1. 100 cm^3 of a solution of 1 mol/dm^3 sodium hydroxide is added to 100 cm^3 of a solution of 1 mol/dm^3 hydrochloric acid.

The maximum rise in temperature recorded was T_1.

The experiment is repeated with 50 cm^3 of each solution.

The maximum rise in temperature recorded was T_2.

Which of these statements about temperatures T_1 and T_2 is true?

A T_1 is equal to T_2
B T_1 is half the value of T_2
C T_2 is half the value of T_1
D T_2 is a quarter the value of T_1

Your answer ☐

[1]

2. Hydrogen reacts with fluorine to make hydrogen fluoride.

$$H—H + F—F \rightarrow 2H—F$$

Look at these bond energies.

Bond	Bond energy in kJ/mol
H—H	436
F—F	142
H—F	568

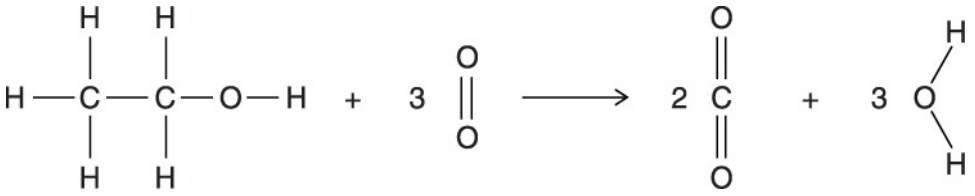
What is the energy change for the reaction between hydrogen and fluorine?

A –558 kJ/mol
B –10 kJ/mol
C +10 kJ/mol
D +558 kJ/mol

Your answer ☐

[1]

3. Look at the equation for the burning of ethanol.



During the reaction, bonds are broken and new bonds are made.

(i) Complete the sentence.

Choose words from this list.

absorbed

destroyed

magnified

neutralised

released

When bonds are broken, energy is _____ [1]

(ii) Complete the sentence.

Choose words from this list.

catalytic

continuous

endothermic

exothermic

limiting

Making new bonds is _____ [1]

4(a). Soldiers use ‘flameless heaters’ to heat their meals.

The ‘flameless heater’ heats the food safely and quickly without using a flame.

The heater uses a chemical reaction between magnesium metal and water.

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$

Look at the equation.

Write down the formula for one **reactant** in this reaction.

---

[1]

(b). The reaction is **exothermic**.

What is meant by an exothermic reaction?

---

[1]

(c). A scientist is trying to improve the ‘flameless heaters’ so that they heat the food more quickly.

Look at her results.

Heater	Temperature rise in the heater in °C	Time taken in minutes
A	40	8
B	42	7
C	24	6
D	50	10

Which heater heats up quickest?

Explain your answer using the temperature rise and time taken.

---

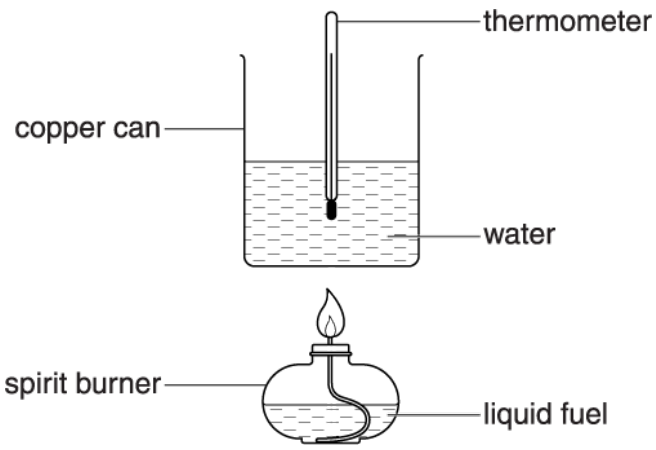
[2]

5(a). Mike wants to find a fuel to heat his garden shed.

He decides to investigate the energy given out by four different fuels.

Look at the diagram.

It shows the apparatus Mike uses.



Look at the table. It shows Mike's results.

Fuel	Temperature at start in ° C	Temperature at end in ° C	Mass of fuel burned in grams
A	18	38	1.1
B	22	42	0.9
C	16	36	0.6
D	25	45	0.7

Look at the results for fuel **C**.

Mike calculates that fuel **C** transfers **4200 J** of energy to the water.

Use the equation

energy = mass × specific heat capacity × temperature change

to calculate the **mass of water** that Mike used in his experiment.

The specific heat capacity of water is 4.2 J / g °C.

---

answer _____ g **[2]**

(b). Burning fuels is an **exothermic** reaction.

Explain, in terms of bonds between atoms, why burning fuels is an exothermic reaction.

---

[3]

6. Megan is investigating the energy given out by four different liquid fuels.

She wants to compare the energy transferred when 1.0 g of each fuel is burned.

Look at her table of results.

Fuel	Temperature of water at start in °C	Temperature of water at end in °C	Mass of fuel burned in g	Energy transferred to the water in J
A	19	44	0.6	7875
B	21	41	1.2	6300
C	18	48	1.8	9450
D	20	46	1.0	8190

Megan knows that the energy transferred is related to the mass of water used.

energy transferred = mass × specific heat capacity × temperature change

The specific heat capacity of water is 4.2 J/g°C.

In each experiment Megan uses the same mass of water.

Megan decides that fuel **D** is the best fuel to use in a camping stove.

Is she correct?

Use the results from Megan's experiments to explain your answer.

---

[2]

7. When hydrochloric acid reacts with magnesium hydroxide bonds are broken.

What type of process is bond breaking?

Choose from the list.

batch

catalytic

continuous

endothermic

exothermic

[1]

8. When fuels burn, energy is given out as heat.

What is the name of the type of reaction that gives out heat?

Choose from the list.

catalysed

continuous

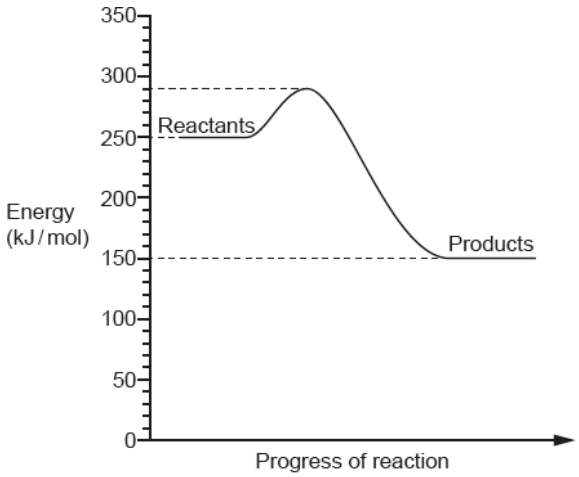
endothermic

exothermic

answer _____

[1]

9. The diagram shows a reaction profile.



What is the energy change of the reaction?

A +40 kJ / mol

B –100 kJ / mol

C +140 kJ / mol

D –140 kJ / mol

Your answer [1]

10(a)

. A student adds 5 cm^3 of hydrochloric acid (HC*l*) to 55 cm^3 of sodium hydroxide (NaOH).

He measures the highest temperature reached during the reaction.

He also measures the pH at the end of the reaction.

He repeats this experiment three times and works out the mean temperature.

He then repeats the experiment with different volumes of hydrochloric acid and sodium hydroxide.

Look at his results.

Experiment	Volume of HC*l* (cm^3)	Volume of NaOH (cm^3)	Highest temperature reached during reaction (°C)				pH at the end of the reaction
			1	2	3	Mean	
A	10	50	29.3	30.6	30.7	30.2	12.0
B	20	40	34.5	35.3	35.2	35.0	7.8
C	30	30	37.3	37.6	36.7	37.2	7.0
D	40	20	34.3	35.5	34.6		6.3

(i) Calculate the mean temperature for experiment **D**.

Answer = ---------- °C **[1]**

(ii) Describe the pattern of the highest temperature reached for experiments **A** to **C**.

---**[1]**

(iii) Describe the pattern of pH at the end of the reaction for experiments **A** to **D**.

---

[1]

(iv) How could the student measure the pH?

---

[1]

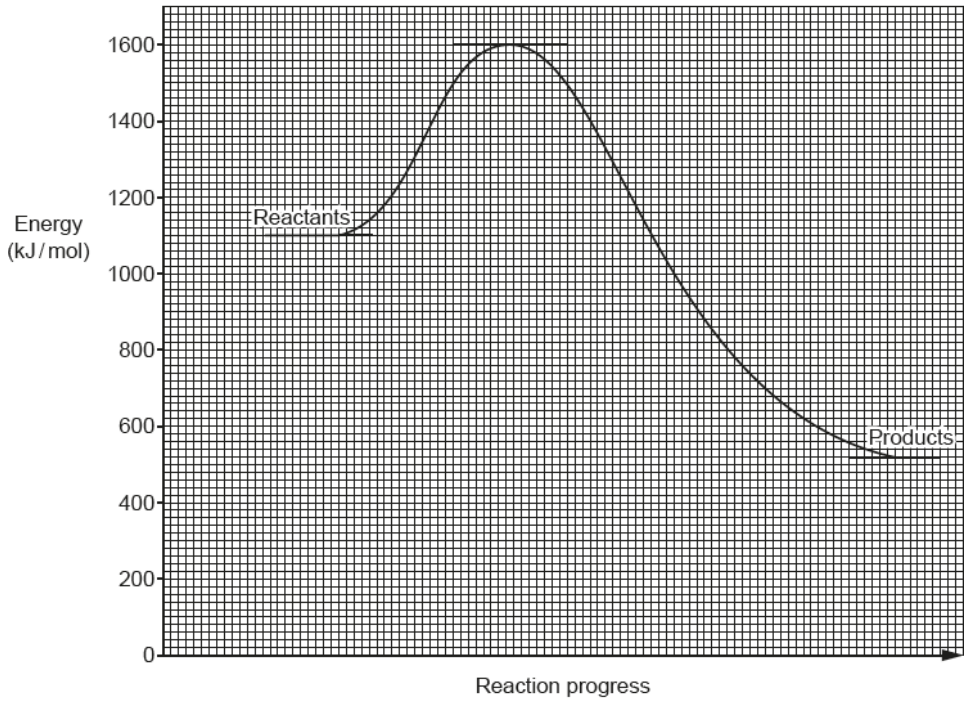
(b). What conclusion can you draw from the student's experiments?

---

[1]

11(a)

. The graph below shows the energy changes during a chemical reaction.



(i) Draw an arrow on the graph to show the **activation energy**.

Label your arrow **A**. **[1]**

(ii) Draw another arrow on the graph to show the overall **energy change** in the reaction.

Label your arrow **E**. **[1]**

(b). The reaction in the graph is **exothermic**.

Explain why. Use ideas about bonds.

---

[2]

(c). Hydrogen burns in oxygen to form water.

Look at the equation for the reaction.

$2H_2 + O_2 \rightarrow 2H_2O$

Bond	Average bond energy (kJ / mol)
H – H	436
H – O	464
O = O	498

Calculate the **energy change** for this reaction.

Use the average bond energies shown in the table.

Answer = ---------- kJ / mol **[3]**

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			A	1	
			Total	**1**	
2			A	1	
			Total	**1**	
3		i	absorbed (1)	1	**allow** other ways of showing answer e.g. word ticked or circled but answer in sentence takes precedence **Examiner's Comments** Few candidates correctly completed the sentence 'When bonds are broken, energy is absorbed'.
		ii	exothermic (1)	1	**allow** other ways of showing answer e.g. word ticked or circled but answer in sentence takes precedence **Examiner's Comments** The majority of candidates correctly completed the sentence 'Making new bonds is exothermic'.
			Total	**2**	
4	a		Mg / H_2O (1)	1	**any incorrect formula is zero** **allow** $2H_2O$ / Mg + H_2O / Mg + $2H_2O$ **allow** correct answer ticked, circled or underlined in equation if answer line is blank **ignore** magnesium and water **Examiner's Comments** Most candidates did not score here. If they could identify a reactant they usually named it rather than giving the formula. Of those that got it correct, Mg was much a more common response than H_2O.

Question			Answer/Indicative content	Marks	Guidance
	b		energy given out or heat given out (1)	1	**allow** temperature increase **allow** heat or energy produced / made / exits / released **allow** energy or heat is lost (limit of acceptability) **ignore** gives more energy **NOT** energy or heat is created **Examiner's Comments** Many candidates knew this, or if not, left it blank.
	c		B (1) largest temperature rise per minute (1)	2	**allow** all correct calculations of temperature rise per minute in table (A ? 5°/min; B ? 6°/min; C ? 4°/min; D ? 5°/min) **Examiner's Comments** Of the candidates that scored on this question many candidates got B but few gave the correct reason. Those that got the second mark normally got it for a correct column of numbers against the table, but most struggled to manipulate data to make a comparison.
			Total	4	

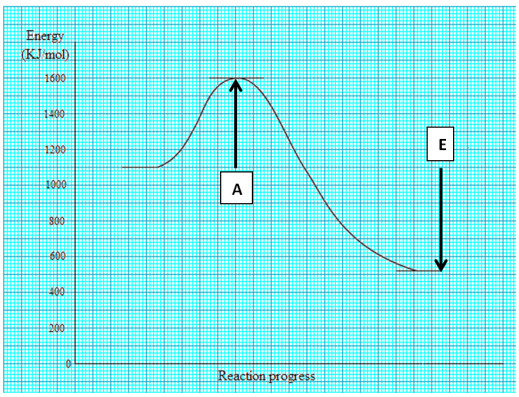
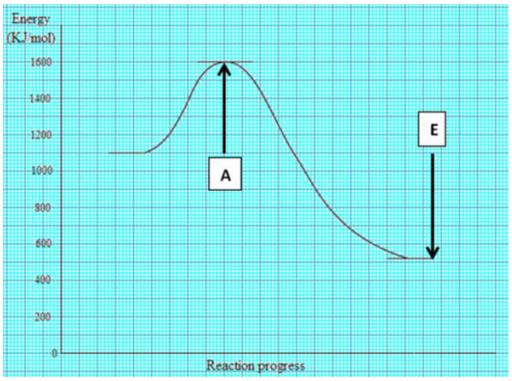
Question			Answer/Indicative content	Marks	Guidance
5	a		50(g) scores (2) **but** mass = $\frac{4200}{4.2 \times 20}$ **or** mass = $\frac{4200}{84}$ scores (1) **or** mass = $\frac{\text{energy}}{\text{specific heat capacity x temp change}}$ (1)	2	look for correct answer first, 50(g) on own scores (2) but also check for correct working if included not 50.4 (g) unit not needed Examiner's Comments About a third of candidates correctly calculated the mass of water in this question. The most common incorrect answer was 50.4g. This was invariably arrived at by multiplying 0.6 (mass of fuel C) by 4.2 (specific heat capacity) and by 20 (temperature change). These candidates did not understand the need to rearrange the equation and use the value of 4200J as the energy transferred when 0.6g of fuel C burns.
	b		idea that bond breaking is endothermic (1) idea that bond making is exothermic (1) more energy is given out (in bond making) than is taken in (in bond breaking) (1)	3	allow bond breaking absorbs energy (1) allow bond making releases energy (1) allow more energy released than absorbed (1) ignore references to different numbers of bonds, eg more bonds made than broken not references to intermolecular bonds allow exothermic reactions give out energy or heat (1) if no other mark awarded Examiner's Comments This question was targeted up to A* and was poorly answered with few candidates able to describe the energy changes involved in making and breaking bonds. Where 1 mark was scored, it was usually the catch mark for recognising that exothermic reactions transfer heat to the surroundings.
			Total	5	

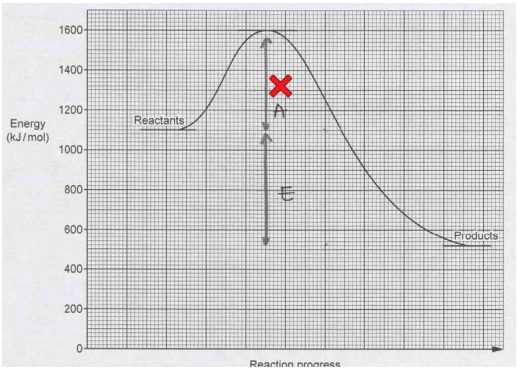
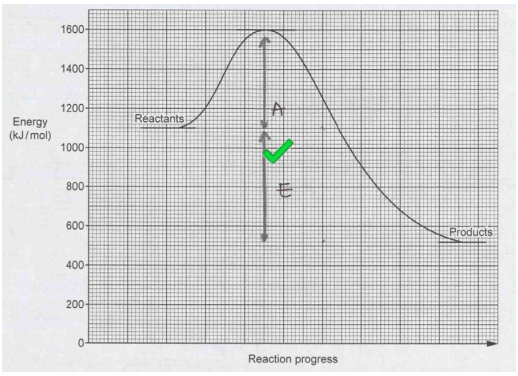
Question			Answer/Indicative content	Marks	Guidance
6			(no) no marks fuel **A** transfers more energy **per gram** (1) fuel **A** transfers 13125 (J/g) (1) **but** fuel **A** transfers 13125 (J/g) but fuel **D** only transfers 8190 (J/g) (2)	2	**if yes then no marks** **allow** fuel **A** increases the temperature more **per gram** (1) Examiner's Comments Candidates also found this question challenging. They needed to use all the results from the experiment but many did not consider the energy per gram of fuel. A few candidates realised that only a small amount of A had to be burned to give a large amount of energy. Candidates who identified A and then calculated the correct energy per gram also calculated the energy per gram of all the fuels. Answer C was a common incorrect answer, because candidates noticed that it gave out the most energy and biggest temperature rise, without realising that a lot of fuel was burned to achieve this.
			Total	2	
7			endothermic (1)	1	**allow** correct answer ticked, circled or underlined in list if answer line is blank Examiner's Comments The majority of candidates identified correctly the bond breaking process as endothermic, although exothermic and catalytic were common incorrect answers.
			Total	1	

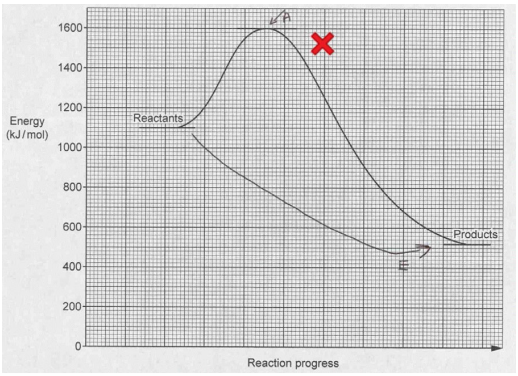
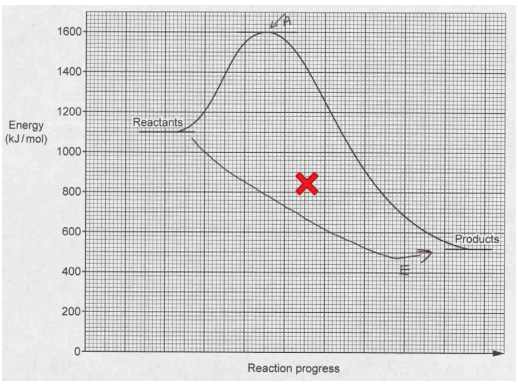
Question			Answer/Indicative content	Marks	Guidance
8			exothermic (1)	1	**allow** correct answer ticked circled or underlined in list if answer line is blank Examiner's Comments ??This was another high scoring question, possibly as a result of exothermic being the most common type of reaction candidates meet. Surprisingly, catalysed was a common error, possibly due to familiarity with the word.
			Total	1	
9			B ✓	1 (AO2.1)	ALLOW -100 Examiner's Comments Some candidates correctly answered B, but C and D were the main wrong choices.
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
10	a	i	34.8 (oC) ✓	1 (AO2.1)	ALLOW answer written in the table. Examiner's Comments Most candidates were able to calculate the mean of 34.8 correctly but a few made mathematical errors. A small number appeared to have just guessed.
		ii	The temperature increases (from experiment A to C / as volume of HC*l* increases / as volume of NaOH decreases / as pH decreases) ✓	1 (AO3.1a)	DO NOT ALLOW any other qualification e.g. the temperature increase from 1 to 3 Examiner's Comments Candidates gained the mark by stating that the temperature increased. However, the more they wrote the more likely they were to lose the mark for qualifying their answer incorrectly e.g. the temperature increased as the volume of hydrochloric acid ***and*** sodium hydroxide increased. Others just gave an observation from the table rather than a pattern e.g. A had the highest temperature. Some candidates were confused because there were three repeats in the table. A few misread the question and described the pattern from A to D rather than A to C.
		iii	(pH) decreases (as the volume of HC*l* increases / as the volume of NaOH decreases / as the ratio of HC*l* to NaOH increases) / ORA ✓	1 (AO3.1a)	Examiner's Comments Most candidates gained the mark by stating that pH decreased, but others who tried instead to describe the change from alkalinity to acidity got confused. A few did not gain the mark because they qualified their answer incorrectly in a similar way to question 16(b)(ii). More candidates gained credit in this question than the previous one as there was only one set of pH data, unlike temperature.

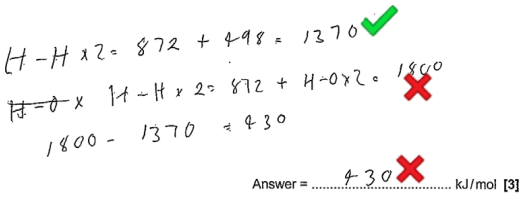
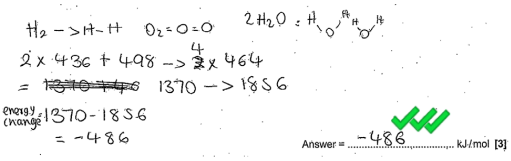
Question			Answer/Indicative content	Marks	Guidance
		iv	Use of universal indicator (solution / paper) ✓ OR reference to pH meter / probe ✓	1 (AO1.2)	DO NOT ALLOW use of litmus paper or other indicators IGNORE universal (on its own) Examiner's Comments A few candidates gained the mark for knowing that pH was measured using universal indicator, but some used a pH probe or meter. Some lost credit by including litmus as well as universal indicator. The most common incorrect answer was to use a pH scale. Other incorrect answers included litmus, using a ruler, adding acid or merely looking at the colour of the solution.
	b		Any one from: The largest temperature rise occurred at pH 7 (neutral) ✓ The largest temperature rise occurred when the volume of HCl and NaOH are equal ✓ The final solution is neutral when the volume of HCl and NaOH are equal ✓ The mixture becomes acidic when more than 30 cm3 HCl is added ✓ The temperature drops again after it has become neutral ✓ It is an exothermic reaction ✓ Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.	1 (AO3.2b)	ALLOW any correct conclusion including any valid pattern (please refer to table). IGNORE balanced amounts of solution Examiner's Comments Candidates could score the mark for a wide variety of valid conclusions drawn from the table of data. However, a lot of candidates did not seem to understand what a conclusion was, so just gave an observation or quoted data from the table. Many gained credit by just repeating the answer they had given in questions 16(b)(ii) or (iii). A common wrong answer was that as temperature increased pH decreased, as candidates had not spotted that temperature had dropped at D. Some candidates thought that a conclusion meant that a graph or diagram should be drawn.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
11	a	i	Labelled arrow (activation energy / A) from 1100 to 1600 ✓  	1 (AO 2.1)	**ALLOW** +/- 1 small square **ALLOW** label of E_A for activation energy <u>Examiner's Comments</u> Candidates struggled to accurately draw an arrow to describe the activation energy. Arrows were often drawn diagonally, pointing to the peak of the graph or if they were drawn vertically, they were inaccurately drawn. The lines were often too short either at the top or bottom of the range. Centres should encourage candidates to carefully draw such lines in future examinations. The direction of the arrow was often incorrect with arrow heads in both directions or pointing down rather than up. For the purposes of this examination the direction of the arrow was ignored but must be correct in future examinations.
		ii	Labelled arrow (energy change / E) from 1100 to 520 ✓  	1 (AO 2.1)	**ALLOW** +/- 1 small square <u>Examiner's Comments</u> As with (a)(i) Candidates struggled to draw accurate lines. The most common errors were lines drawn diagonally or from the top of the graph to the products line rather than vertically from the reactants to products. Centres should encourage candidates to carefully draw such lines in future examinations. Accuracy of the line is important. As with (a)(i) the direction of the arrows must be correct in future examinations.

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 3   The arrow for A is poorly drawn and does not reach the peak of the graph. Only one small square margin is allowed in graphs or constructions like this so please encourage candidates to take care with graph drawing and diagrams for future examinations. The arrow heads were allowed at both sided of the line to show the difference in the energy at the 2 points identified but ideally one arrow head at the peak of the graph should be shown. For 13ai in this example the arrow gains credit as it is accurately drawn.

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 4   This was a frequently seen response, with arrows pointing at the peak and labels rather than using the graph to show the precise values.

Question			Answer/Indicative content	Marks	Guidance
	b		Bond breaking is endothermic / takes in energy **AND** bond making is exothermic / gives out energy. ✓ More energy is given out (in bond making) than is taken in (in bond breaking) ✓	2 (AO 2 × 1.1)	**ALLOW** bond breaking absorbs energy or heat **ALLOW** bond making releases energy or heat **IGNORE** references to different numbers of bonds, e.g. more bonds made than broken **DO NOT ALLOW** references to intermolecular bonds **ALLOW** exothermic reactions give out energy or heat / temperature rises / reactants have more energy than products **✓ if no other mark awarded** Examiner's Comments Only very high ability candidates gained credit here. There was almost no description of endothermic and exothermic processes related to breaking and forming of bonds. If candidates did gain credit it was for the recognition that an exothermic reaction releases energy to the surroundings. This appears well taught as well over half the candidates gained this mark.
	c		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = - 486 KJ / mol award 3 marks** (2 × 436) + 498 = 1370 ✓ 4 × 464 = 1856 ✓ 1370 – 1856 = - 486 KJ / mol ✓	3 (AO 3 × 2.2)	**ALLOW** (2 × 436) + 498 – (4 × 464) for 2 marks Examiner's Comments Candidates were generally able to calculate the energy needed to break the bonds as 1370. Fewer candidates could

Question			Answer/Indicative content	Marks	Guidance
					correctly calculate the energy released when new bonds form as 1856. The most common incorrect value was 1868. Candidates who correctly calculated these values struggled to subtract the bigger value from the smaller value to give a negative number. These compounded errors meant only the very high ability candidates 3 marks. **Exemplar 5**  The organisation of answers was generally poor. This candidate has correctly calculated the energy needed to break the bonds in H2 and O2 but has not correctly identified the bonds present in H2O. The final subtraction also is incorrect and would give a positive number rather than subtracting the energy released when new bonds form from the energy needed to break the bonds. **Exemplar 6**  This is an excellent example of where the candidate has laid out their workings carefully, even drawing the structures to ensure the correct binds were identified. The calculation is easy to follow. They have also included the essential negative sign.
			Total	7	