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A' Level Chemistry

Year 1

Unit 8: Energetics

Summer Examination Revision Pack

The questions in this pack should be attempted **AFTER** completing all other revision.

Grade Accelerator

Recall Definitions
Drawing Diagrams
Using Equations
Drawing Graphs

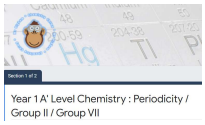
Quizlet

Quizlet Classes

Flashcard Based
Games
Tests & Quizzes
Keyword Spell Checker

Condensed Notes

Keywords & Definitions
Key Concepts
Application
Key Skills



Online Forms

Take Time to Answer
Use Paper & Calculator
Work It Out
Review Missed Marks

Use the 3 Wave Process when completing these revision packs.

1. Complete the questions without assistance
(Can't answer a question? Leave it and move on)
2. Use your notes to fill any gaps after step 1
3. Use the mark scheme to fill in any remaining gaps.

1. Having gaps after step 1 is normal, that's why we are doing revision!
2. If your notes don't help during step 2, they are not good enough!
(Change your note taking method and try to understand the problem)
3. If you don't understand why the mark scheme answer is correct, **see Andy.**

If you struggle with the questions in the pack, **STOP!** and complete some more revision.

If you come to a complete dead-end, **STOP!** and speak to **Andy** asap.

0 2 This question is about energetics.

0 2 . 1 Write an equation, including state symbols, for the reaction with an enthalpy change equal to the enthalpy of formation for iron(III) oxide.

[1 mark]

0 2 . 2 **Table 2** contains some standard enthalpy of formation data.

Table 2

	$CO(g)$	$Fe_2O_3(s)$
$\Delta_f H^\ominus$ / kJ mol^{-1}	−111	−822

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$ $\Delta H = -19$ kJ mol^{-1}

Use these data and the equation for the reaction of iron(III) oxide with carbon monoxide to calculate a value for the standard enthalpy of formation for carbon dioxide.

Show your working.

[3 marks]

$\Delta_f H^\ominus$ _____ kJ mol^{-1}

0 2 . 3 Some enthalpy data are given in **Table 3.**

Table 3

Process	**ΔH / kJ mol^{-1}**
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	−92
$N_2(g) \rightarrow 2N(g)$	+944
$H_2(g) \rightarrow 2H(g)$	+436

Use the data from **Table 3** to calculate the bond enthalpy for N–H in ammonia.

[3 marks]

N–H bond enthalpy _____ kJ mol^{-1}

0 2 . 4 Give one reason why the bond enthalpy that you calculated in Question **2.3** is different from the mean bond enthalpy quoted in a data book (388 kJ mol^{-1}).

[1 mark]

_____

_____

_____

8

0 3 A student planned and carried out an experiment to determine the enthalpy of reaction when magnesium metal displaces zinc from aqueous zinc sulfate.

$$Mg(s) + Zn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Zn(s)$$

The student used this method:

- A measuring cylinder was used to transfer 50 cm^3 of a 1.00 mol dm^{-3} aqueous solution of zinc sulfate into a glass beaker.
- A thermometer was placed in the beaker.
- 2.08 g of magnesium metal powder were added to the beaker.
- The mixture was stirred and the maximum temperature recorded.

The student recorded a starting temperature of 23.9 °C and a maximum temperature of 61.2 °C.

0 3 . 1 Show by calculation which reactant was in excess.

Use the data to calculate the experimental value for enthalpy of reaction in kJ mol^{-1} (Assume that the specific heat capacity of the solution is 4.18 J $K^{-1}g^{-1}$ and the density of the solution is 1.00 g cm^{-3}).

[6 marks]

Reactant in excess _____

Enthalpy of reaction _____ kJ mol^{-1}

0 3 . 2 Another student used the same method and obtained a value for the enthalpy of reaction of -142 kJ mol^{-1}

A data book value for the enthalpy of reaction is -310 kJ mol^{-1}

Suggest the most likely reason for the large difference between the student's experimental value and the data book value.

[1 mark]

Question 3 continues on the next page

0 3 . 3 Suggest how the students' method, and the analysis of the results, could be improved in order to determine a more accurate value for the enthalpy of reaction.

Justify your suggestions.

Do not refer to the precision of the measuring equipment. Do not change the amounts or the concentration of the chemicals.

[6 marks]

13

Question	Marking Guidance	Mark	Additional Comments/Guidance
02.1	$2Fe(s) + {}^{3}/_{2}O_2(g) \rightarrow Fe_2O_3(s)$ ONLY	1	Don't allow multiples. States must be shown
02.2	M1 Correct cycle or equation M2 $(3x\Delta_f HCO_2) = -19 + (-822) + 3(-111) - 0$ $(3x\Delta_f HCO_2) = -1174$ M3 $\Delta_f HCO_2 = -391$ kJmol^{-1}	1 1 1	If M1 and M2 not awarded then M3 can be awarded for their M2 divided by 3 -317 for 1 mark +391 for 1 mark Allow 2 sig fig or more
02.3	M1 Correct Hess's law cycle or equation M2 $(6(N\text{-}H)) = 944 + 3(+436) + 92$ $(6(N\text{-}H)) = 2344$ M3 N-H = (+)391kJmol^{-1}	1 1 1	If M1 and M2 not awarded then M3 can be awarded for their M2 divided by 6 -391 for 1 mark Allow 2 sig fig or more
02.4	Data book value derived from (a number of) different compounds (not just different NH_3 molecules)	1	

Question	Marking Guidance	Mark	Additional Comments/Guidance
03.1	M1 Amount $ZnSO_4$ = 1.0 x $^{50}/_{1000}$ mol or Amount $ZnSO_4$ =0.050 mol	1	Mark M1 and M2 independently
	M2 Amount Mg = $^{2.08}/_{24.3}$ mol or Amount Mg= 0.0856 mol	1	
	(Hence Mg in excess)		
	M3 $Q=mc\Delta T$	1	M3 could be scored in M4
	M4 Q=50.0 x 4.18 x 37.3 or Q=7795.7J	1	If an error in M4, lose M4 and M5 and only award M6 for correct use of their incorrect M4 and division by their correct limiting reagent
	M5 (Energy released per mole) = $^{7.796}/_{0.05}$kJmol^{-1} or $^{7796}/_{0.05}$ Jmol^{-1}	1	M5 division by their limiting reagent
	M6 ΔH= − 156 kJmol^{-1}	1	
03.2	Heat loss (from the apparatus would mean the experimental value is smaller/lower/less exothermic than the data source)	1	

Question	Marking Guidance		Mark	Comments
03.3	Marks awarded for this answer will be determined by the as well as the standard of the scientific response. Examiners should apply a 'best-fit' approach to the marking.		6	**Indicative Chemistry Content** **Stage 1 Improved insulation** 1a Insulate the beaker or use a polystyrene cup or a lid 1b To reduce heat loss **Stage 2 Improved temperature recording** 2a Record the temperature for a suitable time before adding the metal 2b To establish an accurate initial temperature OR 2c Record temperature values at regular time intervals 2d To plot the temperature results against time on a graph **Stage 3 Improved analysis of results** 3a Extrapolate the cooling back to the point of addition 3b To establish a (theoretical) maximum temperature OR temperature change (e.g. at the 4th minute) OR adjust for the cooling /apply a cooling correction 3a and 3b could be seen on an extrapolated sketch graph (Note- IGNORE use of measuring equipment with greater precision)
	Level 3 (5—6 marks)	**Covers 3 Stages with matching justifications** Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below: - argument is well structured with minimum repetition or irrelevant points - accurate and clear expression of ideas with only minor errors in the use of technical terms, spelling and punctuation and grammar		
	Level 2 (3—4 marks)	**Covers 2 Stages with matching justification. OR covers 3 Stages with incomplete justification** Answer has some omissions but is generally supported by some of the relevant points below: - the argument shows some attempt at structure - the ideas are expressed with reasonable clarity but with a few errors in the use of technical terms, spelling, punctuation and grammar		
	Level 1 (1—2 marks)	**Covers 1 Stage with matching justification. OR covers 2 Stages with incomplete justification** Answer is largely incomplete. It may contain valid points which are not clearly linked to an argument structure. Unstructured answer. Errors in the use of technical terms, spelling, punctuation and grammar or lack of fluency		

Do not write outside the box

0 1 . 5 Hydrogen fluoride reacts with ethyne (C_2H_2) as shown in the equation. All compounds are in the gaseous state.

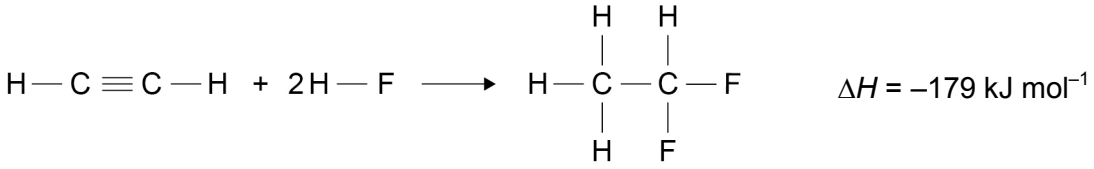


Table 1 shows some mean bond enthalpy data.

Table 1

Bond	C–H	C≡C	H–F	C–C
Mean bond enthalpy / kJ mol^{-1}	412	837	562	348

Use the data in **Table 1** to calculate a value for the bond enthalpy of a C–F bond in the product.

[3 marks]

C–F bond enthalpy _____ kJ mol^{-1}

13

Turn over for the next question

01.5	$\Delta H = \sum\Delta H$(Bonds broken) - $\sum\Delta H$(Bonds Formed) -179 = 2(412) + 837 + 2(562) – [348 + 4(412) + 2(C—F)] -179 = 2785 – (1996 +2(C—F)) 2(C—F) = 968 C—F = 484	Allow M1 if 2785 <u>and</u> 1996 seen (or allow M1 if 1961 <u>and</u> 1172 seen) M3 consequential on any M2 if it is clear that M2 is for 2(C-F) -484 scores 2	1 1 1

Do not write outside the box

0 4 This question is about enthalpy changes.

0 4 . 1 State the meaning of the term enthalpy change as applied to a chemical reaction.

[1 mark]

0 4 . 2 A student determines the enthalpy change for the reaction between calcium carbonate and hydrochloric acid.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

The student follows this method:

- measure out 50 cm^3 of 1.00 mol dm^{-3} aqueous hydrochloric acid using a measuring cylinder and pour the acid into a 100 cm^3 glass beaker
- weigh out 2.50 g of solid calcium carbonate on a watch glass and tip the solid into the acid
- stir the mixture with a thermometer
- record the maximum temperature reached.

The student uses the data to determine a value for the enthalpy change.

Explain how the experimental method and use of apparatus can be improved to provide more accurate data.

Describe how this data from the improved method can be used to determine an accurate value for the temperature change.

[6 marks]

Do not write outside the box

Question 4 continues on the next page

Do not write outside the box

0 4 . 3 In a different experiment 50.0 cm^3 of 0.500 mol dm^{-3} aqueous hydrochloric acid are reacted with 50.0 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) \quad \Delta H = -57.1 \text{ kJ mol}^{-1}$$

The initial temperature of each solution is 18.5 °C

Calculate the maximum final temperature of the reaction mixture.

Assume that the specific heat capacity of the reaction mixture, $c = 4.18 \text{ J K}^{-1} \text{ g}^{-1}$

Assume that the density of the reaction mixture = 1.00 g cm^{-3}

[5 marks]

Final temperature _____ °C

0 4 . 4 Suggest how, without changing the apparatus, the experiment in Question **04.3** could be improved to reduce the percentage uncertainty in the temperature change.

[1 mark]

_____

_____

_____

13

<table>
<tr><th>Question</th><th>Marking guidance</th><th>Additional Comments/Guidelines</th><th>Mark</th></tr>
<tr><td>04.1</td><td>Heat energy change at constant pressure</td><td></td><td>1</td></tr>
<tr><td>04.2</td><td>This question is marked using levels of response.
<table><tr><td>Level 3:
All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is well structured with no repetition or irrelevant points.
Accurate and clear expression of ideas with no errors in use of technical terms.</td><td>5-6</td></tr><tr><td>Level 2:
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer shows some attempt at structure
Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points.
Some minor errors in use of technical terms.</td><td>3-4</td></tr><tr><td>Level 1:
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show some confusion.
Answer may contain valid points which are not clearly linked to an argument structure. Errors in the use of technical terms.</td><td>1-2</td></tr><tr><td>Level 0
Insufficient correct chemistry to gain a mark.</td><td>0</td></tr></table></td><td>Indicative Chemistry

Stage 1: Apparatus
1a. Use a burette/pipette (instead of a measuring cylinder)
1b. Use a polystyrene cup (instead of a beaker) / insulate beaker
1c. Reweigh the watchglass after adding the solid
1d: Use powdered solid

Stage 2: Temperature Measurements
2a. Measure and record the initial temperature of the solution for a few minutes before addition
2b. Measure and record the temperature after the addition at regular intervals (eg each minute) for 8+ minutes/until a trend is observed

Stage 3: Temperature Determination
3a. Plot a graph of temperature against time
3b. Extrapolate to the point of addition
3c. Determine ΔT at the point of addition</td><td>6</td></tr>
</table>

04.3	n(HCl) or n(NaOH) = 50 x 0.500 / 1000 = 0.025 moles q = –ΔH x n = 57.1 x 0.025 = 1.4275 kJ ΔT = q/mc ΔT = (1.4275 x 1000) / (100 x 4.18) = 3.4(2) °C Final Temperature = 18.5 + 3.4 = 21.9 °C	M2 = 57.1 × M1 M4 = (M2 × 1000) / (100 × 4.18) M5 = M4 + 18.5 (but final temperature must be higher than 18.5 °C)	1 1 1 1 1

04.4	Increase the concentration of the solutions		1

0 2 . 2 Suggest **one** reason, other than incomplete combustion or heat transfer to the atmosphere, why the student's value for the enthalpy of combustion of methanol is different from that in a Data Book.

[1 mark]

0 2 . 3 The uncertainty in each of the temperature readings from the thermometer in this experiment was ±0.25 °C. This gave an overall uncertainty in the temperature rise of ±0.5 °C.

Calculate the percentage uncertainty for the use of the thermometer in this experiment.

[1 mark]

0 2 . 4 The student said correctly that using a thermometer with an overall uncertainty for the rise in temperature of ±0.5 °C was adequate for this experiment.

Explain why this thermometer was adequate for this experiment.

[1 mark]

0 2 . 5 The enthalpy of combustion of ethanol is −1371 kJ mol^{-1}. The density of ethanol is 0.789 g cm^{-3}.

Calculate the heat energy released in kJ when 0.500 dm^3 of ethanol is burned. Give your answer to an appropriate number of significant figures.

[3 marks]

Question	Marking Guidance	Mark	Comments
02.1	M1 ($q = mc\Delta T = 100 \times 4.18 \times 38(.0)$) = 15 884 / 15 880 / 15 900 / 16 000 (J) (OR 15.884 / 15.88 / 15.9 / 16 (kJ)) M2 Moles (methanol = 1.65 / 32.0) = 0.0516 or 0.052 M3 Heat change per moles = M1/M2 (15 884 / 0.0516 / 1000 = 308 (kJ mol^{-1}) (allow 305 to 310) M4 Answer = −308 (kJ mol^{-1}) (allow −305 to −310)	1 1 1 1	Award full marks for correct answer M1 mark is for value not expression (at least 2sf); penalise incorrect units here only if M1 is the only potential scoring point in M1-M3 M2 at least 2sf M3 at least 2sf; answer must be in kJ mol^{-1} M4 this mark is for – sign (mark independently)
02.2	Heating up copper / calorimeter / container / thermometer / heat capacity of copper / calorimeter / thermometer not taken into account OR Evaporation of alcohol/methanol OR Experiment not done under standard conditions	1	Not human errors (e.g. misreading scales) Not impure methanol Allow evaporation of water
02.3	(100 x 0.5 / 38 =) 1.3 or 1.32 or 1.316% (minimum 2 sf)	1	Allow correct answer to at least 2sf; Allow 1.31 or 1.315%
02.4	Idea that heat loss is more significant issue OR Idea that temperature change/rise is (significantly / much) bigger than uncertainty	1	One of these two ideas only and each one must involve a comparison

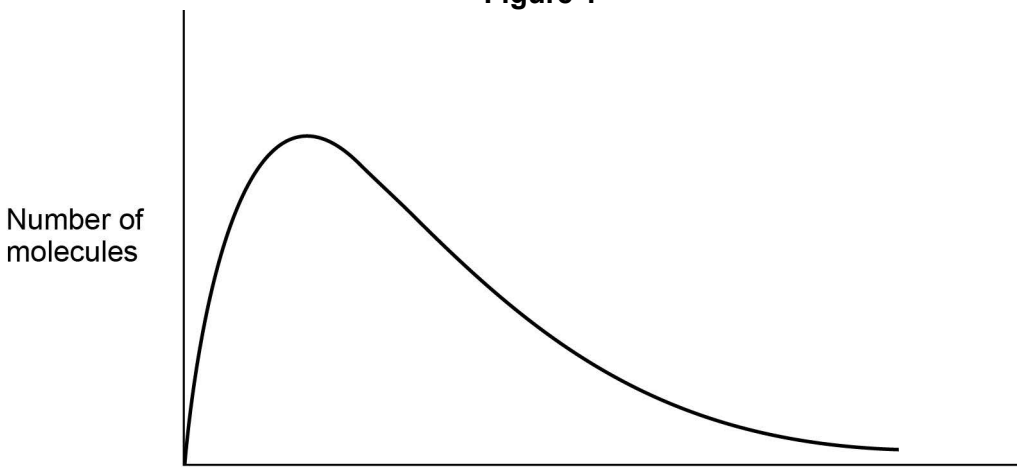
02.5	M1 Mass of ethanol = 500 x 0.789 (= 394.5 or 395 (g)) M2 Moles of ethanol = M1 / 46.0 (= 8.576 or 8.58) M3 Heat released = M2 x 1371 = 11800 (kJ) must be 3 sf	1 1 1	Correct answer to 3sf scores 3; correct value to 2sf or more than 3sf scores 2 Answers that are a factor of 10^x out score 2 if given to 3sf or 1 if given to a different number of sf M3 ignore units, but penalise incorrect units M3 ignore sign M2 and M3 – allow consequential marking

Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows the Maxwell−Boltzmann distribution of molecular energies in a sample of gas at a fixed temperature.

Figure 1



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0 1 . 1 Label the horizontal axis in **Figure 1.**

[1 mark]

0 1 . 2 On **Figure 1**, sketch a distribution of molecular energies for this sample of gas at a higher temperature.

[2 marks]

0 1 . 3 This gas decomposes on heating.

Explain why an increase in temperature increases the rate at which this gas decomposes.

[2 marks]

5

Question	Marking Guidance	Mark	Comments
01.1	energy	1	Ignore reference to • any units (e.g. J, kJ, J mol^{-1}, kJ mol^{-1}) • particles • molecules • kinetic **NOT** mean energy or average energy **NOT** E
01.2	**M1** maximum peak height is lower and displaced to the right of the original	1	
	M2 all of the following • starts at the origin but does not follow the original line • shows separation as soon as possible from the original line • crosses the original curve once only • similar area to original curve • an attempt has been made to draw the new curve correctly towards the energy axis above the original curve but not to touch the original curve (or axis)	1	

Question	Marking Guidance	Mark	Comments
01.3	**M1** an increase in the number/amount/proportion/fraction of molecules with $E \geq E_a$ / with activation energy **or** more molecules have $E \geq E_a$ / with activation energy **or** more molecules have enough / sufficient energy (to react)	1	**M1** Ignore - Molecules have more energy - More energetic collisions - More collisions Allow $E > E_a$ in place of $E \geq E_a$
	M2 more successful / effective / productive collisions in a given time / period **or** higher rate of successful / effective / productive collisions **or** higher frequency of successful / effective / productive collisions	1	Credit particles for molecules (but not atoms) Penalise for **M1** reference to increased activation energy **M2** Must refer to <u>both</u> idea of successful/effective/productive collisions and the rate/frequency of collisions Ignore 'chance of collision'

0 4 When alkanes are burned in an excess of oxygen they produce carbon dioxide and water.

0 4 . 1 Write an equation for the complete combustion of propane in oxygen.

[1 mark]

0 4 . 2 An expression can be derived using bond enthalpy data to estimate the enthalpy of combustion ($\Delta_c H$) of an alkane.

For an alkane with ***n*** carbon atoms: $\Delta_c H = -(496\boldsymbol{n} + 202)$ kJ mol^{-1}

The enthalpy of combustion of an alkane was calculated to be –6650 kJ mol^{-1} using this expression.

Deduce the molecular formula of this alkane.
Show your working.

[2 marks]

Molecular formula of alkane _____

0 4 . 3 Suggest **one** reason, other than the use of mean bond enthalpies, why a value for the enthalpy of combustion of a liquid alkane is different from the value obtained using the expression in Question **4.2**

[1 mark]

0 4 . 4 Values of the enthalpy change for combustion of 1 g of some alkanes are shown in **Table 2**.

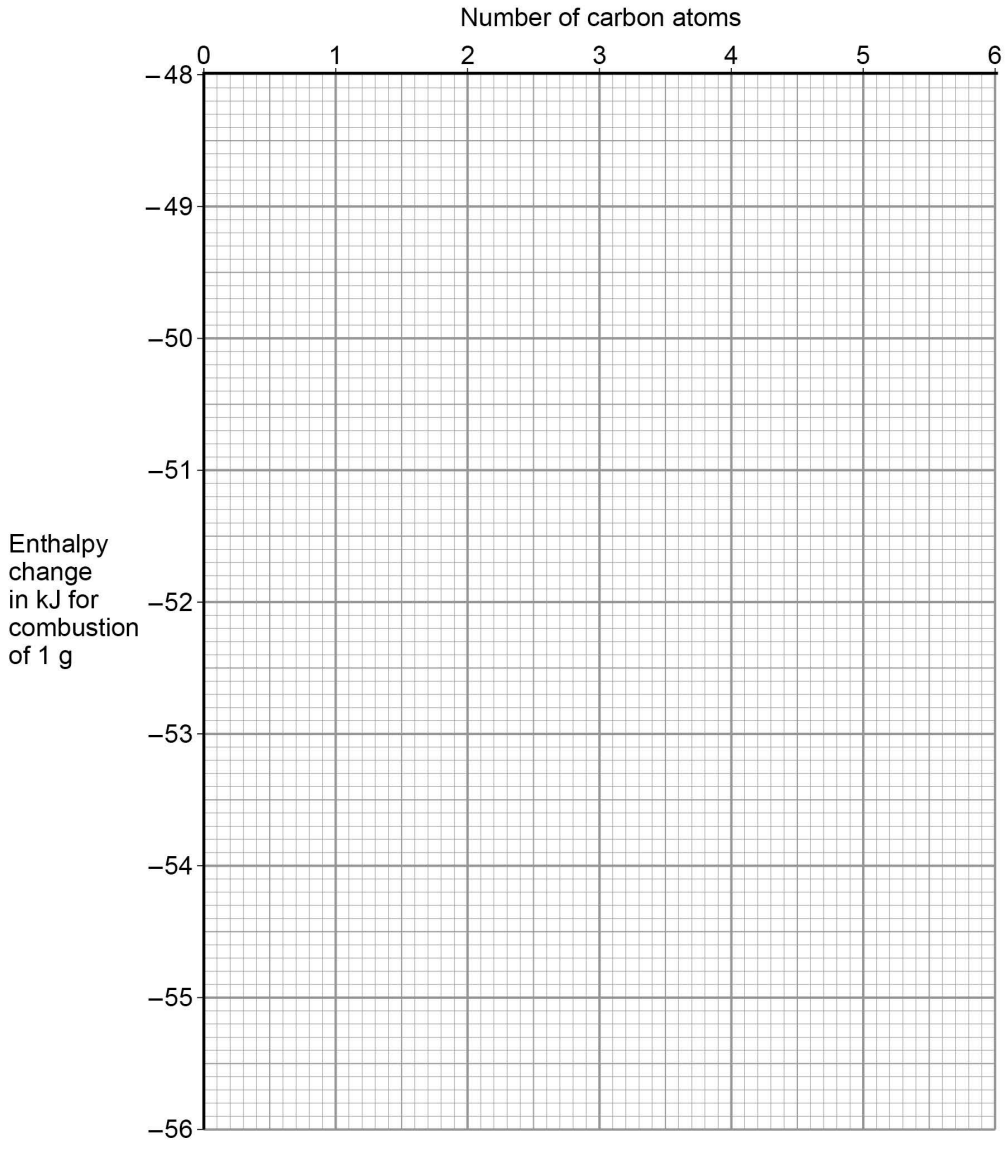
Table 2

	methane	**ethane**	**propane**	**butane**	**pentane**
Enthalpy change in kJ for combustion of 1 g	–55.6	–52.0		–49.6	–48.7

Plot the enthalpy change for the combustion of 1 g against the number of carbon atoms in the alkanes in **Table 2.**

Draw a best fit line and use this to estimate the enthalpy change for combustion of 1 g of propane.
Write your answer in **Table 2.**

[3 marks]



0 4 . 5 Isooctane (2,2,4-trimethylpentane) is an important component of petrol used in cars.

When isooctane is burned, the enthalpy change is -47.8 kJ g^{-1}

Isooctane is a liquid at room temperature with a density of 0.692 g cm^{-3}

Calculate the heat energy released, in kJ, when 1.00 dm^3 of isooctane burns in excess oxygen.
Give your answer to the appropriate number of significant figures.

[2 marks]

Heat energy released _____ kJ

9

Question	Marking Guidance	Mark	Comments
04.1	$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$	1	allow fractions / multiples allow any correct structural representation of molecules ignore state symbols
04.2	**M1** working that leads to n = 13 **M2** $C_{13}H_{28}$	1 1	e.g. –6650 = –(496**n** + 202) and/or 496**n** = 6650 – 202 and/or 496**n** = 6448 (**n** = 13) $C_{13}H_{28}$ scores **M1** and **M2** if some correct working shown $C_{13}H_{28}$ with no working scores **M2** only allow error carried forward for **M2** for a correct formula of an alkane from the value of **n** worked out for **M1** (but there must be some working shown leading to this incorrect value of **n**); for example, allow $C_{14}H_{30}$ if error in **M1** stemming from error in rearranging equation
04.3	Idea that • alkane is not gaseous or • equation relates to gaseous alkanes or • it takes energy to convert it into a gas or • that water/alkane/substances are gaseous in calculations using bond enthalpies	1	ignore references to heat loss, incomplete combustion, loss of evaporation, not being in standard conditions or that it is not standard state

Question	Marking Guidance	Mark	Comments
04.4	**M1** plotting the <u>four</u> values correctly (allow one error where point is ±1 square out) **M2** smooth best fit <u>curve</u> **M3** value from their best fit line for 3 C atoms (allow ± 1 square)	1 1 1	If plotted points for wrong number of C atoms for two or more compounds, cannot score **M1** or **M2**, but could score **M3** if read value off for 3C atoms **M2** best fit curve for their <u>four</u> points for the correct number of C atoms **M3** need – sign (but ignore units); cannot score **M**3 unless there is a line on the graph
04.5	**M1** mass of isooctane = 692 (g) **M2** 3.31×10^4 or 33100 (kJ) (**<u>3sf only</u>**)	1 1	correct answer scores **M1** and **M2** **M2** correct value to incorrect number of sig figs is 1 mark; ignore sign ; no error carried forward for **M2**

0 3 This question is about enthalpy changes.

0 3 . 1 When ethanoic acid reacts with sodium hydroxide, the enthalpy change, ΔH, is -56.1 kJ mol^{-1}

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$$

Calculate the temperature rise when 25 cm^3 of 2.0 mol dm^{-3} aqueous ethanoic acid react with 25 cm^3 of 2.0 mol dm^{-3} aqueous sodium hydroxide.

Assume that both solutions have the same initial temperature, have a density of 1.0 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}

[4 marks]

Temperature rise _____ °C

0 3 . 2 A student recorded the temperature of aqueous ethanoic acid in a polystyrene cup for three minutes.

At the fourth minute, the student added sodium hydrogencarbonate.

The student stirred the mixture and carried on recording the temperature every minute for several minutes.

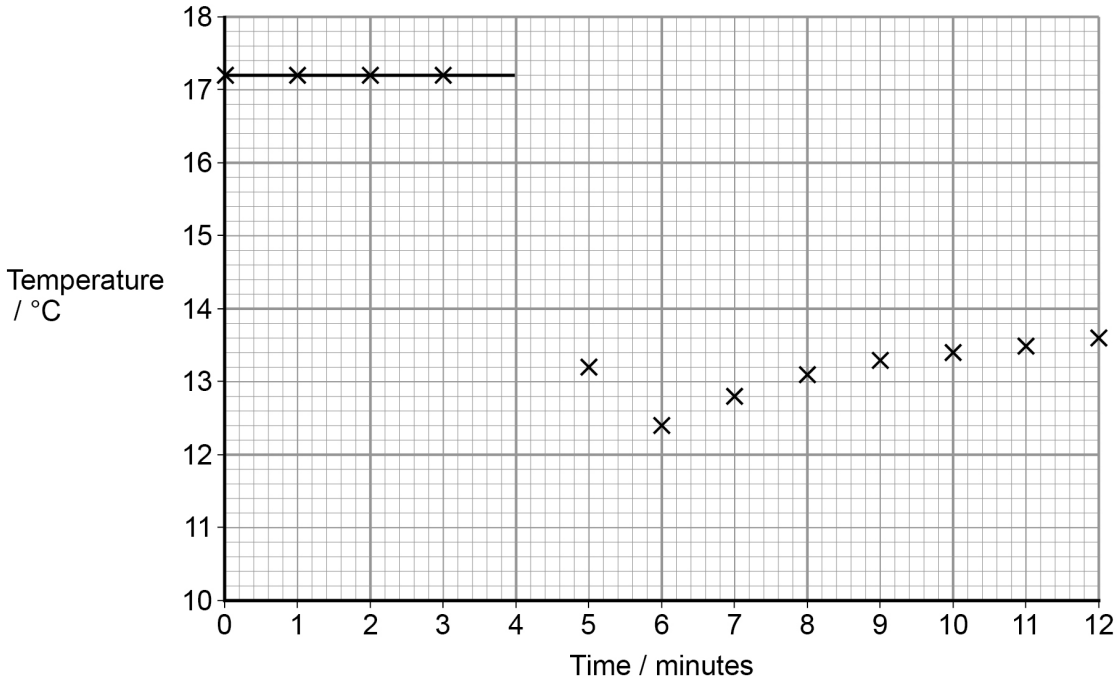
The student's measurements are shown in **Figure 2**.

A best-fit line showing the temperature before mixing has been drawn.

Draw an appropriate best-fit line on **Figure 2** and use it to find the temperature change at the time of mixing.

[2 marks]

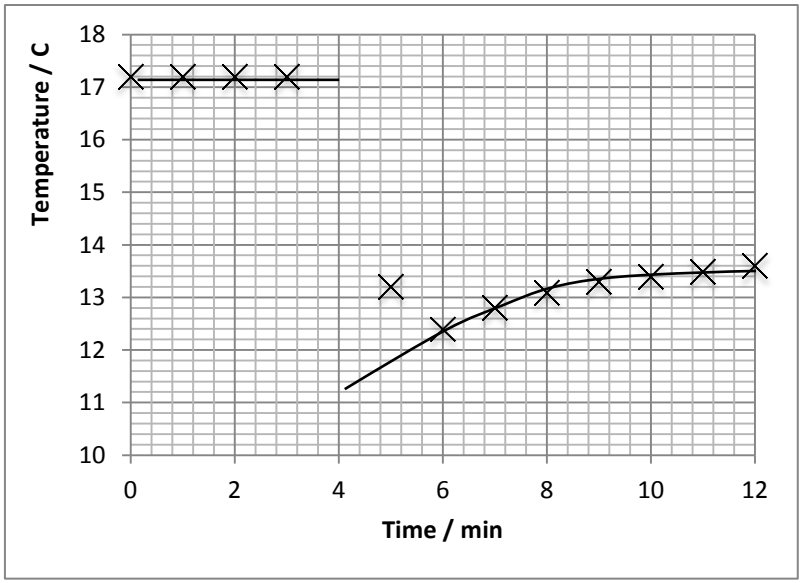
Figure 2



Temperature change at time of mixing _____ °C

6

Question	Marking Guidance	Mark	Comments
3.1	**M1** moles (= $\frac{25}{1000}$ x 2.0) = 0.050 **M2** heat released = 0.050 x 56.1 (= 2.805 kJ or 2805 J) **M3** $\Delta T = \frac{q}{mc}$ **M4** $\Delta T = \frac{2805}{50 \times 4.18}$ or $\frac{1000 \times 0.050 \times 56.1}{50 \times 4.18}$ = 13(.4) (°C)	1 1 1 1	Correct answer (to at least 2 sig fig) scores 4 marks 27 or 26.8°C (from moles of two reagents being added together for **M2**, or use of 25 cm^3 in **M4**) scores 3 marks 0.013(.4)°C (from not converting kJ to J) scores 3 marks (loses **M4**) [0.027 or 0.0268°C would score 2 marks (loses **M2** and **M4**) **M1** moles can be shown for either substance or without specifying the substance; if it is shown for both substances, must be correct for both for **M1** Allow ECF from **M1** to **M2** Allow ECF from **M2** to **M4** (providing an attempt to calculate q has been made – no ECF if 56100 or 56.1 is used as q) Correct **M4** scores **M3**. If error made in **M4**, **M3** could score from substituted values in this expression in **M4** **M4** final answer to at least 2 sig fig. Penalise **M4** for negative temperature rise

3.2	**M1** draws suitable best fit curve to 4 minutes  **M2** **(**17.2 – value read from graph line at 4 minutes) ± 0.2 (°C)	1 1	**M1** line must be a curve and ignore value at 5 minutes **M1** line should not go to times before 4 minutes **M2** allow use of any curved or straight line that is an attempt to draw a line through the values after 4 minutes (that may include the point at 5 minutes) **M2** allow negative values

Do not write outside the box

0 3 This question is about enthalpy changes.

0 3 . 1 A student determined the enthalpy of combustion of cyclohexane (C_6H_{12}).

The student
- placed a pure sample of cyclohexane in a spirit burner
- placed the spirit burner under a beaker containing 50.0 g of water and ignited the cyclohexane
- extinguished the flame after a few minutes.

The results for the experiment are shown in **Table 1**.

Table 1

Initial temperature of the water / °C	19.1
Initial mass of spirit burner and cyclohexane / g	192.730
Final mass of spirit burner and cyclohexane / g	192.100

The student determined from this experiment that the enthalpy of combustion of cyclohexane is –1216 kJ mol^{-1}

Use the data to calculate the final temperature of the water in this experiment.

The specific heat capacity of water = 4.18 J K^{-1} g^{-1}
The relative molecular mass (M_r) of cyclohexane = 84.0

[4 marks]

Do not write outside the box

Final temperature of the water _____ °C

0 3 . 2 A data book value for the enthalpy of combustion of cyclohexane is –3920 kJ mol^{-1}

The student concluded that the temperature rise recorded in the experiment was smaller than it should have been.

Suggest a practical reason for this.

[1 mark]

_____

_____

_____

Question 3 continues on the next page

0 3 . 3 **Table 2** gives some values of standard enthalpies of combustion ($\Delta_c H^{\ominus}$).

Table 2

Substance	C(s)	$H_2(g)$	$C_6H_{12}(l)$
Standard enthalpy of combustion, $\Delta_c H^{\ominus}$ / kJ mol^{-1}	–394	–286	–3920

Use the data in **Table 2** to calculate the enthalpy change for the reaction represented by this equation

$$6\,C(s) + 6\,H_2(g) \rightarrow C_6H_{12}(l)$$

[3 marks]

Enthalpy change _____ kJ mol^{-1}

8

Question	Marking guidance	Additional Comments/Guidelines	Mark
03.1	**M1** moles cyclohexane = $\frac{192.730-192.100}{84(.0)}$ or $\frac{0.630}{84(.0)}$ (= 0.00750) **M2** heat released = 1216 x 1000 x 0.0075 (= 9120) (J) [or 1216 x 0.0075 = (9.12) (kJ)] **M3** $\Delta T \left(= \frac{q}{mc} = \frac{9120}{50(.0)\text{x } 4.18}\right)$ = 43.6 **M4** final temperature = 19.1 + **M3** = 62.7 or 63 (°C) Alternative **M3/4** **M3** 9120 = 50 x 4.18 x (Final T – 19.1) **M4** Final T = 62.7 or 63 (°C)	Correct answer scores 4 marks 0.0075 scores **M1** with or without working 9120 or 9.12 scores **M1** and **M2** with or without working allow ECF at each stage correct **M3** scores **M1** and **M2** ignore negative sign for q in **M2** and/or ∆T in **M3**, but penalise if used as a temperature fall in **M4** (if alternative method used for **M3/4** and negative value for q is used, allow **M3** for expression with negative q value but do not allow **M4**) (temperatures to at least 2sf) If candidates use a value in kJ rather than J to find ∆T / final T then they lose **M3**, but ECF to **M4** [e.g. 9.12 rather than 9120 giving ∆T = 0.0436 and final temperature = 19.1(436) – this would give 3 marks] If candidates use 0.63 g for m in **M3**, they will get ∆T = 3.46 and final temperature = 22.56 – this would give 3 marks] Cannot score **M2** using moles = 1	1 1 1 1

03.2	thermal energy / heat loss or incomplete combustion or evaporation	or idea of heat being transferred to calorimeter allow idea that it is not under standard conditions allow no lid / poor/no insulation	1

03.3	**M1** 6 x (–394), 6 x (–286) and –3920 **M2** **(**ΔH =) [6 x (–394)] + [6 x (–286)] + 3920 (or (ΔH **=**) [–2364)] + [–1716)] + 3920) (or (ΔH **=**) –4080 + 3920) **M3** = –160 (kJ mol^{-1})	–160 scores 3 marks; +160 scores 2 marks –8000 scores 2 marks; +8000 scores 1 mark –1876 scores 2 marks; +1876 scores 1 mark **M1** is for correct coefficients, i.e. 6 x Δ_cH H_2 & 6 x Δ_cH C & 1 x Δ_cH C_6H_{12} (ignore whether + or –) ECF from **M1** to **M2/3** for incorrect coefficients / arithmetic error / transposition ECF from **M2** to **M3** for use of products – reactants Ignore any cycle	1 1 1

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 This question is about 1-chloropropane.

0 1 . 1 Define the term standard enthalpy of formation.

[2 marks]

0 1 . 2 The equation for a reaction used to manufacture 1-chloropropane is

$$3\,CH_3CH_2CH_2OH(l) + PCl_3(l) \rightarrow 3\,CH_3CH_2CH_2Cl(l) + H_3PO_3(s)$$

The enthalpy change for this reaction, ΔH, is –114 kJ mol^{-1}

Table 1 contains some standard enthalpy of formation data.

Table 1

Substance	$PCl_3(l)$	$CH_3CH_2CH_2Cl(l)$	$H_3PO_3(s)$
$\Delta_f H^{\ominus}$ **/ kJ mol^{-1}**	–339	–130	–972

Calculate a value for the standard enthalpy of formation of propan-1-ol using the enthalpy change for the reaction and data from **Table 1**.

[3 marks]

Standard enthalpy of formation _____ kJ mol^{-1}

Question	Marking guidance	Additional Comments/Guidelines	Mark
01.1	**M1** The <u>enthalpy / heat energy change</u> when 1 mol (of a substance / compound / product) is formed from its (constituent) elements **M2** with (all) reactants and products / <u>all</u> substances in standard states	**M1** energy change is not sufficient – must refer to enthalpy change or heat energy change **M2** or with (all) reactants and products / substances in normal states under standard conditions / 100 kPa and any specified temperature (usually 298 K) Ignore reference to 1 atmosphere If enthalpy of combustion given rather than formation, then mark **M1** and **M2** independently, and **M2** could score.	1 1
01.2	**M1** ΔH = [sum $\Delta_f H$ products] – [sum $\Delta_f H$ reactants] **or** –114 = [3(–130) – 972] – [3X – 339] **or** 3X = 3(–130) – 972 + 339 + 114 **M2** 3X = –909 **M3** X = –303 (kJ mol^{-1})	–303 scores 3 marks (+303 scores 2 marks) –909 scores 2 marks (+909 scores 1 mark) ignore units **M2** No ECF from **M1 (**except +909 or arithmetic error) **M3** ECF from **M2**, ie **M3** ÷ 3	1 1 1

Do not write outside the box

0 7 This question is about combustion.

0 7 . 1 State the meaning of the term standard enthalpy of combustion.

[2 marks]

0 7 . 2 A student does an experiment to determine the enthalpy of combustion of propan-1-ol ($CH_3CH_2CH_2OH$, M_r = 60.0).
Combustion of 0.497 g of propan-1-ol increases the temperature of 150 g of water from 21.2 °C to 35.1 °C

Calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of propan-1-ol in this experiment.

The specific heat capacity of water is 4.18 J K^{-1} g^{-1}

[3 marks]

Enthalpy of combustion _____ kJ mol^{-1}

Do not write outside the box

0 7 . 3 The enthalpy of combustion determined experimentally is less exothermic than that calculated using enthalpies of formation.

Give **one** possible reason for this, other than heat loss.

[1 mark]

6

Turn over for the next question

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.1	Enthalpy change when one mole of a substance burns completely in oxygen With all substances in their standard states (at stated temperature and 100kPa)	Allow heat energy change / allow fully combust	1 1

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.2	$q = m\ c\ \Delta T = 150 \times 4.18 \times 13.9 = 8715.3$ J n(propan-1-ol)= $\frac{0.497}{60.0} = 0.00828$ mol $\Delta H = -\frac{8.7153}{0.00828} = -1050$ kJ mol^{-1}	 M3 = – M1×10^{-3}/M2 Minimum of 2 sf needed Must be negative	1 1 1

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.3	Incomplete combustion	Evaporation of fuel Experiment not completed under standard conditions	1

Do not write outside the box

0 8 This question is about enthalpy changes.

0 8 . 1 Define the term enthalpy change.

[1 mark]

0 8 . 2 Propane undergoes complete combustion.

$$C_3H_8(g) + 5\,O_2(g) \longrightarrow 3\,CO_2(g) + 4\,H_2O(l) \qquad \Delta H = -2046\ kJ\ mol^{-1}$$

Table 3 shows some bond enthalpy data.

Table 3

Bond	C–H	C=O	O–H
Mean bond enthalpy / kJ mol^{-1}	412	743	463

The bond enthalpy for O=O is 496 kJ mol^{-1}

For $H_2O(l) \longrightarrow H_2O(g)$ $\Delta H = +41$ kJ mol^{-1}

Use these data to calculate a value for the C–C bond enthalpy in propane.

[4 marks]

C–C bond enthalpy _____ kJ mol^{-1}

Do not write outside the box

0 8 . 3 Explain why the value given for the O=O bond enthalpy in Question **08.2** is **not** a mean value.

[1 mark]

6

Turn over for Section B

Question	Marking guidance	Additional Comments/Guidelines	Mark
08.1	Heat (energy) change at constant pressure	allow transfer for change	1
08.2	**M1** correctly showing how many of which types of bonds are broken / made (broken) 2(C–C) + 8(C–H) + 5(O=O) *(5776 + 2(C-C))* (made) 6(C=O) + 8(O–H) *(8162)* **M2** including 4(41) for vaporisation of water **M3** 2(C–C) **=** 6(C=O) + 8(O–H) + 4(41) – 2046 – 8(C–H) – 5(O=O) = 6(743) + 8(463) + 4(41) – 2046 – 8(412) – 5(496) = 504 **M4** (C–C) = $\frac{\mathbf{M3}}{\mathbf{2}}$ = 252 (kJ mol^{-1})	252 scores 4 170 scores 3 (omits vaporisation of water) 168 scores 3 (3 C-C bonds) 113 scores 2 (3 C-C bonds & omits vaporisation of water) 88 scores 3 (vaporisation of water on wrong side) **M1** is for identifying the number and type of bonds broken / made (does not have to explicit if they are broken or made, it is just which bonds and the number of each) **M2** is for including 4(41) in some way in the calculation **M3** is for calculating total for C-C bonds; allow 340 for 2 marks for omitting 4(41) **M4** is for dividing their **M3** by two (ie allow ECF from **M3** to **M4**; ECF for 3(C-C) to divide their **M3** by three) Ignore units	1 1 1 1
08.3	Oxygen / O_2 is the only substance that has O=O bond		1

Do not write outside the box

0 7 . 3 **Table 2** shows the enthalpies of combustion of the three fuels from the fermentation of silverskin.

Table 2

Fuel	**Standard enthalpy of combustion / kJ mol^{-1}**	**Energy released per mole of CO_2 produced / kJ**
ethanol, $C_2H_5OH(l)$	–1371	
butan-1-ol, $C_4H_9OH(l)$	–2673	
propanone, $C_3H_6O(l)$	–1786	

One way to measure a fuel's environmental impact is to measure the amount of energy released per mole of CO_2 produced.

Complete **Table 2**.

Use your answers to deduce the fuel with the lowest environmental impact by this measure.

[2 marks]

Question 7 continues on the next page

Do not write outside the box

0 7 . 4 A student investigated the combustion of propanone (C_3H_6O) using calorimetry.

A copper calorimeter containing water was heated by the complete combustion of some propanone. The student did not record the final temperature of the water.

Table 3 shows the student's results.

Table 3

Mass of propanone burned / g	1.18
Mass of water / g	260
Initial temperature of water / °C	22.3
Final temperature of water / °C	Not recorded

Use the results in **Table 3** to calculate a value for final temperature of the water in the experiment.

Assume that no heat was lost in the experiment and that the heat capacity of the calorimeter is negligible.

For propanone, enthalpy of combustion = –1786 kJ mol^{-1}

For water, specific heat capacity = 4.18 J g^{-1} K^{-1}

[4 marks]

Final temperature of water _____ °C

Do not write outside the box

0 7 . 5 Butan-1-ol can be added to petrol for cars.

An equation for the complete combustion of gaseous butan-1-ol is shown.

$$C_4H_9OH(g) + 6\,O_2(g) \rightarrow 4\,CO_2(g) + 5\,H_2O(g) \quad \Delta H = -2504 \text{ kJ mol}^{-1}$$

Table 4 shows some mean bond enthalpy data.

Table 4

Bond	C=O	C–H	C–O	O–H	O=O
Mean bond enthalpy / kJ mol^{-1}	805	412	360	463	496

Use these data to calculate a value for the mean C–C bond enthalpy in gaseous butan-1-ol.

[3 marks]

C–C bond enthalpy _____ kJ mol^{-1}

Question 7 continues on the next page

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.3	**M1** 685.5 (686), 668(.25), 595(.33…) in third column of table **M2** depends on their answer to **M1** – must be the compound giving most energy per mole of CO_2 released (correct **M1** would give ethanol)	**M1** ignore any minus sign on values **M2** need evidence of attempt to calculate energy released per C atom (i.e. per mole of CO_2 formed)	1 1 (2 x AO3)
07.4	**M1** amount propanone $= \frac{1.18}{58.0}$ (= 0.0203 mol) **M2** q = **M1** x 1786 (= 36.3 kJ = 36300 J) **M3** $\Delta T \left(= \frac{q}{mc} = \frac{\textbf{M2 (in J)}}{260 \times 4.18}\right)$ = 33.4 (°C) (allow 32.8-33.4) **M4** final temperature = (22.3 + **M3**) = 55.7 (°C) (allow 55-56)	Correct answer scores 4 marks Allow ECF at each stage **M3** ignore sign **M4** must show a temperature rise	1 1 1 1 (4 x AO2)

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.5	**M1** correctly showing how many of which types of bonds are broken and made (broken) 3(C-C) + 9(C-H) + (C-O) + (O-H) + 6(O=O) (made) 8(C=O) + 10(O-H) **M2** (bonds broken) – (bonds made) = –2504 7507 + 3(C-C) – 11070 = –2504 3(C–C) = 1059 **M3** (C–C) = $\frac{\text{M2}}{3}$ = 353 (kJ mol^{-1})	Correct answer scores 3 marks; 265 scores 2 marks if from 4(C-C) bonds 1188 scores 2 marks (not included –2504) 2022 scores 2 marks (using (made – broken)) –353 scores 2 marks ±834 scores 2 marks (use of C-O in CO_2) ±836 scores 1 marks (use of C-O in CO_2 and using (made – broken)) **M1** could show broken as: 3(C-C) + 9(412) + (360) + (463) + 6(496) or 7507 + 3(C-C) and, could show made as 8(805) + 10(463) or 11070 **M2** Allow ECF from **M1** to **M2** Ignore incorrect number of C-C bonds in **M1/2**, but should be 3 for **M3** **M3** Allow ECF from **M2** to **M3** (if **M2** is negative value, then ignore sign for **M3**)	1 1 1 (3 x AO2)