1(a). Methane and hydrogen can both be used in fuel cells for cars.

The table shows some information about the reactions that happen in a hydrogen / oxygen fuel cell and in a methane / oxygen fuel cell.

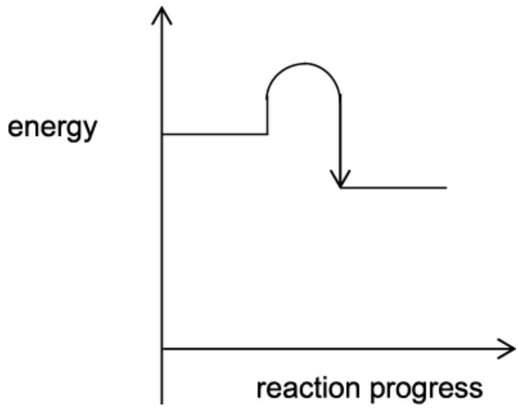
Fuel	Source of fuel	Equation for reaction in fuel cell	Energy change for reaction in fuel cell (kJ/mol)
hydrogen	High temperature reaction between natural gas and steam.	$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(g)$	–286
methane	Directly extracted as natural gas.	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	–890

Evaluate the use of hydrogen and methane in fuel cells for cars.

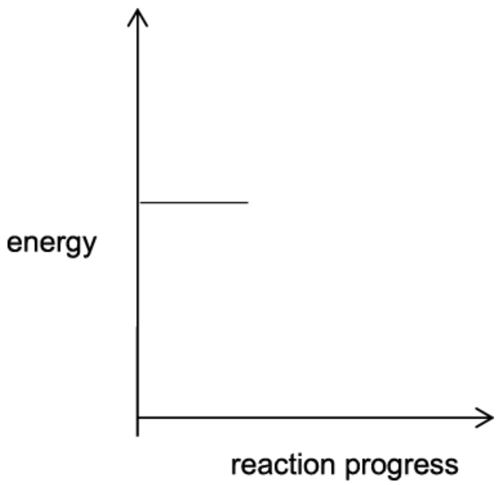
Use the information in the table in your answer.

[3]

(b). The graph shows the energy change when **hydrogen** reacts with oxygen.



(i) Complete the diagram below to show the energy change when **methane** reacts with oxygen.



[1]

(ii) Use data from the table on the opposite page to explain the energy change you have drawn in **(b)(i)**.

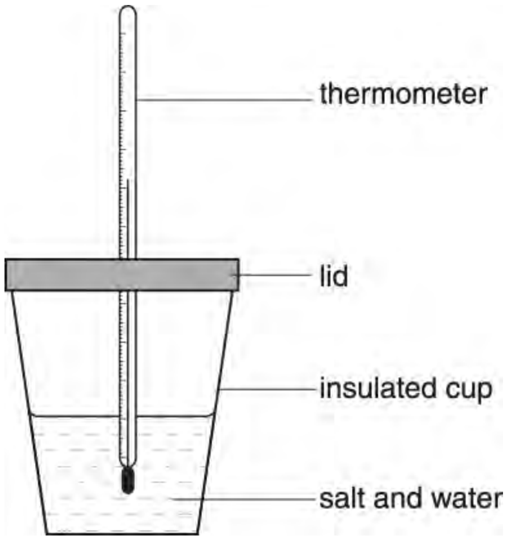
____

____ **[1]**

2. Rose investigates the energy changes when three salts dissolve in water.

She adds the same amount of each salt to the same amount of water.

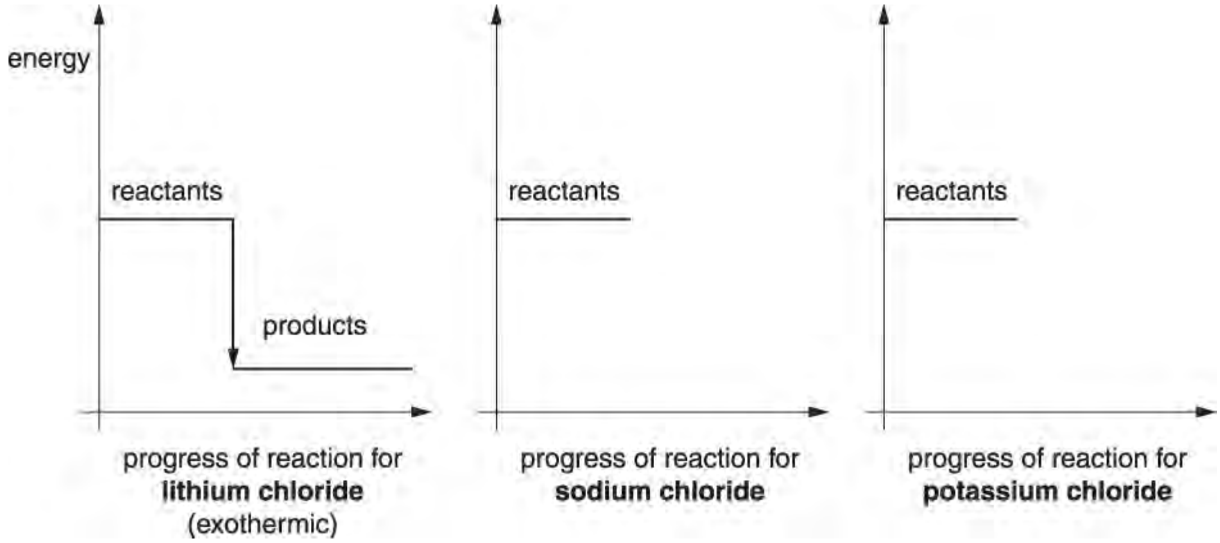
She measures the maximum temperature change when each salt dissolves.



The table shows her results.

Salt	Temperature change in °C	Type of energy change
lithium chloride	+7.0	exothermic
sodium chloride	?0.5	endothermic
potassium chloride	?4.0	endothermic

Complete and label the energy level diagrams. Compare the changes in temperature and energy that happen when each salt dissolves.



The quality of written communication will be assessed in your answer.

[6]

3(a). Len investigates the bond energies of some Group 7 elements and their compounds.

He calculates the energy change of the reaction when hydrogen and fluorine react together to make hydrogen fluoride.

$$H_2 + F_2 \rightarrow 2HF$$

He uses this data.

Type of bond	Bond energy (kJ / mol)
H–H	432
F–F	155
H–F	567

The boxes below show some of his working.

<table>
<tr><td colspan="2">Energy change when bonds break</td><td colspan="2">Energy change when bonds form</td></tr>
<tr><td>H–H

F–F</td><td>+ 432</td><td></td><td></td></tr>
<tr><td colspan="2">Total energy change = ______________ kJ / mol</td><td colspan="2">Total energy change = ______________ kJ / mol</td></tr>
</table>

(i) Complete the boxes above to show the total energy change when bonds **break** and bonds **form** in the reaction.

[3]

(ii) Use your answers to calculate the overall energy change for the reaction that happens when hydrogen and fluorine make hydrogen fluoride.

energy change = ____________________________ kJ / mol

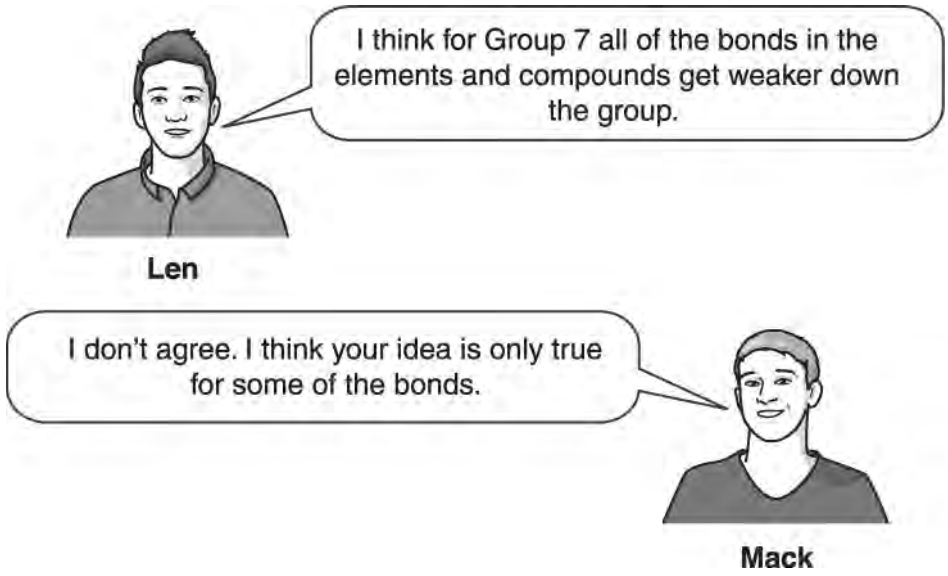
[1]

(b). Len finds some data about the bond energies of group 7 elements and their compounds.

Group 7 element	Bond energy (kJ / mol)
F_2	155
Cl_2	242
Br_2	193
I_2	151

Group 7 compound	Bond energy (kJ / mol)
HF	567
HBr	431
HCl	366
HI	299

He talks about the data with Mack.



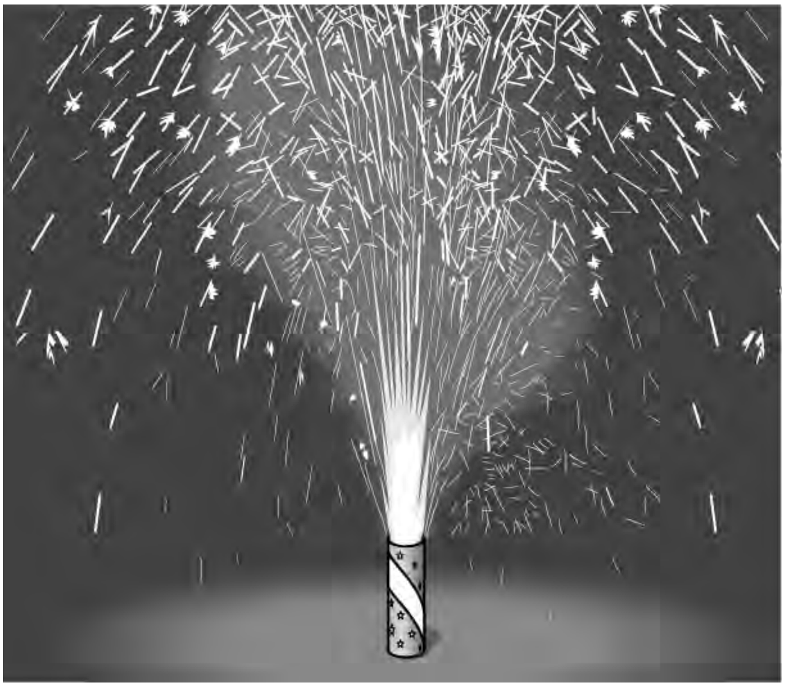
Use examples and data from the table to explain why Len's idea is only true for some of the bonds.

The quality of written communication will be assessed in your answer.

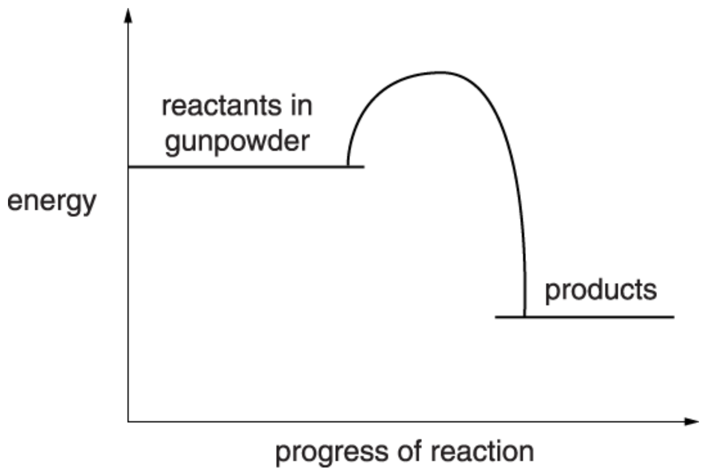
[6]

4(a). Fireworks contain gunpowder.

The gunpowder reacts when the firework is lit.



Look at the energy level diagram for this reaction.



What does the diagram tell you about the energy changes during the reaction?

-- [3]

(b). Gunpowder doesn't react until it is lit.

Use ideas about bonds to explain why.

-- [2]

(c). Some space rockets use the reaction between hydrogen and oxygen.

$$\begin{matrix} H-H \\ H-H \end{matrix} \; + \; O=O \; \rightarrow \; \begin{matrix} H-O-H \\ H-O-H \end{matrix}$$

(i) In this reaction, bonds in the hydrogen and oxygen are broken.

Fill in the blank spaces in the table.

Type of bond	**Energy needed to break each bond in kJ**	**Number of bonds**	**Energy needed in kJ**
H−H	436		
O=O	498	1	498
		Total energy needed	1370

[2]

(ii) New bonds are made when water is made.

The total amount of energy given out when the bonds form = 1856 kJ.

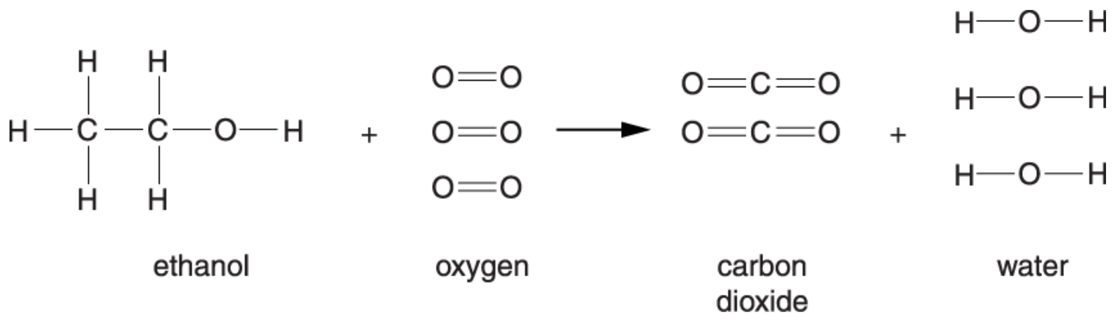
Calculate the total energy change for the whole reaction.

_______________________________ kJ **[1]**

5(a). The table shows the energy involved in the breaking of some bonds.

Bond	Bond energy in kJ/mol
C—H	411
C—O	358
O═O	498
C═O	799
O—H	459
C—C	348

Ethanol burns to make carbon dioxide and water.



The energy needed to break all of the bonds in the oxygen, $3O_2$, is 1494 kJ.

Work out the energy needed to break all of the bonds in ethanol, C_2H_5OH.

energy = ______________________________ kJ/mol **[2]**

(b). The energy given out when new bonds in $2CO_2$ are made is 3196 kJ.

Work out the energy given out when new bonds in the water, $3H_2O$, are made.

energy = ______________________________ kJ/mol **[2]** (c). Use the information given, and your answers from **(a)** and **(b)**, to complete the table.

	Energy in kJ/mol
energy **needed** to break all the bonds in ethanol and oxygen	
energy **given out** when all the bonds in carbon dioxide and water are made	
energy change when ethanol burns	

[2]

(d). The table shows information about some bonds.

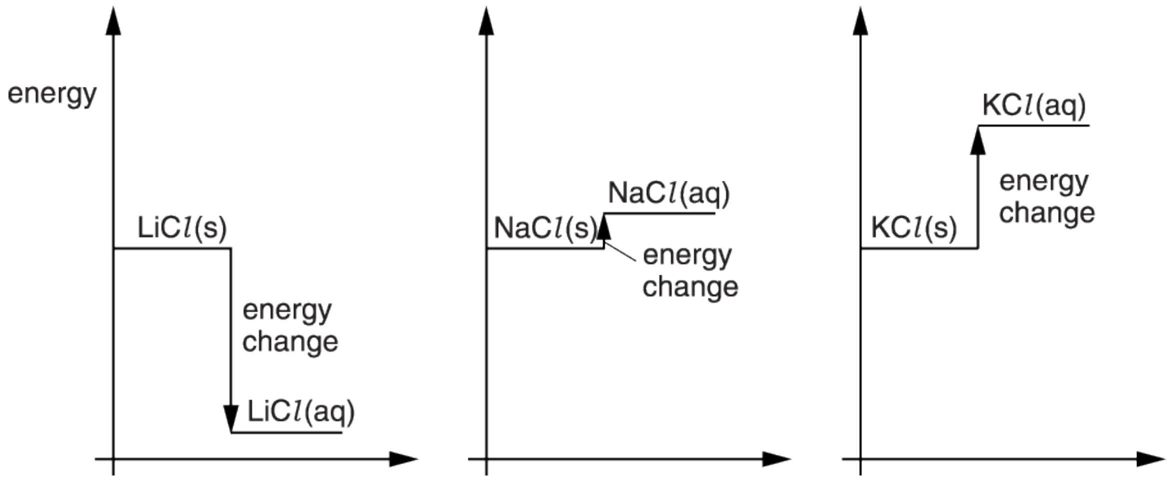
Bond	**Bond energy in kJ/mol**	**Bond length in pm**
C—C	348	154
C=C	614	134
C≡C	839	120

What conclusions can you make from this data?

--- [2]

6(a). Lithium chloride, sodium chloride and potassium chloride are all soluble in water.

The diagrams show the energy change when each salt dissolves in water.



Tom does an experiment.

He dissolves each compound in water and measures the temperature change that happens when the compound dissolves.

He uses the same amount of each compound and water each time.

Use the energy level diagrams to help you to explain the results Tom should expect from his experiment.


The quality of written communication will be assessed in your answer.

[6]

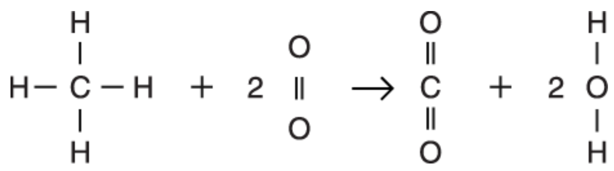
(b). Draw straight lines to show the correct input and output variable in Tom's experiment.

	temperature
input variable	volume of water
output variable	solubility
	compound

[1]

7. Mary wants to know the energy change when methane burns.

She writes out the equation to show all the chemical bonds.



(i) Complete the table to show how many of each type of bond are broken and how many are made when methane reacts with the oxygen in the air.

Bonds broken			**Bonds made**	
Type of bond	**Number of bonds**		**Type of bond**	**Number of bonds**
C–H				
O=O	2			

[2]

(ii) Use the table of bond energies to calculate the overall energy change when methane burns.

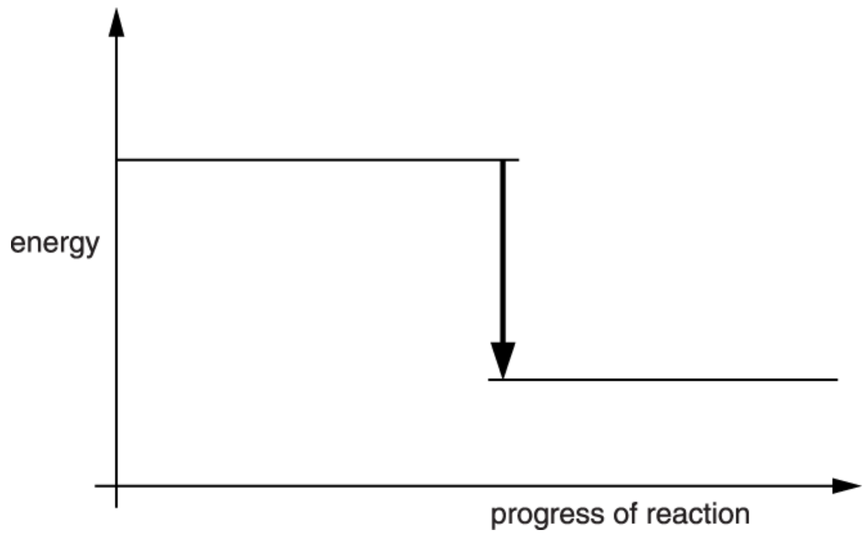
Bond	Energy to break the bond for a formula mass (kJ)
C–H	435
C=O	805
H–H	436
H–O	464
O=O	498

You must show your working.

_______________________________ kJ **[3]**

8. Liz does an experiment to investigate the rate of reaction between zinc and dilute hydrochloric acid.

This is the energy level diagram for the reaction between zinc and hydrochloric acid.



Which statements about the diagram are **true** and which are **false**?

Put a tick (✓) in one box in each row.

	true	false
The products are at a lower energy level than the reactants.		
The reaction is endothermic.		
The chemicals give out energy during the reaction.		
There is a temperature change during the reaction.		

[1]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1	a		hydrogen needs more energy to produce / ora ✓ hydrogen only produces water (which is not a pollutant) / does not produce carbon dioxide / methane produces carbon dioxide ✓ methane gives out more energy (per mole) ✓	3	
	b	i	shows products lower than reactants and energy change greater than for hydrogen ✓	1	
		ii	$\frac{-890}{-286} \approx 3$ therefore 3 x as much energy produced so energy change on diagram 3 x as large ✓	1	**DO NOT ALLOW** just 'more energy produced' without calculation
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
2			[Level 3] Draws both diagrams with basic features for NaCl **and** KCl with correct direction of energy change **and** shows or comments on relative size of energy change for all diagrams. Quality of communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Draws both diagrams with basic features and either comments on or shows correct direction of energy change for NaCl/KCl . Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1] Draws product lines in same direction for both diagrams or makes a correct statement about a temperature or energy change. Quality of written communication impedes communication of the science at this level. (1 – 2 marks) [Level 0] Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)		**This question is targeted at grades up to C** **Indicative scientific points may include:** **Basic features** • Line drawn with products labelled (for L1 direction does not have to be correct) • energy change arrow starts at level of reactants and ends with point at level of products **Consider QWC impeded** if products not labelled **or** energy arrow not drawn with single arrow pointing at products (ie double ended arrow or single line) **Diagram features all levels:** • product line drawn above reactants for both NaCl and KCl) • Size of energy change KCl bigger than NaCl • Size of energy change LiCl is biggest **Allow** (5) if KCl change is not obviously smaller than LiCl **Temperature and energy changes (written statements)** • Exothermic reactions give out energy (e.g LiCl)/ endothermic reactions take in energy (e.g. NaCl/KCl) • Bigger temperature change means more energy in/out • LiCl exothermic AND NaCl AND KCl endothermic • LiCl temperature increases • LiCl energy given out / products have less energy than reactants • NaCl/KCl temperature decreases • NaCl/KCl energy taken in/ products have more energy than reactants • LiCl gives biggest temperature change • LiCl gives biggest energy change • Temperature change for KCl is bigger than NaCl • Energy change for KCl is bigger than NaCl

Question			Answer/Indicative content	Marks	Guidance
					Use the L1, L2, L3 annotations in RM Assessor; do not use ticks. Examiner's Comments Clear, unambiguous, correctly drawn diagrams could gain all six marks for this question. This meant that many candidates gained marks in the level 2 and level 3 mark bands. Candidates generally seemed to handle energy level diagrams better than they managed the longer reasoned answers which the other level of response questions demanded. Common basic diagram errors were to miss the 'product' labels off the diagrams; to omit the arrow heads on the enthalpy changes or to draw the arrow heads in the wrong place (upside down or not clearly meeting the product line). In terms of the chemistry involved, most realised that both the reactions for sodium chloride and potassium chloride were endothermic and showed this on the diagrams. Some recognised that the energy change for sodium chloride was smaller in value, and represented this correctly. Only the most able further recognised that the value of the potassium chloride energy change was smaller in value than that of lithium chloride.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
3	a	i	587 1134 (ignore signs); (2) **+** **—** ie correct signs (1)	3	Examiner's Comments The thermochemical calculation for bond making was slightly better attempted than for bond breaking, with the most able candidates gaining credit for giving the correct signs in front of their answers.
		ii	(?) 547	1	**Allow** ECF from a i [i.e.. difference between the two values.] if sign given, must be correct for ecf.
	b		[Level 3] Identifies fluorine as an exception **AND** Makes a correct statement about element trends **AND** Makes a correct statement about compound trends Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Identifies fluorine as an exception **AND** Makes a correct statement about element trends **OR** compound trends Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1] Makes a correct statement to show why Len is partly right. Quality of written communication impedes communication of the science at this level. (1 – 2 marks) [Level 0] Insufficient or irrelevant science. Answer not worthy of credit. (0 marks) ALTERNATIVE [Level 3]	6	**This question is targeted at grades up to A** **Indicative scientific points may include:** **Statement about Exception** • fluorine is the exception [may be by implication] • fluorine (bond energy) is too low • fluorine (bond energy) is lower than chlorine • Links values for fluorine and chlorine to Len's idea **Statement about Element trends** • bond energies/bond strengths go down in general • compares values from chlorine to iodine, doesn't just quote numbers **Ignore** 'There is ***no*** trend in the elements **Statement about Compound trends** • Len is right for the compounds • Bond energies get lower down the group **Ignore** statements about reactivity of the elements • Bonds get weaker down the group. **Use the L1, L2, L3 annotations in RM Assessor; do not use ticks. Examiner's Comments** This question was designed to allow the most able candidates to demonstrate their

Question			Answer/Indicative content	Marks	Guidance
			Identifies HBr/HCl as anomalous **AND** fluorine **[Level 2]** Identifies HBr/HCl as anomalous **BUT NOT** fluorine		ability, and it worked well. The pattern in the halides was identified by many. When discussing the elements, more able candidates identified a problem with the bond energy of fluorine and chlorine. Few seemed to be aware of traditional labelling of fluorine as anomalous, and appeared to be working this out from inspection of the table. Many candidates suggested that fluorine and iodine fitted the pattern and the anomaly lay with the bond energies of chlorine and bromine. Others suggested that there was no pattern whatsoever for the halogens as elements.
			Total	10	

Question			Answer/Indicative content	Marks	Guidance
4	a		**energy levels** reactants have more energy than products / energy decreases / energy change negative; **what happens to the energy** given out / is lost / exothermic; **the hump** reference to activation energy / energy in to start reaction / energy increases [before decreasing]/ energy in to break bonds;	3	Allow 'gets hot' / 'heat released' Energy in to make bonds is CON for third marking point **Examiner's Comments** Most candidates realised that the reaction is exothermic and that energy is given out to the surroundings. Contradictions were often seen, and there was the usual confusion over whether energy is released or taken in to make bonds.
	b		[activation] energy / heat taken in / needed; Bonds break;	2	**ignore** reference to 'starting the reaction' – stem **Examiner's Comments** Candidates were much more confident in describing the need for energy to break bonds.
	c	i	2 872	2	
		ii	486	1	Ignore signs **Examiner's Comments** The number of bonds to be broken in the reaction was well understood, as was the calculation of the overall energy change. Many candidates even included the negative sign.
			Total	8	

Question			Answer/Indicative content	Marks	Guidance
5	a		(5 x 411) + 348 + 358 + 459 = (1) 3220 (1)	2	**allow** both marks for correct answer without working **Examiner's Comments** Stronger candidates corrected calculated the energy to break bonds in ethanol. (5 x 411) + 348 + 358 + 459 = 3220 kJ/mol A common error was omission of the energy needed to break the C-C bond (348 kJ/mol).
	b		6 x 459 = (1) 2754 (1)	2	**allow** both marks for correct answer without working **Examiner's Comments** Most candidates corrected calculated the energy released when the water is made. 6 x 459 = 2754 kJ/mol
	c		4714 in first box and 5950 in second box (1) in third box (?) 1236 (1)	2	**allow** ecf from **(a)** and **(b)** give first mark for correct addition and transfer of both figures second mark for correct subtraction of figures they have used **ignore** sign **Examiner's Comments** Most candidates correctly added and transferred data from (a) and (b) into the table and subtracted correctly to gain two marks. A common error was to make a mistake in one of the two additions.
	d		**any two from** as number of bonds (between two carbon atoms) increases bond length decreases (1) as number of bonds (between two carbon atoms) increases bond energy increases (1) as bond energy increases bond length decreases (1)	2	or a throughout **ignore** references to strength or weakness of bonds **allow** triple bond has more energy than double which has more energy than single **Examiner's Comments** Most candidates described one of the trends shown in the table. Stronger candidates described two trends.
			Total	8	

Question			Answer/Indicative content	Marks	Guidance
6	a		**Level 3 (5–6 marks)** Links all three diagrams to correct energy changes and correctly predicts direction and / or relative size of temperature changes. Quality of written communication does not impede communication of the science at this level. **Level 2 (3–4 marks)** Links all three diagrams to correct energy changes or direction of temperature change. Quality of written communication partly impedes communication of the science at this level. **Level 1 (1–2 marks)** Links at least one diagram to a correct energy change or to a correct direction of temperature change. Quality of written communication impedes communication of the science at this level. **Level 0 (0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	6	**This question is targeted at grades up to A** **Indicative scientific points may include:** **Energy changes** (during dissolving) • lithium chloride gives out energy / gives out heat / is exothermic • sodium chloride and potassium chloride both take in energy / take in heat / are endothermic **Ignore** 'energy goes down' / 'energy goes up' **Temperature change** • when lithium chloride dissolves temperature increases • when sodium chloride and potassium chloride dissolve temperature decreases • the temperature decrease / change is greater for potassium chloride than for sodium chloride • the value of the temperature change is greatest when lithium chloride dissolves **Level 3**: If direction of temperature change is given, it must be correct to allow L3. **Ignore** discussion of rate of dissolving **Ignore** references to bond making / breaking even if incorrect **Allow Level 1** (1–2 marks) for Error Carried Forward if all energy changes are given the wrong way round but then correctly linked to temperature changes. **Ignore** incorrect use of terms 'endothermic' and 'exothermic' when marking science but consider quality of written communication impeded (award lower mark of the level). **Use the L1, L2, L3 annotations in Scoris; do not use ticks.**

Question			Answer/Indicative content	Marks	Guidance
					Examiner's Comments This last six-mark extended-writing answer was the most difficult of the three six-mark questions. About half of the candidates did not score any marks. Many were not able to relate the shapes of the graphs to energy changes. Some gave the wrong energy change (for example saying that the dissolving of lithium chloride is an endothermic reaction). Of those who correctly linked the energy changes to the diagram, few went on to then predict the correct direction of the temperature changes. In common with question 5a, this may have been caused by poor examination technique. It is important that candidates fully re-check the question to ensure they have addressed every part of the task. About a fifth of the candidates scored marks at the highest level, Level 3.
	b		input variable – compound output variable – temperature	1	**Examiner's Comments** About half of the candidates correctly identified the input and output variable. A common error was to attempt to join all of the boxes on the right to the boxes on the left. Questions with 'extra boxes' are relatively common and candidates should be aware that it is not always appropriate to try to connect every box.
			Total	7	

Question			Answer/Indicative content	Marks	Guidance
7		i	C?H = 4 C = O = 2 [O = O = 2] O?H = 4	2	Left hand column = 1 Right hand columns = 1 bonds can be written either way round, eg C?H or H?C Right hand bonds in either order [but numbers must match!] **Examiner's Comments** As in other years, examiners noted that candidates' ability to state which bonds are made and which broken is often independent of their ability to do the thermochemical calculation.
		ii	Answer = ?730 [3 marks]	3	If not correct, look for Answer = 730 [2 marks] Use of 2736 or 3466 [1 mark] **Examiner's Comments** It was gratifying to see that the majority of candidates realised that the energy change would be negative.
			Total	**5**	
8			TFTT	1	**Examiner's Comments** This is an example of an objective question that demands all answers to be correctly chosen for a single mark. In most cases candidates made at least one error and so failed to score.
			Total	**1**	