Calorimetry

Question Paper

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	The Core Principles of Chemistry
Sub Topic	Calorimetry
Booklet	Question Paper

Time Allowed: **75 minutes**

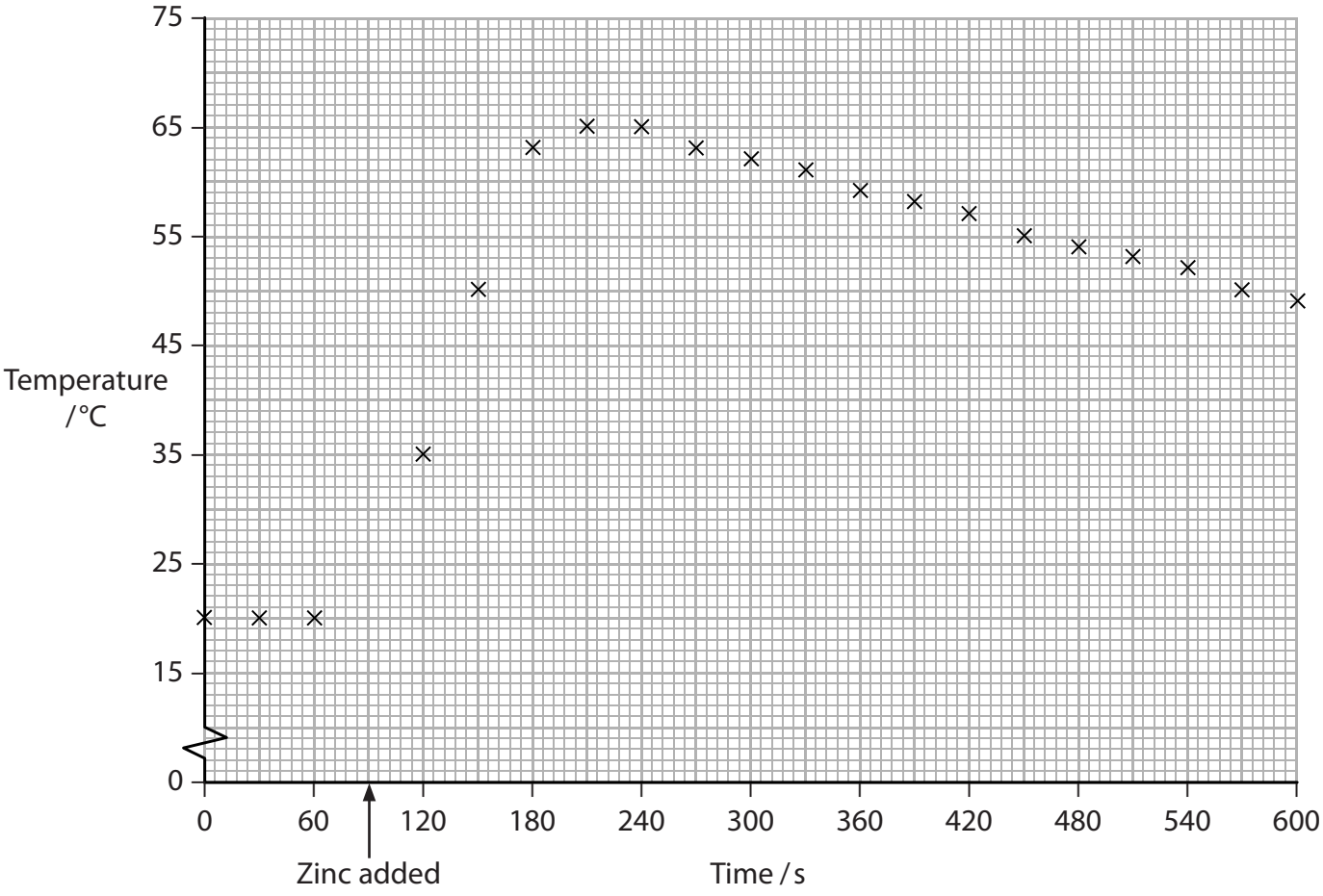
Score: **/62**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 An excess of zinc powder was added to 50.0 cm^3 of 1.0 $mol\,dm^{-3}$ copper(II) sulfate in a polystyrene cup. The temperature of the copper(II) sulfate solution was measured at 30 s intervals. The zinc was added after 90 s. The results are shown on the graph.



What temperature change should be used when calculating the energy transfer?

- ☒ **A** 45 °C
- ☒ **B** 52 °C
- ☒ **C** 65 °C
- ☒ **D** 72 °C

(Total for Question 1 = 1 mark)

2 Which of the following enthalpy changes cannot be measured **directly** by experiment?

The enthalpy change of

☒ **A** formation of methane.

☒ **B** combustion of hydrogen.

☒ **C** formation of carbon dioxide.

☒ **D** combustion of carbon monoxide.

(Total for Question 2 = 1 mark)

3 Compound **X** has the molecular formula C_5H_{12}.

(a) Draw the **displayed** formulae of the **three** structural isomers of C_5H_{12}.

(2)

(b) C_5H_{12} reacts with chlorine to form a mixture of products.

(i) Classify the type and mechanism of this reaction.

(2)

(ii) Write the equations for the two propagation steps for this mechanism. Use the molecular formula, C_5H_{12}, in your first equation. Curly arrows are not required.

(2)

(iii) Write the equation for **one** termination step for this mechanism. Curly arrows are not required.

(1)

(c) An experiment was carried out to determine the enthalpy change of combustion of compound **X**, C_5H_{12}.

100.0 g of water was heated by burning 0.144 g of compound **X**.

The temperature rise of the water was 14.5 °C.

(i) Calculate the energy transferred, in **kJ**, in this experiment.

Use the equation

heat energy produced (J) = mass of water × 4.18 × temperature change

(1)

energy transferred = ... kJ

(ii) Calculate the number of moles of compound **X** used in this experiment.

(1)

moles of **X** = ...

(iii) Calculate the enthalpy change of combustion of compound **X**. Include a sign and units in your answer.

(2)

enthalpy change of combustion = ...

(iv) The Data Book values for the enthalpy changes of combustion of the three structural isomers with the formula C_5H_{12} are:

-3509.1 kJ mol^{-1}

-3503.4 kJ mol^{-1}

-3492.5 kJ mol^{-1}

The experimental value calculated in (c)(iii) is very different from these values. Give **two** reasons, other than heat loss, for this large difference.

(2)

(v) Explain why it is **not** possible to deduce which of the isomers is compound **X** by comparing this experimental value and the Data Book values.

(1)

*(d) Complete the Hess cycle and use it to calculate the enthalpy change of combustion of C_5H_{12} from the following data.

Show all of your working.

Standard enthalpy change of formation of $C_5H_{12}(l)$	–173.2 kJ mol^{-1}
Standard enthalpy change of combustion of $H_2(g)$	–285.8 kJ mol^{-1}
Standard enthalpy change of combustion of carbon(s, graphite)	–393.5 kJ mol^{-1}

(4)

$C_5H_{12}(l) + 8O_2(g)$ ⟶ $5CO_2(g) + 6H_2O(l)$

..... + ... + ...

(Total for Question 3 = 18 marks)

4 For some reactions, the enthalpy change can be determined by experiment.

(a) Define the term **enthalpy change of reaction**.

(2)

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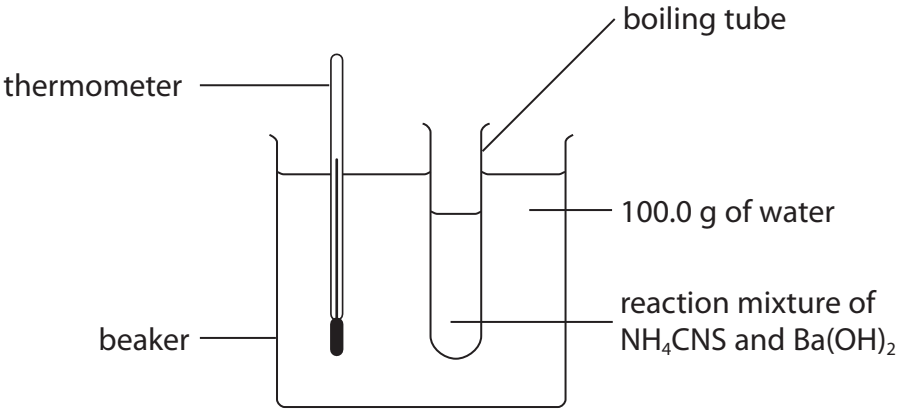
(b) An equation for the reaction between the two solids ammonium thiocyanate, NH_4CNS, and barium hydroxide, $Ba(OH)_2$, is shown below.

$$2NH_4CNS(s) + Ba(OH)_2(s) \rightarrow Ba(CNS)_2(s) + 2H_2O(l) + 2NH_3(g)$$

The following apparatus was set up in order to determine the enthalpy change for the reaction.



In the experiment, 15.22 g of NH_4CNS was reacted with an excess of $Ba(OH)_2$. The reaction absorbed heat energy from the surroundings. The temperature of the 100.0 g of water fell from 22.0 °C to 16.5 °C.

(i) Calculate the heat energy absorbed, in joules, during the reaction.

Use the equation

Heat energy absorbed (J) = mass of water × 4.2 × temperature change

(1)

(ii) Calculate the number of moles of NH_4CNS used in the experiment.

(1)

(iii) Calculate the enthalpy change of the reaction, in kJ mol^{-1}, to **two** significant figures. Include a sign in your answer.

$$2NH_4CNS(s) + Ba(OH)_2(s) \rightarrow Ba(CNS)_2(s) + 2H_2O(l) + 2NH_3(g)$$

(3)

(c) Standard enthalpy changes of reaction can also be calculated using mean bond enthalpies.

(i) What is meant by the term **mean bond enthalpy**?

(2)

(ii) Describe the bonding in a C═C double bond in terms of the different ways in which the orbitals overlap.

You may draw a diagram if you wish.

(2)

Space for diagram:

(iii) Suggest why the mean bond enthalpy of a C═C bond is less than twice the mean bond enthalpy of a C—C bond.

(1)

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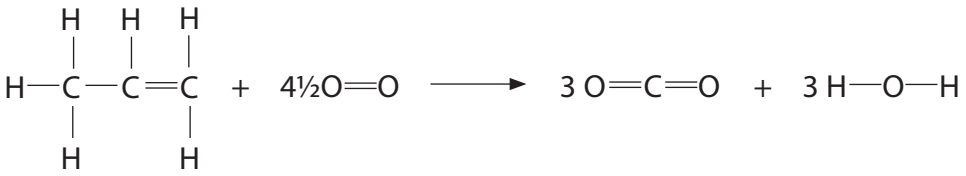
(iv) Use the mean bond enthalpy data in the table, and the equation given below, to calculate a value for the standard enthalpy change of combustion of propene.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
C═C	612
C—C	347
C—H	413
O═O	498
C═O	805
O—H	464



Answer = ... kJ mol^{-1}

*(v) The Data Booklet value for the standard enthalpy change of combustion of propene is –2058 kJ mol^{-1}.

Explain why the value calculated in (c)(iv) is less exothermic than the Data Booklet value.

(2)

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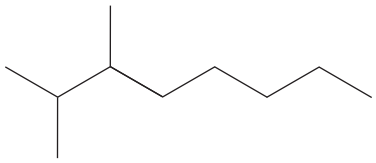
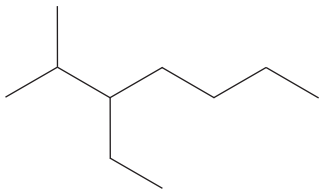
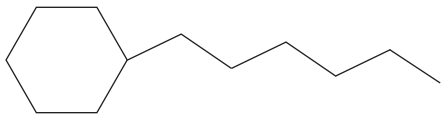
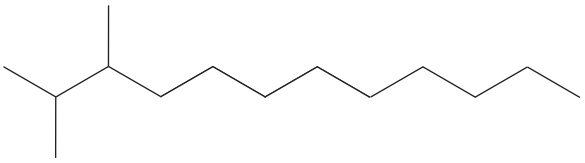
(Total for Question 4 = 17 marks)

5 A propellant for a rocket consists of a fuel, kerosene, and an oxidizer, liquid oxygen.

(a) The formulae of some hydrocarbons present in kerosene are shown in the table below.

Hydrocarbon	Formula
A	
B	$CH_3(CH_2)_{10}CH_3$
C	
D	
E	

(i) Name the homologous series to which the compounds **A**, **B**, **C** and **E** belong.

(1)

(ii) Name the compound **A**.

(1)

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(iii) Explain the term **structural isomers**, by reference to two molecules selected from the table in part (a).

(3)

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(iv) Give the **molecular** formula of the compound **D**.

(2)

(b) In the petrochemical industry, other fuels are obtained by the cracking and reforming of kerosene.

Using appropriate letters, **A** to **D**, identify a molecule listed in the table that could be formed from **E** by

(i) cracking alone

(1)

.....

(ii) cracking and then reforming

(1)

.....

(c) Suggest how engine performance is improved by using a fuel containing the molecule that you have identified in (b)(ii).

(1)

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(d) The **energy density** of a fuel is defined as the energy produced per kilogram of fuel.

Calculate the energy density of dodecane, $C_{12}H_{26}$, in kJ kg^{-1}. Give your answer to **two** significant figures.

The enthalpy change of combustion of dodecane is −8086 kJ mol^{-1}.

[Molar mass: $C_{12}H_{26}$ = 170 g mol^{-1}]

(3)

energy density = ... kJ kg^{-1}

(Total for Question 5 = 13 marks)

6 This question is about the flammable liquid, methanol, CH_3OH.

(a) Methanol starts to have toxic effects when it is present in blood at levels of above 200 mg in 1000 g.

Express this concentration in parts per million.

(1)

(b) The enthalpy change of combustion of methanol was measured using a spirit burner to heat a known mass of water in a calorimeter. The temperature increase of the water in the calorimeter was measured when a known mass of methanol was burned.

(i) Write an equation for the complete combustion of methanol, CH_3OH, under standard conditions. Include state symbols in the equation.

(2)

(ii) Identify **two** other products that could form if the combustion was **incomplete**.

(1)

1 .....

2 .....

(c) The results of the experiment are summarised in the table below.

Mass of water in the calorimeter	150.0 g
Mass of spirit burner + contents (initial)	52.24 g
Mass of spirit burner + contents (final)	51.60 g
Temperature of water (initial)	21.4 °C
Temperature of water (final)	37.2 °C

(i) Calculate the heat energy produced in this experiment using the equation

Heat energy produced (J) = mass of water × 4.18 × temperature change

(1)

(ii) Calculate the number of moles of methanol burned in this experiment.

(1)

(iii) Calculate the enthalpy change of combustion of methanol in kJ mol^{-1}. Give your answer to **three** significant figures.

(2)

(iv) The experimental result differs from the true value for the enthalpy change of combustion of methanol.

State **one** factor in the experimental method, other than heat losses or incomplete combustion, which causes the result to differ from the true value.

Explain the effect this factor has on the magnitude of the experimental value compared to the true value.

(2)

Factor .....

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Explanation .....

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(d) The value of the enthalpy change for the combustion of methanol can be calculated from the mean bond enthalpies of the substances in the reaction.

Give **two** reasons why this value differs from the value obtained in the experiment, even after corrections are made for experimental error.

(2)

Reason 1 .....

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Reason 2 .....

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(Total for Question 6 = 12 marks)