Electrolysis

Question Paper 2

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Electrolysis- Equilibria
Booklet	Question Paper 2

Time Allowed: **43 minutes**

Score: **/36**

Percentage: **/100**

Grade Boundaries:

1. **(a)** The reaction shown represents the hydrogenation of a vegetable oil.

$$RCH{=}CHR'(l) + H_2(g) \rightarrow RCH_2CH_2R'(l)$$

This reaction can be catalysed by several different transition metals and gives an example of heterogeneous catalysis.

State the three stages involved in a typical reaction involving a heterogeneous catalyst.

1. .....

2. .....

3. ..... [1]

(b) An example of homogeneous catalysis is the use of iron(II) ions or iron(III) ions to catalyse the reaction between iodide ions and peroxodisulfate ions, $S_2O_8^{2-}$, as shown.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

The relevant half-equations and standard electrode potentials are given in the table.

half-equation	$E^\ominus$ / V
$S_2O_8^{2-}(aq) + 2e^- \rightleftharpoons 2SO_4^{2-}(aq)$	+2.01
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54

(i) What is meant by the term *homogeneous catalysis*?

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.....[1]

(ii) Use the standard electrode potentials given to calculate the standard cell potential, $E^\ominus_{cell}$, for the reaction between iodide ions and peroxodisulfate ions.

..... V [1]

(iii) Use your answer from **(b)(ii)** to calculate the standard Gibbs energy change, $\Delta_r G^\ominus$, of the reaction between iodide ions and peroxodisulfate ions. Give the sign and units in your answer.

.....[2]

(iv) Explain how your answer to **(b)(iii)** confirms that the reaction between iodide ions and peroxodisulfate ions shown in **(b)** represents the feasible direction of reaction.

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.....[1]

(v) State and explain why, despite being feasible, the reaction between iodide ions and peroxodisulfate ions is not seen to occur in the absence of a catalyst.

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.....[2]

(vi) By constructing suitable equations from the data given, explain why the reaction between iodide and peroxodisulfate can be catalysed by either iron(II) or iron(III) ions.

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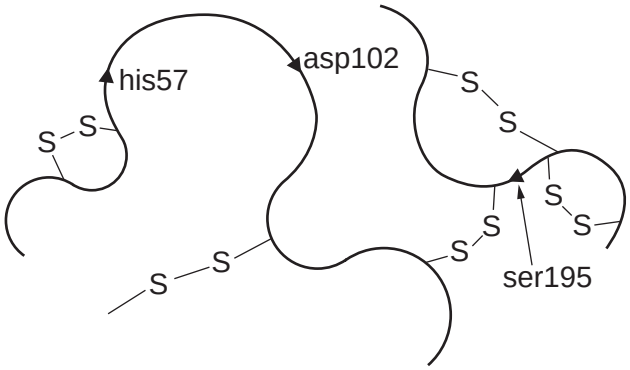
.....[3]

(c) Part of the structure of chymotrypsin, an enzyme produced by the pancreas that is responsible for catalysing the hydrolysis of certain proteins in the small intestine during the digestive process, is shown.

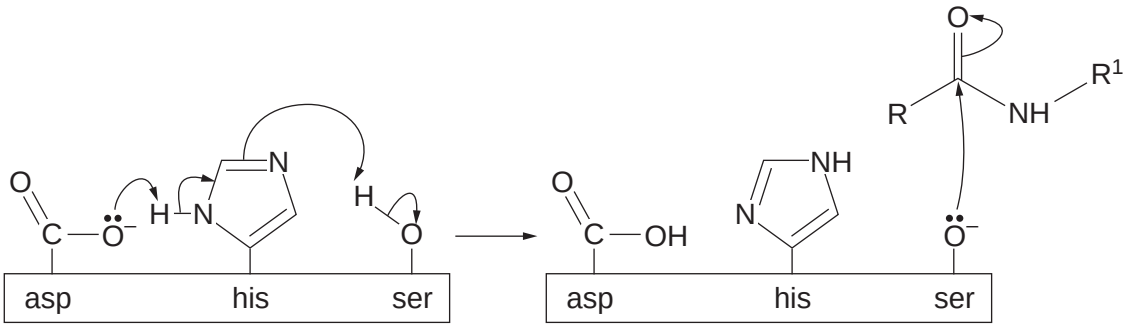


The three main amino acids involved in the catalytic activity of the enzyme are labelled as his57, asp102 and ser195.

(i) What is the name of the region of the enzyme molecule that contains the three labelled amino acids and interacts with the protein being hydrolysed?

.....[1]

The first stage of the mechanism of action of chymotrypsin is illustrated.



(ii) Explain what is represented by a curly arrow as used in the mechanism shown.

.....[1]

(iii) Name the type of acid-base behaviour shown by the O^- in serine in its interaction with the protein chain.

..... [1]

(iv) With reference to the illustration of the mechanism, explain why the action of chymotrypsin would be inhibited if the pH was too low.

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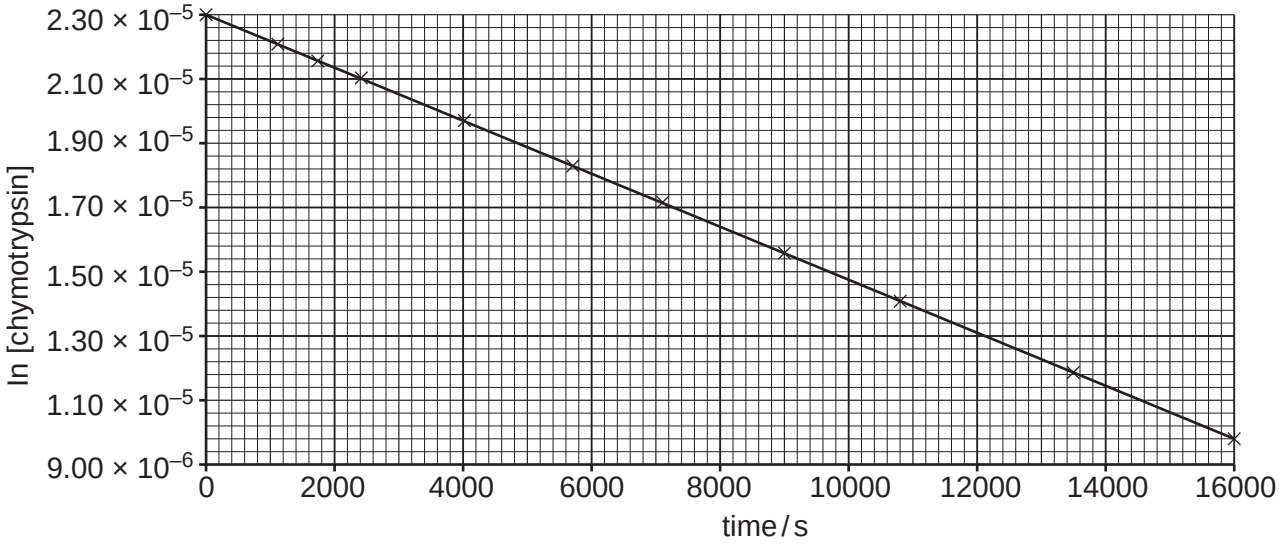
.....[2]

(v) Chymotrypsin is denatured by sodium hydroxide, with the mechanism dependent on the pH.

- At pH12 the reaction is first order with respect to both the chymotrypsin and the hydroxide.
- In the presence of excess alkali the denaturation of the enzyme was monitored.
- The plot of the time course of the reaction is shown.



The first order rate equation given in the *Data Booklet* can be rewritten.

$$\ln C_t = -kt + \ln C_0$$

Given that this equation is in the form $y = mx + c$, explain how the plot of the time course of the reaction confirms that the denaturation is first order with respect to chymotrypsin and how the conditions chosen give rise to first order kinetics overall.

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.....[2]

(vi) Use the plot of the time course of the reaction to calculate the value of the first order rate constant for this denaturation.

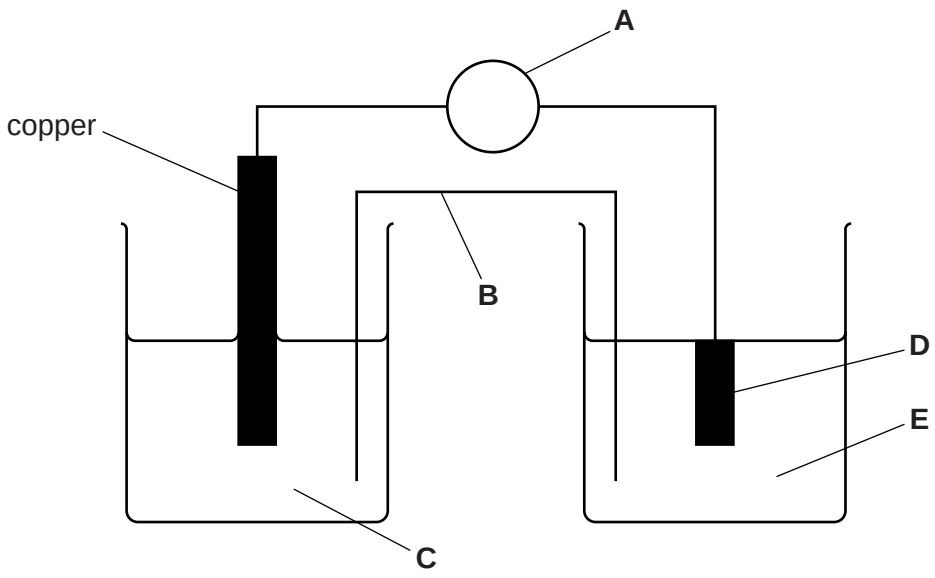
k = ...[2]

[Total: 20]

2. An electrochemical cell was set up as illustrated by the cell diagram.

$Cu(s) \mid Cu^{2+}(aq) \parallel Cr_2O_7^{2-}(aq) + 14H^+(aq), Cr^{3+}(aq) + 7H_2O(l) \mid Pt \quad E^{\ominus}_{cell} = +0.99V$

(a) Some of the labels on a diagram of this electrochemical cell have been replaced with the letters **A** – **E**.



(i) Name the parts of the cell labelled **A** to **E**.
Include any detail necessary to allow the cell to be used to measure the standard cell potential, $E^{\ominus}_{cell}$.

A .....

B .....

C .....

D .....

E .....

.....[6]

(ii) Write the half-equations for the two half-cells that make up the cell.

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.....[2]

(iii) Write the overall equation for the reaction that occurs in the cell when a current is allowed to flow.

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(b) A sample of finely ground copper was contaminated with zinc powder.

Treatment of the sample with excess hydrochloric acid produced 126 cm^3 of hydrogen gas, measured at 303 K and 10^5 Pa, by the reaction shown.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(aq)$$

The remaining copper was then reacted with acidified potassium manganate(VII).

$$5Cu(s) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 5Cu^{2+}(aq) + 2Mn^{2+}(aq) + 8H_2O(l)$$

It was found that 4.88×10^{-3} mol of potassium manganate(VII) was required for complete oxidation of the copper.

(i) Calculate the mass of zinc present in the sample.
Give your answer to three significant figures.

mass of Zn = ... g [2]

(ii) Calculate the mass of copper present in the sample.

mass of Cu = ... g [2]

(iii) Calculate the percentage by mass of copper in the original sample.

percentage by mass of Cu = ... % [1]

(c) In aqueous solution, dichromate(VI) ions exist in equilibrium with chromate(VI) ions.

$$\underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l) \rightleftharpoons \underset{\text{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq)$$

(i) Explain why the solution turns from orange to yellow on the addition of aqueous sodium hydroxide.

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.....[2]

(ii) Following the addition of aqueous sodium hydroxide, the solution was cooled. This caused the colour of the solution to change from yellow back to orange.

Use Le Chatelier's principle to state and explain what you can conclude about the enthalpy change of the forward reaction.

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.....[1]

(iii) Barium chromate(VI), $BaCrO_4$, is sparingly soluble, while barium dichromate(VI), $BaCr_2O_7$, is soluble.

State and explain the effect of adding barium nitrate solution, $Ba(NO_3)_2(aq)$, to the original equilibrium mixture of dichromate(VI) ions and chromate(VI) ions.

Your answer should refer to the effect on equilibrium position, K_c and pH.

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.....[3]

[Total: 20]