

Questions are for both separate science and combined science students unless indicated in the question

## Q1.

A student investigated the reactivity of metals with hydrochloric acid.

This is the method used.

1. Measure 50 cm<sup>3</sup> of hydrochloric acid into a polystyrene cup.
2. Measure the temperature of the hydrochloric acid.
3. Add one spatula of metal powder to the hydrochloric acid and stir.
4. Measure the highest temperature the mixture reaches.
5. Calculate the temperature increase for the reaction.
6. Repeat steps 1 to 5 three more times.
7. Repeat steps 1 to 6 with different metals.

The table below shows the student's results.

Metal	Temperature increase in °C				Mean temperature increase in °C
	Trial 1	Trial 2	Trial 3	Trial 4	
Cobalt	6	7	5	9	7
Magnesium	54	50	37	55	X
Zinc	18	16	18	20	18

- (a) Calculate the mean temperature increase X for magnesium in the table above.

Do **not** include the anomalous result in your calculation.

$$\text{Mean} = \frac{54 + 50 + 55}{3}$$

$$\text{Mean} = 53^{\circ}\text{C}$$

$$X = 53^{\circ}\text{C}$$

(2)

- (b) Determine the order of reactivity for the metals cobalt, magnesium and zinc.

Use the table above.

Most reactive Mg Zn  
(Biggest temp. increase)

Least reactive Co

(1)

- (c) The range of measurements either side of the mean shows the uncertainty in the mean temperature increase.

Complete the sentence.

Use the table above.

20 1 2  
18 1 2  
16

The mean temperature increase for zinc is  $18 \pm$  2 °C

(1)

- (d) What type of variable is the volume of hydrochloric acid in this investigation?

Tick (✓) **one** box.

Control

Dependent

Independent

(1)

- (e) Suggest **one** way of improving **step 3** in the method to give results which are more repeatable.

Use the same mass of metal.

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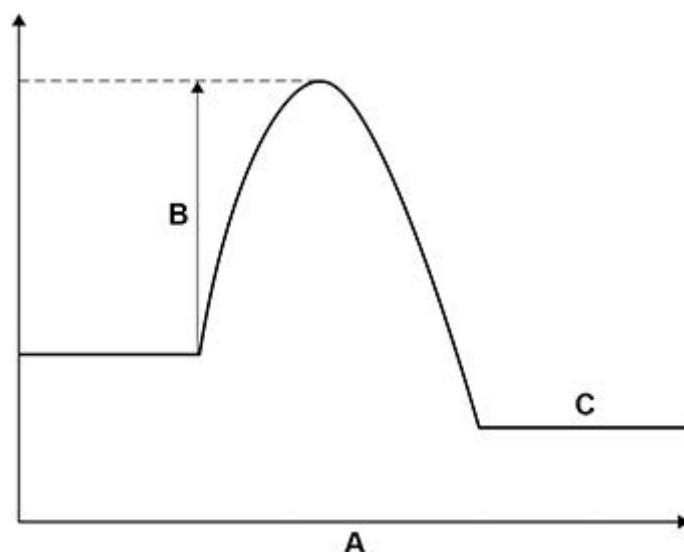
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(1)

- (f) The figure below shows a reaction profile for the reaction of magnesium with hydrochloric acid.



What do labels **A**, **B** and **C** represent on the figure above?

Choose answers from the box.

activation energy	energy	overall energy change
products	progress of reaction	reactants

A Progress of reaction

B Activation energy

C Products

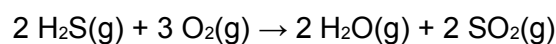
(3)

(Total 9 marks)

**Q2.**

This question is about the reaction between hydrogen sulfide (H<sub>2</sub>S) and oxygen.

The equation for the reaction is:



(a) What does H<sub>2</sub>O(g) represent?

Water vapour (or steam)

(1)

(b) Calculate the volume of oxygen required to react with 50 cm<sup>3</sup> of hydrogen sulfide.

2 H<sub>2</sub>S requires 3 O<sub>2</sub> ∴

$$\frac{3}{2} \times 50 = 75$$

Volume = 75 cm<sup>3</sup>

(1)

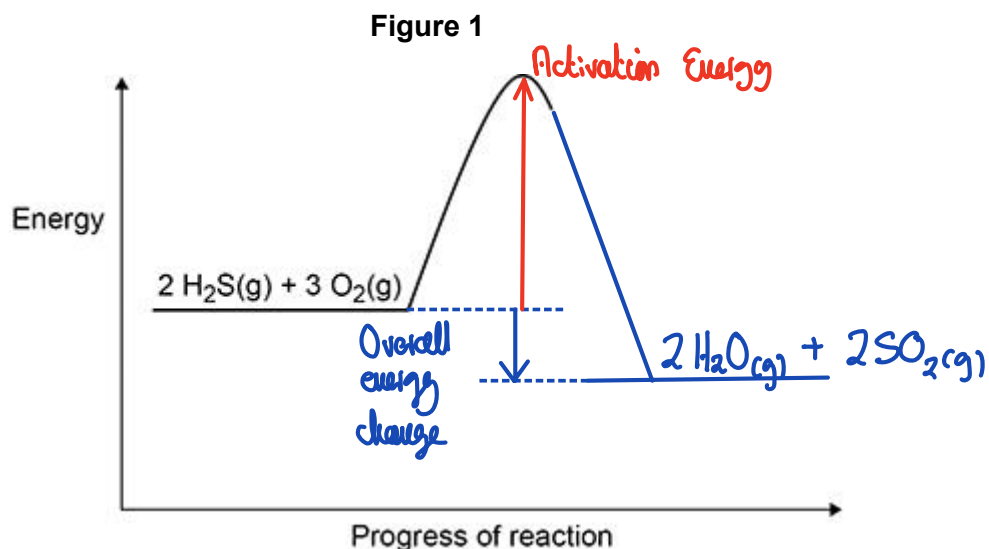
(c) **Figure 1** shows part of the reaction profile for the reaction.

The reaction is **exothermic**.

Complete **Figure 1**.

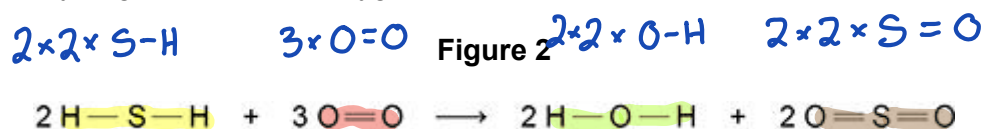
You should:

- complete the profile line
- label the activation energy
- label the overall energy change.



(3)

(d) **Figure 2** shows the displayed formula equation for the reaction of hydrogen sulfide with oxygen.



The table below shows some of the bond energies.

Bond	H-S	O=O	H-O	S=O
Energy in kJ/mol	364	498	464	X

In the reaction the energy released forming new bonds is 1034 kJ/mol greater than the energy needed to break existing bonds.

Heat released  
 $\Delta H = -1034$

Calculate the bond energy **X** for the bond.

Use **Figure 2** and the table above.

$$\text{Energy change} = \text{Bonds broken} - \text{Bonds formed}$$

$$\Delta H = [(2 \times 25-H) + (3 \times 0=0)] - [(2 \times 2 \times 0-H) + (2 \times 2 \times 5=0)]$$

$$-1034 = [(4 \times 364) + (3 \times 498)] - [(4 \times 464) + (4X)]$$

$$-1034 = [1456 + 1494] - [1856 + 4X]$$

$$-1034 = [2950] - [1856 + 4X]$$

$$1856 + 4X = 2950 + 1034$$

$$4X = 3984 - 1856$$

$$4X = 2128$$

$$X = \underline{532} \text{ kJ/mol}$$

(5)

(Total 10 marks)

$$X = \frac{2128}{4} = 532$$

**Q3.**

This question is about chemical reactions and energy.

Hydrogen reacts with oxygen to produce water.

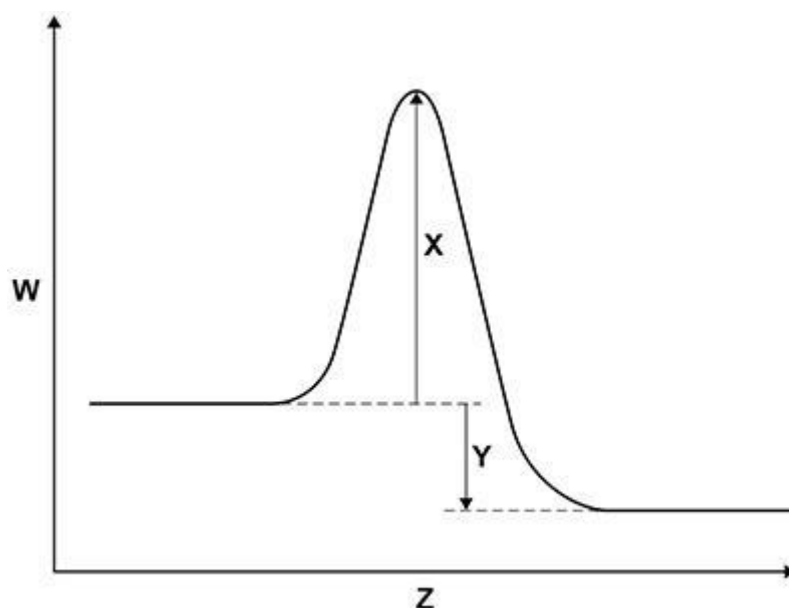
This reaction releases energy.

(a) Complete the word equation for the reaction.

hydrogen + oxygen → water

(1)

(b) The graph below shows a reaction profile for the reaction between hydrogen and oxygen.



What do the labels **W**, **X**, **Y** and **Z** represent?

Choose answers from the box.

activation energy	energy	overall energy change
products	progress of reaction	reactants

W Energy

X Activation Energy

Y Overall Energy change

Z Progress of reaction

(4)

(c) The reaction between hydrogen and oxygen is used in a hydrogen fuel cell.

What is the reason for using this reaction in a fuel cell?

Tick (✓) **one** box. (separate only)

To produce a change of state

To produce a potential difference

To produce a temperature change

(1)

(d) A student investigated the voltage produced by a chemical cell.

The student used different metals as the electrodes in the cell.

The metals used were:

- copper
- iron
- magnesium.

Which **two** metal electrodes would produce the greatest voltage when used in the chemical cell?

Give **one** reason for your answer. (separate only)

Metals Mg and Cu  
 Reason Mg and Cu have the largest difference in reactivity.

(2)

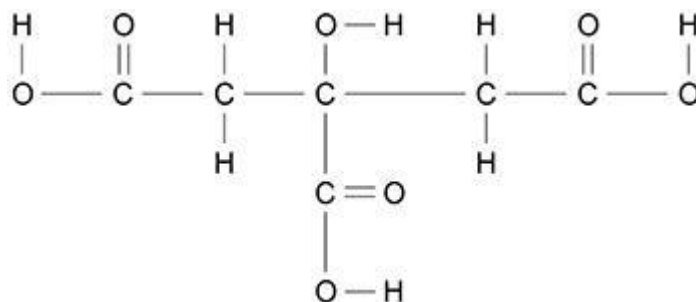
(Total 8 marks)

**Q4.**

This question is about citric acid.

**Figure 1** represents one molecule of citric acid.

**Figure 1**



(a) Complete the molecular formula of citric acid.

Use **Figure 1**.



(1)

(b) What type of bonding is shown in **Figure 1**?

Tick (✓) **one** box.

Covalent



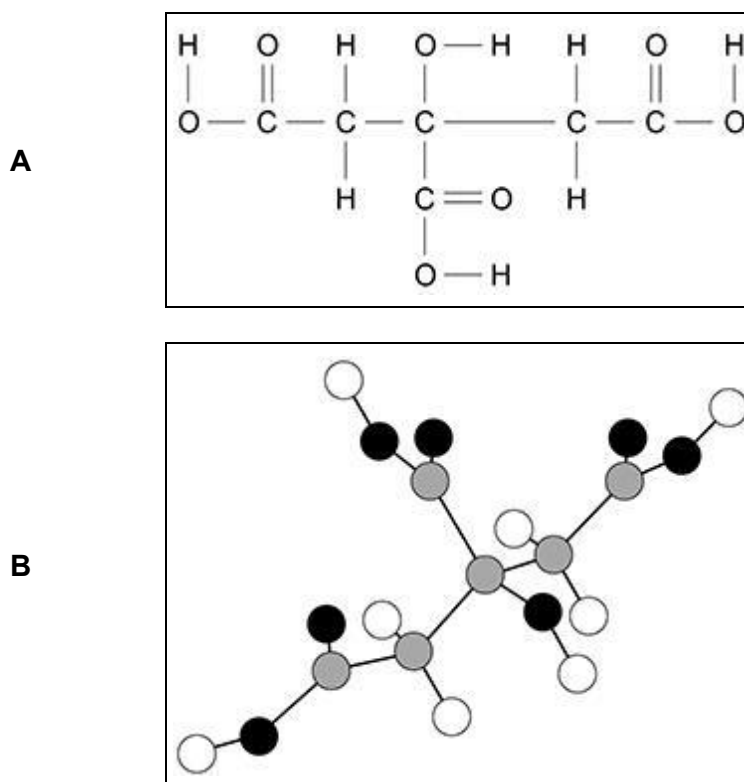
Ionic

Metallic

(1)

(c) **Figure 2** shows two representations of one molecule of citric acid, **A** and **B**.

**Figure 2**



Give **two** advantages of representation **A** compared with representation **B**.

Advantages of **A**:

1 Shows single and double bonds

2 Shows which atoms are which element

(2)

A student investigated the temperature change during the reaction between citric acid and sodium hydrogencarbonate solution.

Citric acid is a solid.

This is the method used.

1. Pour 25 cm<sup>3</sup> of sodium hydrogencarbonate solution into a polystyrene cup.
2. Measure the temperature of the sodium hydrogencarbonate solution.
3. Add 0.25 g of citric acid to the cup.
4. Stir the solution.
5. Measure the temperature of the solution.
6. Repeat steps 3 to 5 until a total of 2.00 g of citric acid has been added.

The table below shows some of the student's results.

Mass of citric acid added in g	Temperature of solution in °C
0.00	22.6
0.25	22.2
0.50	21.8
0.75	21.4
1.00	21.0
1.25	20.6

- (d) How do the results in table above show that the reaction is endothermic?

Temperature decreases during the reaction.

(1)

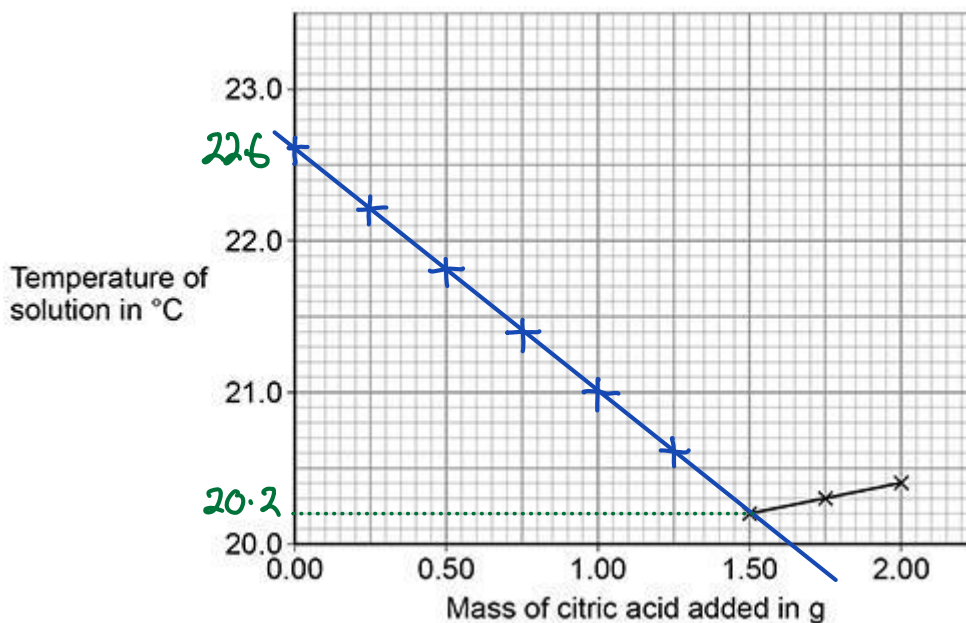
- (e) Three of the student's results are plotted on the graph below.

A line of best fit for these points is drawn.

Complete the graph below.

You should:

- plot the data from table above on the graph below
- draw a line of best fit through the points you have plotted
- extend your line of best fit to meet the line of best fit already drawn on the graph below.



(4)

- (f) Determine the overall temperature change for the reaction.

Use the graph above.

$$22.6 - 20.2 = 2.4^{\circ}\text{C}$$

Overall temperature change = 2.4 °C

(2)

- (g) What is the dependent variable in this investigation?

Tick (✓) **one** box.

Mass of citric acid

Temperature of solution

Volume of solution

(1)

(Total 12 marks)

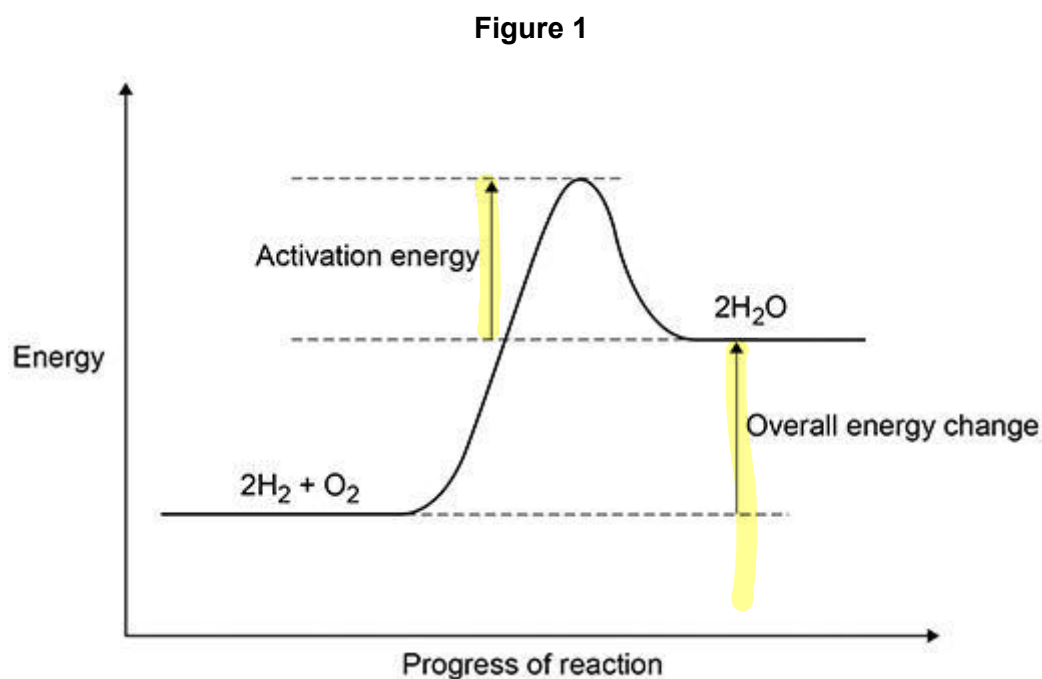
**Q5.**

The reaction between hydrogen and oxygen releases energy.

*Exothermic*

- (a) A student drew a reaction profile for the reaction between hydrogen and oxygen.

Figure 1 shows the student's reaction profile.



The student made **two** errors when drawing the reaction profile.

Describe the **two** errors.

- 1 Activation energy should come from the reactants.
- 2 The products line should be below the reactants line for an exothermic reaction.

(2)

- (b) The reaction between hydrogen and oxygen in a hydrogen fuel cell is used to produce electricity.

Hydrogen fuel cells and rechargeable cells are used to power some cars.

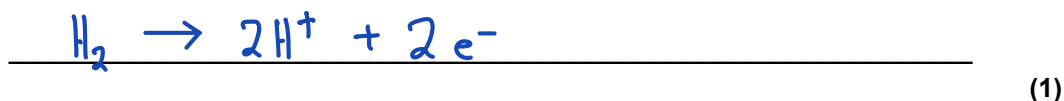
Give **two** advantages of using hydrogen fuel cells instead of using rechargeable cells to power cars. (separate only)

- 1 No toxic chemicals to dispose of at end of lifecycle
- 2 Takes less time to refuel.

(2)

- (c) Reactions occur at the positive electrode and at the negative electrode in a hydrogen fuel cell.

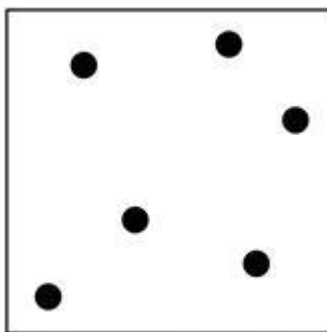
Write a half equation for **one** of these reactions. (separate only)



(d) The three states of matter can be represented by a simple particle model.

**Figure 2** shows a simple particle model for hydrogen gas.

**Figure 2**



Give **two** limitations of this simple particle model for hydrogen gas.

- 1 Hydrogen is not shown as  $\text{H}_2$  molecules
  - 2 Particles are shown as spheres.
- (2)

(e) The hydrogen gas needed to power a car for 400 km would occupy a large volume.

Suggest **one** way that this volume can be reduced.

Under higher pressure,  
cool or adsorb in a solid.

(1)

(f) The energy needed for a car powered by a hydrogen fuel cell to travel 100 km is 58 megajoules (MJ).

The energy released when 1 mole of hydrogen gas reacts with oxygen is 290 kJ

The volume of 1 mole of a gas at room temperature and pressure is  $24 \text{ dm}^3$

Calculate the volume of hydrogen gas at room temperature and pressure needed for the car to travel 100 km (separate only)

\_\_\_\_\_

$$58 \text{ MJ} = 58\,000 \text{ kJ}$$

$$\text{no. moles } \text{H}_2 \text{ needed} = \frac{58\,000}{290} = 200 \text{ moles}$$

$$\begin{aligned} \text{Vol. of 200 moles} &= 200 \times 24 \\ &= 4800 \text{ dm}^3 \end{aligned}$$

Volume of hydrogen gas = 4800 dm<sup>3</sup>

(4)

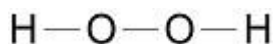
(Total 12 marks)

**Q6.**

This question is about compounds of oxygen and hydrogen.

**Figure 1** represents the structure of hydrogen peroxide.

**Figure 1**



- (a) What is the correct formula of hydrogen peroxide?

Tick (✓) **one** box.

H<sub>2</sub>O<sub>2</sub>

HO<sub>2</sub>

H<sup>2</sup>O<sup>2</sup>

H<sub>2</sub>O<sub>2</sub>

(1)

- (b) Which type of bonding is shown in **Figure 1**?

Tick (✓) **one** box.

Covalent

Ionic

Metallic

(1)

(c) Hydrogen peroxide decomposes in the presence of a catalyst.

Which elements are often used as catalysts?

Tick (✓) **one** box.

Alkali metals

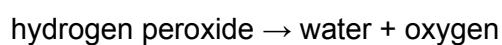
Halogens

Transition metals

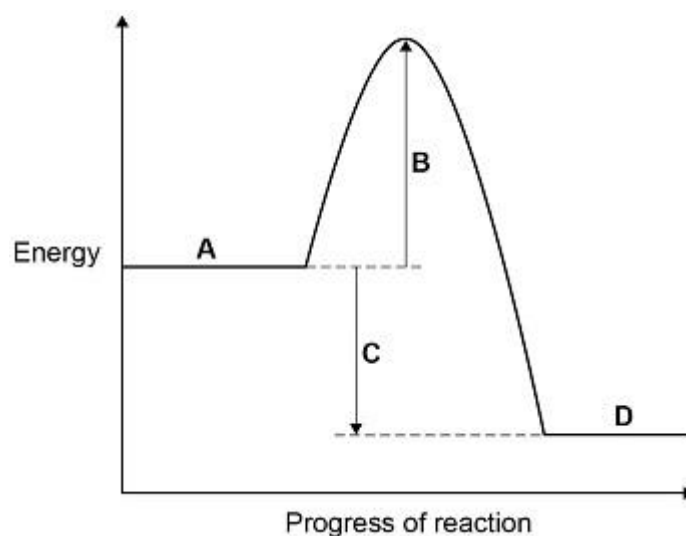
(1)

**Figure 2** shows the reaction profile for the decomposition of hydrogen peroxide.

The word equation for this reaction is:



**Figure 2**



Labels **A**, **B**, **C** and **D** each represent a different part of the reaction profile.

Use **Figure 2** to answer parts (d) and (e).

(d) Which label shows the activation energy?

Tick (✓) **one** box.

A       B       C       D

(1)

(e) Which label shows the energy of hydrogen peroxide?

Tick (✓) **one** box.

A       B       C       D

(1)

(f) The decomposition of hydrogen peroxide gives out energy to the surroundings.

What type of reaction is this?

Tick (✓) **one** box.

Displacement	<input type="checkbox"/>
Endothermic	<input type="checkbox"/>
Exothermic	<input checked="" type="checkbox"/>
Neutralisation	<input type="checkbox"/>

(1)

(g) Hydrogen and oxygen form water.

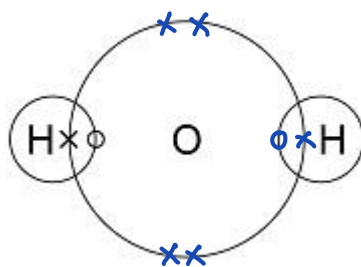
A hydrogen atom contains one electron.

An oxygen atom contains six electrons in the outer shell.

Complete **Figure 3** to show a dot and cross diagram for a water molecule.

Show the outer electrons only.

**Figure 3**



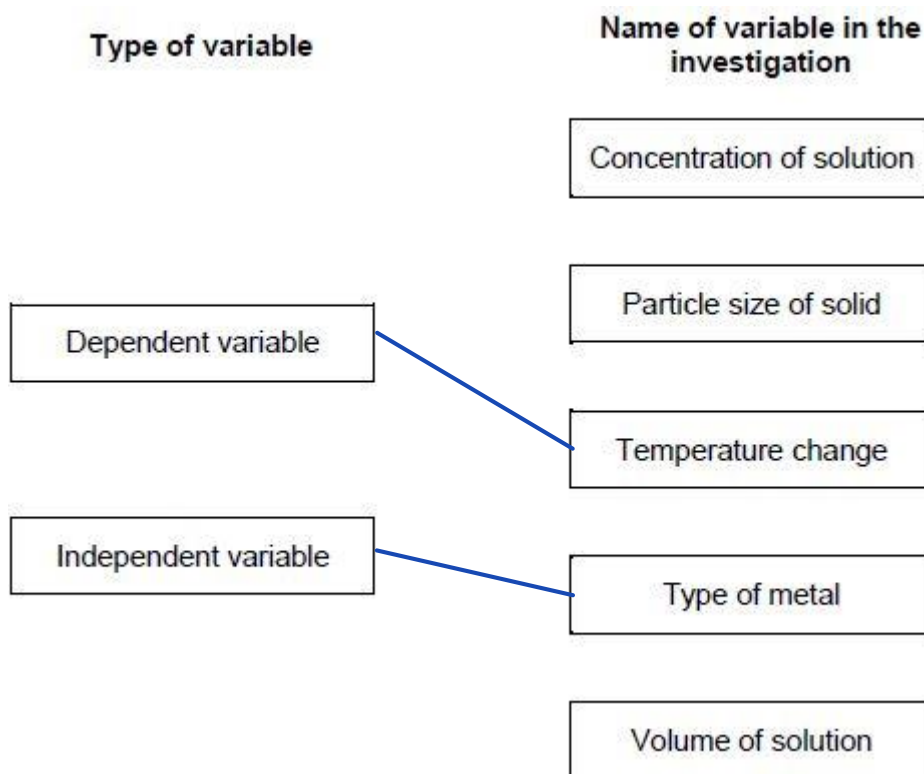
(2)  
(Total 8 marks)

**Q7.**

A student investigated the temperature change in displacement reactions between metals and copper sulfate solution.

This is the method used.

1. Measure 50 cm<sup>3</sup> of the copper sulfate solution into a polystyrene cup.
  2. Record the starting temperature of the copper sulfate solution.
  3. Add the metal and stir the solution.
  4. Record the highest temperature the mixture reaches.
  5. Calculate the temperature increase for the reaction.
  6. Repeat steps 1-5 with different metals.
- (a) Draw **one** line from each type of variable to the name of the variable in the investigation.



(2)

(b) The student used a polystyrene cup and not a glass beaker.

Why did this make the investigation more accurate?

Tick **one** box.

- Glass is breakable
- Glass is transparent
- Polystyrene is a better insulator
- Polystyrene is less dense

(1)

The table below shows the student's results.

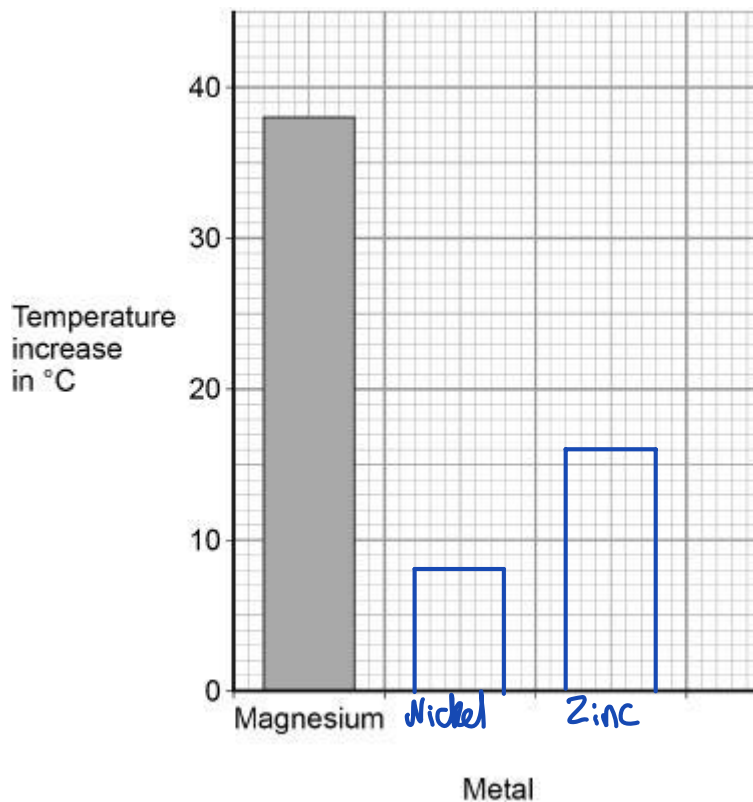
Metal	Temperature increase in °C
Magnesium	38
Nickel	8

Zinc	16
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(c) Complete **Figure 1**.

Use data from the table above.

**Figure 1**



(2)

(d) The student concluded that the reactions between the metals and copper sulfate solution are endothermic.

Give **one** reason why this conclusion is **not** correct.

Because temperature increases

(1)

(e) The temperature increase depends on the reactivity of the metal.

Write the metals magnesium, nickel and zinc in order of reactivity.

Use the table above.

Most reactive Mg  
Zn

Less reactive Ni

(1)

(f) Y is an unknown metal.

Describe a method to find the position of Y in the reactivity series in Question (e)

Add Y to  $CuSO_4$

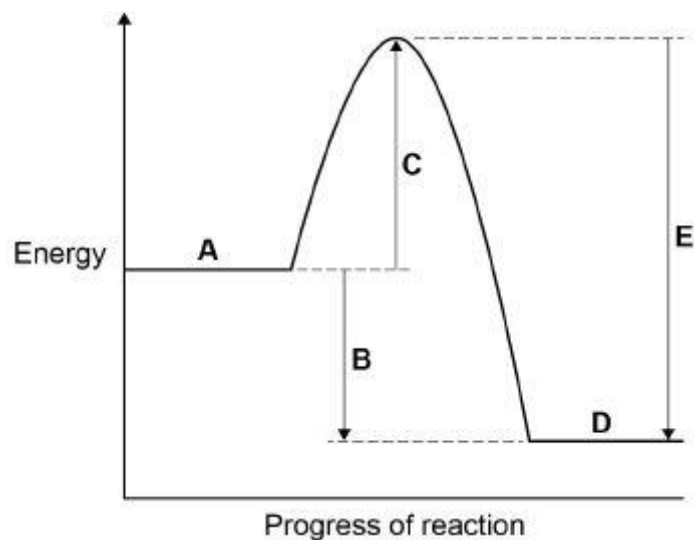
Measure temperature change

Place metals in order of temperature change

(3)

Figure 2 shows the reaction profile for the reaction between zinc and copper sulfate solution.

Figure 2



(g) Which letter represents the products of the reaction?

Tick **one** box.

A	<input type="checkbox"/>	B	<input type="checkbox"/>	C	<input type="checkbox"/>	D	<input checked="" type="checkbox"/>	E	<input type="checkbox"/>
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(1)

(h) Which letter represents the activation energy?

Tick **one** box.

A		B		C	<input checked="" type="checkbox"/>	D		E	
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(1)

(Total 12 marks)

**Q8.**

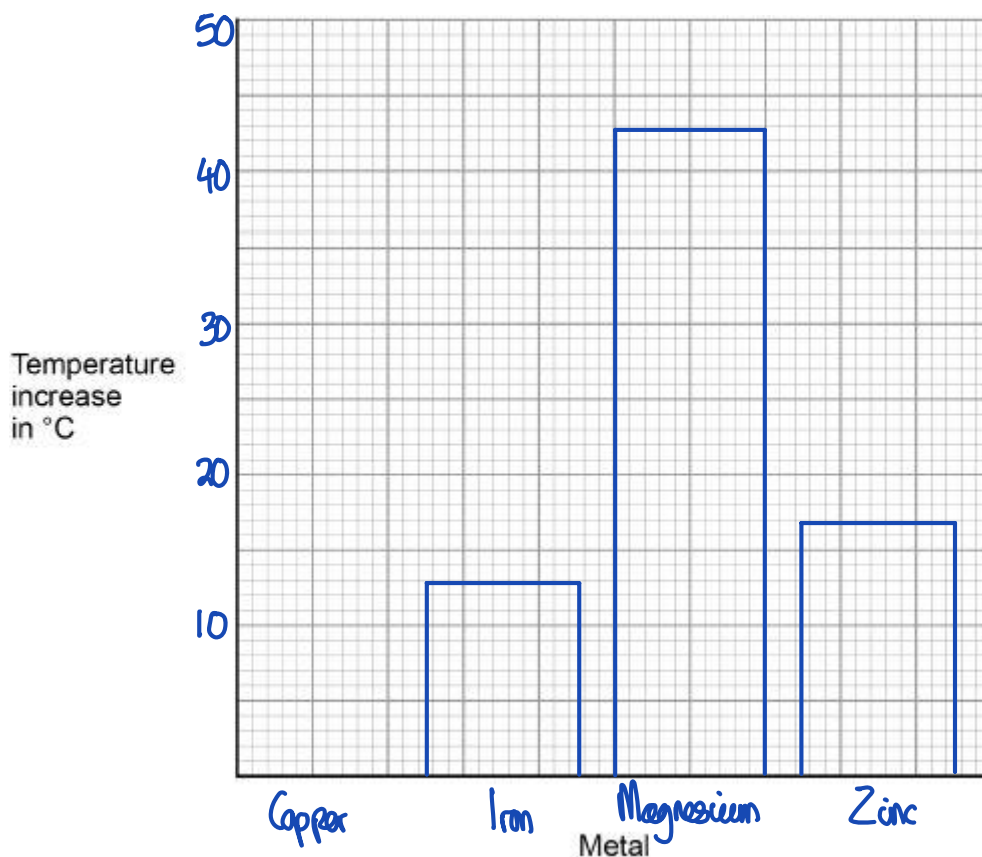
A student investigated the temperature change in displacement reactions between metals and copper sulfate solution.

The table below shows the student's results.

Metal	Temperature increase in °C
Copper	0
Iron	13
Magnesium	43
Zinc	17

(a) Plot the data from the table above on **Figure 1** as a bar chart.

**Figure 1**



(2)

- (b) The student concluded that the reactions between the metals and copper sulfate solution are endothermic.

Give **one** reason why this conclusion is **not** correct.

Temperature increases.

(1)

- (c) The temperature change depends on the reactivity of the metal.

The student's results are used to place copper, iron, magnesium and zinc in order of their reactivity.

Describe a method to find the position of an unknown metal in this reactivity series.

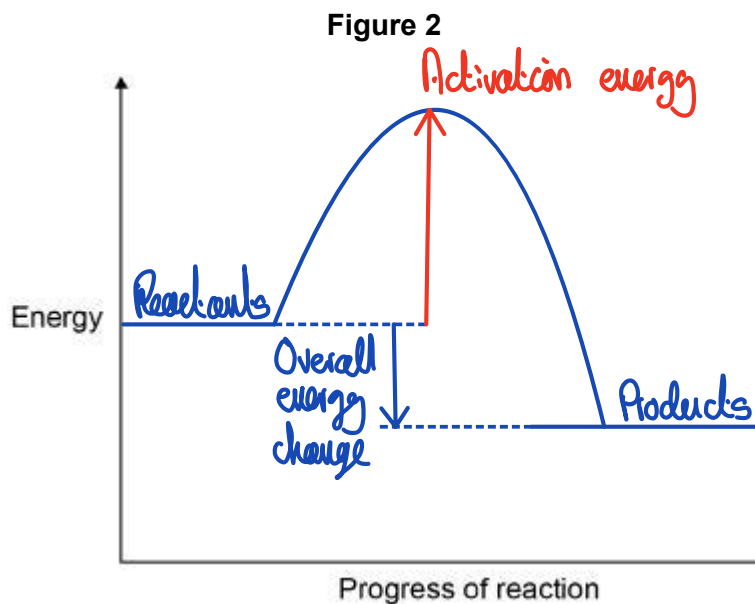
Your method should give valid results.

Add the unknown metal to  $\text{CuSO}_4$  solution and measure the temperature change.  
Place the metals in order of temperature change.

As a control variable, use the same volume of  $\text{CuSO}_4$  solution.

(4)

- (d) Draw a fully labelled reaction profile for the reaction between zinc and copper sulfate solution on **Figure 2**.



(3)

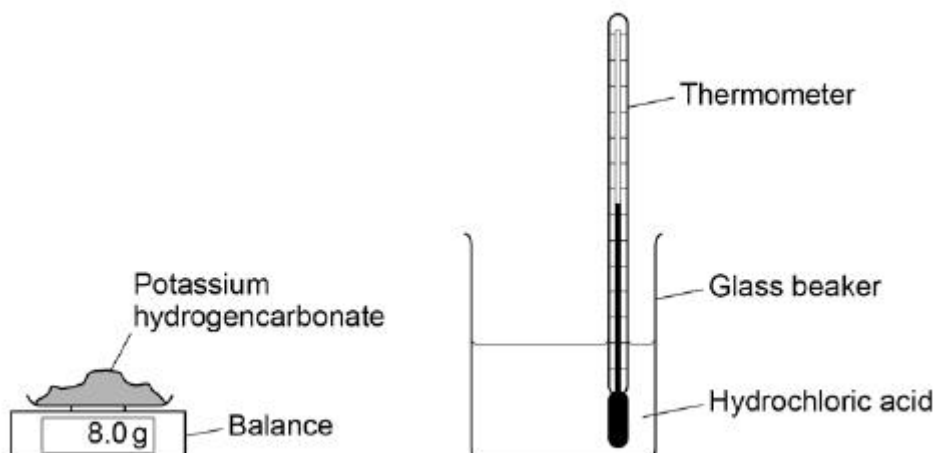
(Total 10 marks)

**Q9.**

A student investigated the energy change occurring in the endothermic reaction between potassium hydrogencarbonate and hydrochloric acid.

**Figure 1** shows the apparatus used.

Figure 1



This is the method used.

1. Measure 50 cm<sup>3</sup> hydrochloric acid into a glass beaker.
2. Measure 1.0 g of potassium hydrogencarbonate.
3. Add the potassium hydrogencarbonate to the hydrochloric acid.
4. Stir until all the potassium hydrogencarbonate has reacted.
5. Record the lowest temperature reached.
6. Repeat steps 1–5 two more times.
7. Repeat steps 1–6 with different masses of potassium hydrogencarbonate.

- (a) Which is the most suitable apparatus to use to measure 50 cm<sup>3</sup> of hydrochloric acid?

Tick (✓) **one** box.

- |                    |                                     |
|--------------------|-------------------------------------|
| Balance            | <input type="checkbox"/>            |
| Conical flask      | <input type="checkbox"/>            |
| Gas syringe        | <input type="checkbox"/>            |
| Measuring cylinder | <input checked="" type="checkbox"/> |

(1)

- (b) The student used a glass beaker for the reaction.

Suggest **one** change to the apparatus that would improve the accuracy of the results.

Give a reason for your answer.

Use a polystyrene cup which is a better insulator.

(2)

- (c) Which **two** variables should the student keep the same to make this a fair test?

Tick **two** boxes.

Mass of potassium hydrogencarbonate

Same balance

Same thermometer

Starting temperature of hydrochloric acid

Volume of hydrochloric acid

(2)

- (d) **Figure 2** shows part of the thermometer used to measure the temperature.



What is the temperature reading on the thermometer?

Temperature = 21.4 °C

(1)

The table shows a set of results.

	Test 1	Test 2	Test 3
Lowest temperature in °C	16.1	15.8	15.9

- (e) What is the range of the lowest temperature?

From 15.8 °C to 16.1 °C

(1)

- (f) Calculate the mean lowest temperature.

Use the table above.

$$\text{Mean} = \frac{16.1 + 15.8 + 15.9}{3}$$

$$\text{Mean} = 15.9^\circ\text{C}$$

Mean lowest temperature = 15.9 °C

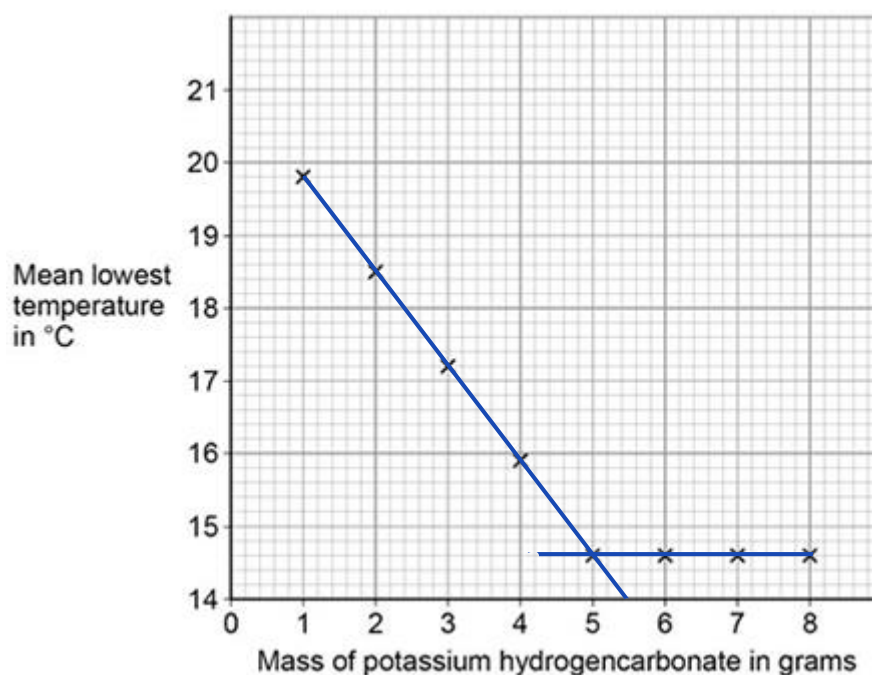
(2)

- (g) How do the results show that the reaction is endothermic?

Temperature decreases.

(1)

The graph shows the student's results.



- (h) Draw **two** straight lines of best fit on the graph above.

(2)

- (i) Describe how the lowest temperature changes as the mass of potassium hydrogencarbonate added increases.

The lowest temperature decreases, until 5g of  $\text{KHCO}_3$  is added, then there is no further change in temperature.

(3)

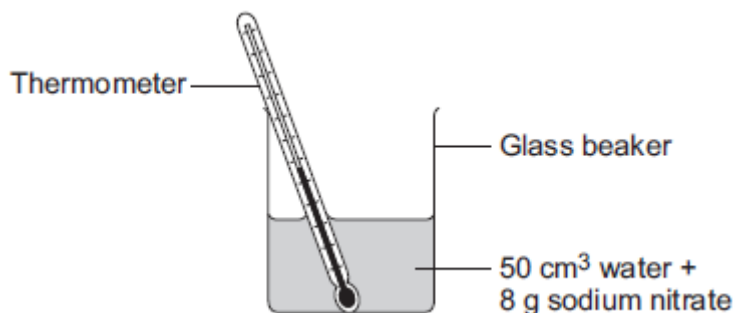
(Total 15 marks)

**Q10.**

This question is about temperature changes.

- (a) A student investigated the temperature change when 8 g of sodium nitrate dissolves in 50 cm<sup>3</sup> of water.

The diagram below shows the apparatus the student used.



The student did the experiment five times.

**Table 1** shows the results.

**Table 1**

Experiment	Decrease in temperature of water in °C
1	5.9
2	5.7
3	7.2
4	5.6

Anomalous result

5	5.8
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- (i) Calculate the mean decrease in temperature.  
Do not use the anomalous result in your calculation.

$$\text{Mean} = \frac{5.9 + 5.7 + 5.6 + 5.8}{4} = \frac{23}{4}$$

Mean decrease in temperature = 5.75 °C

(2)

- (ii) Suggest **one** change in the apparatus in the diagram above which would improve the accuracy of the results.  
Give a reason for your answer.

Use a polystyrene cup or lid. to prevent energy/heat gain.

(2)

- (b) The student investigated the temperature change when different masses of sodium carbonate were added to 50 cm<sup>3</sup> of water at 20 °C.

**Table 2** below shows the results.

**Table 2**

Mass of sodium carbonate in g	Final temperature of solution in °C
2.0	21.5
4.0	23.0
6.0	24.5
8.0	26.0
10.0	26.6
12.0	26.6
14.0	26.6

Describe the relationship between the mass of sodium carbonate added and the final temperature of the solution.

Use values from **Table 2** in your answer.

As mass increases, the final temperature increases.

then remains constant once  $10g$  has been added.

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(3)  
(Total 7 marks)

**Q11.**

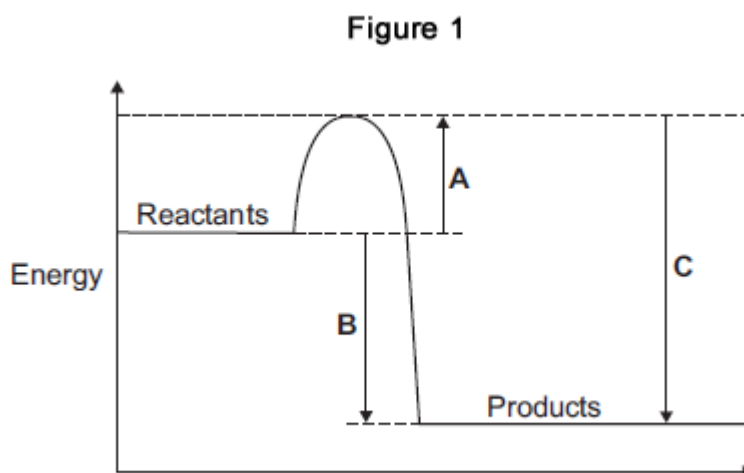
This question is about energy changes in chemical reactions.

- (a) Complete the word equation for the combustion of hydrogen.



(1)

- (b) **Figure 1** shows a simple energy level diagram.



- (i) Which arrow, **A**, **B** or **C**, shows the activation energy?

Tick (✓) **one** box.

<b>A</b>	<input checked="" type="checkbox"/>
<b>B</b>	<input type="checkbox"/>
<b>C</b>	<input type="checkbox"/>

(1)

- (ii) What type of reaction is shown by the energy level diagram in **Figure 1**?

Give a reason for your answer.

Type of reaction Exothermic

Reason Energy of products lower than energy of reactants.

(2)

- (iii) For a reaction, the value of **A** is 1370 kJ and **C** is 3230 kJ.  
Calculate the value of **B**.

$$B = C - A$$

$$B = 3230 - 1370 = 1860$$

$$B = \underline{1860} \text{ kJ}$$

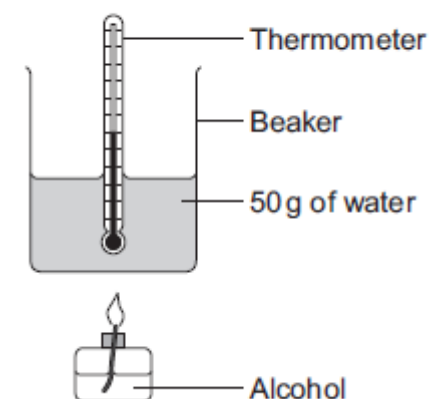
(1)

- (c) Alcohols are used as fuels.

A group of students investigated the amount of energy released when different alcohols are burned.

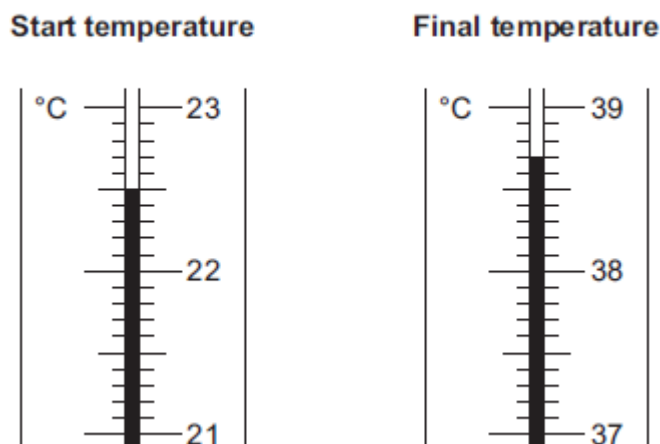
The students used the apparatus shown in **Figure 2**.

**Figure 2**



- (i) **Figure 3** shows the start temperature and the final temperature of the water.

Figure 3



Write the start temperature and the final temperature of the water in **Table 1**.

Work out the increase in temperature to complete **Table 1**.

Table 1

Start temperature of the water in °C	22.5
Final temperature of the water in °C	38.7
Increase in temperature in °C	16.2

(3)

- (ii) The students worked out the heat energy released by burning 1 g of each alcohol.

The students used the equation:

$$\text{Heat energy released} = m \times 4.2 \times \text{increase in temperature}$$

Look at **Figure 2**. What is the value of  $m$ ? (Mass of water)

$$m = 50 \text{ g}$$

(1)

- (iii) **Table 2** shows the students' results.

Table 2

Name of alcohol	Number of carbon atoms in one molecule of alcohol	Heat energy released when 1 g of alcohol is burned in kJ
Methanol	1	11.4
Ethanol	2	13.5
Propanol	3	20.1



(Total 14 marks)