Core practical 9: Determine K_a for a weak acid

Objective

- To determine K_a for a weak acid

Safety

- Wear a lab coat and use eye protection.
- Tie long hair back.
- Sodium hydroxide solution is an irritant.

Specification links

- Practical techniques 1, 3, 4, 6, 11
- CPAC 1a, 2a, 2b, 3a, 4a, 4b

Procedure

1. Set up the datalogger to read the pH, or calibrate the pH meter.
2. Pipette 25.0 cm^3 of 0.1 mol dm^{-3} ethanoic acid solution into a 250 cm^3 conical flask.
3. Fill a burette with sodium hydroxide solution.
4. Add two or three drops of phenolphthalein to the conical flask.
5. Titrate the ethanoic acid with sodium hydroxide solution until the mixture *just* turns pink.
6. Pipette a further 25.0 cm^3 of 0.1 mol dm^{-3} ethanoic acid solution into the 250 cm^3 conical flask.
7. Record the pH of this solution.

Notes on procedure

- Explain to students that titre values should be recorded to 2 decimal places with the second figure being 0 or 5 only.
- Explain to students that the titration should be repeated until concordant results are obtained.

Answers to questions

1. Depends on students' findings but the pH should be 4.77; so $[H^+] = 1.7 \times 10^{-5}$ mol dm^{-3}
2. 1.7×10^{-5} mol dm^{-3}
3. Sources of uncertainty include inaccuracy of burette readings, and difficulty identifying the exact end-point. Read glassware from the bottom of the meniscus; use a white tile so you can see the colour change clearly.

Sample data

The pH of the solution will be 4.77, though students' results may vary.

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All the maths you need

- Use logarithms in relation to quantities that range over several orders of magnitude.
- Change the subject of an equation.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.

Equipment

- 100 cm^3 of 0.1 mol dm^{-3} ethanoic acid solution
- 100 cm^3 of 0.1 mol dm^{-3} sodium hydroxide solution
- datalogger and pH probe or pH meter
- stand, clamp and boss for pH probe
- 50 cm^3 burette
- burette stand
- 250 cm^3 conical flask
- 25 cm^3 pipette and filler
- phenolphthalein indicator

Procedure

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7. Record the pH of this solution.

Analysis of results

- Record the pH of the solution after the second addition of ethanoic acid.

Learning tips

- The ionisation of an acid is shown by:

  $HA_{(aq)} \rightleftharpoons H^+_{(aq)} + A^-_{(aq)}$

  Because there is an equilibrium set up, an equilibrium constant, K_a, can be written:

  $$K_a = \frac{[H^+][A^-]}{[HA]}$$

- The K_a value is an indication of acid strength. The larger the value of the K_a, the stronger the acid.
- The K_a of a weak acid can be measured by titrating a known volume of the acid against sodium hydroxide using phenolphthalein as an indicator. A further equal volume of acid is then added, and the pH of the resulting solution is measured. Because effectively half of the acid has been titrated:

  $[H^+] = [HA] = [A^-]$

  $[A^-]$ and [HA] can be cancelled in the K_a expression

  And so $K_a = [H^+]$

  The pH value of the combined solutions can be converted to $[H^+]$ to give a K_a value.

Questions

1. Use the pH of your solution to calculate $[H^+]$.
2. Calculate a value of K_a for ethanoic acid.
3. What are some of the sources of uncertainty in this experiment? What can you do to overcome them?

Exam-style questions

1. Folic acid behaves as a weak acid – it can be represented as HA.

   Write the equation for the ionisation of a weak acid HA in water. Write the terms *conjugate acid* and *conjugate base* under the relevant formulae for an acid–base pair in your equation.

   (2)

2.

   (a) Write the expression for the acidity constant K_a for the ionisation of folic acid.

   (1)

   (b) If $K_a = 5.0 \times 10^{-3}$ mol dm^{-3}, calculate pK_a.

   (1)

   (c) Calculate the pH of a 0.10 mol dm^{-3} solution of this acid.

   (2)

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- Wear a lab coat and use eye protection.
- Consult CLEAPSS Hazcards® 38A and 91. Perform a risk assessment using up-to-date information before this practical is carried out.

Equipment per student/group	Notes on equipment
100 cm^3 of 0.1 mol dm^{-3} ethanoic acid solution	Low hazard If prepared from fresh, remember that pure ethanoic acid is corrosive.
100 cm^3 of 0.1 mol dm^{-3} sodium hydroxide solution	Irritant
datalogger and pH probe or pH meter	
stand, clamp and boss for pH probe	
50 cm^3 burette	
burette stand	
250 cm^3 conical flask	
25 cm^3 pipette and filler	
phenolphthalein indicator	

Notes