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THE KENYA NATIONAL EXAMINATIONS COUNCIL

Kenya Certificate of Secondary Education

233/2 **CHEMISTRY (Theory)** **Paper 2**

Nov. 2023 - 2 hours

MARKING SCHEME

Serial No.
14544252

Name: ..... **Index Number:** .....

Candidate's signature: ..... **Date:** .....

Instructions to candidates

(a) Write your name and index number in the spaces provided above.
(b) Sign and write the date of examination in the spaces provided above.
(c) Answer **all** the questions in the spaces provided in the question paper.
(d) **Non-programmable** silent electronic calculators and KNEC mathematical tables may be used.
(e) All working **must** be clearly shown where necessary.
(f) **This paper consists of 16 printed pages.**
(g) **Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.**
(h) **Candidates should answer the questions in English.**

For Examiner's use only

Question	Maximum Score	Candidate's Score
1	13	
2	11	
3	12	
4	10	
5	12	
6	12	
7	10	
Total Score	**80**	

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1 **Table 1** gives some properties of the elements in period 3 of the periodic table.

Table 1

2.8.3 2.8.6

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	15	16	17	18
Atomic radius (nm)	0.186	0.160	0.143	0.117	0.110	0.104	0.099	0.097

(a) Give the formula and name of the compound formed by the reaction between **Al** and **S**.

Formula Al_2S_3 (1 mark)

Name Aluminium Sulphide (1 mark)

(b) Explain the variations in the atomic radius of the elements across the period. (2 marks)

Atomic radius decreases across the period ✓1

Exp 1 Increase in proton number / Increase in nuclear charge results into stronger pull of outermost electrons. ✓1

Exp 2 This is due to stronger effective nuclear charge. ✓1

* Electrons do not increase nuclear force of attraction

(c) Select the element with the highest ionisation energy. Give a reason. (2 marks)

Argon (Ar) ✓1

✓ Has a stable electronic configuration ✓1

✓ Its a noble gas ✓

✓ Has smallest atomic radius / Strongest nuclear attraction for outermost electrons.

(d) Write the electron arrangement of phosphorus in PCl_3. (1 mark)

PCl_3 $P + (Cl \times -1) = 0$ 2.8.8

$P = +3$

$15 - 3 = 12$ Conf 2.8.2

(e) Select an element that forms an ion with the smallest ionic radius. Give a reason. (2 marks)

Aluminium

Loses highest number of electrons hence has stronger nuclear charge which attracts remaining electrons

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(f) **Table 2** gives the melting points (°C) of some of the elements.

Table 2

Element	Na	Mg	Cl	Ar
Melting point (°C)	98	650	-101	-189

Explain, in terms of structure and bonding, the differences in the melting points of:

(i) Na and Mg; (2 marks)

Mg has more delocalised electrons than Na hence has stronger metallic bond.

(ii) Cl and Ar. (2 marks)

Cl exists as a diatomic molecule while Ar exists as a monoatomic molecule. Cl_2 has therefore more Van der Waal forces than Ar.

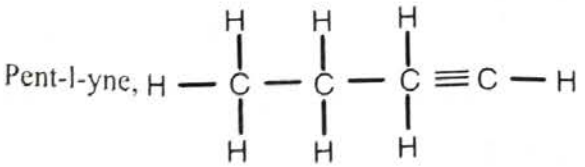
* Argon molecule does not exist as its stable and does not form molecules.

2 (a) Complete the following equation: (1 mark)

$CaC_2(s) + H_2O(l) \rightarrow$

$CaC_{2(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} + C_2H_{2(g)}$

✓ No penalty for absence or wrong state symbols.
✓ Must be balanced, formula must be correct.

(b) Pent-1-yne, 

reacts with bromine to form compounds **B** and **C** as shown in **Figure 1**.

Figure 1

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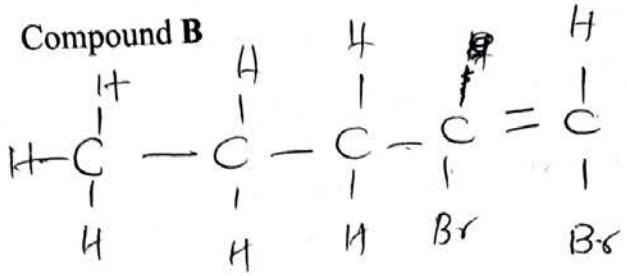
Draw the structures of compounds **B** and **C**.

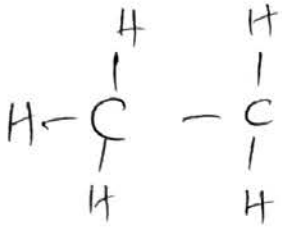
(1 mark)

Compound **B**



(1 mark)

Compound **C**



(c) Study the flow chart in **Figure 2** and answer the questions that follow.

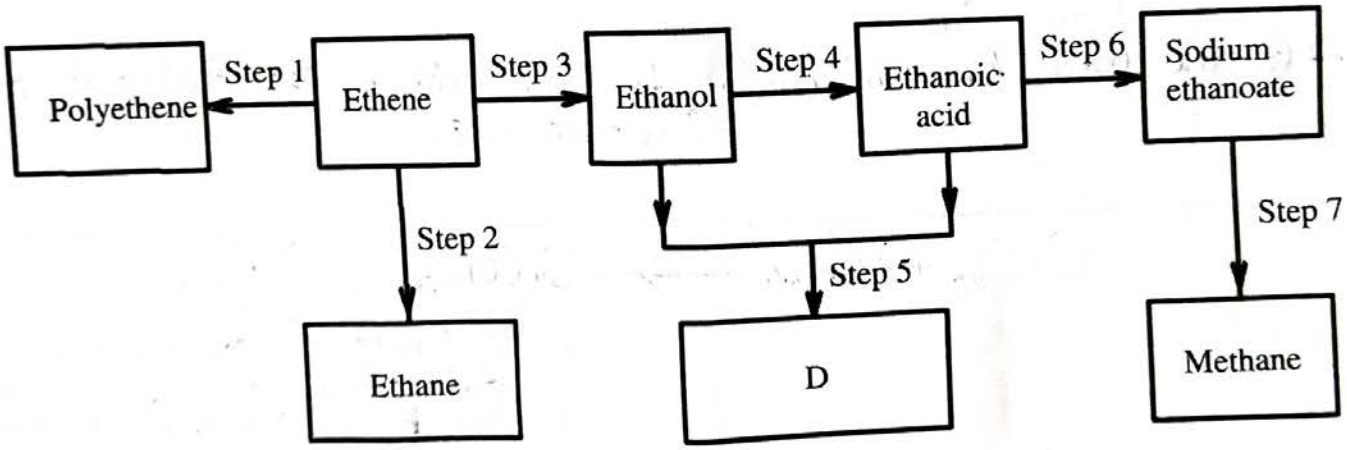


Figure 2

(i) Give the reagents and conditions used in:

I. Step 2;

(1 mark)

Reagent : Hydrogen ✓1

Condition: Nickel catalyst ✓1

Palladium / Platinium

High temperatures of 150°c - 250°c (Never give a range)

- Avoid giving a wrong extra condition as it cancels the right one.

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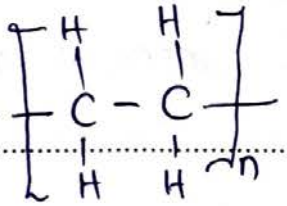
II. Step 7. (1 mark)

Reagent – Sodalime or (Sodium hydroxide mixed with Calcium Oxide)

Condition – Heat / Heating

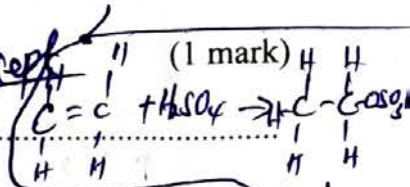
(ii) Write an equation for the reaction that takes place in:

I. Step 1; (1 mark)

$n(CH_2CH_2) \longrightarrow$ 

II. Step 3. (1 mark)

$C_2H_{4(g)} + H_2O_{(l)} \xrightarrow[H_3PO_4,\ 300^oC,\ 60atm]{Conc\ H_2SO_4} C_2H_5OH_{(l)}$

Accept 

Note: When $H_2O_{(g)}$. We use $H_3PO_4, 300^oC, 60atm$

$C_2H_5OH + H_2SO_4 \xrightarrow{+H_2O}$ ~~(1 mark)~~

(iii) Name the type of reaction that takes place in:

I. Step 4; Oxidation reaction

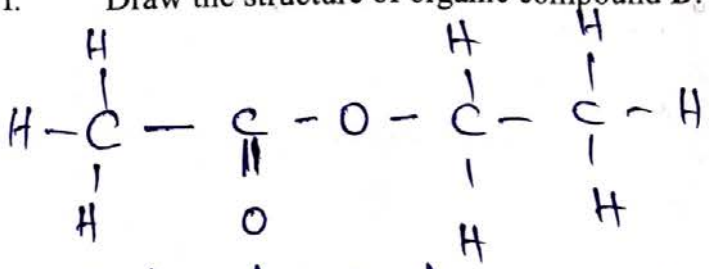
II. Step 2. (1 mark)

Hydrogenation / Addition hydrogenation / Addition of hydrogen.

(The addition must be specific)

(iv) I. Draw the structure of organic compound **D**. (1 mark)

NB:



* Stick to Conventional Way.

* Condensed structure is not a drawn structure

II. Give the name of compound **D**. (1 mark)

Ethylethanoate

* Marked independent of the structure drawn in Part I.
* No penalty for separation of the two names but is advised that they are not separate together.

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* Explanation only marked if the effect is stated. Explanation alone does not score.

3 (a) Explain how an increase in temperature affects the rate of a chemical reaction. (2 marks)

Increase in temperature increases rate of reaction.
Increase in temperature increases kinetic energy of the particles causing more collisions that result into more successful collisions hence increased reaction rate. (Successful | effective | fruitful)

(b) Consider the following gaseous reaction:

$$2NO(g) + H_2(g) \rightleftharpoons N_2O(g) + H_2O(g)$$

Explain how an increase in pressure affects the rate of this reaction. (2 marks)

Rate of forward reaction increases
Particles are brought together | closer leading to more effective collisions.

(c) At high temperatures, NO_2 and CO gases react as shown in the following equation:

$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

The reaction was monitored by measuring the changes in the concentration of NO(g) with time. **Table 3** shows the data obtained.

Table 3

Time/seconds	Concentration of NO × 10^3 / moles per litre
0	0
50	16
100	22
150	26
200	29
250	31
300	32

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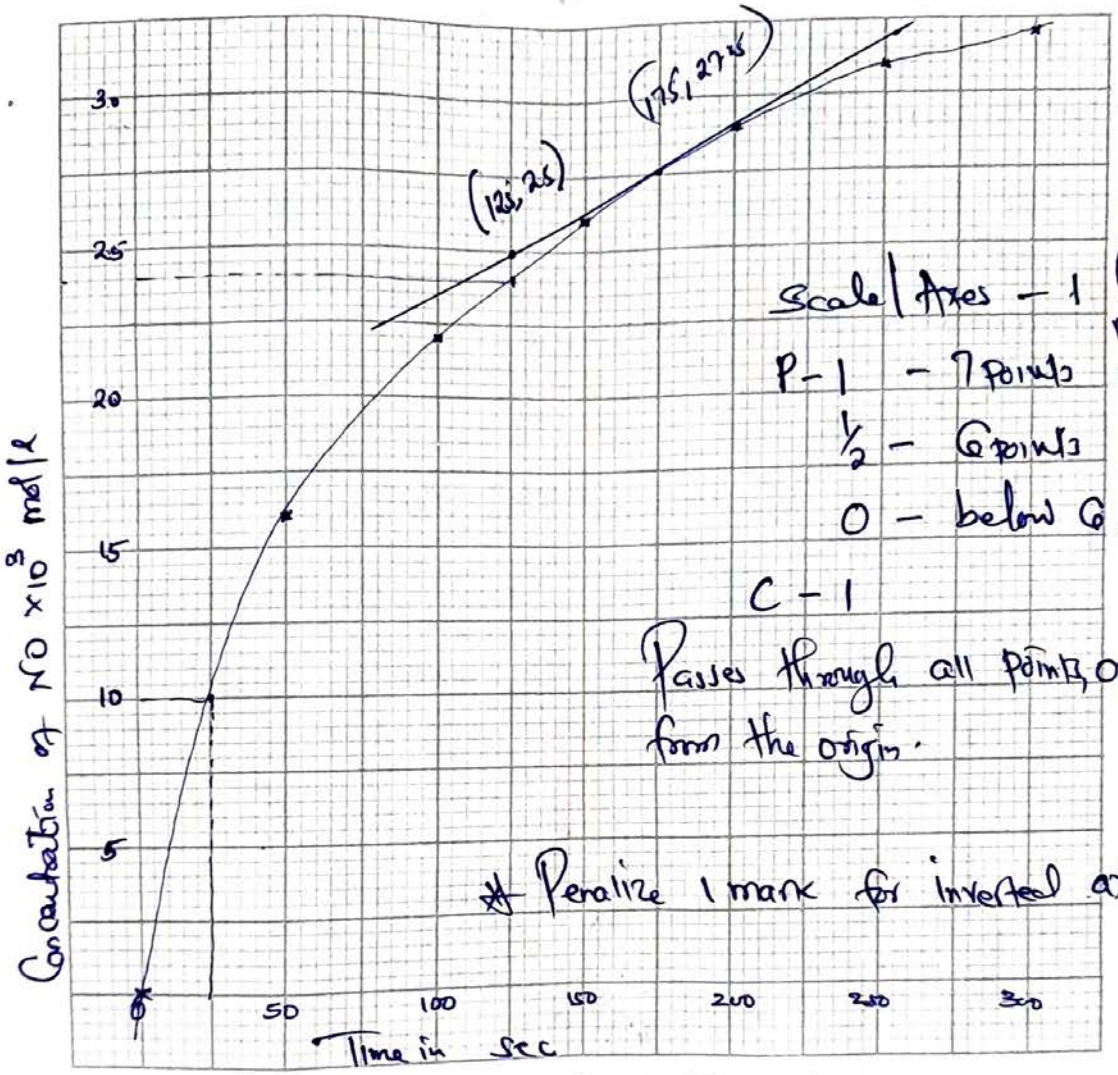
* do not use ruler in joining the points.
* Curve drawn using a dotted line award ½ mk for the curve.

(i) Plot on the grid provided, a graph of concentration of NO (vertical axis) against time. (3 marks)



Scale/Axes – 1 (Must cover more than half of grid)
P – 1 – 7 points
½ – 6 points
0 – below 6.
C – 1
Passes through all points, originating from the origin.
* Penalize 1 mark for inverted axis.

(ii) Use the graph, to determine the rate of the reaction:

I. In the time interval 25 seconds and 75 seconds; (2 marks)

* Reading from graph should be within range of ±1.

(25, 10) (75, 24)

Rate of rxn = $\frac{(24-10)\times10^3}{75-25} = \frac{(14\times10^3)}{50}$

= M/s (Moles/l/s)

* drawing a tangent for average range the answer is not marked.

NB: Use Candidates graph to solve (i) and (ii)

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II. At the 175th second. (2 marks)

If no tangent is drawn, do not mark. ½ mark for drawing the tangent

(Tangent must touch the curve, Must not cross the curve.) $= \frac{27.5 - 25}{175 - 125} = \left(\frac{2.5}{50}\right) \times 10^{3}$

= 50 marks/sec

(iii) Give a reason why the rate of the reaction decreases with time. (1 mark)

- Concentration of reactants decreases with time
- Reactants are used up

4 (a) **Figure 3** shows how the temperature of lead changes as it is heated.

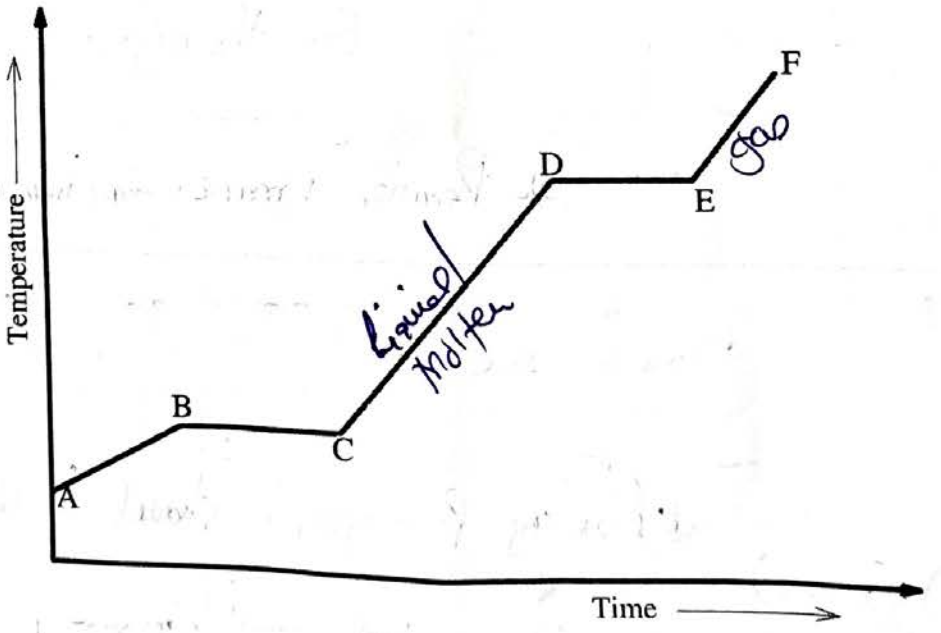

Figure 3

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(i) Label on the diagram the states present on the regions:

I. **CD**; (1 mark)

.....

II. **EF**. (1 mark)

.....

(ii) Explain why the temperature remains constant in regions:

I. **BC**; (1 mark)

Energy absorbed is used to convert solid to liquid at constant temperature.

II. **DE**. (1 mark)

The heat energy absorbed is used to convert liquid to gas (vapour) at constant temperature.

(b) **Figure 4** shows an energy cycle diagram for processes involving potassium bromide.

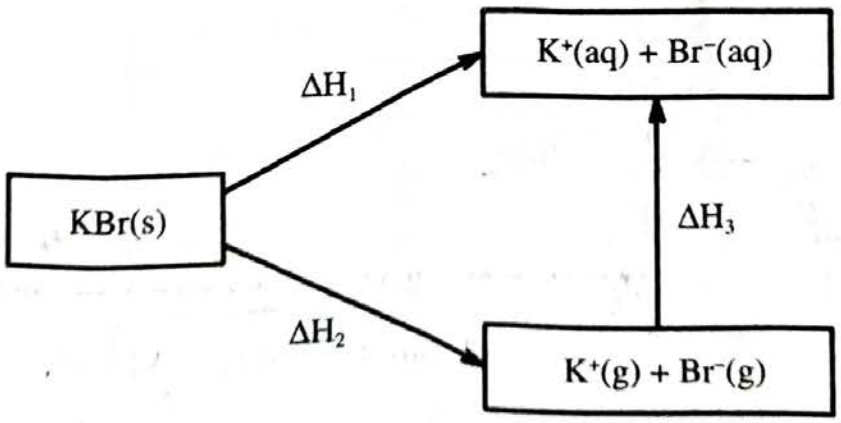

Figure 4

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(i) Name the following enthalpy changes:

I. ΔH_1 ; (1 mark)

Enthalpy of solution

II. ΔH_2 ; (1 mark)

Enthalpy of lattice

III. ΔH_3 (1 mark)

Enthalpy of hydration.

(ii) Write an expression showing how ΔH_3 can be obtained from ΔH_1 and ΔH_2. (1 mark)

$\Delta H_3 = \Delta H_1 - \Delta H_2$

(c) Using the thermochemical data given in **Table 4**, calculate the enthalpy change for the reaction:

$BF_3(g) \rightarrow B(g) + 3F(g)$ (2 marks)

Table 4

Process	ΔH / kJmol^{-1}
$B(s) \rightarrow B(g)$	590
$B(s) + \frac{3}{2}F_2(g) \rightarrow BF_3(g)$	-1111
$F_2(g) \rightarrow 2F(g)$	158

$BF_3(g) \rightarrow B(s) + 3/2 F_2(g)$ $+1111$

$B(s) \rightarrow B(g)$ $+590$ +

$3/2 F_2 \rightarrow \frac{3}{2} \times 2F = 3/2 \times 158$ $+237$

$+1938$ kJ/mol.

$590 + \frac{3}{2}(2 \times 158) = \Delta H + (-1111)$

$906 = \Delta H - 1111$

$\Delta H = 2017$ kJ/mol. (1½)

Solving in the opposite direction up with −1938 scores 0.

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(a) Use the standard electrode potentials in **Table 5** to answer this question.

Table 5

Number	Electrode reaction	E^{θ}, V
I	$2H^{+}(aq) + 2e \rightarrow H_2(g)$	0.00
II	$Zn^{2+}(aq) + 2e \rightarrow Zn(s)$	- 0.76
III	$Sn^{2+}(aq) + 2e \rightarrow Sn(s)$	- 0.14
IV	$Cu^{2+}(aq) + 2e \rightarrow Cu(s)$	+ 0.34
V	$Fe^{2+}(aq) + 2e \rightarrow Fe(s)$	- 0.44
VI	$Pb^{2+}(aq) + 2e \rightarrow Pb(s)$	- 0.13
VII	$Cu^{+}(aq) + e \rightarrow Cu(s)$	+ 0.52
VIII	$Ag^{+}(aq) + e \rightarrow Ag(s)$	+ 0.80

(i) Select **two** electrodes which when connected gives the cell with the lowest e.m.f. (1 mark)

III and VI

Accept E^{θ} values for the 2 i.e (-0.14 and -0.13)

(ii) Arrange the metals Ag, Fe, and Sn and in order of their reactivity with dilute hydrochloric acid, starting with the most reactive. Give a reason. (2 marks)

Fe, Sn, Ag

Fe is the most negative. Strongest reducing agent / hence most reactive.

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(iii) An electrochemical cell is made up of electrode numbers **IV** and **VII**.

I. Calculate the e.m.f of the cell. (1 mark)

Ignore units as it is given in volts

$0.52 - 0.34$

$= 0.18V$

II. Write an equation for the cell reaction. (1 mark)

$Cu_{(s)} + 2e^- \rightarrow Cu^{2+}$

$2Cu^+ + 2e^- \rightarrow 2Cu_{(s)}$

$Cu_{(s)} + 2Cu^+ \rightarrow Cu^{2+} + 2Cu_{(s)}$ Simplify.

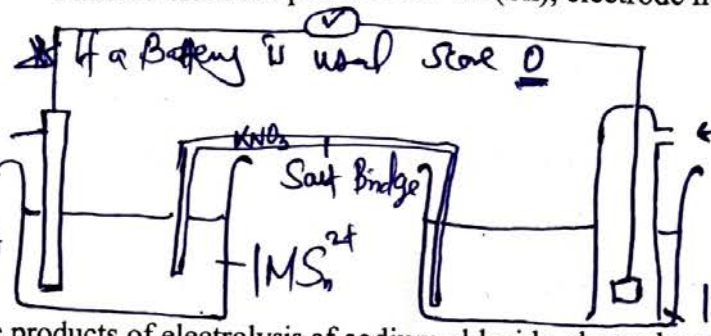
$2Cu^+_{(aq)} \rightarrow Cu^{2+}_{(aq)} + Cu_{(s)}$

(iv) Draw a labelled diagram of an electrochemical cell that is used to measure the standard electrode potential for tin (Sn), electrode number **III**. (3 marks)

Penalty
Failure to indicate concentration of electrolytes as 1M
- Failure to state pressure of H_2 as 1 atm

If a Battery is used score 0

Must not indicate KNO_3 in salt bridge. 6



Do not award if H_2 gas cell is missing (ref electrode).

(b) The products of electrolysis of sodium chloride, depend on the conditions used. Give the products obtained under each set of conditions in **Table 6**.

Table 6

Conditions	Product at:	
	Anode	Cathode
Dilute aqueous sodium chloride	O_2 $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$	H_2 $2H^+ + 2e^- \rightarrow H_2$
Concentrated aqueous sodium chloride	Cl_2 $2Cl^- \rightarrow Cl_2 + 2e^-$	H_2 $2H^+ + 2e^- \rightarrow H_2$.

Do not score for O_2 as the question is specific Concentrated.

(2 marks)

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(c) Aqueous chromium(III) sulphate was electrolysed using inert electrodes. The equation for the reaction is:

$Cr^{3+}(aq) + 3e \rightarrow Cr(s)$

Ignore units in the steps

Calculate the time in seconds required to deposit 2.6 g chromium using a current of 5.5 amperes. (1 Faraday = 96,500 Coulombs; Cr = 52.0) (2 marks)

Mass = $\frac{Q \times RAM}{n \times Faraday}$

$2.6 = \frac{Q \times 52}{3 \times 96500}$

$2.6 = \frac{5.5 \times t \times 52}{3 \times 96500}$

$\frac{286t}{286} = \frac{752700}{286}$

$t = 2631.8$ sec

Moles of Cr $= \frac{2.6}{52} = 0.05$ moles

52g → 3F $= 3 \times 96500 = 289500$C

0.05 moles require (X) $= 289500 \times 0.05 = 14475$C

Amount of Electricity = Current × Time

Time $= \frac{14475}{5.5}$

$= 2631.81$ sec

(a) (i) State Charles' law of gases. (1 mark)

At Constant Pressure, the volume of a fixed mass of gas is directly proportional to its absolute temperature.

or $V \propto T$ or $V = KT$.

(ii) **Table 7** shows the data obtained in an experiment using 0.012 moles of neon gas.

Table 7

Temperature/ K	Volume/ dm³	Pressure/ atm
250	0.005	50
300	0.006	50

Alternative

Make T_2 to be unknown and leave for it.

Show that the data is consistent with Charles' law. (2 marks)

$\frac{V_1}{T_1} = \frac{0.005}{250} = 2 \times 10^{-5}$ l/K.

$\frac{V_2}{T_2} = \frac{0.006}{300} = 2 \times 10^{-5}$ l/K

$\frac{V_1}{T_1} = \frac{V_2}{T_2} = K$

Ratio is a constant.

For Only score 0 or 2 marks. Be careful as you read the values given

(b) (i) State Graham's law of diffusion of gases. (1 mark)

Rate of diffusion of a gas is inversely proportional to the square root of its density at Constant temperature and Pressure.

Rate $\propto \frac{1}{\sqrt{\text{density}}}$

Rate $= \frac{K}{\sqrt{\text{density}}}$

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(ii) Given that 1 mole of a gas occupies a volume of 24.0 dm^3 at 298 K, calculate the density in grams per litre of:

I. oxygen gas (O = 16) (1 mark)

Be careful with the units required. *(do not convert value to cm^3)

Rfm of O_2 = 16x2 = 32

density = M/V = 32/24 = 1.33 g/l.

II. hydrogen gas (H = 1.0) (1 mark)

Rfm of H_2 = 1x2 = 2

density = 2/24 = 0.083 g/l.

(iii) Determine the rate of diffusion of hydrogen gas compared to that of oxygen gas at 298 K. (2 marks)

$\frac{Rate\ H_2}{Rate\ O_2} = \sqrt{\frac{Rmm\ O_2\ (32)}{Rmm\ H_2\ 2}}$

= 4.

Hydrogen diffuses 4 times faster than Oxygen.

Penalize $\left(\frac{R_{O_2}}{R_{H_2}} = \sqrt{\frac{Rmm\ H_2}{Rmm\ O_2}}\right)$

(c) Ammonia gas was prepared in the laboratory by warming a mixture of solid ammonium chloride and solid calcium hydroxide. The equation for the reaction is:

$2NH_4Cl(s) + Ca(OH)_2(s) \rightarrow CaCl_2(s) + 2H_2O(l) + 2NH_3(g)$

The gas was dried and then collected. If the volume of ammonia collected was 1340 cm^3 measured at 312 K and 1 atmosphere pressure:
(N = 14.0; Cl = 35.5; H = 1.0; Volume of one mole of gas at 298K = 24 dm^3)

(i) Calculate the volume that ammonia gas will occupy at 298 K and 1 atmospheric pressure. (2 marks)

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ ½

$V_2 = \frac{298 \times 1340}{312} = 1279.87 cm^3$

$NH_3 \rightarrow 14.0 + 3 = 17$

1 mole → 24 dm³ } 1340 / 24dm³ = 0.055833 mole

NB: at 312K molar gas volume is not 24dm³ hence wrong chemistry.

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Taking 1340/2 moles 1/2 mole, Salt Correctly stated.

(ii) Determine the mass of ammonium chloride that reacted. (2 marks)

Moles = 1277.81 / 2 = 0.053 moles.

Mole ratio 1:1

Moles of NH_4Cl = 0.053 moles

Mass = 0.053 × RFM (53.5) = 2.84g

(a) Give the names of the processes represented by the following equations:

(i) $HCOOH(aq) \xrightarrow{H_2SO_4(l)} CO(g) + H_2O(l)$ (1 mark)

Dehydration

Hydration ✓

(ii) $Na_2CO_3 \cdot 10H_2O(s) \xrightarrow{\text{in air}} Na_2CO_3 \cdot H_2O(s) + 9H_2O(l)$ (1 mark)

Efflorescence

Penalize Efflorescence - has a different meaning.

(b) Sodium carbonate is manufactured through a series of reactions involving sodium chloride, ammonia and carbon(IV) oxide.

(i) Ammonia is obtained by reacting hydrogen and nitrogen in the Haber process. State how the other two materials are obtained:

I. Sodium chloride; (1 mark)

✓ Evaporation of Sea Water.

✓ Mining of rock salt.

II. Carbon(IV) oxide. (1 mark)

- Heating of limestone and Coke. / Burning.
- Thermal decomposition of $NaHCO_3$.

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(ii) Concentrated sodium chloride solution, saturated with ammonia is passed into a carbonation tower in which carbon(IV) oxide is bubbled through. Reactions in the tower involve formation of ammonium hydrogen carbonate which then reacts with sodium chloride to form sodium hydrogen carbonate.

Write the equations for the formation of:

I. Ammonium hydrogen carbonate; (1 mark)

$NH_{3(g)} + CO_{2(g)} + H_2O_{(l)} \rightarrow NH_4HCO_{3(aq)}$ Rules of writing equations applied fully.

II. Sodium hydrogen carbonate. (1 mark)

$NH_4HCO_{3(aq)} + NaCl_{(aq)} \rightarrow NaHCO_{3(s)} + NH_4Cl_{(aq)}$

(iii) Describe how the:

I. sodium hydrogen carbonate is separated; (1 mark)

✓ Filtration

II. Sodium hydrogen carbonate is converted to sodium carbonate. (1 mark)

Heating

(iv) One of the uses of sodium carbonate is in the removal of water hardness.

I. Explain how sodium carbonate removes water hardness. (1 mark)

✱ Addition of Sodium Carbonate precipitates Ca^{2+} & Mg^{2+} from Solution

Accept: through double decomposition

II. State **one** other industrial use of sodium carbonate. (1 mark)

- Manufacture of detergents, Soap, Paper, Glass
- Manufacture of Borax, Sodium silicate, Sodium Phosphate

NB ✱ giving 2 uses and one is wrong cancels the right.

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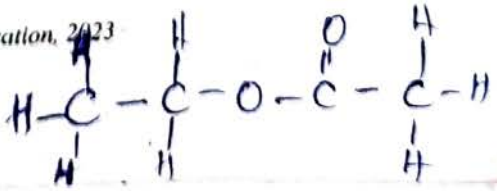
do not accept ✱ Q2



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