OCR
Oxford Cambridge and RSA

Friday 20 June 2025 – Morning

A Level Chemistry A

H432/03 Unified chemistry

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry A

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

ADVICE
- Read each question carefully before you start your answer.

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1 This question is about spectra.

(a) The mass spectrum for Br_2 has peaks at *m*/*z* values of 79, 81, 158, 160 and 162.
The peaks at *m*/*z* 79 and 81 have virtually the same relative abundance.

(i) Complete the table to show the number of protons, neutrons and electrons in the particles that cause the peaks at *m*/*z* 79 and 81.

m*/*z	**Number of protons**	**Number of neutrons**	**Number of electrons**
79			
81			

[2]

(ii) Explain why there are peaks with *m*/*z* values of 158, 160 and 162 and predict their relative abundances.

Explanation .....

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Relative abundances .....

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[3]

(b) This question looks at proton NMR spectra of dibromoalkanes.

Predict the following.

Compound	**Number of peaks**	**CH_2 splitting pattern(s)**
$BrCH_2CH_2Br$		
$BrCH_2CH_2CH_2Br$		

[3]

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2 This question is about different compounds that each contain O and H atoms covalently bonded together.

(a) The alcohol 2,3-dimethylhexan-1-ol has the molecular formula $C_8H_{18}O$.

(i) Draw the skeletal formula of 2,3-dimethylhexan-1-ol.

[1]

(ii) What is the number of H atoms in 8.45 g of 2,3-dimethylhexan-1-ol?

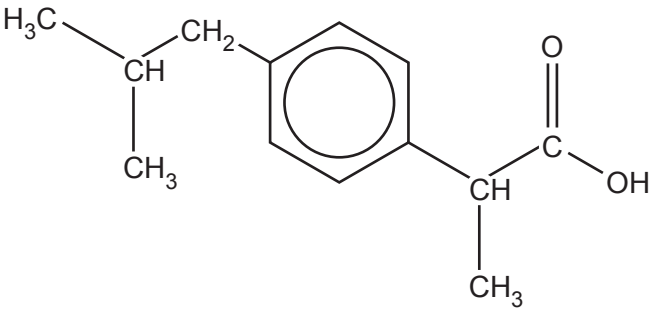
Give your answer to **3** significant figures and in standard form.

Number of H atoms = ... **[3]**

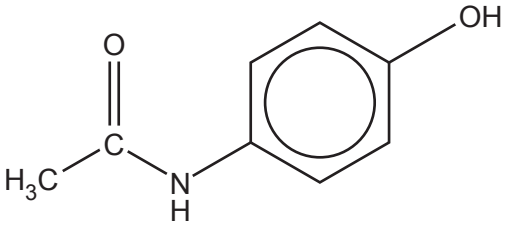
(b) Nuromol tablets are used to relieve pain.

Nuromol tablets contain a mixture of ibuprofen and paracetamol.

The structures of ibuprofen and paracetamol are shown.



Ibuprofen



Paracetamol

A student carries out an investigation to determine the mass of ibuprofen and the mass of paracetomol in one nuromol tablet.

- Ibuprofen reacts with aqueous sodium carbonate, $Na_2CO_3(aq)$, to produce a gas.

  $2RCOOH + Na_2CO_3 \rightarrow 2RCOONa + CO_2 + H_2O$

- Paracetamol does **not** react with $Na_2CO_3(aq)$.

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(i) Why does paracetamol **not** react with $Na_2CO_3(aq)$?

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..... **[1]**

(ii) The student uses the reaction of nuromol tablets with $Na_2CO_3(aq)$ to determine the mass of ibuprofen and the mass of paracetomol in one nuromol tablet.

The student's method is outlined below.

- Weigh **four** nuromol tablets.
- Add the tablets to an excess of aqueous sodium carbonate.
- Collect the gas produced and measure its volume.

Results
Mass of four nuromol tablets = 2.80 g
Volume of gas collected at RTP = 48.0 cm^3

Assume that ibuprofen is the only compound in nuromol tablets that reacts with $Na_2CO_3(aq)$.

Determine the mass of ibuprofen and the mass of paracetomol, in mg, in **one** nuromol tablet.

Mass of ibuprofen = ... mg

Mass of paracetamol = ... mg
[4]

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(c) Barium hydroxide, $Ba(OH)_2$, is an alkali.
A student is supplied with a solution of $Ba(OH)_2$ with a concentration of 46.80 g dm^{-3} at 25 °C.

The student dilutes 20.0 cm^3 of this solution of $Ba(OH)_2$ with water and the solution is made up to 100.0 cm^3 at 25 °C.

Calculate the pH of the diluted solution of $Ba(OH)_2$ at 25 °C.

Give your answer to **2** decimal places.

pH = ... **[5]**

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3 This question is about equilibrium and rates.

(a) Methanol, CH_3OH, can be made industrially by the reaction of carbon monoxide, CO, with hydrogen, H_2, in the presence of a catalyst. This is a reversible reaction.

The equilibrium below is set up.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\,kJ\,mol^{-1}$$

The concentrations of CO(g) and $CH_3OH(g)$ in the equilibrium mixture are shown in the table below.

	CO(g)	**$CH_3OH(g)$**
equilibrium concentration / mol dm^{-3}	0.27	0.11

The value of the equilibrium constant, K_c, for this reaction is $1.8\,dm^6\,mol^{-2}$.

- Explain the conditions of pressure and temperature that would give the maximum equilibrium yield of $CH_3OH(g)$.
- Calculate the concentration of $H_2(g)$ in the equilibrium mixture to an **appropriate** number of significant figures.

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..... **[5]**

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(b)* A reaction takes place when aqueous solutions of propanone, $CH_3COCH_3(aq)$, and bromine, $Br_2(aq)$, are mixed in the presence of dilute acid, $H^+(aq)$.

The overall equation for this reaction is shown below.

$CH_3COCH_3 + Br_2 \rightarrow CH_3COCH_2Br + HBr$ **Reaction 3.1**

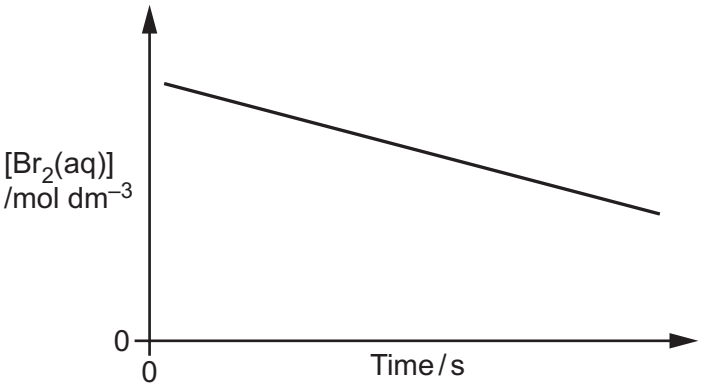
- A student carries out three experiments to investigate the rate of this reaction.
- In each experiment, the student investigates the effect of changing the concentration of one of the three chemicals whilst keeping the concentrations of the other chemicals constant.

The student's results are shown below.

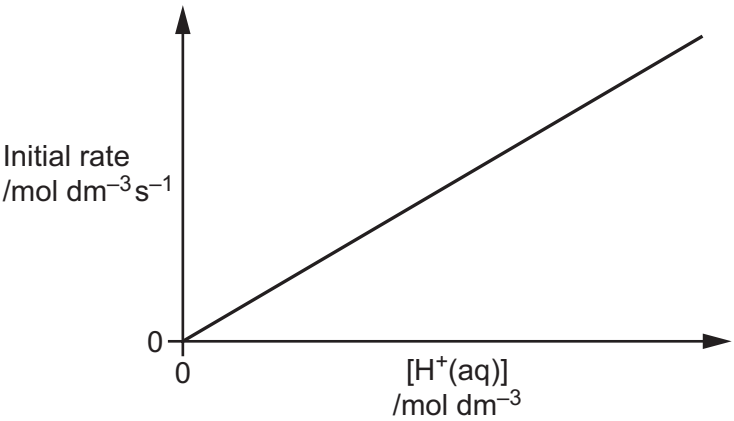
Experiment 1
Only $[CH_3COCH_3(aq)]$ is varied.

Initial concentrations			**Initial rate / mol dm^{-3} s^{-1}**
$CH_3COCH_3(aq)$ / mol dm^{-3}	**$Br_2(aq)$ / mol dm^{-3}**	**$H^+(aq)$ / mol dm^{-3}**	
1.50×10^{-3}	2.00×10^{-1}	2.50×10^{-1}	1.70×10^{-7}
4.50×10^{-3}	2.00×10^{-1}	2.50×10^{-1}	5.10×10^{-7}

Experiment 2
Only $[Br_2(aq)]$ is varied.



Experiment 3
Only $[H^+(aq)]$ varied.



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Use the student's results to determine the order with respect to each of the three chemicals, the rate equation and rate constant for **Reaction 3.1**. Explain your reasoning.

Explain how the student's results can be used to show that the mechanism of **Reaction 3.1** has more than one step.

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Extra answer space if required.

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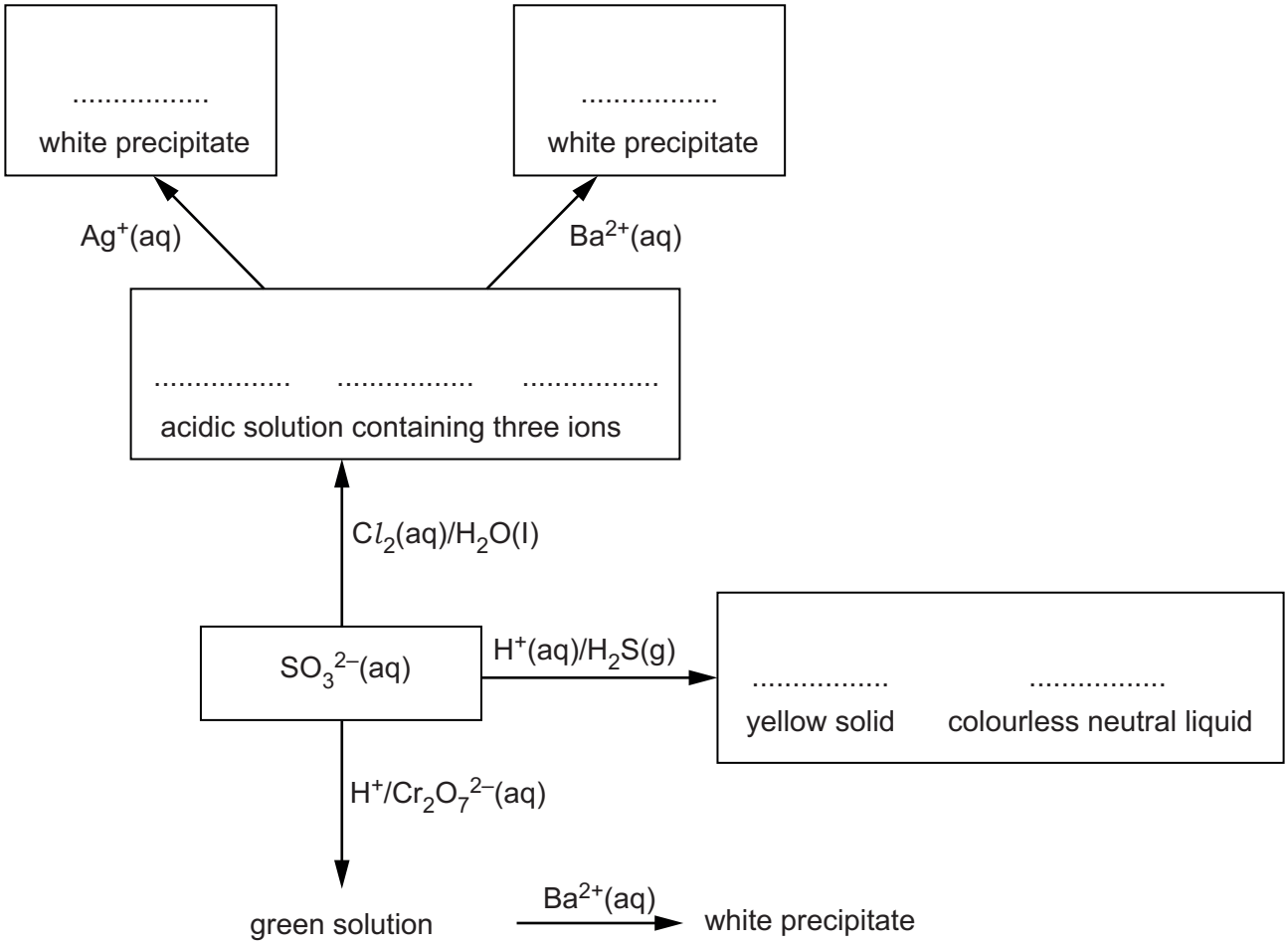
4 This question is about inorganic chemistry.

(a) The flowchart shows reactions involving SO_3^{2-}(aq) ions.

(i) What is the systematic name of a SO_3^{2-} ion?

..... **[1]**

(ii) Complete the flowchart by adding formulae in the boxes.



[7]

(iii) Construct an ionic equation for the reaction of SO_3^{2-} with $H^+/Cr_2O_7^{2-}$.

..... **[2]**

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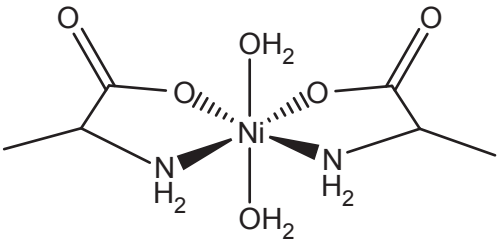
(b) The structure of a neutral nickel(II) complex, **A**, is shown below.



Complex A

(i) What is the empirical formula of complex **A**?

..... **[1]**

(ii) Complex **A** can be prepared by reacting an aqueous solution of nickel(II) sulfate with amino acid **B** and potassium hydroxide.

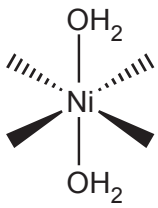
Aqueous nickel(II) sulfate contains the octahedral hexaaquo complex ion **C**.

Draw the structure of amino acid **B** and the 3D structure, including the overall charge, of complex ion **C**.

Amino acid B	**Complex ion C**

[3]

(iii) Complete the 3D diagram below to show a stereoisomer of complex **A**.



[1]

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5 This question is about two metal hydrides, lithium aluminium hydride, $LiAlH_4$, and sodium borohydride, $NaBH_4$. Both hydrides are used as reducing agents in organic chemistry.

(a) $LiAlH_4$, is a stronger reducing agent than $NaBH_4$, and can reduce esters to alcohols.

A student plans to use $LiAlH_4$ to reduce the liquid ester, ethyl phenylmethanoate, $C_6H_5COOC_2H_5$ (density = 1.05 g cm^{-3}) to the alcohol, $C_6H_5CH_2OH$ (M_r = 108).

The student uses $C_6H_5COOC_2H_5$ and $LiAlH_4$ (an excess) in a 1.0 : 2.5 molar ratio.

The student's method is outlined below.

Step 1 7.50 cm^3 of $C_6H_5COOC_2H_5$ is dissolved in an organic solvent.

Step 2 $LiAlH_4$ is added to the solution from **Step 1**. The reduction takes place.

Step 3 The mixture from **Step 2** is heated with dilute aqueous acid.

Step 4 The impure $C_6H_5CH_2OH$ is purified.

The student carries out this preparation and obtains 4.40 g of pure $C_6H_5CH_2OH$.

(i) What is the systematic name of the alcohol $C_6H_5CH_2OH$?

..... **[1]**

(ii) Calculate the mass of $LiAlH_4$ that the student should use in **Step 2** and the percentage yield of pure $C_6H_5CH_2OH$ obtained in **Step 4**.

Give the mass of $LiAlH_4$ and the percentage yield of pure $C_6H_5CH_2OH$ to **3** significant figures.

Mass of $LiAlH_4$ = ... g

Percentage yield of pure $C_6H_5CH_2OH$ = ...%

[4]

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(iii) In the preparation, $LiAlH_4$ behaves as a nucleophile.

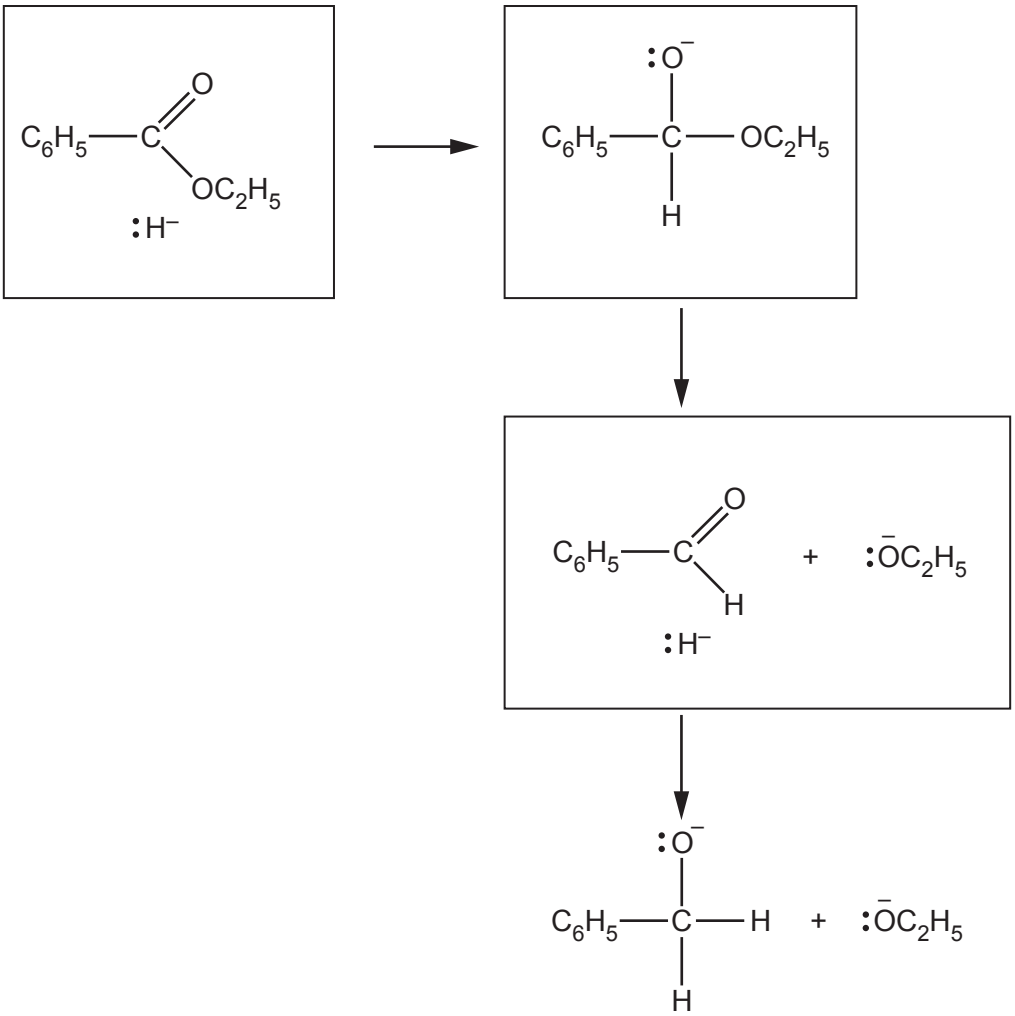
What is meant by the term **nucleophile**?

.....

..... **[1]**

(iv) The mechanism for **Step 2** in the reduction of $C_6H_5COOC_2H_5$ is shown below.
In the mechanism, $LiAlH_4$ can be represented as H^-.

Complete the mechanism by adding curly arrows to the three boxes.



[4]

(v) Suggest why the student heated the mixture from **Step 2** with dilute aqueous acid in **Step 3**.

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..... **[1]**

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(b) $NaBH_4$ contains Na^+ and BH_4^- ions.

Draw a 'dot-and-cross' diagram for $NaBH_4$.

Use a different symbol for the electrons from each element.

Show outer electrons only.

[2]

(c) $NaBH_4/O_2$ cells are being investigated as potential fuel cells.

- The positive electrode contains O_2.
- The negative electrode contains $NaBH_4$.

The reaction at the positive electrode and the overall cell reaction for a $NaBH_4/O_2$ fuel cell are shown below.

Reaction at positive electrode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ $E^{\ominus} = +0.40\,V$

Overall cell reaction: $NaBH_4 + 2O_2 \rightarrow NaBO_2 + 2H_2O$ $E^{\ominus}_{cell} = 1.64\,V$

(i) What is the standard electrode potential of the negative electrode in this cell?

Standard electrode potential = ... V **[1]**

(ii) Construct the equation for the reaction at the negative electrode of this cell.

..... **[2]**

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6* The enthalpy change of **Reaction 6.1**, ΔH_1, shown below, is difficult to measure directly by experiment.

$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$ ΔH_1 **Reaction 6.1**

The enthalpy changes of reaction for the reactions of Na_2CO_3 and $NaHCO_3$ with excess $HNO_3(aq)$ can be measured by experiment.

The reactions are shown below as **Reaction 6.2** and **Reaction 6.3**.

$Na_2CO_3(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$ ΔH_2 **Reaction 6.2**

$NaHCO_3(s) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l) + CO_2(g)$ ΔH_3 **Reaction 6.3**

A student reacts $Na_2CO_3(s)$ with $HNO_3(aq)$ to find ΔH_2 for **Reaction 6.2**.

Student's method

Weigh a bottle containing $Na_2CO_3(s)$ and weigh a polystyrene cup.
Add about 30 cm^3 of 1.00 mol dm^{-3} $HNO_3(aq)$ to the polystyrene cup and measure its temperature.
Add the $Na_2CO_3(s)$, stir the mixture, and measure the maximum temperature reached.
Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

Mass of bottle + $Na_2CO_3(s)$ / g	3.26
Mass of empty bottle / g	1.29
Mass of polystyrene cup / g	21.08
Mass of polystyrene cup + final solution / g	54.58

Temperature readings

Initial temperature of $HNO_3(aq)$ / °C	20.0
Maximum temperature of final solution / °C	24.0

The student follows a similar method and reacts $NaHCO_3(s)$ with $HNO_3(aq)$ to find ΔH_3 for **Reaction 6.3**.

The student calculates ΔH_3 for **Reaction 6.3** as +19.8 kJ mol^{-1}.

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Calculate ΔH_2 for **Reaction 6.2** and determine the enthalpy change of **Reaction 6.1**, ΔH_1.

Assume that the density and specific heat capacity, *c*, of the final solution are the same as for water.

Show your working, including an energy cycle linking the enthalpy changes.

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END OF QUESTION PAPER

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EXTRA ANSWER SPACE

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