AQA A2 CHEMISTRY

TOPIC 4.1

KINETICS

1. (a) A fixed mass of marble is reacted with dilute hydrochloric acid at a constant temperature. Explain why the rate of the reaction is increased if the lumps of marble are reduced in size.

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(2)

(b) The initial rate of the reaction between substances **A** and **B** was measured in a series of experiments and the following rate equation was deduced.

$$\text{rate} = k[\mathbf{A}][\mathbf{B}]^2$$

(i) Complete the table of data below for the reaction between **A** and **B**.

Expt	Initial [**A**] /mol dm^{-3}	Initial [**B**] /mol dm^{-3}	Initial rate /mol dm^{-3} s^{-1}
1	0.020	0.020	1.2×10^{-4}
2	0.040	0.040	
3		0.040	2.4×10^{-4}
4	0.060	0.030	
5	0.040		7.2×10^{-4}

(ii) Using the data for Experiment 1, calculate a value for the rate constant, k and state its units.

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(7)
(Total 9 marks)

2. (a) The initial rate of reaction between ester **A** and aqueous sodium hydroxide was measured in a series of experiments at a constant temperature. The data obtained are shown below.

Experiment	Initial concentration of NaOH / mol dm^{-3}	Initial concentration of **A** / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.040	0.030	4.0×10^{-4}
2	0.040	0.045	6.0×10^{-4}
3	0.060	0.045	9.0×10^{-4}
4	0.120	0.060	to be calculated

Use the data in the table to deduce the order of reaction with respect to **A** and the order of reaction with respect to NaOH. Hence calculate the initial rate of reaction in Experiment 4.

*Order with respect to **A*** .....

Order with respect to NaOH .....

Initial rate in Experiment 4 .....

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(3)

(b) In a further experiment at a different temperature, the initial rate of reaction was found to be 9.0×10^{-3} mol dm^{-3} s^{-1} when the initial concentration of **A** was 0.020 mol dm^{-3} and the initial concentration of NaOH was 2.00 mol dm^{-3}.
Under these new conditions with the much higher concentration of sodium hydroxide, the reaction is first order with respect to **A** and appears to be zero order with respect to sodium hydroxide.

(i) Write a rate equation for the reaction under these new conditions.

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(ii) Calculate a value for the rate constant under these new conditions and state its units.

Calculation .....

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Units .....

(iii) Suggest why the order of reaction with respect to sodium hydroxide appears to be zero under these new conditions.

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(6)
(Total 9 marks)

3. The rate of the reaction between substance **A** and substance **B** was studied in a series of experiments carried out at the same temperature. In each experiment the initial rate was

measured using different concentrations of **A** and **B**. These results were used to deduce the order of reaction with respect to **A** and the order of reaction with respect to **B**.

(a) What is meant by the term *order of reaction* with respect to **A**?

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(1)

(b) When the concentrations of **A** and **B** were both doubled, the initial rate increased by a factor of 4. Deduce the **overall** order of the reaction.

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(1)

(c) In another experiment, the concentration of **A** was increased by a factor of three and the concentration of **B** was halved. This caused the initial rate to increase by a factor of nine.

(i) Deduce the order of reaction with respect to **A** and the order with respect to **B**.

*Order with respect to **A*** .....

*Order with respect to **B*** .....

(ii) Using your answers from part (c)(i), write a rate equation for the reaction and suggest suitable units for the rate constant.

Rate equation .....

Units for the rate constant .....

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(4)
(Total 6 marks)

4. The rate equation for a reaction between substances **A**, **B** and **C** is of the form:

$$\text{rate} = k[A]^x[B]^y[C]^z \text{ where } x + y + z = 4$$

The following data were obtained in a series of experiments at a constant temperature.

Experiment	Initial concentration of **A**/mol dm^{-3}	Initial concentration of **B**/mol dm^{-3}	Initial concentration of **C**/mol dm^{-3}	Initial rate/ mol dm^{-3} s^{-1}
1	0.10	0.20	0.20	8.0×10^{-5}
2	0.10	0.05	0.20	2.0×10^{-5}
3	0.05	0.10	0.20	2.0×10^{-5}
4	0.10	0.10	0.10	to be calculated

(a) Use the data in the table to deduce the order of reaction with respect to **A** and the order of reaction with respect to **B.** Hence deduce the order of reaction with respect to **C.**

*Order with respect to **A***.....

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*Order with respect to **B***.....

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*Order with respect to **C***.....

(3)

(b) Calculate the value of the rate constant, *k*, stating its units and also the value of the initial rate in experiment 4.

Value of k.....

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Units of k.....

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Initial rate .....

(4)

(c) How does the value of *k* change when the temperature of the reaction is increased?

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(1)

(Total 8 marks)

5. (a) A large excess of zinc was added to 100cm^3 of 0.2 M hydrochloric acid. After the reaction had ended, 240 cm^3 of hydrogen had been formed. In three further experiments, extra substances were added to the original mixture as shown in the table below. Fill in the table to show the total volume of hydrogen formed in each experiment and the qualitative effect of these additions on the initial rate of reaction compared to the original experiment.

Substances **added** to an excess of zinc and 100 cm^3 of 0.2 M hydrochloric acid	Volume of hydrogen/cm^3	Effect on initial rate of reaction
100cm^3 water		
l0g zinc		
50 cm^3 0.2 M hydrochloric acid		

(6)

(b) The rate of reaction between compounds **A** and **B** was studied at a fixed temperature and some results obtained are shown in the table below.

Experiment	Initial concentration of **A**/mol dm^{-3}	Initial concentration of **B**/mol dm^{-3}	Initial rate/ mol dm^{-3} s^{-1}
1	0.16	0.20	5.0×10^{-5}
2	0.24	0.20	7.5×10^{-5}
3	0.32	0.10	5.0×10^{-5}
4	0.12	0.15	to be calculated

Use the data in the table to deduce the order of reaction with respect to compound **A** and the order of reaction with respect to compound **B.** Hence calculate the initial rate of reaction in experiment 4.

*Order with respect to **A***.....

*Order with respect to **B***.....

Initial rate.....

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(4)

(c) The rate equation for a reaction between substances **C** and **D** is:

$$\text{rate} = k[\mathbf{C}]^2\,[\mathbf{D}]^2$$

The initial rate is found to be 7.5×10^{-3} mol dm^{-3} s^{-1} when the initial concentration of **C** is of 0.25 mol dm^{-3} and the initial concentration of **D** is 0.50 mol dm^{-3}.

(i) Calculate the value of the rate constant, *k*, at this temperature and deduce its units.

Calculation.....

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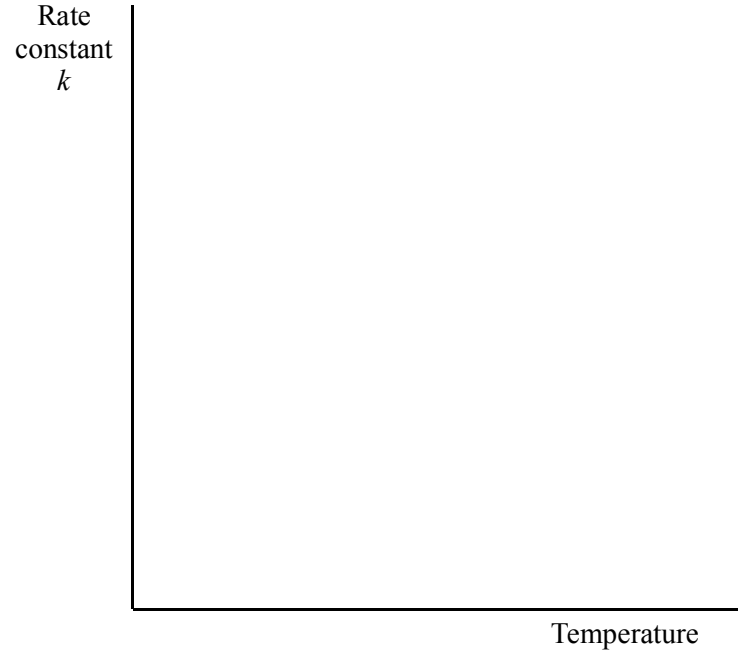
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Units.....

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(ii) On the axes below sketch a graph to show how the value of *k* varies as temperature is increased over a considerable range.



(4)
(Total 14 marks)

6. The initial rate of the reaction between the gases NO and H_2 was measured in a series of experiments at a constant temperature and the following rate equation was determined.

$$\text{rate} = k[\text{NO}]^2[\text{H}_2]$$

(a) Complete the table of data below for the reaction between NO and H_2

Experiment	Initial [NO] / mol dm^{-3}	Initial [H_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	3.0×10^{-3}	1.0×10^{-3}	1.8×10^{-5}
2	3.0×10^{-3}		7.2×10^{-5}
3	1.5×10^{-3}	1.0×10^{-3}	
4		0.50×10^{-3}	8.1×10^{-5}

(3)

(b) Using the data from experiment 1, calculate a value for the rate constant, *k*, and state its units.

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(3)
(Total 6 marks)

7. (a) The following data were obtained in a series of experiments on the rate of the reaction between compounds **A** and **B** at a constant temperature.

Experiment	Initial concentration of **A**/mol dm^{-3}	Initial concentration of **B**/mol dm^{-3}	Initial rate/mol dm^{-3} s^{-1}
1	0.12	0.15	0.32×10^{-3}
2	0.36	0.15	2.88×10^{-3}
3	0.72	0.30	11.52×10^{-3}

(i) Deduce the order of reaction with respect to **A**.

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(ii) Deduce the order of reaction with respect to **B**.

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(2)

(b) The following data were obtained in a series of experiments on the rate of the reaction

between NO and O_2 at a constant temperature.

Experiment	Initial concentration of NO/mol dm^{-3}	Initial concentration of O_2/mol dm^{-3}	Initial rate/mol dm^{-3} s^{-1}
4	5.0×10^{-2}	2.0×10^{-2}	6.5×10^{-4}
5	6.5×10^{-2}	3.4×10^{-2}	To be calculated

The rate equation for this reaction is

$$rate = k[NO]^2[O_2]$$

(i) Use the data from experiment 4 to calculate a value for the rate constant, *k*, at this temperature, and state its units.

Value of k .....

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Units of k .....

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(ii) Calculate a value for the initial rate in experiment 5.

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(4)
(Total 6 marks)

8. (a) The initial rate of the reaction between substances **P** and **Q** was measured in a series of experiments and the following rate equation was deduced.

$$\text{rate} = k[\mathbf{P}]^2[\mathbf{Q}]$$

(i) Complete the table of data below for the reaction between **P** and **Q**.

Experiment	Initial [**P**] / mol dm^{-3}	Initial [**Q**] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.20	0.30	4.8×10^{-3}
2	0.10	0.10	
3	0.40		9.6×10^{-3}
4		0.60	19.2×10^{-3}

(ii) Using the data from experiment 1, calculate a value for the rate constant, k, and deduce its units.

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(6)

(b) What change in the reaction conditions would cause the value of the rate constant to change?

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(1)

(Total 7 marks)

9. (a) The following data were obtained in a series of experiments on the rate of the reaction between compounds **A** and **B** at a constant temperature.

Experiment	Initial concentration of **A**/mol dm^{-3}	Initial concentration of **B**/mol dm^{-3}	Initial rate/mol dm^{-3} s^{-1}
1	0.15	0.24	0.45×10^{-5}
2	0.30	0.24	0.90×10^{-5}
3	0.60	0.48	7.20×10^{-5}

(i) Show how the data in the table can be used to deduce that the reaction is first-order with respect to **A**.

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(ii) Deduce the order with respect to **B**.

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(2)

(b) The following data were obtained in a second series of experiments on the rate of the reaction between compounds **C** and **D** at a constant temperature.

Experiment	Initial concentration of **A**/mol dm^{-3}	Initial concentration of **B**/mol dm^{-3}	Initial rate/mol dm^{-3} s^{-1}
4	0.75	1.50	9.30×10^{-5}
5	0.20	0.10	To be calculated

The rate equation for this reaction is

$$\text{rate} = k[\mathbf{C}]^2[\mathbf{D}]$$

(i) Use the data from Experiment 4 to calculate a value for the rate constant, *k*, at this temperature. State the units of *k*.

Value for k .....

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Units of k .....

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(ii) Calculate the value of the initial rate in Experiment 5.

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(4)
(Total 6 marks)

10. (a) The initial rate of the reaction between substances **A** and **B** was measured in a series of experiments and the following rate equation was deduced.

$$\text{rate} = k[\mathbf{A}][\mathbf{B}]$$

Expt	Initial [**A**]/mol dm^{-3}	Initial [**B**]/mol dm^{-3}	Initial rate/mol dm^{-3} s^{-1}
1	0.30	0.30	1.5×10^{-2}
2		0.60	6.0×10^{-2}
3	0.45		9.0×10^{-2}
4	0.90	0.60	

(i) Complete the table of data above.

(ii) Using the data from experiment 1, calculate a value for the rate constant, k, and state its units.

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(6)

(b) Explain why the rate of the reaction between magnesium and dilute hydrochloric acid is increased much more by changing the magnesium from ribbon to powder than by doubling the concentration of the acid.

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(2)
(Total 8 marks)

11. (a) The following table shows the results of three experiments to investigate the rate of the reaction between compounds **J** and **K**. All three experiments were carried out at the same temperature.

	Experiment 1	Experiment 2	Experiment 3
Initial concentration of **J**/mol dm^{-3}	0.50×10^{-3}	1.00×10^{-3}	1.50×10^{-3}
Initial concentration of **K**/mol dm^{-3}	1.00×10^{-3}	1.00×10^{-3}	1.50×10^{-3}
Initial rate/mol dm^{-3} s^{-1}	0.15×10^{-3}	0.60×10^{-3}	1.35×10^{-3}

Use the data in the table to deduce the order of reaction with respect to **J** and the order of reaction with respect to **K**. Hence write an overall rate equation for the reaction.

Order of reaction with respect to J .....

Order of reaction with respect to K.....

Overall rate equation …….....

(3)

(b) In a reaction between compounds **L** and **M**, the order of reaction with respect to **L** is two and the order of reaction with respect to **M** is one. Given that the initial rate of reaction is 4.00×10^{-4} mol dm^{-3} s^{-1} when the initial concentration of **L** is 2.00×10^{-2} mol dm^{-3} and the initial concentration of **M** is 5.00×10^{-2} mol dm^{-3}, calculate the value of the rate constant for this reaction at this temperature and deduce its units.

Calculation .....

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Units of rate constant .....

(3)

(c) The rate equation for the decomposition of a compound **N** has a rate constant with the unit s^{-1}. The rate constant is 4.31×10^{3} s^{-1} at 700 K and 1.78×10^{4} s^{-1} at a temperature *T*. Use this information to deduce the overall order of reaction and whether temperature *T* is greater or smaller than 700 K.

Overall order .....

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Change in temperature .....

(3)
(Total 9 marks)