IG.C10 Rates of Reaction: Collision Theory and Measuring Rate

EDEXCEL 4CH1 · Calculator allowed · about 60 minutes

Total Marks

Name: ______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 State, in the context of collision theory, the two main requirements for reactant particles to react when they collide in a gas or solution.

(Total for Question 1 is 1 mark)

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2 Describe how increasing the concentration of a reactant in solution affects the rate of reaction, using collision theory to explain the change.

(Total for Question 2 is 2 marks)

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3 Explain how increasing the temperature from 20 degrees C to 50 degrees C increases reaction rate in terms of both collision frequency and collision energy.

(Total for Question 3 is 2 marks)

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4 A student investigates the reaction of marble chips (calcium carbonate) with dilute hydrochloric acid and measures the loss of mass every 30 seconds using a balance. Describe two control variables the student should keep constant to make the test fair, and explain why each must be controlled.

(Total for Question 4 is 3 marks)

5 Sketch and describe the expected shape of a graph showing mass of flask plus contents against time for the marble chips and dilute acid experiment, starting at time zero when acid is added.

(Total for Question 5 is 3 marks)

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6 A reaction is monitored by collecting gas in a gas syringe. The student records volume of gas every 10 seconds. Give one practical advantage of using a gas syringe compared with measuring loss of mass on a balance for a gas-producing reaction.

(Total for Question 6 is 2 marks)

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7 In the disappearing cross experiment, sodium thiosulfate reacts with hydrochloric acid to produce a cloudy mixture. Explain how the time taken for the cross to disappear depends on particle collisions, and suggest one way to make the reaction faster.

(Total for Question 7 is 3 marks)

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8 A student measures the volume of hydrogen gas produced when 0.50 g magnesium reacts with excess dilute hydrochloric acid. The readings are: 0 s: 0.0 cm3, 10 s: 12.0 cm3, 20 s: 20.0 cm3, 30 s: 24.0 cm3. Calculate the mean rate of gas production between 10 s and 30 s in cm3 per second. Show working.

(Total for Question 8 is 3 marks)

9 Data from a loss of mass experiment are: time 0 s: mass 52.00 g; 30 s: 51.60 g; 60 s: 51.35 g. Calculate the mean rate of mass loss between 0 s and 60 s in grams per second. Show working and give answer to 3 significant figures.

(Total for Question 9 is 3 marks)

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10 A student records the volume of gas produced every 15 seconds and plots a volume-time graph. Explain how the initial rate of reaction is determined from the graph and what it represents physically.

(Total for Question 10 is 2 marks)

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11 A student repeats the reaction of sodium thiosulfate and hydrochloric acid three times at the same concentration and records times for the cross to disappear: 32.0 s, 28.5 s, 30.5 s. Calculate the mean time and state one simple reason for repeating measurements.

(Total for Question 11 is 4 marks)

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12 Explain how a catalyst increases the rate of a reaction, using collision theory language but do not draw an energy profile diagram.

(Total for Question 12 is 4 marks)

13 Predict qualitatively how reducing the particle size of a solid reactant, while keeping its mass constant, will change the initial rate measured by loss of mass in the marble chips experiment, and explain why.

(Total for Question 13 is 2 marks)

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14 A student measures gas volume from a reaction and obtains a straight-line section on the volume-time graph between 40 s and 70 s. The volume at 40 s is 36.0 cm3 and at 70 s is 63.0 cm3. Calculate the rate during this section in cm3 s^{-1} and give the unit in final answer.

(Total for Question 14 is 2 marks)

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15 Explain, with reference to collision theory, how increasing concentration of acid affects the rate of the reaction between hydrochloric acid and magnesium ribbon in a gas syringe experiment. In your answer include a clear chain of reasoning linking concentration to collision frequency, probability of successful collisions and observed rate.

(Total for Question 15 is 6 marks)

Mark scheme · IG.C10 Rates of Reaction: Collision Theory and Measuring Rate

Question 1

- **B1** particles must collide with sufficient energy (≥ activation energy) and with the correct orientation
- **Answer: They must collide with enough energy (at least the activation energy) and with a suitable orientation**

Question 2

- **B1** increasing concentration increases the number of particles per unit volume so collisions are more frequent
- **B1** more frequent collisions lead to a higher rate of reaction
- **Answer: Higher concentration means more particles per unit volume so collisions happen more often, increasing the reaction rate**

Question 3

- **B1** higher temperature gives particles more kinetic energy so they move faster and collide more often
- **B1** higher energy means a larger proportion of collisions have energy ≥ activation energy, so more successful collisions
- **Answer: Raising temperature increases particle speed so collisions are more frequent, and increases collision energy so a greater fraction exceed the activation energy, raising the rate**

Question 4

- **B1** control the mass or surface area of marble chips, to ensure the amount of reactive solid is the same
- **B1** control concentration and volume of acid, to ensure the number of acid particles available is the same
- **B1** control temperature, to prevent temperature changes affecting collision frequency and energy
- **Answer: Keep marble chip mass or particle size constant so the amount of solid is the same; keep acid concentration and volume constant so reactant quantity is constant; keep temperature constant so collision energy is unchanged**

Question 5

- **B1** sketch: steep initial downward slope that becomes less steep and levels off towards a horizontal line
- **B1** description: mass decreases over time as CO_2 gas is lost, rate is fastest at the start and slows as reactants are used up
- **B1** explain leveling: graph levels off when reaction is nearly complete and mass stops changing
- **Answer: Graph: mass falls quickly at first (steep negative slope) then the slope becomes less steep and the curve levels off to horizontal as reaction finishes**

Question 6

- **B1** more accurate measurement of gas volume than inferring from mass loss
- **B1** gas syringe gives direct, continuous volume readings and is less affected by drafts or vibration
- **Answer: A gas syringe measures gas volume directly and continuously and is often more accurate and less affected by drafts or balance instability than measuring mass loss**

Question 7

- **B1** disappearance time depends on rate at which reactant particles collide to form cloudy product so more frequent successful collisions give faster clouding
- **B1** suggestion: increase temperature or increase concentration or use smaller particle size if solids present
- **B1** link: increasing temperature or concentration raises collision frequency and energy so time is reduced
- **Answer: The cross disappears faster when particles collide more often or with more energy; increasing temperature or concentration will increase collision frequency and energy and so speed the reaction**

Question 8

- **M1** calculates change in volume: 24.0 - 12.0 = 12.0 cm3
- **M1** divides by time interval 20 s to find rate
- **A1** gives mean rate = 0.60 cm3 s^{-1} cao with units
- **Answer: Mean rate = 12.0 cm3 / 20 s = 0.60 cm3 s^{-1}**

Question 9

- **M1** calculates change in mass: 52.00 - 51.35 = 0.65 g
- **M1** divides by time interval 60 s to find rate
- **A1** gives mean rate = 0.0108 g s^{-1} cao to 3 s.f. as 0.0108 g s^{-1}
- **Answer: Mean rate = 0.65 g / 60 s = 0.0108 g s^{-1} (3 s.f.)**

Question 10

- **B1** initial rate found by drawing a tangent at time zero and finding its gradient (change in volume / change in time)
- **B1** physically represents the rate when reactant concentrations are at their initial values, the fastest rate
- **Answer: Draw a tangent at t = 0 and calculate its gradient (delta volume / delta time); it represents how fast gas is produced at the start when reactant concentrations are highest**

Question 11

- **M1** adds times: 32.0 + 28.5 + 30.5 = 91.0 s
- **M1** divides by 3 to find mean = 30.333... s
- **A1** gives mean time = 30.3 s cao to 3 s.f.
- **B1** states reason: to improve reliability by reducing effect of random error or anomalies
- **Answer: Mean = (32.0 + 28.5 + 30.5) / 3 = 30.3 s; repeating improves reliability and reduces the effect of random error**

Question 12

- **B1** states that a catalyst provides an alternative reaction pathway
- **B1** states that the alternative pathway has a lower activation energy so more collisions are successful
- **B1** links to collision theory: with lower activation energy a larger proportion of collisions have sufficient energy to react
- **B1** may state that the catalyst is not used up at the end of the reaction
- **Answer: A catalyst provides an alternative pathway with lower activation energy so a larger fraction of collisions are successful, increasing the rate; the catalyst is not consumed**

Question 13

- **B1** prediction: initial rate will increase
- **B1** explanation: smaller particles give larger total surface area so more frequent collisions at the surface
- **Answer: Initial rate increases because smaller particles give a larger surface area for the same mass, increasing collision frequency with acid**

Question 14

- **M1** calculates change in volume 63.0 - 36.0 = 27.0 cm3 and change in time 30 s
- **A1** gives rate = 0.90 cm3 s^{-1} cao with unit
- **Answer: Rate = 27.0 cm3 / 30 s = 0.90 cm3 s^{-1}**

Question 15

- **Level 1** (1-2): Basic statements about concentration and rate with little or no reference to collision theory or lacking links between ideas
- **Level 2** (3-4): Some correct chemistry and partial chain of reasoning: states that higher concentration gives more particles and more collisions, with limited explanation of why collisions are more likely to be successful
- **Level 3** (5-6): A full, logical chain using collision theory: increasing concentration increases particle number per unit volume, raising collision frequency; explains that this increases the number of collisions per second and, therefore, the number of collisions with energy >= activation energy, so the measured gas production rate increases; may mention units and that magnesium is solid so collisions occur at the surface
- **Indicative content:**
  - Increasing acid concentration increases the number of acid particles per unit volume
  - More particles per unit volume means a higher collision frequency between acid particles and magnesium surface atoms
  - Higher collision frequency increases the number of collisions per second that could lead to reaction
  - A larger number of collisions raises the number of successful collisions per second, so the rate of hydrogen gas production increases
  - For a solid magnesium ribbon the active collisions occur at the surface, so concentration affects how often acid particles strike the metal surface
  - Clear linking sentences that show how the observed increase in slope on a volume-time graph or increased gradient from mass loss follows from more successful collisions