RAFFLES INSTITUTION
2019 YEAR 5 TERM 3 COMMON TEST

Higher 2

CHEMISTRY 9729

5 July 2019

2 hours 15 minutes

Additional Materials: Multiple Choice Answer (OMR) Sheet
Writing Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number and civics tutorial group in the spaces provided on the OMR Sheet, the cover sheets on **pages 11 and 13**, and the writing paper used for Section **C**.
Do not use staples, paper clips, highlighters, glue or correction fluid.

This paper consists of three sections, **A**, **B** and **C**.

Section A (15 marks)

Answer this section first. The OMR sheet will be collected after the **first 30 minutes.**

There are **fifteen** questions in this section. For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the one you consider correct and record your choice in **soft pencil** on the OMR Sheet.

Read the instructions on the OMR Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in the question paper.

Section B (30 marks)

There are **three** questions in this section. Answers to this section are to be written in the spaces provided in the question paper.

Section C (35 marks)

There are **two** questions in this section. Answers to this section are to be written on the writing paper provided. You are to begin each question on a fresh sheet of paper.

Write in dark blue or black pen. You may use a pencil for any diagrams or graphs.
You are reminded of the need for good English and clear presentation in your answers.

At the end of the examination, fasten your answers to Section **C** securely together. Answers to Sections **A**, **B** and **C** are to be handed in separately.
The number of marks is given in brackets [ ] at the end of each question or part question.

Section A (15 marks)

For each question, there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 *Use of the Data Booklet is relevant to this question.*

A sample of boron contains sodium as the only impurity. The information in the table was obtained by mass spectrometry of the sample.

mass number	10	11	23
% abundance	15.52	74.48	10.00

What is the A_r of boron in the sample?

A 9.74
B 10.83
C 12.04
D 13.08

2 Under acidic conditions, V_2O_5 undergoes a redox reaction with Fe^{2+}.
The products are Fe^{3+}, water and a vanadium-containing species.

Given that the mole ratio of V_2O_5 to Fe^{2+} is 1 : 2, what could be the vanadium-containing species formed in the reaction?

A V
B VO
C VO_2
D V_2O_3

3 Beams of charged particles are deflected by an electric field.
In an experiment, protons are deflected by an angle of +15°. In another similar experiment under identical conditions, particle **Z** is deflected by an angle of –5°.

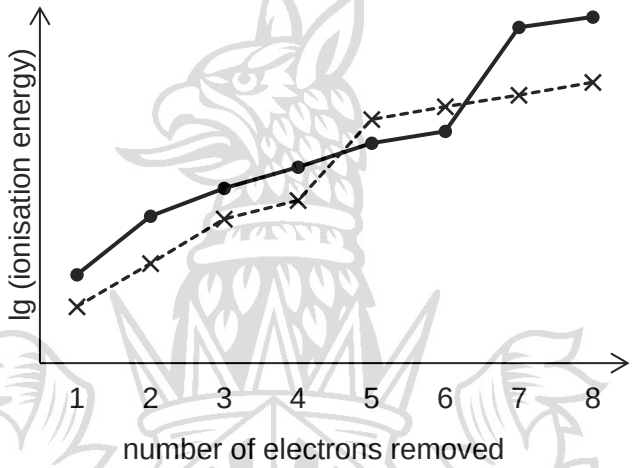
What could be the composition of particle **Z**?

	proton	neutron	electron
1	1	0	4
2	1	2	2
3	3	3	1
4	3	3	5

A 2 and 3
B 2 and 4
C 3 and 4
D 1, 3 and 4

4 *Use of the Data Booklet is relevant to this question.*

The graph shows the logarithm, lg, of the first eight ionisation energies of two elements with atomic numbers less than 18.



What is the most likely compound that will be formed between the two elements?

A CS_2 **C** $AlCl_3$

B SiO_2 **D** NO_2

5 **X** and **Y** are elements found in Period 2 of the Periodic Table, with proton numbers n and (n+1) respectively.

The ion of **X** has a charge of +1, and the ion of **Y** is isoelectronic with the ion of **X**.

Which statement correctly describes **X** and **Y**?

A **X** and **Y** are isotopes.

B **X** has a higher electronegativity than **Y**.

C **X** and **Y** have the same electronic configuration.

D The ion of **Y** has a higher charge density than the ion of **X**.

6 Which molecule has a greater number of π bonds than σ bonds?

A CO_2 **C** N_2

B HCN **D** NO_2

7 Which pairs of compounds have the same shape around the underlined atom?

1 $\underline{B}Cl_3$ and $\underline{Al}Cl_3$
2 $\underline{C}O_2$ and $\underline{Si}O_2$
3 $H_2\underline{O}$ and $\underline{S}O_2$

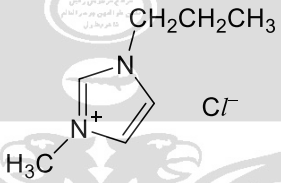
A 1 and 2
B 1 and 3
C 2 and 3
D 1, 2 and 3

8 Which statement best describes polar compounds?

A Polar compounds are always soluble in water.
B Compounds containing polar bonds must be polar.
C A stream of a polar compound can be deflected by a charged rod.
D A polar compound experiences only one type of intermolecular force.

9 Some ionic compounds have very low melting points and are liquids at temperatures below 100 °C. They are commonly referred to as *ionic liquids*.

1-propyl-3-methylimidazolium chloride is one such example. It has a melting point of 60 °C.



1-propyl-3-methylimidazolium chloride

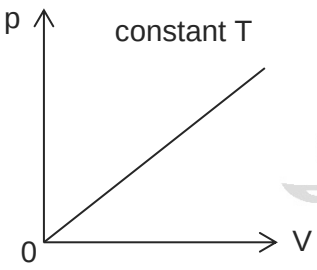
Which statements are applicable to this compound?

1 It can form hydrogen bonds with itself.
2 It can form ion-dipole interactions with water.
3 The magnitude of its lattice energy is small because of the large cationic radius.

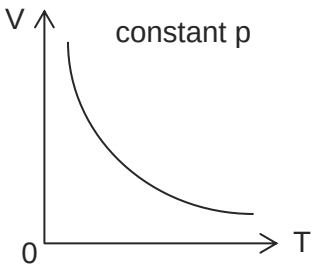
A 1 and 2
B 1 and 3
C 2 and 3
D 1, 2 and 3

10 Which diagram correctly describes the behaviour of a fixed mass of an ideal gas? (T is measured in K)

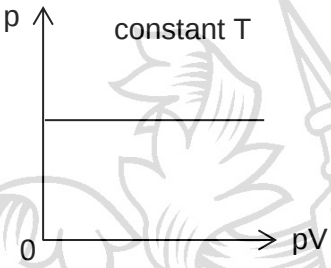
A



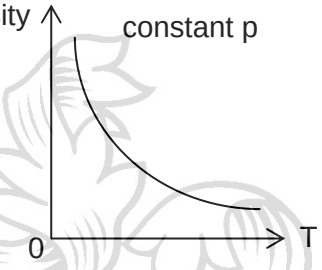
C



B



D



11 Which gas behaves most ideally at room temperature and pressure?

A neon
B chlorine
C ammonia
D carbon dioxide

12 Which equations correspond to the enthalpy change stated?

1	$Br_2(l) \longrightarrow 2Br(g)$	$\Delta H_{atom}^{\ominus}(Br_2(l))$
2	$C(s) + O_2(g) \longrightarrow CO_2(g)$	$\Delta H_c^{\ominus}(C(s))$
3	$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$	$\Delta H_f^{\ominus}(H_2O(l))$

A 2 only
B 1 and 2
C 1 and 3
D 1, 2 and 3

13 Thermal decomposition of $MgCO_3$ happens only at high temperatures.

Which row correctly describes the signs of ΔH and ΔS for this thermal decomposition?

	ΔH	ΔS
A	−	−
B	−	+
C	+	−
D	+	+

14 Using the information given in the table, what is the standard enthalpy change of reaction for the following reaction?

$$NH_3(g) + 3Cl_2(g) \longrightarrow 3HCl(g) + NCl_3(l)$$

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$NH_3(g)$	−45.9
$HCl(g)$	−92.3
$NCl_3(l)$	+230.0

A −1.0 kJ mol^{-1}

B +1.0 kJ mol^{-1}

C −183.6 kJ mol^{-1}

D +183.6 kJ mol^{-1}

15 1.20 g of compound **P** undergoes complete combustion in excess oxygen to form 1.76 g of carbon dioxide and 0.72 g of water only.

What is the empirical formula of **P**?

A CH

B CHO

C CH_2

D CH_2O

Section C (35 marks)

Answer **all** questions in this section.

Write your answers on the writing paper provided. Begin **each** question on a **fresh sheet** of paper.

1 Breaking wind is a necessity, a relief and under certain circumstances an embarrassing episode. Flatulence is the accumulation of gases that results in a pressure build up in the digestive system, which causes discomfort that ultimately leads to an urge to break wind. The gas expelled is known as flatus.

Assuming all gases behave ideally, a typical composition of flatus by volume is shown in Table 1.1.

Table 1.1

gas	M_r	% by volume
N_2	28.0	58
H_2	2.0	21
CO_2	44.0	9
CH_4	16.0	7
O_2	32.0	4
H_2S	34.1	1

(a) **(i)** State two assumptions of the kinetic theory as applied to an ideal gas. [2]

(ii) Fig. 1.1 illustrates the behaviour of 1 mol of CH_4 at 293 K.

Fig. 1.1

Copy Fig. 1.1 onto your writing paper.

Sketch and label the corresponding graph for 1 mol of CO_2 at 293K on the same axes. Explain your answer. [2]

(b) Using the data in Table 1.1, calculate the average relative molecular mass, M_r, of typical flatus. [1]

(c) An average human has a rectal volume of 250 cm^3 and a body temperature of 37 ^oC. If 300 cm^3 of flatus can be collected at r.t.p., calculate the initial pressure of the flatus in the rectum assuming all the flatus is released. [1]

There are two acidic gases listed in Table 1.1, of which H_2S is responsible for the smell in flatus.

100 cm^3 of typical flatus at r.t.p. was passed through a 50 cm^3 solution of NaOH(aq).

(d) **(i)** State the total volume of acidic gases in 100 cm^3 of typical flatus. [1]

(ii) Given that the acidic gases are dibasic in nature, calculate the minimum concentration of NaOH(aq) required for the removal of the acidic gases, hence eliminating the smell. [2]

Studies have shown that typical flatus is combustible due to the CH_4 and H_2 present. The enthalpy change of combustion for CH_4 and H_2 at 20 °C and 1 atm are given in Table 1.2.

Table 1.2

gas	ΔH_c / kJ mol^{-1}
CH_4	–880
H_2	–280

In an experiment, 100 cm^3 of typical flatus was ignited in excess oxygen at room temperature and pressure.

(e) **(i)** Write two balanced equations that represent the enthalpy change of combustion, ΔH_c, of CH_4 and H_2. [2]

(ii) Calculate the heat evolved in this combustion experiment. [2]

(iii) Using your answer to **(e)(i)**, explain if the combustion of H_2 is spontaneous at all temperatures. [2]

[Total: 15]

2 This question is mainly about halogens and its compounds.

(a) Cyanogen chloride, C*l*–C≡N, is a linear molecule used in bazookas in chemical warfare.

Table 2.1 shows the electronegativity values of the atoms in C*l*CN.

Table 2.1

atom	electronegativity / Pauling units
C	2.5
N	3.0
C*l*	3.0

(i) Explain what is meant by the term *electronegativity*. [2]

(ii) With reference to Table 2.1, predict all possible intermolecular forces which could exist between C*l*CN molecules. Explain how these forces arise. [3]

(iii) In the presence of a catalyst, C*l*CN reacts with itself to form compound **Q**.

$$3ClCN \longrightarrow \underset{\mathbf{Q}}{Cl_3C_3N_3}$$

Molecules of **Q** have no overall dipole moment. Suggest a possible structure of **Q**. [1]

(b) Carbon monoxide reacts with boron trifluoride, BF_3, at high pressure to give the compound F_3BCO, in which carbon is bonded to both boron and oxygen.

(i) Draw the dot-and-cross diagram of carbon monoxide, CO, clearly indicating any co-ordinate (dative covalent) bonds it contains. [1]

(ii) Draw the structure of F_3BCO, showing clearly the type of bond between the boron and carbon atoms. [1]

(iii) By considering the number of regions of electron density around the boron atom in BF_3 and F_3BCO, deduce the change in shape around the boron atom. [2]

(c) The melting point of phosphorus trifluoride, PF_3, is –152 °C, while that of magnesium fluoride, MgF_2, is 1263 °C.

Explain, in terms of structure and bonding, why the melting point of PF_3 is lower than that of MgF_2. [2]

(d) Magnesium chloride, $MgCl_2$, is used as a source of magnesium ions which are essential for many cellular activities.

Lattice energies of compounds such as $MgCl_2$ are not measured directly. By using Hess' law and the Born-Haber cycle, they can be obtained from experimental data.

(i) The following data will be useful in this question.

first electron affinity of Cl(g)	=	–349 kJ mol^{-1}
enthalpy change of atomisation of Mg(s)	=	+147 kJ mol^{-1}
enthalpy change of formation of $MgCl_2$(s)	=	–642 kJ mol^{-1}

By constructing an energy level diagram to represent the Born-Haber cycle and applying Hess' law, calculate the lattice energy of $MgCl_2$ using relevant data from the above list and the *Data Booklet*. [4]

(ii) Explain why the lattice energy of $MgCl_2$ is more exothermic than that of NaCl. [1]

Coordination number of an ion in an ionic crystal lattice structure is the number of oppositely charged neighbouring ions adjacent to it.

The coordination geometry of a cation in an ionic compound can be predicted from the ratio of the ionic radii of the cation and anion involved as shown in Table 2.2.

Table 2.2

$\frac{\text{cation radius}}{\text{anion radius}}$	coordination geometry	coordination number
0.155 – 0.225	trigonal planar	3
0.225 – 0.414	tetrahedral	4
0.414 – 0.732	octahedral	6

(iii) Using data from the *Data Booklet* and Table 2.2, predict the coordination geometry and coordination number of Mg^{2+} in $MgCl_2$. [1]

(iv) In the crystal lattice of $BaCl_2$, the coordination number is different from that of $MgCl_2$. Suggest and explain which cation, Ba^{2+} or Mg^{2+}, has a larger coordination number. [2]

[Total: 20]

RAFFLES INSTITUTION
2019 Year 5 Term 3 Common Test
H2 Chemistry

COVER SHEET

C

Name:	**( )**	**Class:**

For Examiner's Use Only

Question	Marks
C1	/ 15
C2	/ 20

Attach this cover sheet to your writing paper.

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H

RAFFLES INSTITUTION
2019 YEAR 5 TERM 3 COMMON TEST

Higher 2

CANDIDATE NAME

CLASS | INDEX NUMBER

CHEMISTRY 9729

5 July 2019

Section		Marks
A		/ 15
B	B1	/ 8
	B2	/ 13
	B3	/ 9
C	C1	/ 15
	C2	/ 20
Total		/ 80
Percentage		/100
Penalty		
Overall		/100
Grade		

For examiner's use

Section B (30 marks)

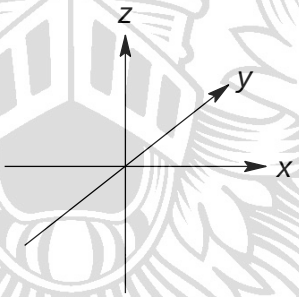
This section consists of **3** questions.
Answer **all** the questions in this section in the spaces provided.

1 *Use of the Data Booklet is relevant to this question.*

(a) **(i)** State the electronic configuration of sodium.

……[1]

(ii) On the axes provided, draw and label the orbital from which the second electron of sodium is removed.



[1]

(iii) With the aid of a relevant equation, explain what is meant by the second ionisation energy of sodium.

……

……

……

……[2]

(iv) Explain why the successive ionisation energies of sodium increase.

……

……

……[1]

For examiner's use

Sodium vapour lamp is a gas-discharge lamp that is commonly used in street lighting due to its characteristic yellow-orange hue.

Such lamps consist of a gas tube containing solid sodium and a small amount of neon gas.

The process of producing light involves the ionisation of gaseous sodium and neon atoms in an electric field.

(b) (i) Explain why sodium has a lower first ionisation energy than neon.

……

……

……

……[2]

(ii) Explain why the pinkish glow of neon is observed before the orange glow of sodium when the lamp is first turned on.

……

……

……[1]

[Total: 8]

For examiner's use

2 Ascorbic acid is a water-soluble antioxidant that plays a vital role in protecting the body from infection and disease. Ascorbic acid is not synthesised in the human body and can be supplemented by consuming vitamin C syrup.

The concentration of ascorbic acid in a vitamin C syrup can be determined by a redox titration with potassium iodate(V), KIO_3, in the presence of potassium iodide, KI.

In an experiment, KIO_3 is added from a burette to a conical flask containing vitamin C syrup, excess H_2SO_4, excess KI and starch indicator.

The iodate(V) ions, IO_3^-, first react with the iodide ions, I^-, to form iodine and water only.

(a) (i) By using oxidation numbers or otherwise, construct a balanced equation for the reaction of IO_3^- with I^- in an acidic medium.

……[1]

The iodine formed immediately oxidises the ascorbic acid present.

$$\underset{\text{ascorbic acid}}{C_6H_8O_6} + I_2 \longrightarrow C_6H_6O_6 + 2I^- + 2H^+$$

Once all the ascorbic acid has been oxidised, the iodine produced in **(a)(i)** is free to react with the starch indicator, forming a dark blue starch-iodine complex. This is the end-point of the titration.

(ii) In an experiment, 25.0 cm^3 of vitamin C syrup was mixed with an excess of acid and potassium iodide. The solution was titrated with potassium iodate(V) solution.

Given that 19.80 cm^3 of 0.120 mol dm^{-3} of potassium iodate(V) solution was required to reach the end-point, and using your answer to **(a)(i)**, calculate the molar concentration of ascorbic acid in the vitamin C syrup.

[2]

(iii) The concentration of ascorbic acid in the vitamin C syrup can also be determined by a direct redox titration with aqueous iodine. Suggest why the direct titration is a less reliable method.

……

……[1]

For examiner's use

Ascorbic acid also helps with the absorption of iron in our bodies. Iron tablets are used for preventing and treating anemia caused by low iron levels, and commonly contain iron(II) sulfate, $FeSO_4$ (M_r = 151.9).

$FeSO_4$ can be oxidised by acidified potassium manganate(VII), $KMnO_4$.

$$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

(b) (i) You are required to write a plan for determining the mass of $FeSO_4$ present in one iron tablet. This can be done by titrating solution **A** against $KMnO_4$ under acidic conditions.

You may assume that you are provided with:

- 250 cm^3 solution **A**, prepared by dissolving five iron tablets and contains a total of about 1 g of $FeSO_4$;
- 0.00500 mol dm^{-3} $KMnO_4$;
- 0.05 mol dm^{-3} H_2SO_4;
- the apparatus and chemicals normally found in a school or college laboratory.

Your plan should include:

- a suitable volume of H_2SO_4 to be used for each titration;
- the essential details of the titration procedure.

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For examiner's use

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……[4]

(ii) Show how the experimental results may be used to determine the mass of $FeSO_4$ in **one** iron tablet.

You may assume V cm^3 to be the average volume of $KMnO_4$ used in the experiment.

[2]

(iii) Lincoln conducted the experiment and missed one step in the procedure. As a result, he obtained a titre volume that was much higher than the expected titre volume. The formation of a black precipitate was also observed.

Identify the black precipitate and suggest which step was missed in the experiment.

……

……

……[2]

(iv) Ferrograd® is an iron supplement which contains two active ingredients, ascorbic acid and $FeSO_4$.

Suggest why the amount of $FeSO_4$ in a tablet of Ferrograd® cannot be determined by a similar titration as described in **(b)(i)**.

……

……[1]

[Total: 13]

For examiner's use

3 An experiment was carried out to determine the enthalpy change of neutralisation for the reaction between a solid monobasic acid HX and $Ba(OH)_2(aq)$, as well as the concentration of $Ba(OH)_2(aq)$. The procedure of the experiment is described below.

1. 60 cm^3 of $Ba(OH)_2(aq)$ was measured into a Styrofoam cup.
2. The initial temperature of $Ba(OH)_2(aq)$ in the cup was measured with a thermometer and recorded.
3. 0.025 mol of solid HX was added into the cup and the mixture was stirred.
4. The highest temperature of the solution was measured and used to calculate the temperature change, ΔT.
5. Steps 1−4 were repeated 5 times, with decreasing volumes of $Ba(OH)_2(aq)$ used.
6. The values of $\frac{1}{V_{Ba(OH)_2}}$ were calculated and the data obtained was plotted using the axes shown in Fig. 3.1.

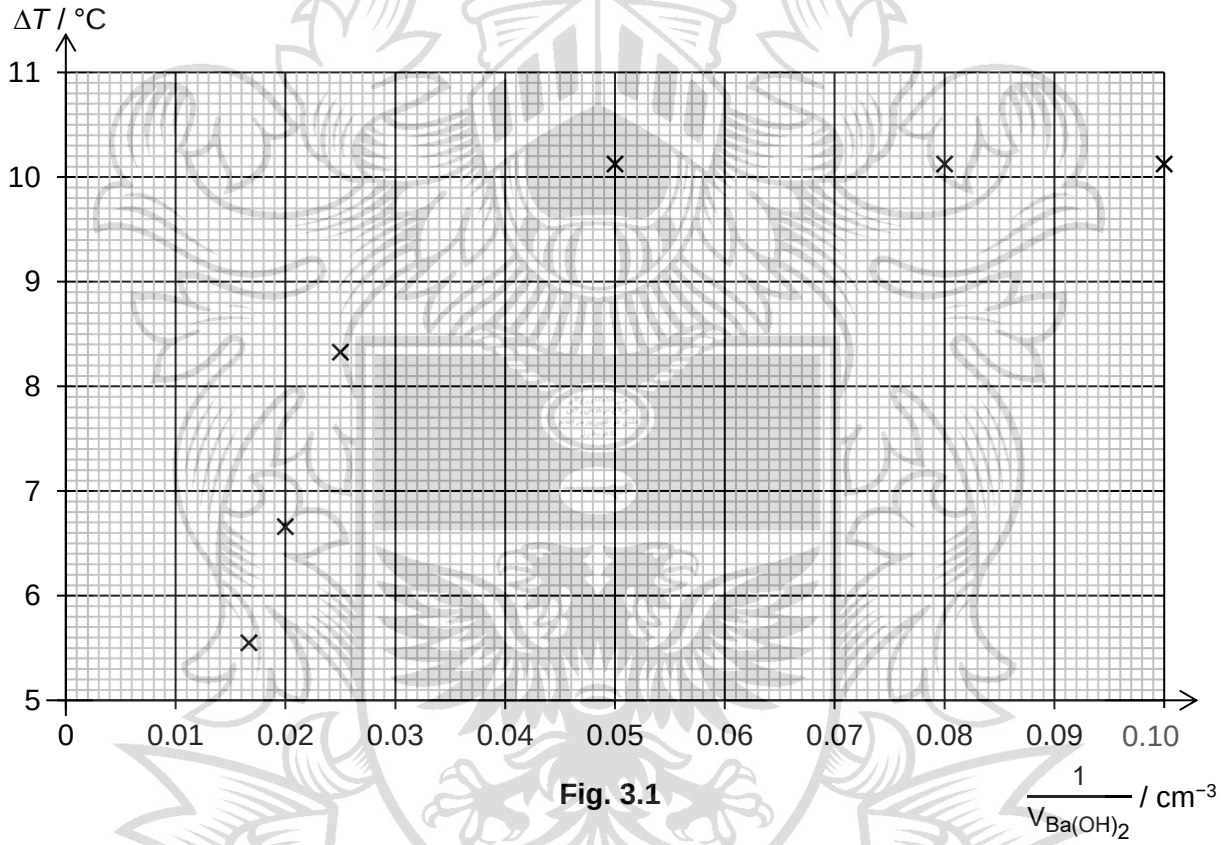

Fig. 3.1

(a) Define what is meant by *standard enthalpy change of neutralisation*, and write down the ionic equation, including state symbols, that represents this enthalpy change.

definition: ……

……

ionic equation: ……[2]

For examiner's use

(b) As the volume of $Ba(OH)_2(aq)$ decreases, $\frac{1}{V_{Ba(OH)_2}}$ increases.

- **When HX is limiting:**
  The heat change, q, will be a constant.
  However, since the volume, and hence mass, of the mixture is decreasing, ΔT will increase.

$$q = mc\Delta T$$

$$\Delta T = \frac{q}{c} \times \frac{1}{m}$$

Assuming that the density of $Ba(OH)_2(aq)$ is 1.0 g cm^{-3},

$$\Delta T = \frac{q}{c} \times \frac{1}{V_{Ba(OH)_2}}$$

By plotting a graph of ΔT on the y-axis against $\frac{1}{V_{Ba(OH)_2}}$ on the x-axis, the gradient will give $\frac{q}{c}$.

- **When HX is in excess:**
  The heat change, q, will be proportional to the volume of $Ba(OH)_2(aq)$ added.
  However, since the volume, and hence mass, of the mixture is decreasing proportionally to the heat change, ΔT will remain a constant.

(i) On Fig. 3.1, draw two straight lines of best fit and calculate the value of the gradient when HX is the limiting reactant.

Show all construction lines and working clearly.

[2]

For examiner's use

(ii) Hence, using your answer in **(b)(i)**, calculate the enthalpy change of neutralisation for the reaction.

(You may assume the specific heat capacity of the mixture to be 4.18 J K^{-1} cm^{-3}.)

[2]

(iii) State whether the enthalpy change of neutralisation would change if 0.05 mol of solid HX was used in the experiment instead. Explain your answer.

……

……

……[1]

(c) **(i)** Using the graph, determine the minimum volume of $Ba(OH)_2(aq)$ required for 0.025 mol of acid HX to react.

Show all working clearly.

[1]

(ii) Hence, using your answer in **(c)(i)**, determine the concentration of $Ba(OH)_2(aq)$.

[1]

[Total: 9]

– END OF PAPER –