Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Tuesday 21 May 2024

Morning (Time: 1 hour 30 minutes)

Paper reference **8CH0/02**

Chemistry

Advanced Subsidiary

PAPER 2: Core Organic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over

P 7 6 8 9 4 A 0 1 3 2

Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The relative molecular mass of a solid dicarboxylic acid, $HOOC(CH_2)_nCOOH$, can be found using a titration. The acid, which can be represented as H_2A, was dissolved in deionised water and the solution made up to 250 cm^3.

(a) Which piece of apparatus should be used for making a solution with a volume of exactly 250 cm^3?

(1)

☒ **A** burette

☒ **B** measuring cylinder

☒ **C** pipette

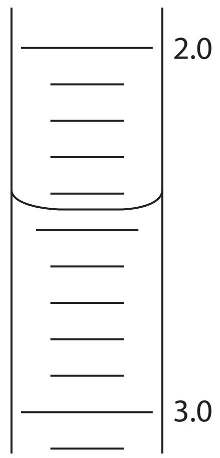
☒ **D** volumetric flask

(b) A solution of 0.100 mol dm^{-3} sodium hydroxide solution was added to a burette. A rough titration was carried out on a 25.0 cm^3 portion of the acid solution.

(i) The diagram shows the burette before the rough titration.

What is the initial burette reading for this titration?

(1)



☒ **A** 2.40 cm^3

☒ **B** 2.45 cm^3

☒ **C** 3.55 cm^3

☒ **D** 3.60 cm^3

(ii) The final burette reading for the rough titration was 26.50 cm^3.

Calculate the volume of sodium hydroxide solution added in the rough titration, using your answer to (b)(i).

(1)

(iii) Describe how you would use the rough titration value when carrying out the accurate titrations.

(1)

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(c) 25.0 cm^3 portions of the acid solution were titrated with 0.100 mol dm^{-3} sodium hydroxide solution.

The equation for the reaction is shown.

$$H_2A(aq) + 2NaOH(aq) \rightarrow Na_2A(aq) + 2H_2O(l)$$

The acid solution was pipetted into a conical flask and titrated.
The accurate titrations were carried out three times.

The following results were recorded for the accurate titrations.

Titration number	1	2	3
Burette reading (final) / cm^3	47.80	24.35	47.60
Burette reading (initial) / cm^3	24.50	1.00	24.35
Volume of NaOH used / cm^3	23.30	23.35	23.25

(i) Calculate the mean titre for these accurate titrations.

(1)

(ii) Calculate the number of moles of sodium hydroxide in the mean titre.

(1)

(iii) The mass of H_2A used to make up 250 cm^3 of solution in the experiment was 1.54 g.

Calculate the relative molecular mass of H_2A and therefore the value of n in $HOOC(CH_2)_nCOOH$.
You **must** show your working.

(3)

(Total for Question 1 = 9 marks)

2 This question is about chemical equilibria.

Potassium dichromate(VI), $K_2Cr_2O_7$, is an orange solid which dissolves in water. An equilibrium forms as shown.

$$\underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l) \rightleftharpoons \underset{\text{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq)$$

(a) (i) Explain the effect on the appearance of the solution of adding a small volume of sodium hydroxide solution to the equilibrium mixture.

(3)

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(ii) Which is the expression for the equilibrium constant, K_c, for this reaction?

(1)

☒ **A** $K_c = \dfrac{[CrO_4^{2-}]^2\,[H^+]^2}{[Cr_2O_7^{2-}]\,[H_2O]}$

☒ **B** $K_c = \dfrac{2[CrO_4^{2-}]\,2[H^+]}{[Cr_2O_7^{2-}]\,[H_2O]}$

☒ **C** $K_c = \dfrac{[CrO_4^{2-}]^2\,[H^+]^2}{[Cr_2O_7^{2-}]}$

☒ **D** $K_c = \dfrac{2[CrO_4^{2-}]\,2[H^+]}{[Cr_2O_7^{2-}]}$

(b) A gas syringe contains a mixture of the gases nitrogen dioxide (NO_2) and dinitrogen tetroxide (N_2O_4).
Its plunger is fixed at half the volume of the syringe.

The mixture is allowed to reach equilibrium at room temperature.

$$\underset{\text{brown}}{2NO_2(g)} \rightleftharpoons \underset{\text{colourless}}{N_2O_4(g)}$$

The plunger is then pulled out to the maximum volume, while the temperature is kept constant.
The mixture is left to stand until equilibrium is reached again.

(i) Justify all the colour changes of the contents of the syringe during this process.

(3)

(ii) The syringe is placed into hot water.
The contents of the syringe become a darker brown.

Explain what can be deduced about the reaction from this change.

(2)

(Total for Question 2 = 9 marks)

3 But-1-ene, but-2-ene and methylpropene are three isomeric alkenes.

Name	Structural formula
but-1-ene	$CH_3CH_2CH{=}CH_2$
but-2-ene	$CH_3CH{=}CHCH_3$
methylpropene	$(CH_3)_2C{=}CH_2$

(a) Give the molecular formula and empirical formula of but-1-ene.

(1)

Molecular formula

....

Empirical formula

....

(b) The major product of the reaction between methylpropene and hydrogen bromide is 2-bromo-2-methylpropane.

(i) What is the name and type of the mechanism of this reaction?

(1)

☒ **A** electrophilic addition

☒ **B** nucleophilic addition

☒ **C** electrophilic substitution

☒ **D** nucleophilic substitution

(ii) Draw the mechanism for the formation of 2-bromo-2-methylpropane. Include curly arrows, and any relevant charges, dipoles and lone pairs.

(4)

(iii) A minor organic product is also formed in this reaction.

Justify why this minor product is formed in smaller amounts. Include the structure of the minor organic product.

(3)

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(iv) State what a curly arrow represents in your diagram of the mechanism in (b)(ii).

(1)

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(c) But-2-ene exists as two stereoisomers.

(i) Give the displayed formula and name of each of these isomers.

(2)

Isomer 1 | Isomer 2

Name .... Name ....

(ii) Explain how the presence of the double bond in but-2-ene results in these two isomers.

(2)

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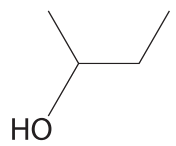
(d) One of the three alkenes can be hydrated to form a **tertiary** alcohol.

Name	Structural formula
but-1-ene	$CH_3CH_2CH{=}CH_2$
but-2-ene	$CH_3CH{=}CHCH_3$
methylpropene	$(CH_3)_2C{=}CH_2$

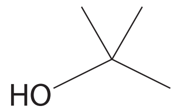
(i) Which is the skeletal structure of this alcohol?

(1)

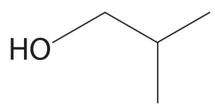
☒ **A**



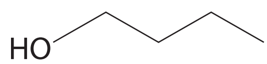
☒ **B**



☒ **C**



☒ **D**



(ii) Explain why tertiary alcohols resist oxidation, but primary or secondary alcohols are readily oxidised.

(2)

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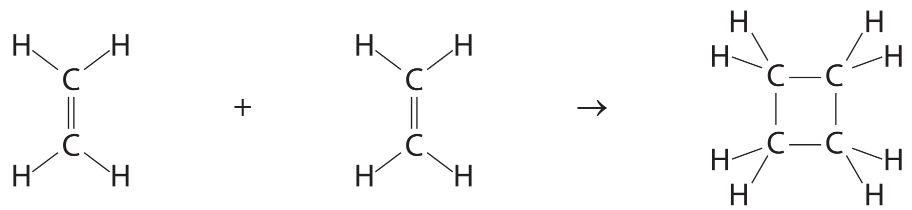
(Total for Question 3 = 17 marks)

4 This question is about the formation of cyclobutane, a gas at 298 K.

(a) Cyclobutane can be made by the dimerisation of ethene.



(i) Some mean bond enthalpy values are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—H	413
C—C	347
C═C	612

Calculate the enthalpy change of this dimerisation by selecting appropriate data from the table.

(3)

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(ii) A different value for the enthalpy change of the reaction can be calculated using bond enthalpies instead of mean bond enthalpies.
This value is more accurate.

Explain why the use of bond enthalpies gives a more accurate enthalpy change value.

(2)

(b) The enthalpy change of formation of cyclobutane can be calculated using the enthalpy change data in the table.

Enthalpy change	Value / kJ mol^{-1}
Enthalpy change of combustion of cyclobutane	–2721
Enthalpy change of formation of carbon dioxide	–394
Enthalpy change of formation of water	–286

(i) Complete the enthalpy cycle using Hess's Law.
Include reactants, products, state symbols and arrows in your cycle.

(4)

.... + ... $\xrightarrow{\Delta_f H}$ $C_4H_8(g)$

....

.... + ...

(ii) Calculate the enthalpy change of formation of cyclobutane.

(2)

(Total for Question 4 = 11 marks)

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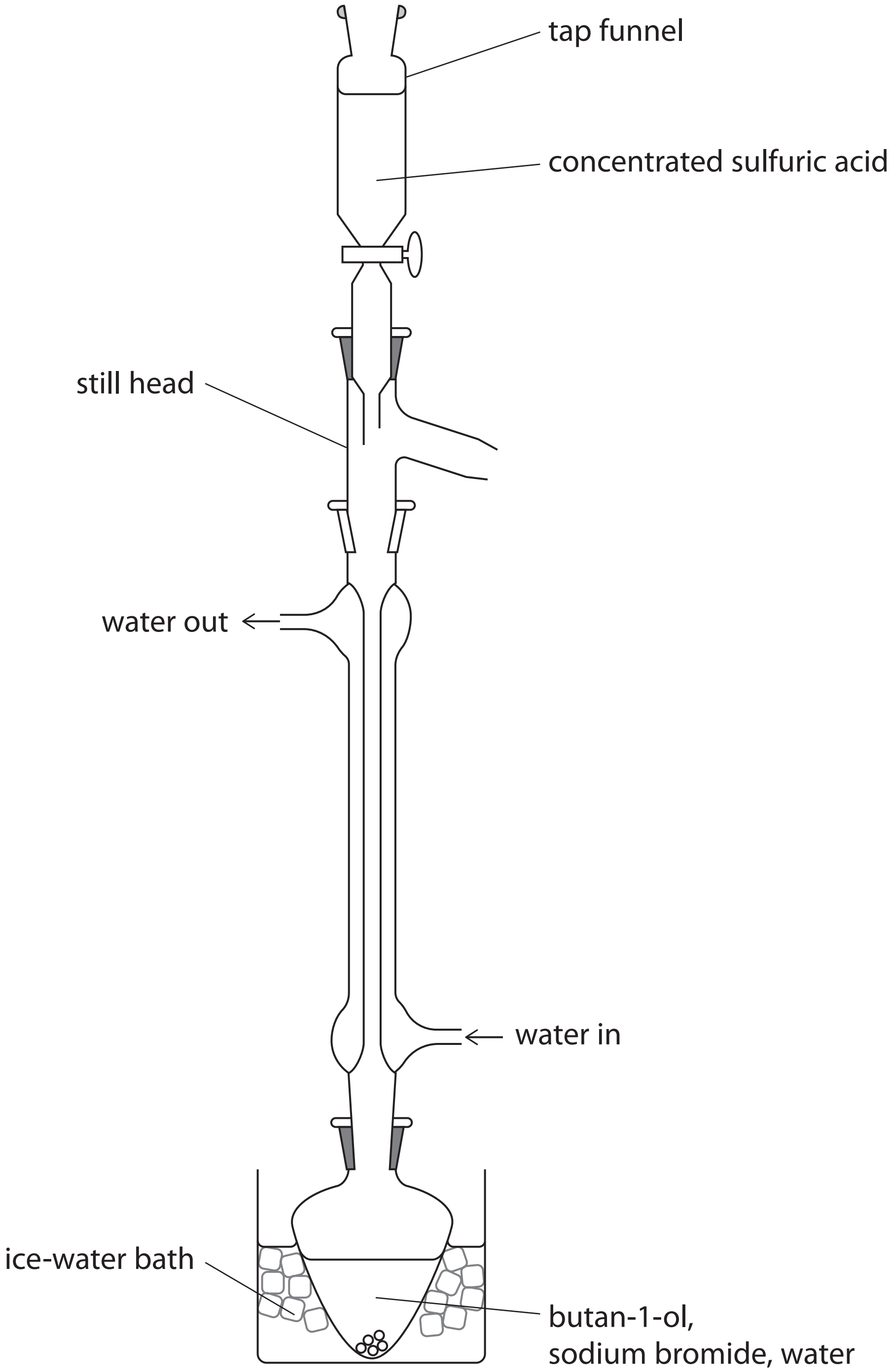
5 The apparatus shown can be used for the conversion of butan-1-ol to 1-bromobutane.



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Procedure

Step **1** In a fume cupboard, 10 g of sodium bromide, 10 cm^3 of deionised water and 7.5 cm^3 of butan-1-ol are placed in a pear-shaped flask containing some anti-bumping granules in the apparatus shown.

Step **2** 10 cm^3 of concentrated sulfuric acid is dripped slowly from a tap funnel into the reaction mixture in the pear-shaped flask.

Step **3** The tap funnel and still head are removed from the top of the condenser. The flask and condenser are taken out of the ice-water bath. The flask is heated for about 45 minutes.

Step **4** The apparatus is then rearranged for distillation and the distillate of 1-bromobutane and water is collected in a small beaker, forming two layers.

Step **5** The aqueous layer is separated from the 1-bromobutane layer.

Step **6** The 1-bromobutane layer is washed with concentrated hydrochloric acid to remove any unreacted butan-1-ol, and then separated.

Step **7** The 1-bromobutane is then washed with dilute sodium carbonate solution and then separated.

Step **8** A drying agent is added to the 1-bromobutane.

Step **9** The 1-bromobutane is separated from the drying agent. The 1-bromobutane is distilled again and collected between 101 °C and 103 °C.

(a) In Steps **1** and **2** of the procedure, an ice-water bath and a condenser are used. The ice helps to prevent side reactions. Redox reactions are one possible type of reaction which may result in the formation of unwanted organic and inorganic products.

(i) Give **one** reason for the presence of the condenser and **one** reason for the still head in Steps **1** and **2**.

(2)

Condenser

....

....

Still head

....

....

(ii) Give the name or formula of the oxidising agent responsible for the unwanted redox reactions.

(1)

....

(iii) Identify, by name or formula, **one** of the unwanted inorganic products and **one** of the organic products resulting from these **redox** reactions.

(2)

Inorganic product

....

Organic product

....

(iv) Give a reason why ice helps to prevent the formation of these redox products.

(1)

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(b) Describe how the apparatus is rearranged for distillation, including the name of any additional apparatus required.

(3)

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(c) The method of separation of the aqueous and organic layers in Step **5** is different from that used in Steps **6** and **7**.

(i) Draw a labelled diagram of the beaker immediately before the separation in Step **5**.

[Density of water = 1.00 g cm^{-3}
Density of 1-bromobutane = 1.28 g cm^{-3}]

(1)

(ii) Describe how the aqueous layer can be removed from the beaker in Step **5**.

(1)

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....

(iii) Name the piece of apparatus used to separate the organic layer in Steps **6** and **7**.

(1)

....

(Total for Question 5 = 12 marks)

6 Sodium thiosulfate solution reacts with aqueous hydrochloric acid as shown.

$$Na_2S_2O_3 + 2HCl \rightarrow S + SO_2 + H_2O + 2NaCl$$

During the reaction the mixture becomes cloudy.

A student carried out an investigation to determine the effect of the concentration of sodium thiosulfate on the rate of the reaction.

Procedure

Step **1** Place 10 cm^3 of a solution of sodium thiosulfate and 40 cm^3 of deionised water in a clean 200 cm^3 conical flask.

Step **2** Place the flask on a piece of paper with a black cross marked on it.

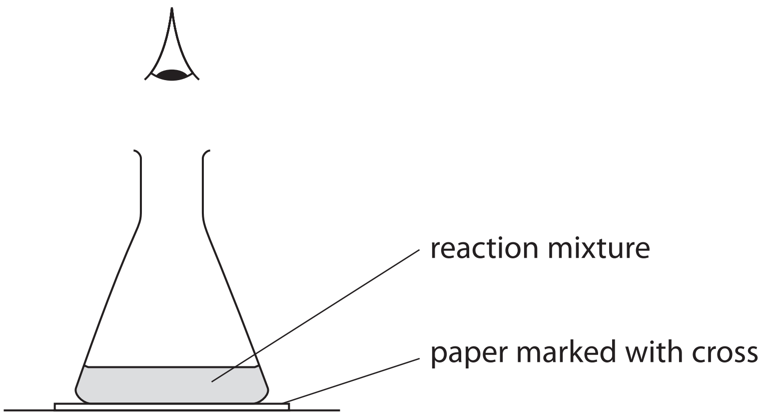
Step **3** Add 20 cm^3 of hydrochloric acid (an excess) to the flask, swirl the solution and start a timer.

Step **4** Look down through the solution at the black cross and record the time taken for the cross to no longer be visible through the solution.

Step **5** Calculate 1/time to find the average rate of reaction.

Step **6** Change the concentration of sodium thiosulfate by repeating Steps **1**–**5** using different volumes of the sodium thiosulfate solution and deionised water.

Apparatus



(a) State why the reaction mixture becomes cloudy.

(1)

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....

(b) A student carried out the investigation using five different concentrations of sodium thiosulfate solution.

Experiment	1	2	3	4	5
Volume of $Na_2S_2O_3$ solution added in Step **1** / cm^3	10	20	30	40	50
Volume of water added in Step **1** / cm^3	40	30	20	10	0
Volume of hydrochloric acid added in Step **3** / cm^3	20	20	20	20	20
Concentration of $Na_2S_2O_3$ immediately after adding the acid in Step **3** / $mol\,dm^{-3}$	0.03	0.06	0.09	0.12	0.15

(i) What was the concentration, in $mol\,dm^{-3}$, of the original solution of sodium thiosulfate?

(1)

☒ **A** 0.03

☒ **B** 0.15

☒ **C** 0.21

☒ **D** 0.71

(ii) State why water is added in Experiments 1 to 4, but not in Experiment 5.

(1)

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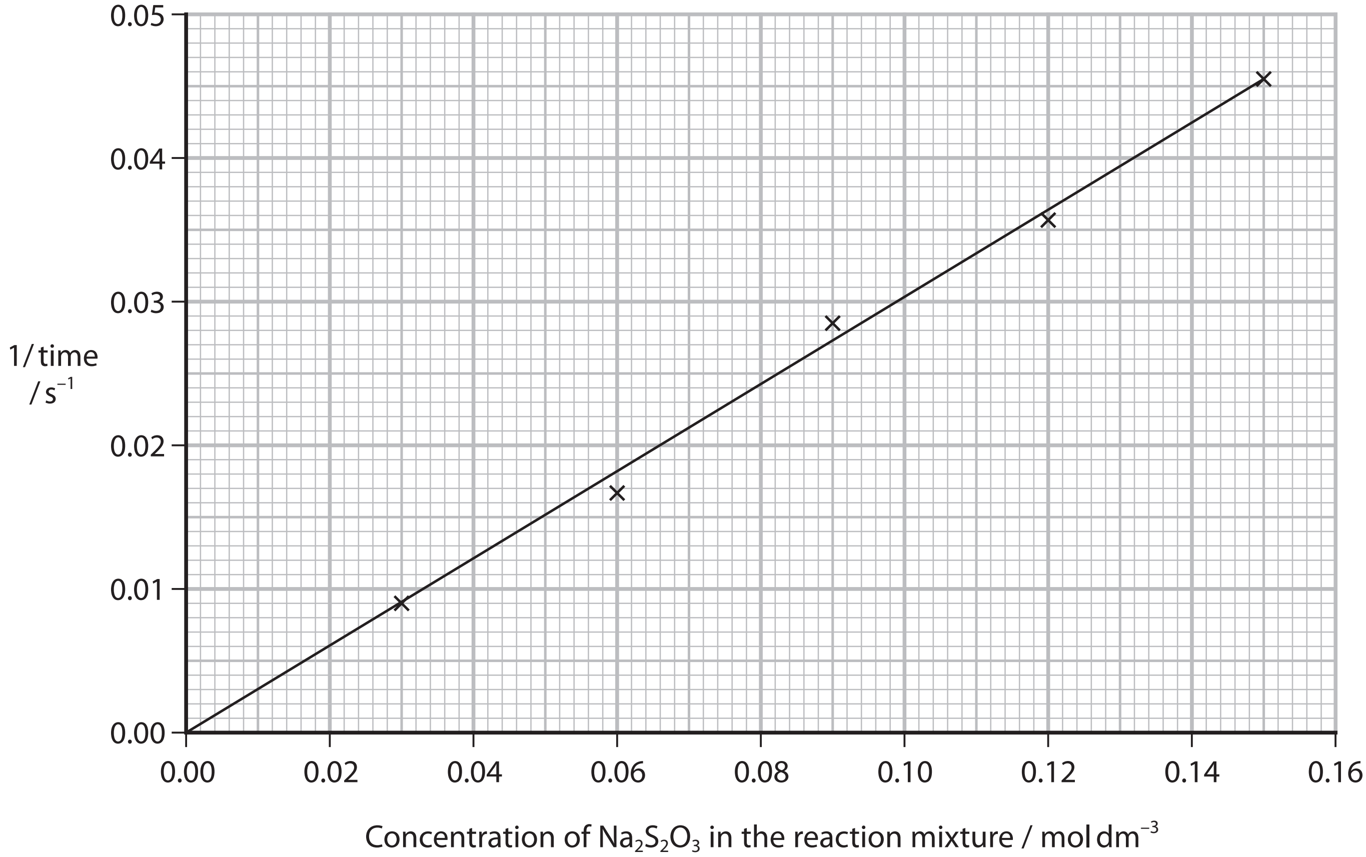
(c) The student plotted a graph of 1/time against concentration of sodium thiosulfate.



(i) Calculate, using the graph, the **time taken** for the cross to be obscured using a concentration of sodium thiosulfate of 0.10 mol dm^{-3}.

(1)

(ii) State and justify the relationship between the rate of reaction and the concentration of sodium thiosulfate as shown by the graph.

(1)

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(d) Which will **decrease** the accuracy of the experiment?

(1)

☒ **A** rinsing the flask with deionised water before each new experiment

☒ **B** stirring the solution throughout each experiment

☒ **C** using a different 50 cm^3 measuring cylinder for each solution

☒ **D** using the same piece of paper in each experiment

(e) Experiment 1 is repeated at the same temperature, but using a 100 cm^3 conical flask in place of the 200 cm^3 flask.

Which statement is correct about the repeated experiment?

(1)

☒ **A** it is not possible to predict how the time taken will be affected

☒ **B** the time taken will decrease using the 100 cm^3 flask

☒ **C** the time taken will increase using the 100 cm^3 flask

☒ **D** the time taken will be the same using the 100 cm^3 flask

(Total for Question 6 = 7 marks)

***7** Methanol can be produced by reacting carbon dioxide and hydrogen in the exothermic reaction shown.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Discuss, with reasons, the effects of changing the conditions on the yield of methanol and the rate of reaction.

- increasing temperature at constant pressure
- increasing pressure at constant temperature

(6)

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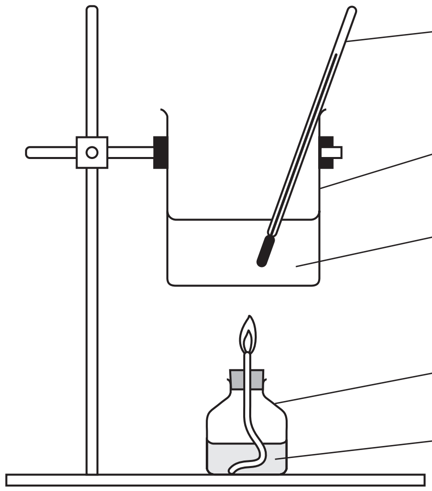
(Total for Question 7 = 6 marks)

8 A student carried out an experiment to determine the enthalpy change of combustion of methanol.

Diagram



Student's results

Measurement	Value
Mass of spirit burner and methanol before combustion	152.2 g
Mass of spirit burner and methanol after combustion	150.2 g
Mass of water in the beaker	200.0 g
Temperature of water before heating	20.5 °C
Temperature of water after heating	52.5 °C

Data

The enthalpy change of combustion of methanol, $\Delta_c H = -726\ \text{kJ mol}^{-1}$

The specific heat capacity of water, $c = 4.18\ \text{J g}^{-1}\ °\text{C}^{-1}$

Molar mass of methanol = $32.0\ \text{g mol}^{-1}$

(a) (i) Write the equation to represent the enthalpy change of combustion of methanol. Include state symbols.

(2)

(ii) Calculate the expected **final temperature** of the water in the student's experiment, assuming no experimental errors.

(4)

(iii) Calculate the percentage error in the experimental temperature **rise** compared to the theoretical temperature **rise** from your calculation.

(1)

(b) Instead of waiting in a queue for a balance which recorded the mass of the spirit burner to 2 decimal places, the student used a balance which recorded the mass to 1 decimal place.

Explain whether or not the student would have been better to wait for the balance with greater precision to give a final answer with greater accuracy.

(2)

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(Total for Question 8 = 9 marks)

TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1.0 **H** hydrogen 1

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
																	4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

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