4.2 Reactions of acids and making salts

Name: _____ Class: _____ Date: _____ **Total: 48 marks**

KEY WORDS neutralisation • titration • strong acid

Objective

Predict salt products, describe salt preparation and titration, and use strong/weak acid ideas. Original questions for spec statements 4.4.2.1–4.4.2.6.

1 Key knowledge and worked examples

Neutralisation products: acid + alkali/base → **salt + water**; acid + carbonate → **salt + water + CO_2**. The acid sets the salt's negative ion – HCl → **chloride**, HNO_3 → **nitrate**, H_2SO_4 → **sulfate**; the base supplies the positive ion. magnesium + hydrochloric acid → magnesium chloride + hydrogen.

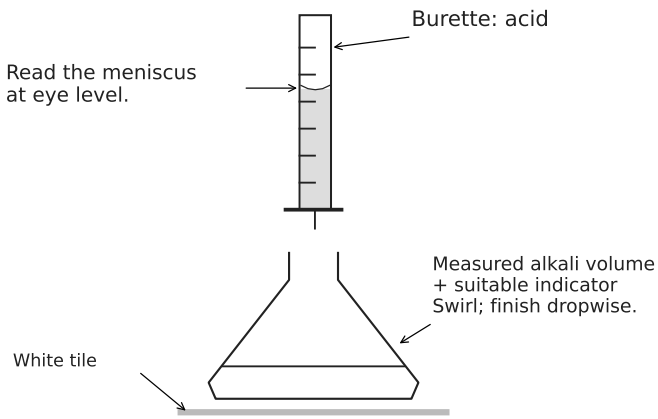
RP1 – pure dry salt from an insoluble base: warm dilute acid; add the insoluble oxide/carbonate **until no more reacts**; **filter** off excess; **evaporate** until crystals form on cooling; **dry** the crystals.

pH: acids < 7 give $\mathbf{H^+(aq)}$; alkalis > 7 give $\mathbf{OH^-(aq)}$; neutralisation is $\mathbf{H^+ + OH^- \rightarrow H_2O}$.

(Chem) RP2 titration: rinse and fill the burette with acid; pipette a fixed alkali volume using a filler; add suitable indicator; swirl and add dropwise near the endpoint. Read at eye level; titre = final − initial. Exclude the rough trial; average concordant accurate titres. (HT) compute concentrations (moles = C × V).

(HT) Strong vs weak: strong acids (HCl, HNO_3, H_2SO_4) **completely ionised**; weak (ethanoic, citric, carbonic) **partially**. Same concentration – stronger acid, lower pH. **pH down 1 unit = $[H^+] \times 10$.** Dilute/concentrated is about amount per volume – independent of strength.

Titre = final burette reading − initial burette reading



Worked example (3 marks, HT). pH 2 HCl has $[H^+] = 0.01$ mol/dm^3. What is $[H^+]$ at pH 4, and how does that compare for a weak acid of the same concentration?

pH 4 → $[H^+] = 0.0001$ mol/dm^3; each pH unit is a factor of 10, so 2 units = ÷100; a weak acid at the same concentration as a strong one is only partially ionised, so its $[H^+]$ is lower and its pH higher.

2 Practice

2.1 Name the salt formed from sulfuric acid and potassium hydroxide. [1]

2.2 Write the ionic equation for neutralisation. [1]

2.3 *(HT)* Give one example each of a strong acid and a weak acid. [2]

2.4 Solutions A, B and C have measured pH values 3, 7 and 11. Classify each as acidic, neutral or alkaline. Describe how universal indicator gives an approximate pH, and name an instrument that gives a numerical pH reading. [5]

3 Exam-style questions

3.1 Copper oxide reacts with dilute nitric acid. Write the word equation and describe how pure dry crystals of the salt are separated. [6]

3.2 A student claims both an acid and the water added to dilute it contain H^+ ions, so dilution does not change the pH. Explain the mistake. [3]

3.3 *(HT)* Explain why 0.1 mol/dm^3 ethanoic acid has a higher pH than 0.1 mol/dm^3 hydrochloric acid. [3]

3.4 Calcium carbonate reacts with nitric acid. Given Ca^{2+} and NO_3^-, deduce the salt formula and write a balanced equation. Explain why the gas here differs from the gas formed when magnesium reacts with dilute hydrochloric acid. *(HT)* For the magnesium reaction, identify the species oxidised and reduced in terms of electrons. [6]

3.5 A student wants pure dry copper(II) sulfate crystals from dilute sulfuric acid and copper(II) oxide. They add too little oxide, then try to filter out the remaining acid and boil the filtrate dry. Explain three errors and give the correct separation and drying stages. [6]

3.6 A pipette delivers 20.0 cm^3 NaOH to a flask. A burette contains sulfuric acid. Explain why a suitable indicator, a white tile, swirling and dropwise addition near the endpoint are used. Explain why rinsing the flask walls with distilled water does not change the titre needed. [5]

3.7 *(Chemistry HT)* Sulfuric acid reacts with 20.0 cm^3 of 0.100 mol/dm^3 NaOH. Accurate acid titres are 25.00, 24.90 and 25.10 cm^3; a rough titre is 26.20 cm^3. The stated concordance tolerance is 0.20 cm^3. Calculate the mean accurate titre and the acid concentration in mol/dm^3 and g/dm^3. Use $M(H_2SO_4) = 98$ g/mol and $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$. [6]

3.8 *(HT)* Solution P is dilute strong hydrochloric acid; solution Q is concentrated weak ethanoic acid. Can their names alone decide which has the lower pH? Explain. A measured solution R has pH 2 and S has pH 5. Compare their H^+ concentrations and explain why a neutral solution still contains ions. [4]

Solutions

2.1 Potassium sulfate.

2.2 $H^+ + OH^- \rightarrow H_2O$.

2.3 Strong – hydrochloric/nitric/sulfuric acid; weak – ethanoic/citric/carbonic acid.

2.4 A acidic, B neutral, C alkaline. Add universal indicator to a small sample and compare its colour with the indicator's chart. A suitable calibrated pH probe gives a numerical reading; a colour band does not justify invented decimal precision.

3.1 Copper oxide + nitric acid → copper nitrate + water. Warm the dilute nitric acid; add copper oxide until no more dissolves – excess proves all the acid has reacted; filter off the excess black solid; evaporate the filtrate to the crystallisation point and allow it to cool/crystallise; dry the crystals between filter paper/in a warm oven.

3.2 Dilution lowers the concentration of H^+ ions – the same amount of acid in more water; pH measures H^+ concentration, not presence; so pH rises toward 7 as the solution is diluted.

3.3 Ethanoic acid is a weak acid – only partially ionised in water; so its H^+ concentration is lower than hydrochloric's at the same 0.1 mol/dm^3; hydrochloric acid ionises completely, so it has the higher $[H^+]$ and the lower pH.

3.4 $Ca(NO_3)_2$, since two singly negative nitrate ions balance one Ca^{2+}. $CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$. Carbonate produces CO_2, whereas magnesium with hydrochloric acid produces H_2. HT: magnesium loses electrons and is oxidised; H^+ ions gain electrons to form H_2 and are reduced.

3.5 Too little oxide leaves acid: add oxide until some remains unreacted. Dissolved acid passes through filter paper; filtering removes the excess insoluble oxide. Boiling dry is not the crystallisation method: gently concentrate without drying out, then cool to crystallise. Filter and wash crystals with a little cold distilled water; dry between filter papers.

3.6 A suitable indicator changes colour close to the endpoint; a white tile makes the change easier to see. Swirling mixes the added acid with the alkali; dropwise addition limits overshooting. Distilled water adds no alkali, so the reacting amount and required acid titre stay the same.

3.7 Exclude the rough result. The three accurate titres span the permitted 0.20 cm^3.

$$\bar{V} = \frac{V_1 + V_2 + V_3}{3} = \frac{25.00 + 24.90 + 25.10}{3}\ \text{cm}^3 = 25.00\ \text{cm}^3$$

Mean 25.00 cm^3.

$$n(\text{NaOH}) = cV = (0.100\ \text{mol/dm}^3)(0.0200\ \text{dm}^3) = 0.00200\ \text{mol}$$

Known amount.

$$n(H_2SO_4) = \frac{n(\text{NaOH})}{2} = \frac{0.00200\ \text{mol}}{2} = 0.00100\ \text{mol}$$

Equation ratio.

$$c = \frac{n}{V} = \frac{0.00100\ \text{mol}}{0.02500\ \text{dm}^3} = 0.0400\ \text{mol/dm}^3$$

Acid concentration.

$$c_m = cM = (0.0400\ \text{mol/dm}^3)(98\ \text{g/mol}) = 3.92\ \text{g/dm}^3$$

Mass concentration. The 1:2 mole ratio is essential; equal volumes would not imply equal concentrations.

3.8 No: concentration and degree of ionisation both affect H^+ concentration; the labels do not give enough numerical information. Strong/weak describes degree of ionisation, whereas dilute/concentrated describes amount per volume. R has $10^{5-2} = 1000$ times S's H^+ concentration. Neutrality means a balance of H^+ and OH^-, not no ions.