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

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

Fuel	Source of fuel	Products of reaction in fuel cell	Energy given out per mole of fuel in kJ
hydrogen	High temperature industrial process.	only water vapour	286
methane	Fossil fuel.	carbon dioxide and water vapour	890

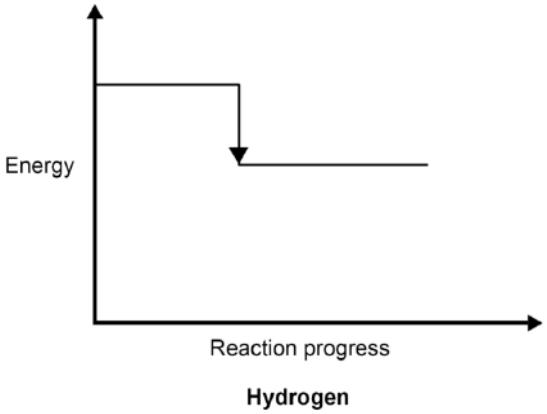
Use the information in the table to evaluate the advantages and disadvantages of using these fuels for a car fuel cell.

---

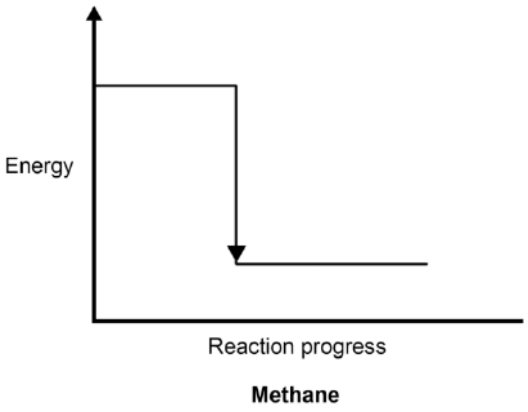
[3]

(b). The diagrams show the energy changes in the hydrogen and methane fuel cells.

Explain the shapes of the two diagrams.



Hydrogen



Methane

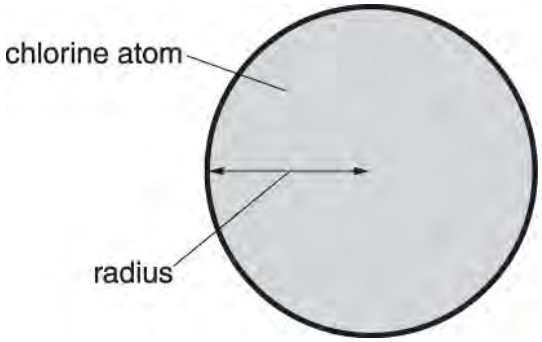
Use the data in the table in your answer.

---

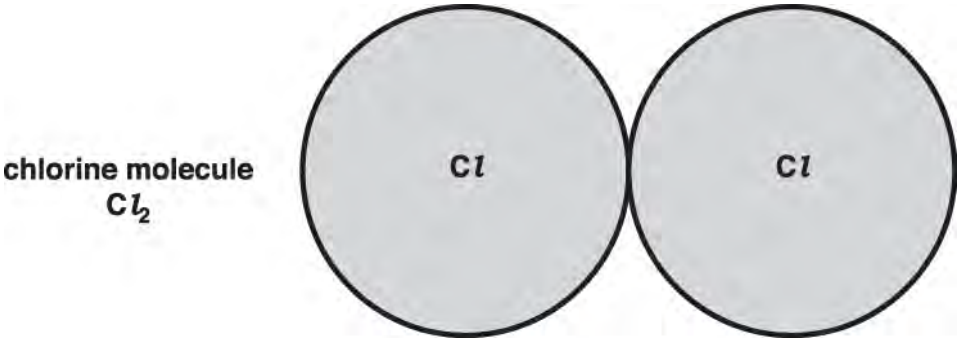
[2]

2(a). Len looks up data about the sizes of atoms of chlorine and some other Group 7 elements.

The size of an atom is measured by measuring its **radius**.



Two atoms bond together to make a molecule.

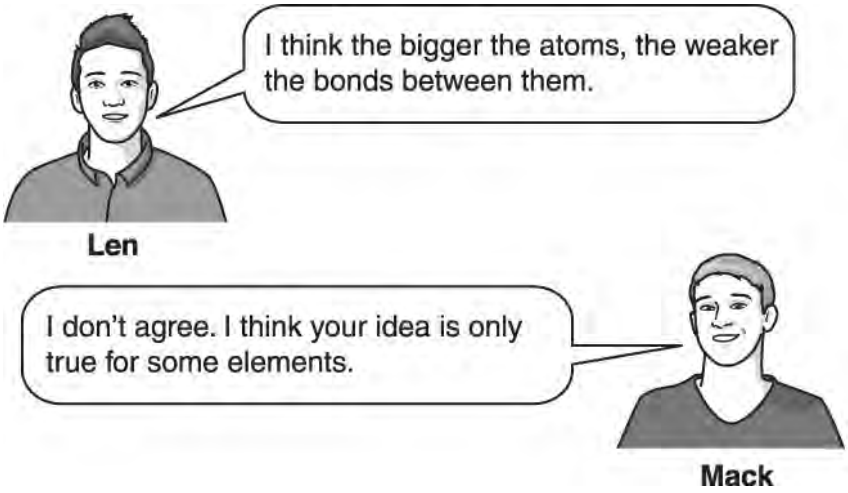


Len also finds out the **energy needed to break the bond** that holds the atoms together in a molecule.

This is his data.

Element	Radius of an atom (pm)	Energy needed to break bond(kJ / mol)
Fluorine F_2	42	155
Chlorine Cl_2	79	242
Bromine Br_2	94	193
Iodine I_2	115	151

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 elements.

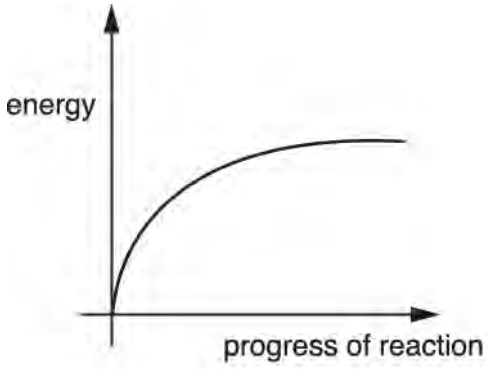
The quality of written communication will be assessed in your answer.

[6]

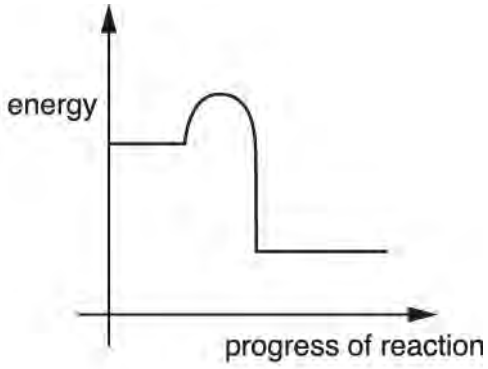
(b). Shining a bright light on a mixture of chlorine gas and hydrogen gas makes it explode.

The reaction is very exothermic.

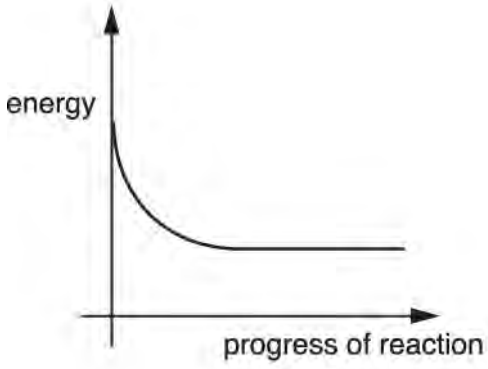
(i) Which energy level diagram, **A**, **B**, **C** or **D**, is correct for the reaction between chlorine and hydrogen?



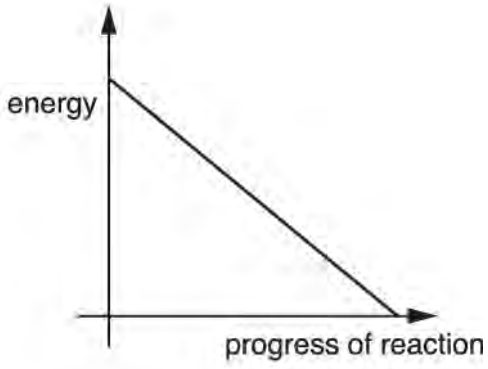
A



B



C



D

Put a ring around the correct answer.

A B C D

[1]

(ii) Complete the sentences about this reaction between chlorine and hydrogen by putting a ring around the correct words in each sentence.

To start the reaction bonds need to **break / form**.

To start the reaction, energy is **taken in / given out**.

The reaction is exothermic and so overall energy is **taken in / given out**.

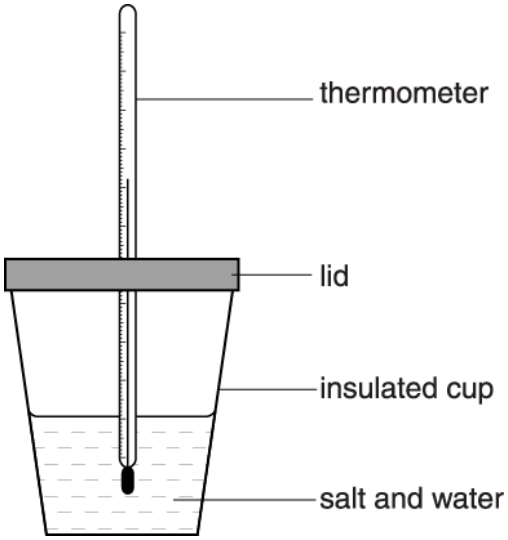
During the reaction **more / less** energy is taken in than given out.

[3]

3. 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.

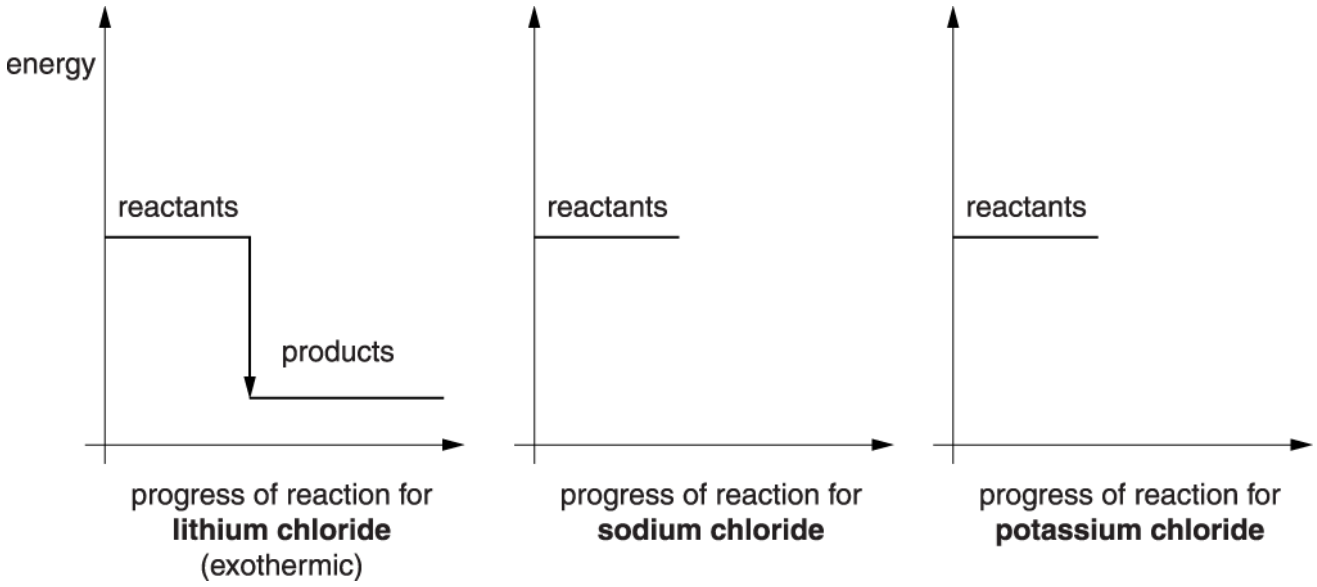
She measures the maximum temperature change when each salt dissolves.



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.



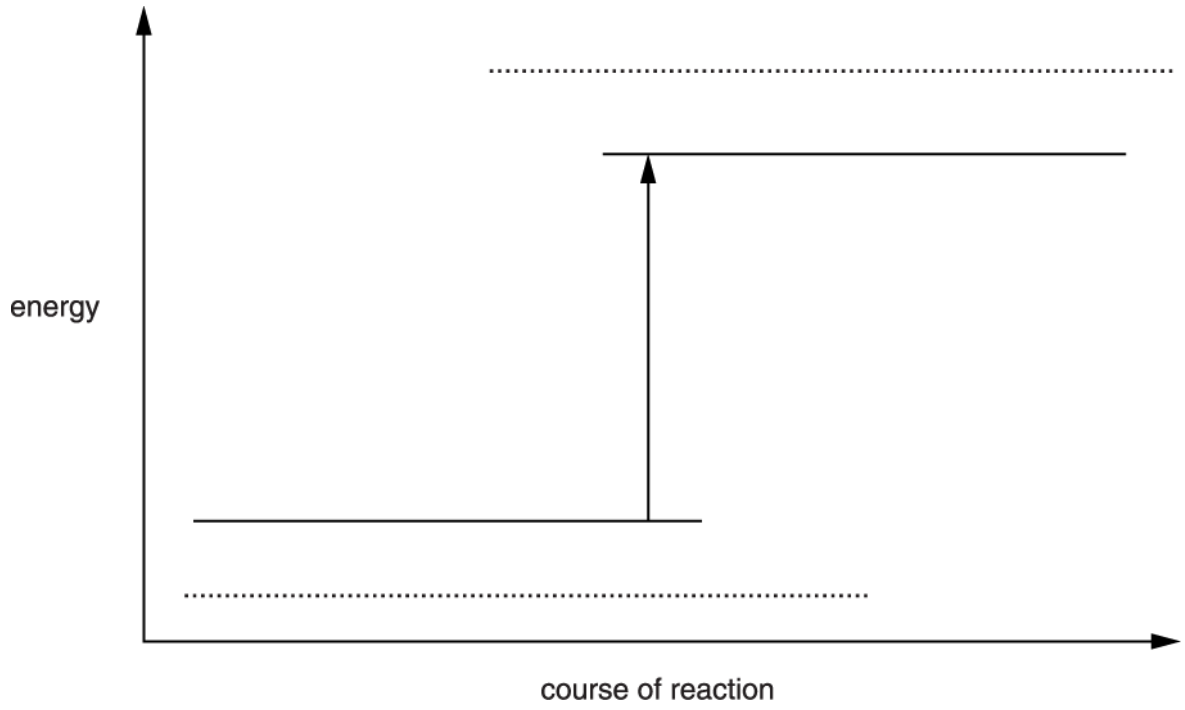
The quality of written communication will be assessed in your answer.

[6]

4(a). Citric acid reacts with sodium hydrogencarbonate.

citric acid + sodium hydrogencarbonate → sodium citrate + carbon dioxide + water

The diagram shows the energy change that takes place in this reaction.



Write the names of the reactants and the products of the reaction in the correct places on this diagram.

[2]

(b). Finish these sentences to describe what happens in the reaction.

Use words or phrases from the list.

endothermic

exothermic

gained from

less

lost to

more

The reactants have _____ energy than the products, so during the reaction, energy is

_____ the surroundings.

The reaction is _____ .

[3]

(c). A solution of citric acid is added to a solution of sodium hydrogencarbonate in a test tube.

Sam says that the solution will bubble and the tube will get hot.

Sally says that there will be no bubbles and the tube will get cold.

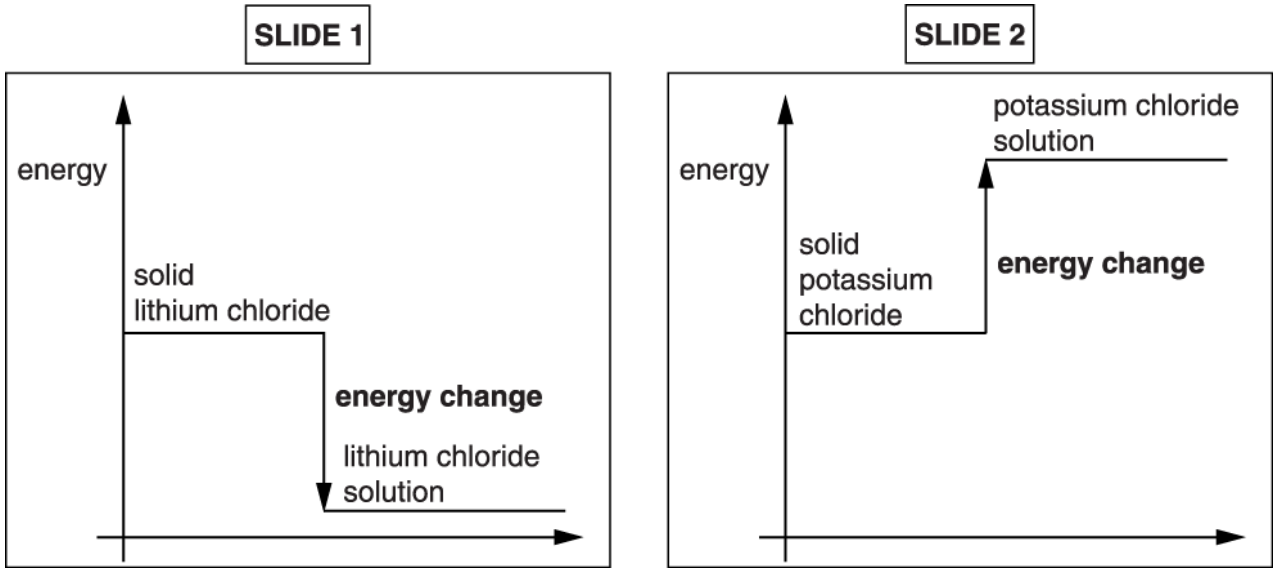
Both are wrong. Explain why.

---

[2]

5. Tom is doing a presentation on energy changes in reactions.

He uses slides that show the energy changes when lithium chloride and potassium chloride dissolve in water.



Tom uses the slides to explain:

- what exothermic and endothermic mean
- how you can tell which reaction is exothermic and which is endothermic.

Write down what Tom should say.

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

---

[6]

6. When chemical engineers design an industrial process, they make it as sustainable as possible. One of the things that they consider is the energy changes during the chemical reaction.

During a reaction, chemical bonds are broken and new bonds are made.

Put ticks (?) in the boxes to complete these sentences.

When chemical bonds are broken, energy is

taken in	
given out	
not needed	

.

When chemical bonds are made, energy is

taken in	
given out	
not needed	

.

If more energy is taken in than is given out the reaction is

endothermic	
exothermic	

.

Some energy is usually needed to start the reaction.

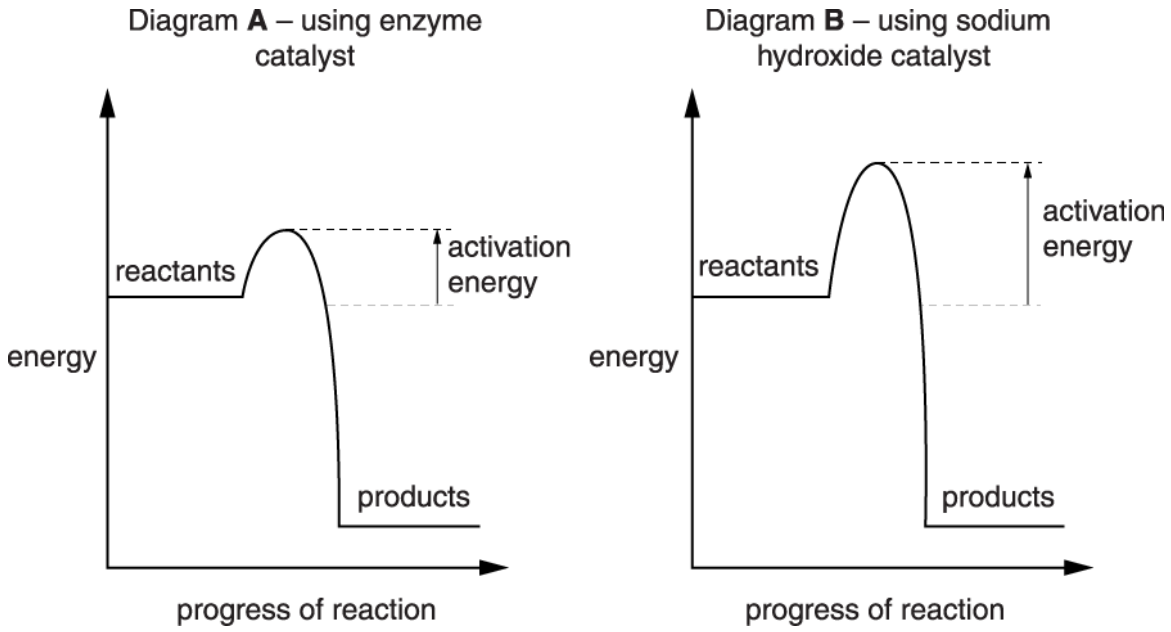
This energy is the

activation energy	
green energy	
geothermal energy	
energy output	

.

[3]

7. Scientists draw energy level diagrams for a reaction using two different catalysts.



Give **one** similarity and **one** difference between the changes shown in these diagrams.

---

[2]

8. A water company measures the temperature of the surface of a lake after neutralisation.

They find that the temperature has increased.

Why do some reactions cause an increase in temperature?

Put a tick (✓) in the box next to the correct answer.

Some reactions give out energy. ☐

Some reactions are endothermic. ☐

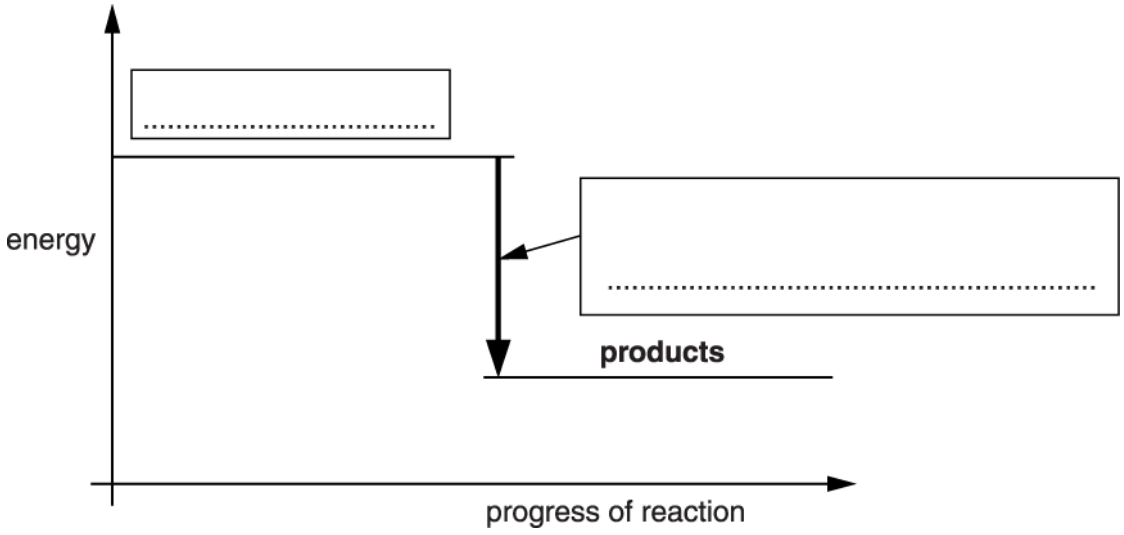
Reactions need energy to start. ☐

Reactions are faster at higher temperatures. ☐

[1]

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

The diagram shows an energy level diagram for the reaction.



Write the correct words in the boxes to label the diagram.

Choose words from this list.

energy change of reaction

catalyst

rate of reaction

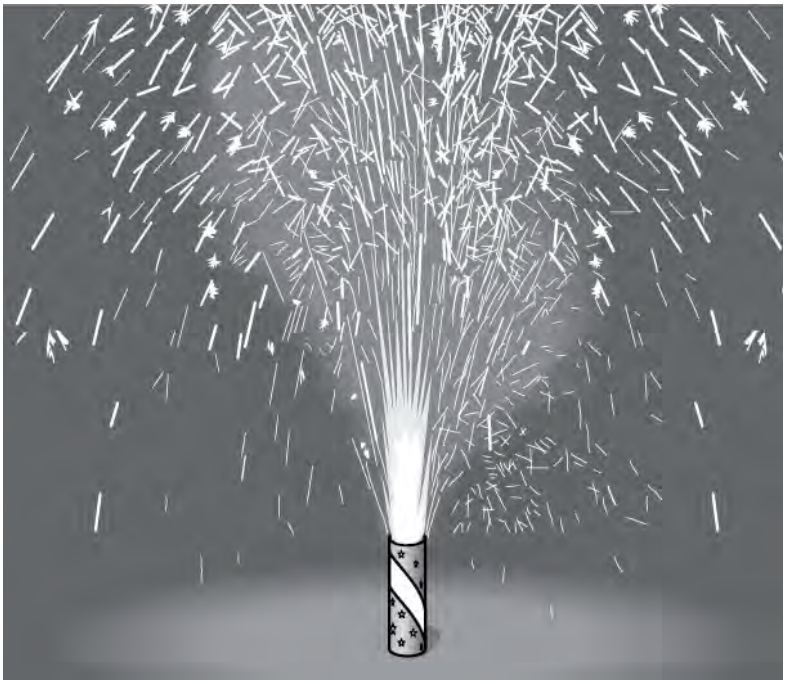
gas given off

reactants

[2]

10(a) Most fireworks contain gunpowder.

.



When the gunpowder burns it gives out energy.

What do we call a reaction which gives out energy?

Put a ring around the correct answer.

endothermic equilibrium exothermic explosive

[1]

(b). Here are some statements about the energy changes in a firework.

Put a ring around the correct word in each statement or phrase.

Jo uses a match to start the reaction.

The reaction starts when energy from the match ***breaks / makes / reacts with*** chemical bonds in the gunpowder.

When new bonds are made they ***concentrate / dilute / give out / take in energyin*** energy.

In a firework the energy change when bonds break is ***less than / the same as / more than*** when bonds are made.

The energy needed to start the reaction is the ***activation / initiation / starting*** energy.

[3]

11(a) 'Sherbet' is a powder that fizzes on your tongue. This happens because the powder reacts with water.

.

Beth thinks that the reaction between sherbet and water is endothermic.

She does an experiment to find out if she is right.

Describe what she does.

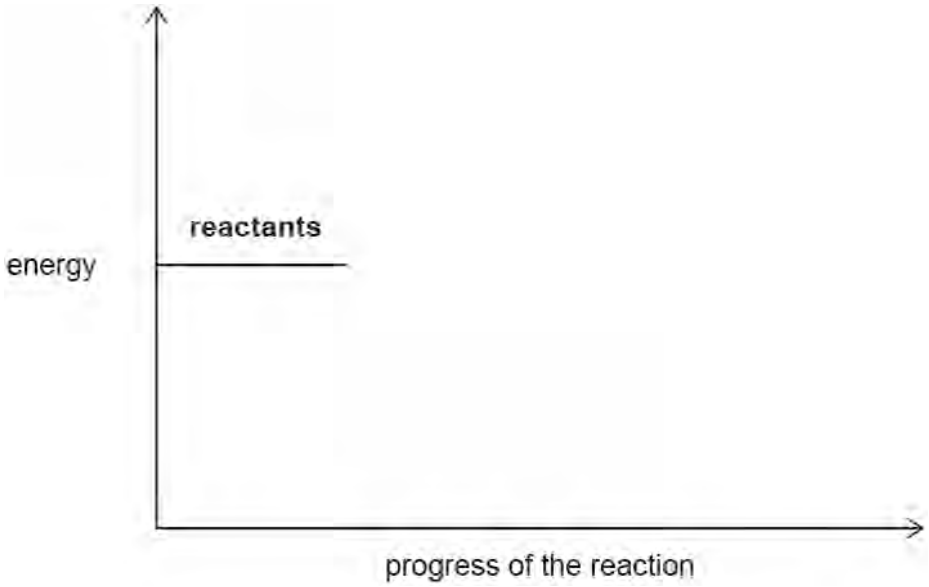
What result will she get if the reaction is endothermic?

---

[2]

(b). Complete the reaction profile for an **endothermic** reaction.

Label your diagram with these words: **products, activation energy**



[3]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1	a		hydrogen needs a high temperature to produce / uses energy in production / methane is a finite fossil fuel / will run out idea ✓ hydrogen only produces water which is not a pollutant / does not produce carbon dioxide / methane produces carbon dioxide which is a pollutant ✓ methane gives out more energy (per mole) ✓	3	
	b		both give out energy / exothermic ✓ 890 ÷ 286 = approx. 3 therefore 3x more energy is given out by methane therefore energy gap 3x larger ✓	2	
			Total	5	
2	a		[Level 3] Makes correct statements about energy and size of atoms. AND Identifies, with a reason, that fluorine does not fit the pattern. Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Makes correct statements about energy and size of atoms. OR Identifies, with a reason, that fluorine does not fit the pattern. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1]	6	This question is targeted at grades up to C Indicative scientific points may include: Statements about energy and size of atoms • chlorine needs most energy to break bond • iodine needs least energy to break bond • compares energy needed to break bonds for two atoms. • the bond energy decreases (down the group) • compares size of two atoms • fluorine is smallest atom • iodine is largest atom • the radius increases (down the group) • (generally) as the atoms get larger/radius increases, bond energies get smaller. Ignore 'the bigger the atom, the weaker the bonds (in the question)

Question			Answer/Indicative content	Marks	Guidance
			Makes a statement about energy or size of atom. 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)		**Fluorine does not fit**… • because bond energy for fluorine is lower than expected / lower than rest of pattern / lower than chlorine/bromine • because bond energy of fluorine is similar to bond energy of iodine **Accept** 'stonger' for more energy and 'weaker' for less energy throughout **Use the L1, L2, L3 annotations in RM Assessor; do not use ticks**. **Examiner's Comments** Candidates produced high quality answers, many gaining marks in the level 2 marking band. Typically they discussed or compared either the bond energies of two or more atoms, or the sizes. Many recognised that fluorine did not fit the pattern, but did not always express their ideas clearly enough to access level 3.
	b	i	B	1	**Examiner's Comments** About half of the candidates correctly identified the most appropriate energy level diagram.
		ii	break taken in given out less	3	All four correct (3) 3 correct (2) 1 or 2 correct (1) **Examiner's Comments** Almost every candidate showed some understanding of energy changes during reactions. About a third gained full marks.
			Total	**10**	

Question	Answer/Indicative content	Marks	Guidance
3	**[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)	6	**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 There were some very good energy level diagrams drawn which clearly showed the relative size of the energy changes. Marks were often lost for lack of arrow heads or labelling. Some candidates struggled with the diagrams but were able to use the data given to compare energy or temperature changes.
			Total	6	

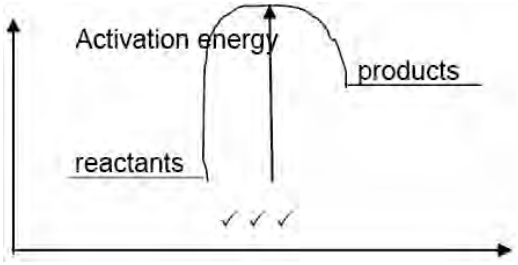
Question			Answer/Indicative content	Marks	Guidance
4	a		citric acid + sodium hydrogen carbonate lower left line (1) sodium citrate + carbon dioxide + water upper right line (1)	2	Examiner's Comments Most candidates understood that the reactants should be on the left of the energy level diagram and the products on the right. A few gave incomplete lists, others just wrote 'reactants' and 'products' and a small number put them the wrong way round.
	b		less (1) gained from (1) endothermic (1)	3	Examiner's Comments Most candidates were able to recognise that energy had been gained from the surroundings during the reaction and many were able to identify either that the reactants had less energy than the products or that the reaction was endothermic. Good candidates were able to select all three responses correctly. Errors were almost all to give the reverse of the expected answers e.g. more than instead of less than etc., with randomly selected guesses from the list being rare.
	c		reaction produces a gas / carbon dioxide so bubbles will appear (1) reaction is endothermic / takes in heat / energy so test tube feels cold (1)	2	**allow** does have bubbles / gives a gas / gives CO_2 **and** doesn't get hot for 1 mark. Examiner's Comments Candidates were expected to recognise that there would be bubbles due to the formation of carbon dioxide and that the tube would get cold as the reaction is taking heat from the surroundings. However, few candidates were able to explain the expected observations from the information given. Many stated that there would be no reaction, in spite of having been given the reaction in the stem of the question, while others gave no explanation e.g. just saying that it will bubble without explaining why.
			Total	7	

Question			Answer/Indicative content	Marks	Guidance
5			**Level 3 (5–6 marks)** Explains what exothermic and endothermic mean in terms of energy being released / absorbed **AND** links each diagram to the correct energy change **AND** explains how to use the diagrams to decide. Quality of written communication does not impede communication of the science at this level. **Level 2 (3–4 marks)** Explains what exothermic **OR** endothermic means **AND** links each diagram to the correct energy change **OR** identifies the diagrams correctly **AND** explains how to use the diagram to decide. Quality of written communication partly impedes communication of the science at this level. **Level 1 (1–2 marks)** Either explains what exothermic or endothermic means **OR** links one of the diagrams to the correct energy change **OR** makes a correct statement about energy level diagrams. 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 C** **Indicative scientific points may include:** **How to use diagrams to decide** • Energy change goes up for endothermic reactions / energy change is positive • Energy change goes down for exothermic reactions / energy change is negative • Reactants lower than products for endothermic reactions • Reactants higher than products for exothermic reactions. **Which is which** • Lithium chloride reaction is exothermic / gives out energy • Potassium chloride reaction is endothermic / takes in energy. **What exothermic and endothermic mean** • Exothermic gives energy / heat out or is losing energy • Endothermic takes energy / heat in or is gaining energy **Use the L1, L2, L3 annotations in Scoris; do not use ticks.** **Examiner's Comments** This was the least well-answered of the six-mark extended-writing questions. There were a few good responses, but equally there was a higher omission rate. The best responses were those that gave simple definitions for exothermic and endothermic reactions, followed by the slide selection and a reason. Many candidates were unable to explain the difference between the two reactions, and common

Question			Answer/Indicative content	Marks	Guidance
					misconceptions included the idea that one had a bigger energy change than the other.
			Total	6	
6			taken in given out endothermic activation energy	3	4 correct = 3 3/2 correct = 2 1 correct = 1 Examiner's Comments Most candidates knew that the reaction was exothermic and that energy to start a reaction is activation energy. Candidates need to remember that breaking bonds involves energy being taken in, making bonds involves energy given out. Most inverted the two selections.
			Total	3	
7			similarity [1] reactants / products have the same energy (on both diagrams) / both reactions need an activation energy / both reactions are exothermic / energy level decreases / products have less energy than reactants difference [1] activation energy [of enzyme / diagram A] lower	2	Accept 'different' Do not allow produces / gives out activation energy Examiner's Comments Most candidates correctly identified that A has a lower activation energy than B. However, the second mark was much less frequently scored. This was usually either because the candidate did not go on to make a second point or because the candidate thought that both reactions were endothermic. A common misconception seems to be that if products have less energy than reactants the reaction is endothermic.
			Total	2	

Question			Answer/Indicative content	Marks	Guidance
8			box 1; (1)	1	Examiner's Comments Many responses showed an understanding that an increase in temperature was caused by a release of energy from the reaction. Some thought that this was because the reaction was endothermic or due to the higher rate when temperature increases..
			Total	1	
9			reactants; energy change of reaction;	2	Examiner's Comments Most candidates understood that the arrow showed the energy change of reaction with many also correctly selecting reactants for the start of the reaction. Many others chose catalyst or rate of reaction for the start of the reaction.
			Total	2	
10	a		Exothermic	1	Examiner's Comments The majority of candidates were able to select the correct definition for a reaction that gave off energy.
	b		Breaks Give out Less Activation	3	4 correct = 3 3 correct = 2 2 correct = 1 1 correct = 0 SSU – may wish to allow 1 or 2 correct = 1 Examiner's Comments There was a great deal of confusion in the answering of this question. Selected responses often seemed random; one mark was often achieved, but three marks wereseldom achieved. The most commonly selected correct response was the energy needed to start the reaction being the activation energy.
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
11	a		Adds sherbet powder to water / carries out the reaction ✓ Temperature falls / AW ✓	2 (AO 3.3a) (AO 1.1)	Result must relate to an experimentally observable factor i.e. temp [rather than energy] Examiner's Comments Almost all candidates, whatever their ability, responded to the second command line, though the concept of an endothermic reaction proved to be very problematic. Most candidates appreciated that endothermic reactions take in energy. Relating that energy change to temperature change was a much harder leap to make. Most candidates suggested that an endothermic reaction takes in heat from the surroundings and so warms up the contents of the beaker. Higher ability candidates answered the first command line as well, giving an indication of how the experiment was performed. Even when that was not the case, sometimes enough detail leaked out incidentally and examiners were able to give credit.

Question			Answer/Indicative content	Marks	Guidance
	b			3 (AO 1.1 × 3)	Curve with single hump ✓ Products line labelled and above reactants line ✓ Activation energy unambiguously labelled ✓ This point can only be gained if the products line is above the reactants line <u>Examiner's Comments</u> Examiners were pleased that most candidates were familiar with the concept of a reaction profile and their most common response, that of an exothermic reaction, was able to gain at least some credit. The answers showed a major disjunction between candidates' knowledge of the energy change and how it is represented diagrammatically, suggesting an insecure understanding. Most candidates who, in the previous question, stated that the reaction takes in energy, actually went on to put the product energy level lower than that for the reactant. Higher ability candidates not only drew the correct graph shape, but indicated the activation energy. Unfortunately, in many cases the levels at which their arrows started and ended were not clear enough to gain credit.
			Total	5	