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ANSWER BOOK

Collision theory, activation energy and the rate of reaction

Kinetics · Unit C05

AQA 3.1.5.1, 3.1.5.3, 3.1.5.4 · OCR A 3.2.2

13 questions · 44 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 CTA-Q14

B1 for the large molecules only collisions in which the two reactive groups meet can succeed, so a smaller fraction of collisions have the correct orientation. **B1** the activation energy is the same, so the fraction of collisions with enough energy is the same, and the lower rate comes from orientation. [2]

SECTION B · Standard, 3 to 5 marks

B1 CTA-Q2

B1 the particles must collide with energy at least equal to the activation energy; reject 'enough energy' without reference to the activation energy. **B1** the particles must collide in the correct orientation, with the reacting parts facing each other. **B1** at room temperature most colliding particles have less energy than the activation energy, so the bonds that must break are not broken. **B1** many collisions are in the wrong orientation, so the reacting parts of the particles do not meet and they bounce apart unchanged. [4]

B2 CTA-Q10

M1 rate of production of CO_2 = 1.8 ÷ 24 000 = 7.5×10^{-5} mol s^{-1}. **M1** rate of use of HCl = 2 × 7.5×10^{-5} = 1.5×10^{-4} mol s^{-1}, from the 2 : 1 ratio in the equation. **M1** divide by the volume of acid in dm^3: 1.5×10^{-4} ÷ 0.0250. **A1** 6.0×10^{-3} mol dm^{-3} s^{-1}, to two significant figures; allow error carried forward from a missing factor of two, 3.0×10^{-3}, for the last mark only. [4]

B3 CTA-Q19

B1 halving the volume doubles the pressure, so there are twice as many reactant molecules in each unit volume. **B1** collisions between reactant molecules are more frequent, so there are more successful collisions per unit time. **B1** argon does not react, and at fixed volume the number of reactant molecules in each unit volume is unchanged, so their collisions are no more frequent. **B1** the temperature is unchanged in both cases, so the same fraction of collisions have at least the activation energy; only the collision frequency decides the change. [4]

B4 CTA-Q3

B1 activation energy is the minimum energy that colliding particles must have for a reaction to take place; the word minimum is needed. **B1** rate of reaction is the change in the concentration of a reactant or a product per unit time. **B1** the units are mol dm^{-3} s^{-1}. [3]

B5 CTA-Q5

B1 there are more hydrogen ions in the same volume of solution. **B1** so collisions between the ions and the magnesium surface are more frequent. **B1** the same fraction of collisions have at least the activation energy, so there are more successful collisions per unit time; reject 'the particles collide harder'. [3]

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B6 CTA-Q6 — [3]

B1 the powder has a larger surface area, so more calcium carbonate particles are exposed to the acid. **B1** so collisions between acid particles and the solid are more frequent. **B1** the energy of each collision is unchanged, so the larger number of collisions per unit time gives more successful collisions per unit time.

B7 CTA-Q7 — [3]

B1 the hydrochloric acid is used up as it reacts, so its concentration falls. **B1** there are fewer acid particles in each unit volume, so collisions with the marble are less frequent. **B1** there are fewer successful collisions per unit time, and the reaction stops when the acid, the limiting reactant, has been used up.

B8 CTA-Q12 — [3]

B1 a smooth curve is drawn through the plotted points. **B1** a tangent is ruled that touches the curve at t = 0, extended across at least half of the grid. **B1** the gradient of the tangent, its rise divided by its run between two well-separated points, is the initial rate in $cm^3\ s^{-1}$.

B9 CTA-Q13 — [3]

B1 dust has a far larger surface area than flour packed in a sack, and every particle is surrounded by air. **B1** collisions between oxygen molecules and flour particles are therefore far more frequent, so the rate of combustion is very high. **B1** the heat released by the exothermic reaction spreads the reaction to neighbouring particles faster than it is lost, so the whole cloud burns at once.

B10 CTA-Q15 — [3]

B1 the mean rate is 90 ÷ 120 = 0.75 $cm^3\ s^{-1}$. **B1** the initial rate is greater, about 2.7 times the mean rate. **B1** the rate is highest at the start, when the reactant concentration is highest, and falls as reactants are used up, so the mean includes the slow later stages.

B11 CTA-Q16 — [3]

B1 the claim is not valid: the rate depends on the activation energy, not on the enthalpy change. **B1** the fraction of collisions with at least the activation energy decides how many succeed, and ΔH does not fix the height of the barrier. **B1** methane burning has $\Delta H = -890\ kJ\ mol^{-1}$ yet does not react with air at room temperature until lit, so a very exothermic reaction can be very slow.

SECTION C · Long, 6 marks or more

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C1 CTA-Q17 **Indicative content** [6]

B1 a reaction happens only when particles collide with at least the activation energy and in the correct orientation. **B1** in B the powder has a larger surface area, so more calcium carbonate particles are exposed to the acid. **B1** in C there are more hydrogen ions in each unit volume of the acid than in A. **B1** in both B and C collisions are more frequent than in A, so there are more successful collisions per unit time. **B1** the temperature is the same in all three, so the fraction of collisions with at least the activation energy is unchanged. **B1** calcium carbonate is the limiting reactant and the same mass is used each time, so the same amount of carbon dioxide forms in all three.

Levels

Level 3 (5–6 marks) all three results are explained through collision theory: the condition for a successful collision, the larger surface area in B and the higher concentration in C both giving more frequent collisions, the unchanged fraction with the activation energy at the same temperature, and the same final volume from the same limiting mass of carbonate.

Level 2 (3–4 marks) the faster rates of B and C are put down to more frequent collisions from surface area and concentration; the condition for a successful collision, the unchanged temperature, or why the final volume is the same is left out.

Level 1 (1–2 marks) powder or stronger acid is said to react faster, typically because the particles have more energy, and the same final volume is not explained.

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