

Reaction Kinetics

Question Paper 1

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Reaction Kinetics
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 1

Time Allowed: 60 minutes

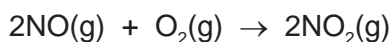
Score: /50

Percentage: /100

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

- 1 (a) The oxidation of nitrogen(II) oxide is shown in the equation.



The initial rate of this reaction was measured, starting with different concentrations of the two reactants. The following results were obtained.

experiment number	[NO] / mol dm ⁻³	[O ₂] / mol dm ⁻³	initial rate / mol dm ⁻³ s ⁻¹
1	0.032	0.012	4.08 × 10 ⁻³
2	0.032	0.024	8.15 × 10 ⁻³
3	0.064	0.024	3.28 × 10 ⁻²
4	0.096	0.036	

- (i) Use the data in the table to determine the order with respect to each reactant. Show your reasoning.

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- (ii) Calculate the initial rate in experiment 4. Give your answer to **two** significant figures.

initial rate = mol dm⁻³ s⁻¹

- (iii) Write the rate equation for this reaction.

.....

- (iv) Use the results of experiment 1 to calculate the rate constant, *k*, for this reaction. Include the units of *k*.

rate constant, *k* = units

(b) On the following axes

- draw two Boltzmann distribution curves, at two different temperatures, T_1 and T_2 ($T_2 > T_1$),
- label the curves and the axes.

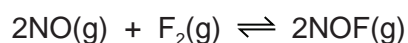


(ii) State and explain, using your diagram, the effect of increasing temperature on the rate of reaction.

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.....
.....

[5]

(c) The compound nitrosyl fluoride, NOF, can be formed by the following reaction.



The rate is first order with respect to NO and F_2 .

The reaction mechanism has **two** steps.

Suggest equations for the two steps of this mechanism, stating which is the rate determining slower step.

.....
.....
..... [2]

[Total: 13]

- 2 (a) Bromate(V) ions, BrO_3^- , react with bromide ions in the presence of acid to produce bromine. Write an **ionic** equation for this reaction.

.....
 [2]

- (b) The initial rate of this reaction was measured, starting with different concentrations of the three reactants.

The following results were obtained.

experiment number	$[\text{BrO}_3^-]$ / mol dm^{-3}	$[\text{Br}^-]$ / mol dm^{-3}	$[\text{H}^+]$ / mol dm^{-3}	initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$
1	0.040	0.020	0.50	2.64×10^{-4}
2	0.040	0.020	1.00	1.06×10^{-3}
3	0.040	0.080	0.50	1.06×10^{-3}
4	0.080	0.020	0.50	5.21×10^{-4}

- (i) Use the data in the table to determine the order with respect to each reactant. Show your reasoning.

.....

- (ii) Write the rate equation for this reaction.

.....

- (iii) Use the results of experiment 1 to calculate the rate constant, k , for this reaction. Include the units of k .

rate constant, $k =$ units [6]

[Total: 8]

3 Alcohols such as methanol, CH₃OH, are considered to be possible replacements for fossil fuels because they can be used in car engines.

(a) Define, with the aid of an equation which includes state symbols, the standard enthalpy change of combustion, ΔH_c^\ominus , for methanol at 298 K.

equation

definition

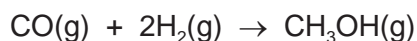
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..... [3]

Methanol may be synthesised from carbon monoxide and hydrogen. Relevant ΔH_c^\ominus values for this reaction are given in the table below.

compound	$\Delta H_c^\ominus / \text{kJ mol}^{-1}$
CO(g)	-283
H ₂ (g)	-286
CH ₃ OH(g)	-726

(b) Use these values to calculate $\Delta H_{\text{reaction}}^\ominus$ for the synthesis of methanol, using the following equation. Include a sign in your answer.



$$\Delta H_{\text{reaction}}^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

(c) The operating conditions for this reaction are as follows.

pressure 200 atmospheres (2×10^7 Pa)

temperature 600 K

catalyst oxides of Cr, Cu, and Zn

In the spaces below, explain how **each** of these conditions affects the **rate of formation** of methanol.

pressure

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.....
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temperature

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.....
.....

catalyst

.....
.....
.....

[6]

[Total: 12]

4 Nitrogen monoxide, NO, is formed in a reversible reaction when air is heated to the temperature of a car engine.

(a) Suggest a ‘dot-and-cross’ electronic structure for nitrogen monoxide.

(ii) The enthalpy change of formation of nitrogen monoxide is +90 kJ mol⁻¹. What is the enthalpy change for the following reaction?



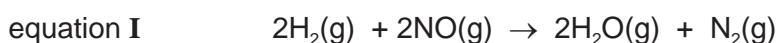
(iii) Explain why nitrogen monoxide is formed in the car engine.

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(iv) Using bond enthalpy values from the *Data Booklet* and your answer in (ii) above, calculate a value for the bond energy of nitrogen monoxide.

bond energy = kJ mol⁻¹
[5]

(b) At 800 K, nitrogen monoxide reacts with hydrogen according to the following equation.



The following table shows how the initial rate of this reaction depends on the partial pressures of the reagents.

experiment	p(H ₂)/atm	p(NO)/atm	initial rate/atm s ⁻¹
1	0.64	1.60	1.50 × 10 ⁻⁷
2	0.64	0.80	3.75 × 10 ⁻⁸
3	0.32	1.60	7.50 × 10 ⁻⁸

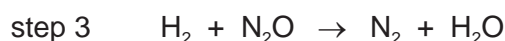
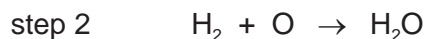
(i) Find the order of the reaction with respect to each reactant, explaining how you arrive at your answer.

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- (ii) Write down the rate equation and the units of the rate constant.

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The following mechanism has been put forward for this reaction.



- (iii) Show how the overall stoichiometric equation **I** can be derived from the three equations for the individual steps given above.

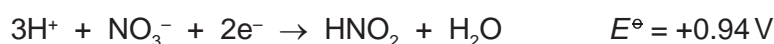
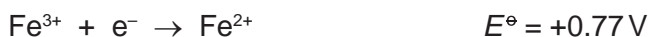
- (iv) Suggest which of the three reactions in the mechanism is the rate determining step. Explain your answer.

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[8]

- (c) The following information on half-reactions relates to the reaction between HNO_3 and an excess of FeSO_4 .



- (i) Suggest the formula of the nitrogen-containing final product of this reaction.

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- (ii) Write an equation for the formation of this nitrogen-containing product.

- (iii) Nitrogen monoxide forms a dark brown complex with an excess of $\text{FeSO}_4(\text{aq})$. What kind of bonding is involved in the complex formation?

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- (iv) Suggest a formula for this complex.

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[4]

[Total: 17]