3.2 Rates and equilibria

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

Objective

Build the skills to answer exam questions on **rates of reaction and equilibria** : measuring rates, collision theory, catalysts, reversible reactions and how conditions shift a dynamic equilibrium.

You must be able to:

- calculate a mean rate of reaction from results
- explain changes in rate with collision theory
- describe reversible reactions and dynamic equilibrium
- plan an experiment to measure the effect of a factor on rate

1 Key knowledge and worked examples

■ Rate and equilibrium

idea	rule
mean rate	amount of product formed (or reactant used) ÷ time
collision theory	particles must collide with at least the activation energy; more successful collisions per second means a faster rate
factors that increase rate	higher concentration or gas pressure, higher temperature, larger surface area (smaller pieces), a catalyst
dynamic equilibrium	in a closed system the forward and backward rates are equal; amounts stay constant
changing conditions	the equilibrium moves to oppose the change

Worked example 1: mean rate. 60 cm^3 of gas is collected in 40 s. Find the mean rate.

1. Known: 60 cm^3; 40 s.
2. Rule: amount ÷ time.

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3. Numbers: $60 \div 40$.
4. Result: 1.5 $\mathbf{cm^3/s}$.

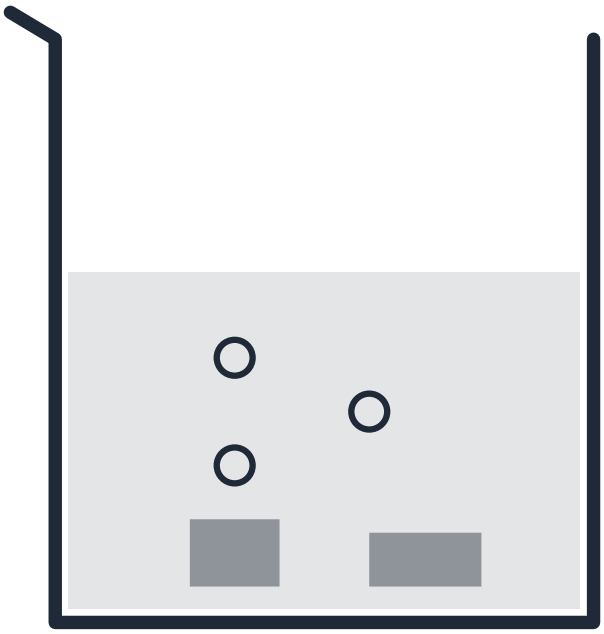
Worked example 2: equilibrium. $N_2 + 3H_2 \rightleftharpoons 2NH_3$. Predict the effect of raising the pressure.

1. Known: 4 molecules of gas on the left, 2 on the right.
2. Rule: higher pressure moves the equilibrium to the side with fewer gas molecules.
3. Numbers: $4 \to 2$.
4. Result: **the equilibrium moves right; more ammonia**.

Answer shapes: for rate, say what happens to the frequency of successful collisions, and why.

2 Practice

2.1 Give **two** ways to make zinc react faster with dilute sulfuric acid. [2]

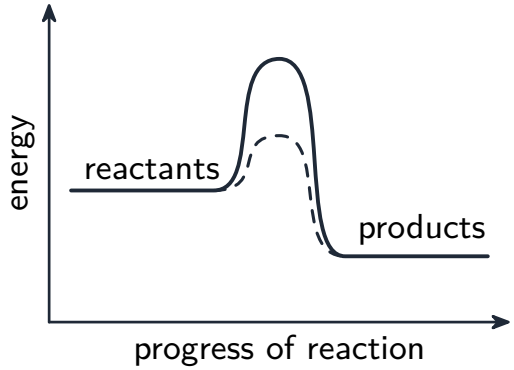


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2.2 48 cm^3 of hydrogen is collected in the first 30 s of a reaction. Calculate the mean rate. [2]

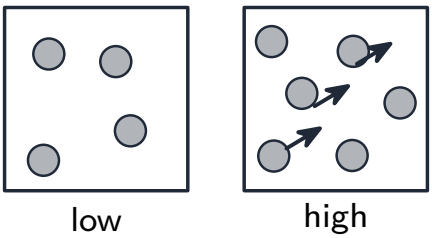


2.3 The dashed line on the energy profile shows the reaction with a catalyst. Explain how a catalyst increases the rate. [2]



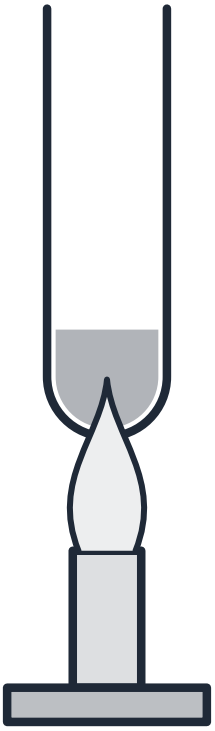
3 Exam-style questions

3.1 Use collision theory to explain why a reaction is faster at a higher temperature. [3]



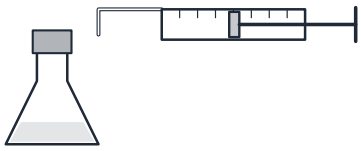
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3.2 Hydrated copper(II) sulfate is heated: $CuSO_4 \cdot 5H_2O \rightleftharpoons CuSO_4 + 5H_2O$. Describe the colour changes in the forward and the backward reaction, and state whether the backward reaction is exothermic or endothermic. [3]



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3.3 A student adds 5.0 g of marble chips (calcium carbonate, in excess) to 50 cm^3 of dilute hydrochloric acid and collects the carbon dioxide in a gas syringe. The results are shown.



time / s	0	20	40	60	80	100	120
volume / cm^3	0	24	42	54	60	63	64

(a) Calculate the mean rate for the first 40 s, and explain why the reaction slows down. [3]

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(b) The student repeats the experiment with 5.0 g of marble **powder** and the same acid. State how the initial rate and the final volume of gas compare with the first experiment, and explain. [3]

(c) Describe how the student could use this apparatus to find how the concentration of the acid affects the rate. Include the variables to control. [6]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

Any two (1 mark each):

- use more concentrated acid
- heat the acid
- use zinc powder instead of lumps
- add a catalyst (copper(II) sulfate)

2.2

- $48 \div 30$
- **1.6** cm^3/s

2.3

- it gives a different reaction pathway with a lower activation energy
- so more collisions have enough energy to react

3.1

- particles have more kinetic energy and move faster
- so they collide more often
- and a larger fraction of collisions have at least the activation energy, so more collisions are successful

3.2

- forward (heating): blue to white
- backward (adding water): white to blue
- the backward reaction is exothermic

3.3

(a) $42 \div 40 =$ **1.05** cm^3/s; the acid is used up, so there are fewer acid particles and fewer collisions per second

(b) the initial rate is faster, because powder has a larger surface area, so more frequent collisions; the final volume is the same (64 cm^3), because the same amount of acid reacts

(c) points to include:

- use several concentrations of acid, e.g. 0.5, 1.0, 1.5, 2.0 mol/dm^3 (App)
- add the marble chips, put the bung in straight away and start the timer (K)
- record the volume of gas every 20 s (or the time to collect a fixed volume) (K)
- keep the same mass and size of marble chips and the same volume of acid (App)
- keep the temperature the same (App)

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- plot volume against time; compare the initial gradients, or the mean rates, for each concentration (An)

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.

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