

Heat Energy Changes

Mark Scheme



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1. All chemical reactions involve an energy change, which we most commonly observe as heat being either released to or absorbed from the surroundings.

Circle the letter of the correct answer for each of the following questions.

- a. A reaction pathway diagram is shown below.

Which statement about this reaction is correct?

B – is the correct answer.	1 mark
	Total: 1 mark

- b. Which reaction pathway diagram below shows an endothermic reaction?

B – is the correct answer.	1 mark
	Total: 1 mark

- c. Which of the following changes of state releases heat energy into the surroundings?

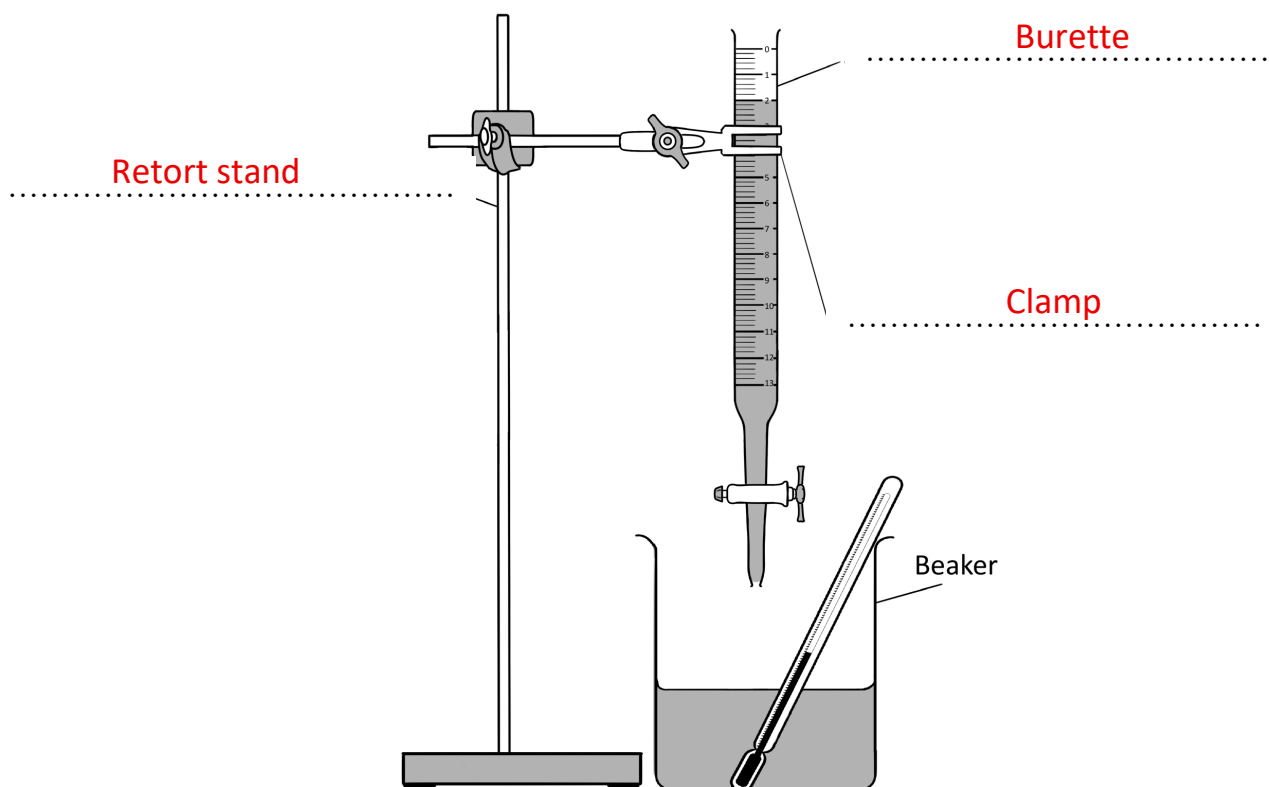
A – is the correct answer.	1 mark
	Total: 1 mark

- d. Which of the following processes does **not** require an input of energy from the surroundings to occur?

A – is the correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. A student wants to investigate the heat energy released when an acid neutralises an alkali. They assemble the apparatus shown in the diagram.
- a. Name the items of equipment they are using for their experiment.



Award 1 mark for each correct label.	
	Total: 3 marks

- b. Suggest **one** change to the experimental setup that would improve the accuracy of the final temperature reading.

Accept any one of the following:	
- Replace the beaker with a polystyrene cup. - Allow insulate the beaker (e.g., with cotton wool / bubble wrap).	
	Total: 1 mark

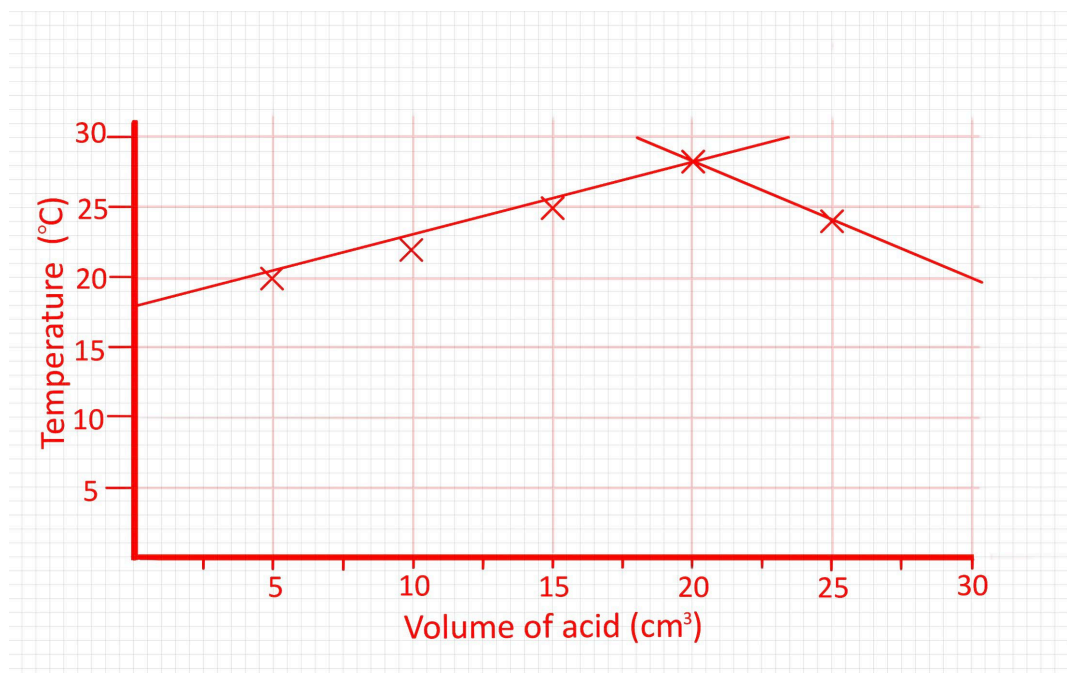
- c. Explain why the improvement you suggested in part (b) would lead to a more accurate value for the temperature change.

Explanation linked to answer in question 2 part (b):	
It reduces energy / heat transfer to the surroundings.	1 mark
Allow reduces heat loss.	
So the measured temperature change is closer to the true value / more accurate.	1 mark
Allow prevents heat escaping so the mixture reaches a higher maximum temperature.	
	Total: 2 marks

- d. In the experiment, the student adds the acid to the alkali in 5 cm³ portions.

Volume of acid (cm ³)	Temperature (°C)
5	20
10	22
15	25
20	28
25	24

Plot the results from the table on the graph paper below.



Award 1 mark for each of the following: • Correctly labelled axes: x axis = Volume of acid (cm³) y-axis = Temperature (°C) • Scale: suitable scale chosen so that data covers at least half the grid. • Plotting: All 5 points plotted correctly. • Line of best fit: Two straight lines of best fit drawn that intersect at the maximum.	
	Total: 4 marks

- e. Describe the relationship between the volume of acid added and the temperature of the mixture.

As the volume of acid increases, the temperature increases up to 20 cm ³ / a maximum.	1 mark
(After the maximum) the temperature decreases.	1 mark
	Total: 2 marks

(Total for Question 2 is 12 marks)

3. A student is investigating chemical reactions that give out heat to their surroundings.

- a. The student adds magnesium to a solution of sulfuric acid, H_2SO_4 .
Magnesium sulfate, MgSO_4 , and hydrogen gas are made.

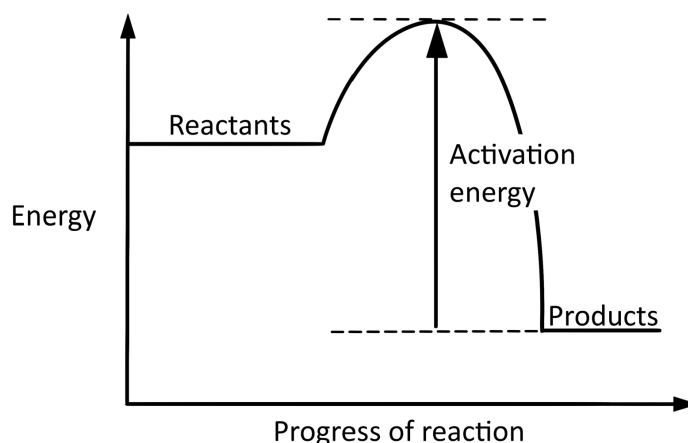
- i. Write the **balanced** symbol equation for this reaction.

$\text{Mg} + \text{H}_2\text{SO}_4 \rightarrow \text{MgSO}_4 + \text{H}_2$	
Award 1 mark for the correctly balanced reactants and one for the products.	
	Total: 2 marks

- ii. What term is used to describe a reaction that gives out heat to its surroundings?

Exothermic.	1 mark
	Total: 1 mark

- b. The student draws the reaction profile for this reaction.
The figure below shows the student's reaction profile.



- i. Identify an error that the student made on their reaction profile.

Accept any one of the following:	
- The profile shows an endothermic reaction (but the reaction is exothermic). - The products are at a higher energy level than the reactants. - The activation energy arrow is in the wrong place / starts from the products line (instead of the reactants).	
	Total: 1 mark

- ii. The activation energy is mentioned in the reaction profile above.
Explain what is meant by the term **activation energy**.

The minimum amount of energy.	1 mark
Accept: the energy required to start the reaction for 1 mark only.	
That particles must have to react / for a collision to be successful.	1 mark
	Total: 2 marks

(Total for Question 3 is 6 marks)

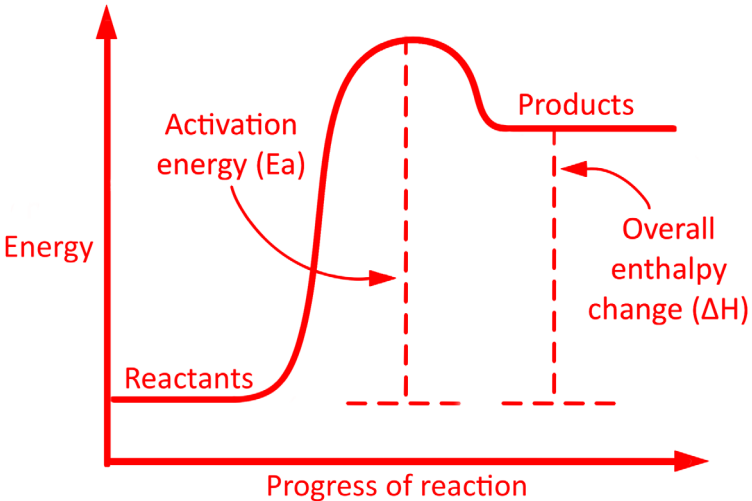
4. The thermal decomposition of calcium carbonate is an important industrial process that is endothermic.

It requires a large input of heat energy to break down the calcium carbonate into calcium oxide and carbon dioxide. A reaction profile diagram can show the energy pathway for this reaction.

- a. In the space below draw a fully labelled reaction profile diagram for an **endothermic** reaction.

Your diagram must show and label:

- The reactants and products
- The activation energy (E_a)
- The overall enthalpy change (ΔH)
- Labels for both axes

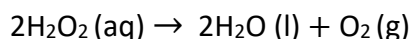
	
(Diagram markings): • y-axis labelled 'Energy' AND x-axis labelled 'Progress of reaction'. • Reactants and Products lines drawn with Products above Reactants. • Reactants and Products lines labelled correctly. • Curved line connecting reactants and products with a peak above the products. • Activation energy (E_a) arrow correctly labelled (from reactants line to top of peak). • Enthalpy change (ΔH) arrow correctly labelled (from reactants line to products line).	
	Total: 6 marks

- b. Explain, in terms of bond breaking and bond making, why the reaction is endothermic.

An explanation to include:	
Energy is required to break bonds AND energy is released when bonds are formed	1 mark
(The reaction is endothermic because) less energy is released when making bonds than is required to break bonds.	1 mark
	Total: 2 marks

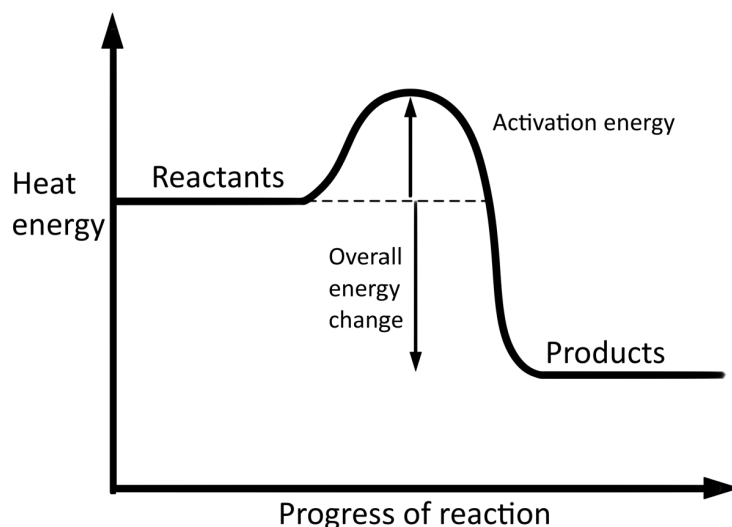
(Total for Question 4 is 8 marks)

5. A student investigates the decomposition of hydrogen peroxide solution into water and oxygen.



The reaction is slow at room temperature.

The reaction profile for this uncatalysed reaction is shown below.



The student adds a small amount of manganese(IV) oxide powder, which acts as a catalyst.

- a. On the reaction profile diagram, **draw a second line** to show the pathway for the reaction when a **catalyst is added**.

Award 1 mark for the following:	
- Line starting at the same level of the reactants. - Curve rises but is lower than the original activation energy. - Line ends at the same level as the products.	
	Total: 3 marks

- b. Describe, in terms of activation energy, how the catalyst increases the rate of reaction.

A description to include:	
As catalyst lowers the activation energy.	1 mark
So, it provides an alternative reaction pathway.	1 mark
	Total: 2 marks

- c. What would be the mass of the manganese(IV) oxide at the end of the reaction?
Explain your answer.

An explanation to include:	
The mass remains the same (or is unchanged).	1 mark
Because a catalyst is not used up (or not consumed) in the reaction.	1 mark
	Total: 2 marks

(Total for Question 5 is 8 marks)

6. Ammonia is manufactured from nitrogen and hydrogen in the Haber process.

The process involves a reversible reaction which is often run at high temperatures and pressures.

Step 1: Nitrogen and hydrogen gases react to form ammonia.

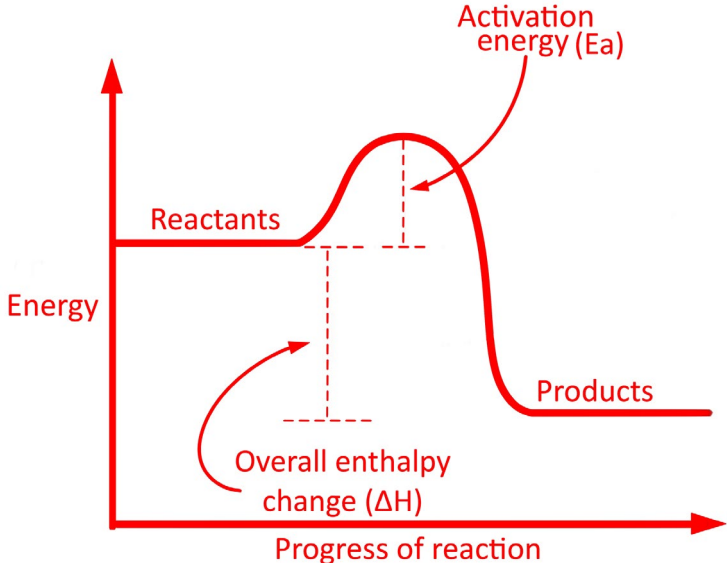
Step 2: The ammonia is then cooled, liquefied, and removed.

The forward reaction in step 1 is an exothermic reaction.

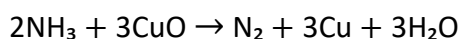
a. Draw a labelled reaction profile diagram for an exothermic reaction.

Label the following in your diagram:

- **Reactants** and **products**.
- **Activation energy**.
- The **energy change** (enthalpy change, ΔH).
- **Products**.

	
(Diagram markings): • Reactants and products lines drawn with Products below Reactants. • Reactants and products lines labelled correctly. • Curved line connecting reactants and products with a peak above the products. • Activation energy (E_a) arrow correctly labelled. • Enthalpy change (ΔH) arrow correctly labelled.	
	Total: 4 marks

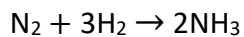
In a different reaction, ammonia can be used to reduce copper(II) oxide to copper.



b. Explain, in terms of electron transfer, why ammonia (NH_3) is called a reducing agent in this reaction.

An explanation to include:	
Ammonia loses electrons .	1 mark
Allow: Nitrogen (in ammonia) loses electrons.	
It donates electrons to the copper ions (or CuO).	1 mark
Allow: It gives electrons to the substance being reduced.	
	Total: 2 marks

- c. A chemical engineer reacts hydrogen with an excess of nitrogen to produce ammonia.
The balanced equation for the reaction is:



Calculate the number of moles of ammonia (NH_3) that would be produced from 12.0 g of hydrogen.
(Relative atomic masses: H = 1, N = 14)

Give your answer to 2 significant figures.

moles of $\text{H}_2 = 12 \div 2$ moles of $\text{H}_2 = 6.0$ mols	1 mark
Ratio of moles is 3 : 2	1 mark
Therefore the moles of $\text{NH}_3 = 6 \times 2 \div 3 = 4.0$ mols	1 mark
	Total: 3 marks

(Total for Question 6 is 9 marks)