

2.3.5 Ion evidence and standard-solution transfer

Name: _____ Class: _____ Date: _____

Total: 30 marks

KEY WORDS standard solution

Objective

Combine separate tests, a non-unit mole ratio and measurement uncertainties without contaminating evidence. All questions and marking guidance are original.

1 Key knowledge and worked examples

A standard solution has an accurately known concentration. Use separate aliquots. Dilute acid releases CO_2 from carbonate/hydrogencarbonate; confirm the gas with limewater. Warm aqueous NaOH releases NH_3 from ammonium ions; damp red litmus turns blue and HCl gives white fumes. Neither test alone identifies both ions in a salt.

■ Worked standard-solution route

A solid acid H_2A reacts as $\text{H}_2\text{A} + 2\text{NaOH} \rightarrow \text{Na}_2\text{A} + 2\text{H}_2\text{O}$. Dissolve 1.260 g of H_2A , $M = 126.0 \text{ g mol}^{-1}$, and make to 250.0 cm^3 . $n = m/M = 1.260/126.0 = 0.01000 \text{ mol}$; $c = n/V = 0.01000/0.2500 = 0.04000 \text{ mol dm}^{-3}$. A 25.00 cm^3 aliquot contains 0.001000 mol acid and neutralises 0.002000 mol NaOH. Divide that alkali amount by its actual titre in dm^3 to find alkali concentration.

Indicators change colour within a pH interval. Methyl orange is red in acid/yellow in alkali; phenolphthalein is colourless in acid/pink in alkali. Use the method's endpoint, not a colour chosen because it looks stronger.

2 Practice

2.1 Write separate ionic equations for carbonate and hydrogencarbonate with acid. State the gas test, and explain why observing bubbles alone does not identify either anion uniquely. [4]

2.2 An unknown salt gives gas X with dilute acid. X turns limewater milky. A fresh aliquot gives gas Y with warm NaOH; Y turns damp red litmus blue and gives white fumes with HCl. State supported cation/anion conclusions, write two equations for Y, and explain why X does not distinguish carbonate from hydrogencarbonate. [5]

2.3 Hydrochloric acid is added from a burette to NaOH in a flask. Give the start-to-end colour change for methyl orange and for phenolphthalein. Explain why the flask may be rinsed with deionised water but the pipette must be rinsed with the NaOH solution before delivering its measured aliquot. [4]

3 Exam-style questions

3.1 A pure diprotic solid acid H_2A has $M = 126.0 \text{ g mol}^{-1}$. 1.575 g is made to 250.0 cm^3 . A 25.00 cm^3 aliquot needs 23.80 cm^3 NaOH. Write the equation and calculate the NaOH concentration. State two steps that prevent loss of acid while making the standard. [6]

3.2 In the preceding method, mass uncertainty is $\pm 0.002 \text{ g}$, flask uncertainty $\pm 0.12 \text{ cm}^3$, pipette uncertainty $\pm 0.06 \text{ cm}^3$ and each burette reading uncertainty $\pm 0.05 \text{ cm}^3$. Estimate the maximum overall percentage uncertainty in NaOH concentration. Identify the largest contribution and suggest a change that targets it without claiming repeats correct apparatus calibration. [5]

3.3 A student adds HCl, then AgNO_3 , to an unknown solution and calls the white precipitate proof that the unknown contains chloride. Explain the problem and give a valid fresh-aliquot method distinguishing chloride, bromide and iodide, including both ammonia strengths and the ionic precipitation equation. [6]

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

2.1 $\text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$; $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$. Pass gas into limewater: it becomes milky. Both anions release CO_2 , and other reactions can bubble, so this observation does not distinguish the two.

2.2 NH_4^+ is supported; carbonate or hydrogencarbonate is supported, not a unique choice. $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$; $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$. Both candidate anions give CO_2 with acid.

2.3 Methyl orange: yellow to the specified orange endpoint, becoming red with excess acid. Phenolphthalein: pink to just colourless. Flask water does not change the amount of NaOH already delivered; pipette water would dilute the solution before measuring/delivering it, reducing the alkali amount in the nominal aliquot.

3.1 $\text{H}_2\text{A} + 2\text{NaOH} \rightarrow \text{Na}_2\text{A} + 2\text{H}_2\text{O}$. $n(\text{acid}) = m/M = 1.575/126.0 = 0.01250 \text{ mol}$; $c = 0.01250/0.2500 = 0.05000 \text{ mol dm}^{-3}$. The aliquot has $0.05000 \times 0.02500 = 0.001250 \text{ mol}$ acid, requiring 0.002500 mol NaOH. $c(\text{NaOH}) = 0.002500/0.02380 = 0.1050 \text{ mol dm}^{-3}$. Dissolve fully before transfer and rinse all transferring vessels/funnel into the flask.

3.2 Mass contribution $100(0.002/1.575) = 0.127\%$; flask $100(0.12/250.0) = 0.048\%$; pipette $100(0.06/25.00) = 0.240\%$. Titre contribution $100(0.10/23.80) = 0.420\%$. Sum = 0.835% , about 0.84% . Burette/titre is largest. Use suitable more precise volume measurement, or a safely larger titre with appropriate concentrations and apparatus capacity. Repetition addresses random endpoint variation, not a calibration bias.

3.3 HCl introduces Cl^- and can itself cause AgCl , so the conclusion is invalid. On a fresh aliquot use dilute HNO_3 , then aqueous AgNO_3 . AgCl is white and dissolves in dilute NH_3 ; AgBr is cream, remains in dilute but dissolves in concentrated NH_3 ; AgI is yellow and remains in both. $\text{Ag}^+(\text{aq}) + \text{X}^-(\text{aq}) \rightarrow \text{AgX}(\text{s})$.