

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

2.1.4-2.1.5 ACIDS AND REDOX

SCORE

/153

PERCENTAGE

%

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1 Calcium phosphate(V), $\text{Ca}_3(\text{PO}_4)_2$, is a salt used in fertilisers.

Calcium phosphate(V) can be prepared by reacting together an acid and a base.

(i) Suggest the **formula** of the acid used to prepare $\text{Ca}_3(\text{PO}_4)_2$.

----- [1]

(ii) **Name** a base which could be used to prepare $\text{Ca}_3(\text{PO}_4)_2$.

----- [1]

2 Cerium behaves as a typical metal when it reacts with dilute sulfuric acid to form the salt cerium(III) sulfate and a second product.

(i) Identify the second product.

----- [1]

(ii) Write the formula of cerium(III) sulfate and, explain what has happened to the cerium in this reaction in terms of the number of electrons transferred.

Formula -----

Explanation -----

----- [2]

(iii) How has a salt been formed in this reaction?

----- [1]

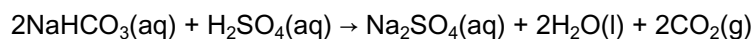
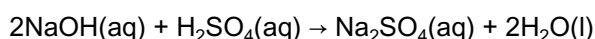
3(a) A student was given 200 cm³ of solution X in which sodium hydroxide, NaOH, and sodium hydrogencarbonate, NaHCO₃, had **both** been dissolved.

The student carried out **two different** titrations on samples of solution X using 0.100 mol dm⁻³ sulfuric acid, H₂SO₄.

- In the first titration, **both** NaOH and NaHCO₃ were neutralised.
- In the second titration, **only** NaOH was neutralised.

The student's results for the titrations of 25.0 cm³ samples of solution X are shown.

volume of H ₂ SO ₄ needed to neutralise both NaOH and NaHCO ₃	29.50 cm ³
volume of H ₂ SO ₄ needed to neutralise only NaOH	18.00 cm ³



(i) Calculate the amount, in mol, of H₂SO₄ used to neutralise **only** the NaOH in 25.0 cm³ of solution X.

Amount = _____ mol [1]

(ii) Calculate the concentration, in mol dm⁻³, of NaOH in solution X.

Concentration = _____ mol dm⁻³ [1]

(b)

(i) Calculate the amount, in mol, of NaHCO₃ in the 200 cm³ of solution X.

Amount = _____ mol [2]

(ii) Calculate the mass of NaHCO₃ in the 200 cm³ of solution X.

Give your answer to **three** significant figures.

Mass = _____ g [1]

4(a) Calcium hydroxide is both a base and an alkali. Refer to any relevant ions in your answer.

Explain what is meant by the terms *base* and *alkali*.

Base _____

Alkali _____

_____ [2]

(b) A student prepares a solution of calcium nitrate from calcium carbonate.

What reagent would the student need to use?

Write the equation for the reaction.

Reagent _____

Equation _____ [2]

5 Which reagent would exactly neutralise 100 cm³ of 1.00 mol dm⁻³ H₂SO₄(aq)?

- A 0.100 mol Al(OH)₃
- B 0.100 mol NH₃
- C 0.100 mol Ba(OH)₂
- D 0.100 mol NaOH

Your answer

☐

[1]

6 A student prepares a standard solution and carries out a titration.
The standard solution is placed in the burette.

Which of the following would result in a titre that is larger than it should be?

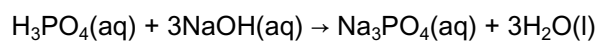
- 1: Water is added to completely fill the volumetric flask, rather than to the graduation line.
 - 2: The conical flask is washed out with water before carrying out each titration.
 - 3: The pipette is washed out with water before carrying out each titration.
- A 1, 2 and 3
 - B Only 1 and 2
 - C Only 2 and 3
 - D Only 1

Your answer

☐

[1]

- 7 The equation for the reaction of aqueous phosphoric(V) acid, H_3PO_4 , with aqueous sodium hydroxide, $\text{NaOH}(\text{aq})$ is shown below.



25.0 cm^3 of a 0.200 mol dm^{-3} $\text{H}_3\text{PO}_4(\text{aq})$ is titrated with 0.600 mol dm^{-3} $\text{NaOH}(\text{aq})$.

Which statement is correct?

- A The end point occurs when 25.00 cm^3 of $\text{NaOH}(\text{aq})$ has been added.
- B The end point occurs when 75.00 cm^3 of $\text{NaOH}(\text{aq})$ has been added.
- C After titration the final solution contains 0.0150 mol of Na_3PO_4 .
- D After titration the final solution contains 0.0150 mol of H_2O .

Your answer

[1]

8(a) This question looks at neutralisation reactions.

A student carries out an experiment to determine the enthalpy change for a neutralisation reaction.

The student measures out 35.0 cm^3 of 2.40 mol dm^{-3} KOH and 35.0 cm^3 of 1.20 mol dm^{-3} H_2SO_4 .
The temperature of each solution is 19.5°C .

The student mixes the solutions. The KOH is all neutralised and the maximum temperature reached is 36.0°C .

(i) Write the overall equation for the reaction that takes place.

[1]

(ii) Calculate the enthalpy change for the reaction between 1 mol KOH and 1 mol HCl.

Assume that the density of the mixture is 1.00 g cm^{-3} and that the specific heat capacity for the solution is the same as for water.

$\Delta H =$ _____ kJ [3]

(iii) Explain, why the answer to (ii) is the enthalpy change of neutralisation.

----- [1]

(iv) In this experiment, the student uses a thermometer with an uncertainty of $\pm 0.5^\circ\text{C}$ in each reading.

Calculate the percentage uncertainty in the temperature rise.

percentage uncertainty = _____ % [1]

(b) In an experiment, a scientist prepared a 0.500 g sample of a salt made by neutralisation.

Analysis of the sample gave the following data.

Element	Mass present / g
hydrogen	0.025
oxygen	0.300
nitrogen	0.175

(i) Calculate the empirical formula of the salt.

empirical formula = _____ [2]

(ii) Suggest the formula of the acid and base that the scientist used to prepare this salt.

acid: _____

base: _____

[1]

9 Solid barium chloride has a high melting point. Barium chloride dissolves in water to form a solution that can be used to test for sulfate ions.

- (i) Draw a '*dot-and-cross*' diagram to show the bonding in solid barium chloride.
Show outer electrons only.

[2]

- (ii) A solution of barium chloride can be made in the laboratory using dilute hydrochloric acid.

Suggest a compound that can be reacted with hydrochloric acid to make barium chloride.

-----[1]

10(a) A student carries out an experiment to identify an unknown carbonate.

- The student weighs a sample of the solid carbonate in a weighing bottle.
- The student tips the carbonate into a beaker and weighs the empty weighing bottle.
- The student prepares a 250.0 cm^3 solution of the carbonate.
- The student carries out a titration using 25.0 cm^3 of this solution measured using a pipette with 0.100 mol dm^{-3} hydrochloric acid in the burette.

The sample of carbonate is dissolved in approximately 100 cm^3 of distilled water in a beaker and the solution transferred to a volumetric flask. The volume of the solution is made up to 250.0 cm^3 with distilled water.

Another student suggests two possible sources of error:

- A small amount of solid remained in the weighing bottle.
- A small amount of solution remained in the beaker.

State whether the other student's statements are correct.

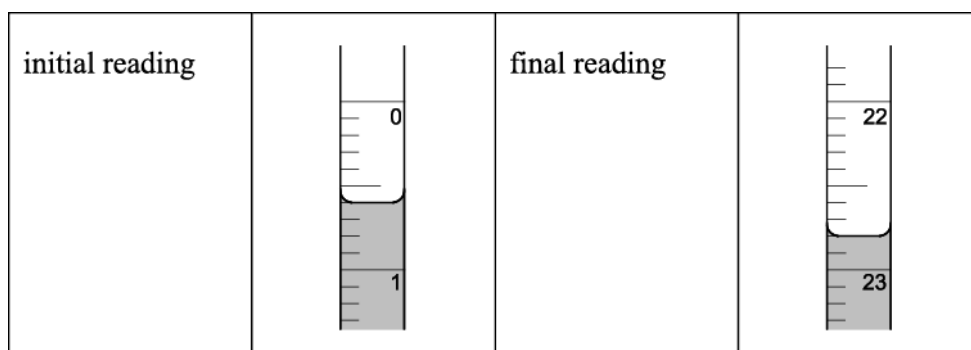
How could the procedure be improved?

----- [2]

- (b) The student carries out the final part of the experiment by adding $0.100 \text{ mol dm}^{-3}$ hydrochloric acid to a burette and performing a titration using a 25.0 cm^3 sample of the aqueous carbonate.

The student reads the burette to the nearest 0.05 cm^3 .

The diagrams below show the initial burette reading and the final burette reading.



- (i) Record the student's readings and the titre.

[1]

- (ii) Describe what the student should do next to obtain reliable results for the titration.

----- [1]

(c) The equation below represents the reaction between the carbonate and hydrochloric acid.



(i) Calculate the amount, in mol, of M_2CO_3 used in the titration.

$$n(\text{M}_2\text{CO}_3) = \text{----- mol [2]}$$

(ii) The student's mass readings are recorded below.

Mass of weighing bottle + carbonate / g	14.92
Mass of weighing bottle / g	13.34

Use the student's results to identify the carbonate, M_2CO_3 .

Show **all** your working.

[4]

11(a) A student carries out a titration to determine the molar mass of an unknown acid, A.

- The student dissolves 2.24 g of acid A in distilled water and makes the solution up to 250.0 cm³.
- The student titrates a 25.0 cm³ portion of this solution with 0.120 mol dm⁻³ NaOH.
- 25.25 cm³ of 0.120 mol dm⁻³ NaOH are required to reach the end point.

Name the apparatus that the student should use to

- make up the acid solution to 250.0 cm³
- measure the 25.0 cm³ portion of acid solution.

make up the acid solution to 250 cm³:

measure the 25.0 cm³ portion: [1]

(b) The acid reacts with NaOH in a 1 : 1 molar ratio.

Calculate the molar mass of acid A.

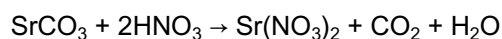
molar mass of acid A = ... g mol⁻¹ [3]

(c) The student is not confident that their titre is accurate.

Suggest what the student should do next to reduce the effect of any random error in the titration.

.....
.....
..... [2]

12(a) A student investigates the reaction between strontium carbonate and dilute nitric acid.



The rate of reaction is determined from the loss in mass over a period of time.

- (i) Explain why there is a loss in mass during the reaction.

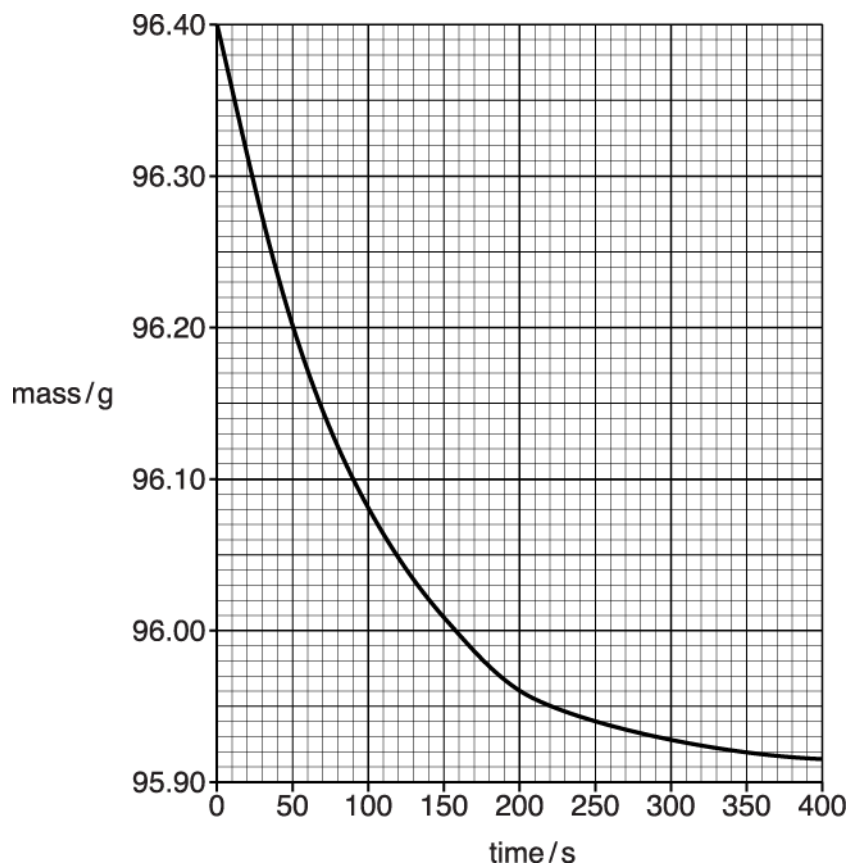
----- [1]

- (ii) An excess of strontium carbonate, SrCO_3 , is mixed with 20.0 cm^3 of 1.25 mol dm^{-3} nitric acid, HNO_3 .

Calculate the mass of SrCO_3 that reacts with the HNO_3 .

mass = ----- g [3]

(b) The student plots a graph of total mass (reagents + container) against time.



(i) Describe and explain the change in the rate of the reaction during the first 200 seconds of the experiment.

[2]

(ii) Using the graph, calculate the rate of reaction, in g s^{-1} , at 200 seconds.

Show your working on the graph.

rate of reaction = _____ g s⁻¹ [2]

- (c) Outline a method that could be used to obtain the results that are plotted on the graph.

Your answer should include the apparatus required and the procedure for the experiment.

----- [3]

- 13 Zinc carbonate, ZnCO₃, reacts with dilute hydrochloric acid.

A student reacts a sample of ZnCO₃ with an excess of dilute hydrochloric acid in a test-tube.

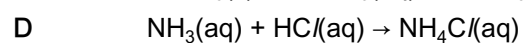
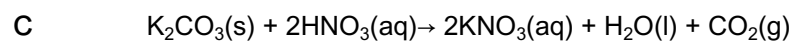
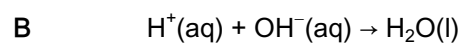
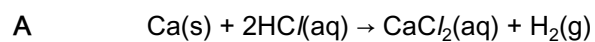
- (i) Describe what the student would see during this reaction.

----- [1]

- (ii) Write the equation for the reaction between ZnCO₃ and dilute hydrochloric acid.

----- [1]

14 Which equation is **not** a neutralisation reaction?



Your answer

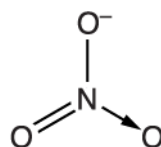
[1]

15 Nickel(II) nitrate, $\text{Ni}(\text{NO}_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

(i) Write the equation for this reaction.

[1]

(ii) $\text{Ni}(\text{NO}_3)_2$ contains the NO_3^- ion. The nitrogen atom bonds to the oxygen atoms with a single covalent bond, a double covalent bond and a dative covalent bond, as shown below.



Draw the 'dot-and-cross' diagram for the NO_3^- ion, showing outer shell electrons only.
Use a different symbol for the extra electron.

[2]

16 The burette readings from a titration are shown below.

Final reading / cm^3	24.95
Initial reading / cm^3	5.00

The burette used has an uncertainty of $\pm 0.05 \text{ cm}^3$ in each reading.
What is the percentage uncertainty of the resulting titre?

- A 0.20%
- B 0.25%
- C 0.45%
- D 0.50%

Your answer

[1]

17 Ethanoic acid, CH_3COOH , is the main dissolved acid in vinegar.

Ethanoic acid is a weak acid.

What is meant by *acid* and *weak acid*?

----- [1]

18(a) A student carries out a titration to determine the molar mass and structure of a weak acid **A**.

The student follows the method below.

- Dissolve a weighed mass of **A** in 100 cm^3 of distilled water and make the solution up to 250 cm^3 in a beaker.
- Add the solution of **A** to a burette.
- Titrate the solution of **A** with a standard solution of sodium hydroxide, NaOH.

What is meant by the term standard solution?

----- [1]

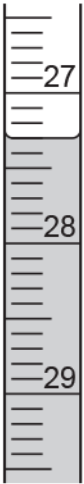
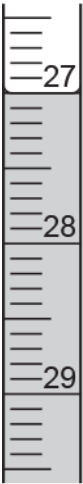
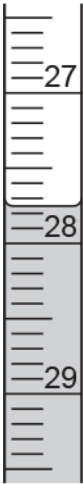
(b) Sodium hydroxide is an alkali.

What is meant by the term alkali?

----- [1]

- (c) The student carries out a trial, followed by three further titrations.
The diagram shows the initial and final burette readings for the three **further** titrations.

The student measures all burette readings to the nearest 0.05 cm^3 .

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

- (i) Record the student's readings and the titres in the table below.

Calculate the mean titre, to the nearest 0.05 cm^3 , that the student should use for analysing the results.

	Titration 1	Titration 2	Titration 3
Final reading/ cm^3			
Initial reading/ cm^3			
Titre/ cm^3			

mean titre = ----- cm^3 [4]

(ii) The uncertainty in each burette reading is $\pm 0.05 \text{ cm}^3$.

Calculate the percentage uncertainty for the titre in **Titration 1**.

percentage uncertainty = ----- % [1]

(iii) The student realised that the solution of **A** had not been prepared correctly.

How should the student have made up the solution?

----- [1]

(d) A student repeats the titration to determine the molar mass and structure of **A**.

- The student prepares a 250.0 cm³ solution from 1.513 g of **A**.
- The solution of **A** is added to the burette and titrated with 25.0 cm³ volumes of 0.112 mol dm⁻³ NaOH(aq).
- 1 mol of **A** reacts with 2 mol of NaOH.
- The student obtains a mean titre of 27.30 cm³.

(i) Calculate the molar mass of **A** from these results.

Give your answer to the nearest whole number.

Show your working.

molar mass of **A** = ----- g mol⁻¹ [4]

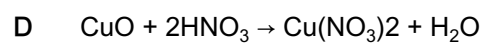
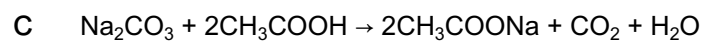
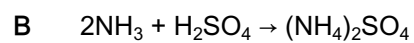
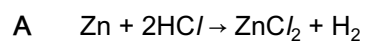
(ii) **A** is an organic acid, containing C, H and O only.

One molecule of **A** contains two COOH groups.

Suggest the structure of **A**.

[1]

19 Which equation does **not** represent a neutralisation reaction?

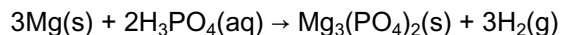


Your answer

[1]

20 This question is about compounds of magnesium and phosphorus.

A student plans to prepare magnesium phosphate using the redox reaction of magnesium with phosphoric acid, H_3PO_4 .



- (i) In terms of the number of electrons transferred, explain whether magnesium is being oxidised or reduced.

----- [1]

- (ii) The student plans to add magnesium to 50.0 cm^3 of $1.24 \text{ mol dm}^{-3} \text{ H}_3\text{PO}_4$.

Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid.

Give your answer to **three** significant figures.

mass of Mg = ----- g [3]

- (iii) How could the student obtain a sample of magnesium phosphate after reacting magnesium with phosphoric acid?

----- [2]

(iv) Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium.

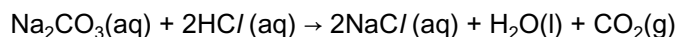
Choose a suitable magnesium compound for this preparation and write the equation for the reaction.

Formula of compound -----

Equation ----- [2]

21(a) A student carries out a titration to determine the concentration of some hydrochloric acid.

The student titrates the hydrochloric acid against a standard solution of sodium carbonate, Na_2CO_3 . The equation is shown below.



- The student prepares $0.150 \text{ mol dm}^{-3}$ Na_2CO_3 in a 250.0 cm^3 volumetric flask.
- The hydrochloric acid is added to a 50.0 cm^3 burette.
- The student pipettes the $\text{Na}_2\text{CO}_3(\text{aq})$ using a 25.0 cm^3 pipette.

The student's burette readings are shown in the table.

The rough titre has been omitted.

(i) Complete the table by adding the titres to the table.

Final reading / cm^3	24.60	48.45	34.30
Initial reading / cm^3	0.40	24.60	10.00
Titre / cm^3			

[1]

(ii) Calculate the mean titre of HCl , to the nearest 0.05 cm^3 , that the student should use for analysing the results.

mean titre = ... cm^3 [1]

(b) Calculate the concentration, in mol dm^{-3} , of the hydrochloric acid.

Give your answer to 3 significant figures.

concentration of HCl = ... mol dm^{-3} [3]

(c) In the titrations, the student measured volumes with a pipette and a burette.

- The pipette had an uncertainty of $\pm 0.04 \text{ cm}^3$ in the volume measured.
- The burette had an uncertainty of $\pm 0.05 \text{ cm}^3$ in the volume measured.

Determine whether the volume measured by the pipette or the volume measured by the burette has the greater percentage uncertainty.

[2]

22 Magnesium nitrate is used in fertilisers as a source of nitrogen.

* A student plans to prepare 250.0 cm^3 of a $0.4000\text{ mol dm}^{-3}$ solution of magnesium nitrate, starting from magnesium nitrate crystals, $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$.

Describe how the student would prepare the solution, giving full details of quantities, apparatus and method.

[6]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	H ₃ PO ₄ ✓	1	ALLOW formula if seen as reactant in an equation IGNORE name Examiner's Comments This question was well answered although it was common to see incorrect formulae such as HPO₄ from weaker candidates.
		ii	Calcium oxide OR calcium hydroxide OR calcium carbonate ✓	1	IGNORE formulae IGNORE lime, quicklime and limestone Examiner's Comments Nearly all candidates knew the answer to this question, but not all gained the mark here as many gave the formula of the base rather than its name, despite the question stressing the need for the name.
			Total	2	
2		i	Hydrogen ✓	1	ALLOW H₂ IGNORE 'H' Examiner's Comments This question was well answered although the erroneous appearance of water as a product of the reaction between an acid and a metal was seen relatively frequently.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\text{Ce}_2(\text{SO}_4)_3$ ✓ (Cerium) loses three electrons (to form 3+ ion) ✓	2	ALLOW alternative phrases for 'loses' eg 'gives away', 'donates' IGNORE '3 electrons transferred' unless a correct direction is given eg ALLOW (Ce) transfers 3 electrons to ... OR (Ce) transfers 3 electrons forming Ce^{3+} IGNORE references to sulfate gaining electrons IGNORE references to reduction and oxidation Examiner's Comments This question was slightly more challenging and discriminated well. Some candidates missed the fact that the cerium was in the +3 oxidation state and gave the formula as CeSO_4 along with an explanation that involved the loss of 2 electrons. However, a significant number of candidates did not focus upon the instruction in the question to explain 'in terms of the number of electrons transferred' and gave responses based solely upon changes in oxidation number.
		iii	A hydrogen ion (of an acid) has been replaced by a metal ion ✓	1	For hydrogen ion: ALLOW 'H⁺' OR 'proton' but DO NOT ALLOW 'H' OR 'hydrogen' without 'ion' For metal ion: ALLOW 'cerium ion' OR 'Ce^{3+}' OR 'Ce^{2+}' OR 'Ce ion' But DO NOT ALLOW 'Ce' without 'ion' OR 'cerium' without 'ion' IGNORE 'ammonium ion' Examiner's Comments A good number of candidates had no problem with this question but slightly weaker students talked vaguely about the reaction of metals with acids and clearly did not realise that the question was really examining how well they understood the definition of a salt.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3	a	i	Mol of $\text{H}_2\text{SO}_4 = 0.100 \times 18.00 / 1000 = 1.80 \times 10^{-3} \text{ mol}$ ✓	1	ALLOW calculator value or rounding to 2 significant figures or more but IGNORE 'trailing zeroes' throughout Q4. eg 0.200 is allowed as 0.2 Examiner's Comments This opening part to the calculation was relatively straightforward and almost all candidates scored this mark. Even when the mark was not awarded it was often not because of a lack of knowledge of the formula but because the student used the incorrect volume of 29.50 cm^3.
		ii	Mol of NaOH in = $1.80 \times 10^{-3} \times 2 \times 1000 / 25.0 = 0.144 \text{ mol dm}^{-3}$ ✓	1	ALLOW ECF for (a)(i) $\times 2 \times 1000 / 25$ Examiner's Comments Candidates who had answered correctly part (i) were able to give the right answer here but some muddled the stoichiometric ratio. Another source of error was to use the wrong volume of NaOH, with some opting to use 200 cm^3 as this was the total volume of solution X.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Check the answer line. If answer = 0.0184 mol award 2 marks Mol of NaHCO_3 in $25.0 \text{ cm}^3 = [0.100 \times 11.50 / 1000] \times 2 = 0.00230 \text{ mol} \checkmark$ Mol of NaHCO_3 in $200 \text{ cm}^3 = 0.00230 \times 200 / 25.0 = 0.0184 \text{ mol} \checkmark$	2	If there is an alternative answer, check to see if there is any ECF credit possible using working below. ALLOW for an alternative method for M1 Total mol of H_2SO_4 used = $[0.100 \times 29.50 / 1000] = 0.00295 \text{ mol}$ Mol of H_2SO_4 reacting with $\text{NaHCO}_3 = 0.00295 - \text{answer to (a)(i)}$ Expected answer = $0.00295 - 0.00180 = 0.00115 \text{ mol}$ Mol of NaHCO_3 in $25.0 \text{ cm}^3 = 0.00115 \times 2 = 0.00230 \text{ mol}$ ALLOW ECF for mol of $\text{NaHCO}_3 \times 200 / 25.0$ For ECF in M2 titration values of 11.50 or 29.50 must have been used in M1 Second marking point is for scaling up number of mol of NaHCO_3 by $200 / 25.0$ (Usually seen as '8') Examiner's Comments This was probably the most challenging question on the paper and many candidates could not see the route to the answer. Encouragingly many did see the need to find the difference in the two titres and so their calculations did involve 11.50 cm^3. The second mark for scaling up the amount was not often awarded.
		ii	Mass of $\text{NaHCO}_3 = 0.0184 \times 84.0 = 1.55 \text{ g} \checkmark$ (must be three significant figures)	1	ALLOW ECF for (b)(i) $\times 84.0$ correctly calculated and rounded to three significant figures. Examiner's Comments In essence this was a very easy question that simply required candidates to multiply their answer to (i) by 84.0 and give the answer to 3 significant figures.
			Total	5	

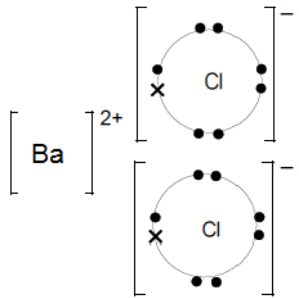
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a		Base: A substance which readily accepts H^+ ions (from an acid) ✓ Alkali: releases OH^- ions into (aqueous) solution ✓	2	ALLOW proton acceptor ALLOW Is soluble and releases OH^- ions (into aqueous solution) Examiner's Comments Of the two parts, the definition of base was more often given correctly. A few weaker candidates described a base in terms of the reaction with acids to give salts but most gave the correct answer. The description of an alkali was less well answered with some commenting on the presence of OH^- ions and others on the solubility but few doing both.
	b		Nitric acid OR HNO_3 ✓ $CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$ ✓	2	ALLOW reagent mark if no response is seen but HNO_3 is seen in the equation IGNORE calcium carbonate on reagent line ALLOW multiples IGNORE state symbols DO NOT ALLOW H_2CO_3 for $H_2O + CO_2$ Examiner's Comments Most students identified the reagent as nitric acid but the equation proved more challenging. Most common errors were to give the formula as H_2NO_3 or calcium nitrate as $CaNO_3$.
			Total	4	
5			C	1	
			Total	1	
6			D	1	
			Total	1	
7			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance						
8	a	i	$\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ (1)	1	allow multiples						
		ii	<i>Energy (into water) mark</i> $70.0 \times 4.18 \times 16.5 = 4827.9$ (J) or 4.8279 (kJ) (1) <i>amount of substance mark</i> $n(\text{H}_2\text{O}) = \frac{35.0}{1000} \times 2.40 = 0.084(0)$ (mol) <i>$\Delta_{\text{neut}}H$ mark</i> $(-)4.8279 / 0.084(0) =$ $(-)57.475$ OR $(-)57.48$ OR $(-)57.5$ (1) Correctly rounded to at least 3 significant figures	3	allow rounding to 4828 OR 4830 allow amount of substance mark to be based upon either HCl or NaOH allow ecf for <u>Energy (into water) mark</u> Amount of substance mark						
		iii	1 mole of water had been formed (1)	1							
		iv	$\frac{2 \times 0.5}{16.5} \times 100 = 6\%$ (1)	1							
	b	i	<i>Amount of each element mark</i> <table><tr><td>H</td><td>O</td><td>N</td></tr><tr><td>$\frac{0.025}{1.0}$</td><td>$\frac{0.300}{16.0}$</td><td>$\frac{0.175}{14.0}$</td></tr></table> $= 0.025 \quad 0.01875 \quad 0.0125$ (1) <i>Simplest whole number ratio empirical formula</i> $\frac{0.025}{0.0125} = 2 \quad \frac{0.01875}{0.0125} = 1.5 \quad \frac{0.0125}{0.0125} = 1$ AND $\text{H}_4\text{O}_3\text{N}_2$ (1)	H	O	N	$\frac{0.025}{1.0}$	$\frac{0.300}{16.0}$	$\frac{0.175}{14.0}$	2	allow 2 marks for correct answer without working
H	O	N									
$\frac{0.025}{1.0}$	$\frac{0.300}{16.0}$	$\frac{0.175}{14.0}$									
		ii	acid: HNO_3 AND base: NH_3 (1)	1	allow atoms within HNO_3 and NH_3 in any order						
			Total	9							

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9		i	 Barium ion with no (or eight) electrons AND two chloride ions with correct <i>dot-and-cross</i> octet (1) Correct charges (1)	2	For the first mark, if eight electrons are shown in the cation then the 'extra' electron in the anion must match the symbol chosen for electrons in the cation ignore inner shell electrons Circles not essential allow One mark if both electron arrangement and charges are correct but only one Cl is drawn allow 2[Cl]⁻ (Bracket not required)
		ii	Barium hydroxide OR barium oxide OR barium carbonate	1	allow Ba(OH) ₂ OR BaO OR BaCO ₃
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	a		Not correct about the solid remaining in the weighing bottle (weighed by difference) AND Correct about the solution in the beaker (1) Rinse out the beaker with distilled water and transfer to the volumetric flask before making up to 250 cm ³ (1)	2	
	b	i	Initial reading = 0.60 (cm ³) Final reading = 22.80 (cm ³) Titre = 22.20 cm ³ Initial and final values recorded to two decimal places AND titre recorded to the nearest 0.05 cm ³ with correct units	1	
		ii	Suggests repeating the titration to obtain consistent / concordant results (those that agree to within 0.1 cm ³) AND calculating the mean titre	1	
	c	i	$n(\text{HCl}) = (0.100)(\text{answer to (c)(i)}/1000) = 0.00222 \text{ (mol) (1)}$ $n(\text{M}_2\text{CO}_3) = 0.00222/2 = 0.00111 \text{ (mol) (1)}$	2	allow ecf from (b)(i)
		ii	$n(\text{M}_2\text{CO}_3) \text{ in total} = 0.00111 \times 10 = 0.0111 \text{ mol (1)}$ Molar mass = $1.58/0.0111 = 142.3 \text{ g mol}^{-1}$ (1) Mass of M = $(142.3 - 60)/2 = 41.15$ (= K) (1) K ₂ CO ₃ (1)	4	Note: molar mass is between K ₂ CO ₃ (138.2) and SrCO ₃ (147.6); only possible match for a Group 1 carbonate is K ₂ CO ₃ .
			Total	10	

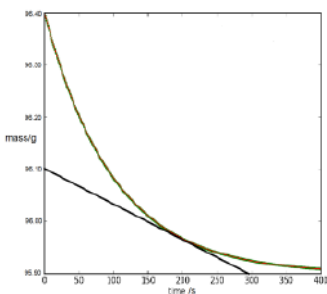
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11	a		volumetric flask AND (graduated) pipette	1	allow graduated flask ignore burette
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 73.9 or 73.93 (g mol^{-1}) award 3 marks for calculation $n(\text{NaOH}) = (25.25/1000) \times 0.120 = 3.03 \times 10^{-3} \text{ (mol) (1)}$ $n(\text{acid in } 250 \text{ cm}^3 \text{ flask}) = 3.03 \times 10^{-3} \times 10 = 3.03 \times 10^{-2} \text{ (mol) (1)}$ molar mass of unknown acid = $2.24/3.03 \times 10^{-2} = 73.9 \text{ (g mol}^{-1}\text{) (1)}$	3	If there is an alternative answer, check to see if there is any ECF credit possible using working below
	c		Repeat titration until (two) titrations are concordant / agree within 0.1 cm^3 (1) Calculate mean titre from concordant titres (1)	2	ignore just 'repeat the titration' (needs qualifying).
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12	a	i	carbon dioxide lost/evolved/given off/or produced as a gas ✓	1	DO NOT ALLOW water or steam or CO₂ evaporates Examiner's Comments Candidates who failed to state that the gas being lost was CO₂ could not access the mark for this question. Vague answers relating to water being produced, products being gases, products being lost or a gas evolved were often given by Candidates.
		ii	FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 1.85 OR 1.845 g award 3 marks ----- $n(\text{HNO}_3)$ $= 1.25 \times \frac{20.0}{1000} = 0.0250 \text{ mol } \checkmark$ $n(\text{SrCO}_3)$ $= \frac{0.0250}{2} = 0.0125 \text{ mol } \checkmark$ $m(\text{SrCO}_3)$ $= 0.0125 \times 147.6 = 1.845 \text{ g OR } 1.85 \text{ g } \checkmark$	3	If there is an alternative answer, check to see if there is any ECF credit possible ALLOW ECF from incorrect $n(\text{HNO}_3)$ molar mass of SrCO₃ = 147.6 (g mol⁻¹) ALLOW ECF from incorrect $n(\text{SrCO}_3)$ Examiner's Comments The vast majority of candidates were able to complete this calculation arriving at the correct answer to score all three available marks. The most common error was in calculating the amount, in moles, of the SrCO₃ from the stoichiometry given in the equation. This resulted in an answer which was twice that expected however two marks could still be obtained by applying error carried forward. Answer = 1.845 g or 1.85 g
	b	i	rate of reaction decreases AND concentration decreases / reactants are used up ✓	1	ALLOW reaction slows down ALLOW concentration of reactants decreases.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		i	less frequent collisions ✓	1	ALLOW fewer collisions per unit time OR collisions less often OR decreased rate of collision IGNORE less successful collisions / less collisions less chance of collisions Examiner's Comments Very few candidates were able to explain the change in the rate of the reaction during the first 200 seconds of the experiment. This relatively straightforward question required a statement that the rate decreases as the concentration of the reactants decreases due to there being less frequent collisions. Although a large number of candidates were able to state that the rate decreases few were able to explain why. This was possibly due to candidates having to apply their understanding in an unfamiliar context rather than from a lack of knowledge
		ii	Attempted tangent on graph drawn to line at approximately $t = 200$ s ✓	1	ALLOW 1 SF up to calculator value, in range 5×10^{-4} to 8×10^{-4} IGNORE units IGNORE sign Examiner's Comments This was the first time AS level candidates have been required to calculate a rate of reaction from a graph and many found this quite testing. Although many knew that a tangent was required only the most able candidates were able to arrive at a value for the gradient that was within the expected range. Candidates sometimes took as their values the point at which their tangent cut the axes rather than calculating the change in mass or change in time. Acceptable range 5×10^{-4} to 8×10^{-4}
		ii	Gradient (y/x) e.g. $\frac{0.20}{290} = 6.9 \times 10^{-4}$ ✓ 	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		Flask OR beaker AND balance AND stopwatch OR stop clock OR other timing device ✓	1	DO NOT ALLOW round-bottomed flask. IGNORE weighing scales
			Records mass at time intervals ✓	1	ALLOW 'weigh at time intervals'
			Time interval quoted between 10-50s ✓	1	Examiner's Comments This was the second question that required candidates to describe an experiment that they could have carried out as part of their course. Even if this experiment had not been completed in class, candidates should be able to recognise that mass needs to be measured over a period of time. As the reaction was between an acid and a carbonate a suitable named reaction vessel such as a beaker or flask was required. A balance was needed for mass measurement and a timing device to monitor time. A simple statement that mass should be recorded at a given time interval scored two marks with one mark being allocated to suitable apparatus. At this level it is expected that candidates will be familiar with the correct names for the apparatus required to carry out an investigation.
			Total	11	

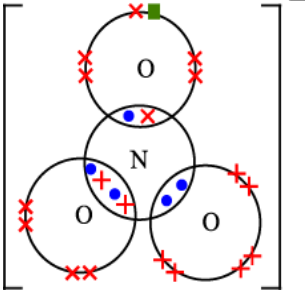
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13		i	Effervescence OR fizzing OR bubbling OR gas produced AND The solid OR zinc carbonate would dissolve OR disappear ✓	1	ALLOW 'carbon dioxide produced' DO NOT ALLOW incorrectly named gas eg H ₂ Examiner's Comments Most candidates realised that effervescence and dissolving would be seen.
		ii	$\text{ZnCO}_3 + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$ ✓	1	ALLOW multiples IGNORE state symbols Examiner's Comments Nearly all candidates were able to write the equation successfully – including those who had omitted effervescence in (i).
			Total	2	
14			A	1	<u>Examiner's Comments</u> Candidates were clearly unsure on how to classify a neutralisation reaction, with D being a common incorrect answer.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15		i	$\text{NiO} + 2\text{HNO}_3 \rightarrow \text{Ni}(\text{NO}_3)_2 + \text{H}_2\text{O} \checkmark$	1	ALLOW multiples IGNORE state symbols (even if wrong) <u>Examiner's Comments</u> This part was surprisingly poorly answered. Common errors included incorrect formulae for nickel(II) oxide and HNO_3, and H_2 shown as a product instead of H_2O.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
ii	 Global rules - N and O electrons must be shown differently, e.g. • for N and × for O 'Extra' electron shown with different symbol MARKING <i>Bonding around central N atom ✓</i> 5 electrons for N shown as • OR × 3 electrons for O, different from N as • OR × - N=O bond with 2 N electrons AND 2 O electrons - N→O bond with 2 N electrons - N-O bond with 1 N electron AND 1 O electron <i>Non-bonded (nb) electrons around 3 O atoms ✓</i> - N=O oxygen has 4 nb 'O' electrons - N□O oxygen has 6 nb 'O' electrons - N-O⁻ oxygen has 5 nb 'O' electrons AND 1 'extra' electron with different symbol	2	NOT REQUIRED - Charge ('-') - Brackets - Circles IGNORE inner shells ALLOW rotated diagram ALLOW diagram with missing N or O symbols. <i>Shown as diagram on QP anyway</i> In N=O bond, ALLOW sequence × × • • In N-O bond, ALLOW 'extra' electron with different symbol for O electron ALLOW non-bonding electrons unpaired If 'extra' electron has been used in N-O⁻ bond, N-O⁻ oxygen MUST have 6 nb 'O' electrons ALLOW 'extra' electron as • OR × if it has been labelled 'extra electron' or similar <u>Examiner's Comments</u> Most candidates attempted this novel 'dot-and-cross' diagram. Many candidates correctly showed the bonding electrons around the central nitrogen atom. The remaining electrons around the oxygen atoms proved to be more difficult, with many omitting to show the 'extra electron'.
	Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16			D	1	Examiner's Comments This question differentiated well. It appeared as if many candidates did not multiply the maximum error by 2 or used the final reading as opposed to a calculated titre.
			Total	1	
17			(Acid) releases H⁺ ions/ H⁺ donor AND (weak acid) partially dissociates/ionises ✓	1	ALLOW H⁺ OR proton IGNORE vague responses that do not imply a number, e.g. poor proton donor IGNORE 'doesn't easily dissociate' IGNORE 'a strong acid completely dissociates' <i>Question is about a weak acid</i> Examiner's Comments Most candidates were aware that an acid is a proton donor but many candidates gave imprecise responses for the concept of a weak acid. Good candidates used the expected term 'partial dissociation', but weaker candidates often focused on a lower concentration of hydrogen ions, pH range or indicator colour.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18	a		A solution of known concentration ✓	1	ALLOW description of concentration <u>Examiner's Comments</u> Many candidates gave a good description of standard conditions or stated 1 mol dm⁻³, but that did not answer the question so no marks could be credited.
	b		Releases OH ⁻ (ions in aqueous solution) ✓	1	ALLOW containing OH⁻ ions IGNORE mention of pH <u>Examiner's Comments</u> Many candidates stated a Brønsted–Lowry definition or gave pH values. Of the candidates that did mention OH⁻ ions, most did not state 'releases' OH⁻ ions in solution, although they were credited with the mark.

Mark Scheme

Question			Answer/Indicative content				Marks	Guidance									
	c	i	<table><tr><td>Final reading/ cm³</td><td>27.30</td><td>27.00</td><td>27.75</td></tr><tr><td>Initial reading/ cm³</td><td>0.45</td><td>0.60</td><td>1.25</td></tr><tr><td>Titre/cm³</td><td>26.85</td><td>26.40</td><td>26.50</td></tr></table> <i>Initial and final readings</i> All burette readings (×6) correct ✓ <i>Titres</i> recorded to two decimal places with the last figure either 0 or 5 Correct subtractions to obtain final titre values ✓ <i>Mean titre calculated from concordant results</i> Correct mean titre = 26.45 (cm³) ✓ Mean titre recorded to accuracy of burette Final answer recorded to two decimal places with the last figure either 0 or 5 ✓	Final reading/ cm ³	27.30	27.00	27.75	Initial reading/ cm ³	0.45	0.60	1.25	Titre/cm ³	26.85	26.40	26.50	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW missing zeroes for burette readings i.e. 0.6 for 0.60 27 OR 27.0 for 27.00 ALLOW ECF from incorrect burette readings IF MEAN IS CALCULATED FROM ECF, IT MUST BE FROM CLOSEST TITRES ALLOW ecf from incorrect mean DO NOT ALLOW 26.5 cm³ <i>Question asks for nearest 0.05 cm³</i> <u>Examiner's Comments</u> Most candidates were able to accurately record the burette readings and made the correct subtractions. Despite the examination question requesting the mean titre to be recorded to the accuracy of the burette, many candidates did not do this. A common error was taking a mean of all three readings instead of only the concordant results; this led the candidates to give an answer of 26.58 which lost them 2 marks.
Final reading/ cm ³	27.30	27.00	27.75														
Initial reading/ cm ³	0.45	0.60	1.25														
Titre/cm ³	26.85	26.40	26.50														
		ii	$\frac{2 \times 0.05}{26.85} \times 100 = 0.37(2) (\%) \checkmark$	1	ALLOW 0.4 up to full calculation display of 0.372439478 ALLOW ECF FOR CORRECT CALCULATION FROM 1 (c) (i) OR USE OF ANY TITRE <u>Examiner's Comments</u> A good attempt by many candidates but some did not know how to calculate this or did not multiply by 2.												

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Use a (250 cm ³) volumetric flask (instead of a beaker)✓	1	IGNORE graduated flask <u>Examiner's Comments</u> Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.
	d	i	FIRST CHECK ANSWER ON ANSWER LINE If answer = 118 (g mol⁻¹) award 4 marks If answer = 108 (g mol⁻¹) award 3 marks $n(\text{NaOH})$ $= 0.112 \times \frac{25.0}{1000} = 0.00280 \text{ (mol)} \checkmark$ $n(\text{A})$ in 25.0 cm³ $= \frac{0.00280}{2} = 0.00140 \text{ (mol)} \checkmark$ $n(\text{A})$ in 250 cm³ $= 0.00140 \times \frac{250.0}{27.30} = 0.0128 \text{ (mol)} \checkmark$ Molar mass, $M(\text{A})$ to nearest whole number. $= \frac{1.513}{0.0128} = 118 \text{ (g mol}^{-1}\text{)} \checkmark$	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Throughout: IGNORE trailing zeroes in intermediate working, e.g. For $n(\text{NaOH})$ ALLOW 0.0028 for 0.00280 ALLOW ECF from incorrect $n(\text{NaOH})$ ALLOW ECF from incorrect $n(\text{A})$ OR $n(\text{NaOH})$ ALLOW 3 sig fig up to full calculator display correctly rounded (0.012820512) ALLOW ECF from incorrect $n(\text{NaOH})$ Possible ECFs for 3 marks $1.513 \div (0.00140 \times 250/25) = 108$ $1.513 \div 0.00140 = 1081$ No $\div 2$ for $n(\text{A})$ - Molar mass A = 59 (g mol⁻¹) Using mean titre of 26.45 cm³ from 1c(i) - Molar mass A = 114 (g mol⁻¹) Using 27.3×0.112 in M1 and then 25.0 in M3 - Molar mass A = 99 (g mol⁻¹) <u>Examiner's Comments</u> Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Structure of dicarboxylic acid $\text{HOOCCH}_2\text{CH}_2\text{COOH}$ OR $\text{HOOCCH}(\text{CH}_3)\text{COOH}$ ✓ STRUCTURE MUST MATCH M_r from answer to 1 d) i) (within 10 AMU)	1	ALLOW correct structural OR skeletal OR displayed formulae OR a combination ALLOW incorrect connectivity e.g. -HO ALLOW ECF from incorrect molar mass in (d)(i) but only if $2 \times \text{COOH}$ possible and M_r is a close match to (d) (i) within 10 AMU <u>Examiner's Comments</u> Most candidates that obtained a sensible value for the previous question managed to draw a creditable structure. Allowing error carried forward meant that feasibly derived structures could be credited a mark.
			Total	13	
19			A	1	<u>Examiner's Comments</u> Candidates found this part difficult with many selecting B, the equation that looked a little different, rather than the correct answer of A (a redox equation). This suggests that many candidates are unaware of the role of ammonia as a base.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20		i	Oxidised AND (Mg) transfers/loses/donates 2 electrons ✓ 2 essential	1	ALLOW Mg loses 6 electrons: 3 Mg in equation ALLOW $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$ IGNORE oxidation numbers (even if wrong) <u>Examiner's Comments</u> Despite the question clearly asking for a response in terms of the number of electrons transferred, most candidates answered in terms of oxidation number changes. Candidates are recommended to read the question and to answer in terms of its requirements. Underlining 'number of electrons' may have helped candidates to answer the question that had been set.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	ii FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 2.26 (3 SF) award 3 marks $n(\text{H}_3\text{PO}_4) = \frac{1.24 \times 50.0}{1000} = 0.062(0) \text{ (mol)}$ ✓ $n(\text{Mg}) = \frac{3}{2} \times 0.062(0) = 0.093(0) \text{ (mol)}$ ✓ mass of Mg = $0.0930 \times 24.3 = 2.26 \text{ (g)}$ ✓ 3 SF required	3	At least 3SF needed throughout BUT ALLOW no trailing zeroes (e.g. 0.062 for 0.0620) ALLOW ECF from $n(\text{H}_3\text{PO}_4)$ ALLOW ECF from $n(\text{Mg})$ COMMON ERRORS for 2 marks 3:2 ratio omitted → $n(\text{Mg}) = 0.062(0) \rightarrow 1.51 \text{ (g)}$ Inverted 2:3 ratio → $n(\text{Mg}) = 0.0413 \rightarrow 1.00 \text{ (g)}$ <u>Examiner's Comments</u> Most candidates are competent at answering questions based on the mole. Almost all candidates were able to calculate the amount of H_3PO_4 as 0.062 mol. Candidates then needed to use the 2:3 mole stoichiometric ratio to show that 0.093 mol of Mg reacts, which has a mass of 2.26 g to the required 3 significant figures. The commonest errors were use of the inverse 3:2 ratio to obtain 1.00 g Mg, or to omit the ratio to obtain 1.51 g Mg, as shown in the exemplar. Candidates are advised to show clear working so that credit can be awarded for such responses by applying error carried forward. Exemplar 1 (ii) The student plans to add magnesium to 50.0 cm^3 of $1.24 \text{ mol/dm}^3 \text{ H}_3\text{PO}_4$. Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid. Give your answer to three significant figures. $1 = CV$ $50 \text{ cm}^3 = 0.05 \text{ dm}^3$ $1.24 \times 0.05 = 0.062 \text{ mol}$ $0.062 \times 24.3 = 1.5066$ $M = n \times m$ mass of Mg = <u>1.51</u> g [3]

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Separation of solid Filter to obtain solid/precipitate ✓ <i>Requires realisation that solid is filtered off.</i> Solid may be stated within in 'removal of water' Removal of water Dry (solid) OR Evaporate (water/solution/liquid) ✓	2	ALLOW Removal of water Evaporate/ distil water/solution/liquid ✓ IGNORE 'distil' if product OR H₂ is distilled Collection of remaining solid ✓ <i>Requires realisation that solid remains</i> IGNORE 'Leave to crystallise' (<i>already solid</i>) <u>Examiner's Comments</u> Candidates often struggle with questions based on practical work. There were many random responses to this question, with relatively few candidates identifying that solid magnesium phosphate could be obtained by filtration, followed by drying.

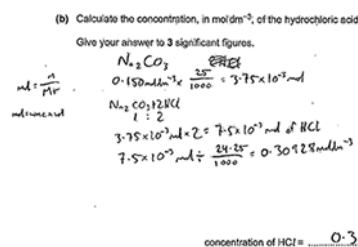
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Formula MgO OR Mg(OH)₂ OR MgCO₃ OR soluble Mg salt ✓ Equation $3\text{MgO} + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{H}_2\text{O}$ OR $3\text{Mg}(\text{OH})_2 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 6\text{H}_2\text{O}$ OR $3\text{MgCO}_3 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{CO}_2 + 3\text{H}_2\text{O}$	2	In equation: NO ECF from incorrect formula ALLOW multiples IGNORE state symbols (even if incorrect) Soluble Mg salts include MgCl₂, MgSO₄, Mg(NO₃)₂, MgBr₂, MgI₂ If unsure, check with TL e.g. $3\text{MgCl}_2 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 6\text{HCl}$ Examiner's Comments Candidates were expected to identify a suitable reagent for this reaction, with most choosing magnesium oxide, hydroxide or carbonate. Credit was also given for using a soluble magnesium salt such as its sulfate, chloride or nitrate. The correct equation often followed, but errors sometimes appeared in the form of incorrect formulae, such as MgOH for magnesium hydroxide. The exemplar shows a good clear response, using MgO as the reagent. Exemplar 2 (iv) Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium. Choose a suitable magnesium compound for this preparation and write the equation for the reaction. Formula of compound MgO ✓ Equation $3\text{MgO} + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{H}_2\text{O}$ [2]
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance					
21	a	i	<table><tr><td>Titre/cm³</td><td>24.20</td><td>23.85</td><td>24.30</td><td>✓</td></tr></table> Correct subtractions to obtain titres to 2 DP	Titre/cm ³	24.20	23.85	24.30	✓	2 (AO2.4)	DO NOT ALLOW 24.2 OR 24.3 <u>Examiner's Comments</u> Most candidates added correct titres for the three titrations. However, an error made by a quarter of candidates was to omit the zero as the second decimal place in the first and third titres. This should have been usual practice from candidate experience of practical work and has also been highlighted as a common error in previous exam series.
Titre/cm ³	24.20	23.85	24.30	✓						
		ii	mean titre = $\frac{24.20 + 22.30}{2} = 24.25 \text{ (cm}^3\text{)} \checkmark$ <i>i.e. using concordant (consistent) titres</i>	(AO2.4)	DO NOT ALLOW mean of all three titres, i.e. $\frac{24.20 + 23.85 + 22.30}{3} = 24.10/24.12$ ALLOW ECF from incorrect concordant titres from 22a(i) <u>Examiner's Comments</u> Most candidates identified that the first and third titres were concordant and calculated the mean titre that should be used as 24.25 cm³. About a third of candidates calculated the mean of all 3 titres as 24.10 or 24.12 cm³. Normal practice in titrations would be to select the closest titres.  OCR support The Practical Skills handbook contains guidance on correct practice for recording titration results and calculating average titre values in Appendix 4: Measurements, which can be shared with students: https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf.					

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	FIRST CHECK THE ANSWER ON ANSWER LINE IF answer = 0.309 (mol dm⁻³) award 3 marks ----- $n(\text{Na}_2\text{CO}_3) = 0.150 \times \frac{25.00}{1000} = 3.75 \times 10^{-3} \text{ (mol) } \checkmark$ $n(\text{HCl}) = 2 \times n(\text{Na}_2\text{CO}_3) = 7.50 \times 10^{-3} \text{ (mol) } \checkmark$ [HCl] to 3 SF $= n(\text{HCl}) \times \frac{1000}{\text{mean titre from b(i)}}$ $= 7.50 \times 10^{-3} \times \frac{1000}{24.25} = 0.309 \text{ (mol dm}^{-3}\text{) } \checkmark$ 3 SF required	3 (AO2.8×3)	ALLOW 3SF or more throughout IGNORE trailing zeroes, e.g. ALLOW 0.075 for 0.00750 ----- ALLOW ECF from 2 × incorrect $n(\text{Na}_2\text{CO}_3)$ ALLOW ECF from incorrect $n(\text{HCl})$, OR from $n(\text{Na}_2\text{CO}_3)$ if $n(\text{HCl})$ stage omitted ALLOW ECF from incorrect mean titre in b(ii) ----- COMMON ERROR for 3 marks From 24.10 cm³ (mean of all 3 titres in b(ii)), [HCl] = 0.311 (mol dm⁻³) <u>Examiner's Comments</u> Exemplar 3  (b) Calculate the concentration, in mol dm⁻³, of the hydrochloric acid. Give your answer to 3 significant figures. $n(\text{Na}_2\text{CO}_3) = 0.150 \text{ mol dm}^{-3} \times \frac{25}{1000} = 3.75 \times 10^{-3} \text{ mol}$ $n(\text{HCl}) = 2 \times n(\text{Na}_2\text{CO}_3) = 7.5 \times 10^{-3} \text{ mol}$ $\text{concentration of HCl} = \frac{7.5 \times 10^{-3} \text{ mol}}{24.25} = 0.309 \text{ mol dm}^{-3}$ Many candidates were able to calculate the amount of Na₂CO₃ in the titration as 0.00375 mol although a common error was to calculate the amount of Na₂CO₃ in the 250 cm³ volumetric flask as 0.0375 mol. Most candidates were credited for the amount of HCl: twice their calculated amount of Na₂CO₃. Candidates then need to scale up this value by 1000/mean titre to obtain the concentration as 0.309 mol dm⁻³, and to quote the answer to 3 significant figures. Many candidates scaled

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					up using 50.0, the burette volume, rather than their mean titre, resulting in a concentration 0.15 or 1.5 mol dm⁻³. A significant number also rounded their value to 2 rather than 3 significant figures. Candidates are advised to show clear working so that credit can be given for such responses by applying error carried forward. The working shown in this response is clear. Many candidates working was more jumbled, with unreferenced numbers common.
	c		Pipette: $\frac{0.04}{25.0} \times 100 = 0.16 \text{ OR } 0.2 (\%) \checkmark$ Burette: (using any of 3 titres or mean titre), e.g. $\frac{0.05 \times 2}{24.20} \times 100 = 0.41 \text{ OR } 0.4 (\%) \checkmark$ Response does NOT need a statement of whether pipette or burette has greater % uncertainty.	2 (AO3.1×2)	ALLOW % uncertainties to 1 SF or more, rounded correctly Other burette volumes: $\frac{0.05 \times 2}{23.85} \times 100 = 0.42 \text{ OR } 0.4 (\%)$ $\frac{0.05 \times 2}{24.30} \times 100 = 0.41 \text{ OR } 0.4 (\%)$ $\frac{0.05 \times 2}{24.25} \times 100 = 0.41 \text{ OR } 0.4 (\%)$ ALLOW burette volume of 50 cm³, i.e. $\frac{0.05 \times 2}{50} \times 100 = 0.2\%$ ALLOW ECF from incorrect titre in 22(a) IF BOTH calculations are 'correct' but ×100 is omitted BOTH times, ALLOW 1 mark Examiner's Comments Most candidates The calculations here should have reflected practical work carried out by candidates. Candidates were expected to realise that the pipette

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					volume involves one measurement requiring the uncertainty of ± 0.04 provided being used. As the volume measured by a burette uses two measurements, the uncertainty of ± 0.05 must then be doubled to obtain the percentage uncertainty. It was very common for the burette value to be obtained using 0.05 rather than the doubled 0.10; some candidates doubled both uncertainties. Another common error was to use the volume of the burette of 50 cm³ rather than the volume of solution measured in the burette.  OCR support The Practical Skills handbook contains guidance on calculating uncertainties in Appendix 4: Measurements, which can be shared with students: https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf.
			Total	7	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
22	<i>Please refer to the marking instructions on this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Calculates the correct mass of $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ or $\text{Mg}(\text{NO}_3)_2$. AND Explains the preparation steps, with most fine detail. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Attempts a calculation which is partly correct. AND Outlines the preparation steps, with some fine detail. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempts the calculation but makes little progress or makes errors. OR Briefly outlines the preparation steps, which may be incomplete <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6(AO2.8×2) (AO2.3×2) (AO2.7×2)	Indicative scientific points may include: Calculation: $n = \frac{250.0}{1000} \times 0.4000 = \mathbf{0.1(000)} \text{ (mol)}$ $M(\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}) = 256.3$ $\text{Mass} = 0.1000 \times 256.3 = \mathbf{25.63 \text{ g}}$ OR $M(\text{Mg}(\text{NO}_3)_2) = 148.3$ $\text{Mass} = \mathbf{14.83 \text{ g}}$ ALLOW small slip/rounding errors such as errors on M_r (e.g. use of 24 instead of 24.3 for Mg A_r) Preparation steps (apparatus and method): • Weigh mass of crystals • Dissolve in (distilled/deionised) water • Transfer to 250 cm³ volumetric flask • Make up to the mark with more water so that bottom of meniscus is on the mark IGNORE removing the water of crystallisation Fine detail: • 2 or more decimal place balance • Rinse beaker and transfer washings to flask • Use of dropping pipette when filling to mark • Stopper, invert several times to mix <u>Examiner's Comments</u> Most candidates focused on removing the water of crystallisation, often going to great depths of explanation, with apparatus diagrams, of how to remove it. Some candidates then went on to explain how to make a standard solution and could be given marks. Calculations for the mass required were often correct or could be given some marks.

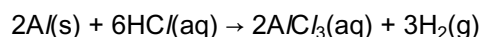
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 3 $C = \frac{M}{V}$ $\frac{250}{1000} \times 0.4 = 0.1 \text{ mol of } Mg(NO_3)_2 \text{ needed}$ $0.1 \text{ mol of } Mg(NO_3)_2$ - add the crystals to a crucible and weigh both separately using weighing scales. Set to zero. - then heat the crystals to a constant mass using a balance burner & ensure their mass of $Mg(NO_3)_2$ is 14.83g - add these crystals to a volumetric flask with 100cm³ of water, then stir it & make sure the crystals dissolve in the solvent (water) - then spill the rest of the volumetric flask up to 250cm³ along the bottom of the neck of it where you are measuring to. Additional answer space if required $0.1 \times (2 \times 24 + 3 \times 16 + 2 \times (14 + 16 \times 3))$ $= 14.83 \text{ g}$ $\Rightarrow$ mass of $Mg(NO_3)_2$ that should be left after heating to constant mass. This is a response of a common approach to this question, it was given 4 marks. Despite calculating the mass properly, the candidate then put all their efforts into describing removing the water of crystallisation and left out the valuable fine detail required for a Level 3 response.
			Total	6	

- 1 An aqueous solution of aluminium chloride can be prepared by the redox reaction between aluminium metal and dilute hydrochloric acid.

A student reacts 0.0800 mol of aluminium completely with dilute hydrochloric acid to form an aqueous solution of aluminium chloride.

The equation for this reaction is shown below.



In terms of electron transfer, explain whether aluminium is being oxidised or reduced.

----- [1]

- 2 Cerium behaves as a typical metal when it reacts with dilute sulfuric acid to form the salt cerium(III) sulfate and a second product.

(i) Identify the second product.

----- [1]

(ii) Write the formula of cerium(III) sulfate and, explain what has happened to the cerium in this reaction in terms of the number of electrons transferred.

Formula -----

Explanation -----

----- [2]

(iii) How has a salt been formed in this reaction?

----- [1]

3 This question is about Group 7 elements

Chlorine can be made by the redox reaction below.



Using oxidation numbers, show what has been oxidised and what has been reduced in this reaction.

Oxidised

.....

Reduced

.....

[2]

4 What is the formula of chromium(III) sulfate?

- A Cr_3SO_4
- B $\text{Cr}(\text{SO}_4)_3$
- C $\text{Cr}_2(\text{SO}_4)_3$
- D Cr_3SO_3

Your answer

[1]

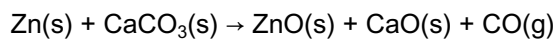
5 Which equation represents a redox reaction?

- A $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$
- B $\text{MgO} + 2\text{HCl} \rightarrow \text{H}_2\text{O} + \text{MgCl}_2$
- C $\text{MgCO}_3 + 2\text{HCl} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{MgCl}_2$
- D $\text{Mg}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{MgCl}_2 + 2\text{H}_2\text{O}$

Your answer

[1]

- 6 Carbon monoxide can be made in the laboratory by heating a mixture of zinc metal and calcium carbonate. An equation for this reaction is shown below.



This reaction is a redox reaction.

Deduce which element has been oxidised and which has been reduced, and state the change in oxidation number in each case.

element oxidised _____ oxidation number change: from _____ to _____

element reduced _____ oxidation number change: from _____ to _____

[2]

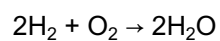
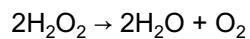
- 7 What is the oxidation number of vanadium in the ion $\text{V}_2\text{O}_7^{4-}$?

- A +5
- B +7
- C +10
- D +14

Your answer

[1]

8 Equations for two reactions that form H₂O are shown below.



Which statement is correct?

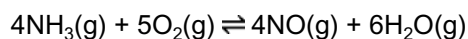
- A Hydrogen is reduced in both reactions.
- B Hydrogen is reduced in only one of the reactions.
- C Oxygen is oxidised in both reactions.
- D Oxygen is oxidised in only one of the reactions.

Your answer

☐

[1]

9 Ammonia is used in the manufacture of nitric acid. The first stage of this process is a dynamic equilibrium.



(i) When the temperature is increased, K_c for this reaction decreases.

State the effect, if any, on the equilibrium yield of NO in this reaction.

Explain your answer.

----- [1]

(ii) Which element has been oxidised and which element has been reduced in the reaction?

Include signs with the oxidation numbers.

Oxidised _____ Oxidation number change from _____ to _____

Reduced _____ Oxidation number change from _____ to _____

[2]

10 Group 2 elements are metals that react with oxygen and water.

Magnesium is oxidised when it burns in oxygen to form an ionic compound.

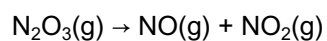
(i) Write the electron configuration, in terms of sub-shells, of a magnesium atom.

----- [1]

(ii) Explain what happens when magnesium is oxidised in terms of electron transfer.

----- [1]

11 N_2O_3 is an unstable oxide of nitrogen that decomposes in a redox reaction.



(i) State the oxidation number of nitrogen in each oxide in the table below.

Oxide	Oxidation number of nitrogen
N_2O_3	
NO	
NO_2	

[1]

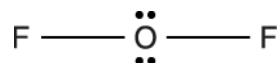
(ii) Name this type of redox reaction.

In your answer you should use appropriate technical terms spelled correctly.

-----[1]

- (i) Fluorine is the most electronegative element.

Indicate any dipoles on the molecule of F_2O below using partial charges.



[1]

- (ii) Suggest the **shape** of the F_2O molecule and the **F–O–F bond angle**.

Shape

Bond angle

[1]

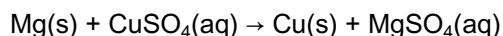
- (iii) What is the oxidation number of oxygen in F_2O ?

Include the sign in your answer.

.....[1]

13 Magnesium will undergo redox reactions with aqueous salts of less reactive metals.

(i) A student reacts magnesium with aqueous copper(II) sulfate.



Explain, in terms of **numbers** of electron transferred, the redox processes taking place in this reaction.

----- [2]

(ii) The student also noticed that the magnesium started fizzing.

The student thought the fizzing was due to the magnesium reacting with water in the mixture.

Write the equation for the reaction of magnesium with water.

Include state symbols.

----- [2]

14 What is the oxidation number of nitrogen in $\text{Mg}(\text{NO}_3)_2$?

- A -3
- B +2
- C +5
- D +6

Your answer

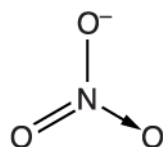
[1]

15 Nickel(II) nitrate, $\text{Ni}(\text{NO}_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

(i) Write the equation for this reaction.

[1]

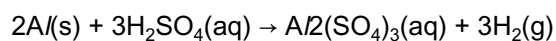
(ii) $\text{Ni}(\text{NO}_3)_2$ contains the NO_3^- ion. The nitrogen atom bonds to the oxygen atoms with a single covalent bond, a double covalent bond and a dative covalent bond, as shown below.



Draw the '*dot-and-cross*' diagram for the NO_3^- ion, showing outer shell electrons only.
Use a different symbol for the extra electron.

[2]

- 16 Salts can be prepared in redox reactions of metals with acids. A student prepares a solution of aluminium sulfate by reacting aluminium with dilute sulfuric acid.



Using oxidation numbers, show which element has been oxidised and which has been reduced in this reaction. State the changes in oxidation numbers, including all signs.

element oxidised _____

oxidation number change: from _____ to _____

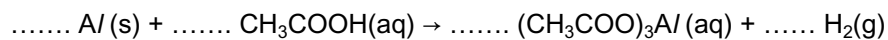
element reduced _____

oxidation number change: from _____ to _____

[2]

- (i) The unbalanced equation for the reaction is shown below.

Balance the equation.



[1]

- (ii) This reaction is a redox reaction.

Deduce which element has been oxidised and which element has been reduced, and state the changes in oxidation number.

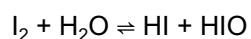
Element oxidised: _____ oxidation number change: from _____ to _____

Element reduced: _____ oxidation number change: from _____ to _____

[2]

18 Iodine can be used for the small-scale purification of drinking water.

(i) Iodine reacts with water as shown below.



Using oxidation numbers, explain why this reaction is a disproportionation.

[3]

(ii) Chlorine is used to purify water on a large scale.

State **one** disadvantage of using chlorine for the purification of drinking water.

[1]

19 What is the oxidation number of Fe in K_2FeO_4 ?

A +4

B +5

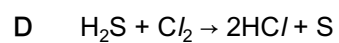
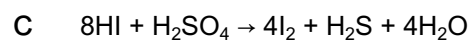
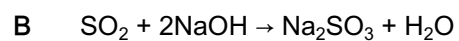
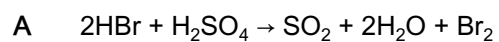
C +6

D +7

Your answer

[1]

20 Which reaction shows oxidation of sulfur?

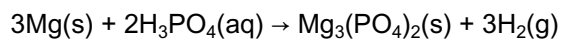


Your answer

[1]

21 This question is about compounds of magnesium and phosphorus.

A student plans to prepare magnesium phosphate using the redox reaction of magnesium with phosphoric acid, H_3PO_4 .



- (i) In terms of the number of electrons transferred, explain whether magnesium is being oxidised or reduced.

----- [1]

- (ii) The student plans to add magnesium to 50.0 cm^3 of $1.24 \text{ mol dm}^{-3} \text{ H}_3\text{PO}_4$.

Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid.

Give your answer to **three** significant figures.

mass of Mg = ----- g [3]

- (iii) How could the student obtain a sample of magnesium phosphate after reacting magnesium with phosphoric acid?

----- [2]

(iv) Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium.

Choose a suitable magnesium compound for this preparation and write the equation for the reaction.

Formula of compound -----

Equation ----- [2]

22 A phosphate(V) ion has the formula PO_4^{3-} .

What is the formula for copper(I) phosphate(V)?

A $\text{Cu}(\text{PO}_4)_5$

B Cu_5PO_4

C $\text{Cu}(\text{PO}_4)_3$

D Cu_3PO_4

Your answer

[1]

23 Magnesium nitrate decomposes when heated, as shown in the equation.



Using oxidation numbers, show which element has been oxidised and which has been reduced when magnesium nitrate decomposes.

State the changes in oxidation numbers, including all signs.

Element oxidised

Oxidation number change: from to

Element reduced

Oxidation number change: from to

[2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1			Oxidised AND because aluminium has lost (three) electrons ✓	1	ALLOW 'donated' for 'lost' IGNORE where electrons are transferred to IGNORE $\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$ DO NOT ALLOW 'an electron' or incorrect number of electrons Examiner's Comments This question was very well answered. Where candidates did not gain the mark it was often because they forgot to discuss the oxidation of aluminium in terms of electron loss, but instead justified it in by using oxidation numbers.
			Total	1	
2		i	Hydrogen ✓	1	ALLOW H_2 IGNORE 'H' Examiner's Comments This question was well answered although the erroneous appearance of water as a product of the reaction between an acid and a metal was seen relatively frequently.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\text{Ce}_2(\text{SO}_4)_3$ ✓ (Cerium) loses three electrons (to form 3+ ion) ✓	2	ALLOW alternative phrases for 'loses' eg 'gives away', 'donates' IGNORE '3 electrons transferred' unless a correct direction is given eg ALLOW (Ce) transfers 3 electrons to ... OR (Ce) transfers 3 electrons forming Ce^{3+} IGNORE references to sulfate gaining electrons IGNORE references to reduction and oxidation Examiner's Comments This question was slightly more challenging and discriminated well. Some candidates missed the fact that the cerium was in the +3 oxidation state and gave the formula as CeSO_4 along with an explanation that involved the loss of 2 electrons. However, a significant number of candidates did not focus upon the instruction in the question to explain 'in terms of the number of electrons transferred' and gave responses based solely upon changes in oxidation number.
		iii	A hydrogen ion (of an acid) has been replaced by a metal ion ✓	1	For hydrogen ion: ALLOW 'H^+' OR 'proton' but DO NOT ALLOW 'H' OR 'hydrogen' without 'ion' For metal ion: ALLOW 'cerium ion' OR 'Ce^{3+}' OR 'Ce^{2+}' OR 'Ce ion' But DO NOT ALLOW 'Ce' without 'ion' OR 'cerium' without 'ion' IGNORE 'ammonium ion' Examiner's Comments A good number of candidates had no problem with this question but slightly weaker students talked vaguely about the reaction of metals with acids and clearly did not realise that the question was really examining how well they understood the definition of a salt.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3			Cl (has been oxidised) from Cl = -1 to Cl = 0 ✓ Mn (has been reduced) from Mn = +4 to Mn = +2 ✓	2	ALLOW 4+ OR 4 OR 2+ OR 2 ALLOW oxidation numbers written above the equation but IGNORE these if oxidation numbers are given in the text ALLOW one mark for Cl is oxidised because the oxidation number increased by 1 AND Mn is reduced because the oxidation number decreased by 2 ALLOW one mark if all oxidation numbers are correct but redox is incorrect. IGNORE HCl is oxidised AND MnO₂ is reduced IGNORE correct references to electron loss / gain DO NOT ALLOW incorrect references to electron loss / gain Examiner's Comments Overall the answer to this question could be determined by most candidates. Some were confused by the fact that Cl appeared in two oxidation states in the products and suggested that this was a type of disproportionation reaction with the Cl in MnCl₂ having a -2 oxidation state.
			Total	2	
4			C	1	
			Total	1	
5			A	1	
			Total	1	
6			Element oxidised: zinc / Zn 0 to +2 (1) Element reduced: carbon / C +4 to +2 (1)	2	allow 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around max 1 mark if missing '+' or 'if given as charges e.g. '2+'
			Total	2	
7			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8			D	1	
			Total	1	
9		i	Yield decreases AND Equilibrium (position) has moved to the left	1	allow moved towards reactants OR moved towards CO and H ₂
		ii	Oxidised Nitrogen AND -3 AND +2 (1) Reduced Oxygen AND 0 AND -2 (1)	2	
			Total	3	
10		i	1s ² 2s ² 2p ⁶ 3s ² ✓	1	ALLOW upper case S and P, and subscripts, e.g. 2S ₂ 3P ₆ Examiner's Comments This part was generally answered well showing a good understanding of electron configuration. Candidates frequently used subscripts rather than superscripts for denoting the number of electrons in a particular sub-shell and although this was still credited the correct use of notation should be emphasised in lessons.
		ii	(Mg) loses / transfers / donates two electrons ✓	1	ALLOW Mg loses the 3s electrons provided electronic configuration in (i) is 3s ² ALLOW Mg → Mg ²⁺ + 2e ⁻ IGNORE reference to oxidation numbers / states Examiner's Comments Most candidates understood that oxidation resulted in the loss of electrons although some answers considered changes in oxidation number. A significant number of candidates did not specify how many electrons were lost when magnesium was oxidised preventing the award of the mark.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11		i	$\text{N}_2\text{O}_3 = +3$ $\text{NO} = +2$ $\text{NO}_2 = +4 \checkmark$	1	ALLOW '3' OR '3+' etc ALLOW oxidation numbers written over the equation but IGNORE if oxidation numbers are given on the answer lines Examiner's Comments The correct answer was almost universally known.
		ii	Disproportionation $\checkmark$	1	QWC 'disproportionation' spelled correctly. Examiner's Comments The correct answer was almost universally known with just the rare misspelling of disproportionation seen.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12		i	δ^- on each F AND δ^+ on O ✓	1	ALLOW δ^+ OR δ^+ δ^+ on O Examiner's Comments The application of dipoles to the molecule was done well.
		ii	Shape: non-linear AND Bond angle: 104.5° ✓	1	For shape ALLOW alternative words eg 'V-shaped' 'bent' 'angular'. In the absence of words allow a diagram with a non-linear shape F – O – F bond angle $> 90^\circ$. For bond angle ALLOW 106° bond angle ≥ 102 (Actual = 102°) Examiner's Comments Only a few candidates failed to realise that two bonding pairs and two non-bonding pairs would lead to the molecule being bent-shaped with an expected bond angle of 104.5°.
		iii	+2 ✓	1	ALLOW 2+ Examiner's Comments The question told candidates that fluorine was the most electronegative element which should have led them to realising that oxygen's oxidation state had to be a positive number. Many chose to ignore this despite allocating the oxygen atom a partial positive charge in part (i).
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13		i	Magnesium (atoms) has been oxidised AND Because it has lost two electrons ✓ Copper (ions) has been reduced AND Because it has gained two electrons ✓	2	IGNORE use of oxidation numbers if electron gain/loss is mentioned. Electrons gain/loss could be in half equations In the absence of text look for evidence on the equation ALLOW 'donated' for 'lost' Assume 'Cu' refers to copper in 'CuSO₄' ALLOW one mark two electrons gained and lost for each species but oxidation/reduction is incorrect or is omitted ALLOW one mark for correct oxidation and reduction if electron transfer is omitted and correct changes of oxidation state are shown (ie Mg 0 --> (+)2 AND Cu (+)2 to 0) ALLOW 'two' electrons transferred from magnesium to copper Examiner's Comments This type of question in the past has proved difficult but the current cohort found little difficulty. By far, the most common error was to use changes in oxidation numbers as the basis of the redox rather than using the number of electrons gained and lost for the explanation of the redox process.
		ii	Mg(s) + 2H₂O(l) → Mg(OH)₂(aq) + H₂(g) Correct reactants and products ✓ Balance and state symbols ✓	2	ALLOW multiples ALLOW Mg(OH)₂(s) ALLOW Mg(s) + H₂O(g) OR H₂O(l) MgO(s) + H₂(g) including state symbols for one mark Examiner's Comments The equation for the reaction between magnesium and water was well known – but many erroneously assumed MgO was formed.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14			C	1	ALLOW +5 OR 5+ in box <u>Examiner's Comments</u> Generally scored well.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15		i	$\text{NiO} + 2\text{HNO}_3 \rightarrow \text{Ni}(\text{NO}_3)_2 + \text{H}_2\text{O}$ ✓	1	ALLOW multiples IGNORE state symbols (even if wrong) <u>Examiner's Comments</u> This part was surprisingly poorly answered. Common errors included incorrect formulae for nickel(II) oxide and HNO_3, and H_2 shown as a product instead of H_2O.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
ii	Global rules - N and O electrons must be shown differently, e.g. • for N and × for O 'Extra' electron shown with different symbol MARKING <i>Bonding around central N atom ✓</i> 5 electrons for N shown as • OR × 3 electrons for O, different from N as • OR × - N=O bond with 2 N electrons AND 2 O electrons - N→O bond with 2 N electrons - N-O bond with 1 N electron AND 1 O electron <i>Non-bonded (nb) electrons around 3 O atoms ✓</i> - N=O oxygen has 4 nb 'O' electrons - N□O oxygen has 6 nb 'O' electrons - N-O⁻ oxygen has 5 nb 'O' electrons AND 1 'extra' electron with different symbol	2	NOT REQUIRED - Charge ('-') - Brackets - Circles IGNORE inner shells ALLOW rotated diagram ALLOW diagram with missing N or O symbols. <i>Shown as diagram on QP anyway</i> In N=O bond, ALLOW sequence × × • • In N-O bond, ALLOW 'extra' electron with different symbol for O electron ALLOW non-bonding electrons unpaired If 'extra' electron has been used in N-O⁻ bond, N-O⁻ oxygen MUST have 6 nb 'O' electrons ALLOW 'extra' electron as • OR × if it has been labelled 'extra electron' or similar <u>Examiner's Comments</u> Most candidates attempted this novel '<i>dot-and-cross</i>' diagram. Many candidates correctly showed the bonding electrons around the central nitrogen atom. The remaining electrons around the oxygen atoms proved to be more difficult, with many omitting to show the 'extra electron'.
	Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16			Element oxidised: aluminium/Al 0 to +3 ✓ Element reduced: hydrogen/H/H⁺ +1 to 0 ✓	2	MAX 1 mark if no '+' sign for oxidation number ALLOW 3+ ALLOW 1+ ALLOW H₂ for hydrogen ALLOW 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around IGNORE numbers around equation <i>i.e. treat as rough working</i> <u>Examiner's Comments</u> A good proportion of candidates were able to achieve the 2 marks here. A minority correctly identified the elements, but not the oxidation numbers. Aluminium was credited more often than hydrogen, perhaps as only some of the hydrogen atoms are reduced. Some amazing oxidation states were claimed for S, O, Al and H with more electrons lost than the atoms had. Very few candidates assigned the oxidation and reduction incorrectly.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17		i	$2 \text{ Al(s)} + 6 \text{ CH}_3\text{COOH(aq)} \rightarrow 2 \text{ (CH}_3\text{COO)}_3\text{Al(aq)} + 3 \text{ H}_2\text{(g)}$ ✓	1	ALLOW multiples, e.g. $\text{Al(s)} + 3 \text{ CH}_3\text{COOH(aq)} \rightarrow \text{(CH}_3\text{COO)}_3\text{Al(aq)} + 1\frac{1}{2} \text{ H}_2\text{(g)}$ Examiner's Comments The majority of candidates were able to balance this equation using whole numbers or half multiples. Where there was an error, it was invariably for the balancing number of H₂.
		ii	Element oxidised: aluminium/Al 0 to +3 ✓ Element reduced: hydrogen/H +1 to 0 ✓	2	ALLOW 3+ for +3 and 1+ for +1 ALLOW H₂ for hydrogen ALLOW 1 mark for elements AND all oxidation numbers correct, but H in oxidised line and Al in reduced line '+' is required in +3 and +1 oxidation numbers IGNORE numbers around equation (<i>treat as rough working</i>) Examiner's Comments This question was not answered as well as expected. It was pleasing to see that almost all candidates recognised the importance of writing oxidation numbers correctly including a '+' or '-' sign where needed. Common mistakes included giving the total contribution from an element as opposed to the oxidation state of each atom of the element.
			Total	3	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
18	i Disproportionation Oxidation AND reduction of same element/iodine OR Iodine has been oxidised and Iodine has been reduced ✓ Oxidation from 0 to +1 in HIO ✓ Reduction from 0 to –1 in HI ✓	3	ALLOW I or I₂ for iodine IGNORE numbers around equation for oxidation states ALLOW 1– for –1 AND 1+ for +1 NOTE (for iodine/I₂) from 0 only needs to be seen once, does not need to be stated twice ALLOW 1 mark for 3 ox nos correct but no mention of words oxidation/reduction: 0 in I₂ AND –1 in HI AND +1 in HIO ALLOW 1 mark for species missing: Iodine oxidised (from 0) to +1 AND iodine reduced (from 0) to –1 <u>Examiner's Comments</u> Most candidates were aware of disproportionation but lost marks by not stating the species or whether the process was oxidation or reduction. Exemplar 2 (i) Iodine reacts with water as shown below. $\overset{-1}{\text{I}}_2 + \text{H}_2\text{O} \rightleftharpoons \overset{+1}{\text{HI}} + \overset{-1}{\text{HIO}}$ Using oxidation numbers, explain why this reaction is a disproportionation. Disproportionation is where the same element is both oxidised and reduced in the same reaction. Iodine is reduced (0 to –1) to form HI and oxidised (0 to +1) in HIO. [3] Here the candidate has lost a mark for not stating the initial oxidation number of elemental iodine as 0.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Chlorine is toxic/poisonous OR forms halogenated hydrocarbons OR forms carcinogens/toxic compounds ✓	1	ALLOW (reacts with hydrocarbons to) form carcinogens/toxic compounds IGNORE • chlorine causes cancer • harmful/dangerous • chlorine causes breathing problems <u>Examiner's Comments</u> The majority of candidates stated that chlorine is toxic or forms carcinogens, although some stated that chlorine is a carcinogen which was not credited. 12
			Total	4	
19			C	1	ALLOW +6 <u>Examiner's Comments</u> Nearly all candidates responded with the correct response of C. Candidates seem to have a very good understanding of applying oxidation number rules.
			Total	1	
20			D	1	<u>Examiner's Comments</u> Candidates needed to do a lot of work to solve this problem and most wrote oxidation numbers around the equations. This systematic process allowed most candidates to find that D is the only option in which sulfur is oxidised.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21		i	Oxidised AND (Mg) transfers/loses/donates 2 electrons ✓ 2 essential	1	ALLOW Mg loses 6 electrons: 3 Mg in equation ALLOW $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^{-}$ IGNORE oxidation numbers (even if wrong) <u>Examiner's Comments</u> Despite the question clearly asking for a response in terms of the number of electrons transferred, most candidates answered in terms of oxidation number changes. Candidates are recommended to read the question and to answer in terms of its requirements. Underlining 'number of electrons' may have helped candidates to answer the question that had been set.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	ii FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 2.26 (3 SF) award 3 marks $n(\text{H}_3\text{PO}_4) = \frac{1.24 \times 50.0}{1000} = 0.062(0) \text{ (mol)}$ ✓ $n(\text{Mg}) = \frac{3}{2} \times 0.062(0) = 0.093(0) \text{ (mol)} \checkmark$ mass of Mg = $0.0930 \times 24.3 = 2.26 \text{ (g)} \checkmark$ 3 SF required	3	At least 3SF needed throughout BUT ALLOW no trailing zeroes (e.g. 0.062 for 0.0620) ALLOW ECF from $n(\text{H}_3\text{PO}_4)$ ALLOW ECF from $n(\text{Mg})$ COMMON ERRORS for 2 marks 3:2 ratio omitted → $n(\text{Mg}) = 0.062(0) \rightarrow 1.51 \text{ (g)}$ Inverted 2:3 ratio → $n(\text{Mg}) = 0.0413 \rightarrow 1.00 \text{ (g)}$ <u>Examiner's Comments</u> Most candidates are competent at answering questions based on the mole. Almost all candidates were able to calculate the amount of H_3PO_4 as 0.062 mol. Candidates then needed to use the 2:3 mole stoichiometric ratio to show that 0.093 mol of Mg reacts, which has a mass of 2.26 g to the required 3 significant figures. The commonest errors were use of the inverse 3:2 ratio to obtain 1.00 g Mg, or to omit the ratio to obtain 1.51 g Mg, as shown in the exemplar. Candidates are advised to show clear working so that credit can be awarded for such responses by applying error carried forward. Exemplar 1 (ii) The student plans to add magnesium to 50.0 cm^3 of $1.24 \text{ mol/dm}^3 \text{ H}_3\text{PO}_4$. Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid. Give your answer to three significant figures. $1 = CV$ $50 \text{ cm}^3 = 0.05 \text{ dm}^3$ $1.24 \times 0.05 = 0.062 \text{ mol}$ $0.062 \times 24.3 = 1.5066$ $M = n \times m$ mass of Mg = <u>1.51</u> g [3]

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Separation of solid Filter to obtain solid/precipitate ✓ <i>Requires realisation that solid is filtered off.</i> Solid may be stated within in 'removal of water' Removal of water Dry (solid) OR Evaporate (water/solution/liquid) ✓	2	ALLOW Removal of water Evaporate/ distil water/solution/liquid ✓ IGNORE 'distil' if product OR H₂ is distilled Collection of remaining solid ✓ <i>Requires realisation that solid remains</i> IGNORE 'Leave to crystallise' (<i>already solid</i>) <u>Examiner's Comments</u> Candidates often struggle with questions based on practical work. There were many random responses to this question, with relatively few candidates identifying that solid magnesium phosphate could be obtained by filtration, followed by drying.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Formula MgO OR Mg(OH)₂ OR MgCO₃ OR soluble Mg salt ✓ Equation $3\text{MgO} + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{H}_2\text{O}$ OR $3\text{Mg}(\text{OH})_2 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 6\text{H}_2\text{O}$ OR $3\text{MgCO}_3 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{CO}_2 + 3\text{H}_2\text{O}$	2	In equation: NO ECF from incorrect formula ALLOW multiples IGNORE state symbols (even if incorrect) Soluble Mg salts include MgCl₂, MgSO₄, Mg(NO₃)₂, MgBr₂, MgI₂ If unsure, check with TL e.g. $3\text{MgCl}_2 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 6\text{HCl}$ <u>Examiner's Comments</u> Candidates were expected to identify a suitable reagent for this reaction, with most choosing magnesium oxide, hydroxide or carbonate. Credit was also given for using a soluble magnesium salt such as its sulfate, chloride or nitrate. The correct equation often followed, but errors sometimes appeared in the form of incorrect formulae, such as MgOH for magnesium hydroxide. The exemplar shows a good clear response, using MgO as the reagent. Exemplar 2 (iv) Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium. Choose a suitable magnesium compound for this preparation and write the equation for the reaction. Formula of compound MgO ✓ Equation $3\text{MgO} + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{H}_2\text{O}$ [2]
			Total	8	
22			D	1 (AO1.2)	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23			Element oxidised: Oxygen/O Change from: -2 to 0 ✓ Element reduced: Nitrogen/N Change from +5 to +4 ✓	2(AO2.2× 2)	MAX 1 mark if no '+' sign for oxidation number ALLOW 2– ALLOW 5+ AND 4+ ALLOW O₂ for oxygen ALLOW 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around IGNORE numbers around equation <i>i.e. treat as rough working</i> <u>Examiner's Comments</u> Less than half the candidates answered this question correctly. This may be because they are not used to assigning oxidation numbers within formulae that contain brackets.
			Total	2	