Name: ( )	Class: 22S0_____

RAFFLES INSTITUTION
2021 YEAR 5 PROMOTION EXAMINATION

Higher 2

CHEMISTRY 9729

28 September 2021

2 hours 10 minutes

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

READ THESE INSTRUCTIONS FIRST

Write your name, index number and civics tutorial group in the spaces provided on the OMR Sheet, and the cover sheets on **pages 1** and **17**.
Do not use staples, paper clips, 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. Answer **all** questions. 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 (35 marks)

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

Section C (25 marks)

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

The use of an approved scientific calculator is expected, where appropriate.

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.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use Only	
B1	**/ 14**
B2	**/ 9**
B3	**/ 12**

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 An element forms a triatomic molecule, E. The Avogadro constant is L.

How many atoms are present in 1 cm^3 of gaseous E at room temperature and pressure?

A $\frac{L}{24000}$ **B** $\frac{3L}{24}$ **C** $\frac{3L}{24000}$ **D** $\frac{3L}{22700}$

2 H_2S reacts with SO_2 to give S and H_2O.

Assuming the reaction goes to completion, how many moles of H_2S and SO_2 would result in a mixture containing equal numbers of moles of H_2S and S?

	moles of H_2S	moles of SO_2
A	3	1
B	4	2
C	4	4
D	5	1

3 The first seven ionisation energies of an element, M, in kJ mol^{-1} are shown below.

1402 ; 2856 ; 4578 ; 7475 ; 9445 ; 53270 ; 64360

M forms its only chloride by heating M with chlorine.

What is the chloride of M formed?

A $M^{2+}(Cl^-)_2$

B $M^{3+}(Cl^-)_3$

C MCl_2

D MCl_3

4 What is the order of increasing enthalpy change for the three reactions shown?

$$Rb^+(g) \longrightarrow Rb^{2+}(g) + e^- \qquad \Delta H_1$$

$$Br^-(g) \longrightarrow Br(g) + e^- \qquad \Delta H_2$$

$$Kr(g) \longrightarrow Kr^+(g) + e^- \qquad \Delta H_3$$

A $\Delta H_1 < \Delta H_2 < \Delta H_3$

B $\Delta H_1 < \Delta H_3 < \Delta H_2$

C $\Delta H_2 < \Delta H_1 < \Delta H_3$

D $\Delta H_2 < \Delta H_3 < \Delta H_1$

5 Which molecule is not polar?

A SF_4 **B** XeF_2 **C** CH_2F_2 **D** SO_2

6 The table below shows the boiling points of three compounds with the same molecular formula, C_4H_8O.

compound	structure	boiling point / °C
butanal	$CH_3CH_2CH_2-\overset{\overset{O}{\|\|}}{C}-H$	74.8
2-methylpropanal	$CH_3\underset{\|}{C}H-\overset{\overset{O}{\|\|}}{C}-H$ (with CH_3)	63.0
but-3-en-1-ol	$H_2C=CHCH_2CH_2OH$	113.5

Which statements account for the differences in boiling points?

1 There is weaker hydrogen bonding in butanal than in but-3-en-1-ol.

2 There is C=C bond in but-3-en-1-ol but not in the other two compounds.

3 There are stronger induced dipole attractions in butanal than in 2-methylpropanal.

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

7 The conversion of graphite into diamond is an endothermic reaction.

Which statements about graphite and diamond are correct?

1 The carbon–carbon bond in graphite is stronger than that in diamond because the carbon atoms in graphite are sp^2 hybridised.

2 The enthalpy change of atomisation of diamond is less endothermic than that of graphite.

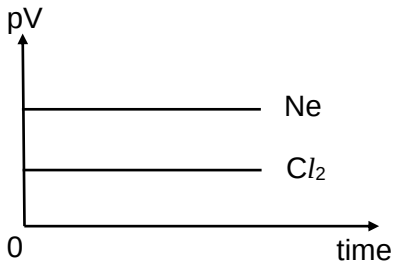
3 The enthalpy change of combustion of diamond is more exothermic than that of graphite.

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

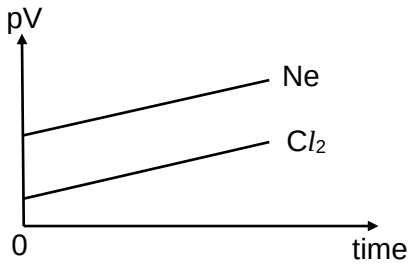
8 Equal masses of Cl_2 and Ne are placed in separate gas syringes with the same initial volume. At constant temperature, the volume of each syringe is increased at the same constant rate.

Assuming both gases behave ideally, which graph shows the results for both gases?

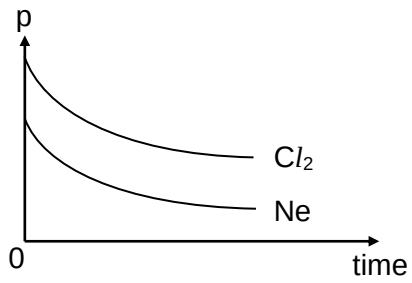
A



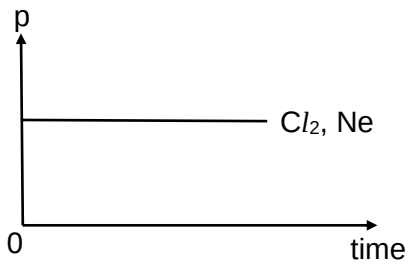
B



C



D



9 Which row shows enthalpy changes of the same value?

A	$\Delta H_{formation}^{\ominus}(H_2O(l))$	$\Delta H_{combustion}^{\ominus}(H_2(g))$
B	$\Delta H_{atomisation}^{\ominus}(I_2(s))$	$\frac{1}{2} \times$ bond energy of I–I
C	$\Delta H_{combustion}^{\ominus}(C(s))$	2 × bond energy of C=O
D	first ionisation energy of O	first electron affinity of O

10 The enthalpy changes involved in the formation of KI(aq) from K(s) and $I_2(s)$ are shown below.

$$K(s) + \frac{1}{2} I_2(s) \xrightarrow{\Delta H_1} K(g) + I(g) \xrightarrow{\Delta H_2} K^+(g) + I^-(g) \xrightarrow{\Delta H_3} KI(s) \xrightarrow{\Delta H_4} KI(aq)$$

Which statements are correct?

1 $\Delta H_{formation}^{\ominus}(KI(s)) = \Delta H_1 + \Delta H_2 + \Delta H_3$

2 ΔH_3 = lattice energy of potassium iodide

3 ΔH_4 = hydration energy of potassium iodide

4 ΔH_2 = first ionisation energy of potassium – first electron affinity of iodine

A 1 and 2 only **B** 1 and 4 only **C** 2 and 3 only **D** 3 and 4 only

11 Which reaction is less spontaneous at higher temperatures?

A $H_2(g) \longrightarrow 2H(g)$

B $2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$

C $2Na^+(g) + O^{2-}(g) \longrightarrow Na_2O(s)$

D $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

12 The decomposition of $X_2(g)$ follows first-order kinetics.

$$X_2(g) \longrightarrow 2X(g)$$

50 cm^3 of $X_2(g)$ was allowed to decompose in a sealed gas syringe at room temperature and pressure. If the half-life of the decomposition is 20 min, calculate the time taken for the syringe to register a volume of 87.5 cm^3 of gas.

A 20 min

B 40 min

C 60 min

D 80 min

13 The kinetics of the following reaction is studied by finding the time taken, *t*, for a coloured reactant, A, to decolourise.

$$A + B + C \longrightarrow D + E$$

A series of experiments was carried out using different volumes of A, B and C. Each reaction mixture was made up to the same total volume with water and the initial rate can be approximated as follows.

$$\text{initial rate} \propto \frac{\text{volume of A}}{\text{time taken for decolourisation of A}}$$

The following results were obtained.

experiment	volume of A added / cm^3	volume of B added / cm^3	volume of C added / cm^3	volume of water added / cm^3	*t* / s
1	10	10	5	25	10
2	10	10	10	20	10
3	10	20	10	10	5
4	20	10	5	15	10
5	30	5	5	10	*y*

Which statements can be deduced from these results?

1 The value of *y* for experiment 5 is 20.

2 The reaction is zero-order with respect to A.

3 The reaction is an overall second-order reaction.

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

14 A reaction, involving gaseous reactants and products, has an equilibrium constant which is independent of temperature.

Which statement about the reaction is correct?

A There are equal number of moles of reactants and products.

B The total bond energy of the reactants is the same as total bond energy of the products.

C The activation energy of the forward reaction is larger than that of the backward reaction.

D The rate constants for the forward and backward reactions do not vary with temperature.

15 A sample containing SO_2Cl_2 and Cl_2 in a molar ratio of 5:3 is placed in an evacuated vessel at 400 K and the following equilibrium is established.

$$SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g)$$

The value of the equilibrium pressure, p, is then found to be 10% greater than the initial total pressure. What is the partial pressure of Cl_2 in the equilibrium mixture?

A 0.432p

B 0.412p

C 0.385p

D 0.091p

For examiner's use

Section B (35 marks)

This section consists of **3** questions.

Answer **all** the questions in this section in the spaces provided.

1 Ethyl propanoate, $CH_3CH_2COOCH_2CH_3$, can be formed from the reaction between propanoic acid, CH_3CH_2COOH, and ethanol, CH_3CH_2OH. The reaction is reversible, and a strong acid catalyst is usually added to speed up the reaction.

equation 1 $CH_3CH_2COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3CH_2COOCH_2CH_3(l) + H_2O(l)$

To determine the equilibrium constant, K_c, of the reaction, the following method is used.

Known equimolar amounts of propanoic acid and ethanol are mixed with 1.00 cm^3 of 2.00 mol dm^{-3} hydrochloric acid, and the resultant mixture is stored in a sealed container for one week at room temperature to reach dynamic equilibrium. A large quantity of cold, deionised water is then added, and the **whole mixture** is titrated against a standard solution of sodium hydroxide. This allows the total amount of acid, made up of the strong acid catalyst and propanoic acid, present in the equilibrium mixture to be determined.

The change in the amount of propanoic acid present in the initial mixture and the equilibrium mixture can then be calculated. This can in turn be used to obtain the amounts of each of the other components in the equilibrium mixture. Using these data, K_c may then be determined.

Table 1.1 gives information about some properties of propanoic acid, ethanol, ethyl propanoate and water.

Table 1.1

chemical	M_r	properties
propanoic acid	74.0	corrosive, flammable, eye irritant
ethanol	46.0	volatile, flammable, eye irritant
ethyl propanoate	102.0	volatile, flammable
water	18.0	—

(a) (i) Explain what is meant by *dynamic equilibrium*.

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……[1]

(ii) With reference to Table 1.1, explain why the reaction mixture needs to be stored in a **sealed** container to reach dynamic equilibrium.

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……[1]

For examiner's use

(b) (i) Using information from page **8**, plan a procedure to determine the equilibrium constant, K_c, for the reaction between propanoic acid and ethanol to form ethyl propanoate and water.

You may assume that you are provided with:
- 1.00 mol dm^{-3} sodium hydroxide, NaOH,
- 2.00 mol dm^{-3} hydrochloric acid, HC*l*,
- propanoic acid,
- ethanol,
- thymolphthalein,
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:
- the quantities of reagents you would use,
- the apparatus you would use,
- the procedure you would follow,
- the measurements you would make.

You do **not** need to show how the equilibrium amounts of each component and the K_c value are calculated.

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For examiner's use

[6]

For examiner's use

(ii) Identify one potential safety hazard in this experiment and state how you would minimise this risk.

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……[1]

(c) **(i)** State and explain how the value of K_c obtained from the experiment would be affected, if at all, by each of the following:

① The experiment was conducted in the absence of a dilute strong acid catalyst.

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……[2]

② A large quantity of cold, deionised water was not added to the mixture before titrating against aqueous sodium hydroxide.

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……[2]

(ii) Suggest how the experiment could be improved to increase reliability of the K_c obtained.

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……[1]

[Total: 14]

[Turn Over

For examiner's use

2 Lewis acids are electron pair acceptors while Lewis bases are electron pair donors. An adduct is formed when a Lewis base forms a dative covalent bond with a Lewis acid.

Borane, BH_3, and its analogues can act as Lewis acids.

(a) Boron trichloride, BCl_3, reacts with phosphine, PH_3, to form the adduct $PH_3 \bullet BCl_3$.

(i) Sketch and label the hybrid orbitals around boron in BCl_3.

[1]

(ii) Explain why BCl_3 can accept an electron pair to act as a Lewis acid.

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……[1]

(iii) By considering the number and types of electron pairs around the boron atom, deduce the Cl–B–Cl bond angles in BCl_3 and in $PH_3 \bullet BCl_3$.

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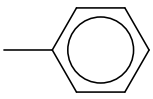
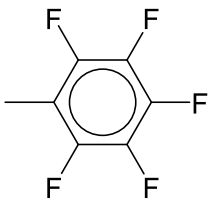
……[2]

(b) Unlike PH_3 and BCl_3, $P(C_6H_5)_3$ and $B(C_6F_5)_3$ cannot form a P–B dative covalent bond easily.

—C_6H_5 represents  and —C_6F_5 represents 

Suggest why.

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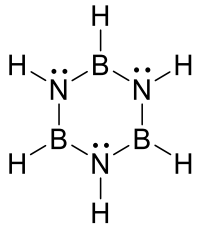
……[1]

For examiner's use

(c) Borazine is a planar molecule, and its structure is shown below.



borazine

Table 2.1 shows some boron–nitrogen bond lengths.

Table 2.1

bond	bond length / nm
B–N single bond	0.158
B=N double bond	0.141

It is found that each boron–nitrogen bond length in borazine is 0.144 nm. With reference to the structure, explain why the boron–nitrogen bond lengths in borazine are identical and intermediate between that of B–N and B=N.

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……..……..[2]

(d) Another compound containing boron and nitrogen is boron nitride, BN. BN has a structure similar to graphite.

With reference to structure and bonding, explain why BN has a higher boiling point than borazine.

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……..……..[2]

[Total: 9]

For examiner's use

3 Table 3.1 shows some properties of the fuels, methane and methanol.

Table 3.1

fuel	boiling point / ^{o}C	energy released per gram of fuel combusted / kJ g^{-1}
methane	–161	55.5
methanol	64.7	22.7

(a) Using the information from Table 3.1, suggest one advantage and one disadvantage of using methanol as a fuel compared to methane.

advantage: ……..……..……..……..

……..…….

disadvantage: ……..……..

…….....[2]

Gaseous methanol is synthesised industrially as shown in equation 1.

equation 1 $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

(b) Table 3.2 shows the equilibrium constant, K_p, for the methanol synthesis at different temperatures.

Table 3.2

temperature / K	K_p / Pa^{-2}
373	1.78×10^{-9}
500	6.61×10^{-13}
700	6.31×10^{-16}
1000	2.83×10^{-18}

(i) Using the K_p value at 1000 K from Table 3.2, suggest the sign and magnitude for $\Delta G_{eqn1}^{\ominus}$ at 1000 K. Explain your answer.

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…….....[2]

For examiner's use

(ii) Deduce whether the forward reaction of methanol synthesis is endothermic or exothermic.

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……[2]

(c) To produce gaseous methanol, a mixture of CO and H_2 in a 1:2 molar ratio was introduced into a 1.0 m^3 sealed vessel at 373 K. At equilibrium, it was found that the mole fraction of CH_3OH was 0.4.

(i) Write an expression for the equilibrium constant, K_p, for the reaction.

[1]

(ii) Using information from Table 3.2, show that the total equilibrium pressure at 373 K is 8.38×10^4 Pa.

[1]

(iii) Hence, calculate the equilibrium amount of CH_3OH formed at 373 K.

[2]

For examiner's use

(iv) At time t_1, a small amount of $CH_3OH(g)$ was removed from this vessel at constant volume and temperature. The system re-established equilibrium at t_2.

Complete Fig. 3.1, showing clearly how the partial pressures of CH_3OH and CO vary with time. Explain your answer.

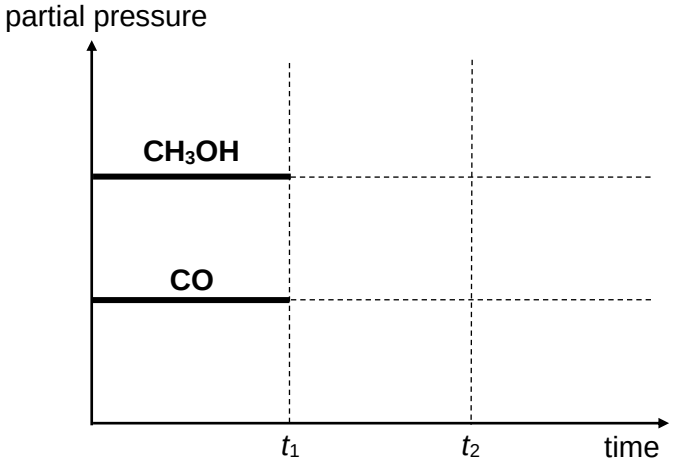

Fig. 3.1

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…….....[2]

[Total: 12]

RAFFLES INSTITUTION
2021 YEAR 5 PROMOTION EXAMINATION

Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

CHEMISTRY 9729

28 September 2021

Section		Marks
A		**/ 15**
B	**B1**	**/ 14**
	B2	**/ 9**
	B3	**/ 12**
C	**C1**	**/ 12**
	C2	**/ 13**
Total		**/ 75**
Percentage		**/ 100**
Penalty		
Overall		**/ 100**
Grade		

[Turn Over

Section C (25 marks)

This section consists of **2** questions.

Answer **all** the questions in this section in the spaces provided.

For examiner's use

1 For contact lens users who are allergic to preservatives present in multipurpose solutions, hydrogen peroxide is an alternative cleaning and disinfecting solution. However, hydrogen peroxide leaves a burning sensation upon contact with the eyes and hence the residual hydrogen peroxide must be removed before the lenses are worn.

While disinfecting the lenses, removal of hydrogen peroxide can occur concurrently when storage cases have a platinum disc built in. The platinum disc catalyses the decomposition of hydrogen peroxide into water and oxygen.

$$2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g) \qquad \Delta H = -196.1 \text{ kJ mol}^{-1}$$

(a) (i) With the aid of a Boltzmann distribution curve, explain how platinum speeds up the rate of hydrogen peroxide decomposition.

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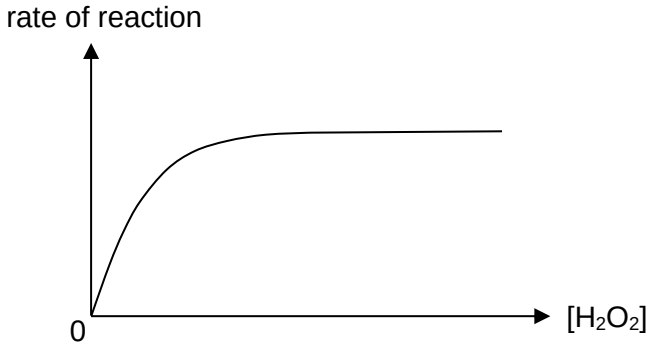
……[3]

For examiner's use

(ii) To study the rate of decomposition of H_2O_2 in the presence of platinum, aqueous H_2O_2 of different concentrations was separately added to the lens container with the platinum disc. The following graph was obtained.



Account for the shape of the graph.

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……[2]

(b) The decomposition of hydrogen peroxide is also catalysed by iodide ions, I^-, and the rate equation is given below.

$$\text{rate} = k[H_2O_2][I^-]$$

(i) Suggest which mechanism, A or B, fits the rate equation. Explain your answer.

A: $H_2O_2(aq) + I^-(aq) \longrightarrow H_2O(l) + IO^-(aq)$ (slow)
$IO^-(aq) + H_2O_2(aq) \longrightarrow H_2O(l) + O_2(g) + I^-(aq)$ (fast)

B: $2H_2O_2(aq) + I^-(aq) \longrightarrow 2H_2O(l) + IO_2^-(aq)$ (slow)
$IO_2^-(aq) \longrightarrow O_2(g) + I^-(aq)$ (fast)

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……[2]

For examiner's use

To study the effect of I^- catalyst on the rate of decomposition of H_2O_2, a student prepared a solution containing 3.00 mol dm^{-3} of H_2O_2 and 0.80 mol dm^{-3} of I^-.

Fig. 1.1 shows how [H_2O_2] varies with time.

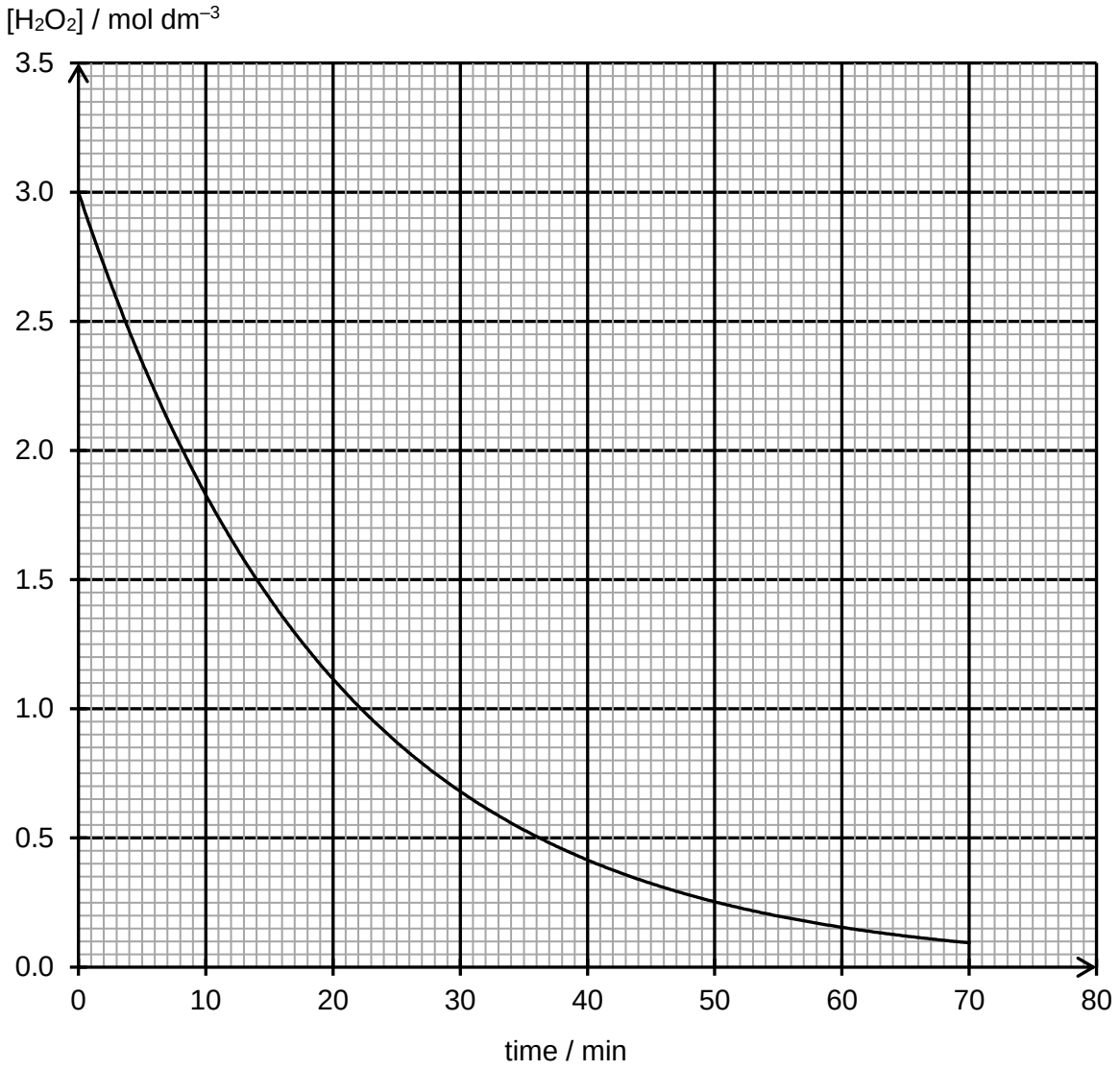


Fig. 1.1

For examiner's use

(ii) Using Fig. 1.1, show that the reaction is first-order with respect to H_2O_2.

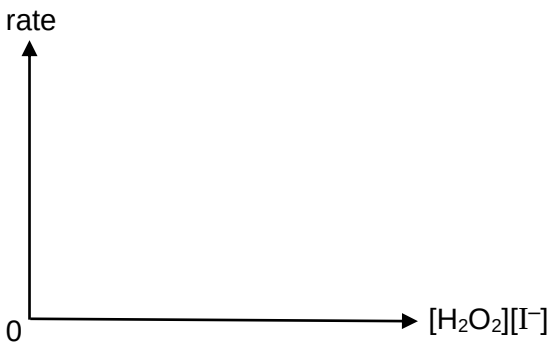
Hence, calculate the rate constant, *k*, and state its units.

[3]

(iii) The student prepared another solution containing 1.50 mol dm^{-3} of H_2O_2 and 0.40 mol dm^{-3} of I^-.

On Fig. 1.1, sketch how the $[H_2O_2]$ varies with time. [1]

(iv) Sketch the graph of rate against $[H_2O_2][I^-]$.

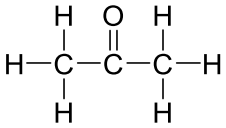


[1]

[Total: 12]

For examiner's use

2 **(a)** Propanone, CH_3COCH_3, is a colourless, highly volatile liquid with a boiling point of 329 K. It is miscible with water and serves as a solvent in organic reactions.



propanone

(i) Using relevant data from the *Data Booklet* and the following data, draw an appropriate energy cycle to calculate the enthalpy change of atomisation of $CH_3COCH_3(l)$.

enthalpy change of formation of $CH_3COCH_3(l)$ = –248 kJ mol^{-1}
enthalpy change of atomisation of C(s) = +715 kJ mol^{-1}

[3]

For examiner's use

(ii) Using relevant data from the *Data Booklet* and your answer in **(a)(i)**, calculate the enthalpy change of vaporisation of $CH_3COCH_3(l)$.

[2]

(iii) Write an equation, with state symbols, which represents $\Delta H_{combustion}^{\ominus}(CH_3COCH_3(l))$.

……..[1]

(iv) Using the data below, calculate the $\Delta G^{\ominus}$ at 298 K for the combustion of $CH_3COCH_3(l)$.

standard entropy change of combustion of $CH_3COCH_3(l)$ = -168 J mol^{-1} K^{-1}
standard enthalpy change of combustion of $CH_3COCH_3(l)$ = -219 kJ mol^{-1}

[1]

(v) Although the $\Delta G^{\ominus}$ for the combustion of $CH_3COCH_3(l)$ is exergonic at room temperature, CH_3COCH_3 will not spontaneously combust when it comes into contact with oxygen gas. Suggest why CH_3COCH_3 combusts only when it is ignited with a spark.

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……[1]

For examiner's use

(vi) Suggest a reason why the entropy change of the combustion reaction is a positive value at 400 K.

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……[1]

(b) The reaction between sodium chlorate(I), NaC*l*O, and sodium thiosulfate, $Na_2S_2O_3$, in an alkaline medium is an exothermic reaction.

$$4NaClO(aq) + Na_2S_2O_3(aq) + 2NaOH(aq) \xrightarrow{\Delta H_1} 4NaCl(aq) + 2Na_2SO_4(aq) + H_2O(l)$$

To find the enthalpy change of reaction, ΔH_1, a student performed a series of experiments by mixing different volumes of NaC*l*O(aq) and 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) in aqueous sodium hydroxide. For each experiment, the total volume of solution was kept constant at **40.0 cm³**. The temperature change, ΔT, for each experiment was determined and a graph of ΔT against the volume of NaC*l*O was plotted as shown in Fig. 2.1.

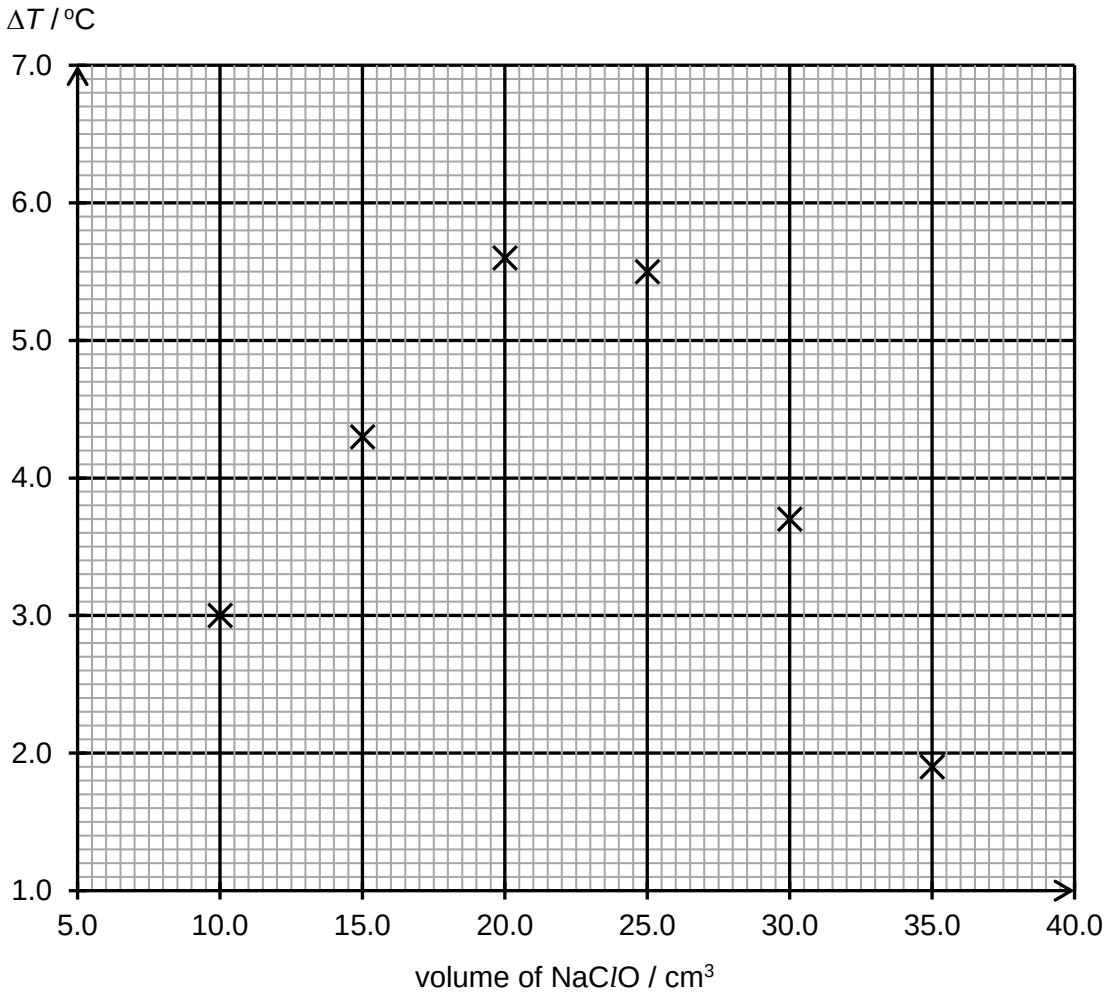

Fig. 2.1

For examiner's use

(i) Draw two best-fit straight lines for the points plotted in Fig. 2.1.

Extrapolate both lines to determine the maximum temperature change, ΔT_{max}, and the volume of NaC*l*O required for complete reaction.

ΔT_{max} = ……

volume of NaC*l*O required for complete reaction = …… [1]

(ii) Using your answers in **(b)(i)**, calculate ΔH_1.

You should assume that the specific heat capacity and density of all solutions are 4.18 J g^{-1} K^{-1} and 1.00 g cm^{-3} respectively.

[3]

[Total: 13]

– END OF PAPER –