2.7 Rate and Extent of Chemical Change: Test Pack

AQA 8462 · Calculator allowed · about 55 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Collision theory explains how chemical reactions occur between particles.

(a) Give one requirement for a collision between reactant particles to lead to a reaction. **(1)**

(b) Give a second factor that increases the rate of collisions between particles in a gas or solution. **(1)**

(Total for Question 1 is 2 marks)

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2 Preparation of ammonia by Haber process is a reversible reaction: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. This is an industrial example of controlling equilibrium.

(a) State one change (temperature, pressure or concentration) that is used industrially to increase yield of ammonia and state the direction the equilibrium shifts. **(2)**

(Total for Question 2 is 2 marks)

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3 A student investigates the effect of temperature on the rate of reaction between magnesium ribbon and excess dilute hydrochloric acid, timing how long it takes for the ribbon to fully react.

(a) Identify the independent variable in this investigation. **(1)**

(b) Identify the dependent variable in this investigation. **(1)**

(c) State two variables that should be controlled (kept the same) in this investigation. **(2)**

(Total for Question 3 is 4 marks)

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4 A student uses the disappearing cross method to investigate the effect of concentration on the rate of the reaction between sodium thiosulfate solution and dilute hydrochloric acid, which produces a precipitate of sulfur:
sodium thiosulfate + hydrochloric acid -> sodium chloride + sulfur dioxide + sulfur + water

(a) Describe how the student could carry out this investigation and use it to compare the rate of reaction at different concentrations of hydrochloric acid. **(3)**

(b) State the equation linking the rate of reaction and the time taken for the cross to disappear. **(1)**

(c) At a hydrochloric acid concentration of 40 g/dm3, the cross disappeared after 25 seconds. Calculate the rate of this reaction, giving the correct unit. **(2)**

(d) The student repeats the investigation using a higher concentration of hydrochloric acid, and the cross disappears more quickly. Explain this observation in terms of collision theory. **(3)**

(Total for Question 4 is 9 marks)

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5 A student reacts magnesium ribbon with dilute hydrochloric acid. Which change would decrease the rate of reaction?

- ☐ A) Using powdered magnesium instead of a ribbon
- ☐ B) Heating the acid before adding the magnesium
- ☐ C) Using a more concentrated acid
- ☐ D) Using a lower concentration of acid

(Total for Question 5 is 1 mark)

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6 A student reacts marble chips (calcium carbonate) with dilute hydrochloric acid.

(a) The student crushes some marble chips into a powder and reacts this powder with the acid, instead of using whole chips of the same total mass. Explain why this increases the rate of reaction. **(2)**

(b) State one safety precaution the student should take when carrying out this experiment. **(1)**

(Total for Question 6 is 3 marks)

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7 In an experiment to find initial rates, a student measures the gradient at t = 0 from a concentration-time graph. The concentration-time data near t = 0 are: 0.000, 5.0, 9.0 mol dm-3 at times 0, 10 and 20 s respectively. Suggest a method to estimate the initial rate using these data and calculate the estimate.

(a) Suggest how to estimate the initial rate from the data and calculate the value in mol dm-3 s-1 using the first two points. **(3)**

(Total for Question 7 is 3 marks)

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8 A heterogeneous catalytic reaction on a solid surface converts gas D to gas E. The rate is limited by the surface area of the catalyst. A student compares two catalyst pellets: Pellet P1 has surface area 0.50 m² and Pellet P2 has surface area 2.00 m² under otherwise identical conditions. The initial rate with P1 is 0.120 mol s-1.

(a) Assuming rate scales directly with catalyst surface area, calculate the expected initial rate with P2. **(2)**

(b) Explain two practical reasons why the real rate increase might be less than predicted by simple surface area scaling. **(4)**

(Total for Question 8 is 6 marks)

9 A student mixes 25.0 cm³ of 0.100 mol dm-3 solution of $Na_2S_2O_3$ with 25.0 cm³ of 0.100 mol dm-3 HCl in a flask to produce SO_2 or other components in a clock reaction. For a rate calculation simplified here assume total reacting volume is 50.0 cm³.

(a) Calculate the initial concentration of $Na_2S_2O_3$ in the reaction mixture after mixing. **(2)**

(b) If the initial rate of appearance of a gaseous product is measured as 1.00 x 10-4 mol dm-3 s-1, calculate the volume of gas formed in the first 120 s, in cm3, in the 50.0 cm³ mixture. Assume 1 mol of gas occupies 24.0 dm3 at room temperature and pressure. Express your answer to three significant figures. **(2)**

(Total for Question 9 is 4 marks)

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10 A reversible esterification equilibrium is: ethanol + ethanoic acid ⇌ ethyl ethanoate + water. A chemist wants to increase the equilibrium yield of ethyl ethanoate for an industrial production process.

(a) Suggest two practical changes to the reaction conditions that would increase yield of ethyl ethanoate and explain briefly why each helps. **(4)**

(Total for Question 10 is 4 marks)

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11 Higher tier only. The forward reaction in the Haber process, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, is exothermic. Predict the effect of increasing the temperature on the position of equilibrium and the yield of ammonia.

(Total for Question 11 is 3 marks)

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Mark scheme · 2.7 Rate and Extent of Chemical Change: Test Pack

Question 1

(a) particles must collide with sufficient energy (to overcome activation energy) or equivalent **B1**

(a) Answer: Particles must collide with sufficient energy.

(b) increase in concentration or increase in temperature or increase in pressure (for gases) or increase in surface area for solids, oe **B1**

(b) Answer: Increase the concentration (or temperature, pressure for gases, or surface area).

Question 2

(a) states a change and direction: e.g. increase pressure, equilibrium shifts to the right (fewer gas molecules) or decrease temperature, equilibrium shifts to the right (exothermic forward), oe **M1**

(a) makes correct link to increased yield of ammonia **A1**

(a) Answer: Increase the pressure; equilibrium shifts to the right to make more ammonia increasing yield.

Question 3

(a) temperature of the acid **B1**

(a) Answer: Temperature of the acid.

(b) time taken for the magnesium ribbon to fully react/disappear **B1**

(b) Answer: Time taken for the magnesium ribbon to fully react.

(c) concentration/volume of hydrochloric acid **B1**

(c) length/mass of magnesium ribbon (any two suitable control variables credited, e.g. same person judging when reaction is complete) **B1**

(c) Answer: The concentration and volume of hydrochloric acid, and the length (mass) of magnesium ribbon used, should be kept the same each time.

Question 4

(a) place the flask containing sodium thiosulfate solution and acid on top of a paper marked with a cross, and view it from above oe **B1**

(a) start a timer as soon as the acid is added, and stop it when the cross can no longer be seen (due to the sulfur precipitate) oe **B1**

(a) repeat using different concentrations of hydrochloric acid, keeping all other variables (e.g. volume of thiosulfate, temperature) the same oe **B1**

(a) Answer: Add the acid to the thiosulfate solution in a flask standing on a paper marked with a cross; time from mixing until the cross disappears from view; repeat at different acid concentrations, keeping the volume of thiosulfate and the temperature constant each time.

(b) rate of reaction = 1 / time **B1**

(b) Answer: Rate of reaction = 1 / time

(c) 1 / 25 **M1**

(c) 0.04 s-1 (or /s) cao **A1**

(c) Answer: 0.04 s-1

(d) a higher concentration means there are more acid particles in the same volume oe **B1**

(d) so reacting particles collide more frequently oe **B1**

(d) more successful collisions happen per second, so the rate of reaction increases and the cross disappears faster **B1**

(d) Answer: A higher acid concentration means more acid particles per unit volume, so collisions with thiosulfate particles happen more often; more successful collisions occur per second, so the reaction is faster and the cross disappears sooner.

Question 5

D **B1**

Answer: D

Question 6

(a) crushing the marble into a powder increases its surface area to volume ratio oe **B1**

(a) this means more particles of acid can collide with (particles on the surface of) the marble per second, increasing the frequency of collisions and so the rate oe **B1**

(a) Answer: Powdering the marble increases its surface area to volume ratio, so more acid particles can collide with the marble's surface per second, increasing the rate of reaction.

(b) wear eye protection oe (any sensible precaution, e.g. work in a well-ventilated area, handle acid with care) **B1**

(b) Answer: Wear eye protection.

Question 7

(a) uses gradient method: rate approx change in concentration / change in time using early points **M1**

(a) calculates using first two points: (5.0 - 0.0) / (10 - 0) = 0.50 **M1**

(a) gives 0.50 mol dm-3 s-1 cao **A1**

(a) Answer: 0.50 mol dm-3 s-1

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Question 8

(a) uses proportional scaling: rate2 = rate1 x (area2/area1) **M1**

(a) gives rate = 0.480 mol s-1 cao **A1**

(a) Answer: 0.480 mol s-1

(b) mentions diffusion or mass transport limits to bring reactants to surface, reducing effectiveness of extra area **B1**

(b) mentions active site availability or site blockage by impurities, meaning not all surface area is catalytic **B1**

(b) mentions agglomeration or pore structure limiting accessible surface area, oe **B1**

(b) mentions heat or local concentration gradients that reduce reaction rate efficiency, oe **B1**

(b) Answer: Real increase may be less because diffusion/mass transport can limit access of reactants to additional surface, and not all surface area may be active due to pore structure or site blockage by impurities. Heat or concentration gradients can also limit effective rate.

Question 9

(a) uses dilution relation: c1v1 = c2v2 or concentration = (moles total)/(total volume) **M1**

(a) gives 0.0500 mol dm-3 cao **A1**

(a) Answer: 0.0500 mol dm-3

(b) uses amount = rate x time to find change in concentration: 1.00e-4 x 120 = 1.20e-2 mol dm-3 **M1**

(b) finds moles = concentration x volume = 1.20e-2 mol dm-3 x 0.0500 dm3 = 6.00e-4 mol, then volume of gas = 6.00e-4 x 24.0 dm3 mol-1 = 0.0144 dm3 = 14.4 cm^3 cao **A1**

(b) Answer: 14.4 cm^3

Question 10

(a) suggests using excess ethanol (or remove ethanoic acid) and explains equilibrium shifts to right **B1**

(a) suggests removing product water as it forms and explains this shifts equilibrium to right **B1**

(a) suggests using a dehydrating agent or molecular sieves to remove water, with brief explanation **B1**

(a) alternative acceptable suggestion: using a catalyst to speed equilibrium attainment (not changing yield), with explanation that catalyst helps reach equilibrium faster **B1**

(a) Answer: Any two: use excess ethanol to shift equilibrium to products; remove water as it forms (e.g. using a dehydrating agent) to shift equilibrium to products. Both increase yield by Le Chatelier principle. A catalyst can be used to reach equilibrium faster.

Question 11

increasing the temperature shifts the position of equilibrium to the left (towards the reactants) oe **M1**

this is the endothermic direction, so the system acts to oppose/reduce the increase in temperature by absorbing the extra energy oe **M1**

less ammonia (and more nitrogen and hydrogen) is present in the equilibrium mixture, so the yield of ammonia decreases **A1**

Answer: The position of equilibrium shifts to the left (the endothermic, reverse direction), absorbing the extra energy to oppose the temperature rise; the equilibrium yield of ammonia decreases.

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