1.75 \times 10^{-5} \text{ M}$

3 (b) Calculate the solubility of Ag₂CrO₄ in water if the value of solubility product K_{sp} is $1.3 \times 10^{-11} \text{ mol}^2/\text{L}^2$

Let solubility of Ag₂CrO₄ be s mol/L.

$\text{Ag}_2\text{CrO}_4 \rightleftharpoons 2\text{Ag}^+ + \text{CrO}_4^{2-}$

$[\text{Ag}^+] = 2s, [\text{CrO}_4^{2-}] = s$

$K_{sp} = [\text{Ag}^+]^2 \times [\text{CrO}_4^{2-}] = (2s)^2 \times s = 4s^3$

$1.3 \times 10^{-11} = 4s^3 \rightarrow s^3 = 3.25 \times 10^{-12}$

$s = 1.48 \times 10^{-4} \text{ mol/L}$

(i) The solubility of AgCl in g/dm³

$$K_{sp} \text{ of AgCl} = 2.72 \times 10^{-10}$$

$$\text{Let solubility be } s \text{ mol/L} \rightarrow s^2 = 2.72 \times 10^{-10} \rightarrow s = 1.65 \times 10^{-5} \text{ mol/L}$$

$$\text{Mass} = 1.65 \times 10^{-5} \text{ mol} \times 143.5 \text{ g/mol} = 2.37 \times 10^{-3} \text{ g/L} = 0.00237 \text{ g/dm}^3$$

(ii) The solubility product of AgCl at the given temperature is already known: $K_{sp} = 2.72 \times 10^{-10} \text{ mol}^2/\text{L}^2$

3 (c) A standard solution of AgCl(aq) at 26°C has a conductivity of $1.32 \times 10^{-4} \text{ cm}^{-1} \text{ mol}^{-1}$. If its molar conductivity at infinite dilution is $120 \text{ cm}^2 \text{ mol}^{-1}$, calculate:

(i) The degree of dissociation α = molar conductivity at current concentration / molar conductivity at infinite dilution

$$\alpha = 1.32 \times 10^{-4} / 120 = 1.1 \times 10^{-6}$$

(ii) Dissociation constant (K_d) = $\alpha^2 \times C$

$$\text{Assuming } C = \text{solubility} = 1.65 \times 10^{-5} \text{ mol/L}$$

$$K_d = (1.1 \times 10^{-6})^2 \times 1.65 \times 10^{-5} = 1.99 \times 10^{-17} \text{ mol/L}$$

4 (a) State the reason(s) for the following facts:

(i) Although Na^+ , Mg^{2+} and Al^{3+} ions have the same electronic configuration, they have different radii. Because they have increasing nuclear charge which pulls the electrons closer. Al^{3+} has the smallest radius, Na^+ the largest.

(ii) At ordinary temperature, phosphorous pentachloride (PCl_5) is a white solid with unexpected high melting point.

PCl_5 exists in ionic form as $[\text{PCl}_4]^+$ and $[\text{PCl}_6]^-$ in solid state, leading to ionic lattice and high melting point.

(iii) Sodium chloride (NaCl) and anhydrous aluminium chloride (AlCl_3) are both chlorides of metals of period III. Molten sodium chloride can be electrolysed while molten anhydrous aluminium chloride cannot. AlCl_3 is covalent and sublimes easily; does not conduct electricity in molten state, unlike ionic NaCl .

(iv) The first ionization energy increases from left to right across a period but the first ionization energy of magnesium is larger than that of aluminium.

Due to electron entering a higher energy p-orbital in aluminium, which is easier to remove than magnesium's s-electron.

(v) Lithium and potassium are metals of group I. In aqueous solution, lithium is a poor conductor of electricity while potassium is a good conductor.

Potassium ion is larger, more hydrated, and moves faster in solution, improving conductivity.

(vi) Boiling point of water (H_2O) is higher than that of hydrogen sulphide (H_2S). All are hydrides of group VI elements.

Due to hydrogen bonding in water which is absent in H_2S , leading to stronger intermolecular forces.

4 (b) (i) Which factors are used to classify elements in the periodic system of elements?

- Atomic number
- Electronic configuration
- Chemical properties
- Physical properties

(ii) Account for the fact that the third period of the periodic system of elements has only eight elements and not eighteen as expected.

The 3d orbitals belong to fourth shell and do not fill in third period. Third period contains only s and p orbitals ($3s^2 3p^6$), giving eight elements.

4 (c) Ammonia NH_3 and phosphene PH_3 are hydrides of the first two elements in group VA. Some physical properties are given in the table:

Compound	Boiling point ($^{\circ}\text{C}$)	Solubility in water (mol/dm^3)
Ammonia, NH_3	-33	31.1
Phosphene, PH_3	-88	8.88×10^{-3}

(i) Suggest one reason for the difference in boiling temperature.

Ammonia forms hydrogen bonds due to N–H bonds, while phosphene does not, hence ammonia has a higher boiling point.

(ii) Why is ammonia more soluble in water than phosphene?

Ammonia forms hydrogen bonds and interacts strongly with water molecules, while phosphene lacks this ability.

4 (d) Why do elements exhibit diagonal relations? Briefly explain by giving two examples.

Diagonal relationship occurs due to similarity in charge density and electronegativity of diagonally adjacent elements in second and third periods.

Examples:

- Lithium and magnesium
- Beryllium and aluminium

5 (a) From the knowledge you have on hydroxyl group, write the chemical reaction equations with their IUPAC names showing what happens when propan-1-ol is treated with:

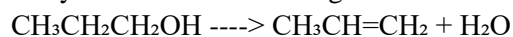
(i) Excess HBr under reflux

Reaction: $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{HBr} \longrightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + \text{H}_2\text{O}$

Product: 1-bromopropane (n-propyl bromide)

(ii) A small amount of concentrated H_2SO_4

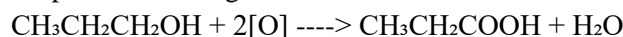
Dehydration occurs forming alkene



Product: Propene

(iii) Acidified KMnO_4

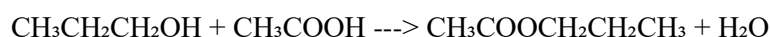
Propan-1-ol undergoes oxidation



Product: Propanoic acid

(iv) Ethanoic acid in the presence of concentrated H_2SO_4

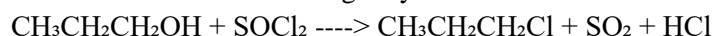
Esterification reaction



Product: Propyl ethanoate (an ester)

(v) SOCl_2

Substitution reaction forming alkyl chloride



Product: 1-chloropropane

5 (b) Compound A ($\text{C}_{10}\text{H}_{12}\text{O}$) gives off oxygen on treatment with sodium metal and decolorizes Br_2 in CCl_4 to give organic compound B. Compound A on treatment with I_2 in NaOH gives iodoform and a salt C which after acidification gives a white solid D ($\text{C}_7\text{H}_6\text{O}_2$). Using knowledge of organic chemistry, identify structures A, B, C, and D.

Clues:

- $\text{C}_{10}\text{H}_{12}\text{O}$ with Br_2 decolorization = presence of double bond
- Iodoform test = presence of CH_3CO group
- Salt C becomes benzoic acid ($\text{C}_7\text{H}_6\text{O}_2$) = D

So:

A = 4-hydroxy-3-phenylbutan-2-one (contains hydroxyl and methyl ketone groups)

B = Unsaturated compound after bromination (removal of double bond)

C = Benzoate salt ($\text{C}_7\text{H}_5\text{O}_2^-\text{Na}^+$)

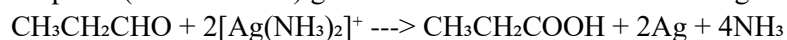
D = Benzoic acid ($\text{C}_7\text{H}_6\text{O}_2$)

6 (a) How can you distinguish the following? Support your answer with chemical equations:

(i) Propanal and propanone

Use Tollens' test:

Propanal ($\text{CH}_3\text{CH}_2\text{CHO}$) gives silver mirror with Tollens' reagent:



Propanone (CH_3COCH_3) gives negative result.

(ii) Ethanol and benzaldehyde

Use Fehling's solution:

Benzaldehyde gives red precipitate of Cu_2O , ethanol does not.

(iii) Pentanal and pentan-2-one

Iodoform test: Pentan-2-one ($\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$) gives yellow precipitate of CHI_3

Pentanal ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$) gives no precipitate.

(iv) 3-pentanone and 2-pentanone

Only 2-pentanone ($\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$) gives iodoform test

3-pentanone ($\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$) does not.

6 (b) An organic compound A with a characteristic odour is treated with 50% NaOH to give B ($\text{C}_7\text{H}_5\text{O}$) and C which is a sodium salt of an organic acid. Oxidation of B gives back A. Heating C with soda lime yields an aromatic hydrocarbon D. Deduce the structures A, B, C and D.

Clues:

- A has an odour and oxidizes back from B
- Reaction in alkali suggests a benzaldehyde derivative
- C is sodium benzoate
- D is benzene (decarboxylation)

So:

A = Benzaldehyde ($\text{C}_6\text{H}_5\text{CHO}$)

B = Benzyl alcohol ($\text{C}_6\text{H}_5\text{CH}_2\text{OH}$)

C = Sodium benzoate ($\text{C}_6\text{H}_5\text{COONa}$)

D = Benzene (C_6H_6)

6 (c) Complete the following equations by giving the missing reagents/products:

(i) $\text{C}_6\text{H}_5\text{CH}=\text{CHCHO} + [\text{Ag}(\text{NH}_3)_2]^+ \longrightarrow \text{C}_6\text{H}_5\text{CH}=\text{CHCOOH}$ (oxidation to carboxylic acid)

(ii) $\text{C}_6\text{H}_5\text{OH} + \text{CrO}_3 \longrightarrow \text{C}_6\text{H}_5\text{COOH}$ (oxidation of phenol to benzoic acid)

(iii) $\text{CH}_3\text{CH}=\text{CHCH}=\text{CHCH}_3 + \text{O}_3/\text{Zn-H}_2\text{O} \longrightarrow 2\text{CH}_3\text{CH}=\text{O}$ (Ozonolysis to ethanal)

(iv) $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}(\text{CH}_3)_2 + \text{O}_3/\text{Zn-H}_2\text{O} \longrightarrow \text{CH}_3\text{COCH}_3 + \text{CH}_3\text{CH}_2\text{COOH}$
(Products: propanone and propanoic acid)

