Chapter 22:Reaction kinetics

Homework questions

1 The compound $(CH_3)_2CClCH_3$ undergoes hydrolysis when added to water.
$(CH_3)_2CClCH_3(l) + H_2O(l) \rightarrow (CH_3)_2C(OH)CH_3(l) + HCl(aq)$

a Explain why the reaction rate can be measured using conductivity changes. [2]

b Name the compounds represented by the formulae:

i $(CH_3)_2CClCH_3$ [1]

ii $(CH_3)_2C(OH)CH_3$ [1]

c It is found that the rate of reaction is first order with respect to $(CH_3)_2CClCH_3$ and depends on the concentration of no other compounds. The mechanism of the reaction is shown below:
$(CH_3)_2CClCH_3(l) \rightarrow (CH_3)_2C^+CH_3(aq) + Cl^-(aq)$
$(CH_3)_2C^+CH_3(aq) + H_2O(l) \rightarrow (CH_3)_2C(OH)CH_3(l) + HCl(aq)$
Which of the two steps is the rate-determining step? Explain your answer. [2]

d Sketch a graph to show how the rate of reaction depends on the concentration of $(CH_3)_2CClCH_3$. [2]

e When the compound $CH_3CH_2CH_2CH_2Cl$ undergoes nucleophilic substitution with sodium hydroxide it is found that the reaction is first order with respect to $CH_3CH_2CH_2CH_2Cl$ and first order with respect to hydroxide ions.

i Write a balanced chemical equation for the reaction. [1]

ii What is the order of reaction overall? [1]

iii Write the rate equation. [1]

iv Draw a graph to show how the concentration of $CH_3CH_2CH_2CH_2Cl$ varies with time. (Hint: set the starting concentration at 32×10^{-3} mol dm^{-3}.) [3]

f Explain why $(CH_3)_2CClCH_3$ undergoes reaction using the first mechanism shown above whilst $CH_3CH_2CH_2CH_2Cl$ does not. [2]

g When $(CH_3)_2CClCH_3$ is heated with ethanolic sodium hydroxide, a different reaction takes place.

i What type of reaction is this? [1]

ii Write a balanced equation for the reaction. [1]

Total = 18

2 Hydrogen peroxide undergoes the following reaction:
$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

a The reaction is catalysed by iodide ions and is thought to proceed by a two-step mechanism:
$H_2O_2(aq) + I^-(aq) \rightarrow H_2O(l) + P$ rate-determining step
$H_2O_2(aq) + P \rightarrow H_2O(l) +$ _____ + _____ fast

i Write the correct formula for P and complete both equations. [3]

ii What is the evidence from the equations that iodide ions would catalyse the reaction? [1]

iii Write the rate equation for the reaction. [1]

iv Suggest a method to measure the rate of the reaction. [1]

b The results below show how the concentration of hydrogen peroxide changes with time.

Time / s	0	50	100	150	200	250	300	350	400
$[H_2O_2]$ / mol dm^{-3}	1.2	0.780	0.460	0.300	0.190	0.120	0.075	0.045	0.030

i Plot a graph of time against concentration of hydrogen peroxide. [2]

ii Use the graph to determine the half-life for the reaction and explain why the reaction is first order with respect to hydrogen peroxide. [2]

iii Use the relationship $k = \frac{0.693}{t_{1/2}}$ to calculate the rate constant. Include the units of k. [2]

c The 'strength' of hydrogen peroxide solutions is usually expressed in terms of 'volume'. For example, 10-volume hydrogen peroxide would give 10 cm^3 of oxygen for every 1 cm^3 of hydrogen peroxide solution. Calculate the concentration, in mol dm^{-3}, of a 10-volume solution of hydrogen peroxide. [3]

d Draw a hydrogen peroxide molecule, labelling the bond angles in the molecule. [2]

Total = 17

3 Peroxodisulfate ions ($S_2O_8^{2-}$) and iodide ions react to give sulfate ions (SO_4^{2-}) and iodine.

a **i** Write the equation for the reaction and explain why it is a redox reaction. [4]

ii Explain why the reaction is quite slow at room temperature. [2]

iii How could the reaction rate be measured? Explain why your method would work. [2]

b The half-equations for the reactions taking place are given below, along with their standard electrode potentials.

$S_2O_8^{2-}(aq) + 2e^- \rightleftharpoons 2SO_4^{2-}(aq)$ $E^\theta = +2.01$ V

$2I^-(aq) \rightleftharpoons I_2(aq) + 2e^-$ $E^\theta = +0.54$ V

Use these standard electrode potential values to explain why it is possible for the reaction to take place. [2]

c The reaction is catalysed by the addition of either Fe^{2+} or Fe^{3+} ions. The relevant half-equation is:

$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ $E^\theta = +0.77$ V

Use the half-equations and the standard electrode potential values to explain how these ions work to catalyse the reaction. [6]

d A student was asked to test various ions to see if they would catalyse the reaction. He was given two ions to test: VO_2^+ and Sn^{4+}. The relevant half-equations and standard electrode values are given below:

$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$ $E^\theta = +1.00$ V

$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$ $E^\theta = +0.15$ V

Predict whether or not these ions would function as catalysts. Explain your answer. [2]

Total = 18