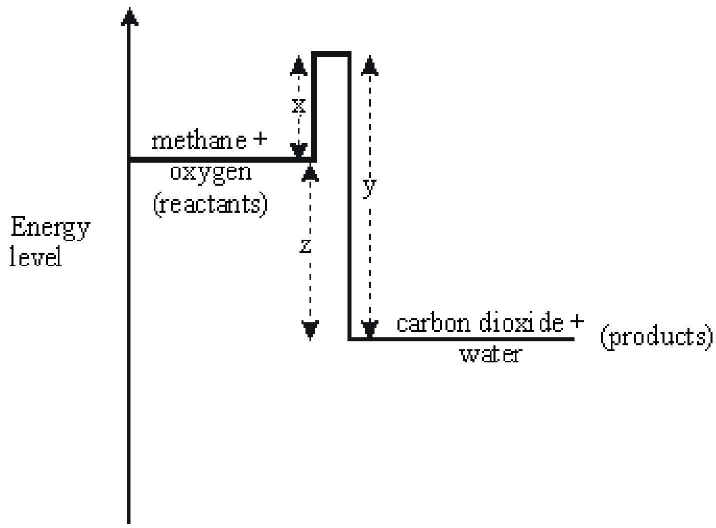
1 The symbol equation below shows the reaction when methane burns in oxygen.

CH_4 + $2O_2$ ® CO_2 + $2H_2O$

An energy level diagram for this reaction is shown below.



(a) Which chemical bonds are broken and which are formed during this reaction?

....

....

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....

(4)

(b) Explain the significance of x, y and z on the energy level diagram in terms of the energy transfers which occur when these chemical bonds are broken and formed.

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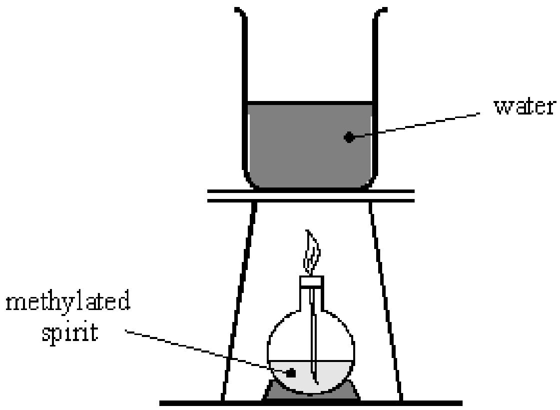
(5)

(Total 9 marks)

2 A student is using a spirit burner to heat some water.



(a) Complete these sentences.

Substances like methylated spirit which we burn to give out energy, are called

.... The energy is given out as .... energy.

(2)

(b) Choose a word from this list to complete the sentence below.

gases **liquids** **solids**

The methylated spirit seems to disappear as it burns.

The new substances produced during burning are mainly ....

(1)

(Total 3 marks)

3 Methane and oxygen react together to produce carbon dioxide and water.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

818 kJ of energy is given out to the surroundings for each formula mass (mole) of methane that reacts.

The methane gas will not burn in oxygen until a flame is applied, but once lit it continues to burn.

(a) Explain why energy must be supplied to start the reaction but it continues by itself once started.

....

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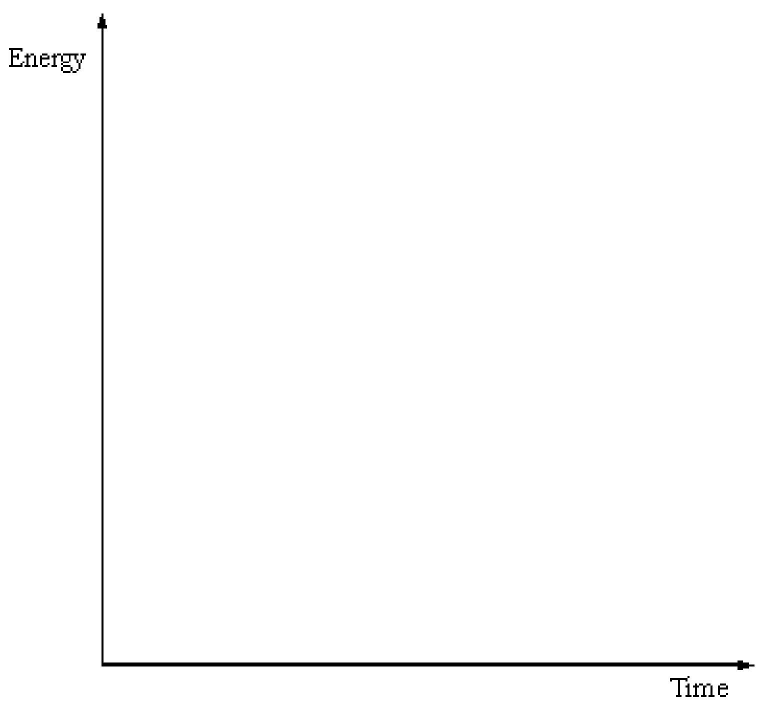
(4)

(b) Sketch an energy level diagram for the reaction and indicate on the diagram the nett energy released.



(3)

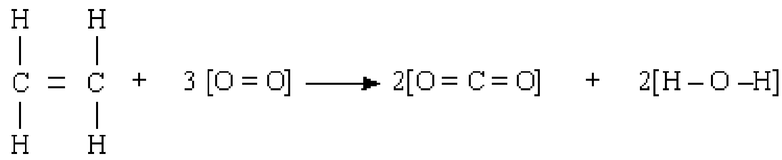
(Total 7 marks)

4 You will find the information on the Data Sheet helpful when answering this question.

This equation shows the reaction between ethene and oxygen.

$$C_2H_4 \quad + \quad 3O_2 \quad \rightarrow \quad 2CO_2 \quad + \quad 2H_2O$$

The structural formulae in the equation below show the bonds in each molecule involved.



Use the three stages shown at (a), (b) and (c) below to calculate the nett energy transfer when the formula mass (1 mole) of ethene reacts with oxygen.

(a) Write down the bonds broken and the bonds formed during the reaction. (Some have already been done for you.)

Bonds broken	
Number	Type
4	[C – H]
1	[C = C]

Bonds formed	
Number	Type
4	[C = O]

(2)

(b) Calculate the total energy changes involved in breaking and in forming all of these bonds. (Some have already been done for you.)

Total energy change in breaking bonds
[4 × 413] = 1652
[1 × 612] = 612
Total = kJ

Total energy change in forming bonds
4 × [805] = 3220
Total = kJ

(4)

(c) Describe, as fully as you can, what the figures in (b) tell you about the overall reaction.

....

....

....

....

....

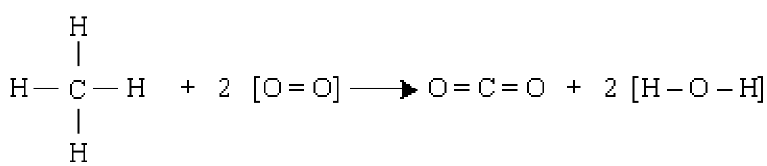
(2)

(Total 8 marks)

5 The symbol equation shows the reaction between methane and oxygen.

CH_4	+	$2O_2$	→	CO_2	+	$2H_2O$
methane		oxygen		carbon dioxide		water

The structural formulae in the equation below show the bonds in each molecule involved.



In the three stages shown at (i), (ii) and (iii) below, calculate the net energy transfer when the formula mass (1 mole) of methane reacts with oxygen.

(i) Write down the bonds broken and the bonds formed during the reaction.

Bonds broken		**Bonds formed**	
number	**type**	**number**	**type**

(4)

(ii) Calculate the total energy changes involved in breaking and in forming each of these bonds.

Total energy change in breaking bonds	**Total energy change in forming bonds**

(4)

(iii) Describe, as fully as you can, what the above figures in (ii) tell you about the overall reaction.

....

....

....

....

....

(2)
(Total 10 marks)

6 Hydrogen chloride is made by reacting hydrogen with chlorine.

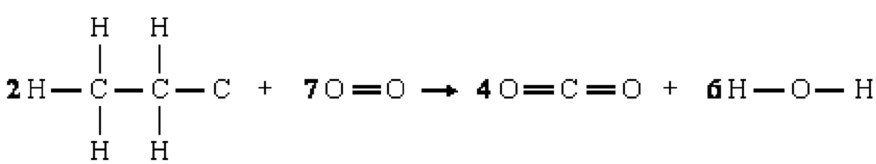
$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Bond	**Bond energy in kJ**
H – H	436
Cl – Cl	242
H – Cl	431

Is the reaction between hydrogen and chlorine exothermic or endothermic?
Use the bond energies to explain your answer.

(Total 3 marks)

7 The balanced equation for the combustion of ethane is shown using structural formulae.



(a) Complete the table to show the number of bonds broken and made when two molecules of ethane react with seven molecules of oxygen.

Type of bond	Number of bonds broken	Number of bonds made
C — C		
C — H		
O = O		
C = O		
H — O		

(2)

(b) The combustion of ethane is a strongly exothermic process. Draw a labelled energy level diagram showing the endothermic and exothermic parts of the overall reaction. Indicate the activation energy on the diagram.

(4)

(c) Explain, in terms of particles and the activation energy of a reaction, how a catalyst is able to increase the rate of reaction.

....

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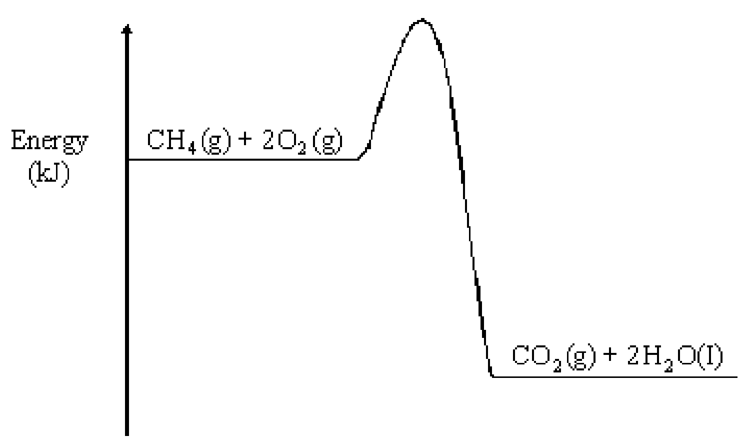
(2)

(Total 8 marks)

8 Many hydrocarbons are used as fuels. An energy level diagram is shown for the combustion of the hydrocarbon methane.



Describe and explain why the line rises and then falls to a lower level.

....

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(Total 4 marks)

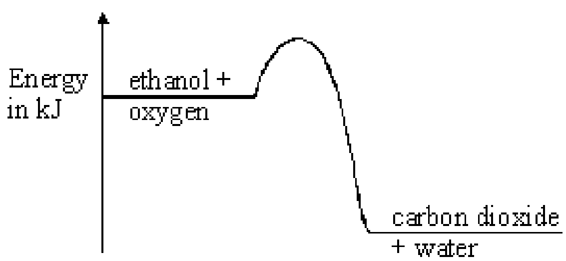
9 Ethanol is used as a fuel.

(a) Balance the symbol equation for the combustion reaction.

$$C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$$

(1)

(b) The energy level diagram represents the combustion of ethanol.



Describe what must happen to the molecules of ethanol and oxygen to allow them to react.

....

....

....

....

....

....

(3)

(c) We can use bond energies to calculate the energy change for the reaction between hydrogen and oxygen.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Bond	Bond energy in kJ
H – H	436
O – H	464
O = O	498

(i) Calculate the total bond energy of the reactants.

....

....

....

Total bond energy of reactants = ... kJ

(2)

(ii) Is the reaction between hydrogen and oxygen exothermic or endothermic? Use bond energies to explain your answer.

....

....

....

....

....

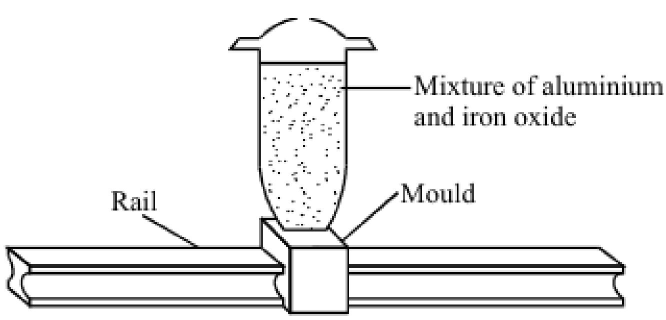
....

....

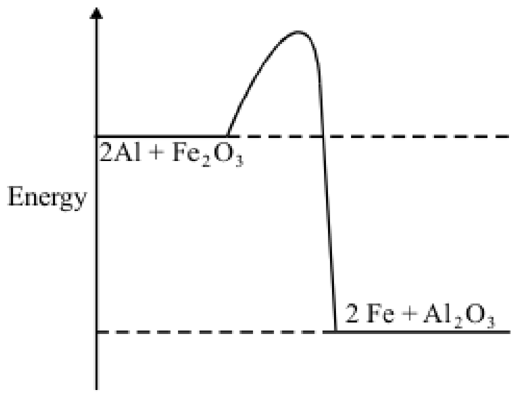
(2)
(Total 8 marks)

10 The reaction between aluminium and iron oxide is used to weld together railway lines.

$$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(l) + Al_2O_3(s)$$



A simple, qualitative energy level diagram for this reaction is shown.



Use the energy level diagram to:

(i) describe the idea of activation energy;

....

....

(1)

(ii) explain why the reaction produces molten iron.

....

....

....

....

(2)

(Total 3 marks)

11

During a thunderstorm lightning strikes the Eiffel Tower.

By M. G. Loppé [Public domain], via Wikimedia Commons

In lightning the temperature can reach 30 000 °C. This causes nitrogen and oxygen in the air to react, producing nitrogen oxide. This reaction has a high *activation energy* and is *endothermic*.

(a) Nitrogen and oxygen in the air do not react easily.

What makes nitrogen and oxygen react during thunderstorms?

....

(1)

(b) Complete the word equation for the reaction of nitrogen with oxygen.

nitrogen + ... → ....

(1)

(c) In an *endothermic* reaction, energy is taken in from the surroundings.

Draw a ring around the correct answer to complete the sentence.

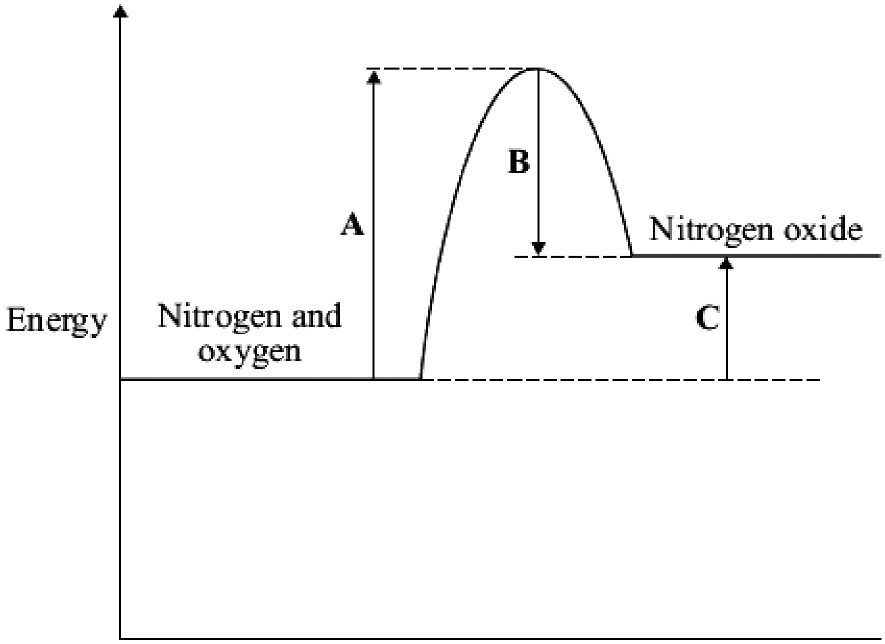
In an *endothermic* reaction, the energy needed to break existing bonds is

less than
more than
the same as

the energy released from forming new bonds.

(1)

(d) The energy level diagram for this reaction is shown.



Use the energy level diagram to help you to answer these questions.

(i) Which energy change, **A**, **B** or **C**, represents the *activation energy*?

(1)

(ii) Which energy change, **A**, **B** or **C**, shows that this reaction is *endothermic*?

(1)

(Total 5 marks)

12 Some of the hydrogen and chlorine are reacted together to form hydrogen chloride.

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Bond	Bond energy in kJ/mol
Cl–Cl	242
H–Cl	431
H–H	436

(i) Use the bond energies to calculate the energy change for the formation of hydrogen chloride.

....

....

....

....

Energy change = ... kJ/mol

(3)

(ii) Is this reaction exothermic or endothermic? Explain your answer.

....

....

....

(2)

(iii) Explain why hydrogen chloride only acts as an acid when dissolved in water.

....

....

....

(3)

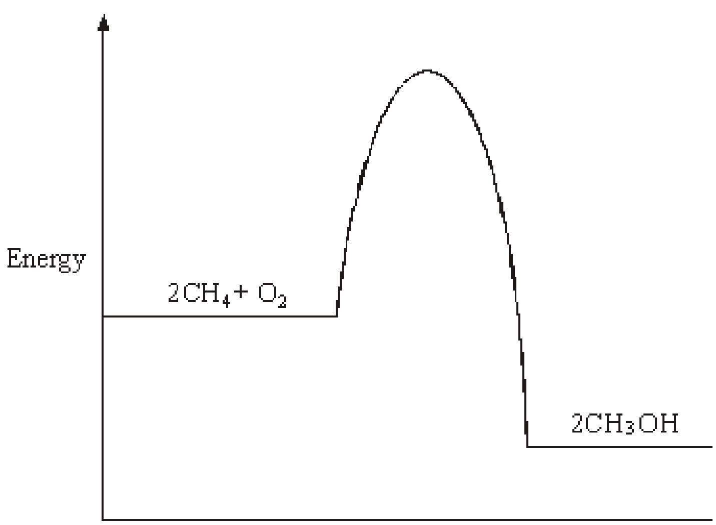
(Total 8 marks)

13 Methanol (CH_3OH) can be made by reacting methane (CH_4) and oxygen (O_2) in the presence of a platinum catalyst. The reaction is exothermic.

An equation that represents the reaction is:

$$2CH_4 + O_2 \rightarrow 2CH_3OH$$

(a) The energy level diagram for this reaction is given below.



(i) Use the diagram to explain how you know that this reaction is exothermic.

....

....

....

(1)

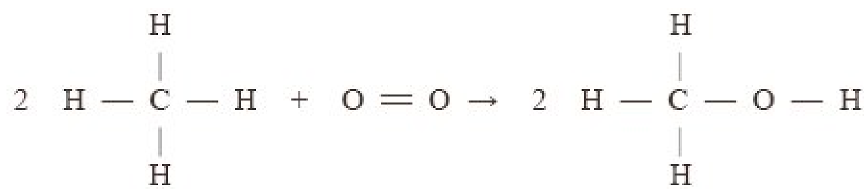
(ii) Explain, in terms of the energy level diagram, how the platinum catalyst increases the rate of this reaction.

....

....

(1)

(b) The equation can also be written showing the structural formulae of the reactants and the product.



(i) Use the bond energies given in the table to help you to calculate the energy change for this reaction.

Bond	Bond energy in kJ
C — H	435
O = O	498
C — O	805
O — H	464

....

....

....

....

....

Energy change = ... kJ

(3)

(ii) In terms of the bond energies, explain why this reaction is exothermic.

....

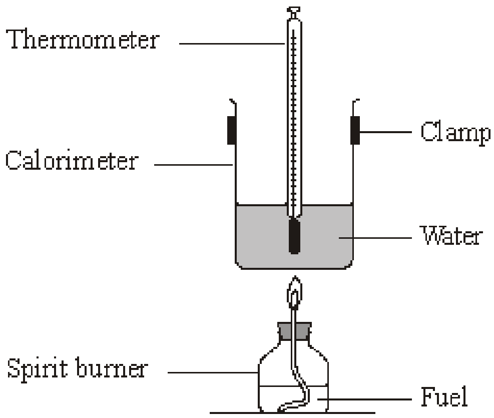
....

(1)

(Total 6 marks)

14 A student burned four fuels and compared the amounts of energy they produced.

The student set up the apparatus as shown in the diagram.



The heat produced when each fuel was burned was used to raise the temperature of 100 g of water. The student noted the mass of fuel burned, the increase in temperature and whether the flame was smoky.

The results are shown in the table.

Fuel	**Mass of fuel burned (g)**	**Temperature increase (°C)**	**Type of flame**
Ethanol	4	24	Not smoky
Methanol	3	9	Not smoky
Peanut oil	2	20	Smoky
Vegetable oil	1	15	Smoky

(a) The student suggested that the vegetable oil was the best fuel for producing heat.

Explain why.

....

....

....

....

(2)

(b) Suggest an environmental problem that could be caused when large amounts of vegetable oil are burned. Suggest how the problem could be overcome.

....

....

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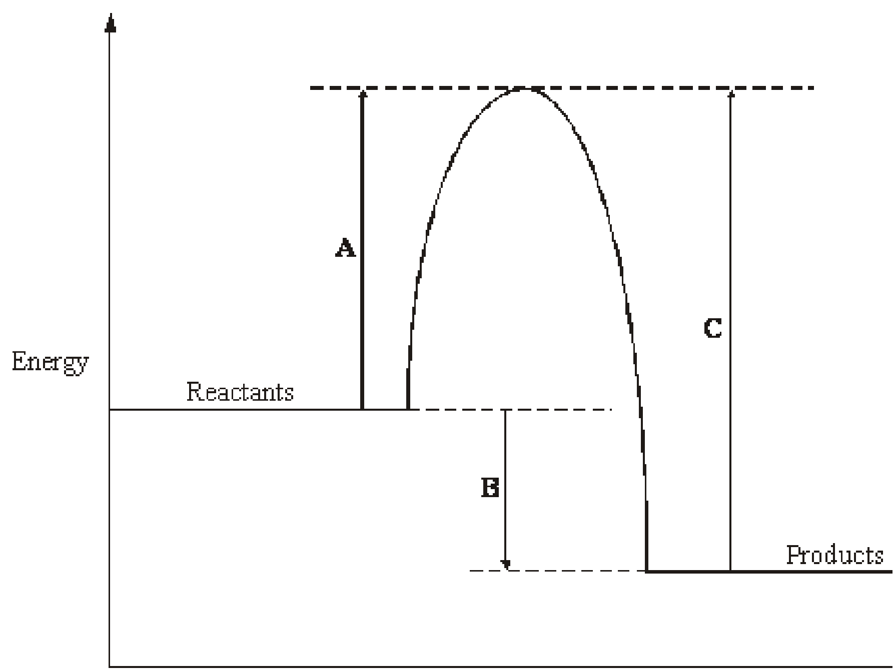
....

(2)

(c) An energy level diagram for the burning of vegetable oil is shown below.



Which of the energy changes **A**, **B** or **C:**

(i) represents the activation energy

....

(1)

(ii) shows the amount of energy given out during the reaction?

....

(1)

(Total 6 marks)

15

An airship caught fire when it was coming in to land in 1937. The airship was filled with hydrogen. A spark or flame ignited the hydrogen. The hydrogen reacted with oxygen in the air to produce water.

(a) The equation for the reaction can be represented using structural formulae for the chemicals.

$$2\,H-H + O=O \rightarrow 2\,H-O-H$$

Use the bond energies given in the table to help you to calculate the energy change for this reaction.

Bond	Bond energy in kJ per mole
H – H	436
O = O	498
O – H	464

....

....

....

....

....

....

Energy change = ... kJ

(3)

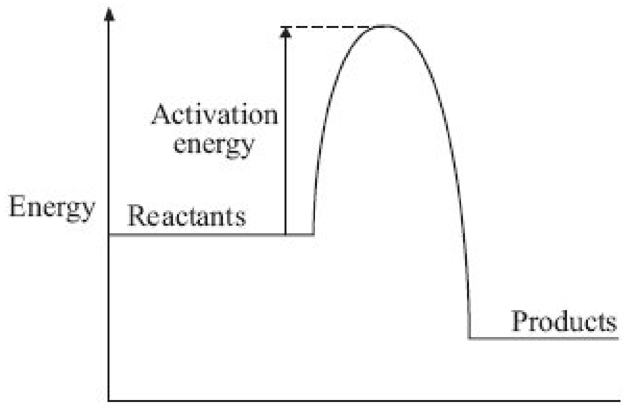
(b) Explain, in terms of making and breaking bonds, why this reaction is exothermic.

....

....

(1)

(c) Use the energy level diagram for this reaction to help you to answer these questions.



(i) The hydrogen did **not** burn until ignited by a spark or flame.

Explain why.

....

....

(1)

(ii) Platinum, a transition metal, causes hydrogen to ignite **without** using a spark or flame.

Explain why.

....

....

....

....

(2)

(Total 7 marks)

16

An airship caught fire when it was coming in to land in 1937. The airship was filled with hydrogen. A spark or flame ignited the hydrogen. The hydrogen reacted with oxygen in the air to produce water.

(a) Write a word equation for the reaction of hydrogen with oxygen.

....

(1)

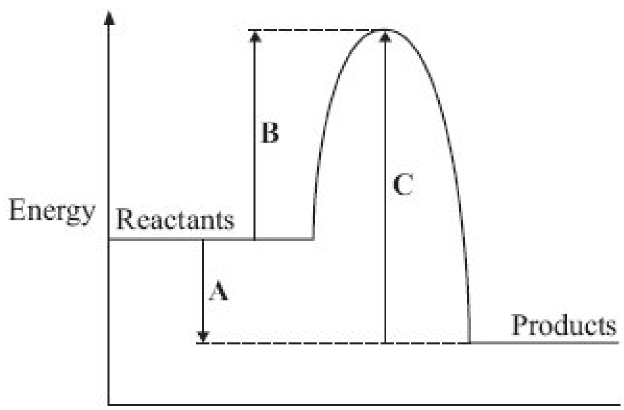
(b) Draw a ring around the correct answer in each box to complete this sentence.

When reactions take place, energy is [released / supplied] to break the existing bonds

and energy is [released / supplied] when new bonds form.

(1)

(c) An energy level diagram for the reaction of hydrogen and oxygen is shown below.



Use the energy level diagram above to help you to answer these questions.

(i) Which energy change, **A**, **B** or **C**, represents the activation energy? ☐

(1)

(ii) Which energy change, **A**, **B** or **C**, shows that the reaction is exothermic? ☐

(1)

(iii) Explain why the hydrogen and oxygen needed a spark or flame to start the reaction.

....

....

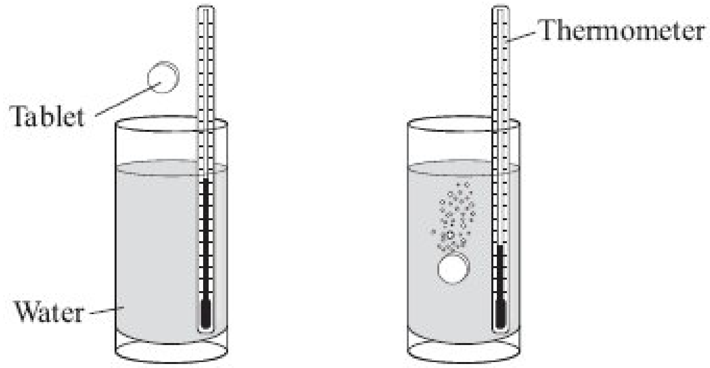
(1)

(Total 5 marks)

17

An indigestion tablet contains sodium hydrogencarbonate and citric acid.

When the tablet is added to cold water a chemical reaction takes place and there is a lot of fizzing.



(a) The formula of the gas that causes the fizzing is CO_2

Name this gas ....

(1)

(b) This chemical reaction is endothermic.

(i) Tick (✓) the statement which describes what happens to the temperature of the solution.

Statement	**Tick (✓)**
The temperature of the solution will increase.	
The temperature of the solution will decrease.	
The temperature of the solution will stay the same.	

(1)

(ii) Tick (✓) the statement which describes what happens to the energy during the reaction.

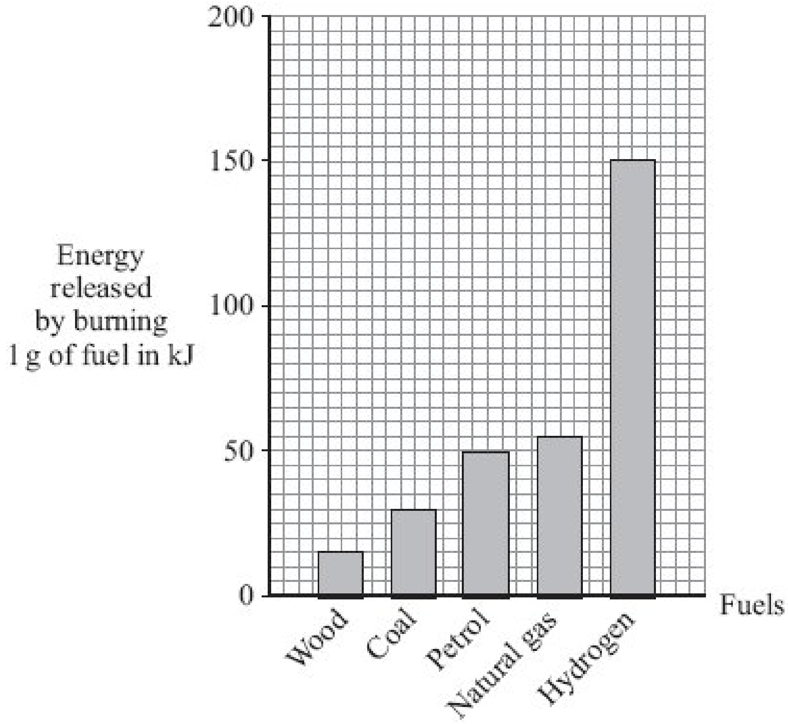
Statement	**Tick (✓)**
Energy is given out to the surroundings.	
Energy is taken in from the surroundings.	
No energy is given out to or taken from the surroundings.	

(1)

(Total 3 marks)

18 Energy is released by burning fuels.

(a) The bar chart shows the energy in kilojoules, kJ, released by burning 1 g of five different fuels.



(i) Which fuel releases the least energy from 1 g?

....

(1)

(ii) How much energy is released by burning 1 g of coal?

Energy = ... kJ

(1)

(iii) Coal burns in oxygen and produces the gases shown in the table.

Name	**Formula**
Carbon dioxide	CO_2
Water vapour	H_2O
Sulfur dioxide	SO_2

Use information from the table to name **one** element that is in coal.

....

(1)

(iv) Use information from the bar chart to calculate the mass of petrol that will release the same amount of energy as 1 g of hydrogen.

....

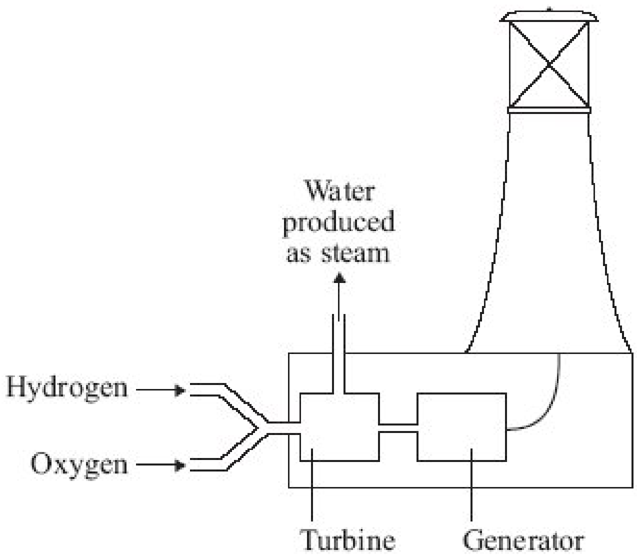
....

Mass = ... g

(1)

(b) Hydrogen can be made from fossil fuels.
Hydrogen burns rapidly in oxygen to produce water only.

A lighthouse uses electricity generated by burning hydrogen.



(i) Use information from the bar chart and the diagram above to suggest **two** advantages of using hydrogen as a fuel.

1 ....

....

2 ....

....

(2)

(ii) Suggest **one** disadvantage of using hydrogen.

....

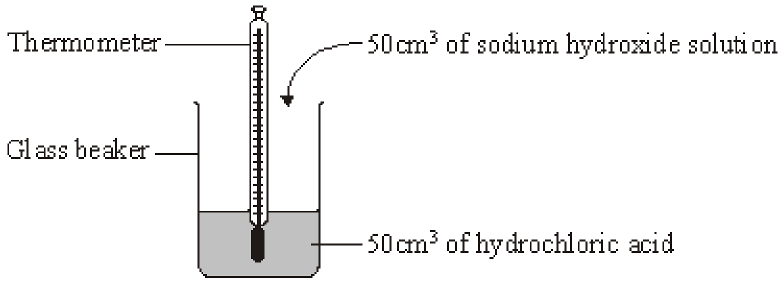
(1)
(Total 7 marks)

19 Read the information about energy changes and then answer the questions.

A student did an experiment to find the energy change when hydrochloric acid reacts with sodium hydroxide. The equation which represents the reaction is:

$HCl + NaOH \rightarrow NaCl + H_2O$

The student used the apparatus shown in the diagram.



The student placed 50 cm^3 of hydrochloric acid in a glass beaker and measured the temperature.

The student then quickly added 50 cm3 of sodium hydroxide solution and stirred the mixture with the thermometer. The highest temperature was recorded.

The student repeated the experiment, and calculated the temperature change each time.

	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Initial temperature in °C	19.0	22.0	19.2	19.0
Highest temperature in °C	26.2	29.0	26.0	23.5
Temperature change in °C	7.2	7.0	6.8	4.5

(a) The biggest error in this experiment is heat loss.

Suggest how the apparatus could be modified to reduce heat loss.

....

....

(1)

(b) Suggest why it is important to stir the chemicals thoroughly.

....

(1)

(c) Which **one** of these experiments was probably carried out on a different day to the others?

Explain your answer.

....

....

(1)

(d) Suggest why experiment 4 should **not** be used to calculate the average temperature change.

....

....

(1)

(e) Calculate the average temperature change from the first three experiments.

....

Answer = ... °C

(1)

(f) Use the following equation to calculate the energy change for this reaction.

energy change in joules = 100 × 4.2 × average temperature change

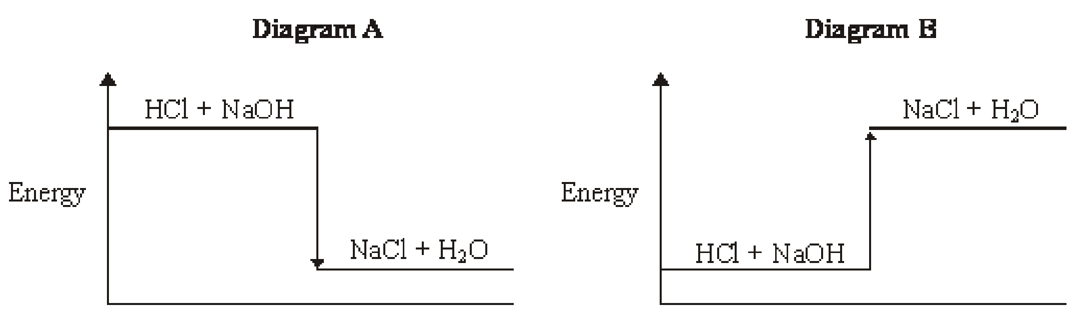
....

Answer = ... J

(1)

(g) Which **one** of these energy level diagrams, **A** or **B**, represents the energy change for this reaction?

Explain why.



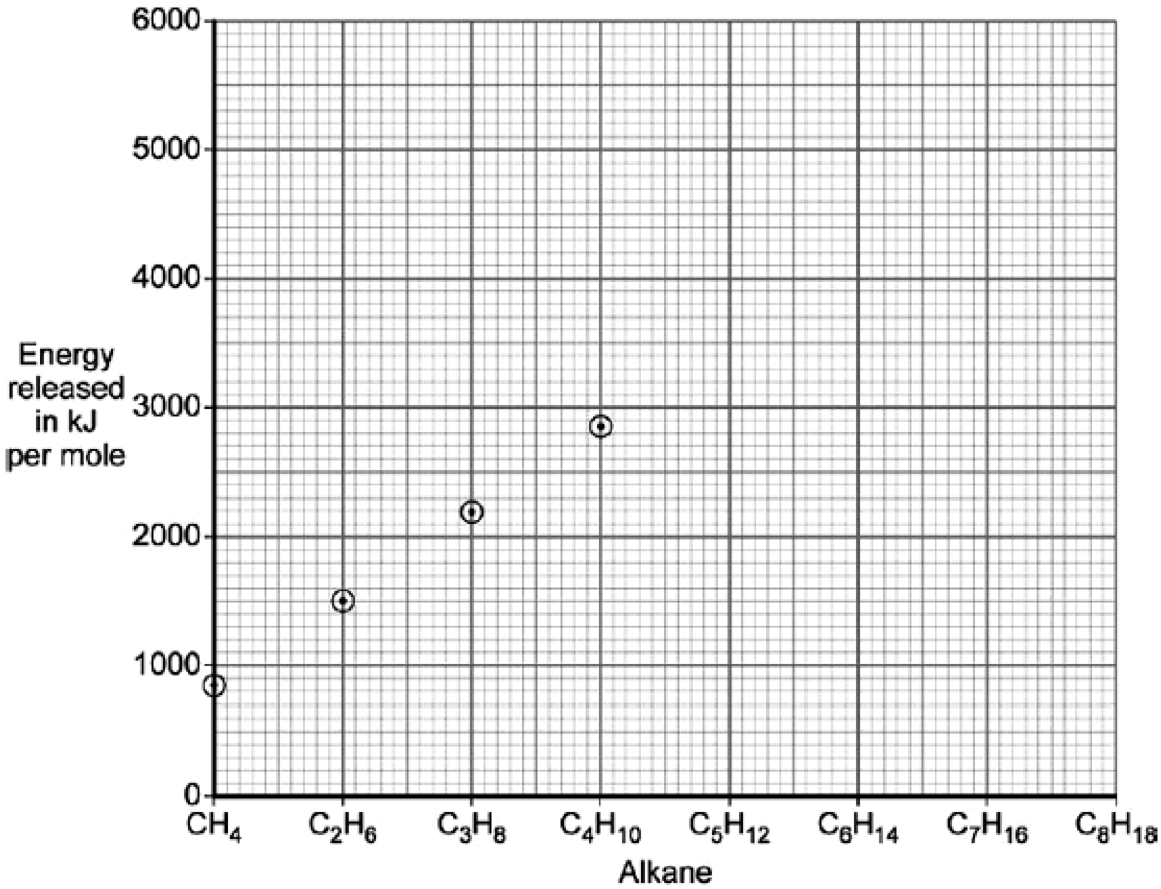
....

....

(1)
(Total 7 marks)

20 (a) Alkanes are important hydrocarbon fuels. They have the general formula C_nH_{2n+2}

The points on the graph show the amount of energy released when 1 mole of methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}) are burned separately.



(i) Draw a line through the points and extend your line to the right-hand edge of the graph.

(1)

(ii) Use the graph to estimate the amount of energy released when 1 mole of octane (C_8H_{18}) is burned.

Energy released = ... kJ

(1)

(iii) Suggest why we can make a good estimate for the energy released by 1 mole of pentane (C_5H_{12}).

....

....

(1)

(iv) A student noticed that octane (C_8H_{18}) has twice as many carbon atoms as butane (C_4H_{10}), and made the following prediction:

"When burned, 1 mole of octane releases twice as much energy as 1 mole of butane."

Use the graph to decide if the student's prediction is correct. You **must** show your working to gain credit.

....

....

....

....

(2)

(b) Some information about four fuels is given in the table.

Fuel	Type	Heat released in kJ per g	Combustion products			Type of flame
			CO_2	SO_2	H_2O	
Bio-ethanol	Renewable	29	✓		✓	Not smoky
Coal	Non-renewable	31	✓	✓	✓	Smoky
Hydrogen	Renewable	142			✓	Not smoky
Natural gas	Non-renewable	56	✓		✓	Not smoky

From this information a student made two conclusions.

For each conclusion, state if it is correct **and** explain your answer.

(i) "Renewable fuels release more heat per gram than non-renewable fuels."

....

....

....

....

(2)

(ii) "Non-renewable fuels are better for the environment than renewable fuels."

....

....

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....

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....

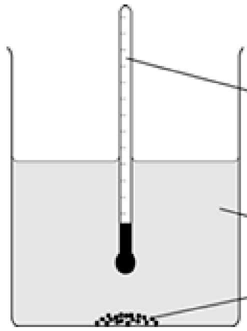
....

(2)

(Total 9 marks)

21 A student investigated the reactivity of different metals.

The student used the apparatus shown in the figure below.



The student used four different metals.

The student measured the temperature rise for each metal three times.

The student's results are shown in the table below.

Metal	**Temperature rise in °C**			**Mean temperature rise in °C**
	Test 1	Test 2	Test 3	
Calcium	17.8	16.9	17.5	
Iron	6.2	6.0	6.1	6.1
Magnesium	12.5	4.2	12.3	12.4
Zinc	7.8	8.0	7.6	7.8

(a) Give **two** variables the student should control so that the investigation is a fair test.

1 ....

....

2 ....

....

(2)

(b) One of the results for magnesium is anomalous.

Which result is anomalous?

Suggest **one** reason why this anomalous result was obtained.

Result ....

....

Reason ....

....

(2)

(c) Calculate the mean temperature rise for calcium.

....

Mean temperature rise = ... °C

(1)

(d) The temperature rose when the metals were added to sulfuric acid.

Give **one** other observation that might be made when the metal was added to sulfuric acid.
How would this observation be different for the different metals?

....

....

....

....

(2)

(e) Aluminium is more reactive than iron and zinc but less reactive than calcium and magnesium.

Predict the temperature rise when aluminium is reacted with dilute hydrochloric acid.

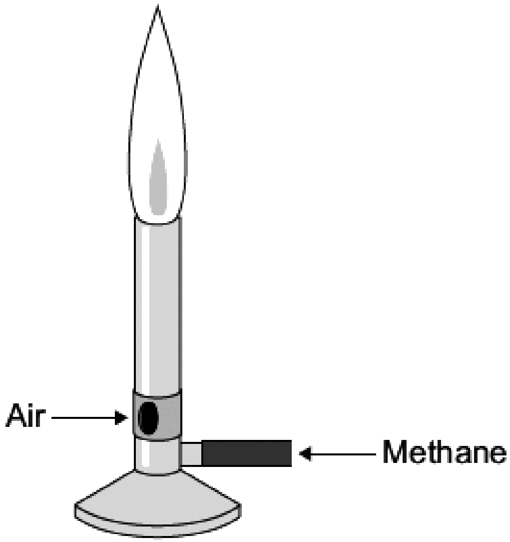
....

Temperature rise = ... °C

(1)

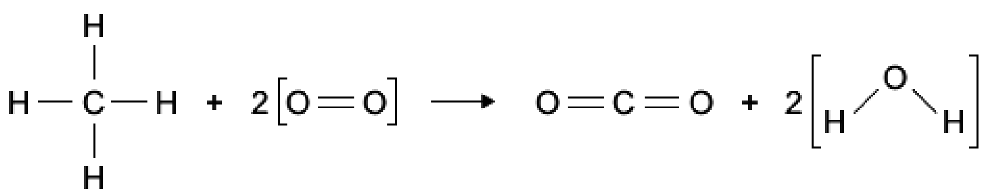
(Total 8 marks)

22 A Bunsen burner releases heat energy by burning methane in air.



(a) Methane (CH_4) reacts with oxygen from the air to produce carbon dioxide and water.

(i) Use the equation and the bond energies to calculate a value for the energy change in this reaction.



Bond	Bond energy in kJ per mole
C — H	414
O = O	498
C = O	803
O–H	464

....

....

....

....

....

....

....

....

Energy change = ... kJ per mole

(3)

(ii) This reaction releases heat energy.

Explain why, in terms of bond energies.

....

....

....

....

(2)

(b) If the gas tap to the Bunsen burner is turned on, the methane does not start burning until it is lit with a match.

Why is heat from the match needed to start the methane burning?

....

....

(1)

(Total 6 marks)

23 Hydrogen peroxide is often used to bleach or lighten hair.

Hydrogen peroxide slowly decomposes to produce water and oxygen.

(a) The equation for the reaction can be represented using structural formulae.

$$2\ H-O-O-H \longrightarrow 2\ H-O-H \quad + \quad O=O$$

Use the bond energies in the table to help you to calculate the energy change for this reaction.

Bond	**Bond energy in kJ per mole**
H – O	464
O – O	146
O = O	498

....

....

....

....

Energy change = ... kJ

(3)

(b) Explain, in terms of bond making and bond breaking, why the reaction is exothermic.

....

....

....

(1)

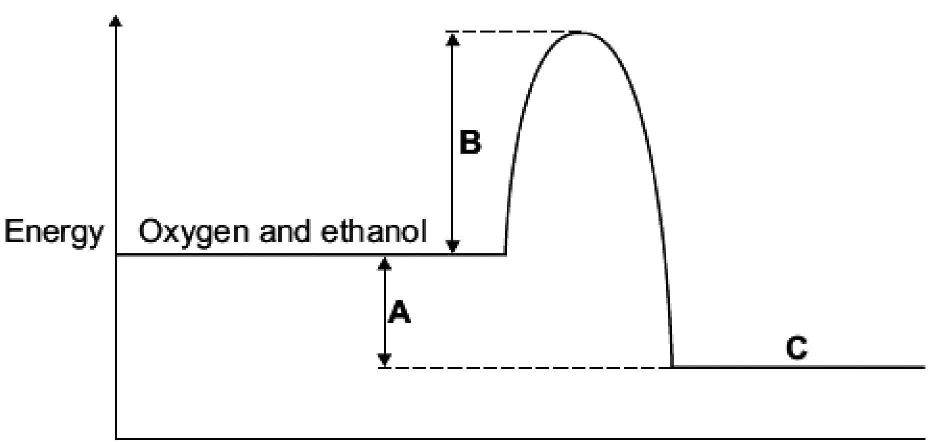
(Total 4 marks)

24 V2 rockets were used during the Second World War.

By aronsson [CC BY-SA 2.0], via Flickr

V2 rockets were powered by liquid oxygen and ethanol. Oxygen and ethanol react to produce carbon dioxide and water.

The energy level diagram represents the energy changes during this reaction.



(a) On the energy level diagram what is represented by the letter:

A ....

B ....

C ....

(3)

(b) What type of reaction is represented by this energy level diagram?

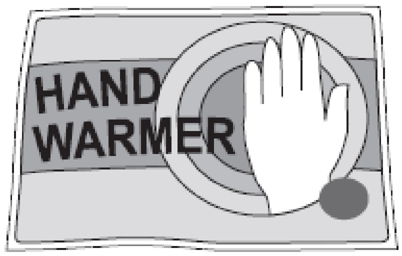
....

....

(1)

(Total 4 marks)

25 Hand warmers use chemical reactions.



(a) The table shows temperature changes for chemical reactions **A**, **B** and **C**.

Reaction	Starting temperature in °C	Final temperature in °C	Change in temperature in °C
A	18	25	+ 7
B	17	....	+ 5
C	18	27	+ 9

What is the final temperature for reaction **B**? Write your answer in the table.

(1)

(b) (i) What name is given to reactions that heat the surroundings? ....

(1)

(ii) Which reaction, **A**, **B** or **C**, would be best to use in a hand warmer?

Reaction ☐

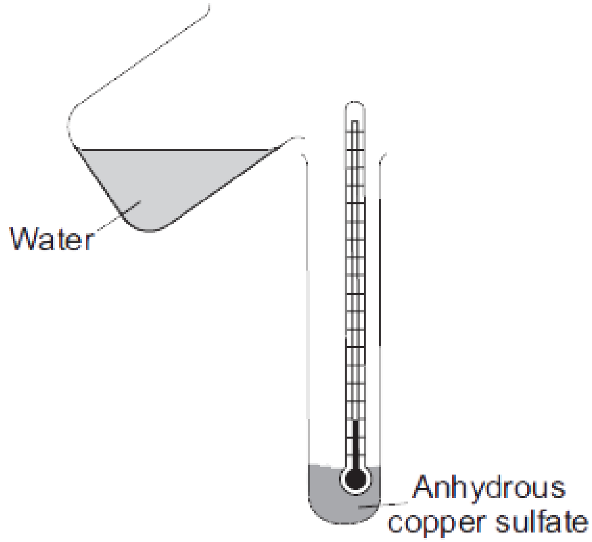
Give a reason why you chose this reaction.

....

....

(2)

(c) A student added water to some anhydrous copper sulfate.



The equation for the reaction is shown.

anhydrous copper sulfate + water ⇌ hydrated copper sulfate

$$CuSO_4 + 5\,H_2O \rightleftharpoons CuSO_4.5H_2O$$

The student measured the temperature before and after the reaction.

(i) The measurements showed that this reaction can be used for a hand warmer.

Draw a ring around the correct answer to complete the sentence.

When water is added to anhydrous copper sulfate the temperature

	increases.
of the mixture	decreases.
	stays the same.

(1)

(ii) Anhydrous copper sulfate is white.

What colour is seen after water is added to the anhydrous copper sulfate?

....

(1)

(iii) What does the symbol ⇌ mean?

....

(1)

(iv) The student heated a tube containing hydrated copper sulfate.

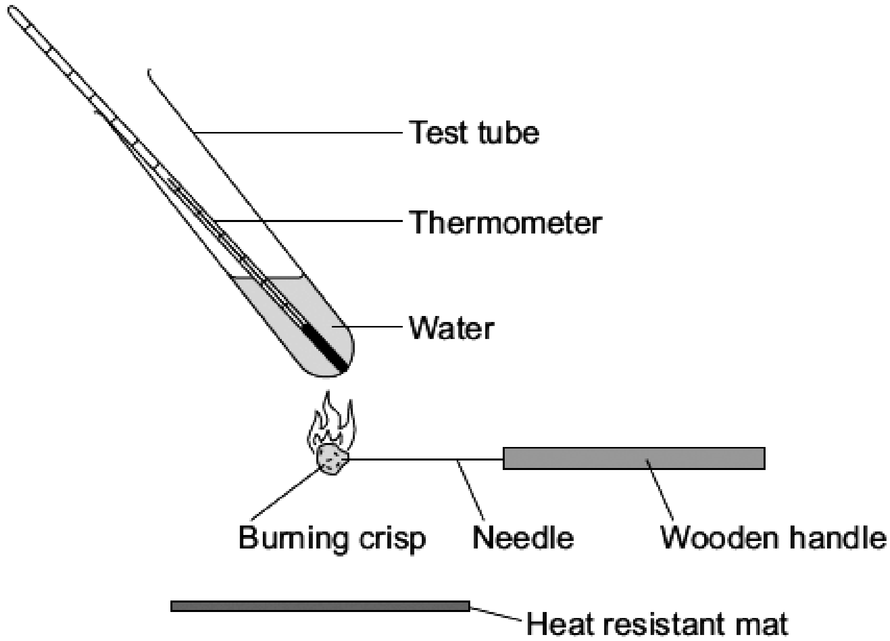
Name the solid substance produced.

....

(1)

(Total 8 marks)

26 A student investigated the amount of energy released when four different makes of plain salted crisps were burned.



The following method was used for each make of plain salted crisp. The pieces of crisp were all the same size.

- The starting temperature of the water was measured.
- The piece of crisp was burned underneath the test tube.
- The final temperature of the water was measured.

(a) The results of the investigation are shown in the table.

	Make 1	**Make 2**	**Make 3**	**Make 4**
Final temperature of the water in °C	26	25	29	25
Starting temperature of the water in °C	19	20	20	21
Temperature rise of the water in °C	7	5	9	

(i) Calculate the temperature rise for **make 4**.

....

Temperature rise = ... °C

(1)

(ii) Which make of crisp, **1**, **2**, **3** or **4**, releases the most energy?

Make ....

Give a reason for your answer.

....

....

(2)

(b) The energy needed by a student is about 9000 kJ each day.

(i) One large bag of crisps states that the energy released by the crisps is 240 kcal.

Calculate the energy of this bag of crisps in kJ.

1 kcal = 4.2 kJ

....

....

Answer = ... kJ

(2)

(ii) Eating too many crisps is thought to be bad for your health.

Use the information above and your knowledge to explain why.

....

....

....

....

(2)

(Total 7 marks)

27 Read the information.

Alumina is a white solid. In 1800, scientists thought that alumina contained an undiscovered metal. We now call this metal aluminium. At that time, scientists could not extract the aluminium from alumina. In 1825, Christian Oersted, a Danish scientist, did experiments with alumina. **Step 1** He reacted a mixture of hot alumina and carbon with chlorine to form aluminium chloride. The reaction is very endothermic. **Step 2** The aluminium chloride was reacted with potassium. He was left with potassium chloride and tiny particles of aluminium metal. Other scientists were **not** able to obtain the same results using his experiment and his work was not accepted at that time. In 1827, Friedrich Wöhler, a German chemist, made some changes to Oersted's experiment. He obtained a lump of aluminium. He tested the aluminium and recorded its properties.

(a) Suggest why scientists in 1800 could not extract aluminium from alumina.

....

....

(1)

(b) Oersted's experiment in 1825 was **not** thought to be reliable.

Explain why

....

....

(1)

(c) Why must the reaction in **Step 1** be heated to make it work?

....

....

(1)

(d) Complete the word equation for the reaction in **Step 2**.

aluminium chloride + potassium → .... + ...

(1)

(e) Suggest how Wöhler was able to prove that he had made a new metal.

....

....

....

....

(2)

(Total 6 marks)

28 When ammonium chloride is dissolved in water, there is a temperature change.

A student investigated how the temperature of water changed when different masses of ammonium chloride were added to the same volume of water.

The water used was at room temperature.

The student's results are shown in the table.

Mass of ammonium chloride in g	**Final temperature of solution in °C**
10	14.5
20	8.5
25	5.5
30	2.5
35	1.0
40	1.0
45	1.0

(a) (i) Use the correct word from the box to complete the sentence.

endothermic	**exothermic**	**reduction**

When ammonium chloride dissolves in water, the change can be

described as ....

(1)

(ii) Give a reason for your answer to part **(a) (i)**. Refer to the table of results in your answer.

....

....

(1)

(b) The student added the ammonium chloride to water and stirred the mixture.

The water was in a glass beaker.

His teacher said that using a glass beaker could cause inaccurate results.

What could the student have used instead of a glass beaker to improve the accuracy?

Give a reason why this would improve the accuracy of his results.

....

....

....

....

....

(2)

(c) The student made sure his investigation was a fair test.

State **two** control variables the student should keep the same.

Give a reason why changing each of these two control variables would affect the temperature change.

Control variable 1 ....

Reason ....

....

....

Control variable 2 ....

Reason ....

....

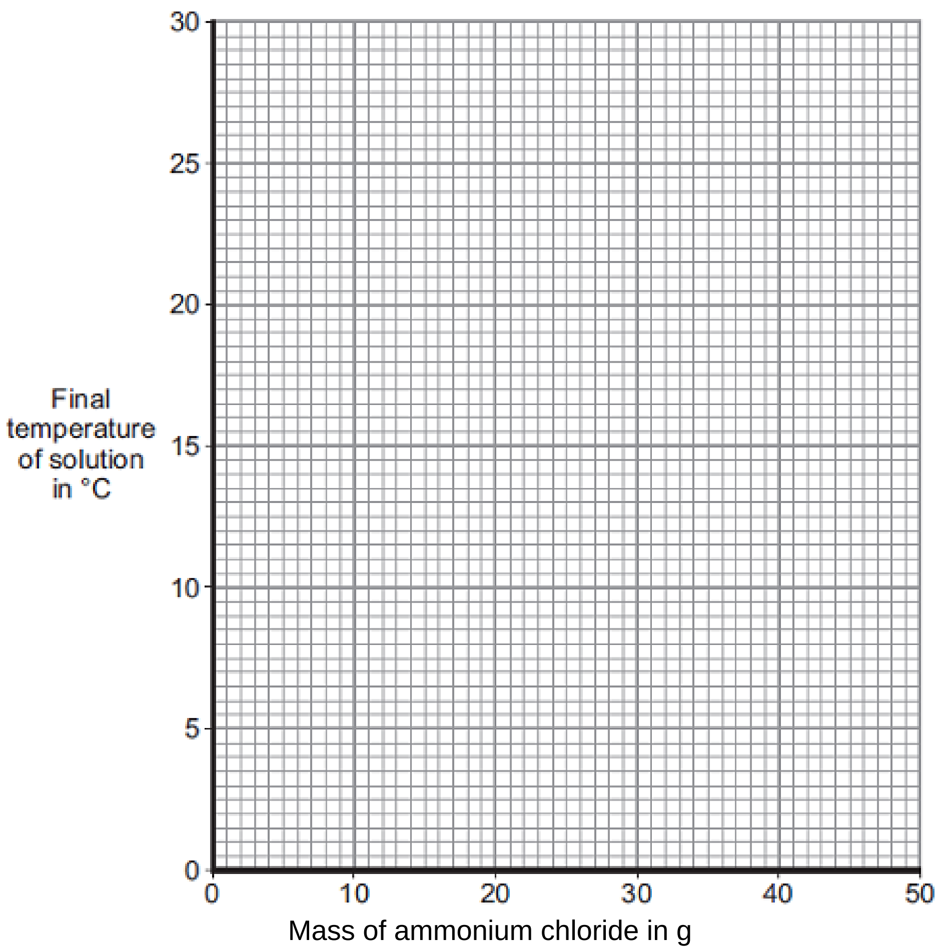
....

(4)

(d) (i) The student's results table has been repeated below.

Mass of ammonium chloride in g	**Final temperature of solution in °C**
10	14.5
20	8.5
25	5.5
30	2.5
35	1.0
40	1.0
45	1.0

Plot the results on the grid.



(2)

(ii) Complete the graph by drawing two straight lines of best fit through the points.

(2)

(iii) Use the graph to estimate the temperature of the room.

Show your working on the graph.

Temperature of room = ... °C

(2)

(e) Explain why the final temperature was the same for all masses of 35 g and greater.

....

....

....

....

(2)

(f) A second student also did one of the experiments.

This student recorded a final temperature of 14.5 °C.

Both students dissolved 20 g of ammonium chloride in water.

Use the graph to explain the difference in the two final temperatures.

....

....

....

....

....

(2)

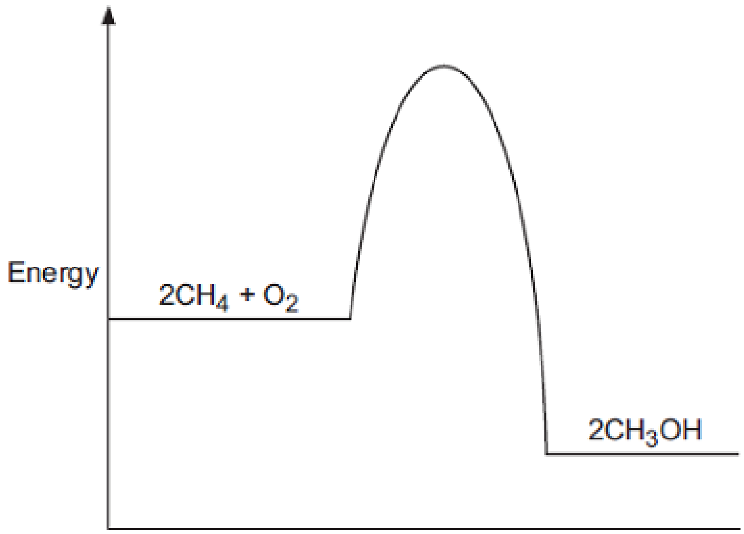
(Total 18 marks)

29 Methanol (CH_3OH) can be made by reacting methane (CH_4) and oxygen (O_2). The reaction is exothermic.

The equation for the reaction is:

$$2CH_4 + O_2 \longrightarrow 2CH_3OH$$

(a) The energy level diagram for this reaction is given below.



(i) How does the diagram show that this reaction is exothermic?

....

....

....

(1)

(ii) A platinum catalyst can be used to increase the rate of this reaction.

What effect does adding a catalyst have on the energy level diagram?

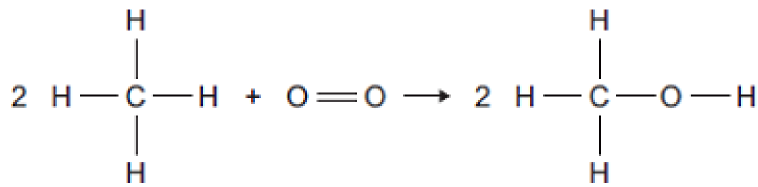
....

....

....

(1)

(b) The equation can also be written showing the structural formulae of the reactants and the product.



(i) Use the bond energies given in the table to help you to calculate the energy change for this reaction.

Bond	Bond energy in kJ
C—H	435
O═O	497
C—O	336
O—H	464

....

....

....

....

Energy change = ... kJ

(3)

(iii) In terms of the bond energies, why is this an exothermic reaction?

....

....

(1)

(Total 6 marks)

30 The equation for the reaction of ethene and bromine is:

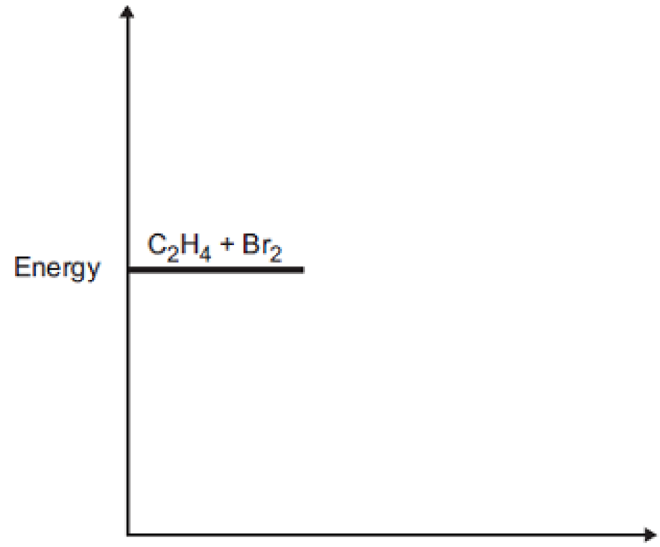
$$C_2H_4(g) + Br_2(l) \longrightarrow C_2H_4Br_2(l)$$

The reaction is exothermic.

(a) Complete the energy level diagram.

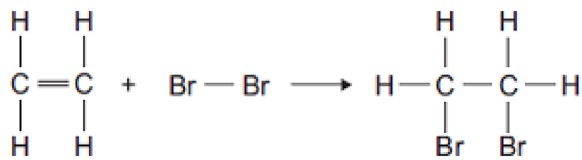
You should label:

- the activation energy
- the enthalpy change (ΔH).



(3)

(b) (i) The equation for the reaction can be represented as:



Bond	Bond dissociation energy in kJ per mole
C — H	413
C = C	614
Br — Br	193
C — C	348
C — Br	276

Use the bond dissociation energies in the table to calculate the enthalpy change (ΔH) for this reaction.

....

....

....

....

....

....

Enthalpy change (ΔH) = ... kJ per mole

(3)

(ii) The reaction is exothermic.

Explain why, in terms of bonds broken and bonds formed.

....

....

....

....

....

(2)

(Total 8 marks)

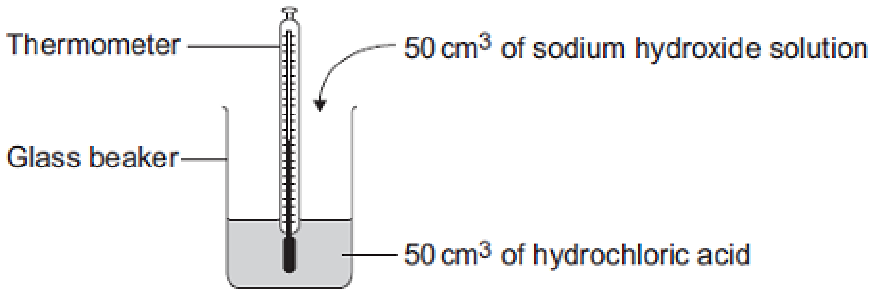
31 Read the information about energy changes and then answer the questions.

A student did an experiment to find the energy change when hydrochloric acid reacts with sodium hydroxide.

The equation which represents the reaction is:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The student used the apparatus shown in the diagram.



The student placed 50 cm^3 of hydrochloric acid in a glass beaker and measured the initial temperature.

The student then quickly added 50 cm^3 of sodium hydroxide solution and stirred the mixture with the thermometer. The highest temperature was recorded.

The student repeated the experiment, and calculated the temperature change each time.

	Experiment 1	**Experiment 2**	**Experiment 3**	**Experiment 4**
Initial temperature in °C	19.0	22.0	19.2	19.0
Highest temperature in °C	26.2	29.0	26.0	23.5
Temperature change in °C	7.2	7.0	6.8	4.5

(a) The biggest error in this experiment is heat loss.

Suggest how the apparatus could be modified to reduce heat loss.

....

....

(1)

(b) Suggest why it is important to mix the chemicals thoroughly.

....

(1)

(c) Which **one** of these experiments was probably done on a different day to the others?

Give a reason for your answer.

....

(1)

(d) Suggest why experiment **4** should **not** be used to calculate the average temperature change.

....

....

(1)

(e) Calculate the average temperature change from the first three experiments.

....

Answer = ... °C

(1)

(f) Use the following equation to calculate the energy change for this reaction.

Energy change in joules = 100 × 4.2 × average temperature change

....

Answer = ... J

(1)

(g) Which **one** of these energy level diagrams represents the energy change for this reaction?

Give a reason for your answer.

Diagram A

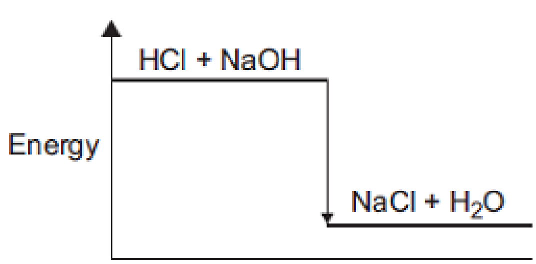
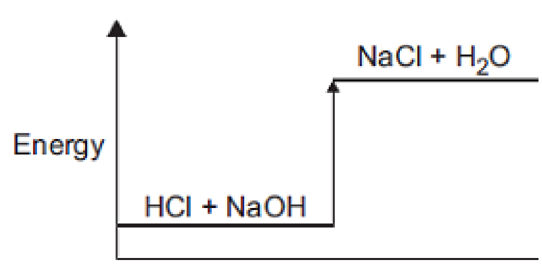


Diagram B



....

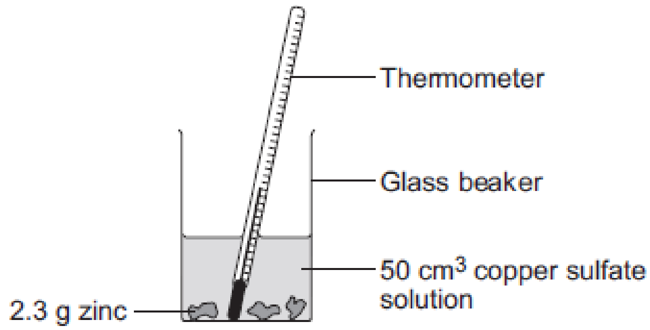
....

(1)
(Total 7 marks)

32 A student investigated the temperature change when zinc reacts with copper sulfate solution.

The student used a different concentration of copper sulfate solution for each experiment.

The student used the apparatus shown below.



The student:

- measured 50 cm^3 copper sulfate solution into a glass beaker
- measured the temperature of the copper sulfate solution
- added 2.3 g zinc
- measured the highest temperature
- repeated the experiment using copper sulfate solution with different concentrations.

The equation for the reaction is:

$$Zn(s) + CuSO_4(aq) \longrightarrow Cu(s) + ZnSO_4(aq)$$

zinc + copper sulfate solution ⟶ copper + zinc sulfate solution

(a) The thermometer reading changes during the reaction.

Give **one** other change the student could **see** during the reaction.

....

....

(1)

(b) Suggest **one** improvement the student could make to the apparatus.

Give a reason why this improves the investigation.

Improvement ....

....

Reason ....

....

(2)

(c) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

The student's results are shown in the table.

Table

Experiment number	Concentration of copper sulfate in moles per dm^3	Increase in temperature in °C
1	0.1	5
2	0.2	10
3	0.3	12
4	0.4	20
5	0.5	25
6	0.6	30
7	0.7	35
8	0.8	35
9	0.9	35
10	1.0	35

Describe **and** explain the trends shown in the student's results.

....

....

....

....

....

....

....

....

....

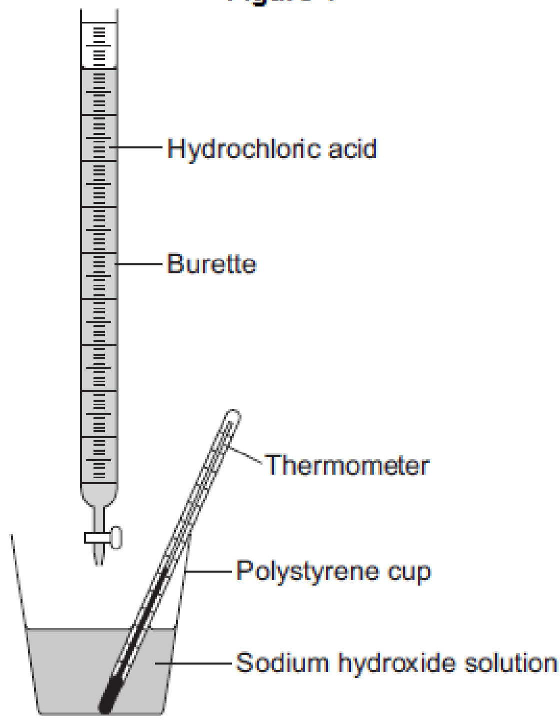
....

(6)

(Total 9 marks)

33 A student investigates the energy released when hydrochloric acid completely neutralises sodium hydroxide solution.
The student uses the apparatus shown in **Figure 1**.

Figure 1



The student:

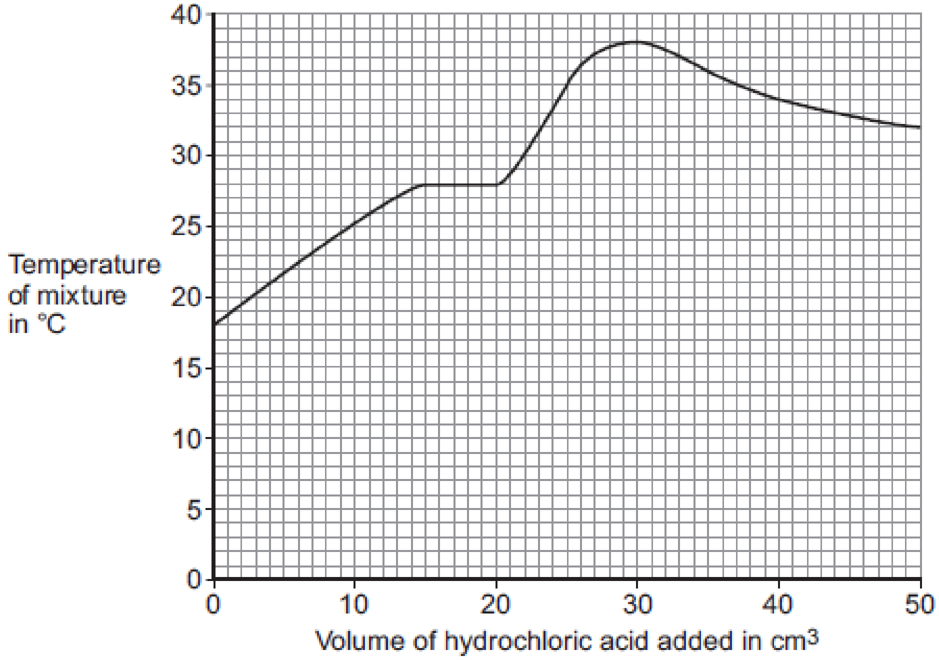
- measures 25 cm^3 sodium hydroxide solution into a polystyrene cup
- fills a burette with hydrochloric acid
- measures the temperature of the sodium hydroxide solution
- adds 5 cm^3 hydrochloric acid to the sodium hydroxide solution in the polystyrene cup
- stirs the mixture and measures the highest temperature of the mixture
- continues to add 5 cm^3 portions of hydrochloric acid, stirring and measuring the highest temperature of the mixture after each addition.

(a) The student has plotted a graph of the results.

The graph line has been incorrectly drawn by including an anomalous result.

The graph is shown in **Figure 2**.

Figure 2



(i) Suggest a cause for the anomalous result when 20 cm^3 of hydrochloric acid is added.

....

....

(1)

(ii) Suggest the true value of the temperature of the anomalous point.

Temperature = ... °C

(1)

(iii) What was the **total** volume of the mixture when the maximum temperature was reached?

....

Total volume of the mixture = ... cm^3

(1)

(iv) Calculate the overall temperature increase in this experiment.

....

Overall temperature increase = ... °C

(1)

(v) Use your answers to (iii) and (iv) and the equation to calculate the energy released in the reaction. Give the unit.

Assume the volume in cm^3 is equivalent to the mass of solution in grams.

Equation: $Q = mc\Delta T$

where:
Q = energy released
m = mass of solution (g)
c = 4.2 (J per g per °C)
ΔT = change in temperature (°C)

....

....

Energy released = ... Unit = ...

(2)

(b) The student did the experiment again, starting with 50 cm^3 of sodium hydroxide solution instead of 25 cm^3.

Explain why this would make no difference to the overall temperature increase.

....

....

....

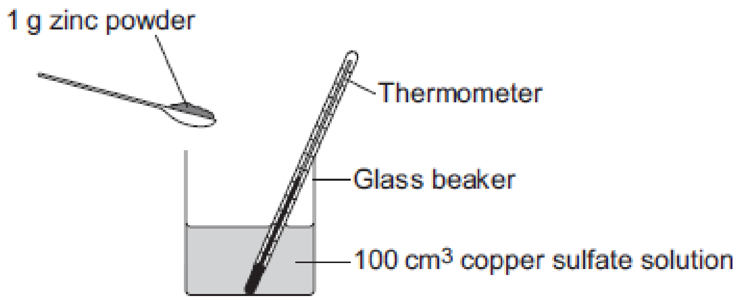
....

(2)

(Total 8 marks)

34 A student investigates the energy released when zinc powder reacts with copper sulfate solution. The student uses the apparatus shown in **Figure 1**.

Figure 1



The student:

- measures 100 cm^3 copper sulfate solution into a beaker
- measures the temperature of the copper sulfate solution
- puts 1 g zinc powder into the beaker
- stirs the mixture with a thermometer
- measures the highest temperature.

The student's results were:

Starting temperature = 21 °C
Highest temperature = 32 °C

(a) (i) Calculate the change in temperature.

....

Change in temperature = ... °C

(1)

(ii) Calculate the energy released in the reaction.

Use the equation

$$\text{energy released in J} = \text{volume of solution in cm}^3 \times 4.2 \times \text{temperature change in °C}$$

....

....

Energy released = ... J

(2)

(b) The reaction of zinc with copper sulfate is exothermic.

How can you tell from the student's results that the reaction is exothermic?

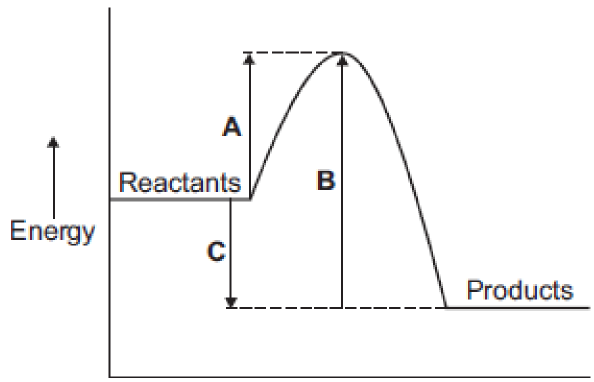
....

....

(1)

(c) The energy diagram for the reaction is shown in **Figure 2**.

Figure 2



(i) How can you tell from the energy diagram that the reaction is exothermic?

....

....

(1)

(ii) Which arrow shows the activation energy in **Figure 2**?

Tick (✓) **one** box.

A ☐

B ☐

C ☐

(1)

(Total 6 marks)

35 During a thunderstorm lightning strikes the Eiffel Tower.

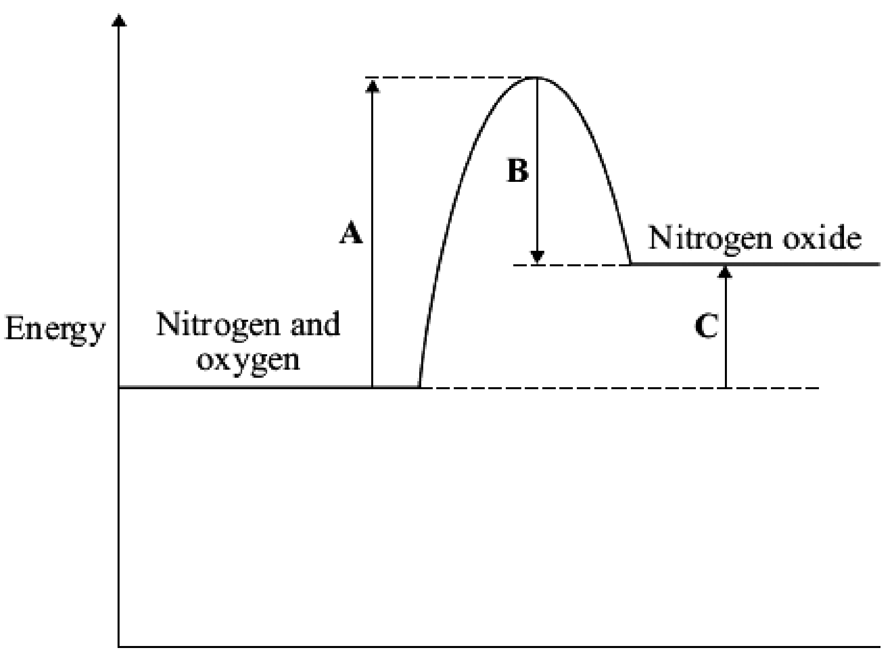
By M. G. Loppé [Public domain], via Wikimedia Commons

In lightning the temperature can reach 30 000 °C. This causes nitrogen and oxygen in the air to react, producing nitrogen oxide. This reaction has a high *activation energy* and is *endothermic*.

An equation that represents this endothermic reaction is:

$$N_2 \quad + \quad O_2 \quad \rightarrow \quad 2NO$$

The energy level diagram for this reaction is given below.



(a) The energy level diagram shows that this reaction is *endothermic*.

Explain how.

....

....

(1)

(b) What is meant by the term *activation energy*?

....

....

(1)

(c) The equation showing the structural formulae of the reactants and products is

$$N \equiv N \quad + \quad O = O \quad \rightarrow \quad 2\ N = O$$

Bond	**Bond energy in kJ**
N ≡ N	945
O = O	498
N = O	630

(i) Use the bond energies in the table to calculate the energy change for this reaction.

....

....

....

....

Energy change = ... kJ

(3)

(ii) In terms of bond energies, explain why this reaction is endothermic.

....

....

....

(1)

(Total 6 marks)

1 (a) breaking of C-H bonds
breaking of O-O bonds
making of C-O bonds

for 1 mark each

making of H-O bonds

4

(b) X energy needed to break bonds
has to be **supplied**/activation energy

Y energy released when bonds form

Z = Y-X
overall, energy is released/reaction is exothermic

each for 1 mark

5

[9]

2 (a) fuels
heat – allow light

for 1 mark each

2

(b) gases

for 1 mark

1

[3]

3 (a) *idea that*
existing bonds must first be broken

for 1 mark

(*credit* molecules / atoms more likely to react when they collide)
energy is released when new bonds form

gains 1 mark

but more energy is released when new bonds form

gains 2 marks

or overall reaction exothermic
this breaks more bonds so the reaction continues

for 1 mark

max 4

(b) • reactant level higher than product level (names of reactants and products not required)

• indication that activation energy required (i.e. the "hump")

• any correct indication of nett energy change

(i.e. between product and reactant levels even if other marks not gained)

for 1 mark each

3

[7]

4

(a) Bonds broken / Bonds formed

number	type	number	type
3	[O=O]	4	[O–H]

each for 1 mark

2

(b)

Total energy change in breaking bonds	Total energy change in forming bonds
3 × 498 = 1494	4 × 464 = 1856

each for 1 mark

Total = 3758 Total = 5076

each for 1 mark

4

(c) net energy transfer = 1318

this energy is released in the reaction/it is an exothermic reaction

each for 1 mark

[N.B. credit e.c.f. (a) → (b) and (b) → (c)]

2

[8]

5

(i) Bonds broken

4 × (C – H)

2 × (O = O)

each for 1 mark

Bonds formed

2 × (C = O)

4 × (O – H)

each for 1 mark

4

(ii) Total energy change in breaking bonds
(4 × 413) + (2 × 498)

each gains 1 mark

Total energy change in forming bonds
(2 × 805) + (4 × 464)
but
to break bonds = 2648
to form bonds = 3466

each gains 2 marks

4

(iii) nett energy transfer = 818 (kj)
this energy is released in the reaction/is an exothermic reaction
(*credit answers consistent with (ii) or derived from the initial information)*

each for 1 mark

2

[10]

6

exothermic does **not** gain any credit

1

reactants: bond breaking (436 + 242 =) 678 (kJ)

1

products: bond making (2 × 431 =) 862(kJ)

so overall 184 (kJ) released / –184(kJ)

1

[3]

7

(a)

	bonds broken	bonds made
C – C	2 (4)	
C – H	12 (10)	
O = O	7	
C = O		8
H – O		12

1 mark for all bond breaking correct
1 mark for all bond making correct

2

(b) 1 mark for the three energy levels drawn

1

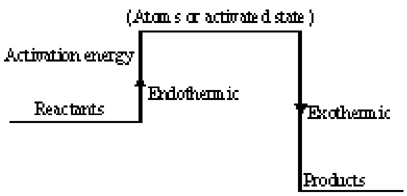
1 mark is for products and reactants labelled, with products shown lower than reactants

1

1 mark for activation energy in the correct position

1

(c) 1 mark (for arrows) and endothermic exothermic labels



arrows not required

1

lowers activation energy

1

more particles have the energy to react

particles do not need as much energy to react

1

[8]

8 rises as energy needed for bond breaking (of reactants)

1

called activation energy **or** correctly labelled on diagram

1

bond making (to form products) releases energy

1

called exothermic reaction **or** more energy given out than taken in **or** releases heat to the surroundings

1

[4]

9 (a) (1) + 3 → 2 + 3

accept correct multiples

1

(b) any **three** from

- to react particles must collide
- with sufficient energy
- reference to activation energy
- (to cause) bond breaking

3

(c) (i) $(436 \times 2) + 498$

1

$= 1370$ (kJ)

*accept $(436 \times 2) + 498$ **or** 934 kJ for one mark*
allow 2 marks for 1370 if no working
***or** correct working is shown*

1

(ii) calculation of bond energy or product

1

$464 + 464 = 928 \times 2 = 1856$

incorrect calculation = 0 marks

correct deduction

allow deduction on ecf exothermic / endothermic on own without calculation are neutral

1

[8]

10

(i) the energy needed by reactants before reaction can occur

accept energy required for particles to collide successfully

accept energy required to break bonds

accept energy needed to start reaction

1

(ii) reference to reactants 'energy' higher than products 'energy'

accept exothermic reaction

accept heat (energy) released

1

melting point of iron is exceeded

accept temperature is above melting point of iron

1

[3]

11

(a) electricity / (high) temperatures

allow lightning / heat

ignore energy

1

(b) nitrogen + oxygen → nitrogen oxide/ monoxide

allow any oxide of nitrogen

1

(c) more than

1

(d) (i) A

1

(ii) C

1

[5]

12 (i) 436 + 242 = 678 (kJ) [1]

2 × 431 = 862(kJ) [1]

answer = 184

*first **two** marks can be awarded if answer is incorrect*

ignore sign

3

(ii) exothermic

1

more energy released by, bond formation than needed for bond breaking

both parts to be marked depending on answers given in (b)(i)

1

(iii) hydrogen chloride is (a) covalent (compound)

1

when added to water it forms ions **or** H^+ (and Cl^-)

1

hydrogen ions **or** H^+ causes a solution to be acidic

1

[8]

13 (a) (i) energy / heat of products less than energy of reactants

owtte

allow products are lower than reactants

allow more energy / heat given out than taken in

allow methanol is lower

allow converse

allow energy / heat is given out / lost allow ΔH is negative

1

(ii) lowers / less activation energy

owtte

allow lowers energy needed for reaction

***or** it lowers the peak/ maximum*

*do **not** allow just 'lowers the energy'*

1

(b) (i) bonds broken: (2 × 435) + 498 = 1368

allow: (8 × 435) + 498 = 3978

1

bonds made: (2 × 805) + (2 × 464) = 2538

allow: (6 × 435) + (2 × 805) + (2 × 464) = 5148

1

energy change: 1368 – 2538 = (–)1170

allow: 3978 – 5148 = (–)1170

ignore sign

allow ecf

*correct answer (1170) = **3** marks*

1

(ii) energy released forming new bonds is greater than energy needed to break existing bonds owtte

allow converse

*do **not** accept energy needed to form new bonds greater than energy needed to break existing bonds*

1

[6]

14 (a) either:
calculations: all correct (ethanol = 6, methanol = 3, peanut oil = 10, vegetable oil = 15)

ignore repetition of data from table unqualified

or

implication of correct calculation

(vegetable oil) gives largest temperature / heat increase <u>per gram</u> (owtte)

*allow 'produced most heat in proportion to the fuel used' owtte for **1** mark*

2

(b) any **one** from:

owtte

- smoke

  ignore references to crops/food

- soot
- carbon
- carbon monoxide
- carbon dioxide
- global warming / climate change / greenhouse gases
- (air) pollution
- harmful/poisonous

1

scrub / wash the gases owtte

filter / remove (gases / fumes / appropriate named substance) owtte

(add extra oxygen) can burn more efficiently owtte

use a cleaner fuel owtte

plant more trees or similar linked to CO_2

any sensible answer

'don't burn so much fuel' insufficient alone

ignore extractor fans / air conditioning

1

(c) (i) A

1

(ii) B

1

[6]

15

(a) (bonds broken) = 1370 (kJ)

1

(bonds made) = 1856 (kJ)

1

change in energy = (–) 486

ecf

ignore sign

*correct answer with **or** without working = **3** marks*

1

(b) energy released from forming new bonds is greater than the energy needed to break existing bonds

allow the energy needed to break bonds is less than the energy released in forming bonds

*do **not** accept energy needed to form bonds*

1

(c) (i) energy barrier needs to be overcome

or

activation energy supplied / needed

*allow energy needed to start reaction **or** energy needed to break bonds*

accept high activation energy

1

(ii) lowers activation energy(*)

or

provides lower energy pathway / route(*)

*(*)**2** mark answers*

*allow provides alternative pathway **or** platinum / it is a catalyst for **1** mark*

2

[7]

16

(a) hydrogen + oxygen → water

accept $2H_2 + O_2 \rightarrow 2H_2O$ or balanced multiples or fractions
allow 1 or 2 correct formulae substituted for words
*allow hydrogen oxide **or** steam for water*

1

(b) supplied

released

both needed, must be in this order

1

(c) (i) B

1

(ii) A

1

(iii) to overcome activation energy to react **or** (activation) energy needed to start reaction

allow to provide energy

1

[5]

17

(a) carbon <u>dioxide</u>

must be name

*do **not** accept carbon oxide*

1

(b) (i) the temperature of the solution will decrease

(list principle)

1

(ii) energy is taken in from the surroundings

(list principle)

1

[3]

18

(a) (i) wood

1

(ii) 30 (kJ)

1

(iii) carbon / C

or hydrogen / H

or sulfur / S

or oxygen / O

1

(iv) 3 / three (g)

1

(b) (i) releases most energy

accept releases a lot of energy / burns rapidly

ignore references to cost

1

no harmful gases / no or less pollution formed / no global warming / no climate change / no greenhouse gas

accept produces water (only) /steam

*accept does **not** produce sulfur dioxide / carbon dioxide / carbon monoxide / particles / smoke*

1

(ii) any **one** from:

- expensive
- difficult to produce
  accept large volume needed
- not available in large quantities
- explosive / dangerous
- not a natural fuel / resource
  allow will run out / non-renewable
- made from fossil fuels
- difficult to store

1

[7]

19 (a) eg plastic (beaker) / insulation / lid / cover **or** any mention of enclosed

any sensible modification to reduce heat loss

ignore prevent draughts

ignore references to gas loss

1

(b) all the substances react **or** all (the substances) react fully / completely **or** heat evolved quickly **or** distribute heat

accept to mix them

'so they react' is insufficient for the mark

accept increase chances of (successful) collisions / collision rate increase

*do **not** accept rate of reaction increase / make reaction faster*

1

(c) experiment 2 **and** different / higher / initial / starting temperature

*accept experiment 2 **and** the room is hotter / at higher temperature*

*do **not** accept temperature change / results higher*

1

(d) temperature change does not fit pattern

*accept anomalous / odd **or** it is the lowest **or** it is lower than the others **or** it is different <u>to the others</u>*

'results are different' is insufficient

1

(e) 7 / 7.0

1

(f) (100 × 4.2 × 7) = 2940

ecf from (e)

1

(g) diagram A **and** reaction exothermic / heat evolved / Δ H is negative / temperature rises

accept energy is lost (to the surroundings)

1

[7]

20 (a) (i) straight line through the ‘points’ and extended to C_8H_{18}

*do **not** accept multiple lines*

1

(ii) 5500

range 5400 to 5600

accept ecf from their graph

1

(iii) it is a straight line graph

allow directly proportional

accept constant difference between (energy) values

accept C_5H_{12} close to values on the graph

***or** C_5H_{12} comes in middle of the graph*

ignore ‘fits the pattern’ unqualified

ignore ‘line of best fit’

ignore ‘positive correlation’

1

(iv) expected ranges for working are:

accept correct numerical answer as evidence of working

(5400 to 5600) – (2800 to 2900) = (2500 to 2800)

or

their value from (a)(ii) – a value from 2800 to 2900

or

(5400 to 5600) / their (a)(ii) divided by 2

or

a value from 2800 to 2900 - 2

1

no / not quite / almost / yes

this mark is only awarded on evidence from their correct working

1

(b) (i) incorrect / no **or** partially correct

ignore references to hydrogen

1

bio-ethanol produces least energy

mark independently

or

bio-ethanol produces 29 kJ

1

(ii) *ignore incorrect / correct*

any **two** from:

- hydrogen produces <u>only</u> H_2O
  accept hydrogen does not produce harmful gases / CO_2 / SO_2
- coal produces SO_2
  allow coal causes acid rain / respiratory problems
- coal produces smoke
  allow coal causes global dimming
- both renewable <u>and</u> non-renewable fuels produce CO_2
  accept bio-ethanol <u>and</u> natural gas / coal produce CO_2 / global warming
- (both) the non-renewable fuels produce CO_2
  accept coal <u>and</u> natural gas produce CO_2 / global warming
- (both) renewable fuel<u>s</u> produce no smoke
  accept hydrogen <u>and</u> bio-ethanol do not produce smoke / global dimming
- (both) renewable fuel<u>s</u> produce no SO_2
  accept hydrogen <u>and</u> bio-ethanol
  do not produce SO_2 / acid rain

2

[9]

21

(a) any **two** from:

- concentration / volume of dilute hydrochloric acid
- mass of metal powder
- surface area of metal powder
- stirring (of any) / rate of stirring

allow reacted for the same length of time

2

(b) 4.2 °C

allow Magnesium Test 2

1

and any **one** from:

- lower mass of magnesium added
- surface area of magnesium too low
- magnesium coated in magnesium oxide (so took a while to start reacting)
- not stirred
- not stirred as quickly as the other metals
- not reacted for as long a time as the other metals

allow reason for break in circuit

1

(c) 17.4(°C)

1

(d) bubbles of gas

1

more (bubbles) seen with calcium than other metals

allow any correct comparison between two metals

1

(e) any value between 7.9 °C and 12.3 °C

1

[8]

22

(a) (i) (-)810

ignore sign

*correct answer gains **3** marks with or without working*

*if the answer is incorrect look at the working up to a maximum of **two***

- *bonds broken = (4 × 414) + (2×498) = 2652 kJ*
- *bonds formed = (2x803) + (4x464) = 3462 kJ*
- *correct subtraction of their bonds formed from their bonds broken*

3

(ii) because energy needed to break the bonds

1

is less than the energy released when bonds are formed

1

(b) to provide <u>activation</u> energy

or

to break bonds

1

[6]

23

(a) *correct answer with or without working = **3** marks*

M1: (bonds broken) = 2148 (kJ)

1

M2: (bonds made) = 2354 (kJ)

1

M3: change in energy
= (-) 206 (kJ)

ecf

ignore sign

1

(b) energy released from forming new bonds is greater than energy needed to break existing bonds

allow the energy needed to break bonds is less than the energy released in forming bonds

*do **not** accept energy needed to form bonds*

1

[4]

24

(a) A = <u>energy</u> / <u>enthalpy</u> change / difference

*allow heat change **or** ΔH*

allow energy released

1

B = activation energy / EA

allow definition of activation energy

1

C = carbon dioxide and water

accept products

1

(b) exothermic

allow combustion / redox / oxidation

ignore reduction / burning

1

[4]

25 (a) 22

1

(b) (i) exothermic

1

(ii) C

1

gives out most heat energy

accept has largest temperature change / increase

*allow has highest (final) temperature **or** hottest*

1

(c) (i) increases

1

(ii) blue

ignore pale / dark etc

1

(iii) reversible (reaction)

*allow goes both ways **or** two / either way*

1

(iv) <u>anhydrous</u> copper sulfate

1

[8]

26 (a) (i) 4

1

(ii) (Make) 3

1

biggest <u>temperature</u> <u>rise</u>

1

(b) (i) 1008 (kJ)

*correct answer with or without working gains **2** marks*

*if incorrect answer given allow evidence of 240 × 4.2 for **1** mark*

2

(ii) crisps have a high energy content

allow crisps have lots of calories / kilojoules / fat / one ninth of daily energy intake

1

so if you take in more energy than you need the excess is stored as fat

accept consequences: obesity; heart disease; high blood pressure; diabetes; arthritis

or

crisps contain salt (1)

too much salt can cause high blood pressure **or** heart problems or kidney problems (1)

1

[7]

27

(a) any **one** from:

- no method / electrolysis / equipment / technology

  allow 'didn't know how to' ***or*** *'no knowledge'*
- aluminium is a very reactive metal
- high melting point

  allow 'couldn't heat it enough'
- potassium had not been discovered

1

(b) because <u>others</u> / <u>scientists</u> / <u>they</u> could not repeat the experiment

ignore he could not repeat the experiment

or

<u>others</u> / <u>they</u> could not obtain the same results

1

(c) reaction is endothermic **or**

reaction <u>takes in</u> heat / energy

accept activation energy

ignore rate / high temperature

ignore bonds broken

1

(d) (aluminium chloride + potassium) → aluminium + potassium chloride

in either order

accept correct formulae

ignore metal

ignore balancing

1

(e) when tested it had the properties of a metal

accept a test for a metal property eg conductivity / reaction with acid

1

properties were different (from other known metals)

accept properties compared with other metals

1

[6]

28 (a) (i) endothermic

could be answered by indicating the correct word in the box

1

(ii) final temperatures got lower **or** temperature went down

ignore comments on energy

1

(b) polystyrene / plastic cup **or** description of insulation / lagging container

ignore references to a lid

1

because (polystyrene) is an insulator **or** prevents heat / energy gain (and so temperature is more accurate)

*allow references to heat loss **or** glass conducts / absorbs heat*

1

(c) **variable**: volume **or** mass **or** amount of water

***1** mark for variable and **1** mark for reason linked to that variable*

*maximum of **4** marks for two variables and two explanations*

reason: the greater the volume / mass of water, the more heat energy it contains **or** the smaller the temperature change will be

*do **not** allow 'time taken to heat'*

variable: start temperature **or** temperature of water

reason: the higher the start temperature, the more heat energy it contains **or** the higher the final temperature will be

*do **not** allow higher temperature change*

variable: the time at which the temperature is measured

reason: if left longer may gain heat energy from surroundings **or** warm up **or** if measured too soon not all ammonium chloride will have dissolved so less temperature change

variable: rate of dissolution **or** speed of dissolving **or** amount of stirring

reason: if it dissolves faster **or** is stirred faster then it will cool more quickly **or** small particles dissolve faster

max. 4

(d) (i) all 7 points correct

*at least 4 points plotted correctly scores **1** mark*

2

(ii) straight line through first 3 or 4 points

lines must be drawn with a ruler

1

straight line through last three points

*if no other marks awarded allow curve joining lines for **1** mark*

1

(iii) valid extrapolation of line back to mass of 0 g

1

correct value read from graph

*award **1** mark for 20 − 21 if no extrapolation shown*

1

(e) not all of the ammonium chloride would dissolve

*allow water limiting factor **or** all water used*

1

so no more heat would be absorbed

or

the solution is saturated (1)

*allow water limiting factor **or** all water used*

so some ammonium chloride remains solid **or** not all will dissolve (1)

1

(f) greater volume of water was used **or** volume was twice as large

allow different volume of water

1

so temperature decrease was less than the first student's result

allow so final temperature was higher

or

starting temperature / room temperature was higher (1)

so final temperature was greater than the first student's result (1)

*accept by 6 °C **or** was any value in range 26 − 27°C*

1

[18]

29

(a) (i) energy / heat of products less than energy of reactants

allow converse

allow products are lower than reactants

allow more energy / heat given out than taken in

allow methanol is lower

allow energy / heat is given out / lost

allow ΔH is negative

1

(ii) lowers / less activation energy

allow lowers energy needed for reaction
***or** it lowers the peak/ maximum*

*do **not** allow just 'lowers the energy'*

1

(b) (i) $(8 \times 435) + 497 = 3977$

accept: bonds broken: $(2 \times 435) + 497 = 1367$

1

$(6 \times 435) + (2 \times 336) + (2 \times 464) = 4210$

bonds made: $(2 \times 336) + (2 \times 464) = 1600$

1

$3977 - 4210 = (-)\ 233$

energy change:

$1367 - 1600 = (-)\ 233$

ignore sign

allow ecf

*correct answer (233) = **3** marks with or without working*

1

(ii) energy released forming (new) bonds is greater than energy needed to break (existing) bonds

allow converse

*do **not** accept energy needed to form (new) bonds greater than energy needed to break (existing) bonds*

1

[6]

30

(a) products are at a lower energy level than reactants

if candidate has drawn a profile for an endothermic reaction penalise first marking point only

1

activation energy correctly drawn and labelled

1

ΔH correctly labelled

1

(b) (i) –93 (kJ per mole)

*correct answer with or without working gains **3** marks*

*allow **2** marks for +93 kJ per mole*

*if any other answer is seen award up to **2** marks for any two of the steps below:*

*bonds broken (614 + 193) = 807 (kJ) **or** (614 + 193 + (4 × 413)) = 2459(kJ)*

*bonds formed (348 + 276 + 276) = 900(kJ) **or** 348 + (2 × 276) + (4 × 413) = 2552(kJ)*

bonds broken – bonds formed

allow ecf for arithmetical errors

3

(ii) more energy is released when the bonds (in the products) are formed

1

than is needed to break the bonds (in the reactants)

*if no other marks gained, allow **1** mark for energy released for bond making **and** energy used for bond breaking*

1

[8]

31

(a) eg plastic (beaker) / insulation / lid / cover **or** any mention of enclosed

any sensible modification to reduce heat loss

ignore prevent draughts

ignore references to gas loss

ignore bomb calorimeter

1

(b) all the substances react **or** all (the substances) react fully / completely **or** heat evolved quickly **or** distribute heat

'so they react' is insufficient for the mark

accept increase chances of (successful) collisions / collision rate increase

*do **not** accept rate of reaction increase / make reaction faster*

1

(c) experiment 2 **and**
different / higher / initial / starting temperature

*accept experiment 2 **and** the room is hotter / at higher temperature*

*do **not** accept temperature change / results higher*

1

(d) temperature change does not fit pattern

*accept anomalous / odd **or** it is the lowest **or** it is lower than the others **or** it is different <u>to the others</u>*

'results are different' is insufficient

1

(e) 7 / 7.0

1

(f) $(100 \times 4.2 \times 7) = 2940$

ecf from (e)

1

(g) diagram A **and**

reaction exothermic / heat evolved / Δ H is negative / temperature rises

accept energy is lost (to the surroundings)

accept energy of products lower than reactants

allow arrow goes downwards

1

[7]

32

(a) any **one** from:

- solution becomes colourless or colour fades
- zinc becomes bronze / copper coloured

  allow copper (forms) or a solid (forms)
- zinc gets smaller

  allow zinc dissolves
- bubbles or fizzing.

  ignore precipitate

1

(b) improvement:

use a plastic / polystyrene cup or add a lid

accept use lagging / insulation

1

reason - must be linked

reduce / stop heat loss

OR

improvement:

use a digital thermometer

allow use a data logger

reason - must be linked

more accurate or easy to read or stores data

allow more precise or more sensitive

ignore more reliable

ignore improvements to method, eg take more readings

1

(c) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information in the Marking Guidance and apply a 'best–fit' approach to the marking.

0 marks
No relevant content

Level 1 (1−2 marks)
There is a statement about the results.

Level 2 (3−4 marks)
There are statements about the results. These statements may be linked or may include data.

Level 3 (5−6 marks)
There are statements about the results with at least one link and an attempt at an explanation.

Examples of chemistry points made in the response:
Description:
Statements
Concentration of copper sulfate increases
Temperature change increases
There is an anomalous result
The temperature change levels off
Reaction is exothermic

Linked Statements
Temperature change increases as concentration of copper sulfate increases
The temperature change increases, and then remains constant
After experiment 7 the temperature change remains constant

Statements including data
The trend changes at experiment 7
Experiment 3 is anomalous

Attempted Explanation
Temperature change increases because rate increases
Temperature change levels off because the reaction is complete

Explanation
As more copper sulfate reacts, more heat energy is given off
Once copper sulfate is in excess, no further heat energy produced

6

[9]

33 (a) (i) any **one** from:

- incorrect measurement of temperature or volume
- incorrect recording of temperature
- failure to stir
- heat loss

ignore faulty equipment

1

(ii) 32 - 33

1

(iii) 55

1

(iv) 20

1

(v) 4620

*allow 4.62 kJ for **2 marks***

1

J / joules

allow kJ if evidence of dividing by 1000

mark independently, but if a numerical answer has been divided by 1000 must be kJ.

allow ecf from their answers to (iii) and (iv)

1

(b) twice as much energy released

1

but twice as much water to heat

*allow more energy released but more water to heat for **2 marks***

*if no other mark awarded, allow twice the amount of hydrochloric acid used for **1 mark***

1

[8]

34 (a) (i) 11

1

(ii) 4620 (J)

*correct answer gains **2** marks with or without working*

*allow 4.62kJ for **2** marks*

if answer is incorrect:

*100 × 4.2 × 11 gains **1** mark*

or

*100 × 4.2 × (their temp. rise) gains **1** mark*

or

*100 × 4.2 × (their temp. rise) correctly calculated gains **2** marks*

2

(b) the temperature increases

allow gets hotter

allow heat / energy is given off

1

(c) (i) (energy of) products lower than (energy of) reactants

allow converse

allow arrow C points downwards

1

(ii) A

1

[6]

35 (a) energy of product greater than energy of reactants

allow converse

allow energy = heat

*do **not** accept temperature for energy*

allow product / nitrogen oxide is higher than reactants

allow less energy / heat given out than taken in

allow energy / heat is taken in / gained

allow Δ H is positive

1

(b) (minimum) energy needed to start the reaction / overcome energy barrier

accept (minimum) energy needed for a collision to be successful

1

(c) (i) *correct answer with or without working= **3** marks*

bonds broken = 945 + 498 = 1443 (kJ)

1

bonds made = 2 × 630 = 1260 (kJ)

1

energy change = 1443 - 1260 = (+) 183

ignore sign

allow ecf

1

(ii) energy released forming new bonds is less than energy needed to break existing bonds owtte

allow converse

accept energy change (ΔH) is + / positive

*do **not** accept energy <u>needed to form new bonds</u> is less than energy needed to break existing bonds*

1

[6]

Examiner reports

1 Though there were some very good answers to this conceptually quite difficult question, many candidates lost marks because of insufficiently precise answers, eg. not specifying , in part (a), the particular <u>atoms</u> between which bonds were broken or made or not identifying, in part (b), the particular energy changes indicated by x, y and z on the diagram.

2 Many candidates did not recognise the definition of a fuel but otherwise the question was usually answered correctly.

4 Parts (a) and (b) of this question were encouragingly well answered, presumably due to its very structured format. However, few candidates gained full marks for part (c); most candidates thought that the reaction took in energy overall (i.e. was endothermic) and/or did not work out the net energy transfer for the overall reaction.

5 In (i) the commonest fault in this item was a failure to specify the number and type of bonds sufficiently precisely e.g. 4 C—H, 2 O=O.

In (ii) of those who understood what was required in this question, a sizeable minority lost marks because of arithmetical errors.

In (iii) candidates quite often gave answers which contradicted their figures for (ii). (Where candidates had been unable to produce a response to (ii), credit was given for using their knowledge that the combustion of methane is an exothermic reaction.)

6 Most candidates could use the balanced symbol equation and the bond energies to correctly calculate the energy required to break bonds and the energy released on bond formation. The third mark was not always gained because although the energy difference was found to be – 184kJ (or 184kJ released), candidates often then stated that the reaction was endothermic. A number of candidates gained no credit because they confined their answer to a description of an exothermic reaction without mentioning bond energies.

7

This question was only attempted by the most able candidates. Some extremely good answers were seen but there were many which showed that the concepts of activation energy and energy level diagrams were unfamiliar.

Again few could explain that a lower activation energy is produced by a catalyst and this allows more reactant particles to have the required energy to react.

8

Descriptions were so poor that it seemed that many candidates had no basic ideas about what energy diagrams represented. The rise in the line was often explained as 'heat being released' and the fall in the line was because 'the energy was running out' or 'the fuel was being used up'. Often the only marks awarded were for the idea that the reaction was 'exothermic' or for the use of the term activation energy.

9

(a) Only the best candidates were able to balance the symbol equation.

(b) Most candidates simply stated that the reactants needed energy to react; this was not usually linked to molecules or activation energy. Only the best candidates answered in terms of the activation energy needed and bond breaking.

(c) In the first part, a majority of candidates failed to distinguish between reactants and products, often giving calculations involving both. Again, only the most able candidates understood the relationship between bond breaking, bond forming, endothermic and exothermic.

10

Activation energy was generally well understood. The explanation for iron being molten was not always linked to the exothermic nature of the reaction and that the melting point of the iron must have been exceeded.

11

(a) Some candidates wrote in terms of energy or activation energy while others put down water or carbon dioxide.

(b) While a majority of the candidates got oxygen correct, many different things appeared as the product eg lightening, sound, energy, water and nitrate oxide

(c) Two thirds of the candidates realised that in an endothermic reaction more energy is needed to break existing bonds than is released when new bonds form.

(d) (i) Most of the candidates were able to identify 'A' as the activation energy.

(ii) This seemed to be a major problem for about half of the candidates. They could not correctly identify the energy change which shows the reaction is endothermic.

12

Double and Single Award

The use of bond energies was required to find the 'Difference between the energy transferred for bond breaking and that transferred in bond making'. What was not required, although acceptable, was use of the ΔH convention. The answer in (i) was often correct, the main error being to use only one molecule instead of two molecules of HCl in the calculation. This error lead to an endothermic reaction but the mark scheme allowed credit for this in (ii). Only the more able candidates discussed bond making and bond breaking as the cause of exothermic, or endothermic, reactions. Very few candidates appreciated that HCl is a covalent compound unless water is present. Many candidates realised that the hydrogen ion was produced when water was present and that it was this ion that was responsible for acidity in solution.

13

This was a challenging question that discriminated well.

For parts (a)(ii) and (b)(ii), there was evidence that some candidates had not read the question carefully and did not take notice of the key phrases in terms of the energy level diagram and in terms of bond energies respectively. Many candidates had difficulty expressing their ideas accurately and precisely without contradiction.

For part (a)(i) most candidates were able to use the diagram to explain how they knew that the reaction was exothermic, and some candidates gave a response based on bond energies when in fact this understanding was better placed in (b) (ii). Some candidates thought that the energy given out was represented by the activation energy being released.

For part (a)(ii) good candidates wrote about the lowering of the activation energy but weaker candidates suggested that the catalyst provided additional energy for the reaction. Some candidates did not refer to the energy level diagram but gave responses based on surface area or increasing the rate of the reaction.

Part (b)(i) discriminated well and with the help of consequential marking most candidates gained some credit for the calculation. Some ignored the balancing numbers on one side or the other and scored 2 marks, while others got both energy totals incorrect but were able to obtain 1 mark if they calculated the difference correctly.

The most common error on part (b)(ii) was the suggestion that energy is used up in both bond breaking and bond forming. Some candidates thought the reaction was exothermic because there were more reactants than products.

14

Foundation Tier

Very few candidates gained credit on part (a). There were vague answers like a small amount of fuel gives a lot of heat, 1g of fuel gives a large increase in temperature or simply a repeat of the question 1g gives a temperature of 15°C.

In part (b) almost all candidates got at least the first mark. Some candidates were unable to suggest the solution to the problem. Quite a few suggested an extractor fan.

In part (c)(i) the majority of the candidates identified the activation energy correctly. In part (ii) only a minority of candidates gained this mark.

Higher Tier

In part (a) the most common error involved candidates just repeating the question and saying, the smallest amount gave a rise of 15°C which was quite high. Better candidates worked logically through the calculation.

In part (b) most candidates were able to suggest an environmental problem associated with the burning of vegetable oil, although some suggested acid rain. Fewer candidates went on to say how the problem could be overcome and focussed on containing the smoke rather than removing it, or suggested it should be burned in remote areas.

While *activation energy* was well known in part (c)(i), less than half the candidates knew that **B** (rather than **C**) represented the energy given out during the reaction.

15

(a) A very well answered, high scoring question, with nearly two thirds of candidates gaining full credit and most of the candidates gaining at least two of the three marks. The energy released as bonds are made was often calculated to be 928 rather than 1856.

(b) This was a challenging question that discriminated between the candidates well. Many candidates did not read the question carefully but gave an answer in terms of the energy of reactants and products rather than in terms of making and breaking bonds. Many candidates had difficulty expressing their ideas accurately and precisely without contradiction. A common error was the suggestion that energy is needed to form bonds as well as break them.

(c) (i) A majority of candidates realised the significance of the activation energy and that the spark provided the energy to initiate the reaction.

(ii) A good discriminating question, the better candidates stated that platinum lowered the activation energy. Many of the candidates. responses were confused and many thought that the platinum reacted with the hydrogen exothermically to provide the (activation) energy for the reaction or that platinum itself was the source of the activation energy. Some candidates appeared to misread platinum and wrote about potassium being a highly reactive metal. Those candidates who recognised that platinum is a catalyst for the reaction invariably knew that the catalyst lowers the activation energy.

16

(a) The question asked for a word equation and many of those who wrote a word equation got it right.

A large number of candidates included other substances in the equation eg carbon dioxide. Too many opted for symbols and then made small errors which resulted in them scoring no marks. Others wrote unbalanced equations. The most common error was
$H_2 + O \rightarrow H_2O$

(b) (ii) This was quite poorly answered.

(c) (iii) A large number of candidates wrote it is a catalyst. Some just wrote it supplies heat for the reaction, so they can react or particles start to move faster. Only a few actually used the term activation energy.

17

(a) Most of the candidates were able to correctly name CO_2 as carbon dioxide although answers such as carbon oxide, carbon monoxide and cobalt were seen.

(b) (i) The majority of candidates correctly thought that the temperature of the solution would decrease in this part but a sizeable number thought that it would increase.

(ii) This was poorly answered with a large number of the candidates thinking that energy would be given out to the surroundings. It has been noticeable in recent years that most candidates can define the meaning of exothermic and endothermic, but they seem to find great difficulty in applying these definitions to make decisions about whether the temperature will increase or decrease.

18

(a) (i) Candidates usually could use the bar chart to identify wood as the fuel that releases least energy from 1g.

(ii) The majority of candidates were able to read correctly from the bar chart that burning 1g of coal releases 30kJ.

(iii) There were a surprising number of candidates who could not name an element in coal, given the names and formulae of the products of combustion of coal. Most candidates named one of the compounds given in the table.

(iv) Most candidates could not use the bar chart to calculate that 3g of petrol would release the same amount of energy as 1g of hydrogen.

(b) (i) Candidates were instructed to use the information from the bar chart and the diagram. There were several who made vague statements such as it's a clean fuel, it's eco-friendly or it's harmless to the environment. Most gained one mark usually for stating that water/steam was formed or that there would be no carbon dioxide/global warming. Several candidates thought that hydrogen is a major constituent of the atmosphere and as such is an unlimited source of energy and therefore cheap.

(ii) Many candidates obtained the mark by using the information provided that hydrogen is made from fossil fuels. Common incorrect responses were that hydrogen is flammable or hydrogen would produce too much water.

19

Foundation Tier

Very few candidates gained a mark in part (a)(i). Some candidates gave the symbol with no charge while quite a few wrote chlorine. A few other incorrect named ions or atoms appeared occasionally.

For part (a)(ii) many candidates were aware that Universal Indicator could be used but were unable to give the correct colour changes. A large number of candidates used titration as their answer. Some also mentioned litmus. A few candidates talked in terms of number of atoms in each acid. Most correct responses came from reactivity differences. No candidates gave answers in terms of conductivity differences.

The candidates were able to pick out the points from the information given and almost all gained full marks on parts (b)(i) and (b)(ii).

Higher Tier

Apart from part (g) this question was well answered by the candidates.

Most candidates in part (a) made sensible suggestions about insulating the beaker to reduce heat loss. Several candidates were unaware that bomb calorimeters are used to measure enthalpies of combustion rather than enthalpies of neutralisation.

In part (b) the idea that the chemicals were stirred to mix them thoroughly and ensure a complete reaction was well known. Typical vague responses included "so they react properly" and "to get the correct results".

Many candidates in part (c) identified experiment 4. Of those candidates who correctly identified experiment 2, a significant number were less than precise with their reason, making only some vague reference to the results rather than the initial temperature.

Part (d) was very well answered, although many candidates were again less than precise with their language and referred to results rather than temperature change. While many different spellings of 'anomalous' often gained credit, the mark scheme did not extend to 'enormous' or "miscellaneous".

Parts (e) and (f) were very well answered.

Calculating the average proved difficult for some candidates but they usually gained credit in part (f) with the help of consequential marking.

Only just over a third of the candidates in part (g) gained credit for this part. However, most candidates chose diagram B and some of them then went on to give the correct reason. Candidates appeared to confuse temperature increase and energy decrease.

20

(a) (i) Some candidates drew a curve while others produced multiple lines.

(ii) The majority of the candidates were able to read off the correct value from the graph. However, there were some candidates who got the scale wrong, 5500 was read as 5050.

(iii) A lot of candidates gave quite vague answers here, eg because you follow the line up and across, because of the line of best fit and it fits the pattern.

(iv) A large number of candidates read off the value for butane as 2850, multiplied by 2, got the answer as 5700 and then went back to part (ii) and changed their answer to 5700 so that they could say yes, the student's prediction is correct. In doing so, many of them lost the mark in part (ii) as 5700 did not correspond to the value from their graph. Candidates need to know that the answer does not always have to be yes.

Some candidates just showed the working and lost the second mark while others showed no working and just wrote yes or no.

Here again, there were some candidates who got the scale wrong and misread the value for butane.

(b) (i) Some candidates misinterpreted the question. They added the values for coal and natural gas to get 87, then added the values for hydrogen and bio-ethanol to get 171 and came up with yes as their answer.

(ii) Some candidates answered the question in terms of the number of products formed by each fuel while others wrote in terms of the amount of heat released by each fuel. A few candidates wrote sulfur instead of sulfur dioxide while a small number of candidates wrote that non-renewable fuels will run out.

22

(a) (i) Most encouragingly, the majority of students calculated the correct answer and obtained a full three marks. A common incorrect answer gaining two marks was 118, caused by counting two O-H bonds instead of four. Two marks were also frequently awarded for a single error in either bond breaking or bond making calculation followed by a correct subtraction. Elementary errors such as incorrect transcription, where a correct answer is wrongly copied onto the next line, are still common.

(ii) As usual for questions on this part of the specification, there was much confusion over energy in and out, and careless language using the same for both e.g. less energy is needed to break bonds than to make them'. Many students ignored the instruction to give an explanation in terms of bond energies, for example by stating that more energy is given out than taken in but neglecting to state why.

(b) The majority of students answered correctly, mainly by mentioning activation energy. Some mentioned catalysts or lowering of activation energy. Some answered at an elementary level, quoting the 'fire triangle' by stating that a fire needs heat as well as fuel and oxygen.

23

(a) Although half the candidates gained full credit, this type of calculation was not attempted quite so well as in previous examinations. There were many careless errors - incorrect bond energies used and many candidates were unable to work out how many bonds were broken or formed.

(b) Many candidates did not read the question carefully but gave an answer in terms of the energy of reactants and products rather than "in terms of bond energies". Many candidates also had difficulty expressing their ideas accurately and precisely without contradiction. A very common error was the suggestion that energy is needed to form bonds as well as break them.

24

(a) Almost half of the candidates scored no marks here. A large number wrote about the rocket taking off, landing or accelerating. B was often given as 'energy increase' and C as 'energy of the products' or 'final energy'.

(b) About one third of the candidates did not gain this mark. Many wrote 'chemical', 'endothermic 'or 'burning'.

25

(a) A minority of students were unable to correctly complete the table.

(b) (i) A few incorrect responses such as endothermic or thermal.

(ii) Generally well answered showing an awareness of greater temperature change rather than just referring to starting and final temperatures. Some students thought that the answer was B because you would not want the hand warmer to be too hot in case it burnt the hands.

(c) Generally well answered apart from part (iv). Despite the use of the term 'anhydrous' earlier in the stem of the question most students failed to recognise and identify anhydrous copper sulfate. Copper sulfate, copper sulfate crystals and copper were answers showing a lack of knowledge and understanding.

26 (a) (i) Some candidates worked out the average of the temperature rises for the other makes of crisps instead of subtracting the starting temperature from the final temperature.

(ii) The majority of the candidates scored 2 marks, although a significant minority could not give the correct reason. Many wrote ‘because it was the highest final temperature’ or repeated the question by writing ‘it produces the highest amount of energy’. Others just wrote that ‘it gives off the most heat’.

(b) (i) A minority of the candidates scored no marks here. Some divided 240 by 4.2 while others tried to use ‘9000’ in their calculation.

(ii) The majority of the candidates knew that crisps had high energy content but the reason given was either very vague or not given at all.

27

(a) The vast majority of answers were correct. Many students discussed the lack of technology, equipment or resources. The idea that scientists did not know how to was also common and some students mentioned the unavailability of electrolysis. Among the answers that did not receive credit were restatements of the information in the passage such as ‘Scientists thought that alumina … … an undiscovered metal’ and ‘alumina is a white solid’.

(b) Many students were awarded a mark for quoting information from the passage that ‘scientists were not able to obtain the same results or able to repeat the experiment. Common incorrect answers stated that ‘he did not repeat the work’, he could not prove it’ and ‘he needed to repeat the work for it to be a fair test’.

(c) The most common creditable answer was reference to the endothermic reaction in Step 1. A few students correctly mentioned activation energy. A small number of students made errors confusing endothermic and heat out, and exothermic and heat in. The most common errors related to increasing the rate of the reaction. This idea was expressed in a variety of ways,‘particles with more energy moved quicker’,‘more collisions’ and ‘more successful collisions’. Vague references ‘to make the reaction happen’ and ‘reaction only starts if hot‘scored no marks.

(d) Many students successfully completed the word equation. References to metal or particles after aluminium were ignored. Incorrect formulae received no credit and potassium chlorine or just chloride were penalised. Occasional answers suggested carbon, magnesium and chlorine

(e) A good discriminating question with only the more able students scoring any marks. Copying from the stem of the question ‘he tested the metal and recorded its properties’ was a very common response and scored no credit. Many students simply stated that he had made a huge lump of metal compared with only tiny particles which also did not receive any credit. The most common correct response included some comparison with the properties of other metals although testing it to prove it was a metal first was often omitted. The idea of testing conductivity or reaction with acids was only realised by a minority of students.

28

(a) (i) The majority of students could identify the reaction as being endothermic.

(ii) While most students gained credit, there were some very confused explanations about why the temperature decreased. It is fortunate for the students that these were ignored! A small minority of students failed to refer to the table of results, as instructed in the question, referring entirely to energy change rather than temperature change.

(b) Correct use of a polystyrene / plastic cup was common. Credit was given for stating that this would then prevent heat loss (it would prevent heat gain in this case) as students had the idea of energy transfer being prevented. Some students stated that a calorimeter should be used – this was insufficient to gain credit as there are different types, such as copper calorimeters, which would not be appropriate. Other students specified the use of a metal container.

(c) Most students could correctly identify one or two control variables, but correct reasons were scarce. Vague answers that just stated that the variable would change the result, without giving the correct direction of change were not credited. It was a common misconception that larger volumes of water would react faster and so get colder and students clearly had difficulty with the idea that the dissolving took energy from the water and so the water got colder. Some students did not understand the difference between a control variable and the independent variable – wanting to keep the mass of ammonium chloride constant.

(d) (i) While most students managed to plot all seven points correctly, it was not uncommon for students to plot only 5 or 6 of the points. A common plotting error was to put the point for 45 g at 50 g.

(ii) The instructions clearly stated that **two** straight lines should be drawn. Despite this some students decided to draw curves, freehand lines or more than two lines. Some students had multiple lines visible – this may have been because they drew the lines in pen and so could not erase errors. While examinations should be answered in black ink, graphs should be drawn in pencil.

(iii) Many students gained the mark for the extrapolation of their line to 0 g of ammonium chloride, but it was surprisingly common for them to then misread the graph scale (despite having just used the scale correctly to plot the graph) by using one small square as 1 rather than 0.5.

(e) Most students failed to gain either of the marks available. The most common error was to claim that all of the ammonium chloride had been used up – despite the fact that the results clearly showed that adding more ammonium chloride made no difference. Many students thought, incorrectly, that it could not go below 1 °C because the water would freeze or that at such a low temperature the water had no more energy to lose. Good students referred to the solution being saturated and so no more ammonium chloride was able to dissolve.

(f) While there were some excellent answers seen, there were a number of mathematical errors, with students not being able to work out that the difference between 8.5 and 14.5 is 6. Common errors included suggesting that the second student had used less water, so it lost less energy and so was warmer (this error would have made the final temperature lower rather than higher) and stating the second student must have used 10 g, despite the question stating they had both used 20 g. This was the second most common question part to show no attempt at an answer.

29

(a) (i) About two thirds of students answered correctly. A lack of comparison of energy levels was the main cause of marks being lost.

(ii) Over half of students were awarded the mark. A surprisingly common wrong answer was the prediction that a catalyst would move the two energy levels closer together horizontally as a result of the reaction rate being increased.

(b) (i) This question was generally well answered in terms of the process required but marks were frequently lost because of the miscalculation of subtotals through the miscounting of numbers of bonds.

(ii) This question was poorly answered, with only a small proportion of students explaining correctly. Some ignored the instruction to answer in terms of bond energies and related the question back to the energy level diagram. Most fell prey to the usual error of writing about the energy needed to both break and make bonds, failing to realise that bond making is exothermic. This may well be caused by careless expression as much as lack of scientific understanding, but it is a mistake that has been frequently highlighted in the past.

31

(a) This was quite well answered and the students made suitable suggestions about insulation or covering the beaker.

(b) Quite a large number of students did not gain this mark. Many repeated the question by writing ‘to mix them properly’ while others were answering in terms of getting reliable / accurate results.

(c) This was quite poorly answered. A lot of students thought that it was experiment 4 and the reason given was ‘change in temperature was lower’. Some students correctly identified experiment 2 but did not gain the mark as they answered in terms of ‘results being higher’.

(d) The majority of the students were able to realise that it was an anomalous result but some students gave answers such as ‘unreliable’, ‘inaccurate’ and ‘not done on the same day’.

(e) Quite a few students got this wrong. Some just left it as ‘21’ while others put down any number that they could think of.

(f) Because of consequential marking the majority of the students scored this mark even if they got (e) wrong.

(g) This was very poorly answered with a large number of students scoring no mark. A lot of them suggested it was diagram ‘B’ while others wrote ‘A’ but could not give the correct explanation.

32

(a) This question was incorrectly answered by over half the students. Credit was given for the zinc dissolving / getting smaller or bubbles. Vague references to colour changes and heat were common.

(b) Most students were unable to suggest a suitable improvement to the apparatus and few scored credit for the idea of reducing heat losses or using a digital thermometer. The majority of the wrong responses suggested changing the mass of the zinc or volume of the solution which were not improvements to apparatus. Frequent references to using a Bunsen burner to heat the reactants or to using a stop clock were ignored.

(c) The vast majority of students were able to describe the trends in the results with linked statements to achieve level 2. Only a minority attempted an explanation and therefore comparatively few attained level 3.
Common creditworthy explanations were in terms of more particles producing more collisions and a faster rate to explain the trend up to Experiment 7, or that the reaction finished to explain the trend after Experiment 7.

33

(a) (i) This was well answered by many. Inadequate responses usually mentioned unspecified human error. A few students did not gain the mark by suggesting that too much acid was added − which would result in an anomalous point higher than the (correct) line of best fit.

(ii) Most students were able to interpolate a correct value. A few suggested values significantly lower than 32 °C.

(iii) Fewer than half of students were able to add the initial 25 cm^3 to the additional 30 cm^3. Several other volumes were seen, with no clear indication of where they had come from.

(iv) Here too, students struggled to extract information from the graph. At least a dozen different incorrect temperature rises were given in addition to the just over half of students who correctly gave 20 °C.

(v) Despite quite a number of students having incorrect values for (a)(iii) and / or (a)(iv), the majority were able to gain a mark here by means of error carried forward. A few did not gain the unit mark, usually with units of specific heat capacity given, but most stated J or joules.

(b) This question was poorly answered, with the majority of students receiving no credit. Very few understood that twice as much energy was released, but twice as much water needed to be heated. Students who scored in this question generally gained the one compensation mark by realising that double or twice the amount of hydrochloric acid was used. Many students just wrote that more acid was needed, or that the temperatures would be the same as in the first experiment.

34

(a) (i) Quite well attempted. A few students added the two numbers and got 53.

(ii) The majority gained two marks and a few got at least one mark for the working. A very small number attempted to convert their answer into kilojoules.

(b) This was quite well attempted. A few students wrongly wrote in terms of the amount of product e.g. ‘more product is given out than put in’ while others said ‘it’s a positive number, not negative’.

(c) (i) The question was quite poorly attempted. Less than half of the students scored the mark. Most could not express themselves well. There were responses like ‘energy level increases’, ‘it’s losing energy’, ‘positive change’, ‘more energy taken in and less given out’ and ‘diagram curves up’. A few students wrote in terms of the amount of product rather than the energy of product and said ‘amount of product is less than the amount of reactant’. Others repeated their answer to 3(b) by saying ‘temperature increases’.

(ii) Well answered − around three quarters of students identified the activation energy as arrow A.

35

(a) The majority of the candidates were able to use the energy diagram to suggest why the reaction was endothermic. Poor use of English let candidates down and typical incorrect responses include products produce more energy than reactants, energy in is less than energy out meaning energy has been adsorbed and more energy taken in than was used.

(b) Most candidates knew that the activation energy is the energy needed to start a reaction. Simply stating it is the energy to activate a reaction received no credit. Some candidates thought it was the energy produced by the reaction.

(c) (i) Three-quarters of the candidates calculated the energy change for the reaction.The majority of the errors were made by candidates failing to take the stoichiometry of the equation into account or making simple arithmetic errors.

(ii) Many candidates did not read the question carefully but gave an answer in terms of the energy of reactants and products rather than in terms of bond energies. Many candidates also had difficulty expressing their ideas accurately and precisely without contradiction. Once again, a very common error was the suggestion that energy is needed to form bonds as well as break them.