Section Four Structured questions

Suggested Answer

1 a) Magnesium dissolves. / Gas bubbles are given off. (1)

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ (1)

b) Iron(II) hydroxide dissolves. / A pale green solution is formed. (1)

$Fe(OH)_2(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + 2H_2O(l)$ (1)

c) Effervescence occurs. / Gas bubbles are given off. (1)

$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$ (1)

d) A pale blue precipitate is formed. / The blue copper(II) sulphate solution becomes paler. (1)

$2NaOH(aq) + CuSO_4(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$ (1)

e) A white precipitate is formed. (1)

$CaCl_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2NaCl(aq)$ (1)

f) A green precipitate is formed. / The green nickel(II) sulphate solution becomes paler.(1)

$Na_2CO_3(aq) + NiSO_4(aq) \rightarrow NiCO_3(s) + Na_2SO_4(aq)$ (1)

g) A white precipitate is formed. (1)

$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ (1)

2 a) Sodium hydrogencarbonate (1)

When sodium hydrogencarbonate is heated, it is decomposed and carbon dioxide is given off which makes the cake rise. (1)

$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$ (1)

b) Dilute sulphuric acid (1)

Rust (iron(III) oxide) dissolves in dilute sulphuric acid. (1)

$Fe_2O_3(s) + 3H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + 3H_2O(l)$ (1)

c) Sodium chloride solution (1)

Chloride ions react with silver ions to form insoluble silver chloride which can be removed by filtration. (1)

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ (1)

d) Sodium hydroxide solution (1)

Sodium hydroxide solution reacts with iron(II) sulphate solution and iron(III) sulphate solution to form green and brown precipitates respectively. (1)

$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ (dirty green precipitate) (1)

$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$ (brown precipitate) (1)

3 When ammonia solution is added to each of them separately, coloured precipitate or white precipitate will be formed. Some of them can be identified by their characteristic colours.

Iron(II) nitrate solution will form a green precipitate (1)

and copper(II) nitrate solution will form a pale blue precipitate with ammonia solution. (1)

$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ (green precipitate) (1)

$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ (pale blue precipitate) (1)

Both zinc nitrate solution and lead(II) nitrate solution will form white precipitate with ammonia solution. (1)

$Zn^{2+}(aq) + 2OH^{-}(aq) \rightarrow Zn(OH)_2(s)$ (white precipitate) (1)

$Pb^{2+}(aq) + 2OH^{-}(aq) \rightarrow Pb(OH)_2(s)$ (white precipitate) (1)

However, zinc hydroxide will redissolve in excess ammonia solution to give a colourless solution while lead(II) hydroxide does not. (1)

4 a) Nitrogen dioxide: brown (1)

Copper(II) hydroxide: blue (1)

b) Potassium hydroxide (1)

Potassium hydroxide is soluble in water while the other two solids are not. The solution contains hydroxide ions and thus is an alkaline solution. (1)

c) Carbon dioxide (1)

Nitrogen dioxide (1)

d) Carbon dioxide:

Adding calcium carbonate to dilute hydrochloric acid / Heating calcium carbonate (1)

Ammonia:

Heating an ammonium compound (e.g. NH_4Cl) with an alkali (e.g. NaOH) (1)

e) Ammonia gas turns moist pH paper (or moist red litmus paper) blue. (1)

f) Add a piece of pH paper (or a few drops of universal indicator) to each solution. (1)

1 M potassium hydroxide solution has a higher pH value than 1 M ammonia solution. (1)

It is because ammonia solution is a weak alkali while potassium hydroxide solution is a strong alkali. / Ammonia does not react with water completely. Only very few hydroxide ions are present in ammonia solution. Potassium hydroxide completely ionizes to give hydroxide ions in water. (1)

or, Measure the electrical conductivity of the solutions.

1 M potassium hydroxide solution has a higher electrical conductivity than 1 M ammonia solution.

It is because ammonia solution is a weak alkali while potassium hydroxide solution is a strong alkali. / Ammonia does not react with water completely. Only very few hydroxide ions are present in ammonia solution. Potassium hydroxide completely ionizes to give hydroxide ions in water.

g) A lot of heat energy is released when vinegar reacts with potassium hydroxide solution. (1)

This will cause skin burn. (1)

Proper action:

Wash the hand with a large amount of water. (1)

5 a) $Mg(s) + 2H^{+}(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ (1)

b) Using syringe / By displacement of water (1)

c) By comparing the volume of gas given off per unit time (1)

d) To ensure a fair comparison. (1)

e) Sodium reacts explosively with acid. (1)

f) i) 0.0010 M HCl = 0.10 M ethanoic acid < 0.10 M HCl (1)

The concentration of hydrogen ions is related to the pH value of an acid. The lower the pH value, the higher the concentration of hydrogen ions and the faster the acid reacts with magnesium. (1)

ii) Strength of acid and (1)

concentration of acid used (1)

g) Use a pipette to transfer 25.0 cm^3 of 0.10 M hydrochloric acid into a 250.0 cm^3 volumetric flask. (1)

Then add distilled water to the graduation mark. (1)

The resulting solution is 0.010 M hydrochloric acid.

Repeat the above procedures for 0.010 M hydrochloric acid. 0.0010 M hydrochloric acid will be obtained. (1)

6 a) The pH paper would turn red. (1)

b) Use pH meter / universal indicator / data-logger with pH sensor. (1)

c) i) An acid which partially ionizes (1)

to give hydrogen ions in water. (1)

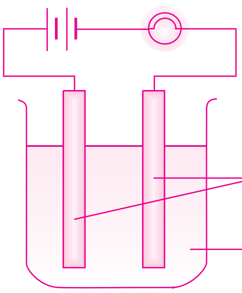
ii) It is a weak acid. (1)

d) Baking powder dissolves. (1)

Effervescence occurs. / Gas bubbles are given off. (1)

e) $CH_3COOH(aq) + NaHCO_3(s) \rightarrow CH_3COONa(aq) + CO_2(g) + H_2O(l)$ (1)

f) i)



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ii) Yes. (1)

Aqueous solution of ethanoic acid contains mobile ions. It can conduct electricity. It is also decomposed in the process. (1)

7 a) A: Zinc (1)

B: Zinc oxide (1)

C: Zinc sulphate (1)

D: hydrogen (1)

E: Zinc hydroxide (1)

b) i) $2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$ (1)

ii) $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$ / $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

(1)

iii) $Zn^{2+}(aq) + 2OH^{-}(aq) \rightarrow Zn(OH)_2(s)$ (1)

c) Carbon reduction (1)

d) Gas D gives a 'pop' sound with a burning splint. (1)

8 a) i) Copper(II) hydroxide (1)

ii) $Cu(OH)_2(s) + 2H^{+}(aq) \rightarrow Cu^{2+}(aq) + 2H_2O(l)$ (1)

b) i) Copper(II) carbonate / $CuCO_3$ (1)

ii) $Cu^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CuCO_3(s)$ (1)

iii) $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$ (1)

c) i) Copper(II) sulphate solution (1)

ii) $Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$ /
$CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$ (1)

iii) (1) Dilute sulphuric acid (1)

(2) $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$ (1)

d) Warm copper(II) sulphate solution (solution D) to obtain a concentrated (or saturated) solution. (1)

Cool the solution slowly, large crystals of copper(II) sulphate are obtained. (1)

Filter the mixture. (1)

Wash the crystals with a small amount of cold distilled water and dry them with filter paper. (1)

9 a) Cation in X: copper(II) ion

It gives a bluish-green flame in flame test and gives a blue precipitate, copper(II) hydroxide, with dilute sodium hydroxide solution. (1)

$Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$ (1)

Cation in Y: ammonium ion

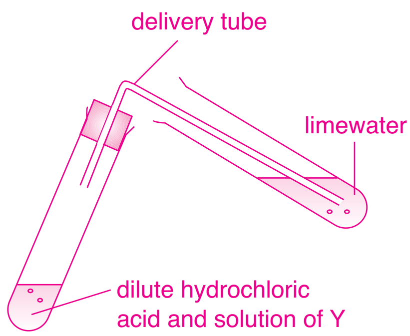
It gives ammonia gas when heated with dilute sodium hydroxide solution. (1)

$NH_4^{+}(aq) + OH^{-}(aq) \rightarrow NH_3(g) + H_2O(l)$ (1)

b) i) $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ (1)

ii) X is $CuSO_4$. (1)

c) i)



(2)

ii) The gas given off is carbon dioxide. (1)

$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$ (1)

iii) Y is $(NH_4)_2CO_3$. (1)

$CO_3^{2-}(aq) + 2H^{+}(aq) \rightarrow CO_2(g) + H_2O(l)$ (1)

10 a) Reason: Citric acid crystals do not give hydrogen with magnesium because water must be present for an acid to show its acidic properties. (1)

Suggest method: Add water to dissolve the citric acid crystals. / Use dilute hydrochloric acid. (1)

b) Reason: Sodium hydroxide is very corrosive. (1)

Suggest method: Use calcium hydroxide. (1)

c) Reason: Concentrated sulphuric acid absorbs moisture from the air and thus cannot be weighed accurately. (1)

Suggest method: Use solid ethanedioic acid to prepare the standard solution. / Standardize the sulphuric acid prepared before use. (1)

11 a) i) Copper(II) sulphate solution and sodium carbonate solution. (1)

ii) $Cu^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CuCO_3(s)$ (1)

iii) Mix copper(II) sulphate solution with sodium carbonate solution. Separate the insoluble copper(II) carbonate from the mixture by filtration. (1)

Wash the insoluble salt with distilled water several times. Dry the salt with filter paper. (1)

b) i) Copper(II) sulphate solution. (1)

ii) $Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$ (1)

iii) Number of moles of $Pb^{2+}(aq) = 0.250 \text{ mol dm}^{-3} \times 0.100 \text{ dm}^3$

$= 0.0250$ mol (1)

Molar mass of $PbSO_4 = (207.2 + 32.1 + 4 \times 16.0) \text{ g mol}^{-1}$

$= 303.3 \text{ g mol}^{-1}$ (1)

Mass of $PbSO_4 = 0.0250 \text{ mol} \times 303.3 \text{ g mol}^{-1}$

$= 7.58$ g (1)

c) Lead(II) carbonate / lead(II) chloride / magnesium carbonate (1)

12 a) i) "heated": The acid is heated so that copper(II) oxide can react with the acid readily / to speed up the reaction. (1)

"with stirring": The copper(II) oxide is uniformly distributed throughout the acid for a fast and complete reaction. (1)

"in excess": To make sure that all acid has been reacted. (1)

"cool": This allows the concentrated filtrate to lose heat and hence copper(II) sulphate crystals form. (1)

"without heating": To prevent the loss of water of crystallization from hydrated copper(II) sulphate crystals. (1)

ii) (1) Larger crystals would form. (1)

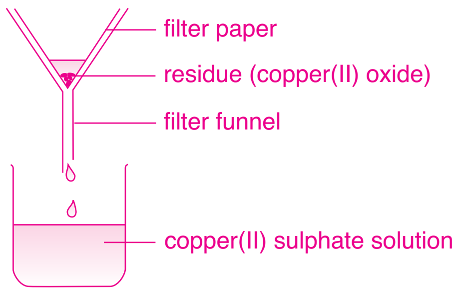
(2) Smaller crystals would form. (1)

iii) $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$ (1)

The black solid dissolved. (1)

The solution changed from colourless to blue. (1)

iv)



(1 mark for correct set-up; 1 mark for labelling filter funnel and filter paper) (2)

v) The filtrate was not saturated (concentrated enough). (1)

b) A pale blue precipitate is initially formed when ammonia solution is added. (1)
When excess ammonia solution is added, the pale blue precipitate dissolves to give a deep blue solution. (1)

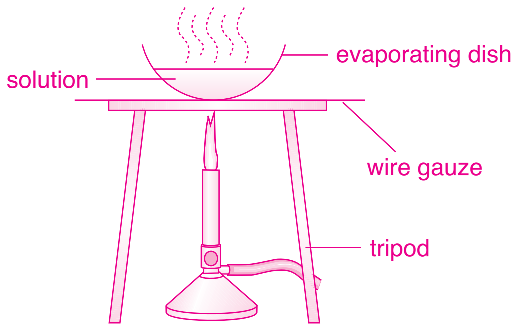
13 a) It refers to a salt containing water of crystallization. (1)

b) $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$ (1)

c) To make sure all the hydrochloric acid has been reacted. (1)

d) When no more gas bubbles were given off. (1)

e)



(2)

f) This will boil away all the water and hydrated salt cannot be prepared. (1)
Moreover, some impurities may be trapped in the salt. (1)

g) To remove any soluble impurities. (1)

h) No. of moles of HCl= 2.0 mol $dm^{-3} \times 0.100\ dm^3$
= 0.20 mol
According to the equation, 2 moles of HCl gives 1 mole of $CaCl_2$.
No. of moles of $CaCl_2 \bullet 6H_2O$ = 0.20 mol ÷ 2
= 0.10 mol (1)
Molar mass of hydrated calcium chloride= $[40.1 + 2 \times 35.5 + 6 \times (16.0 + 2 \times 1.0)]$ g mol^{-1}
= 219.1 g mol^{-1} (1)
Mass of hydrated calcium chloride obtained = 0.10 mol × 219.1 g mol^{-1}
= 22 g (1)

14 a) Inappropriate, there is no reaction between copper and dilute hydrochloric acid. (1)
Suitable reagents:
copper(II) oxide / copper(II) hydroxide / copper(II) carbonate + dilute hydrochloric acid (1)

Equation:

$CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$
/ $Cu(OH)_2(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + 2H_2O(l)$
/ $CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$ (1)

b) Inappropriate, calcium carbonate reacts with dilute sulphuric acid to form insoluble calcium sulphate on the surface of calcium carbonate which prevents further reaction. (1)

Suitable reagents:
calcium nitrate solution + sodium sulphate solution (1)
(Any soluble calcium salt + any soluble sulphate are acceptable.)
Equation:
$Ca(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2NaNO_3(aq)$ (1)

c) Appropriate, $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ (1)

d) Inappropriate, there is no reaction between zinc nitrate solution and sodium sulphate solution. (1)
Suitable reagents:
zinc / zinc oxide / zinc carbonate + dilute sulphuric acid (1)
Equation:
$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$
/ $ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l)$
/ $ZnCO_3(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l) + CO_2(g)$ (1)

e) Inappropriate, potassium reacts explosively with dilute hydrochloric acid. (1)
Suitable reagents:
dilute potassium hydroxide solution and dilute hydrochloric acid (using titration method) (1)
Equation:
$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$ (1)

15 a) i) $NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l)$ (1)

ii) No. of moles of HNO_3 $= 0.120\ mol\ dm^{-3} \times 0.150\ dm^3$
$= 0.0180\ mol$ (1)
According to the equation, 1 mole of NaOH reacts with 1 mole of HNO_3.
Volume of NaOH used $= 0.0180\ mol \div 0.200\ mol\ dm^{-3}$
$= 0.0900\ dm^3\ (90.0\ cm^3)$ (1)

b) i) Ammonia solution is a weak alkali while sodium hydroxide solution is a strong alkali. (1)

ii) $NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$ (1)

iii) No. The volume of ammonia solution used is the same as the volume of sodium hydroxide solution used. (1)

c) The heat released in the neutralization between ammonia solution and nitric acid is less than that between sodium hydroxide solution and nitric acid. (1)

16 a) A solution of known concentration. (1)

b) Weigh an empty dry weighing bottle accurately. Add about 1.575 g of oxalic acid crystals to the bottle. Weigh the weighing bottle and the solid accurately. (1)

Tip out the solid into a beaker as much as possible. Reweigh the weighing bottle and any remaining solid accurately. (1)

Dissolve the acid crystals in 100 cm^3 of distilled water in a beaker. (1)

After dissolving, transfer the solution into a 250.0 cm^3 volumetric flask. Add distilled water to the flask until the meniscus reaches the graduation mark. Stopper the flask and shake. (1)

c) i) Pipette (1)

ii) It should be washed with distilled water first and then with the standard solution of oxalic acid. (1)

d) i) The colour changed from colourless to pink. (1)

ii) To make the observation of the colour change of the indicator at the end point easier. (1)

iii) Number of moles of oxalic acid in 25.0 cm^3 solution

$= 0.0500 \text{ mol dm}^{-3} \times 0.0250 \text{ dm}^3$

$= 1.25 \times 10^{-3}$ mol (1)

Number of mole of KOH

$= 0.112 \text{ mol dm}^{-3} \times 0.0224 \text{ dm}^3$

$= 2.51 \times 10^{-3}$ mol (1)

Basicity of oxalic acid $= \dfrac{2.51 \times 10^{-3}}{1.25 \times 10^{-3}} = 2$ (1)

iv) $2KOH(aq) + H_2C_2O_4(aq) \rightarrow K_2C_2O_4(aq) + 2H_2O(l)$ (1)

17 a) i) Magnesium hydroxide in antacid neutralizes the excess hydrochloric acid in the stomach. (1)

$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$ (1)

ii) Calcium carbonate reacts with hydrochloric acid to give carbon dioxide gas. (1)

The gas builds up pressure in the stomach and causes discomfort. (1)

iii) Chewing breaks down the tablets into smaller pieces. This increases the surface area of the tablets and thus increases the reaction rate (brings faster relief of pain). (1)

b) i) The metal ions may poison aquatic lives. (1)

ii) Copper(II) ions can be removed by adding sodium hydroxide solution into the waste solution. Insoluble copper(II) hydroxide is formed. (1)

The precipitate is then removed by filtration. (1)

$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ (1)

iii) To recover copper metal. (1)

iv) $2HCl(aq) + Ca(OH)_2(s) \rightarrow CaCl_2(aq) + 2H_2O(l)$

No. of moles of $Ca(OH)_2$ used $= 300 \text{ g} \div [40.1 + 2 \times (16.0 + 1.0)] \text{ g mol}^{-1}$

$= 4.05$ mol (1)

No. of moles of HCl in waste solution $= 4.05 \text{ mol} \times 2$

= 8.10 mol (1)

Rate of discharged of waste solution = 8.10 mol min^{-1} ÷ 0.15 mol dm^{-3}

= 54 dm^3 min^{-1} (1)

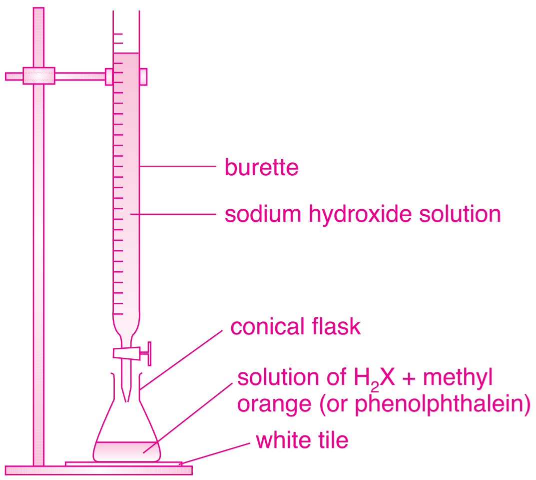
18 a) Dibasic acid is an acid that can produce two ionizable hydrogen ions per molecule. (1)

Example: sulphuric acid. (1)

b) $H_2X(aq) + 2NaOH(aq) \rightarrow Na_2X(aq) + 2H_2O(l)$ (1)

c) Methyl orange: from red to yellow / Phenolphthalein: from colourless to pink (2)

d)



(1+1/2 mark for correct titration set-up; 1/2 mark for each correct label of apparatus) (3)

e) Volume: [(32.70 - 0.50) + (40.80 - 8.80) + (45.40 -13.60)] cm^3 ÷ 3 = 32.0 cm^3 (1)

f) No. of moles of NaOH used in titration = 0.450 mol dm^{-3} × 0.0320 dm^3

= 1.44 × 10^{-2} mol

According to the equation, 1 mole of H_2X requires 2 moles of NaOH for complete neutralization.

No. of moles of H_2X in 25.0 cm^3 solution = 1.44 × 10^{-2} mol ÷ 2

= 7.20 × 10^{-3} mol (1)

No. of moles of H_2X in 250.0 cm^3 solution = 10 × 7.20 × 10^{-3} mol

= 7.20 × 10^{-2} mol (1)

Molar mass of H_2X = 14.04 g ÷ (7.20 × 10^{-2}) mol

= 195 g mol^{-1} (1)

19 a) i) $Na_2CO_3(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + CO_2(g) + H_2O(l)$ (1)

ii) No. of moles of HNO_3 = 2.00 mol dm^{-3} × 0.0312 dm^3

= 0.0624 mol

According to the equation, 1 mole of Na_2CO_3 requires 2 moles of HNO_3 for complete reaction.

No. of moles of Na_2CO_3 = 0.0624 mol ÷ 2

= 0.0312 mol (1)

Mass of Na_2CO_3 in the sample= 0.0312 mol × (23.0 × 2 + 12.0 + 16.0 × 3) g mol^{-1}

= 3.31 g (1)

Percentage purity of the sample = (3.31 g ÷ 7.50 g) × 100%

= 44.1% (1)

iii) The impurities are insoluble in water. / The impurities do not react with nitric acid. (1)

b) i) $Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$ (1)

ii) The colour changed from yellow to red. (1)

iii) No. of moles of H_2SO_4 = $0.100 \text{ mol dm}^{-3} \times 0.0270 \text{ dm}^3$

= 2.70×10^{-3} mol

According to the equation, 1 mole of Na_2CO_3 requires 1 mole of H_2SO_4 for complete reaction.

No. of moles of Na_2CO_3 in 25.0 cm^3 of solution = 2.70×10^{-3} mol

No. of moles of $Na_2CO_3 \bullet nH_2O$ in the sample = $10 \times 2.70 \times 10^{-3}$ mol

= 2.70×10^{-2} mol (1)

Molar mass of $Na_2CO_3 \bullet nH_2O$ = $3.35 \text{ g} \div 2.70 \times 10^{-2}$ mol

= 124 g mol^{-1}

$23.0 \times 2 + 12.0 + 16.0 \times 3 + n(16.0 + 1.0 \times 2) = 124$ (1)

n = 1 (1)

iv)
- The funnel had not been removed.
- The burette was not set up vertically.
- A white tile should be placed under the conical flask to make the observation of colour change of the indicator at the end point easier. (1×3)

20 a) Weak acid is an acid which partially ionizes in water to give hydrogen ions. (1)

b) Measure the pH value of these two acids. (1)

0.1 M citric acid has a higher pH value than 0.1 M hydrochloric acid. (1)

or, Dip two carbon electrodes into each acid and connect the electrodes to a d.c. supply with a light bulb in the circuit. Compare the brightness of the light bulbs.

0.1 M hydrochloric acid has better electrical conductivity than 0.1 M citric acid and makes the light bulb brighter.

or, Compare the degree of vigor of their reactions with magnesium.

Hydrochloric acid is a strong acid. 0.1 M hydrochloric acid has a higher concentration of hydrogen ions than 0.1 M citric acid. Therefore, magnesium reacts with 0.1 M hydrochloric acid faster than with 0.1 M citric acid.

c) There will be no observable change. (1)

Citric acid does not ionize to give hydrogen ions in methylbenzene. (1)

d) i) It refers to the maximum number of hydrogen ions produced by an acid molecule. (1)

ii) 3 (1)

e) i) No. of moles of citric acid = $0.200 \text{ mol dm}^{-3} \times 0.100 \text{ dm}^3$

= 0.0200 mol

Molar mass of citric acid= $[12.0 \times 6 + 1.0 \times 8 + 16.0 \times 7] \text{ g mol}^{-1}$

= 192.0 g mol^{-1} (1)

Mass of citric acid required = $0.0200 \text{ mol} \times 192.0 \text{ g mol}^{-1}$

= 3.84 g (1)

ii) Let the formula of citric acid be H_3A.

$H_3A(aq) + 3KOH(aq) \rightarrow K_3A(aq) + 3H_2O(l)$

No. of moles of H_3A = $0.200\ mol\ dm^{-3} \times 0.0250\ dm^3$

= 0.00500 mol

No. of moles of KOH = 3×0.00500 mol

= 0.0150 mol (1)

Volume of KOH used = $0.0150\ mol \div 0.460\ mol\ dm^{-3}$

= $0.0326\ dm^3$ ($32.6\ cm^3$) (1)

21 a) $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$ (1)

b) i) Conical flask (1)

ii) It should be washed with distilled water only. (1)

c) No. of moles of HCl = $0.220\ mol\ dm^{-3} \times 0.0244\ dm^3$

= 0.00537 mol

Molarity of ammonia = $0.00537\ mol \div 0.0250\ dm^3$

= $0.215\ mol\ dm^{-3}$ (1)

Concentration of ammonia = $0.215\ mol\ dm^{-3} \times (14.0 + 1.0 \text{ x } 3)\ g\ mol^{-1}$

= $3.66\ g\ dm^{-3}$ (1)

d) Mass of NH_3 in brand X = $3.96\ g\ dm^{-3} \times 0.2\ dm^3$

= 0.792 g

Price per gram of NH_3 = $4 ÷ 0.792

= $5.05 (1)

Mass of NH_3 in brand Y = $3.66\ g\ dm^{-3} \times 0.5\ dm^3$

= 1.83 g

Price per gram of NH_3 = $8 ÷ 1.83

= $4.37 (1)

Brand Y is better buy. (1)

e) Ammonia solution is volatile (will not leave stain on glass). / Sodium hydroxide solution is corrosive to skin (can attack glass). (1)

22 a) i) Nitric acid (1)

Sodium hydroxide solution (1)

ii) It is because sodium hydroxide, nitric acid and sodium nitrate are soluble in water. (1)

b) i) Lead(II) nitrate solution (1)

Potassium bromide solution (1)

(Any soluble lead(II) compound and bromide compound are acceptable.)

ii) It is because the reactants ($PbNO_3$ and KBr) are soluble in water and the product ($PbBr_2$) is an insoluble salt which can be easily separated from the reaction mixture. (1)

iii) Filter the product from the reaction mixture. (1)

Wash the residue with distilled water. (1)

Dry the residue with filter paper, under a lamp or use air-dry. (1)

23 a) Adding a few drops of phenolphthalein (or methyl orange) to the conical flask. (1)

The indicator changes from colourless to pink (or from red to yellow) at the end point. (1)

b) To save chemicals. (1)

c) $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

No. of moles of NaOH used $= 1.00 \text{ mol dm}^{-3} \times 0.0206 \text{ dm}^3$

$= 0.0206 \text{ mol}$

According to the equation, 1 mole of H_2SO_4 requires 2 moles of NaOH for complete neutralization.

No. of moles of H_2SO_4 in 25.0 cm^3 of diluted cleaner

$= 0.0206 \text{ mol} \div 2$

$= 0.0103 \text{ mol}$ (1)

Molarity of H_2SO_4 in the drain cleaner

$= \frac{1000.0}{25.0} \times 0.0103 \text{ mol} \div 0.0250 \text{ dm}^3$

$= 16.5 \text{ M}$ (1)

Concentration of sulphuric acid in the cleaner

$= 16.5 \text{ mol dm}^{-3} \times (1.0 \text{ x } 2 + 32.1 + 16.0 \times 4) \text{ g mol}^{-1}$

$= 1\ 620 \text{ g dm}^{-3}$ (1)

d) It may cause corrosion to iron drainage pipes. / A large amount of heat will be released in the dilution of concentrated sulphuric acid. This may cause deforming of plastic pipes. (1)

e) Wear protective gloves. / Wear safety goggles. (1)

It is because concentrated sulphuric acid is highly corrosive. (1)

f) Wash the burette with distilled water, (1)

and then with 1.00 M sodium hydroxide solution. (1)

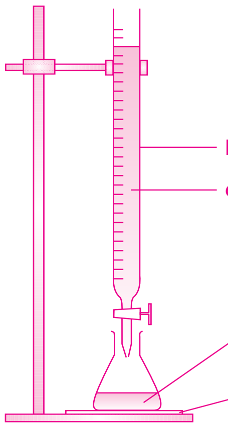
Fill the burette with the sodium hydroxide solution. Make sure that the space between the tap and the tip of the burette is filled. (1)

24 a) Pipette (1)

b) Wash the pipette with distilled water (1)

and then with sodium hydroxide solution. (1)

c)



(1 mark for correct titration set-up; 2 marks for all four labels) (3)

d) From pink to colourless (1)

e) i) $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$ (1)

ii) Number of moles of NaOH in 25.0 cm^3 solution

$= 0.600\ mol\ dm^{-3} \times 0.0250\ dm^3$

$= 0.0150$ mol

Number of moles of H_2SO_4 in 15.0 cm^3 solution

$= 0.0150\ mol \div 2$

$= 0.00750$ mol (1)

Molarity of H_2SO_4

$= 0.00750\ mol \div 0.0150\ dm^3$

$= 0.500$ M (1)

f) i) Sodium sulphate (1)

ii) Mix 25.0 cm^3 of the sodium hydroxide solution and 15.0 cm^3 of the sulphuric acid. (1)

Heat the mixture to obtain a saturated solution. (1)

Allow the saturated solution to cool in air until crystals are obtained. (1)

Wash the crystals with a small amount of cold distilled water and dry them with filter paper. (1)

25 a) *Step 1 -* Should not prepare the standard sodium hydroxide solution using the method described. (1)

This is because sodium hydroxide is deliquescent and would absorb water vapour from the atmosphere. (1)

Step 2 - Should not use a measuring cylinder to transfer the lemon juice. (1)

This is because a measuring cylinder cannot give accurate measurements of liquid volumes. (1)

Step 3 - Should not rinse the burette with water only. (1)

This is because water that remains in the burette would dilute the sodium hydroxide solution. (1)

Step 5 - Should not perform the calculation using only one titration result. (1)

This is because errors may occur in the titration. (1)

b) *Step 1-* Standardize the sodium hydroxide solution before use. (1)

Step 2 - Use pipette to transfer the lemon juice. (1)

Step 3 - Rinse the burette with distilled water and sodium hydroxide solution before use. (1)

Step 5 - Repeat the titration at least 3 times. Use the mean titre for the calculation. (1)

26 a) $Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$ (1)

b) i) When the acid was first added, the conductivity decreased because the number of hydroxide ions in the solution decreased. (1)

At neutralization, all the hydroxide ions reacted. The conductivity was the lowest. (1)

After neutralization, the conductivity increased because the number of hydrogen ions increased. (1)

ii) 10.0 cm^3 (1)

iii) Number of the moles of H_2SO_4 = 1.00 mol dm^{-3} × 0.0100 dm^3

= 0.0100 mol

= Number of moles of $Ba(OH)_2$ (1)

Molarity of barium hydroxide solution = 0.0100 mol ÷ 0.100 dm^3

= 0.100 M (1)

c) Only barium sulphate and water are produced in the reaction. Barium sulphate can be obtained by filtration. (1)

27 a) $CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$ (1)

b) i) Methyl orange / phenolphthalein (1)

ii) From red to yellow / From colourless to red (1)

c) Number of moles of NaOH used to react with excess HNO_3 in *Step 3*

= 0.600 mol dm^{-3} × 0.0220 dm^3

= 0.0132 mol

Number of moles of HNO_3 left after reaction with $CaCO_3$ = 0.0132 mol (1)

Number of moles of HNO_3 originally used = 0.860 mol dm^{-3} × 0.0250 dm^3

= 0.0215 mol (1)

Number of moles of HNO_3 reacted with $CaCO_3$ = (0.0215 - 0.0132) mol

= 0.00830 mol (1)

Mass of $CaCO_3$ in sample = 0.00830 mol × 100.1 g mol^{-1}

= 0.831 g (1)

Percentage by mass of $CaCO_3$ in sample $= \frac{0.831g}{1.05g} \times 100\%$

= 79.1% (1)

d) i) No (1)

ii) Dilute sulphuric acid reacts with calcium carbonate to form insoluble calcium sulphate. The calcium sulphate would cover the surface of calcium carbonate and prevent further reaction. (1)

28 a) $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$ (1)

b) In *Stage 3*, the excess sodium hydroxide solution reacted with the hydrochloric acid according to the following equation:

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Number of moles of HCl used for neutralization

$= 0.300 \text{ mol dm}^{-3} \times 0.0108 \text{ dm}^3$

$= 0.00324$ mol

= Number of moles of excess NaOH (1)

Number of moles of NaOH added in *Stage 2*

$= 0.250 \text{ mol dm}^{-3} \times 0.0250 \text{ dm}^3$

$= 0.00625$ mol (1)

Number of moles of NaOH reacted in *Stage 2*

= (0.00625 - 0.00324) mol

= 0.00301 mol

= Number of moles of N in 25.0 cm^3 of sample solution (1)

Number of moles of N in 250.0 cm^3 of sample solution= 0.0301 mol (1)

Mass of N in 4.65 g of fertilizer $= 0.0301 \text{ mol} \times 14.0 \text{ g mol}^{-1}$

$= 0.421$ g (1)

Percentage by mass of nitrogen in fertilizer $= \frac{0.421\text{g}}{4.65\text{g}} \times 100\%$

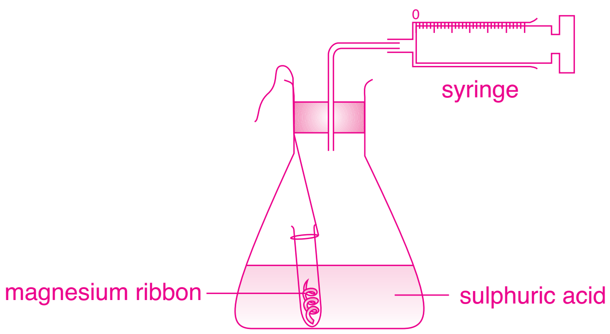
= 9.05% (1)

c) Wash the burette first with water and (1)

then with hydrochloric acid. (1)

Fill the burette with the acid. Make sure that the space between the tap and the tip of the burette is filled. (1)

29 a)

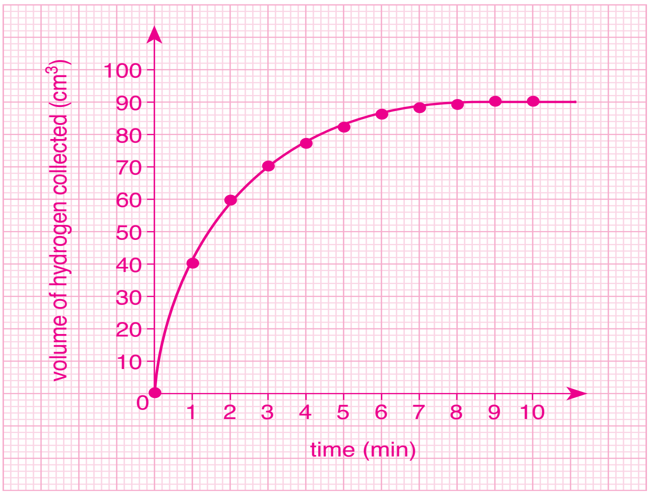


(2)

b) Clean the magnesium ribbons with sand paper before experiment. (1)

c) $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ (1)

d) i)



(1 mark for correct labels of the axis; 1 mark for the curve) (2)

ii) The reaction rate can be reflected by the slope of the curve. The faster the reaction rate, the steeper the curve. (1)

The initial rate was the fastest since the concentration of acid was the highest initially. (1)

The rate gradually decreased as some of the acid reacted and the concentration of the acid decreased. (1)

Reaction stopped at 9th min as all acid had reacted and hence the curve flattened. (1)

e) i) Calcium reacts faster than magnesium initially as calcium is more reactive than magnesium. (1)

The reaction stops quickly as insoluble calcium sulphate forms on the calcium granules and prevents further reaction. (1)

The volume of hydrogen collected is less than the theoretical value. (1)

ii) Magnesium powder reacts at a faster rate as it has a larger surface area. (1)

The volume of hydrogen collected remains unchanged. (1)

iii) The reaction will be slower as the concentration of hydrogen ions is lower because ethanoic acid is a weak acid. (1)

The volume of hydrogen collected remains unchanged. (1)

30 a) An acid is solid form (1)

b) $HCO_3^-(aq) + H^+(aq) \rightarrow CO_2(g) + H_2O(l)$ (1)

c) Mass of CO_2 evolved = 0.340 g (1)

Number of moles of CO_2 = 0.340 g ÷ 44.0 g mol^{-1}

= 0.00773 mol

= Number of moles of $NaHCO_3$ (1)

Mass of $NaHCO_3$ = 0.00773 mol × (23.0 + 1.0 + 12.0 + 3 × 16.0) g mol^{-1}

= 0.649 g (1)

d) More accurate / experimental results presented in graph form can be obtained immediately / save time in the interpretation of experimental results (1)

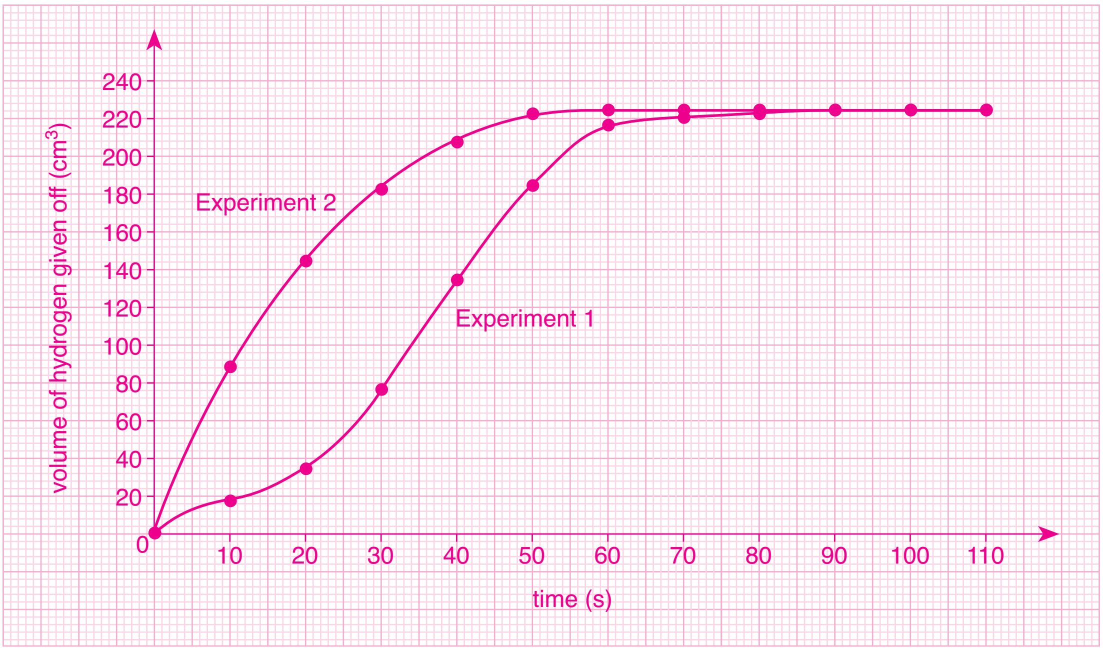
e) Use warm water. (1)

31 a) i) (1) $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$ (1)

(2) $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$ (1)

ii) Calcium dissolves. / Gas bubbles are given off. / Calcium sinks in water. (1)

b)



(1 mark for correct labels of the axis; 1 mark for curve of Experiment 1; 1 mark for curve of Experiment 2) (3)

c) (2) (1)

Hydrochloric acid has a higher concentration of hydrogen ions than water. (1)

d) (1) (1)

The slope of curve (1) is steeper than that of curve (2) at the 50th second. (1)

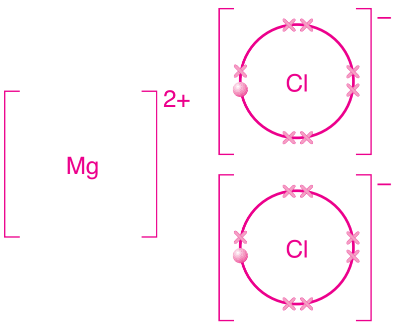
e) Reaction (1) stops at the 90th second. (1)

Reaction (2) stops at the 60th second. (1)

f) The same mass of calcium (limiting reactant) is used in each experiment. (1)

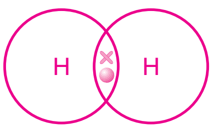
32 a) $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ / $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ (1)

b) Magnesium chloride:



(1)

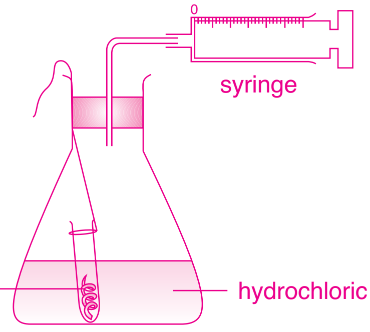
Hydrogen gas:



(1)

c) Measure the volume of $H_2(g)$ given off at regular time intervals. (1)

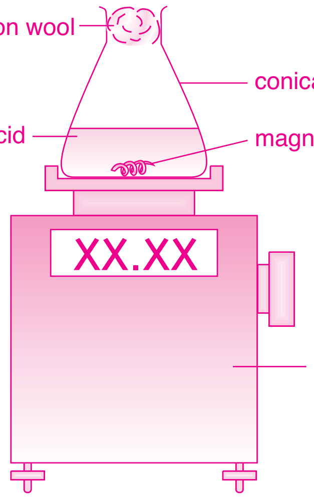
Diagram of set-up



(2)

or Place the vessel on a balance and record the mass of the conical flask plus its content at regular time intervals.

Diagram of set-up



d) The volume of hydrogen collected remains unchanged. / The mass of the conical flask plus its content remains unchanged. (1)

e) The reaction rate will increase. (1)

There will be no change in the amount of products formed. (1)

f) The reaction rate will increase. (1)

Magnesium powder has a larger surface area than magnesium ribbons. (1)

g) The reaction rate will increase. (1)

Sulphuric acid is a dibasic acid while hydrochloric is a monobasic acid. (1)

Hence, sulphuric acid of the same molarity has a higher concentration of hydrogen ions than hydrochloric acid. (1)

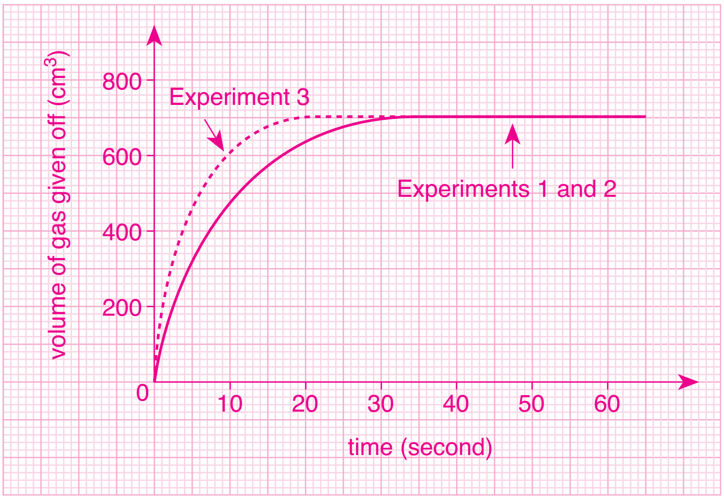
33 a) $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$ / $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ (1)

b) By connecting the reaction vessel to a gas syringe / by measuring the change of pressure inside the reaction container which is a closed system. (1)

c) The reaction rate at X is higher than that at Y. / The concentration of hydrogen ions at X is higher than that at Y. (1)

d) 34^{th} second (1)

e)



(2)

The reaction rate of experiment 1 is the same as that of experiment 2. This is because the concentration of hydrogen ions in both experiments is the same. (1)

The reaction rate of experiment 3 is faster than that of experiment 2. This is because the concentration of hydrogen ions in experiment 3 is higher than that in experiment 2. (1)

The final volume of hydrogen given off in experiments 1, 2 and 3 are the same because magnesium is the limiting reactant in the three experiments. (1)

f) i) The time would be longer (1)

as ethanoic acid is a weak acid and it contains a lower concentration of hydrogen ions. (1)

ii) The same volume of hydrogen would be give in off. (1)

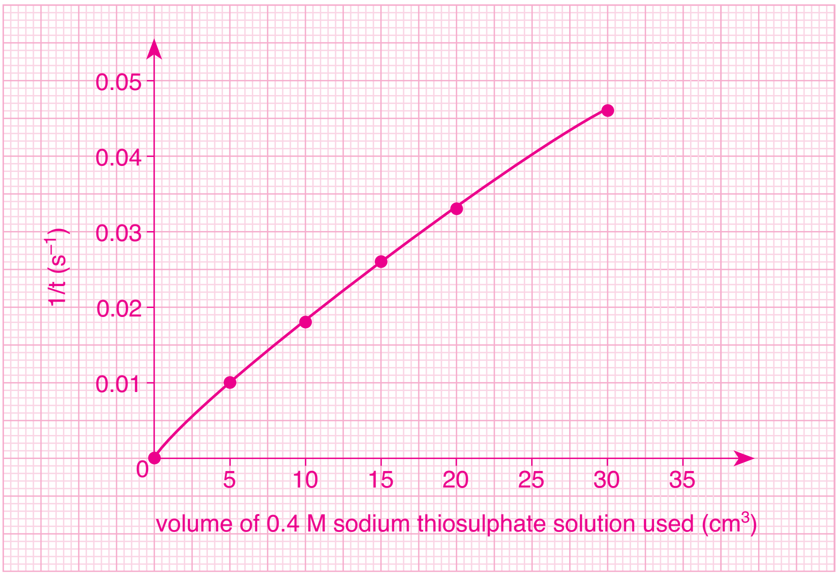
The same mass of magnesium (limiting reactant) is used in both experiments. (1)

34 a) i) To find the time for the cross to disappear. / To find the time to produce a certain amount of sulphur. (1)

ii) To vary the concentration of sodium thiosulphate solution while keeping the total volume of the solution constant. (1)

iii) To ensure that only the concentration of sodium thiosulphate solution is varied. (1)

b)



(1 mark correct labels of the axis; 1 mark for straight line through the origin) (2)

c) As the volume of sodium thiosulphate solution used is directly proportional to its concentration (1)

and 1/t is directly proportional to the rate of reaction, (1)

the concentration of sodium thiosulphate solution used is directly proportional to the rate of reaction. (1)

d) The slope of the curve will increase. (1)

35 Add dilute sodium hydroxide solution to the sample and heat the mixture. (1)

A gas which turns moist red litmus paper blue is given off. This indicates the presence of ammonium ion. (1)

Add dilute sodium hydroxide solution to the sample solution. (1)

A brown precipitate ($Fe(OH)_3$) is formed. This indicates the presence of iron(III) ion. (1)

Heat a sample of the salt. (1)

Water vapour given off will turn dry cobalt(II) chloride paper from blue to pink / anhydrous copper(II) sulphate from white to blue. This indicates the presence of water. (1)

(3 marks for effective communication)

36 First wash a 25.0 cm^3 pipette with distilled water and then with the sodium carbonate solution. Transfer 25.0 cm^3 of the sodium carbonate solution to a clean conical flask using a pipette and pipette filler. (1)

Add a few drops of methyl orange to the solution as an indicator. (1)

Wash a burette first with distilled water and then with 0.200 M nitric acid. Fill the burette with the acid. (1)

Place the conical flask containing the sodium carbonate solution on a white tile. Run the acid from the burette until the indicator in the conical flask just changes colour. (1)

Note the volume of nitric acid added. This is the titre reading of the first trial.

Repeat the titration 2 or 3 times to check if the titre readings are coincident. Record the results. (1)

The exact concentration of the sample of sodium carbonate solution can be calculated from the volume and concentration of nitric acid used with reference to the following equation:

$2HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + CO_2(g) + H_2O(l)$

Number of moles of HNO_3

= Average volume of $HNO_3(aq)$ used × concentration of $HNO_3(aq)$

Number of moles of Na_2CO_3 in 25.0 cm^3 of solution = number of moles of HNO_3 ÷ 2

Molarity of $Na_2CO_3(aq)$ = $\dfrac{\text{Number of moles of } Na_2CO_3}{\frac{25.0}{1000} dm^3}$ (1)

(3 marks for effective communication)

37 Weigh the sample with an electronic balance to obtain its mass (m_1). (1)

Prepare a 250.0 cm^3 solution of the sample using a volumetric flask. Transfer 25.0 cm^3 of the solution into a conical flask. Add a few drops of methyl orange. (1)

Titrate the sample solution with sulphuric acid (or other suitable acid) with a known concentration (M_A) from a burette.
Record the volume of acid (V_A) added when the colour of indicator changes from yellow to red. (1)
Determine the number of moles of sulphuric acid used from the calculation of $M_A \times V_A$.
Number of moles of sodium carbonate in the sample = $(M_A \times V_A) \times 10$ (1)
Mass of sodium carbonate (m_2) in the sample
= Number of moles of sodium carbonate in the sample × Molar mass of sodium carbonate (1)
Calculate the percentage by mass of sodium carbonate in the sample by $(m_2 \div m_1) \times 100\%$. (1)
(3 marks for effective communication)

38 Titrate dilute sodium hydroxide solution with dilute hydrochloric acid until the end point is reached. (1)
Mix the same volumes of alkali and acid as in the previous experiment. Do not use any indicator this time. (or, add dilute hydrochloric acid to dilute sodium hydroxide solution in the mole ratio of 1 : 1) (1)
Heat the resulting solution until a saturated (more concentrated) solution is obtained. (1)
Cool the solution slowly to obtain large crystals of sodium chloride. (1)
Filter to separate the crystals. (1)
Wash the crystals with distilled water and then dry with filter paper. (1)
(3 marks for effective communication)

39 The rate of a reaction can be measured by the inflation rate of a balloon using a stop-watch when calcium carbonate reacts with an acid to give carbon dioxide. (1)
The first factor to be investigated is the surface area of the reactant.
First, add a certain amount of calcium carbonate granules to a test tube. Then, a certain volume of 1 M hydrochloric acid is added. Immediately fill the mouth of the test tube with a balloon (1)
Repeat the experiment with the same volume of acid and the same amount of calcium carbonate granules which have been crushed into powder. (1)
The inflation rate of the balloon increases when calcium carbonate powder is used because the surface area is greater. (1)
The second factor to be investigated is the concentration of the reactant.
First, add a certain amount of calcium carbonate granules to a test tube. Then, a certain volume of 1 M hydrochloric acid is added. Immediately fill the mouth of the test tube with a balloon. (1)
Repeat the experiment with 0.1 M hydrochloric acid of the same volume (prepared by diluting the 1 M hydrochloric acid) and the same amount of calcium carbonate granules. (1)
The inflation rate of the balloon decreases because the concentration of hydrogen ions in the acid is lower. (1)

(3 marks for effective communication)

40 To determine which antacid is the most effective, use recommended dose of each antacid and find out which antacid can neutralize the greatest amount of acid. (1)

Dissolve the recommended dose of brand A antacid in 50 cm^3 of distilled water in a conical flask. Add a few drops of methyl orange. (1)

Titrate the antacid with dilute hydrochloric acid until the indicator changes from yellow to red. Record the volume of acid neutralized by the antacid. (1)

Repeat the experiment with recommended dose of the other two antacids. (1)

The antacid that neutralizes the greatest volume of hydrochloric acid is the most effective. (1)

To compare the antacids fairly, it is necessary to use the recommended dose of each antacid and hydrochloric acid of the same concentration for titration. (1)

(3 marks for effective communication)