1 Vinegar is used as a food preservative. It is an acidic solution containing ethanoic acid, CH_3COOH.

(a) A titration was carried out to measure the concentration of ethanoic acid in a sample of vinegar. 25.0 cm^3 of a vinegar solution was titrated with a solution of sodium hydroxide, concentration 0.250 mol dm^{-3}. The concentration of the ethanoic acid in the vinegar solution was found to be 0.125 mol dm^{-3}.

(i) Calculate the pH of 0.250 mol dm^{-3} sodium hydroxide at 298 K.

[$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 298 K.]

(2)

(ii) Write the expression for the acid dissociation constant, K_a, for ethanoic acid.

(1)

(iii) Calculate the pH of 0.125 mol dm^{-3} ethanoic acid at 298 K.

[K_a for ethanoic acid is 1.7×10^{-5} mol dm^{-3} at 298 K.]

(2)

(iv) When half the ethanoic acid is neutralized, the concentration of the remaining ethanoic acid equals the concentration of the sodium ethanoate which has formed. What is the pH of the mixture at this point? Justify your answer.

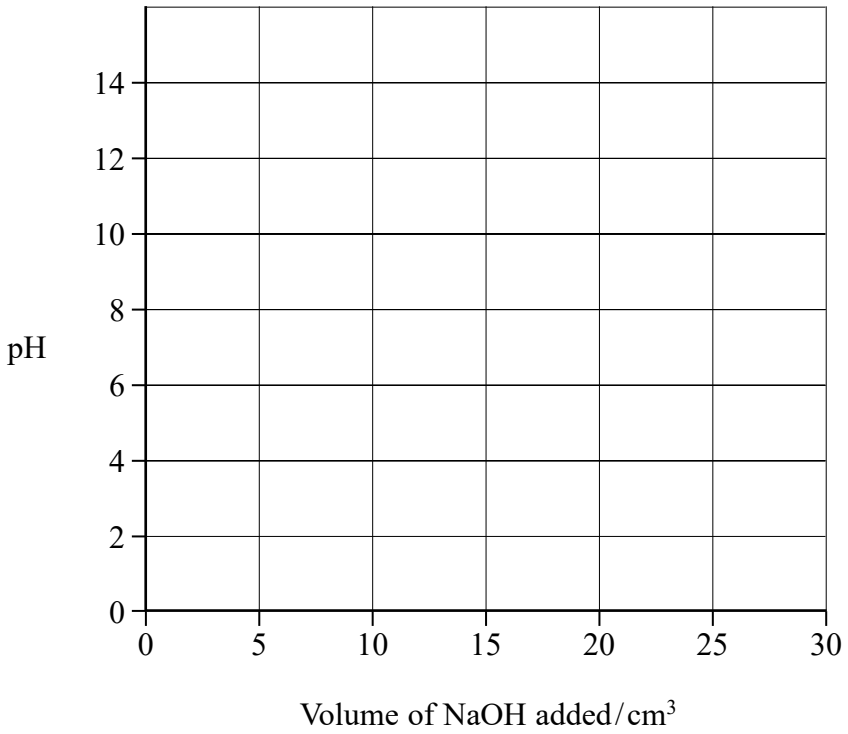
(2)

pH

Justification

(v) On the axes below, sketch the titration curve for this reaction when 30 cm^3 of the sodium hydroxide is added to 25.0 cm^3 of the vinegar solution.

(3)



*(vi) The only indicators which were available for this titration were methyl yellow (in ethanol) and thymolphthalein. Explain which indicator is more suitable for this titration and why the other is unsuitable. You will need to refer to your data booklet.

(2)

(b) In the food industry, ethanoic acid is described as an acidity regulator, additive number E260.

Ethanoic acid can neutralize alkalis. What substance could be mixed with ethanoic acid so that it regulates pH as a buffer in foodstuffs?

(1)

(Total for Question = 13 marks)

2 Methanoic acid, HCOOH, is present in ant stings.

A scientist analyzed 25.0 cm^3 of an aqueous solution of methanoic acid, solution **Z**, by titrating it with dilute sodium hydroxide, NaOH(aq).

- 20.0 cm^3 of sodium hydroxide was required to neutralize the methanoic acid
- The equation for the neutralization of methanoic acid is

$$HCOOH(aq) + NaOH(aq) \rightarrow HCOONa(aq) + H_2O(l)$$

(a) (i) Give the expression for K_w, the ionic product of water.

(1)

(ii) The concentration of the sodium hydroxide, NaOH(aq), used in the titration was 0.00750 mol dm^{-3}.

Calculate the pH of the sodium hydroxide solution.

[$K_w = 1.00 \times 10^{-14}$ $mol^2\,dm^{-6}$]

(2)

(b) Use the equation for the reaction and the data from the titration to show that the concentration of the methanoic acid in solution **Z** was 6.00×10^{-3} mol dm^{-3}.

(2)

(c) Methanoic acid is a weak acid.

(i) Explain the term **weak acid**.

(2)

Weak .....

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Acid .....

.....

(ii) The equation for the dissociation of methanoic acid in aqueous solution is shown below.

$$HCOOH(aq) \rightleftharpoons HCOO^-(aq) + H^+(aq)$$

Write the expression for the acid dissociation constant, K_a, for methanoic acid.

(1)

*(iii) At 298 K, the acid in ant stings has a concentration of 6.00×10^{-3} mol dm^{-3} and a pH of 3.01.

Calculate the value of K_a for methanoic acid at 298 K.

State clearly any assumptions that you have made.

(4)

Calculation:

Assumption(s):

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(Total for Question = 12 marks)

3 The bubble bath 'Colour Change Matey' has amongst its ingredients the weak acid benzoic acid, as well as the indicator bromocresol green. When it is added to bath water, its colour changes from yellow to blue.

(a) (i) Write the K_a expression for the dissociation of benzoic acid, C_6H_5COOH.

(1)

(ii) Use the data on page 18 of the data booklet to calculate the pH of a solution of benzoic acid, C_6H_5COOH, of concentration 0.0025 mol dm^{-3}.

(2)

*(b) Use the data on page 19 of the data booklet, and your answer to (a)(ii), to suggest why the bubble bath changes colour when it is diluted by being added to the bath water.

(4)

(Total for Question = 7 marks)

4 (a) Calculate the pH of 0.25 mol dm ^{3} hydrochloric acid.

(1)

(b) Propanoic acid, CH_3CH_2COOH, is a weak acid with K_a 1.3×10^{5} mol dm ^{3} at 25 °C.

(i) Write the expression for K_a for propanoic acid.

(1)

(ii) Calculate the pH of 0.25 mol dm ^{3} propanoic acid at 25 °C.

(2)

(c) During a titration, 10 cm^3 0.10 mol dm ^{3} sodium hydroxide was added to 10 cm^3 of 0.25 mol dm ^{3} propanoic acid.

(i) Write an equation for the reaction which occurs. State symbols are **not** required.

(1)

(ii) At this point the titration mixture contains 1.5×10^{3} moles of propanoic acid and 1.0×10^{3} moles of propanoate ion.

Use your expression for K_a for propanoic acid to calculate the pH of the mixture.

(2)

*(iii) When a further small amount of 0.10 mol dm ^{3} sodium hydroxide is added in the titration, the pH changes very little. Explain why the pH change is small.

(3)

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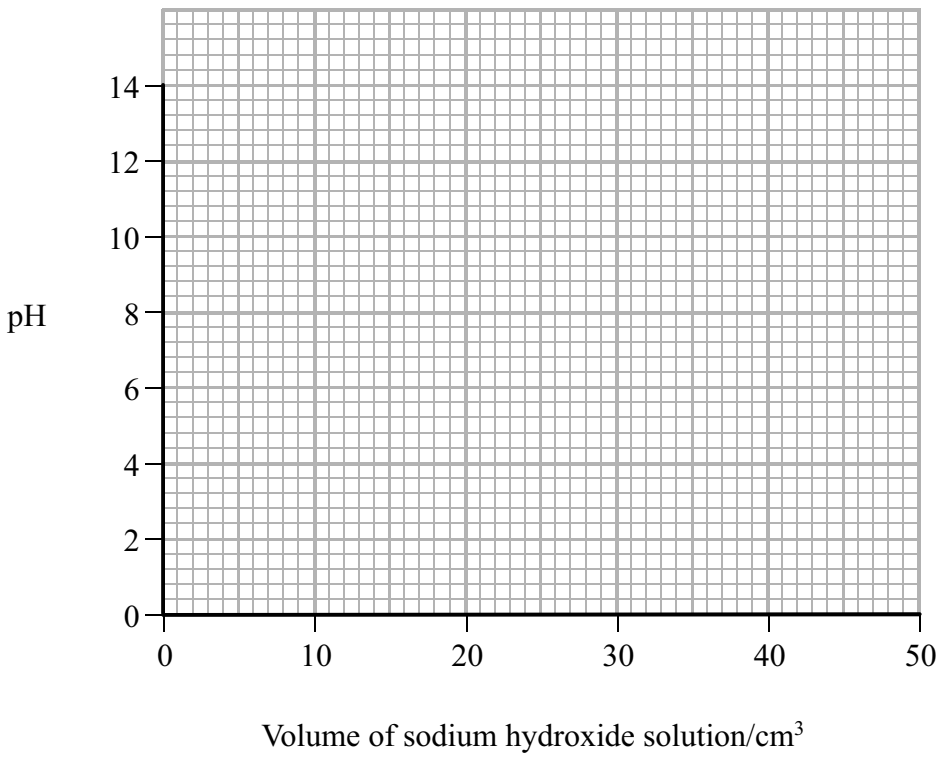
(iv) Draw the titration curve showing the change in pH when 0.10 mol dm ^{3} sodium hydroxide is added to 10 cm^{3} of 0.25 mol dm ^{3} propanoic acid until present in excess. The equivalence point is 25 cm^{3}.

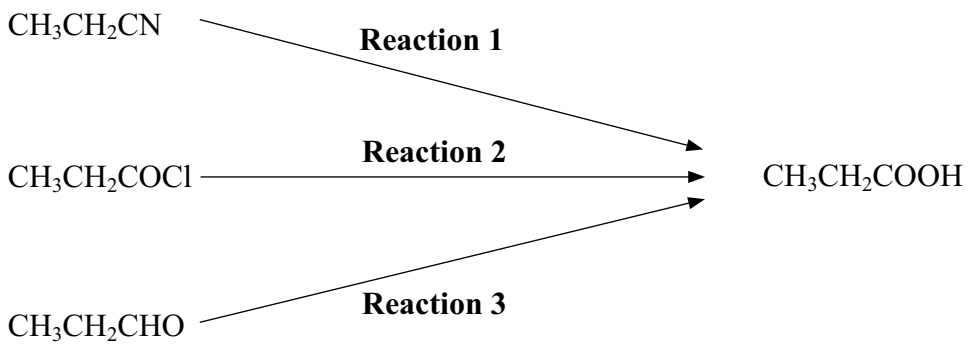
(3)



(v) Explain, referring to your data booklet, whether bromocresol green would be a suitable indicator for this titration.

(2)

(d) Propanoic acid is produced in the reactions shown below.



(i) Suggest a reagent which could be used to carry out **reaction 1**.

(1)

(ii) Write an equation for **reaction 2**. State symbols are **not** required.

(1)

(iii) What would be observed if **reaction 3** was carried out using potassium dichromate(VI) and sulfuric acid?

(1)

(e) What type of reagent would be used to convert propanoic acid to propan-1-ol? Identify a suitable reagent for this reaction.

(2)

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(Total for Question 20 marks)

5 (a) (i) Define **pH**.

(1)

(ii) Calculate the pH of 0.0100 mol dm^{-3} hydrochloric acid, which is a strong acid.

(1)

(b) Ethanoic acid is a weak acid with an acid dissociation constant, K_a, of value 1.75×10^{-5} mol dm^{-3} at 25 °C.

(i) Calculate the pH of 0.0100 mol dm^{-3} ethanoic acid at 25 °C, stating any ONE assumption that you have made.

(4)

Assumption

(ii) The pH of hydrochloric and of ethanoic acid at two different concentrations is given in the table.

	pH of 0.00100 mol dm^{-3} solution	pH of 0.000100 mol dm^{-3} solution
Hydrochloric acid	3.0	4.0
Ethanoic acid	3.9	4.4

In the case of hydrochloric acid, dilution by a factor of 10 increases the pH by one unit. Suggest why ethanoic acid behaves differently.

(2)

(c) Orange marmalade usually contains sodium citrate as a preservative. Together with the fruit in the marmalade, it forms a buffer solution which, at a suitable pH, inhibits mould growth.

(i) Define the term **buffer solution**.

(2)

(ii) What is the substance in the fruit that produces a buffer with sodium citrate?

(1)

(iii) Explain how a buffer solution works using this system or any other of your choice. Support your explanation with equations.

(4)

(Total for Question = 15 marks)