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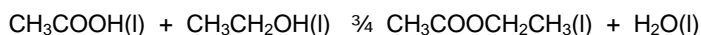
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## FINDING $K_c$ FOR ESTERIFICATION



### Aim



You are going to find the value of  $K_c$  for the following equilibrium:



You will set up an equilibrium mixture and then leave it for several days to reach equilibrium. Both the forward and reverse reactions are slow so it takes a long time to reach equilibrium. You are going to mix together some ethanoic acid, some ethanol and some hydrochloric acid (to act as a catalyst to speed up the time it takes to reach equilibrium). Note that the acid catalyst contains water which is one of the components of the equilibrium.

After a few days, you will find how much ethanoic acid is present at equilibrium by titration with sodium hydroxide, and use this and other data to find the equilibrium concentration of each species.

### Safety

	hydrochloric acid ethanoic acid sodium hydroxide		ethanol ethyl ethanoate
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### Method

- 1) Find the mass of a clean, dry, stoppered boiling tube.
- 2) Using a shared class burette, put  $5 \text{ cm}^3$  of  $3 \text{ mol dm}^{-3}$  hydrochloric acid in the tube, and then reweigh it.
- 3) Using a shared class burette, add  $2 \text{ cm}^3$  of ethanoic acid into the tube.
- 4) Using a shared class burette, add  $3 \text{ cm}^3$  of ethanol into the tube.
- 5) Stopper the tube, shake it well, and then leave it in the class rack in the water bath for a few days.

You are going to titrate the equilibrium mixture against sodium hydroxide to find the amount of ethanoic acid at equilibrium. **You will only get one chance to do this, so you must do your one and only titration accurately.**

- 6) Fill a burette with  $1 \text{ mol dm}^{-3}$  sodium hydroxide ready for the titration.
- 7) Transfer the equilibrium mixture to a conical flask, washing all the contents into the flask.
- 8) Add a few drops of phenolphthalein indicator (colourless to pink end point).
- 9) Titrate the equilibrium mixture against the sodium hydroxide (**you only get one chance**).

### Analysis

- 10) Work through the calculation overleaf. The instructions lead you to the number of moles of each species at equilibrium which you then use to find  $K_c$ . Remember that the acid in the titration will be a mixture of the remaining ethanoic acid and the acid catalyst.

- 11) Calculate the maximum percentage apparatus error using the information below.

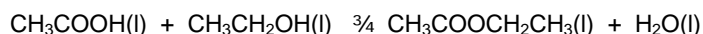
burette (start & end readings)	$\pm 0.10 \text{ cm}^3$
burette (start & end readings & end point)	$\pm 0.15 \text{ cm}^3$
balance	$\pm 0.001 \text{ g}$

### Evaluation

- 12) Write down the mean class value for  $K_c$ .
- 13) Find the percentage difference between your value and the class mean value.
- 14) Comment on the size of your experimental error compared to the maximum apparatus error.
- 15) If your value is outside the apparatus error, suggest reasons why it is too high or too low (be specific, give reasons why it is too *high* or too *low*, not just why it is outside apparatus error). If your value is within apparatus error, give reasons why somebody else's value may be too high.

## Calculating $K_c$

Remember that:



<i>initial moles</i>	A	B	0	C
<i>equilibrium moles</i>	A - x	B - x	x	x
<i>equilibrium concentration</i>	$\frac{A - x}{V}$	$\frac{B - x}{V}$	$\frac{x}{V}$	$\frac{C + x}{V}$

The volume, V, will cancel out when  $K_c$  is calculated and so its actual value does not matter.

$$K_c = \frac{[\text{CH}_3\text{COOCH}_2\text{CH}_3]_{(t)} [\text{H}_2\text{O}]_{(t)}}{[\text{CH}_3\text{COOH}]_{(t)} [\text{CH}_3\text{CH}_2\text{OH}]_{(t)}} = \frac{[x/V] [(C + x)/V]}{[(A - x)/V] [(B - x)/V]} = \frac{x(C + x)}{(A - x)(B - x)}$$

Initial moles	CH <sub>3</sub> COOH	1) Calculate how many moles of CH <sub>3</sub> COOH you started with (the density of CH <sub>3</sub> COOH is 1.05 g cm <sup>-3</sup> ).
	CH <sub>3</sub> CH <sub>2</sub> OH	2) Calculate how many moles of CH <sub>3</sub> CH <sub>2</sub> OH you started with (the density of CH <sub>3</sub> CH <sub>2</sub> OH is 0.79 g cm <sup>-3</sup> ).
	CH <sub>3</sub> COOCH <sub>2</sub> CH <sub>3</sub>	3) There was none present at the start.
	H <sub>2</sub> O	4) Calculate the total mass of the water and HCl in the tube at the start. 5) Calculate how many moles of HCl there are in the 5 cm <sup>3</sup> of 3 M HCl. 6) Calculate the mass of this number of moles of HCl. 7) Calculate the mass of the water using your answers to (4) and (6). 8) Now write out the equilibrium showing the initial quantities.

Equilibrium moles	CH <sub>3</sub> COOH	9) Calculate how many moles of acid were present in the equilibrium mixture using your titration results (remember that it is a mixture of the CH <sub>3</sub> COOH left over and the HCl catalyst). 10) How many moles of HCl were present in the acid mixture (remember - you put in 5 cm <sup>3</sup> of 3 M HCl, and as it is a catalyst, it will all be present at equilibrium). 11) Use your answers to (9) and (10) to calculate how many moles of CH <sub>3</sub> COOH were in the mixture.
	CH <sub>3</sub> CH <sub>2</sub> OH	12) Calculate how many moles of CH <sub>3</sub> COOH had been used up in establishing the equilibrium (i.e. x, the difference between how many moles of CH <sub>3</sub> COOH there were initially and how many there were at equilibrium). 13) Calculate how many moles of CH <sub>3</sub> CH <sub>2</sub> OH were used up in establishing the equilibrium. 14) Calculate how many moles were left at equilibrium.
	CH <sub>3</sub> COOCH <sub>2</sub> CH <sub>3</sub>	15) Calculate how many moles of CH <sub>3</sub> COOCH <sub>2</sub> CH <sub>3</sub> were produced by looking at how many moles of CH <sub>3</sub> COOH and CH <sub>3</sub> CH <sub>2</sub> OH were used up.
	H <sub>2</sub> O	16) Calculate how many moles of H <sub>2</sub> O were produced by looking at how many moles of CH <sub>3</sub> COOH and CH <sub>3</sub> CH <sub>2</sub> OH were used up. 17) Calculate the total number of moles of H <sub>2</sub> O at equilibrium by adding the amount produced to the amount of H <sub>2</sub> O initially.

Calculating $K_c$	18) Now write out the equilibrium showing the equilibrium quantities. 19) Calculate the concentration of each species at equilibrium (use V for volume). 20) Write an expression for $K_c$ for this equilibrium. 21) Calculate $K_c$ , and state its value with units (stating the temperature for which it is valid).
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