InkChemistry

ANSWER BOOK

Titration curves and choosing an indicator

Acids and bases · Unit C11

AQA 3.1.12.5 · OCR A 5.1.3

14 questions · 49 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 TCCI-Q12

B1 away from equivalence the pH changes slowly, so large additions still give enough points to fix the curve. **B1** near equivalence one drop can change the pH by several units, so small additions are needed to put enough points on the vertical section to locate its middle. [2]

SECTION B · Standard, 3 to 5 marks

B1 TCCI-Q1

B1 at equivalence the first solution holds sodium chloride, and neither Na^+ nor Cl^- reacts with water. **B1** so $[H^+] = [OH^-]$ and the pH at equivalence is 7.00. **B1** with ammonia the salt is ammonium chloride, and NH_4^+ is a weak acid that donates protons to water. **B1** $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$ makes the solution acidic, about pH 5.3; an answer naming Cl^- as the cause is rejected. [4]

B2 TCCI-Q10

B1 the indicator is a weak acid in equilibrium: $HIn \rightleftharpoons H^+ + In^-$, and HIn and In^- have different colours. **B1** in acid the high $[H^+]$ keeps the equilibrium to the left, so the colour of HIn, red, is seen. **B1** as alkali removes H^+ the equilibrium shifts to the right, and the colour of In^-, yellow, takes over. **B1** the indicator is itself a weak acid, so a larger amount would react with the alkali and change the titre. [4]

B3 TCCI-Q14

B1 the hydrochloric acid curve starts at pH 1.00 and the ethanoic acid curve at a higher pH, 2.88. **B1** the ethanoic acid curve has a buffer region before equivalence, passing through pH 4.76 at half-neutralisation. **B1** the vertical section is shorter for ethanoic acid, about 7 to 10.5, against about 3.5 to 10.5 for hydrochloric acid. **B1** the equivalence pH is 7.00 for hydrochloric acid and about 8.7 for ethanoic acid, though both reach equivalence at the same volume and finish at the same pH. [4]

B4 TCCI-Q16

B1 after equivalence all the acid has reacted, and the pH is set by the concentration of excess OH^- from the sodium hydroxide. **B1** the OH^- formed by ethanoate ions reacting with water is negligible beside that excess. **M1** excess $OH^- = 1.00 \times 10^{-3}$ mol in 60.0 cm^3, so $[OH^-] = 0.0167$ mol dm^{-3} and $[H^+] = 6.00 \times 10^{-13}$ mol dm^{-3}. **A1** pH = 12.22 for both mixtures. [4]

B5 TCCI-Q19

B1 the hydrochloric acid curve starts lower, at pH 1.00, against 2.88 for ethanoic acid. **B1** the vertical section runs from about 3.5 to 7 with ammonia, but from about 7 to 10.5 with sodium hydroxide. **B1** the equivalence pH is about 5.3 with ammonia, below 7, and about 8.7 with sodium hydroxide, above 7. **B1** the ammonia curve levels off near pH 9.25, far below the 12.5 reached with sodium hydroxide; both reach equivalence at the same volume. [4]

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B6 TCCI-Q2 **B1** (a) phenolphthalein, whose range lies within the vertical section of about 7 to 10.5. **B1** (b) methyl orange, whose range lies within the vertical section of about 3.5 to 7. **B1** (c) neither, because a weak acid–weak base curve has no vertical section. [3]

B7 TCCI-Q7 **B1** at equivalence the solution contains sodium ethanoate. **B1** the ethanoate ion is the conjugate base of a weak acid and accepts protons from water: $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$. **B1** this produces OH^- ions, so $[OH^-] > [H^+]$ and the pH is above 7. [3]

B8 TCCI-Q8 **B1** at half-neutralisation half the HA has been converted to A^-, so $[HA] = [A^-]$. **B1** in $K_a = [H^+][A^-]/[HA]$ the two concentrations cancel, so $K_a = [H^+]$. **B1** taking -log of both sides gives $pK_a = pH$. [3]

B9 TCCI-Q13 **B1** a correct equivalence volume means the volume measurements were sound, and the error is in the pH readings. **B1** the pH meter was most likely not calibrated, or calibrated incorrectly, giving readings about 0.2 too high throughout. **B1** calibrate the meter with two buffers of known pH at the temperature of the titration immediately before use, and repeat. [3]

B10 TCCI-Q17 **B1** both the acid and the base are weak, so the pH changes gradually through equivalence, with no vertical section. **B1** any indicator therefore changes colour over several cubic centimetres, so no single drop marks the end point. **B1** follow the titration with a pH meter and take the equivalence volume where the curve is steepest; allow a conductivity meter. [3]

B11 TCCI-Q18 **M1** $[In^-]/[HIn] = K_{In} \div [H^+] = 10^{(-3.70)} \div 10^{(-4.40)} = 10^{0.70}$. **B1** In^- is five times HIn, so the yellow alkaline colour is seen; allow yellow-orange. **A1** $[In^-]/[HIn] = 5.01$, to three significant figures. [3]

B12 TCCI-Q20 **B1** the equivalence point lies above pH 7, at about pH 8 to 9, because the ethanoate ion formed is a weak base that accepts protons from water. **B1** the near-vertical part of the curve runs from about pH 7 to pH 11, and the whole range of phenolphthalein lies inside it, so its colour changes with one drop at the equivalence point. **B1** methyl orange changes colour at pH 3.1 to 4.4, in the buffer region where the pH is rising slowly, so it would change gradually and well before the equivalence volume; reject 'methyl orange is for strong acids' alone. [3]

SECTION C · Long, 6 marks or more

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C1 TCCI-Q11 **Indicative content** [6]

B1 calibrate the pH meter with buffer solutions of known pH, such as pH 7.00 and pH 4.00, rinsing the electrode with deionised water between them. **B1** pipette 25.0 cm^3 of the acid into a beaker, stir, and record the initial pH with the electrode bulb fully immersed. **B1** add sodium hydroxide from a burette in measured portions, recording the volume and the steady pH after each. **B1** use smaller additions, 0.10 cm^3 or dropwise, near the equivalence point, and continue past it to about twice the equivalence volume. **B1** plot pH against volume added and read the equivalence volume from the middle of the vertical section. **B1** read the pH at half the equivalence volume, which equals the pKa of ethanoic acid.

Levels

Level 3 (5–6 marks) all stages of the practical are described in a workable order, from calibrating the meter through the small additions near equivalence and continuing past it, the equivalence volume is read from the vertical section, and the pKa is read as the pH at half the equivalence volume.

Level 2 (3–4 marks) a pH meter and burette are used, the pH is recorded after each addition and the curve plotted, and the pKa is read at half equivalence; what is lost is the calibration, the smaller additions near the end point, or the readings beyond equivalence.

Level 1 (1–2 marks) sodium hydroxide is added and the pH noted; an indicator is often used in place of the meter, or the pKa is read at the equivalence point instead of half-way to it.

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