2.7 Rate and Extent of Chemical Change: 1-hour Pack

AQA 8462 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A student uses 25.0 cm^3 of 0.10 mol l-1 hydrochloric acid to react with excess magnesium. Calculate the number of moles of HCl used. (Use volume in litres.)

(a) Convert the volume 25.0 cm^3 to litres and show the calculation for moles of HCl. **(3)**

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(Total for Question 1 is 3 marks)

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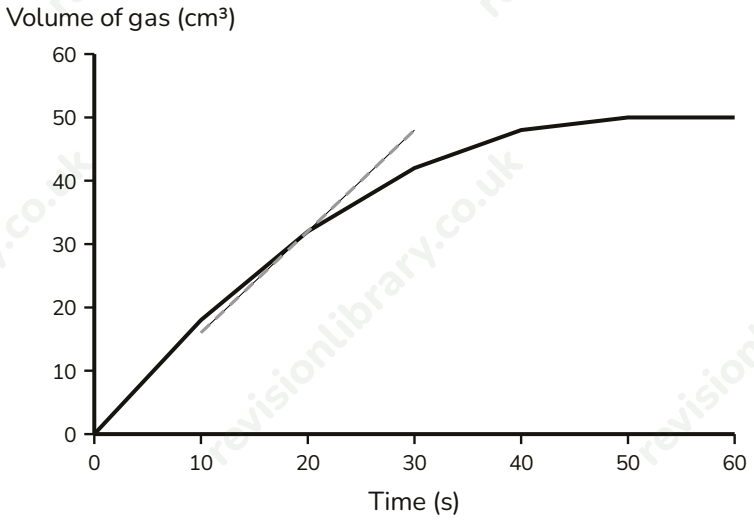
2 Collision theory explains how chemical reactions occur.

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

(Total for Question 2 is 1 mark)

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3 Figure 3 shows a graph of the volume of gas produced against time for a reaction between marble chips and hydrochloric acid. The curve rises steeply at first, then its gradient decreases until the line becomes flat at 60 seconds. A tangent has been drawn to the curve at t = 20 s; this tangent passes through the points (10 s, 10 cm^3) and (30 s, 42 cm^3).



(a) Explain why a tangent must be drawn to calculate the rate of reaction at a specific point in time on this curved graph, rather than simply using two points on the curve. **(2)**

(b) Use the tangent shown in Figure 3 to calculate the rate of reaction at t = 20 seconds. **(2)**

(Total for Question 3 is 4 marks)

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4 A student is asked to investigate how the concentration of hydrochloric acid affects the rate of its reaction with sodium thiosulfate solution. They use the disappearing cross method: they place a flask containing sodium thiosulfate solution over a paper cross, add hydrochloric acid, and time how long it takes until the cross can no longer be seen from above. They test acid concentrations of 10, 20, 30 and 40 g/dm3, keeping the volume of thiosulfate solution, the volume of acid and the room temperature the same, and take one reading at each concentration. Evaluate this method, including its strengths, weaknesses and how it could be improved to establish the relationship between concentration and rate.

(Total for Question 4 is 6 marks)

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5 Higher tier only. In the Haber process, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, there are 4 moles of gas on the reactants side of the equation and 2 moles of gas on the products side. Predict the effect of increasing the pressure on the equilibrium yield of ammonia.

(Total for Question 5 is 3 marks)

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6 Collision theory explains how chemical reactions happen.

(a) State the two conditions that must be met for two particles to react when they collide. **(1)**

(b) Explain, using collision theory, why increasing the temperature of the reaction mixture increases the rate of reaction. **(3)**

(Total for Question 6 is 4 marks)

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7 A student increases the concentration of hydrochloric acid used to react with magnesium ribbon. Explain how this affects the rate of reaction.

(Total for Question 7 is 3 marks)

8 Some chemical reactions are reversible.

(a) State what is meant by a 'reversible reaction'. **(1)**

(b) Blue hydrated copper sulfate crystals can be heated to form white anhydrous copper sulfate powder and water. Write a word equation, using the reversible reaction symbol (⇌), to show this reaction, and state which direction is favoured by adding water to the white powder. **(2)**

(Total for Question 8 is 3 marks)

9 Ammonium chloride is a white solid that decomposes reversibly on heating: $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$

(a) A sample of solid ammonium chloride is heated strongly in a test tube. State which direction of the reaction, forward or backward, is favoured by this heating. **(1)**

(b) The ammonia gas and hydrogen chloride gas produced are collected together in a sealed, cool container. Explain what would happen to these gases over time. **(2)**

(Total for Question 9 is 3 marks)

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10 An experiment studies the effect of temperature on an equilibrium. The student increases the temperature and observes less product formed. State what this suggests about the reaction enthalpy.

(a) State whether the forward reaction is exothermic or endothermic and explain why the amount of product decreased when temperature increased. **(3)**

(Total for Question 10 is 3 marks)

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11 Extended answer. A student investigates the reversible reaction: $P(g) + Q(g) \rightleftharpoons R(g) + S(g)$ in a closed container. They carry out two changes separately: (1) increase temperature, (2) remove some R and S from the container. Explain how each change affects the position of equilibrium and the rate of forward and backward reactions. Your answer should use Le Chatelier's principle and refer to rates.

(Total for Question 11 is 6 marks)

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12 Hydrogen peroxide decomposes in the presence of iodide ions as a catalyst: $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$. A student measures volume of O_2 produced at regular time intervals. The results for two experiments are given below.

Experiment 1 (no catalyst): time / s: 0, 30, 60, 90 ; volume O_2 / cm3: 0, 12, 20, 24
Experiment 2 (with iodide catalyst): time / s: 0, 10, 20, 30 ; volume O_2 / cm3: 0, 20, 32, 36

(a) Compare the rate of O_2 production in the two experiments, and explain the role of the iodide ions. **(4)**

(Total for Question 12 is 4 marks)

13 A student investigates the rate of a reaction between calcium carbonate chips and excess dilute hydrochloric acid by measuring the mass of the reaction flask (which is left unstoppered so gas can escape) over time.

Time (min)	Mass of flask and contents (g)
0	100.00
1	99.82
2	99.70
3	99.64
4	99.61
5	99.61

(a) Calculate the mean rate of reaction, in g/min, over the first 3 minutes. **(2)**

(b) State, with a reason, at approximately what time the reaction stopped. **(1)**

(Total for Question 13 is 3 marks)

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Mark scheme · 2.7 Rate and Extent of Chemical Change: 1-hour Pack

Question 1

(a) converts volume to litres: 25.0 cm^3 = 0.0250 l and substitutes: moles = concentration x volume = 0.10 x 0.0250 **M1**

(a) 0.00250 mol cao **A1**

(a) shows units correct or expresses to appropriate s.f., oe **A1**

(a) Answer: 0.00250 mol

Question 2

(a) particles must collide with sufficient energy (at or above the activation energy), oe **B1**

(a) Answer: Particles must collide with sufficient energy (at or above the activation energy).

Question 3

(a) the gradient of the curve is constantly changing, so a line joining two points on the curve would not give the rate at a single instant oe **B1**

(a) a tangent touches the curve at only one point, so its gradient gives the instantaneous rate of reaction at that point in time oe **B1**

(a) Answer: The curve's gradient keeps changing, so joining two points on the curve gives an average rate over that interval, not the rate at one instant; a tangent touches the curve at a single point, so its gradient gives the true instantaneous rate there.

(b) (42 - 10) / (30 - 10) **M1**

(b) 1.6 cm^3/s cao **A1**

(b) Answer: 1.6 cm^3/s

Question 4

Level 1 Simple, isolated statements are made about the method and/or possible improvements, with little or no linkage between them. No clear conclusion is drawn about how the results would show the relationship between concentration and rate. **1-2**

Level 2 Some relevant strengths and/or weaknesses of the method are identified, with some suggested improvements. There is some linkage between the improvements and how they would affect the reliability or validity of the results. **3-4**

Level 3 A detailed and logically structured evaluation is given, identifying weaknesses in the method and linking clearly justified improvements to how they would improve the reliability and/or validity of the results. The answer explains how the improved results could be used to establish the relationship between concentration and rate. **5-6**

Indicative content:

- Judging by eye exactly when the cross 'disappears' is subjective; different observers (or the same observer on different attempts) may judge the end point differently, reducing the reliability of the timings.
- Only one reading is taken at each concentration, so anomalous results cannot be identified; repeating each concentration and calculating a mean time would improve reliability.
- Only four concentrations are tested, over a limited range; using more concentrations, spread across a wider range (e.g. 5, 10, 15, ... g/dm3), would give a more precise picture of the trend.
- Using the same person to judge the end point each time, the same size of cross, and viewing from the same distance/lighting would reduce this source of error.
- The volume of thiosulfate, volume of acid and temperature have correctly been controlled, which is a strength of the method, since changing any of these would also affect the rate.
- Calculating the rate (1/time) for each concentration and plotting a graph of rate against concentration would show whether rate is directly proportional to concentration (a straight line through the origin) or whether the relationship is more complex.

Question 5

increasing the pressure shifts the position of equilibrium to the right (towards the products) oe **M1**

because this is the side with fewer moles of gas, so the system acts to reduce the pressure (reduce the total number of gas particles) oe **M1**

more ammonia is present in the equilibrium mixture, so the yield of ammonia increases **A1**

Answer: The position of equilibrium shifts to the right, towards the side with fewer gas moles (the products), because the system acts to reduce the increased pressure; the equilibrium yield of ammonia increases.

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Question 6

(a) particles must collide with sufficient energy (equal to or greater than the activation energy) and in the correct orientation oe (both needed for the mark) **B1**

(a) Answer: They must collide with energy greater than or equal to the activation energy, and with the correct orientation.

(b) at a higher temperature the particles have more kinetic energy and move faster oe **B1**

(b) so the particles collide more frequently oe **B1**

(b) a greater proportion of collisions have energy greater than or equal to the activation energy, so a greater proportion of collisions are successful oe **B1**

(b) Answer: Particles have more kinetic energy and move faster, so they collide more often; a greater proportion of these collisions have energy greater than or equal to the activation energy, so more collisions are successful, increasing the rate.

Question 7

increasing the concentration means there are more acid particles in the same volume oe **B1**

so collisions between reacting particles happen more frequently oe **B1**

so there are more successful collisions per second/unit time, increasing the rate of reaction **B1**

Answer: Higher concentration means more acid particles in the same volume, so particles collide more often; this gives more successful collisions per second, increasing the rate of reaction.

Question 8

(a) a reaction in which the products of the reaction can react together to re-form the original reactants oe **B1**

(a) Answer: A reversible reaction is one in which the products can react to reform the original reactants.

(b) hydrated copper sulfate ⇌ anhydrous copper sulfate + water **B1**

(b) adding water favours the backward/reverse reaction (forms hydrated copper sulfate) oe **B1**

(b) Answer: Hydrated copper sulfate ⇌ anhydrous copper sulfate + water. Adding water favours the reverse reaction, re-forming blue hydrated copper sulfate.

Question 9

(a) forward (the solid decomposes into the two gases) **B1**

(a) Answer: Forward.

(b) as the mixture cools, the backward/reverse reaction is favoured oe **M1**

(b) the ammonia and hydrogen chloride gases react together to re-form solid ammonium chloride oe **A1**

(b) Answer: As the gases cool, the reverse reaction is favoured, so the ammonia and hydrogen chloride recombine to re-form solid ammonium chloride.

Question 10

(a) identifies forward reaction is exothermic (gives correct direction) **M1**

(a) explains that increasing temperature favours the endothermic direction (backward) so equilibrium shifts to make less product **A1**

(a) gives clear link between temperature increase and decrease in product amount, oe **A1**

(a) Answer: The forward reaction is exothermic. Increasing temperature favours the endothermic reverse reaction so the equilibrium shifts to make less product.

Question 11

Level 3 Detailed answer that correctly explains the effect of both changes on equilibrium position and rates. Uses Le Chatelier's principle, identifies direction of shift for each change, describes how the forward and backward rates change until a new dynamic equilibrium is reached, and gives cause (temperature favours endothermic direction; removal of products shifts to right). **5-6**

Level 2 Partial answer that explains one change clearly and gives a correct but incomplete explanation for the other, or gives correct direction of shifts for both but with limited comment on rates. **3-4**

Level 1 Basic statements such as 'equilibrium shifts left or right' with little or no justification about Le Chatelier or rates. **1-2**

Indicative content:

- For increase in temperature: identify whether forward or backward is endothermic; state equilibrium shifts to favour endothermic direction; explain that immediately the rate of the favoured direction increases, the other rate decreases, and a new dynamic equilibrium is reached with concentrations changed.
- For removal of R and S: state that removing products shifts equilibrium to the right to make more R and S; explain that forward rate initially exceeds backward rate until new equilibrium is established.
- Refer to Le Chatelier's principle in both parts and mention that rates change because concentrations and/or temperature affect frequency and energy of collisions.
- Mention the system is closed and that at the new equilibrium forward and backward rates are equal again.

Question 12

(a) states that Experiment 2 produces oxygen faster (greater volume earlier) cao **B1**

(a) gives an example from the data, e.g. at 30 s Exp2 gives 36 cm^3 but Exp1 gives 12 cm^3 **B1**

(a) states that iodide ions act as a catalyst, increasing reaction rate without being consumed **B1**

(a) explains catalyst provides an alternative pathway with lower activation energy so more successful collisions, oe **B1**

(a) Answer: Experiment 2 produces oxygen faster; for example at 30 s Exp2 gives 36 cm^3 but Exp1 gives 12 cm^3. Iodide ions act as a catalyst, providing an alternative route with lower activation energy so more collisions are successful.

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Question 13

(a) (100.00 - 99.64) / 3 **M1**

(a) 0.12 g/min cao **A1**

(a) Answer: 0.12 g/min

(b) at (approximately) 4 minutes, because the mass no longer changes after this time (stays at 99.61 g) oe **B1**

(b) Answer: At about 4 minutes, since the mass stays constant at 99.61 g from then on.

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