## **Reaction Kinetics**

## Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Reaction Kinetics
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 2

Time Allowed: 63 minutes

Score: /52

Percentage: /100

### **Grade Boundaries:**

A*	Α	В	С	D	Е	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

Carbon monoxide, CO, occurs in the exhaust gases of internal combustion engines.

(a)	Suggest a dot-and-cross diagram for CO.
(ii)	Suggest <b>one</b> reason why CO is produced in addition to $\mathrm{CO}_2$ in some internal combustion engines.
(iii)	Carbon monoxide can be removed from the exhaust gases by a catalytic converter. Write an equation for a reaction that occurs in a catalytic converter that removes CO.
	[3]
	e standard enthalpy change of formation, $\Delta H_{\rm f}^{\rm e}$ , of CO is $-111{\rm kJmol^{-1}}$ , and that of CO <sub>2</sub> is $94{\rm kJmol^{-1}}$ .
Ca	culate the standard enthalpy change of the following reaction.
	$C(s) + CO_2(g) \rightarrow 2CO(g)$
	$\Delta H^{\circ} = \dots$ kJ mol <sup>-1</sup> [2]
<b>(c)</b> Ca	
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The following table shows how the initial rate of this reaction varies with different concentrations of reactants.

[[Ru(H <sub>2</sub> O) <sub>2</sub> Cl <sub>4</sub> ] <sup>2-</sup> ]/mol dm <sup>-3</sup>	[CO]/moldm <sup>-3</sup>	rate/moldm <sup>-3</sup> s <sup>-1</sup>
1.1 × 10 <sup>-2</sup>	1.7 × 10 <sup>-3</sup>	1.6 × 10 <sup>-7</sup>
1.6 × 10 <sup>-2</sup>	3.6 × 10 <sup>-3</sup>	2.3 × 10 <sup>-7</sup>
2.2 × 10 <sup>-2</sup>	2.7 × 10 <sup>-3</sup>	3.2 × 10 <sup>-7</sup>

(iii)	Use these data to determine the order of reaction with respect to each reagent, and write the rate equation for the reaction.			
The	ere are three pos	sible mechanisms for this reaction, which are described below.		
me	chanism 1	$[Ru(H_2O)_2C \mathit{l}_4]^{2-} + CO \xrightarrow{slow} [Ru(H_2O)(CO)C \mathit{l}_4]^{2-} + H_2O$		
me	chanism 2	$[Ru(H2O)2Cl4]2- \xrightarrow{slow} [Ru(H2O)Cl4]2- + H2O$		
		$[Ru(H2O)Cl4]2- + CO \xrightarrow{fast} [Ru(H2O)(CO)Cl4]2-$		
me	chanism 3	$[Ru(H2O)2Cl4]2- + CO \xrightarrow{slow} [Ru(H2O)2(CO)Cl4]2-$		
		$[Ru(H_2O)_2(CO)C l_4]^{2-} \xrightarrow{fast} [Ru(H_2O)(CO)C l_4]^{2-} + H_2O$		
(iv)		of these three mechanisms is consistent with the rate equation your <b>(iii)</b> . Explain your answer.	эu	

[Total: 15]

2	(a)		the following diagram draw a clear <b>labelled</b> sketch to describe the shape and metry of a typical d-orbital.
			[2]
	(b)		ough the five d-orbitals are at the same energy in an isolated atom, when a transition nent ion is in an octahedral complex the orbitals are split into two groups.
		(i)	Draw an orbital energy diagram to show this, indicating the number of orbitals in each group.
			energy
		(ii)	Use your diagram as an aid in explaining the following.
			Transition element complexes are often coloured.
			The colour of a complex of a given transition element often changes when the ligands around it are changed.

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(c) Heating a solution containing potassium ethanedioate, iron(II) ethanedioate and hydrogen peroxide produces the light green complex  $K_3Fe(C_2O_4)_3$ , which contains the ion  $[Fe(C_2O_4)_3]^{3-}$ .

The structure of the ethanedioate ion is as follows.

$$c-c$$

- (i) Calculate the oxidation number of carbon in this ion.
- (ii) Calculate the oxidation number of iron in  $[Fe(C_2O_4)_3]^{3-}$ .
- (iii) The iron atom in the  $[Fe(C_2O_4)_3]^{3-}$  ion is surrounded octahedrally by six oxygen atoms. Complete the following **displayed** formula of this ion.

(iv) In sunlight the complex decomposes into potassium ethanedioate, iron(II) ethanedioate and carbon dioxide.

Use oxidation numbers to help you balance the following equation for this decomposition.

$$K_3Fe(C_2O_4)_3 \rightarrow \dots K_2C_2O_4 + \dots FeC_2O_4 + \dots CO_2$$
 [5]

[Total: 14]

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**3 (a) (i)** What is meant by the term *ligand* as applied to the chemistry of the transition elements?

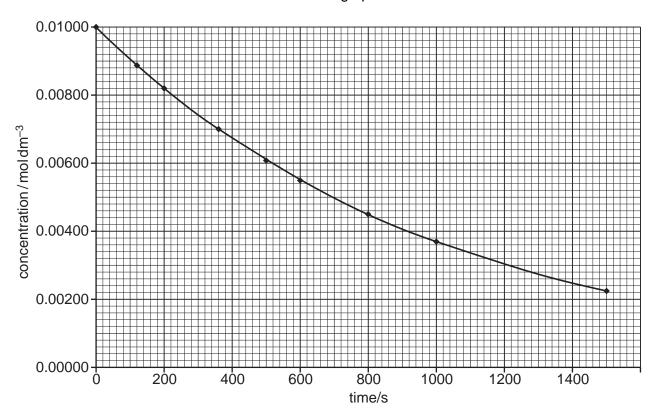
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(ii) Describe the type of bonding that occurs between a ligand and a transition element.

(b) Chromium hexacarbonyl undergoes the following ligand replacement reaction.

$$\mathrm{Cr(CO)}_6 + \mathrm{PR}_3 \rightarrow \mathrm{Cr(CO)}_5 \mathrm{PR}_3 + \mathrm{CO}$$

Two separate experiments were carried out to study the rate of this reaction. In the first experiment, the ligand  $PR_3$  was in a large excess and  $[Cr(CO)_6]$  was measured with time. The results are shown on the graph below.



In the second experiment,  $Cr(CO)_6$  was in a large excess, and  $[PR_3]$  was measured with time. The following results were obtained.

time/s	[PR <sub>3</sub> ]/moldm <sup>-3</sup>
0	0.0100
120	0.0076
200	0.0060
360	0.0028

(i) Plot the data in the table on the graph above, using the same axis scales, and draw the best-fit line through your points.

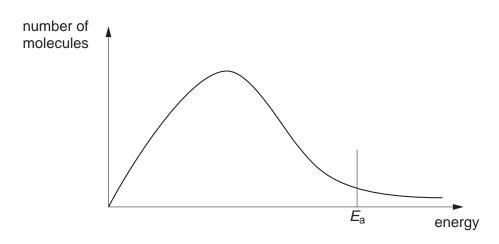
	se the graphs to determine the order of re each case explain how you arrived at yo	
C 	r(CO) <sub>6</sub>	
 P	R <sub>3</sub>	
-	rite the rate equation for the reaction, an	
iv) Si	ate the units of the rate constant.	
th	our possible mechanisms for this reaction e letter next to the <b>one</b> mechanism which ave written in <b>(iii)</b> .	•
Α	$Cr(CO)_6 \rightarrow Cr(CO)_5 + CO$ $Cr(CO)_5 + PR_3 \rightarrow Cr(CO)_5 PR_3$	fast slow
В	$Cr(CO)_6 \rightarrow Cr(CO)_5 + CO$ $Cr(CO)_5 + PR_3 \rightarrow Cr(CO)_5 PR_3$	slow fast
С	$Cr(CO)_6 + PR_3 \rightarrow [OCCr(CO)_4-$ (transition sta	
D	$Cr(CO)_6 + PR_3 \rightarrow Cr(CO)_6 PR_3$ $Cr(CO)_6 PR_3 \rightarrow Cr(CO)_5 PR_3 + CO$	slow fast
E	xplain your answer.	

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4 The diagram below shows, for a given temperature T, a Boltzmann distribution of the kinetic energy of the molecules of a mixture of two gases that will react together, such as nitrogen and hydrogen.

The activation energy for the reaction,  $E_a$ , is marked.



- (a) On the graph above,
  - (i) draw a new distribution curve, **clearly labelled T**′, for the same mixture of gases at a higher temperature, **T**′;
  - (ii) mark clearly, as H, the position of the activation energy of the reaction at the higher temperature, T'.

(b) Explain the meaning of the term activation energy.

The reaction between nitrogen and hydrogen to produce ammonia in the Haber process is an example of a large-scale gaseous reaction that is catalysed.

(c)	(i)	State the catalyst used and give the operating temperature and pressure of the Haber process.		
		catalyst		
		temperature		
		pressure		
	(ii)	On the energy axis of the graph opposite, mark the position, clearly labelled C, of the activation energy of the reaction when a catalyst is used.		
	(iii)	Use your answer to (ii) to explain how the use of a catalyst results in reactions occurring at a faster rate.		
		[3]		
(d)	d) Two reactions involving aqueous NaOH are given below.			
		$CH_3CHBrCH_3 + Na \rightarrow CH_3CH(OH)CH_3 + NaBr$ reaction 1		
		$HCl + NaOH \rightarrow NaCl + H_2O$ reaction 2		
In order for <b>reaction 1</b> to occur, the reagents must be heated together for On the other hand, <b>reaction 2</b> is almost instantaneous at room temperature				
	Sug	gest brief explanations why the rates of these two reactions are very different.		
	rea	ction 1		
	rea	ction 2		
		[4]		
		TT 4 1 401		

[Total: 12]