4 SL+HL

Key

SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

1. A class studied the equilibrium established when ethanoic acid and ethanol react together in the presence of a strong acid, using propanone as an inert solvent. The equation is given below.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

(not propanone, it's simply a product)

One group made the following initial mixture:

Liquid	Volume / cm^3	* % uncertainty
Ethanoic acid	5.00 ± 0.05	$\frac{0.05}{5} = 0.01$ (1%)
Ethanol	5.00 ± 0.05	$\frac{0.05}{5} = 0.01$ (1%)
6.00 mol dm^{-3} aqueous hydrochloric acid	1.00 ± 0.02	$\frac{0.02}{1} = 0.02$ (2%)
Propanone	39.0 ± 0.5	$\frac{0.5}{39.0} = 0.01$ (1%)

Total = 50.00

(a) **The density of ethanoic acid is 1.05 g cm^{-3}. Determine the amount, in mol, of ethanoic acid present in the initial mixture.** *[3]*

$5.00\ cm^3 \times \frac{1.05\ g}{cm^3} = 5.25\ g\ CH_3COOH$

$5.25\ g \times \frac{1\ mol}{60.06\ g} = 0.0874\ mol$

The hydrochloric acid does not appear in the balanced equation for the reaction. State its function. *[1]*

HCl is a catalyst

* Identify the liquid whose volume has the greatest percentage uncertainty. *[1]*

HCl

(Question 1 continued)

$[\uparrow] = \frac{0.0874\,\text{mol}}{0.0500\,\text{dm}^3} = 2$

(b) The concentration of ethanoic acid can be calculated as $1.748\,\text{mol dm}^{-3}$. Determine the percentage uncertainty of this value. (Neglect any uncertainty in the density and the molar mass.) *[3]*

i.e., only volume left!

uncertainty of ethanoic acid:

$\frac{0.05}{5.00} \times 100 = 1\%$

uncertainty of total volume:

$\frac{0.62}{50.0} \times 100 = 1.2\%$

Total uncertainty = $1 + 1.2 = \boxed{2.2\%}$ (2% ok)

(c) After one week, a $5.00 \pm 0.05\,\text{cm}^3$ sample of the final equilibrium mixture was pipetted out and titrated with $0.200\,\text{mol dm}^{-3}$ aqueous sodium hydroxide to determine the amount of ethanoic acid remaining. The following titration results were obtained:

Titration number	1	2	3
Initial reading / cm³ ± 0.05	1.20	0.60	14.60
Final reading / cm³ ± 0.05	28.80	26.50	40.70
Titre / cm³	27.60	25.90	26.10

(i) Calculate the absolute uncertainty of the titre for Titration 1 ($27.60\,\text{cm}^3$). *[1]*

$0.05 + 0.05 = \boxed{+/- 0.10\,\text{cm}^3}$

must have +/-

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(Question 1 continued)

(ii) Suggest the average volume of alkali, a base, required to neutralize the 5.00 cm^3 sample, that the student should use. [1]

$\frac{25.90 + 26.10}{2} = 26.00\ cm^3$

(Note: The 27.60 should be removed as it's too divergent from the other values.)

(iii) 3.00 cm^3 of the 0.200 mol dm^{-3} aqueous sodium hydroxide reacted with the hydrochloric acid present in the 5.00 cm^3 sample. Determine the concentration of ethanoic acid in the final equilibrium mixture. [2]

$26.00 - 3.00 = 23.00\ cm^3$ NaOH that reacted with CH_3COOH

$23.00\ cm^3\ NaOH \times \frac{0.200\ mol}{1000\ cm^3} \times \frac{1\ mol\ CH_3COOH}{1\ mol\ NaOH} = 0.00460\ mol\ CH_3COOH$

$[CH_3COOH] = \frac{0.00460\ mol}{0.00500\ dm^3} = 0.920\ mol\ dm^{-3}$

Referring back to your answer for part (a), calculate the percentage of ethanoic acid converted to ethyl ethanoate. [1]

$\frac{0.0874 - 0.0460}{0.0874} \times 100 = 47.4\ \%$

(f) Deduce the equilibrium constant expression for the reaction. [1]

$K_c = \frac{[CH_3COOC_2H_5][H_2O]}{[C_2H_5OH][CH_3COOH]}$ *

* Water is not the solvent, ∴ must be included!

(Question 1 continued)

(v) The other concentrations in the equilibrium mixture were calculated as follows:

Compound	C_2H_5OH	$CH_3COOC_2H_5$	H_2O
Concentration / mol dm^{-3}	0.884	0.828	1.80

Use these data, along with your answer to part (iii), to determine the value of the equilibrium constant. (If you did not obtain an answer to part (iii), assume the concentrations of ethanol and ethanoic acid are equal, although this is not the case.) *[1]*

$K_c = \frac{(0.828)(1.80)}{(0.884)(0.920)} = 1.83$ (all units cancel! HL only ☺)

(d) Outline how you could establish that the system had reached equilibrium at the end of one week. *[1]*

Titrate the solution again. If it is at equilibrium, the results should be the same.

(e) Outline why changing the temperature has only a very small effect on the value of the equilibrium constant for this equilibrium. *[1]*

ΔH must be very small for this reaction.

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