2.10 Chemistry: Rate Equations and Equilibrium: 30-minute Pack

AQA 7405 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 The units of a rate constant, k, depend on the overall order of reaction. For a reaction with rate = $k[A]^n$, the units of k can be found by dimensional analysis, since rate always has units of mol dm-3 s-1 and concentration [A] always has units of mol dm-3.

(a) A reaction is overall second order, with rate equation rate = $k[A]^2$. Show, using dimensional analysis, that the units of k for this reaction are dm3 mol-1 s-1. **(2)**

(b) State, without further working, the units of the rate constant for a reaction that is (i) zero order overall and (ii) third order overall. **(2)**

(Total for Question 1 is 4 marks)

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2 A reaction between three species, P, Q and R, was investigated using the initial rates method. The table shows the results of four experiments carried out at the same constant temperature.

Experiment	[P] (mol dm-3)	[Q] (mol dm-3)	[R] (mol dm-3)	Initial rate (mol dm-3 s-1)
1	0.020	0.010	0.010	4.0×10^{-4}
2	0.040	0.010	0.010	8.0×10^{-4}
3	0.040	0.020	0.010	8.0×10^{-4}
4	0.040	0.020	0.020	1.6×10^{-3}

(a) Using experiments 1 and 2, determine the order of reaction with respect to P. Show your reasoning. **(2)**

(b) Using experiments 2 and 3, determine the order of reaction with respect to Q. Show your reasoning. **(2)**

(c) Using experiments 3 and 4, determine the order of reaction with respect to R. Show your reasoning. **(2)**

(d) Deduce the overall order of reaction and write the rate equation for this reaction. **(2)**

(e) Using the data from Experiment 1, calculate the rate constant, k, for this reaction, including its units. **(3)**

(f) Predict the initial rate of reaction when [P] = 0.060 mol dm-3, [Q] = 0.050 mol dm-3 and [R] = 0.030 mol dm-3, at the same temperature. **(2)**

(Total for Question 2 is 13 marks)

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3 Dinitrogen pentoxide decomposes according to the equation:

$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$

The concentration of N_2O_5 was monitored during this decomposition at a constant temperature. The results are shown in the table.

Time (min)	0	15	30	45
$[N_2O_5]$ (mol dm-3)	0.640	0.320	0.160	0.0800

You may use: for a first order reaction, $k = \ln 2 / t(1/2)$.

(a) Explain, using the data, why this reaction is first order with respect to N_2O_5. **(2)**

(b) State the half-life of this reaction. **(1)**

(c) Calculate the rate constant, k, for this reaction, in units of s-1. Give your answer to 3 significant figures. **(3)**

(d) Calculate the total time, from t = 0, taken for the concentration of N_2O_5 to fall to 0.0400 mol dm-3. **(2)**

(Total for Question 3 is 8 marks)

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Mark scheme · 2.10 Chemistry: Rate Equations and Equilibrium: 30-minute Pack

Question 1

(a) mol dm-3 s-1 = k x (mol dm-3)^2, so k = (mol dm-3 s-1) / (mol dm-3)^2 oe **M1**

(a) k units = dm3 mol-1 s-1 cao **A1**

(a) Answer: k units = dm3 mol-1 s-1

(b) zero order: units of k = mol dm-3 s-1 **B1**

(b) third order: units of k = mol-2 dm6 s-1 (dm6 mol-2 s-1) **B1**

(b) Answer: Zero order: mol dm-3 s-1. Third order: mol-2 dm6 s-1.

Question 2

(a) [P] doubles (0.020 to 0.040) with [Q] and [R] both constant, and the initial rate doubles (4.0x10^{-4} to 8.0x10^{-4}) oe **M1**

(a) order with respect to P = 1 cao **A1**

(a) Answer: Order with respect to P = 1

(b) [Q] doubles (0.010 to 0.020) with [P] and [R] both constant, but the initial rate is unchanged (8.0x10^{-4} in both experiments) oe **M1**

(b) order with respect to Q = 0 (zero order) cao **A1**

(b) Answer: Order with respect to Q = 0

(c) [R] doubles (0.010 to 0.020) with [P] and [Q] both constant, and the initial rate doubles (8.0x10^{-4} to 1.6x10^{-3}) oe **M1**

(c) order with respect to R = 1 cao **A1**

(c) Answer: Order with respect to R = 1

(d) overall order = 1 + 0 + 1 = 2, ft from (a) to (c) **M1**

(d) rate = k[P][R] (Q does not appear, since it is zero order) **A1**

(d) Answer: Overall order = 2; rate = k[P][R]

(e) k = rate / ([P][R]) = 4.0x10^{-4} / (0.020 x 0.010), ft from (d) **M1**

(e) k = 2.0 cao **A1**

(e) units: dm3 mol^{-1} s^{-1} (mol^{-1} dm3 s-1) **A1**

(e) Answer: k = 2.0 dm3 mol^{-1} s^{-1}

(f) rate = k[P][R] = 2.0 x 0.060 x 0.030, ft from (e) ([Q] is not used, since the reaction is zero order in Q) **M1**

(f) rate = 3.6 x 10^{-3} mol dm-3 s-1 cao **A1**

(f) Answer: 3.6 x 10^{-3} mol dm-3 s-1

Question 3

(a) the time taken for [N_2O_5] to halve is the same (15 minutes) for each interval shown in the table oe **B1**

(a) a constant half-life, independent of concentration, is characteristic of a first order reaction oe **B1**

(a) Answer: The half-life is constant at 15 minutes throughout, which is characteristic of first order kinetics.

(b) 15 minutes cao **B1**

(b) Answer: 15 minutes

(c) t(1/2) = 15 min = 900 s **M1**

(c) k = ln2 / 900 **M1**

(c) k = 7.70 x 10^{-4} s-1 awrt **A1**

(c) Answer: k = 7.70 x 10^{-4} s-1

(d) recognises that 0.0400 mol dm-3 is reached after one further half-life beyond t = 45 minutes (0.0800 halves to 0.0400) **M1**

(d) 60 minutes cao **A1**

(d) Answer: 60 minutes

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