PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 8: ENERGETICS I

SCORE	PERCENTAGE
/96	%

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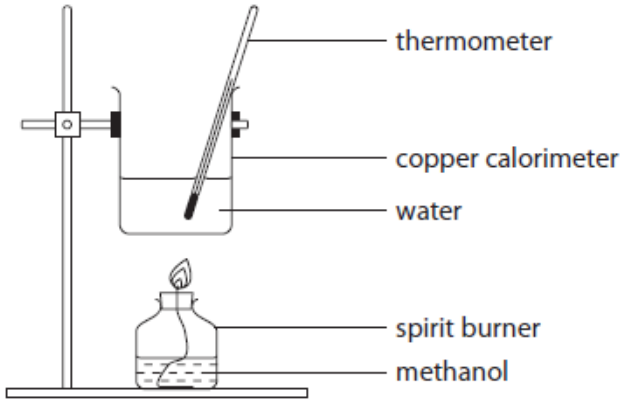
Q1.

This question is about the enthalpy change of combustion of methanol.

A teacher asked two students to carry out a practical task to determine the enthalpy change of combustion of methanol.
Both students were provided with the same apparatus and chemicals.
The following procedure was provided for the students.

Procedure

- Measure out 150 cm^3 of distilled water, using a 250 cm^3 measuring cylinder.
- Transfer the water to a copper calorimeter and note the initial temperature of the water (to the nearest 0.5°C) in **Table 1**.
- Weigh the spirit burner containing methanol and record its mass in **Table 1**.
- Place the spirit burner under the copper calorimeter, as shown in the diagram.
- Ignite the spirit burner and burn the methanol, whilst stirring the water with the thermometer.
- After heating the water for three minutes, extinguish the flame and immediately record the **highest** temperature reached by the water.
- As soon as possible, reweigh the spirit burner containing the methanol and record its mass in **Table 1**.



The results of Student 1 are recorded in **Table 1**.

Mass of spirit burner plus methanol before burning / g	213.47
Mass of spirit burner plus methanol after burning / g	211.87
Mass of methanol burned / g	
Highest temperature of the water / °C	64.5
Initial temperature of the water / °C	22.0
Temperature change of the water / °C	

Table 1

(a) Complete **Table 1**, giving the values to an appropriate number of decimal places.

(2)

(b) Write the equation that represents the reaction that occurs when the standard

enthalpy change of combustion of methanol, $CH_3OH(l)$, is measured. Include state symbols.

(2)

(c) Use Student 1's result to calculate the enthalpy change of combustion of methanol in kJ mol^{-1}.
Give your answer to an appropriate number of significant figures.

Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}
Density of water = 1.00 g cm^{-3}

(4)

(d) Student 1 compared the experimental value for the enthalpy change of combustion of methanol obtained in part (c) with the standard value given on the internet.
The student's value was **less exothermic** than the standard value.

Student 1 decided to evaluate the uncertainty in the measurements made in this experiment.

(i) Student 1 used a 250 cm^3 measuring cylinder to measure the volume of 150 cm^3 distilled water. The uncertainty in this volume measurement is ±1 cm^3.

Calculate the percentage uncertainty in the volume of distilled water that Student 1 measured in the experiment.

(1)

(ii) Compare and contrast the use of a 250 cm^3 measuring cylinder to measure out the 150 cm^3 distilled water with the use of a 25 cm^3 measuring cylinder (uncertainty ±0.2 cm^3 for each volume measurement) six times to measure the same volume.

(3)

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(iii) Student 1 calculated the uncertainties in the remaining measurements. However, Student 1 realised that the measurement uncertainties did **not** explain the difference between the experimental value for the enthalpy change of combustion of methanol calculated in part (c) and the value obtained from the internet.

Other than human error, give **three** reasons for the difference in the values.

(3)

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(e) Student 1 decided to repeat the experiment.

Student 1 used the copper calorimeter and water from the first experiment and recorded the initial temperature as 60.0°C.
Student 1 burned **exactly** the same mass of methanol as in the first experiment.

Explain, with a reason, how the value for the enthalpy change of combustion of methanol from this experiment would differ, if at all, from the value obtained in the first experiment.

(2)

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(f) Student 2 followed the **original** instructions provided, but extinguished the flame after **four** minutes rather than after three minutes.

Explain how the value calculated by Student 2 for the enthalpy change of combustion of methanol compared with that obtained in Student 1's first experiment.

(2)

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(g) Another student, Student 3, used the results from Student 1's first experiment to find the enthalpy change of combustion of methanol. Student 3 incorrectly used a value of 46.0 g mol^{-1} for the molar mass of methanol.

State and justify how this mistake would affect the calculated value for the enthalpy change of combustion of methanol.

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(Total for question = 21 marks)

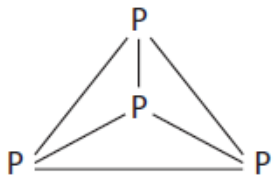
Q2.

The halogens are elements in Group 7 of the Periodic Table.

Chlorine compounds have many uses, including water treatment.

(i) Chlorine and phosphorus (P_4) can react to form phosphorus(V) chloride.

The structure of a molecule of phosphorus is



Some mean bond enthalpy values are shown in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
P—P	+198
Cl—Cl	+243
P—Cl	+326

Calculate the enthalpy change for the reaction between chlorine and phosphorus to form phosphorus(V) chloride.

$$10Cl_2 + P_4 \rightarrow 4PCl_5$$

(3)

(ii) Give a reason why bond enthalpy values are always positive.

(1)

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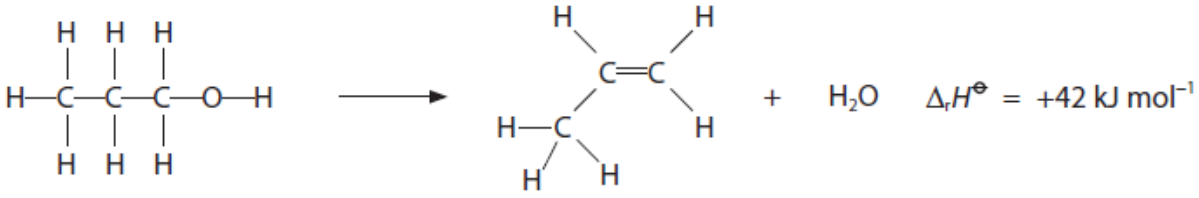
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(Total for question = 4 marks)

Q3.

This question is about enthalpy changes and entropy changes.

Propan-1-ol is dehydrated to form propene.



The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C=C	612
C—H	413
O—H	464

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)

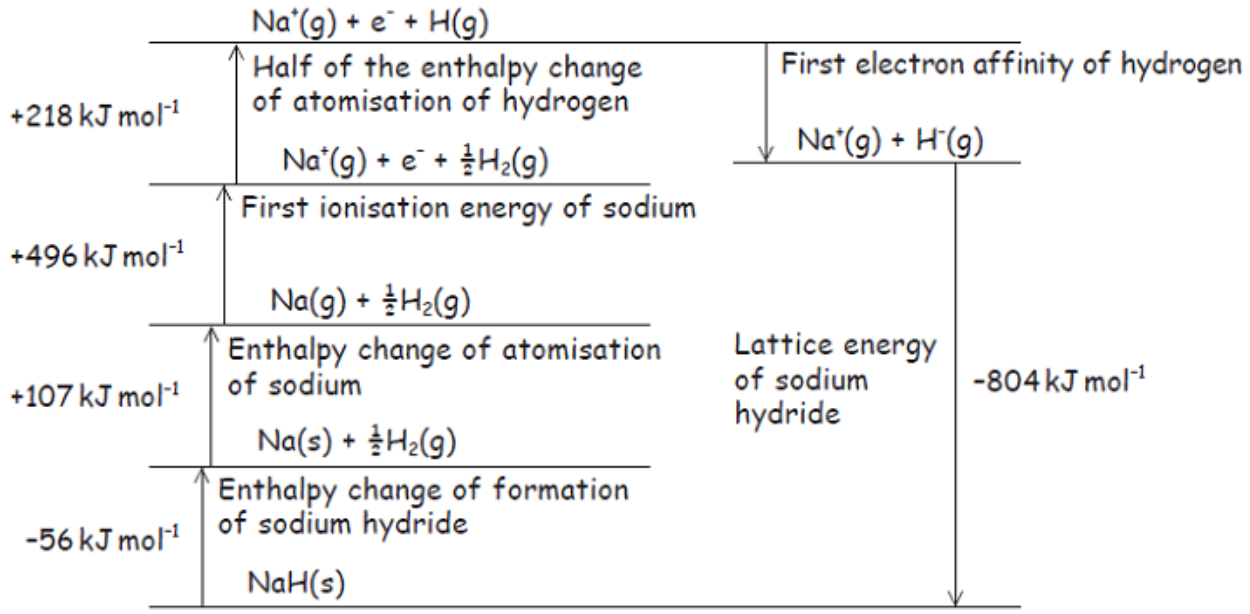
(Total for question = 3 marks)

Q4.

Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.

In order to calculate the first electron affinity of hydrogen, a student was asked to draw a Born-Haber cycle for sodium hydride.

The cycle had **two** errors but the numerical data were correct.



(i) Identify and correct the **two** errors in this Born-Haber cycle.

(2)

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(ii) Calculate the first electron affinity, in kJ mol^{-1}, of hydrogen, using the values given in the cycle.

(1)

(Total for question = 3 marks)

Q5.

In acid-base neutralisation reactions, there is a temperature change.

The enthalpy change when hydrochloric acid reacts with aqueous ammonia is –53.4 kJ mol^{-1}.

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

Calculate the temperature change you would expect when
25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid is mixed with
25.0 cm^3 of 1.00 mol dm^{-3} aqueous ammonia.

Give your answer to an appropriate number of significant figures.

[Assume: the density of the solution is 1.00 g cm^{-3}
the specific heat capacity of the solution is 4.18 J g^{-1} $°C^{-1}$]

(3)

(Total for question = 3 marks)

Q6.

The enthalpy change for the decomposition of sodium hydrogencarbonate can be determined indirectly using Hess's Law.

$$2NaHCO_3(s) \xrightarrow{\Delta_r H} Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

A student carried out two experiments.

Experiment 1 involved the reaction between sodium hydrogencarbonate and hydrochloric acid.

The student used the following procedure:

- use a measuring cylinder to measure 50 cm^3 of 2.00 mol dm^{-3} hydrochloric acid and pour it into a polystyrene cup
- measure the initial temperature of the acid
- weigh the test tube containing sodium hydrogencarbonate
- tip the sodium hydrogencarbonate into the hydrochloric acid in the polystyrene cup, stir the mixture and record the lowest temperature reached
- weigh the empty test tube.

Results

Measurement	Value
Mass of test tube + $NaHCO_3$ / g	21.23
Mass of empty test tube / g	15.61
Mass of $NaHCO_3$ used / g	
Initial temperature / °C	21.0
Final temperature / °C	14.4
Temperature fall / °C	

(i) Complete the table.

(1)

(ii) Show, by calculation, that the hydrochloric acid is in excess.
You must show your working.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

(2)

(iii) Calculate the enthalpy change for the reaction between sodium hydrogencarbonate and hydrochloric acid, using the results of the experiment.
Include a sign and units in your answer.

Assume: mass of reaction mixture = 50.0 g
specific heat capacity of the reaction mixture = 4.18 J g^{-1} $°C^{-1}$

(3)

(Total for question = 6 marks)

Q7.

An experiment is carried out to determine the enthalpy change of the reaction between copper(II) sulfate solution and zinc.

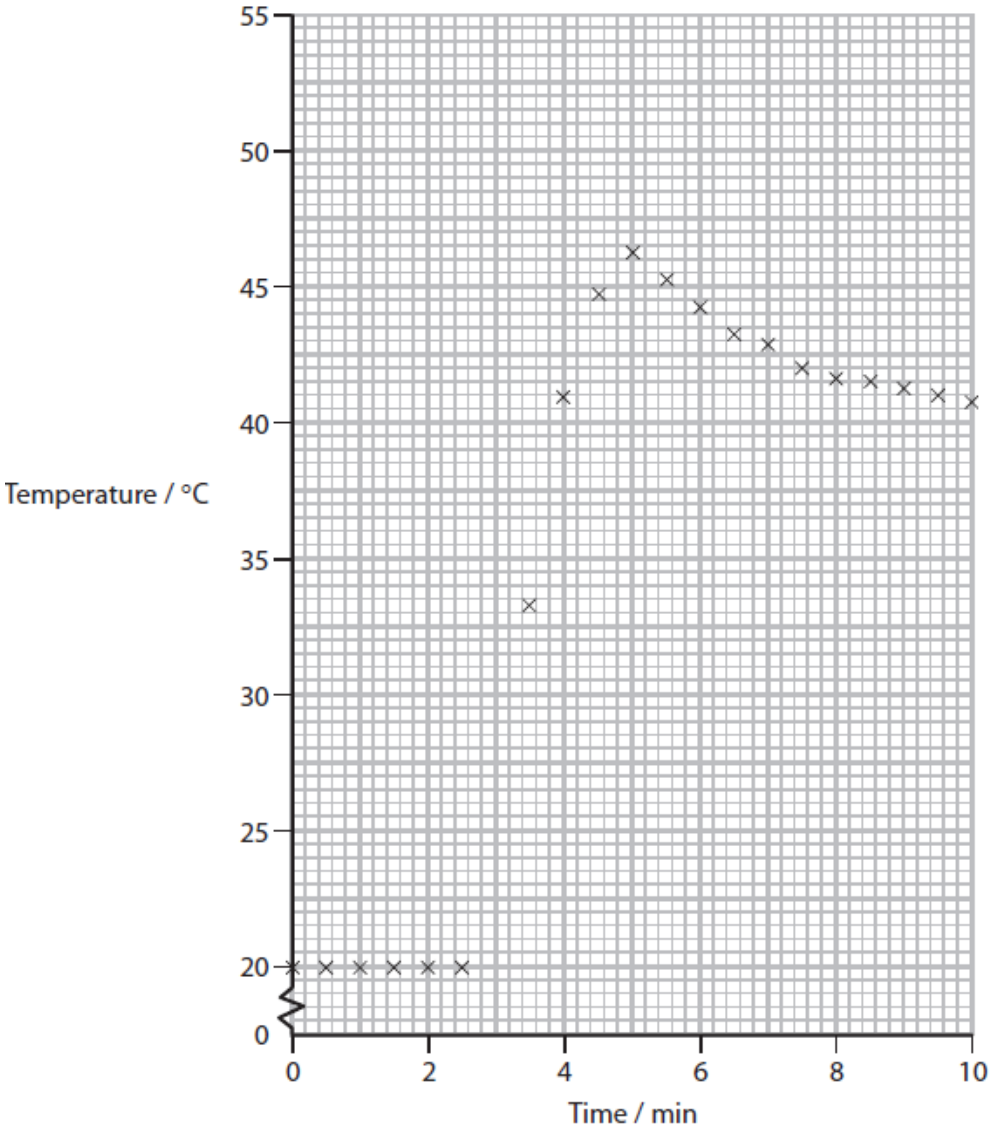
$$CuSO_4(aq) + Zn(s) \rightarrow Cu(s) + ZnSO_4(aq)$$

The procedure is:

- measure out 25.0 cm^3 of 0.720 mol dm^{-3} copper(II) sulfate solution, using a pipette, into a polystyrene cup
- weigh out an excess of zinc granules
- place a thermometer into the cup. Stir and record the temperature to the nearest 0.1°C every 30 seconds, for 2½ minutes

- at 3 minutes, add the zinc granules to the cup
- gently stir the mixture and record the temperature every 30 seconds until a total time of 10 minutes is reached.

The data collected is shown on the graph.



(a) Extrapolate the graph and hence determine the maximum temperature change for the reaction.

(2)

Maximum temperature change = ... °C

(b) (i) Explain why an extrapolation is required to determine an accurate measure of the maximum temperature change.

(2)

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(ii) Explain how the experiment could be amended to allow a value for the maximum temperature change to be determined without the need for an extrapolation.

(2)

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(c) Calculate the enthalpy change for the reaction, $\Delta_r H$. Give your answer to an appropriate number of significant figures.

(4)

(d) The accepted value of $\Delta_r H$ for this reaction is -217 kJ mol^{-1}.

(i) Calculate the percentage error in this experiment.

(1)

(ii) Give reasons why the experimental value calculated in (c) is different from the accepted value.

(2)

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(iii) In the same experiment, another student used a polystyrene cup that contained some distilled water left over from rinsing the cup.

Explain what effect, if any, this would have on the value for the enthalpy change calculated by this student, compared to the answer in (c).

(2)

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(Total for question = 6 marks)

Q8.

Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

In an experiment to determine the enthalpy change of neutralisation, the following results were obtained.

Volume of 1.00 mol dm^{-3} HNO_3 = 25.0 cm^3

Volume of 1.05 mol dm^{-3} NaOH = 25.0 cm^3

Temperature rise = 6.8 °C

Calculate the enthalpy change of neutralisation for the reaction between nitric acid and sodium hydroxide solution, using the results of the experiment.

Give your answer to an appropriate number of significant figures.

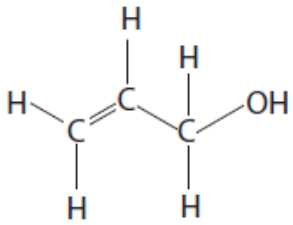
[Assume: density of the reaction mixture = 1.0 g cm^{-3}
specific heat capacity of the reaction mixture = 4.18 J g^{-1} °C^{-1}]

(4)

(Total for question = 4 marks)

Q9.

Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.



A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.

(i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C
bond as they could use the value for a C–C bond and multiply it by two.
Explain why the student is **incorrect**.

(2)

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(ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.

$$C_3H_6O(g) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(g)$$

Bond	C–C	C=C	C–O	C=O	O–H	C–H	O=O
Bond enthalpy / kJ mol^{-1}	347	612	358	805	464	413	498

(3)

(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.

(2)

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(Total for question = 7 marks)

Q10.

The enthalpy change for the decomposition of sodium hydrogencarbonate can be determined indirectly using Hess's Law.

$$2NaHCO_3(s) \xrightarrow{\Delta_r H} Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

A student carried out two experiments.

Experiment 2 involved the reaction between sodium carbonate and hydrochloric acid.

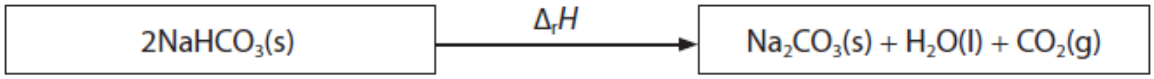
The student repeated the procedure for **Experiment 1** but used sodium carbonate instead of sodium hydrogencarbonate and measured the maximum temperature rise.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

The student calculated the enthalpy change for this reaction as -29.4 kJ mol^{-1}.

(i) Complete the Hess cycle with appropriate formulae and labelled arrows.

(2)



(ii) Calculate the enthalpy change for the decomposition of sodium hydrogencarbonate. Include a sign and units in your answer.

$$2NaHCO_3(s) \xrightarrow{\Delta_r H} Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

(3)

(Total for question = 5 marks)

Q11.

Hess's law can be used to determine enthalpy changes for reactions which cannot be obtained directly.
An example is the reaction of anhydrous copper(II) sulfate with water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

The following outline procedure was carried out.

Step **1** 42.75 g of deionised water was weighed out in a polystyrene cup and the temperature measured.

Step **2** 0.0250 mol of hydrated copper(II) sulfate was added to the water in the polystyrene cup with stirring, making a total of 45.00 g of water.

Step **3** The temperature change was recorded.

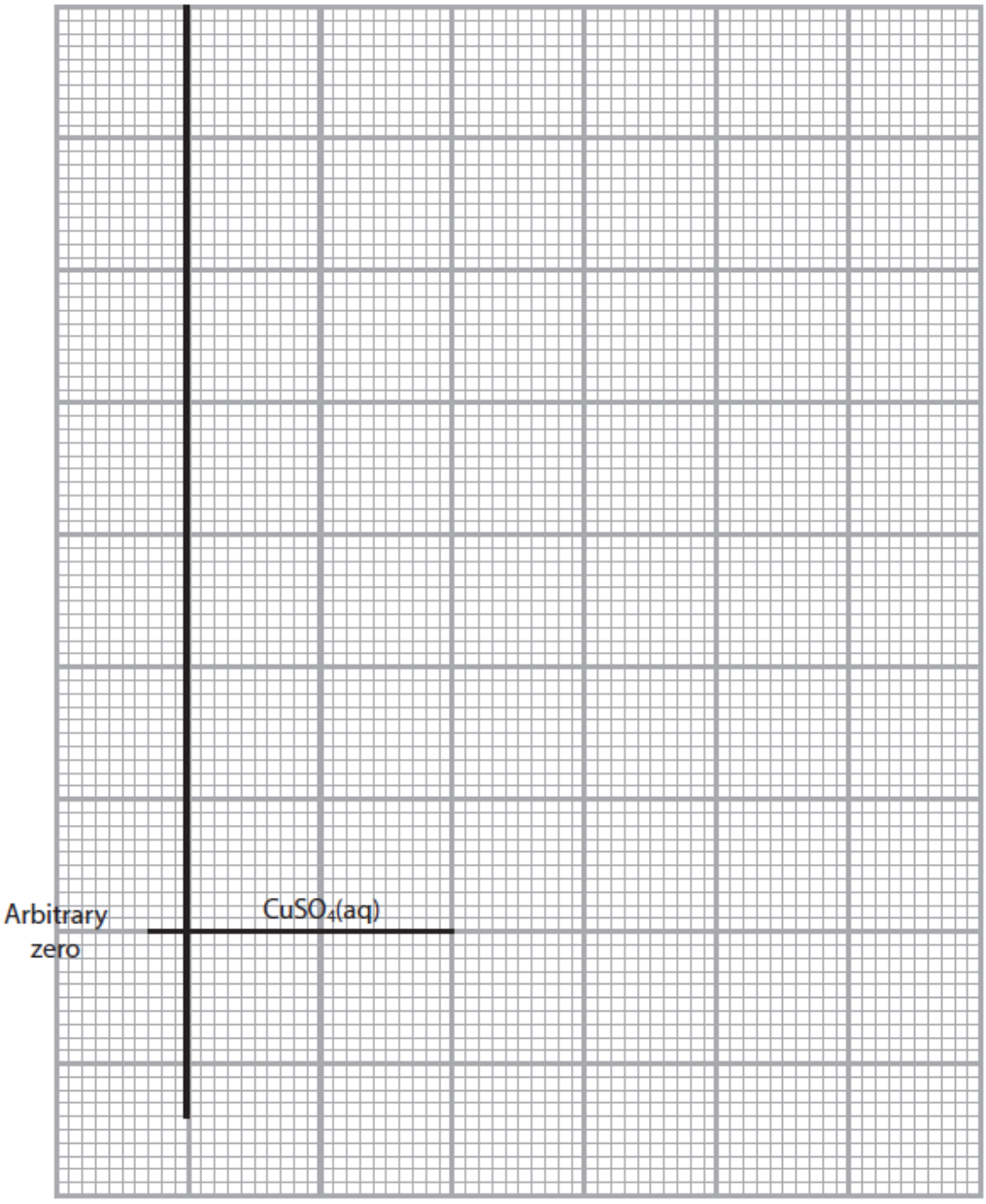
Step **4** Steps **1** to **3** were repeated using 45.00 g of deionised water and 0.0250 mol of anhydrous copper(II) sulfate.

The reaction of anhydrous copper(II) sulfate with water is shown.

$$CuSO_4(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_2 = -84.5 \text{ kJ mol}^{-1}$$

(i) Draw to scale, on the graph paper, a labelled enthalpy level diagram which shows the enthalpy changes
for the reactions of water with hydrated copper(II) sulfate (ΔH_1) and anhydrous copper(II) sulfate (ΔH_2) .

(3)



(ii) Use your enthalpy level diagram in (i) to determine the enthalpy change, $\Delta_r H$, for the reaction

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4.5H_2O(s)$$

You **must** show your working on the diagram.

(1)

$\Delta_r H$ .....

(Total for question = 4 marks)

Q12.

Hess's law can be used to determine enthalpy changes for reactions which cannot be obtained directly.
An example is the reaction of anhydrous copper(II) sulfate with water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

The following outline procedure was carried out.

Step **1** 42.75 g of deionised water was weighed out in a polystyrene cup and the temperature measured.

Step **2** 0.0250 mol of hydrated copper(II) sulfate was added to the water in the polystyrene cup with stirring, making a total of 45.00 g of water.

Step **3** The temperature change was recorded.

Step **4** Steps **1** to **3** were repeated using 45.00 g of deionised water and 0.0250 mol of anhydrous copper(II) sulfate.

The reaction of hydrated copper(II) sulfate with water is shown.

$$CuSO_4.5H_2O(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_1 = +18.2 \text{ kJ mol}^{-1}$$

Calculate the temperature change that would have given this enthalpy change for the stated experimental procedure.
Give your answer to a measurable number of significant figures and state whether the temperature increases or decreases.

[Specific heat capacity of the solution = 4.18 J g^{-1} $°C^{-1}$]

(3)

(Total for question = 3 marks)

Q13.

Hess's law can be used to determine enthalpy changes for reactions which cannot be obtained directly.
An example is the reaction of anhydrous copper(II) sulfate with water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

The following outline procedure was carried out.

Step **1** 42.75 g of deionised water was weighed out in a polystyrene cup and the temperature measured.

Step **2** 0.0250 mol of hydrated copper(II) sulfate was added to the water in the polystyrene cup with stirring, making a total of 45.00 g of water.

Step **3** The temperature change was recorded.

Step **4** Steps **1** to **3** were repeated using 45.00 g of deionised water and 0.0250 mol of anhydrous copper(II) sulfate.

State why the enthalpy change for the reaction of one mole of anhydrous copper(II) sulfate with five moles of water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$, cannot be measured directly.

(1)

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(Total for question = 1 mark)

Q14.

This question is about enthalpy changes and entropy changes.

Which is the equation for the standard enthalpy change of formation, $\Delta_f H^\ominus$, of aluminium oxide?

(1)

☒ **A** $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

☒ **B** $4Al(s) + 6O(g) \rightarrow 2Al_2O_3(s)$

☒ **C** $2Al(s) + 1\frac{1}{2}O_2(g) \rightarrow Al_2O_3(s)$

☒ **D** $2Al(s) + 3O(g) \rightarrow Al_2O_3(s)$

(Total for question = 1 mark)

Q15.

Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

In an experiment to determine the enthalpy change of neutralisation, the following results were obtained.

Volume of 1.00 mol dm^{-3} HNO_3 = 25.0 cm^3

Volume of 1.05 mol dm^{-3} NaOH = 25.0 cm^3

Temperature rise = 6.8 °C

Give a reason why excess sodium hydroxide was used.

(1)

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(Total for question = 1 mark)

Q16.

The enthalpy change for the decomposition of sodium hydrogencarbonate can be determined indirectly using Hess's Law.

$$2NaHCO_3(s) \xrightarrow{\Delta_r H} Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

A student carried out two experiments.

Another student carried out the same two experiments and obtained a value for the enthalpy change of decomposition of sodium hydrogencarbonate of +74 kJ mol^{-1}.

The data book value for this enthalpy change is +90 kJ mol^{-1}.

(i) Calculate the percentage error in this student's value.

(1)

(ii) Calculate the percentage uncertainties in measuring 50 cm^3 of hydrochloric acid using a burette and using a measuring cylinder.

(1)

Apparatus	Uncertainty	Percentage uncertainty
Measuring cylinder	±0.5 cm^3 for each volume measured	
Burette	±0.05 cm^3 for each reading	

(iii) Give a reason why using a burette rather than a measuring cylinder will not improve the accuracy of the experiment.

(1)

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(iv) Describe changes to the method and how the data is used that would improve the accuracy of the determination of the temperature change in **Experiment 2**. Your description should involve the use of a clock and plotting a graph.

(5)

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(Total for question = 8 marks)

Q17.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

An experiment was carried out to determine the enthalpy change of neutralisation for the reaction between propanoic acid and sodium hydroxide.

The equation for this reaction is

$$CH_3CH_2COOH(aq) + NaOH(aq) \rightarrow CH_3CH_2COO^-Na^+(aq) + H_2O(l)$$

50.0 cm^3 of sodium hydroxide solution, of concentration 1.00 mol dm^{-3}, was placed in a polystyrene cup. The initial temperature was measured.

(i) Which piece of equipment has the **smallest** measurement uncertainty for the measurement of 50.0 cm^3 of sodium hydroxide solution?

(1)

		Equipment	Measurement uncertainty for **each** reading
☒	**A**	burette	±0.05 cm^3
☒	**B**	50 cm^3 measuring cylinder	±1 cm^3
☒	**C**	25 cm^3 pipette	±0.06 cm^3
☒	**D**	50 cm^3 pipette	±0.08 cm^3

(ii) 50.0 cm^3 of propanoic acid solution, of concentration 1.00 mol dm^{-3}, was added and thoroughly mixed with the sodium hydroxide solution in the polystyrene cup.

The maximum temperature rise was 6.5 °C.

Calculate the enthalpy change of neutralisation for propanoic acid, in kJ mol^{-1}, giving your answer to the **nearest whole number**.

[Assume density of the mixture = 1.00 g cm^{-3}, specific heat capacity of the mixture = 4.18 J g^{-1} $°C^{-1}$]

(3)

(Total for question = 4 marks)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

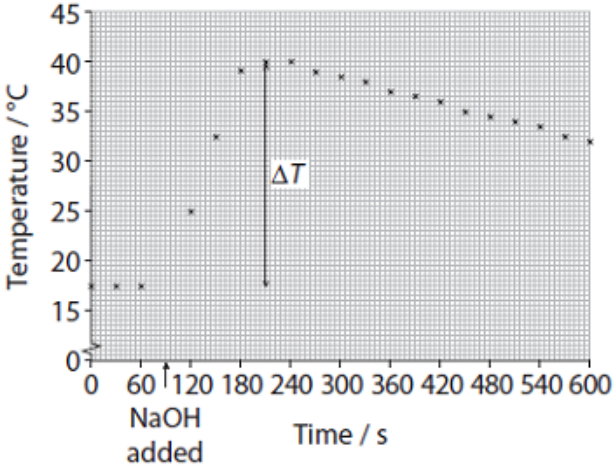
The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

An experiment was carried out with a solution of ethanoic acid and sodium hydroxide solution of the same concentration.

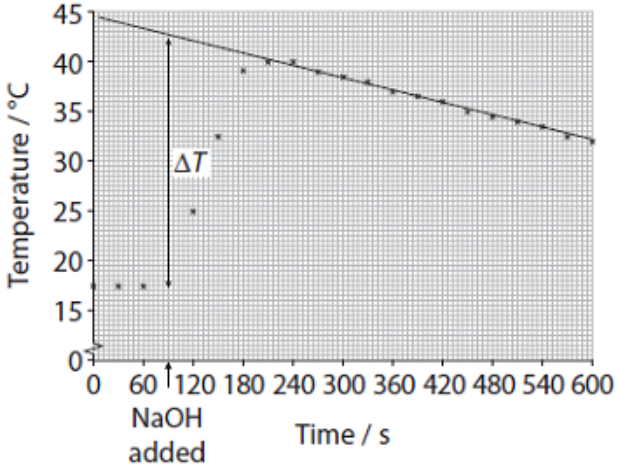
(i) Which graph shows the correct way that the maximum temperature rise should be determined?

(1)

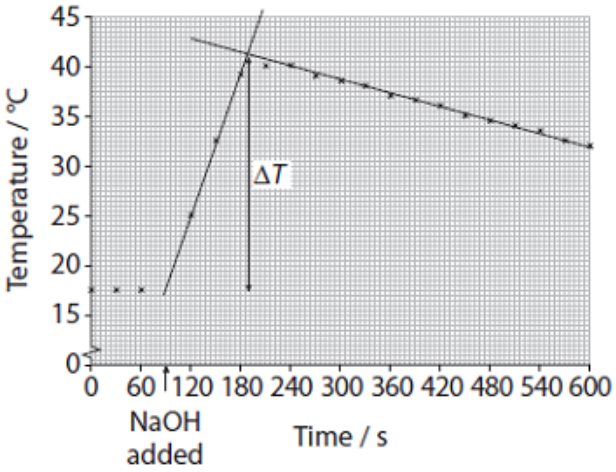
☒ A



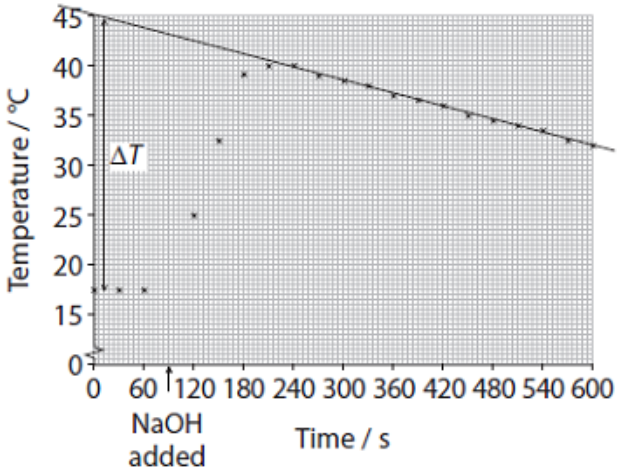
☒ B



☒ C



☒ D



(ii) Explain why the data book value for the standard enthalpy change of neutralisation of ethanoic acid with sodium hydroxide is –55.2 kJ mol^{-1} but the value for hydrochloric acid is –57.1 kJ mol^{-1}.

(2)

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(Total for question = 3 marks)