Equilibria

Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	Rates, Equilibria & Further Organic Chemistry
Sub Topic	Equilibria
Booklet	Question Paper 2

Time Allowed: **66 minutes**

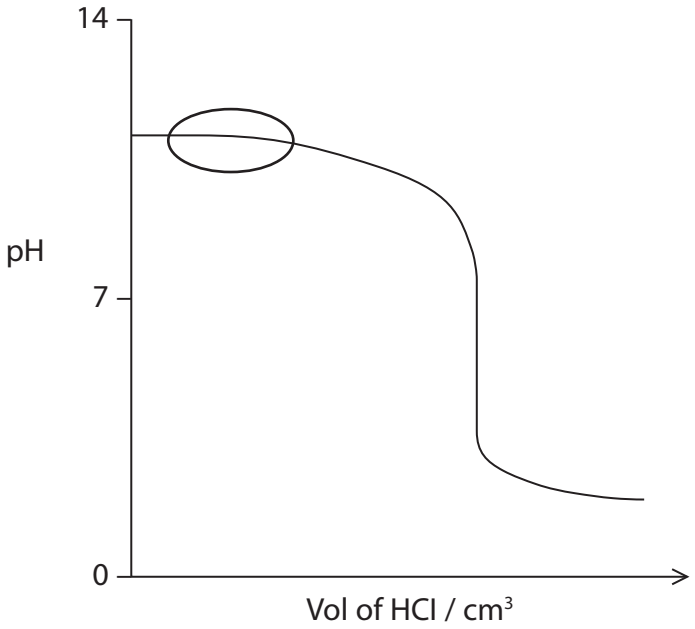
Score: **/55**

Percentage: **/100**

Grade Boundaries:

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

1 A student carried out a titration by adding 0.0540 mol dm^{-3} hydrochloric acid to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution. A sketch graph of pH against volume of hydrochloric acid added is shown below.



(a) *(i) Name the type of solution formed in the region ringed on the sketch graph and explain its chemical behaviour.

(3)

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*(ii) Explain why the pH at the equivalence point of this titration is less than 7. Include an ionic equation in your answer.

(3)

(iii) By considering the amount of excess acid remaining, calculate the pH of the solution formed when 40.0 cm^3 of 0.0540 mol dm^{-3} hydrochloric acid has been added to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution.

(4)

(b) (i) Show, using the data below, that the pH of water at 373 K is 6.13.

- $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
- $K_w = 5.50 \times 10^{-13}$ mol^2 dm^{-6} at 373 K

(2)

(ii) At 373 K, is water neutral, acidic or alkaline? Explain your answer.

(2)

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(Total for Question 1 = 14 marks)

2 (a) Ammonia is a weak alkali. Consider the following equilibrium that exists in an aqueous solution of ammonia.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq) \qquad K_b = 1.8 \times 10^{-5} \text{ mol dm}^{-3}$$

The base dissociation constant, K_b, for this reaction is

$$K_b = \frac{[NH_4^+(aq)][OH^-(aq)]}{[NH_3(aq)]}$$

(i) Calculate the concentration of hydroxide ions at equilibrium in a 4.0 mol dm^{-3} aqueous solution of ammonia.

Assume that the concentration of ammonia at equilibrium is 4.0 mol dm^{-3} and that the equilibrium concentration of hydroxide ions is equal to the equilibrium concentration of ammonium ions.

(2)

(ii) Calculate the pH of 4.0 mol dm^{-3} ammonia solution.

[$K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 298 K]

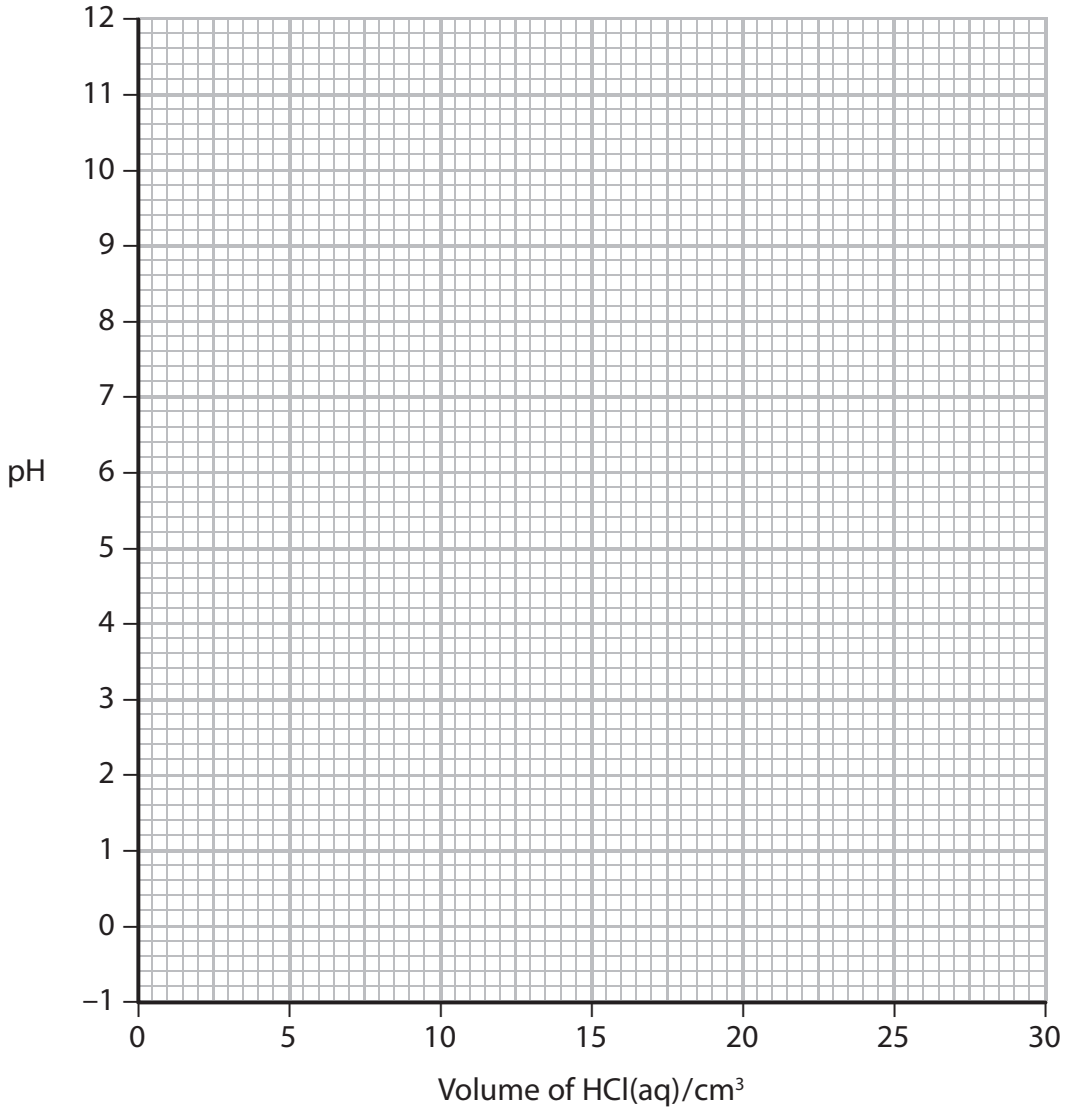
(2)

(b) (i) Calculate the pH of 4.0 mol dm^{-3} hydrochloric acid, assuming it is fully ionized.

(1)

(ii) Draw the titration curve, showing the change in pH when 4.0 mol dm^{-3} hydrochloric acid is added to 25 cm^3 of 4.0 mol dm^{-3} ammonia solution, until 30 cm^3 of the acid have been added.

(4)



*(iii) Select a suitable indicator for this titration, giving the colour change you would expect to see.

Justify your selection.

(3)

(c) The titration above can be used to determine the concentration of ammonia solution when ammonia is distributed between the two immiscible solvents, trichloromethane and water.

An experiment is carried out to find the equilibrium constant for the reaction:

$$NH_3(CHCl_3) \rightleftharpoons NH_3(aq)$$

75 cm^3 of 4.0 mol dm^{-3} aqueous ammonia solution and 75 cm^3 of the trichloromethane are shaken together. The two liquids are allowed to separate and 25.0 cm^3 of the aqueous layer is taken and titrated with 4.0 mol dm^{-3} hydrochloric acid. The whole procedure is repeated.

The average titre is 24.0 cm^3.

(i) Calculate the number of moles of ammonia, and hence the concentration of ammonia, in mol dm^{-3}, in the aqueous layer.

(3)

(ii) The initial volumes of the two solvents are the same.

Hence deduce the concentration of ammonia in the trichloromethane layer in mol dm^{-3}.

(1)

(iii) Write the expression for the equilibrium constant, K_c, for this reaction and calculate its value.

(1)

(iv) Suggest why ammonia is much more soluble in water than in trichloromethane.

(1)

(Total for Question 2 = 18 marks)

3 (a) Ethanoic acid and ethanol react together to form the ester ethyl ethanoate, $CH_3COOC_2H_5$, and water.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l) \qquad \Delta H = -3.5 \text{ kJ mol}^{-1}$$

(i) Give the expression for the equilibrium constant, K_c, for this reaction.

(1)

(ii) By considering the effect of temperature on the entropy change of the surroundings, suggest why changing the temperature has little effect on this equilibrium.

(3)

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*(iii) An experiment was carried out to determine the value of K_c for this reaction.

- 0.120 mol of ethanoic acid was added to 0.220 mol of ethanol.
- 5.00 cm^3 of 1.00 mol dm^{-3} hydrochloric acid was added as a catalyst. This contains 0.278 mol of water.
- The mixture was left to reach equilibrium.
- The mixture was titrated with 1.00 mol dm^{-3} sodium hydroxide, which reacted with **both** of the acids.
- The titre was 45.0 cm^3.

Use these data to determine the value for K_c.

(6)

(b) Ethanoic acid reacts with another alcohol, **Y**, to produce an ester **Z**.

(i) Alcohol **Y** has molar mass 74 g mol^{-1} and the following composition by mass:

carbon, C = 64.9%

hydrogen, H = 13.5%

oxygen, O = 21.6%.

Use all these data to confirm that the molecular formula for **Y** is $C_4H_{10}O$.
Show your working.

(2)

(ii) Draw the displayed formulae of the **four** possible structures of alcohol **Y**.

(2)

Alcohol 1	Alcohol 2
Alcohol 3	Alcohol 4

(iii) The mass spectrum of alcohol **Y** has a major peak at *m*/*e* = 45.
Suggest the structures of two species that could give this peak.

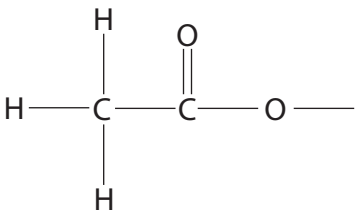
(2)

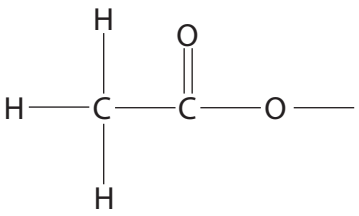
(iv) Use your answers to (b)(ii) and (b)(iii) to identify which two of the alcohols you have drawn in (b)(ii) could be alcohol **Y**.

(1)

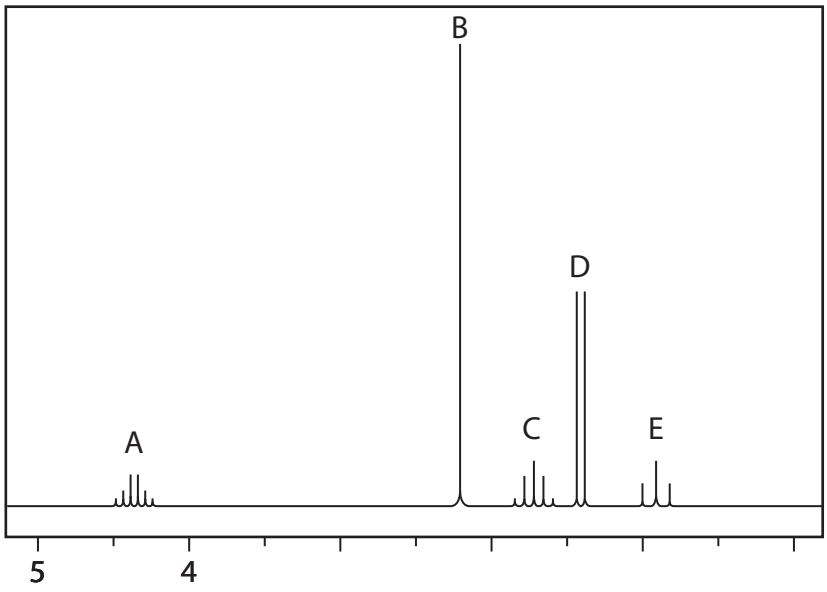
(v) Complete the displayed formulae for the two possible esters that could be **Z**.

(1)





*(vi) The high resolution proton nmr spectrum of ester **Z** is shown below.



The relative number of protons causing the peaks shown are:
A = 1, B = 3, C = 2, D = 3 and E = 3.

Use the nmr spectrum to determine the structural formula for ester **Z** that is consistent with this data.

Draw your formula below and on it label the protons responsible for the peaks A to E.

Explain the splitting patterns of the spectrum.

(5)

Structure

Explanation of splitting patterns

(Total for Question 3 = 23 marks)