FACTFILE: GCSE CHEMISTRY: UNIT 2.8

Rewarding Learning

Energy Changes in Chemistry

Learning outcomes

Students should be able to:

2.8.1 demonstrate knowledge and understanding that chemical reactions in which heat is given out are exothermic and that reactions in which heat is taken in are endothermic;

2.8.2 **draw and interpret reaction profile diagrams for exothermic and endothermic reactions identifying activation energy**;

2.8.3 explain activation energy as the minimum energy needed for a reaction to occur;

2.8.4 recall that bond breaking takes in energy and bond making releases energy, and demonstrate understanding that the overall energy change in a reaction is a balance of the energy taken in when bonds break in the reactants and the energy released when bonds form in the products;

2.8.5 calculate energy changes in a chemical reaction from bond energies by considering bond making and bond breaking energies.

In exothermic reactions, the chemicals give out energy so ΔH (energy change) is negative. The surroundings feel hotter and an increase in temperature is observed.

Examples of exothermic reactions include:

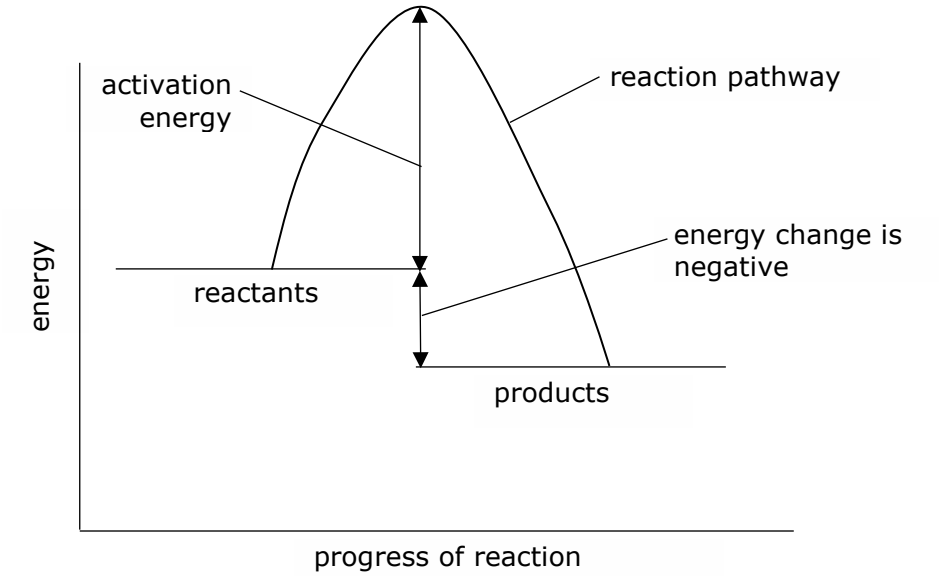
1. Combustion – burning fuels for heating and in engines

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

2. Respiration – oxidation of carbohydrates in living things

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Exothermic reactions can be represented on a reaction profile diagram:



In endothermic reactions, the chemicals take in energy so ΔH is positive. The surroundings feel cooler and a decrease in temperature is observed.

Examples of endothermic processes include:

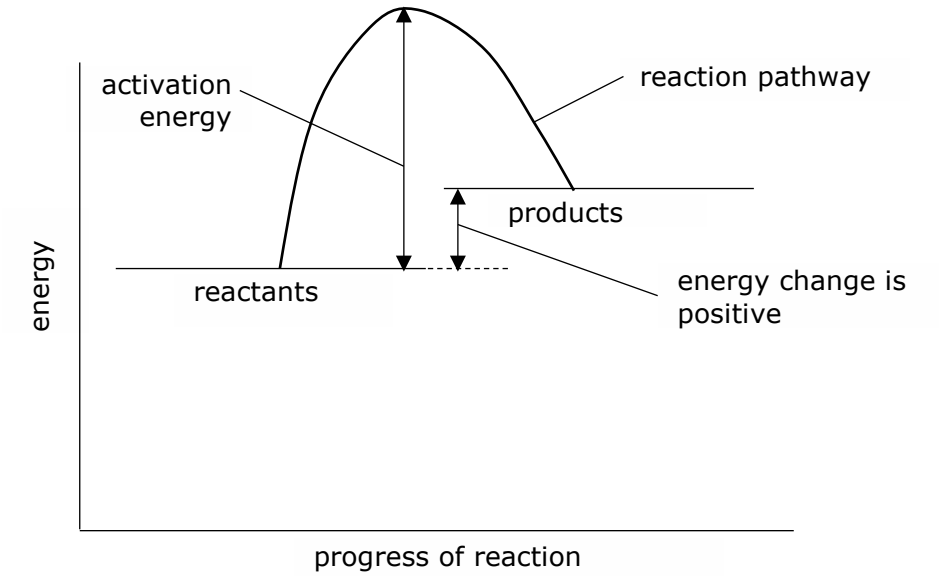
1. Thermal decomposition of calcium carbonate

$$CaCO_3 \longrightarrow CaO + CO_2$$

2. Photosynthesis

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Endothermic reactions can be represented on a reaction profile diagram:



The reaction profile diagrams show the activation energy for each type of reaction. Activation energy is the minimum energy required for a reaction to take place between reacting particles. The activation energy required for endothermic reactions is greater than the activation energy required for exothermic reactions.

Explaining energy changes in a reaction

In all reactions energy is taken in to break the bonds of the reactant molecules and energy is released when new bonds form in the product molecules. The balance of these energy changes determines if a reaction is exothermic or endothermic overall.

REACTANTS	⟶	PRODUCTS
bonds broken		bonds formed
energy taken in		energy given out

EXOTHERMIC – energy taken in to break bonds in the reactants is **less** than the energy released when new bonds form in the products.

$$E_{in} < E_{out}$$

ENDOTHERMIC – energy taken in to break bonds in the reactants is **greater** than the energy released when new bonds form in the products.

$$E_{in} > E_{out}$$

Calculation of the energy change of a reaction

The combustion reaction between methane and oxygen is **exothermic** and using the data provided this can be shown through a calculation. For this calculation bond enthalpy data is required, this will always be provided.

The calculation can be broken down into a number of steps:

Step 1 – write the balanced symbol equation and draw out the molecules showing the bond types.

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

Step 2 – list the number of each type of bond present for the reactants and the products:

Reactants	4 × C—H
	2 × O=O
Products	2 × C=O
	4 × O—H

Step 3 – calculate the **total** bond energies for the reactants and products using the data provided:

Bond type	Bond energy (kJ/mol)
C–H	413
O=O	497
C=O	805
O–H	463

Reactants	4 × C–H	4 × 413 =	1652
	2 × O=O	2 × 497 =	994
		TOTAL =	**2646**
Products	2 × C=O	2 × 805 =	1610
	4 × O–H	4 × 463 =	1852
		TOTAL =	**3462**

Step 4 – use the equation **energy change = ∑(bonds broken) – ∑(bonds formed)** to calculate the energy change for the reaction where ∑ represents the sum off all the bond energies.

energy change = ∑(bonds broken) – ∑(bonds formed)
energy change = 2646 – 3462
energy change = – 816 kJ/mol

The calculation shows a negative energy change confirming that the reaction is **exothermic**.

REVISION QUESTIONS

1. Methane will burn in air to produce carbon dioxide and water in an exothermic reaction.

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

Draw a energy level diagram to represent this reaction and use the diagram to explain why the reaction is exothermic.

[4]

2. The equation for the reaction of hydrogen with oxygen is:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

During the reaction energy is used to break the bonds of the reactants and energy is released when news bonds are formed to make the products.

(a) Calculate the energy change for the reaction using the data in the table.

Bond	Bond energy (kJ/mol)
H—H	436
O=O	498
O—H	464

[4]

(b) Draw a reaction profile diagram for the reaction and label the activation energy.

[4]

3. The presence of nitrogen dioxide (NO_2) in the atmosphere can cause acid rain. It is formed naturally in the reaction between atmospheric nitrogen and oxygen in an endothermic reaction.

(a) Explain in terms of bonds why this reaction is endothermic.

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_____ [3]

(b) Draw a reaction profile diagram for this reaction.

[4]