Exercise walk-through

5.1
Exothermic and endothermic reactions (4.5.1.1–4.5.1.3)

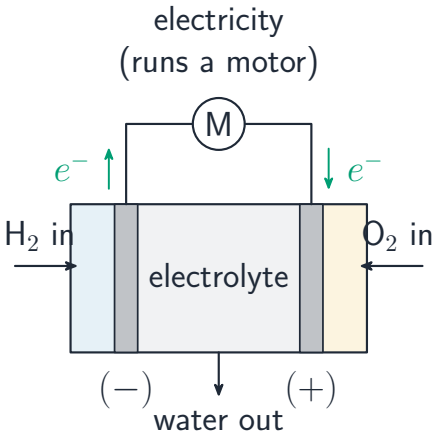
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Bond energies (higher tier)

- Bonds broken: two H–H and one O=O **double bond** : $2(436) + 498 = 1370$ kJ/mol.
- Bonds made: each water molecule has two O–H bonds, so two molecules have four: $4(464) = 1856$ kJ/mol.
- Overall change $= 1370 - 1856 = -486$ kJ/mol. The reaction is exothermic.

overall energy change = energy to break bonds − energy released making bonds

Figure: Hydrogen fuel cells (chemistry only)



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

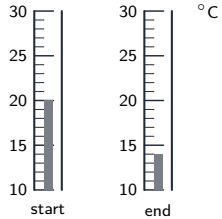
- Hydrogen and oxygen meet at separate electrodes.
- The only product is water.

Sources for this lesson

- AQA, *GCSE Chemistry (8462) specification*, section 4.5, and the required practicals handbook.
- NASA, *Apollo 13 Mission Operations Report* (1970) and the *Report of the Apollo 13 Review Board* (15 June 1970).
- NASA Glenn Research Center, "Fuel cells: a history" (Apollo command and service module power system).
- International Energy Agency, *Global Hydrogen Review 2024*, on how hydrogen is produced.

Exercises 2.1·2.2

2.1 In a reaction, the temperature falls from 20.0 °C to 14.0 °C. Is the reaction exothermic or endothermic? Explain your answer. [2]



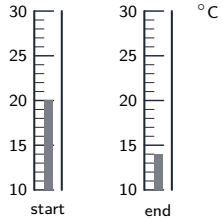
2.2 Give **one** use of an exothermic reaction and **one** use of an endothermic reaction. [2]

hand warmer

cold pack

Exercises 2.1·2.2

2.1 In a reaction, the temperature falls from 20.0 °C to 14.0 °C. Is the reaction exothermic or endothermic? Explain your answer. [2]



2.1

- **endothermic**; the temperature falls, so energy is taken in from the surroundings

2.2 Give **one** use of an exothermic reaction and **one** use of an endothermic reaction. [2]

hand warmer

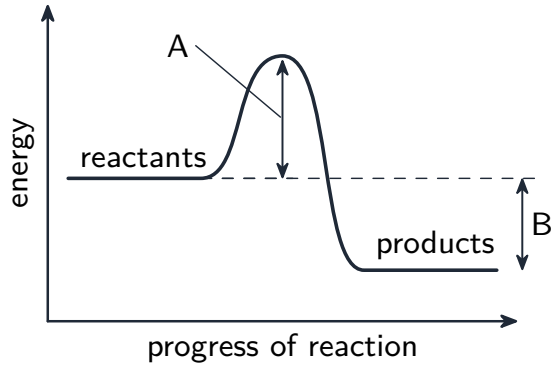
cold pack

2.2

- exothermic, any one: hand warmers; self-heating cans
- endothermic, any one: cold packs for sports injuries; cooling drinks

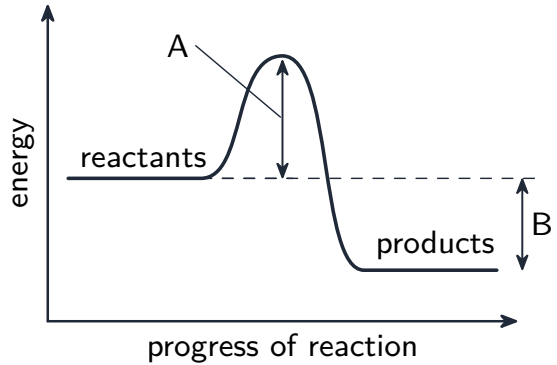
Exercise 2.3

2.3 The diagram shows the reaction profile for a reaction. Which arrow, A or B, shows the activation energy? Is the reaction exothermic or endothermic? [2]



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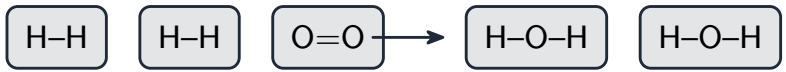


2.3

- **A**; exothermic, because the products have less energy than the reactants

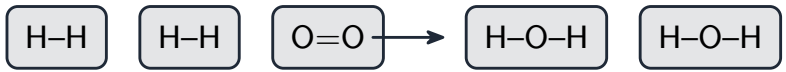
Exercise 3.1

3.1 Hydrogen burns: $2H_2 + O_2 \rightarrow 2H_2O$. Use the bond energies to calculate the energy change. Bond energies in kJ/mol: H–H 436, O=O 498, O–H 464. [3]



Exercise 3.1

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3.1

- bonds broken $= 2 \times 436 + 498 = 1370$ kJ/mol
- bonds made $= 4 \times 464 = 1856$ kJ/mol
- change $= 1370 - 1856 = \mathbf{-486}$ kJ/mol

Exercise 3.2 (a)

3.2 A student adds sodium hydroxide solution, 5 cm^3 at a time, to 25 cm^3 of hydrochloric acid in a polystyrene cup, and records the highest temperature each time.

(a) Use the graph to find the highest temperature reached, and the largest temperature rise. [2]

Exercise 3.2 (a)

3.2 A student adds sodium hydroxide solution, 5 cm^3 at a time, to 25 cm^3 of hydrochloric acid in a polystyrene cup, and records the highest temperature each time.

(a) Use the graph to find the highest temperature reached, and the largest temperature rise. [2]

(a) highest temperature 31.0 °C; rise = 31.0 − 20.0 = **11.0** °C

Exercise 3.2 (b)

3.2 A student adds sodium hydroxide solution, 5 cm^3 at a time, to 25 cm^3 of hydrochloric acid in a polystyrene cup, and records the highest temperature each time.

(b) Explain why the temperature rises at first and then falls. [3]

Exercise 3.2 (b)

3.2 A student adds sodium hydroxide solution, 5 cm^3 at a time, to 25 cm^3 of hydrochloric acid in a polystyrene cup, and records the highest temperature each time.

(b) Explain why the temperature rises at first and then falls. [3]

(b) neutralisation is exothermic, so energy is released; up to 25 cm^3, more acid reacts each time, so more energy is released; after all the acid has reacted, extra cool sodium hydroxide just cools the mixture

Exercise 3.2 (c)

3.2 A student adds sodium hydroxide solution, 5 cm^3 at a time, to 25 cm^3 of hydrochloric acid in a polystyrene cup, and records the highest temperature each time.

(c) Explain why the student uses a polystyrene cup with a lid. [2]

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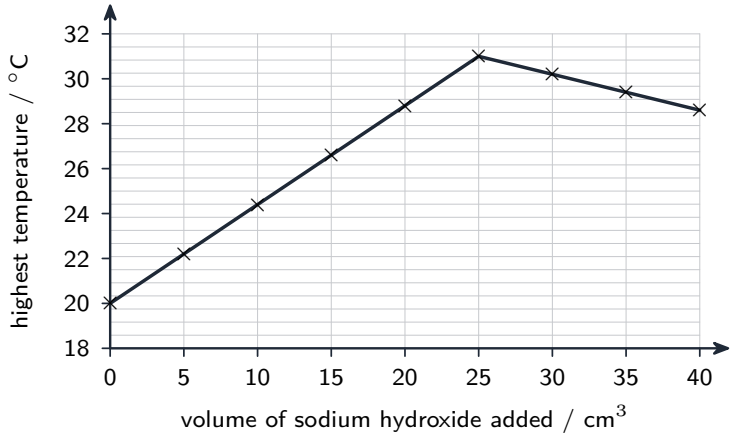
(c) Explain why the student uses a polystyrene cup with a lid. [2]

(c) polystyrene is a good insulator and the lid stops heat escaping from the top; so less energy is lost to the surroundings and the temperature rise is more accurate

Exercise 3.2 (d)

3.2 A student adds sodium hydroxide solution, 5 cm^3 at a time, to 25 cm^3 of hydrochloric acid in a polystyrene cup, and records the highest temperature each time.

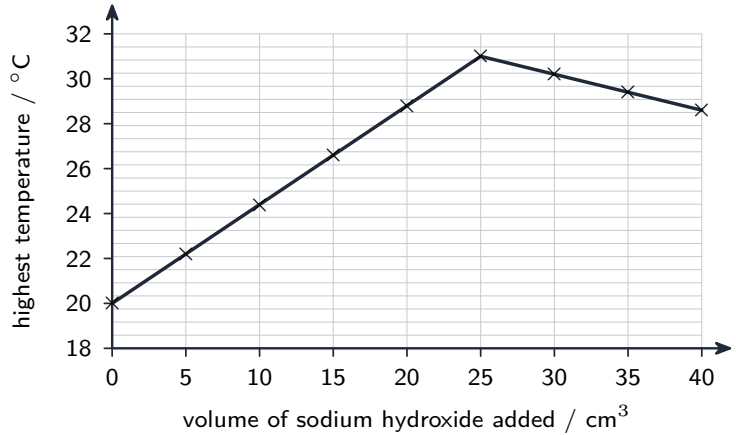
(d) Describe how the student could carry out this investigation. [6]



Exercise 3.2 (d)

3.2 A student adds sodium hydroxide solution, 5 cm^3 at a time, to 25 cm^3 of hydrochloric acid in a polystyrene cup, and records the highest temperature each time.

(d) Describe how the student could carry out this investigation. [6]



Full solution on next slide

Full solution 3.2 (d)

(d) points to include:

- measure 25 cm^3 of hydrochloric acid into a polystyrene cup with a measuring cylinder
- stand the cup in a beaker so it does not fall over, and record the starting temperature
- add 5 cm^3 of sodium hydroxide, put the lid on and stir
- record the highest temperature reached
- repeat, adding 5 cm^3 at a time, up to 40 cm^3
- repeat the whole experiment and plot temperature against volume

Levels: **5–6** a full, logical answer with correct chemistry and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.