THE KENYA NATIONAL EXAMINATIONS COUNCIL

Kenya Certificate of Secondary Education

Paper 2

233/2 **CHEMISTRY (Theory)**

Nov. 2023 - 2 hours

Serial No.
14848389

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	

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

Table 1

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 ..... (1 mark)

Name ..... (1 mark)

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

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

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

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

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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)

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(ii) Cl and Ar. (2 marks)

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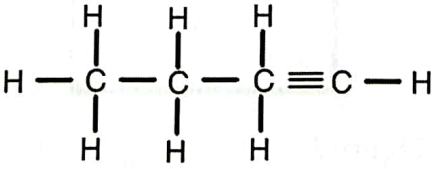
2 (a) Complete the following equation: (1 mark)

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

.....

(b) Pent-l-yne, 

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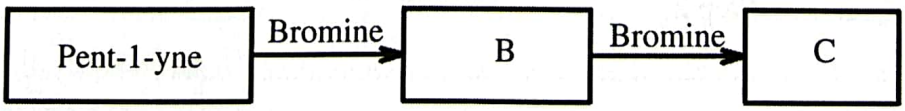

Figure 1

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

Compound **B** (1 mark)

Compound **C** (1 mark)

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

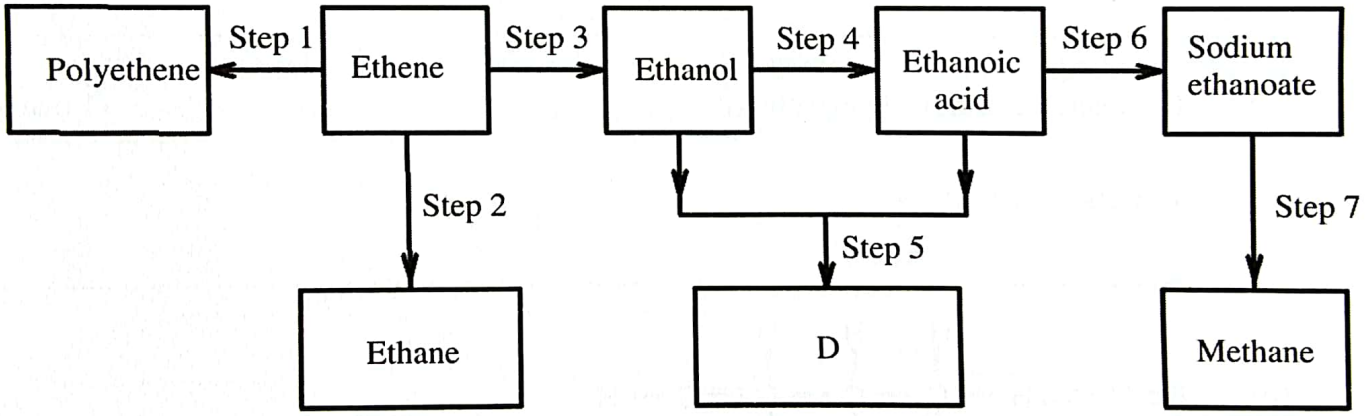

Figure 2

(i) Give the reagents and conditions used in:

I. Step **2**; (1 mark)

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II. Step 7. (1 mark)

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

I. Step 1; (1 mark)

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II. Step 3. (1 mark)

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

I. Step 4; (1 mark)

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II. Step 2. (1 mark)

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

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

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

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(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)

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

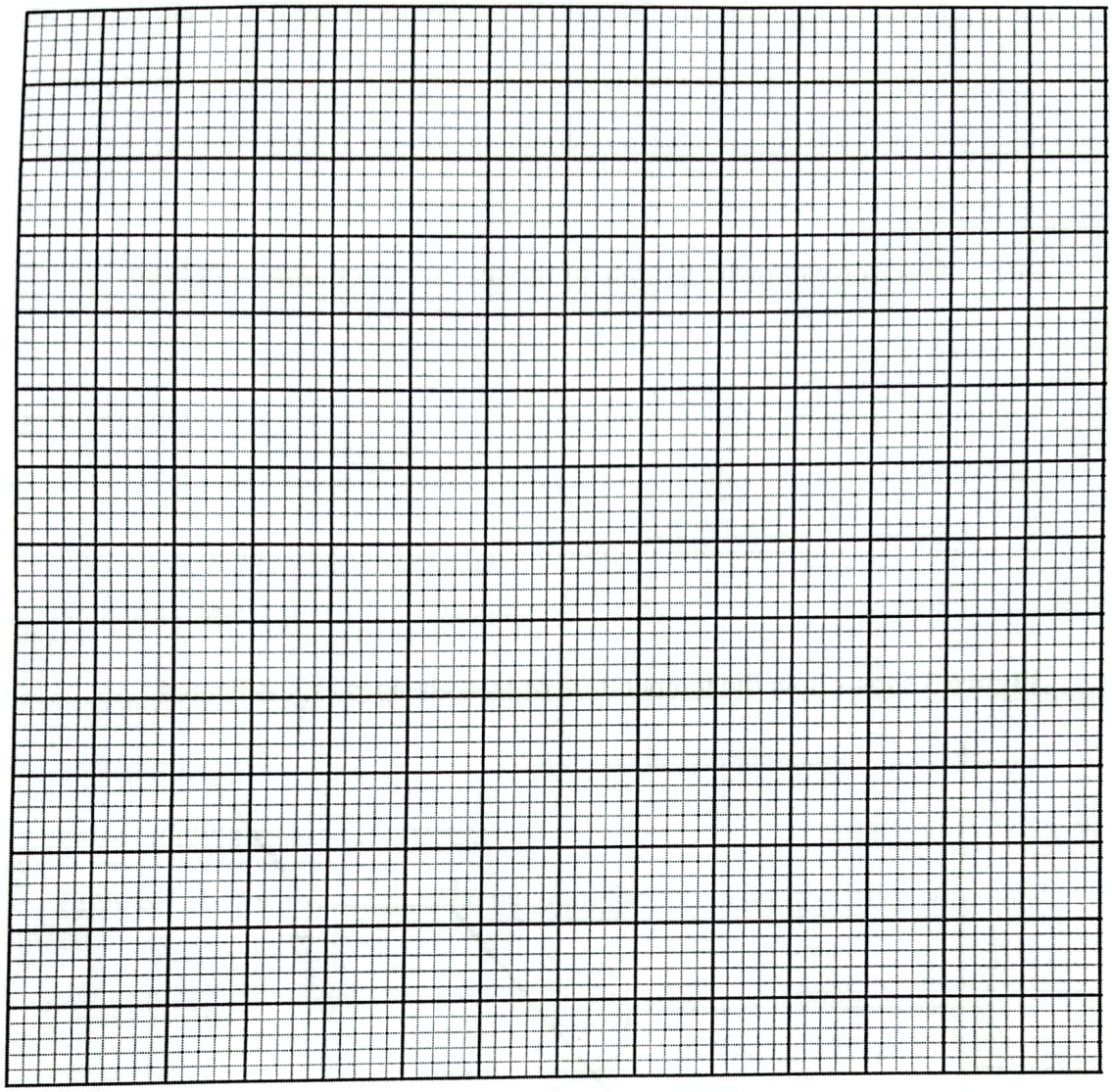
$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

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 $\times 10^3$ / moles per litre**
0	0
50	16
100	22
150	26
200	29
250	31
300	32

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



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

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

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

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

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

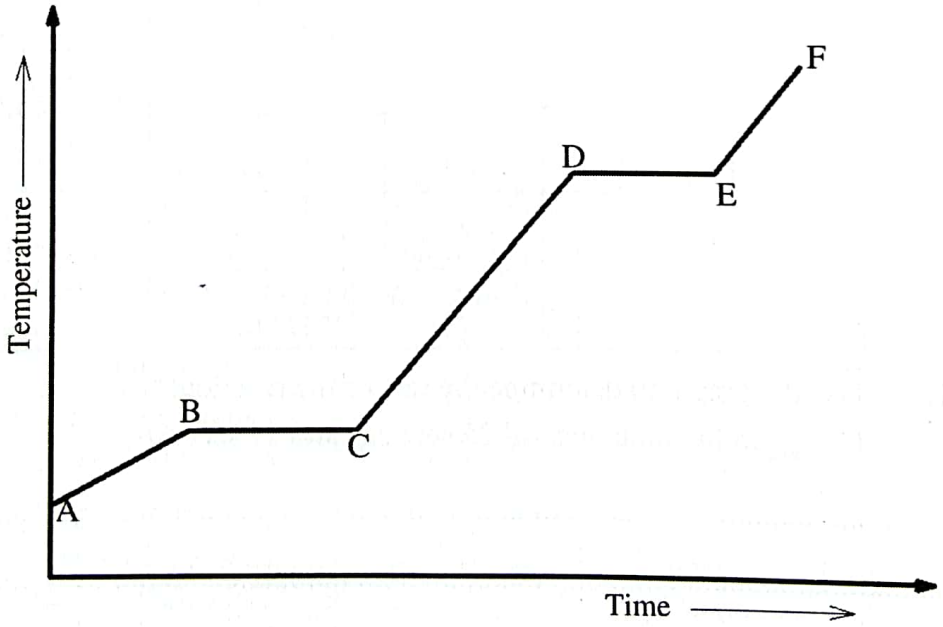

Figure 3

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

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

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

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

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

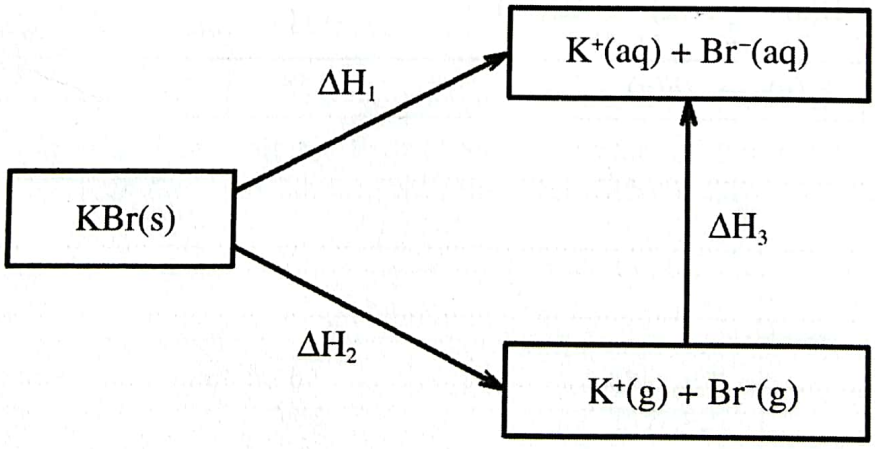

Figure 4

(i) Name the following enthalpy changes:

I. ΔH_1 ; (1 mark)

.....

II. ΔH_2 ; (1 mark)

.....

III. ΔH_3 . (1 mark)

.....

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

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(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

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5 (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)

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(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)

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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)

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

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(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)

(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		
Concentrated aqueous sodium chloride		

(2 marks)

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

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

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)

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

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

Table 7

Temperature/ K	Volume/ dm^3	Pressure/ atm
250	0.005	50
300	0.006	50

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

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

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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)

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

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

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(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)

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

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7 (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)

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

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(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)

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

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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)

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II. Sodium hydrogen carbonate. (1 mark)

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(iii) Describe how the:

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

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

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(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)

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

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

Formula ..... (1 mark)

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

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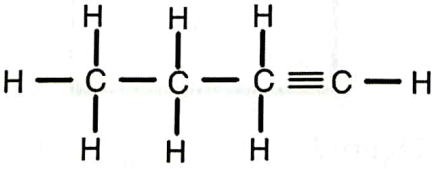
(b) Pent-l-yne, 

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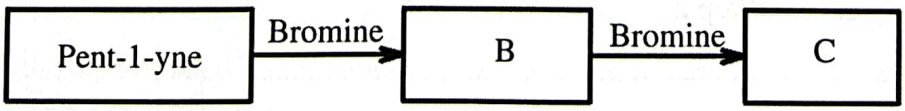

Figure 1

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

Compound **B** (1 mark)

Compound **C** (1 mark)

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

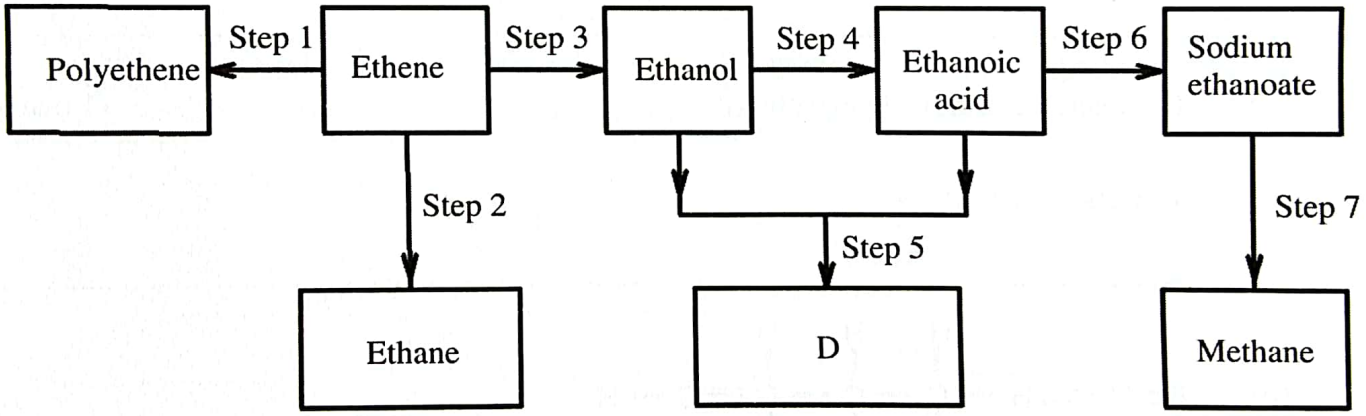

Figure 2

(i) Give the reagents and conditions used in:

I. Step **2**; (1 mark)

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II. Step 7. (1 mark)

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

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

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

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(b) Consider the following gaseous reaction:

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

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

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250	31
300	32

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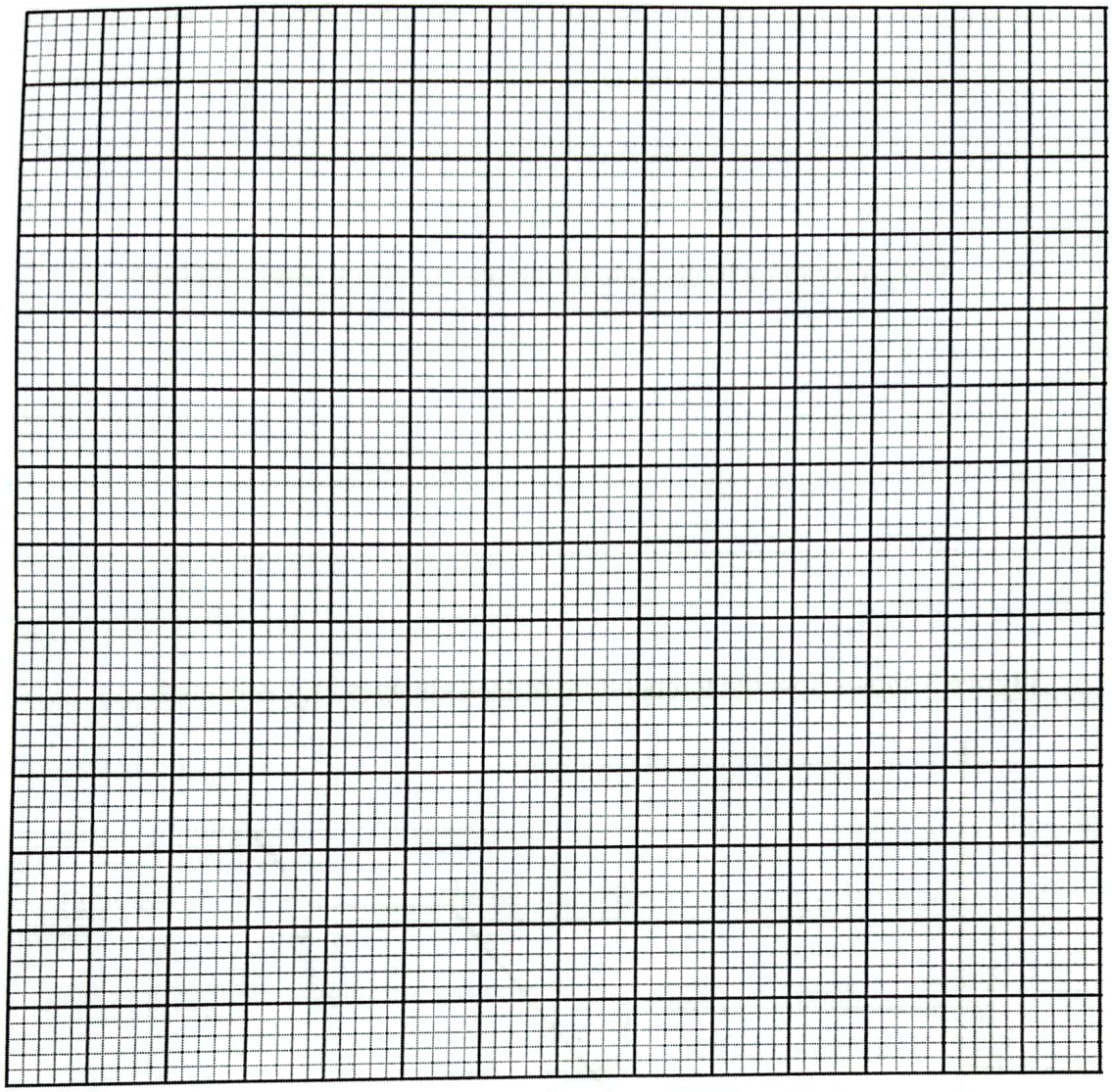

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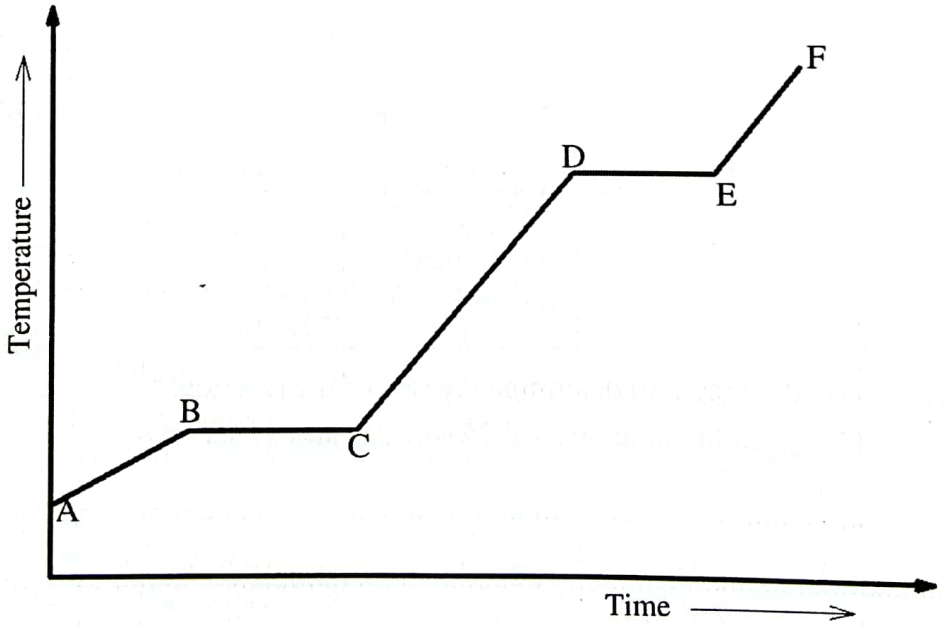

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(b) **Figure 4** shows an energy cycle diagram for processes involving potassium bromide.

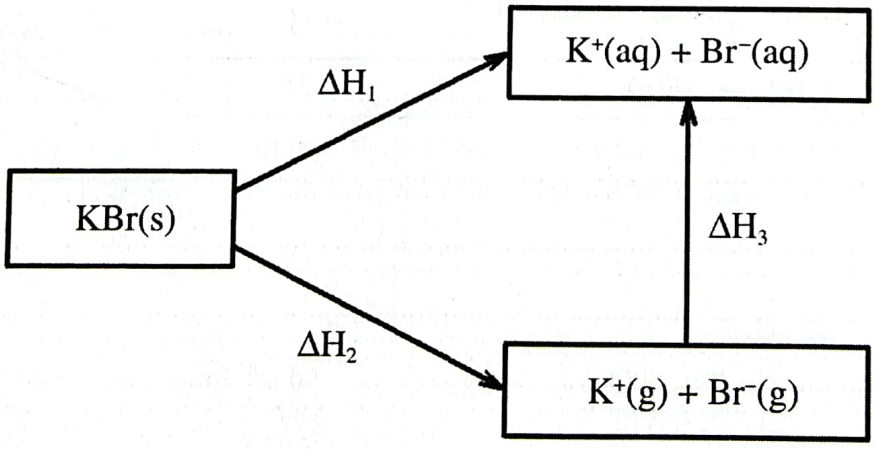

Figure 4

(i) Name the following enthalpy changes:

I. ΔH_1 ; (1 mark)

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II. ΔH_2 ; (1 mark)

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III. ΔH_3 . (1 mark)

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

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(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}
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Number	Electrode reaction	E^{θ}, V
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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
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(i) Select **two** electrodes which when connected gives the cell with the lowest e.m.f. (1 mark)

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(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)

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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)

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(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)

(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		
Concentrated aqueous sodium chloride		

(2 marks)

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

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

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)

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

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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)

.....

II. Sodium hydrogen carbonate. (1 mark)

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(iii) Describe how the:

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

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.....

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

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(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)

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

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THE KENYA NATIONAL EXAMINATIONS COUNCIL

Kenya Certificate of Secondary Education

233/3

CHEMISTRY (Practical)

Paper 3

Nov. 2023 - 2¼ hours

Serial No.
18533274

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) You are **not** allowed to start working with the apparatus for the first 15 minutes of the 2¼ hours allowed for this paper. This time is to enable you to read the question paper and make sure you have all the chemicals and apparatus that you may need.

(e) All working **must** be clearly shown where necessary.

(f) KNEC mathematical tables and silent electronic calculators may be used.

(g) **This paper consists of 8 printed pages.**

(h) **Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.**

(i) **Candidates should answer the questions in English.**

For Examiner's use only

Question	Maximum Score	Candidate's Score
1	19	
2	13	
3	08	
Total Score	40	

1 You are provided with:

- **Solution A** - mixture containing sodium thiosulphate and starch
- **Solution B** - aqueous potassium iodide
- **Solution C** - aqueous hydrogen peroxide
- **Solution D** - 0.01M potassium manganate(VII)

You are required to determine the:

- Concentration in moles per litre of hydrogen peroxide in **solution C**.
- Rate of reaction between hydrogen peroxide and potassium iodide.

PROCEDURE I

Using a pipette and pipette filler, pipette 25.0 cm^3 of solution C into a 250 ml volumetric flask. Add distilled water to the mark and label this as **solution E**.

Fill the burette with **solution D**.
Using a clean pipette and pipette filler, place 25.0 cm^3 of **solution E** into a 250 ml conical flask. Titrate with **solution D** until a permanent pink colour persists. Record the results in **table 1**. Repeat the titration two more times and complete **table 1**.

(a) **Table 1**

	I	II	III
Final burette reading			
Initial burette reading			
Volume of solution D (cm^3) used			

(4 marks)

(b) Determine the:

(i) average volume of solution D used. (1 mark)

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(ii) number of moles of potassium manganate(VII) that reacted. (1 mark)

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(iii) number of moles of hydrogen peroxide in 25.0 cm^3 of solution E (5 moles of hydrogen peroxide react with 2 moles of potassium manganate(VII)). (1 mark)

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(iv) concentration in moles per litre of hydrogen peroxide in solution E. (1 mark)

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(v) concentration in moles per litre of hydrogen peroxide in solution C. (1 mark)

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PROCEDURE II

(i) Rinse the burette with solution E and then with distilled water.
Fill the burette with solution C.
Place 5 test tubes on a test tube rack and label them 1, 2, 3, 4 and 5.
To each test tube place 10 cm^3 of solution C from the burette.

(ii) Clean the burette and fill it with solution B.
Place 25.0 cm^3 of solution B into a 100 ml beaker from the burette.

(iii) Using a 100 ml measuring cylinder, add 20 cm^3 of solution A to the beaker containing solution B.

(iv) Pour the contents of test tube 1 to the mixture in the beaker and immediately start the stop watch. Swirl the contents of the beaker and allow to stand. Record in **table 2** the time, in seconds, taken for a blue colour to just appear. Measure the temperature of the final mixture and record in the space provided. Wash the beaker and proceed to step (v).

(c) Record the temperature of the final mixture .....(1 mark)

(d) **Table 2**

Experiment	Volume (cm^3) of: Solution A	Solution B	Distilled water	Solution C	Time (Seconds)	Rate $= \frac{1000}{time} s^{-1}$
1	20	25	0	10		
2	20	20	5	10		
3	20	15	10	10		
4	20	10	15	10		
5	20	5	20	10		

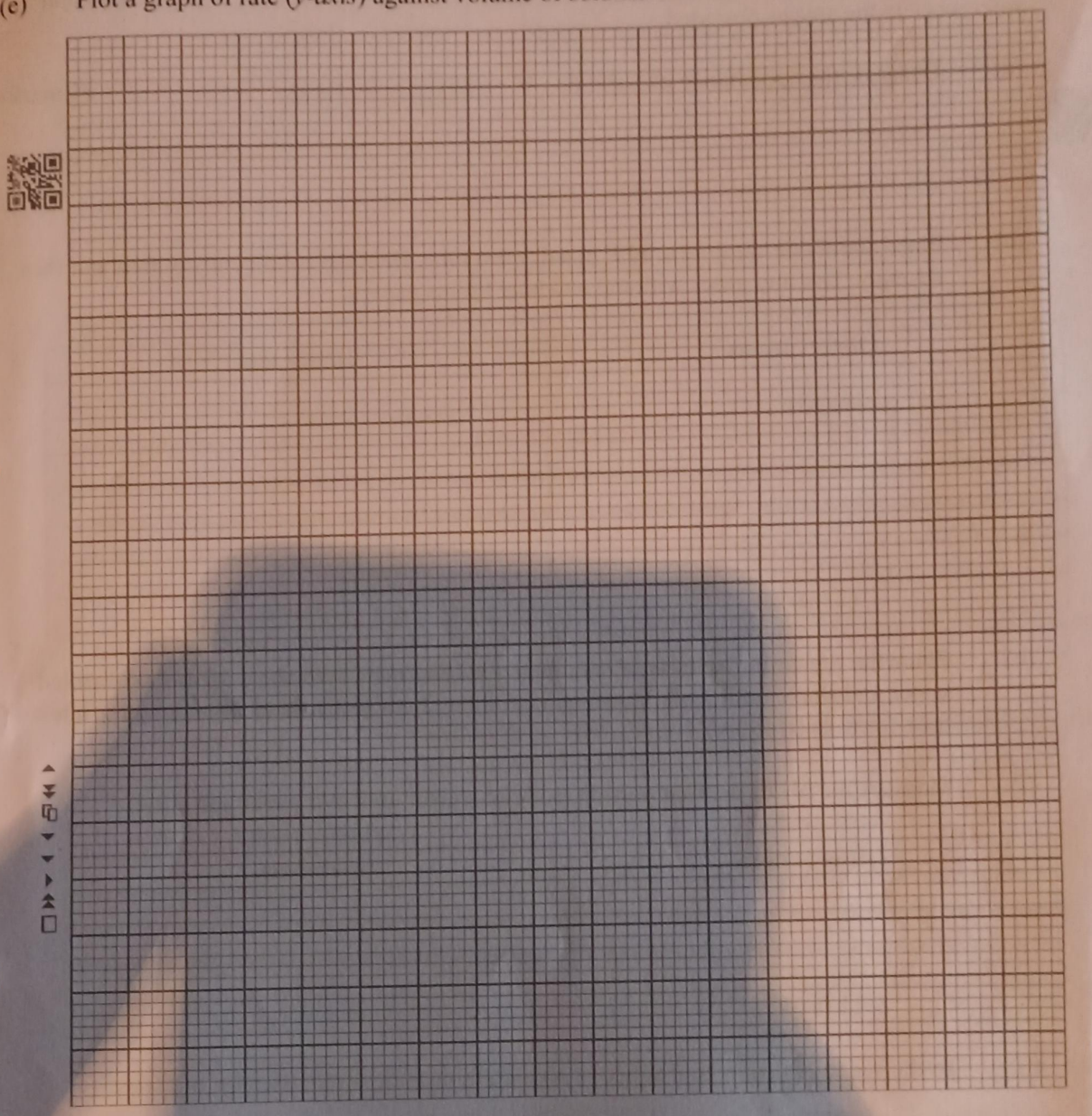
(5 marks)

(v) Place 20.0 cm^3 of **solution B** into the 100 ml beaker from the burette. Using the 100 ml measuring cylinder, add 20 cm^3 of **solution A** to the beaker followed by 5 cm^3 of distilled water measured using a 10 ml measuring cylinder. Add **solution C** in test tube 2 to the mixture in the beaker and immediately start the stop watch. Swirl the contents of the beaker and allow to stand. Record in table 2 the time taken for a blue colour to **just** appear. This is experiment 2 in **table 2**. Wash the beaker.

(vi) Repeat step (v) with **solution C** in test tubes 3, 4 and 5 with the corresponding volumes of **solution B**, **solution A** and distilled water as shown in **table 2** for experiments 3, 4 and 5.

(vii) Complete **table 2** by calculating the rate for each experiment given by:
Rate $= \frac{1000}{time} s^{-1}$ and filling in the table.

(e) Plot a graph of rate (*y-axis*) against volume of solution B. (3 marks)



(f) State why it was necessary to add distilled water to the mixture in experiments 2, 3, 4 and 5. (1 mark)

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2 You are provided with **solid F**. Carry out the following tests and record the observations and inferences in the spaces provided.

(a) Describe the appearance of Solid F. (1 mark)

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(b) Place about one-third of solid F in a dry test tube. Heat the solid gently at first and then strongly. Test any gases with red and blue litmus papers.

Observations	Inferences
(2 marks)	(2 marks)

(c) Place the remaining amount of solid F in a boiling tube. Add about 15 cm^3 of distilled water and shake until it all dissolves. Use about 2 cm^3 portions of the solution in a test tube for tests (i) to (iv).

(i) Measure the pH of the first portion using universal indicator paper and chart.

Observations	Inferences
(1 mark)	(1 mark)

(ii) To the second portion, add aqueous sodium hydroxide dropwise until in excess.

Observations	Inferences
(1 mark)	(1 mark)

(iii) To the third portion, add three drops of aqueous barium chloride. Shake the mixture and then add about 1 cm^3 of dilute hydrochloric acid.

Observations	Inferences
(1 mark)	(1 mark)

(iv) To the fourth portion, add about 3 cm^3 of aqueous hydrogen peroxide.Shake the mixture and then add aqueous ammonia dropwise until in excess.

Observations	Inferences
(1 mark)	(1 mark)

3 You are provided with an organic compound, **solid G**. Carry out the following tests and record the observations and inferences in the spaces provided.

(a) Place all of solid G in a boiling tube. Add about 15 cm^3 of distilled water and shake the mixture. Retain the mixture for use in test (b).

Observations	Inferences
(1 mark)	(1 mark)

(b) Use about 2 cm^3 portions of the mixture, in a test tube, for each of the following tests.

(i) To the first portion, add all of solid sodium hydrogen carbonate provided.

Observations	Inferences
(1 mark)	(1 mark)

(ii) To the second portion, add three drops of acidified potassium manganate(VII).

Observations	Inferences
(1 mark)	(1 mark)

(iii) To the third portion, add about 1 cm^3 of acidified potassium dichromate(VI), warm the mixture.

Observations	Inferences
(1 mark)	(1 mark)

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