



1. 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]

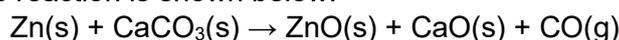
2. Which equation represents a redox reaction?

- 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]

3. 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

element reduced

oxidation number change: from to

oxidation number change: from to

[2]



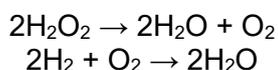
4. What is the oxidation number of vanadium in the ion $V_2O_7^{4-}$?

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

Your answer

[1]

5. Equations for two reactions that form H_2O are shown below.



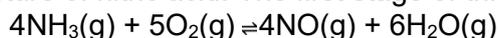
Which statement is correct?

- 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]

6. 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]

7. Which redox reaction contains the largest change in oxidation state for sulfur?

- A. $\text{H}_2\text{SO}_4 + 8\text{HI} \rightarrow \text{H}_2\text{S} + 4\text{I}_2 + 4\text{H}_2\text{O}$
- B. $\text{S} + \text{O}_2 \rightarrow \text{SO}_2$
- C. $\text{S}_2\text{O}_3^{2-} + 2\text{H}^+ \rightarrow \text{SO}_2 + \text{S} + \text{H}_2\text{O}$
- D. $\text{S} + 6\text{HNO}_3 \rightarrow \text{H}_2\text{SO}_4 + 6\text{NO}_2 + 2\text{H}_2\text{O}$

Your answer

[1]

8. This question is about the chemistry of the elements in Group 2 and the halogens.

A student prepares an aqueous solution of magnesium chloride by reacting magnesium with excess hydrochloric acid.

Write an equation, including state symbols, for this reaction and state the observation(s) the student should make whilst carrying out this experiment.

equation:

observation(s):

[2]



9. Concentrated nitric acid, HNO_3 , is an oxidising agent. For example, concentrated HNO_3 reacts with sulfur to form sulfuric acid, nitrogen dioxide and one other product.

- Using oxidation numbers, show the element that is oxidised and the element that is reduced in this reaction. Ensure that the oxidation numbers have signs.
- Construct the balanced equation for this reaction.

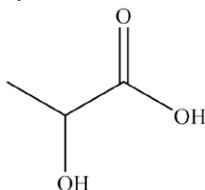
element oxidised oxidation number change: from to

element reduced oxidation number change: from to

equation [4]

10. This question is about organic acids.

Lactic acid, shown below, has two functional groups.



Lactic acid reacts with bases and with many metals.

- An aqueous solution containing 1.125 g of lactic acid is reacted with an excess of magnesium producing hydrogen gas.
- The excess magnesium is removed.
The water is evaporated, leaving a white solid, **A**.

i. Name the type of reaction of lactic acid with bases and with metals.

reaction with bases:

reaction with metals:

[1]



- ii. Calculate the volume of $\text{H}_2(\text{g})$ produced, measured at room temperature and pressure.

volume of H_2 = [2]

- i. What is the empirical formula of the white solid **A**?

..... [1]

- ii. Predict **two** reactions of lactic acid, each involving a different functional group.

Do **not** include reactions with bases or metals.

For each reaction,

- state the type of reaction, the reagents and conditions
- draw the structures of any organic products formed.

[4]



11. This question is about numbers and patterns in chemistry.

This question looks at number relationships. For calculations, show your working.

i. What is the oxidation number of nitrogen in each species?

N_2O_4 NO_3^- NH_4^+

ii. [1]

iii. What mass of KMnO_4 is needed to prepare a 250.0 cm^3 solution with a concentration of $0.200 \text{ mol dm}^{-3}$ KMnO_4 ?

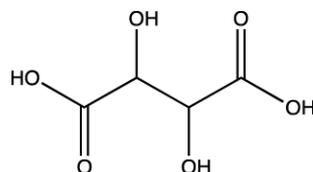
mass = g [2]

iv. What are the units of the rate constant for a reaction with an overall order of 3?

units = [1]

v. How many molecules are in 38.25 g of tartaric acid?

Give your answer to an **appropriate** number of significant figures and in standard form.



tartaric acid

number of molecules = [2]



12. A student carries out two experiments based on redox reactions of iron and chromium.

Use the standard electrode potentials below to help you answer the questions that follow.

$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^{-}$	\rightleftharpoons	$\text{Fe}(\text{s})$	$E^{\ominus} = -0.44 \text{ V}$
$2\text{H}^{+}(\text{aq}) + 2\text{e}^{-}$	\rightleftharpoons	$\text{H}_2(\text{g})$	$E^{\ominus} = 0.00 \text{ V}$
$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-}$	\rightleftharpoons	$\text{Fe}^{2+}(\text{aq})$	$E^{\ominus} = +0.77 \text{ V}$
$\text{O}_2(\text{g}) + 4\text{H}^{+}(\text{aq}) + 4\text{e}^{-}$	\rightleftharpoons	$2\text{H}_2\text{O}(\text{l})$	$E^{\ominus} = +1.23 \text{ V}$
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^{+}(\text{aq}) + 6\text{e}^{-}$	\rightleftharpoons	$2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	$E^{\ominus} = +1.33 \text{ V}$
$\text{Cl}_2(\text{g}) + 2\text{e}^{-}$	\rightleftharpoons	$2\text{Cl}^{-}(\text{aq})$	$E^{\ominus} = +1.36 \text{ V}$
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^{+}(\text{aq}) + 2\text{e}^{-}$	\rightleftharpoons	$2\text{H}_2\text{O}(\text{l})$	$E^{\ominus} = +1.78 \text{ V}$

For each experiment, identify the species causing the observations shown in bold text and write overall equations for any reactions taking place.

State symbols are **not** required in the equations.

i. **Experiment 1**

1. The student adds iron filings to dilute hydrochloric acid.
A **green solution** forms and **gas bubbles** are seen.
2. The student bubbles air through the green solution.
The solution turns an **orange-brown colour**.

1:

2:

[3]

ii. **Experiment 2**

The student heats a **green solution** of chromium(III) sulfate with dilute acid and hydrogen peroxide, H_2O_2 .

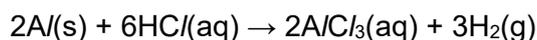
The solution turns an **orange colour**.

[3]

13. 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]

14. 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]



15. 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]

16. This question looks at properties of transition elements, ions and complexes.

What is the oxidation number of Cr in the complex ion $[\text{CrOCl}_5]^{2-}$?

[1]

17. 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]

18. 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]



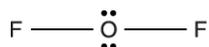
- ii. Name this type of redox reaction.

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

..... [1]

19.

- i. Fluorine is the most electronegative element.
Indicate any dipoles on the molecule of F₂O below using partial charges.



[1]

- ii. Suggest the **shape** of the F₂O molecule and the F–O–F **bond angle**.

Shape

Bond angle

[1]

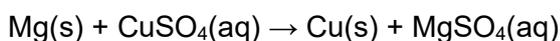
- iii. What is the oxidation number of oxygen in F₂O?

Include the sign in your answer.

..... [1]

20. 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]

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

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

Your answer

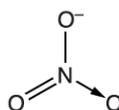
[1]

22. 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.

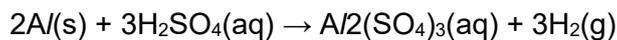


Draw the 'dot-and-cross' diagram for the NO_3^- ion, showing outer shell electrons only. Use a different symbol for the extra electron.

[2]



23. 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

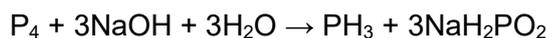
oxidation number change: from to

element reduced

oxidation number change: from to

[2]

24. Phosphorus reacts with aqueous sodium hydroxide as in the equation below.



Which element is oxidised?

- A hydrogen
- B oxygen
- C phosphorus
- D sodium

Your answer

[1]



25. Hydrogen iodide, HI(g), is formed in the reversible reaction below.



Which statement(s) is/are correct?

- 1 This is a redox reaction.
- 2 The equilibrium yield of HI(g) is changed by increasing the pressure.
- 3 The equilibrium yield of HI(g) increases as the temperature is increased.

- A** 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

[1]

26. What is the oxidation number of Mn in K_2MnO_4 ?

- A** +4
B +5
C +6
D +7

Your answer

[1]



27. Sodium oxide, Na_2O , can be prepared by the redox reaction of NaNO_2 and sodium metal. Nitrogen gas is also formed.

i. What is the systematic name for NaNO_2 ?

..... [1]

ii. Using oxidation numbers, with signs, show the element that is oxidised and the element that is reduced in this reaction.

Element oxidised _____

Oxidation number change from _____ to _____

Element reduced _____

Oxidation number change from _____ to _____

[2]

iii. Construct the equation for this reaction.

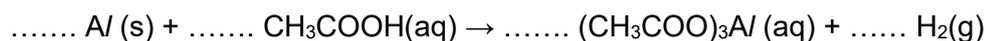
Equation _____

[1]

28. Aluminium is reacted with ethanoic acid.

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]

29. On gently heating, the compound KClO_3 reacts as shown in the equation.



This reaction is an example of disproportionation.

- i. State what is meant by *disproportionation* and use oxidation numbers to show that disproportionation has taken place.

[3]

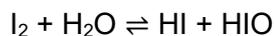
- ii. What is the systematic name for KClO_4 ?

[1]



30. 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]



31. In the compound $[\text{ICl}_2]^+ [\text{SbCl}_6]^-$, the oxidation number of chlorine is -1 .

What are the oxidation numbers of I and Sb in the compound?

	I	Sb
A	+1	+5
B	+1	+7
C	+3	+5
D	+3	+7

Your answer

[1]

32. This question refers to the elements in the first three periods (H \rightarrow Ar) of the Periodic Table.

Select an element from the first three periods that fits each of the following descriptions.

i. The element that forms a $1-$ ion with the same electron configuration as helium.

[1]

ii. The element with the highest first ionisation energy.

[1]

iii. The element in Period 3 which has the successive ionisation energies shown below.

Ionisation number	1st	2nd	3rd	4th
Ionisation energy/ kJ mol^{-1}	738	1451	7733	10541

[1]



iv. The element which forms a compound with fluorine that has octahedral molecules.

[1]

v. An element which reacts with water to form an acidic solution.

[1]

vi. The element **X**, which forms a compound with hydrogen, **XH₃**, with a molar mass of 34.0 g mol⁻¹.

[1]

vii. An element which forms a compound with hydrogen in which the element has an oxidation number of -4.

[1]

viii. The element which has a density of 1.33 × 10⁻³ g cm⁻³ at room temperature and pressure.

[1]

33. This question is about two compounds used in medicine.

Cis-platin, PtCl₂(NH₃)₂, is a complex of platinum which is used in cancer treatment.

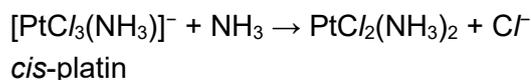
i. What is the oxidation number of platinum in *cis*-platin?

[1]

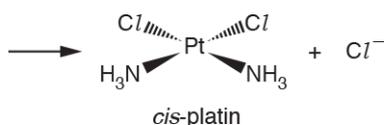


- ii. *Cis*-platin is prepared in a ligand substitution reaction which takes place in multiple steps.

The equation for the final step forming *cis*-platin is shown below.



In the box, outline the mechanism for the formation of *cis*-platin from $[\text{PtCl}_3(\text{NH}_3)]^-$. Use curly arrows and lone pairs where appropriate.



[2]

34. What is the oxidation number of Fe in K_2FeO_4 ?

- A +4
- B +5
- C +6
- D +7

Your answer

[1]



35. Which reaction shows oxidation of sulfur?

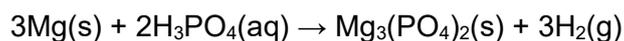
- A** $2\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow \text{SO}_2 + 2\text{H}_2\text{O} + \text{Br}_2$
B $\text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O}$
C $8\text{HI} + \text{H}_2\text{SO}_4 \rightarrow 4\text{I}_2 + \text{H}_2\text{S} + 4\text{H}_2\text{O}$
D $\text{H}_2\text{S} + \text{Cl}_2 \rightarrow 2\text{HCl} + \text{S}$

Your answer

[1]

36. 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]

37. What is the oxidation number of N in $\text{Mg}(\text{NO}_2)_2 \cdot 3\text{H}_2\text{O}$?

- A +2
- B +3
- C +4
- D +5

Your answer

[1]



38. Which reaction is a redox reaction?

- A $\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{NaNO}_3$
- B $\text{NaNO}_2 + \text{HCl} \rightarrow \text{NaCl} + \text{HNO}_2$
- C $\text{CaSO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{SO}_2$
- D $3\text{CuO} + 2\text{NH}_3 \rightarrow 3\text{Cu} + 3\text{H}_2\text{O} + \text{N}_2$

Your answer

[1]

39. 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]

40. 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]

**41.**

The equation for a redox reaction is shown below.



Which statement is correct?

- A** Cl is both oxidised and reduced.
- B** Cl is oxidised and O is reduced.
- C** O is both oxidised and reduced.
- D** O is oxidised and Cl is reduced.

Your answer

[1]

42. Potassium ferrate(VI) contains two potassium ions for every ferrate(VI) ion.

What is the formula of the ferrate(VI) ion?

- A** FeO_3^{2-}
- B** FeO_4^{2-}
- C** FeO_5^{2-}
- D** FeO_6^{2-}

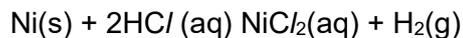
Your answer

[1]



43. This question is about nickel and its compounds.

Nickel reacts with dilute hydrochloric acid in a redox reaction.



Explain, in terms of the number of electrons transferred, whether nickel is oxidised or reduced.

[1]

44. This question is about some elements in Period 4 of the periodic table.

Bromine reacts with concentrated sodium hydroxide at 50 °C as in the equation below.



- i. Write the systematic name for NaBrO_3 .

[1]

- ii. This reaction is an example of disproportionation.

Use oxidation numbers to explain why. Include the meaning of the term **disproportionation**.

[3]



5. A student is provided with a sample of a metal **M**.

The student analyses metal **M** using a 'back-titration' technique:

- The metal is reacted with excess acid.
- The resulting solution is titrated to determine the amount of acid remaining after the reaction.

Stage 1

The student adds 100 cm³ of 2.10 mol dm⁻³ HCl (aq) to 6.90 g of **M**.

An excess of HCl (aq) has been used to ensure that all of metal **M** reacts.

A redox reaction occurs, forming a solution containing **M** in the +2 oxidation state.

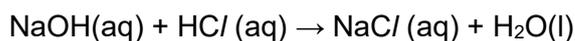
Stage 2

The resulting solution from **Stage 1** is made up to 250.0 cm³ with distilled water.

Stage 3

A 25.00 cm³ sample of the diluted solution from **Stage 2** is titrated with 0.320 mol dm⁻³ NaOH(aq).

The NaOH(aq) reacts with excess HCl (aq) that remains in **Stage 1**:



The student repeats the titration to obtain concordant titres.

Titration results (The trial titre has been omitted.)

The burette readings have been recorded to the nearest 0.05 cm³.

	1	2	3
Final reading / cm ³	27.80	37.55	32.20
Initial reading / cm ³	0.50	10.00	5.00

- i. In **Stage 1**, a redox reaction takes place between **M** and HCl (aq), forming hydrogen and a solution containing **M** in the +2 oxidation state.

Write an overall equation, with state symbols, for this reaction. Write half-equations for the oxidation and reduction processes.

Overall equation

Oxidation half-equation

Reduction half-equation

[3]



ii. In **Stage 1**, suggest **two** observations that would confirm that all of metal **M** has reacted.

1

2

[2]

iii. In **Stage 3**, write the ionic equation for the reaction taking place in the titration.

..... [1]

iv. Metal **M** can be identified following the steps below.

1. The amount, in mol, of excess HCl (aq) that remains after the reaction of **M** with HCl (aq).
2. The amount, in mol, of HCl (aq) that reacted with **M**.
3. The identity of metal **M**.

Analyse the results to identify metal **M**.

Metal **M** = [6]



46. Iodide ions, $\text{I}^{-}(\text{aq})$, react with $\text{MnO}_4^{-}(\text{aq})$. The unbalanced equation is shown below.



What is the ratio of $\text{MnO}_2(\text{s})$ to $\text{OH}^{-}(\text{aq})$ in the balanced equation?

- A 1 : 3
- B 1 : 2
- C 1 : 1
- D 3 : 2

Your answer

[1]

47. This question is about reactions and uses of the weak acids methanoic acid, HCOOH , and ethanoic acid, CH_3COOH .

A student adds magnesium metal to an aqueous solution of ethanoic acid, CH_3COOH .

A redox reaction takes place.

Write the overall equation for this reaction and explain, in terms of oxidation numbers, which element has been oxidised and which element has been reduced.

Equation

Oxidation

Reduction

[3]



48. A compound of nickel, **J**, has the formula $(\text{NH}_4)_2 [\text{Ni}(\text{SCN})_x(\text{NH}_3)_y]$ and contains SCN^- and NH_3 ligands.

The percentage by mass of three of the elements in compound **J** is shown below:
Ni, 16.26%; S, 35.56%; N, 31.00%.

i. Calculate the values of x and y in the formula of compound **J**.

$x =$

$y =$

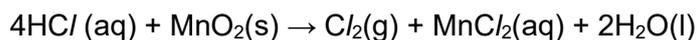
[3]

ii. Determine the oxidation number of nickel in compound **J**.

oxidation number: [1]

49. This question is about halogens.

Chlorine can be prepared by reacting concentrated hydrochloric acid with manganese(IV) oxide, MnO_2 .



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]



50. A chlorate(VII) ion has a 1- charge.

What is the formula for sodium chlorate(VII)?

- A NaClO_3
- B NaClO_4
- C NaClO_7
- D NaClO_8

Your answer

[1]

51. Storage cells and fuels cells are types of electrochemical cell. The electrode potentials for five redox systems are shown in **Table 19.1**.

Redox system	Half-equation	E^{\ominus} / V
1	$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^{-} \rightleftharpoons \text{Cr}(\text{s})$	-0.74
2	$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^{-} \rightleftharpoons 4\text{OH}^{-}(\text{aq})$	+0.40
3	$\text{MnO}_4^{-}(\text{aq}) + \text{e}^{-} \rightleftharpoons \text{MnO}_4^{2-}(\text{aq})$	+0.56
4	$\text{MnO}_4^{-}(\text{aq}) + 8\text{H}^{+}(\text{aq}) + 5\text{e}^{-} \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+0.51
5	$\text{MnO}_4^{2-}(\text{aq}) + 4\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{MnO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l})$	+1.70

Table 19.1

In acid conditions, $\text{MnO}_4^{2-}(\text{aq})$ disproportionates to form $\text{MnO}_2(\text{s})$ and $\text{MnO}_4^{-}(\text{aq})$.

- i. Explain, in terms of oxidation numbers, why disproportionation has taken place.

[2]



- ii. Explain, in terms of electrode potentials and equilibrium shifts why $\text{MnO}_4^{2-}(\text{aq})$ disproportionates in acid conditions. Use the information in **Table 19.1**.

..... [2]

52. Ammonia, NH_3 , and ammonium nitrate, NH_4NO_3 , are compounds of nitrogen.

- i. The boiling point of NH_3 is $-33\text{ }^\circ\text{C}$.

The boiling point of NH_4NO_3 is $210\text{ }^\circ\text{C}$.

Explain why there is a large difference in boiling points.

..... [2]

- ii. Two students discuss the oxidation numbers in ammonium nitrate, NH_4NO_3 .

One student claims that the two nitrogen atoms have the same oxidation number. The other student disagrees and claims that the nitrogen atoms have different oxidation numbers.

Explain with reasons which student is correct.

..... [1]

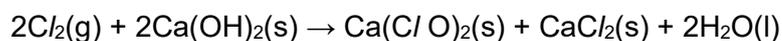


53. This question is about redox reactions.

'Calcium hypochlorite', $\text{Ca}(\text{ClO})_2$, is an ionic compound used in 'bleaching powder'.

The ClO^- ion in $\text{Ca}(\text{ClO})_2$ is the active ingredient that kills bacteria.

Calcium hypochlorite is prepared by reacting chlorine gas with calcium hydroxide.



Equation 2.1

- i. 420 dm³ of chlorine, measured at RTP, is reacted with an excess of $\text{Ca}(\text{OH})_2$.

The solid products are dissolved in water to form 4.00 m³ of solution.

Calculate the concentration of $\text{Ca}(\text{ClO})_2(\text{aq})$ in this solution, in mol dm⁻³.

Give your answer to an **appropriate** number of significant figures and in standard form.

concentration = mol dm⁻³ **[3]**

- ii. Calcium hypochlorite, $\text{Ca}(\text{ClO})_2$, is heated. The $\text{Ca}(\text{ClO})_2$ decomposes to form CaCl_2 and $\text{Ca}(\text{ClO}_3)_2$. This is a disproportionation reaction.

Write an equation for this decomposition and explain, using oxidation numbers, why this is a disproportionation reaction.

equation

explanation

..... **[3]**



54. This question is about some Group 2 elements and their compounds.

Strontium and calcium both react with water.

- i. Write an equation for the reaction of strontium with water.

..... [1]

- ii. Using oxidation numbers, explain why the reaction of strontium with water is a redox reaction.

..... [2]

- iii. Explain why calcium reacts more slowly with water than strontium does.

..... [3]

55. This question is about the reactions of Group 2 metals and their compounds.

A student adds magnesium to dilute hydrochloric acid in one test tube.

The student adds calcium to dilute hydrochloric acid in a second test tube.

A redox reaction takes place in each test tube.

- i. Suggest **two** observations from the student's experiment that would show that calcium is more reactive than magnesium.

1

2

..... [1]



- ii. Write half-equations for the reaction of magnesium with hydrochloric acid.

Oxidation half-equation:

Reduction half-equation:

[2]

56. This question is about different types of bonding.

'Oxyanions' are ions containing oxygen combined with atoms of other elements.

Roman numerals are used to show the oxidation state of the element in the oxyanion.

Complete the table below for three oxyanions.

One row has been completed as an example.

Name of oxyanion	Ionic charge	Formula of oxyanion
.....	1-	BrO_2^-
Sulfate(VI)	2-	SO_4^{2-}
Phosphate(V)	3-

[2]

57. This question is about halogens and practical tests

Chlorine gas reacts with dilute sodium hydroxide, $\text{NaOH}(\text{aq})$. This is a disproportionation reaction. One of the products has the formula NaClO .

- i. What is meant by the term **disproportionation**?

[1]

- ii. Construct the equation for the reaction of chlorine with dilute sodium hydroxide.

Use your equation to explain that disproportionation has taken place.

Equation

Explanation

[3]



58. This question is about compounds that contain the carboxylic acid functional group.

Carboxylic acids react with alkalis, metals and carbonates to form salts.

Write full equations for the following **three** reactions. Show structures for organic compounds.

- the reaction of propanoic acid with aqueous potassium hydroxide:
- the reaction of aqueous methanoic acid with magnesium:
- the reaction of the α -amino acid, aspartic acid ($R=CH_2COOH$), with an excess of aqueous sodium carbonate, Na_2CO_3 :

[4]

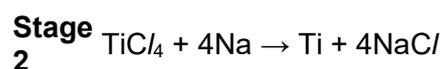
59. This question is about titanium (atomic number 22) and its compounds.

An ore of titanium contains impure TiO_2 .

Titanium is manufactured from TiO_2 in a two-stage process.



Reaction 1.1



Reaction 1.2

- i. The common name for TiO_2 is titanium dioxide.

What is the systematic name of TiO_2 ?

..... [1]



- ii. In **Reaction 1.2**, the percentage yield of titanium from TiCl_4 is 72.0%.

Calculate the minimum mass, in kg, of sodium that is needed to produce 1.00 kg of titanium.

Give your answer to **3** significant figures.

mass of sodium = kg **[4]**

- iii. **Reaction 1.2** produces a mixture of titanium and sodium chloride.

Suggest how titanium could be separated from this mixture at room temperature.

Explain your answer.

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

- 60.** This question is about halogens and halogen compounds.

Chlorine reacts with calcium hydroxide to form $\text{Ca}(\text{OCl})_2$, which is the active ingredient in bleaching powder.



This is a disproportionation reaction.

State what is meant by **disproportionation** and use oxidation numbers to show that disproportionation has taken place.

..... **[3]**



61. Which substance has the lowest oxidation number for sulfur?

- A Na_2SO_4
- B S_8
- C SF_2
- D SO_2

Your answer

[1]

62. This question is about reactions involving acids.

Write equations for the reactions below. State symbols are **not** required.

- i. The reaction of copper(II) oxide with dilute hydrochloric acid.

..... [1]

- ii. The reaction of ammonium carbonate with dilute nitric acid.

..... [2]

63. The equations show the electrode potentials of the half-cells used in a lithium-ion cell.

	E° / V
$\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$	-3.04
$\text{Li}^+ + \text{CoO}_2 + \text{e}^- \rightleftharpoons \text{LiCoO}_2$	+1.16

Which statement is correct in a lithium-ion cell?

- A The cell potential is 2.88 V.
- B The reaction at the positive electrode is: $\text{LiCoO}_2 \rightarrow \text{Li}^+ + \text{CoO}_2 + \text{e}^-$
- C The overall cell reaction is: $\text{Li} + \text{CoO}_2 \rightarrow \text{LiCoO}_2$
- D The oxidation number of Co changes from +2 to +1.

Your answer

[1]



64. Which statement(s) is/are correct for the anti-cancer complex $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$?

- 1 It has bond angles of 90° .
 - 2 The oxidation number of Pt is +4.
 - 3 It forms both optical and *cis-trans* isomers.
- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

[1]

65. These questions are from different areas of chemistry.

This question is about two salts of rubidium (atomic number 37): RbClO_3 and RbClO_4 .

- i. The oxidation number of chlorine is different in the two rubidium salts, RbClO_3 and RbClO_4 .

What is the name of RbClO_4 ?

..... [1]



ii. A student carries out an experiment to determine the enthalpy change of solution of RbClO_3 using the method below.

- A 2.00 g sample of solid RbClO_3 is added to water in a well-insulated container.
The initial temperature is $23.0\text{ }^\circ\text{C}$.
The mixture is stirred until all the RbClO_3 has dissolved.
- The final temperature is $21.5\text{ }^\circ\text{C}$.
The final solution has a mass of 102 g.

Determine the enthalpy change of solution, $\Delta_{\text{sol}} H$, of RbClO_3 in kJ mol^{-1} .

Assume that the specific heat capacity of the solution is the same as that of pure water.

$$\Delta_{\text{sol}} H (\text{RbClO}_3) = \dots\dots\dots \text{kJ mol}^{-1} \text{ [3]}$$

66. The reaction between calcium and hydrochloric acid is a redox reaction.



Equation 2.1

i. Explain, in terms of electron transfer, why the reaction shown in **equation 2.1** is a redox reaction.



[2]

- ii. A student plans to add 0.0100 mol of Ca to 120 cm³ of 0.100 mol dm⁻³ HCl (aq).

When the student carries out this reaction, they are surprised that all the calcium reacts, despite being in excess of the HCl(aq).

- Show by calculation that calcium is in excess of the HCl(aq).
- Suggest a reason for this unexpected result.

[3]

67. Which equation does **not** represent a disproportionation reaction?

- A** $Cl_2 + H_2O \rightarrow HClO + HCl$
B $Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$
C $4KClO_3 \rightarrow KCl + 3KClO_4$
D $4HCl + MnO_2 \rightarrow MnCl_2 + Cl_2 + 2H_2O$

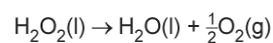
Your answer

[1]



68(a). This question is about energy changes.

Hydrogen peroxide decomposes as shown in **Reaction 16.1**.



Reaction 16.1

The table shows enthalpy changes of formation and entropies.

	$\Delta H_f^\ominus/\text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
$\text{H}_2\text{O}_2(\text{l})$	-188	110
$\text{H}_2\text{O}(\text{l})$	-286	70.0
$\text{O}_2(\text{g})$	0	205

i. Calculate the free-energy change, ΔG , in kJ mol^{-1} , of **Reaction 16.1** at 25°C .

Give your answer to **3** significant figures.

$$\Delta G = \dots\dots\dots \text{kJ mol}^{-1} \text{ [4]}$$

ii. The decomposition of hydrogen peroxide shown in **Reaction 16.1** is feasible.

Suggest why **Reaction 16.1** does **not** take place at 25°C despite being feasible.

[1]

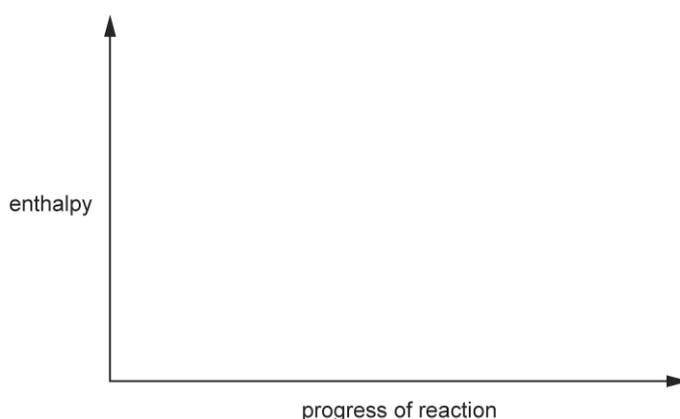


(b). The rate of decomposition of hydrogen peroxide shown in **Reaction 16.1** can be increased by adding a small amount of powdered manganese(IV) oxide, MnO_2 .

The MnO_2 acts as a catalyst.

i. Complete the enthalpy profile diagram for **Reaction 16.1** using formulae for the reactants and products.

- Use E_a to label the activation energy **without** MnO_2 .
- Use E_c to label the activation energy **with** MnO_2 .
- Use ΔH to label the enthalpy change of reaction.



[3]

ii. Explain why MnO_2 is described as a **heterogeneous** catalyst for this reaction.

[1]

iii. Mn_3O_4 is a compound in which Mn has two different oxidation states. The two oxidation states are different from the Mn in MnO_2 .

Suggest the two oxidation states of manganese in Mn_3O_4 .

[1]



69. Which reaction does **not** show disproportionation of chlorine?

- A** $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$
B $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HClO}$
C $2\text{ClO}_2 + 2\text{NaOH} \rightarrow \text{NaClO}_2 + \text{NaClO}_3 + \text{H}_2\text{O}$
D $2\text{NaOH} + \text{Cl}_2 \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$

Your answer

[1]

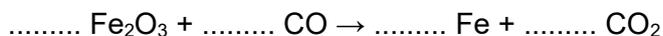
70. This question is about iron.

Iron can be extracted from iron ores containing the oxide Fe_2O_3 .

- i. What is the systematic name for Fe_2O_3 ?

..... [1]

- ii. Balance the equation for the reduction of Fe_2O_3 with carbon monoxide.



[1]

71(a). This question is about the chemistry of compounds containing phosphorus.

Phosphorus forms several acids including H_3PO_4 and H_3PO_3 .

H_3PO_4 is a tribasic acid. The equilibria for the dissociations are shown below.

- 1** $\text{H}_3\text{PO}_4 \rightleftharpoons \text{H}^+ + \text{H}_2\text{PO}_4^-$
2 $\text{H}_2\text{PO}_4^- \rightleftharpoons \text{H}^+ + \text{HPO}_4^{2-}$
3 $\text{HPO}_4^{2-} \rightleftharpoons \text{H}^+ + \text{PO}_4^{3-}$

- i. During the equilibria, H_2PO_4^- behaves both as an acid and as a base.

Explain this statement, using the equilibria **1**, **2** and **3**, as required.

..... [2]



- ii. In a H_3PO_3 molecule, the O atoms are covalently bonded to the P atom. The H atoms are bonded to the O atoms.

Draw the structure of a H_3PO_3 molecule, showing all the bonds.

On your diagram, add the values for the O–P–O and P–O–H bond angles.

[3]

- iii. The systematic name of H_3PO_4 is phosphoric(V) acid.

What is the systematic name of H_3PO_3 ?

[1]

(b). Phosphine, PH_3 , is a poisonous gas.

- i. Phosphine reacts with oxygen gas to form phosphorus(V) oxide and water.

Write the equation for this reaction.

[1]

- ii. Aqueous silver nitrate, AgNO_3 , is reduced by PH_3 .

The unbalanced equation is shown below.

Balance the equation and use oxidation numbers to explain why this is a redox reaction.



Explanation

[3]

END OF QUESTION PAPER



Mark scheme

Question		Answer/Indicative content	Marks	Guidance
1		C	1	
		Total	1	
2		A	1	
		Total	1	
3		Element oxidised: zinc / Zn 0 to +2 (1) Element reduced: carbon / +4 to +2 C (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	
4		A	1	
		Total	1	
5		D	1	
		Total	1	
6	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	
7		A	1	
		Total	1	
8		Mg(s) + 2HCl(aq) → MgCl ₂ (aq) + H ₂ (g) (1) Effervescence AND solid dissolves (1)	2	state symbols are required allow solid disappears
		Total	2	
9		Element oxidised: sulfur / S 0 to +6 Element reduced: nitrogen / N +5 to +4	4	ALLOW 5+, 4+ and 6+ Signs required



			$6\text{HNO}_3 + \text{S} \rightarrow 6\text{NO}_2 + \text{H}_2\text{SO}_4 + 2\text{H}_2\text{O}$ <p>Correct species</p> <p>Balance</p>		<p>ALLOW $4\text{H}^+ + 6\text{NO}_3^- + \text{S} \rightarrow 6\text{NO}_2 + \text{SO}_4^{2-} + 2\text{H}_2\text{O}$</p>
			Total	4	
10	i	<p>reaction with bases: neutralisation AND reaction with metals: redox</p>		1	Enter text here.
	ii	<p>correctly calculates</p> $n(\text{A}) = \frac{1.125}{90} = 0.0125 \text{ (mol)}$ $\text{volume of H}_2 = \frac{0.0125}{2} \times 24,000 = 150 \text{ cm}^3$ <p>units required</p>		2	<p>ALLOW 0.15 dm³ ALLOW ECF from $n(\text{A})$</p>
	iii	C ₆ H ₁₂ O ₆ Mg		1	DO NOT ALLOW (C ₃ H ₆ O ₃) ₂ Mg
	iv	<p>Type of reaction of COOH: e.g. esterification AND reagents and conditions e.g. CH₃OH AND H₂SO₄</p> <p>Organic product of COOH reaction</p> <p>Type of reaction of -OH AND reagents and conditions</p> <p>Organic product of -OH reaction</p>		4	<p>ALLOW esterification with any stated alcohol</p> <p>e.g. product from CH₃OH/H₂SO₄ → CH₃(CHOH)COOCH₃ Many possible reactions of secondary alcohol possible, e.g.</p> <p>oxidation with K₂Cr₂O₇ / H₂SO₄ + heat → CH₃(CO)COOH</p> <p>elimination with H₂SO₄ / H₃PO₄ + heat → CH₂ = CHCOOH</p> <p>esterification with CH₃COOH / H₂SO₄ OR CH₃COC/ → CH₃(CHOOCCH₃)COOH</p> <p>bromination with NaBr / H₂SO₄ → CH₃(CHBr)COOH</p> <p>ALLOW self-polymerisation as reaction for either group (if another reaction example given) condensation</p>



					polymerisation with H ₂ SO ₄ → [OCH(CH ₃)CO] _n
			Total	8	
11		i	N ₂ O ₄ = +4 AND NO ₃ ⁻ = +5 AND NH ₄ ⁺ = -3 ✓	1	ALL 3 oxidation numbers required DO NOT ALLOW missing '+' or '-' OR oxidation numbers shown as charges e.g. N ⁵⁺
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 7.9(0) (g) award 2 marks $n(\text{KMnO}_4) = \frac{0.200 \times 250}{1000} = 0.0500 \text{ (mol)} \checkmark$ mass of KMnO ₄ = 0.0500 × 158.0 = 7.9(0) (g) ✓	2	
		iii	dm ⁶ mol ⁻² s ⁻¹ ✓	1	
		iv	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 1.54 × 10²³ award 2 marks $n(\text{tartaric acid}) = \frac{38.25}{150} = 0.255 \text{ (mol)} \checkmark$ number of molecules = 0.255 × 6.02 × 10 ²³ = 1.54 × 10 ²³ ✓ (3 SF required from least significant data)	2	ALLOW ECF from $n(\text{tartaric acid})$ Common error: use of 148 (<i>missing 2H Structure</i>) → 1.56 × 10 ²³
			Total	6	
12		i	green solution: Fe ²⁺ (aq) OR [Fe(H ₂ O) ₆] ²⁺ AND gas bubbles: H ₂ (g) AND orange-brown solution: Fe ³⁺ (aq) OR [Fe(H ₂ O) ₆] ³⁺ ✓ Fe(s) + 2H ⁺ (aq) → Fe ²⁺ (aq) + H ₂ (g) ✓ 4Fe ²⁺ (aq) + O ₂ (g) + 4H ⁺ (aq) → 4Fe ³⁺ (aq) + 2H ₂ O(l) ✓	3	State symbols are not required in this part IGNORE , even if incorrect ALLOW full equation: Fe(s) + 2HCl(aq) → FeCl ₂ (aq) + H ₂ (g)
		ii		3	State symbols are not required in this part



			<p>orange solution: $\text{Cr}_2\text{O}_7^{2-}$ AND green solution (anywhere) Cr^{3+} OR $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ ✓</p> <p>$2\text{Cr}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 3\text{H}_2\text{O}_2(\text{aq}) \rightarrow \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 8\text{H}^+(\text{aq})$ H^+, H_2O and e^- all cancelled ✓✓</p>		<p>IGNORE, even if incorrect</p> <p>IGNORE Cr(VI) <i>The question asks for species</i></p> <p>ALLOW 1 mark for $\text{H}^+/\text{H}_2\text{O}/\text{e}^-$ not cancelled, e.g. $2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) + 3\text{H}_2\text{O}_2(\text{aq}) + 6\text{H}^+(\text{aq}) \rightarrow \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$ ✓</p>
			Total	6	
13			Oxidised AND because aluminium has lost (three) electrons ✓	1	<p>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</p> <p>Examiner's Comments</p> <p>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.</p>
			Total	1	
14	i		Hydrogen ✓	1	<p>ALLOW H_2 IGNORE 'H'</p> <p>Examiner's Comments</p> <p>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.</p>
		ii	<p>$\text{Ce}_2(\text{SO}_4)_3$ ✓</p> <p>(Cerium) loses three electrons (to form $3+$ ion) ✓</p>	2	<p>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</p>



					<p>IGNORE references to reduction and oxidation</p> <p>Examiner's Comments</p> <p>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.</p>
		iii	A hydrogen ion (of an acid) has been replaced by a metal ion ✓	1	<p>For hydrogen ion: ALLOW 'H⁺' OR 'proton' but DO NOT ALLOW 'H' OR 'hydrogen' without 'ion'</p> <p>For metal ion: ALLOW 'cerium ion' OR 'Ce³⁺' OR 'Ce²⁺' OR 'Ce ion' But DO NOT ALLOW 'Ce' without 'ion' OR 'cerium' without 'ion' IGNORE 'ammonium ion'</p> <p>Examiner's Comments</p> <p>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.</p>
			Total	4	
15			Cl (has been oxidised) from Cl = -1 to Cl = 0 ✓ Mn (has been reduced) from Mn = +4 to Mn = +2 ✓	2	<p>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</p> <p>ALLOW one mark for Cl is oxidised because the oxidation number</p>



					<p>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</p> <p>Examiner's Comments</p> <p>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.</p>
			Total	2	
16			(+)5 ✓	1	<p>ALLOW 5+ OR V OR Cr⁵⁺</p> <p>Examiner's Comments</p> <p>This part was a gentle opener to the paper with almost all candidates obtaining the correct oxidation number of +5.</p>
			Total	1	
17		i	1s ² 2s ² 2p ⁶ 3s ² ✓	1	<p>ALLOW upper case S and P, and subscripts, e.g.2S₂3P₆</p> <p>Examiner's Comments</p> <p>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.</p>



		ii	(Mg) loses / transfers / donates two electrons ✓	1	<p>ALLOW Mg loses the 3s electrons provided electronic configuration in (i) is $3s^2$</p> <p>ALLOW $Mg \rightarrow Mg^{2+} + 2e^-$</p> <p>IGNORE reference to oxidation numbers / states</p> <p>Examiner's Comments</p> <p>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.</p>
			Total	2	
18		i	$N_2O_3 = +3$ $NO = +2$ $NO_2 = +4$ ✓	1	<p>ALLOW '3' OR '3+' etc</p> <p>ALLOW oxidation numbers written over the equation but</p> <p>IGNORE if oxidation numbers are given on the answer lines</p> <p>Examiner's Comments</p> <p>The correct answer was almost universally known.</p>
		ii	Disproportionation ✓	1	<p>QWC 'disproportionation' spelled correctly.</p> <p>Examiner's Comments</p> <p>The correct answer was almost universally known with just the rare misspelling of disproportionation seen.</p>
			Total	2	
19		i	δ^- on each F AND δ^+ on O ✓	1	<p>ALLOW δ^{2+} OR δ^+ δ^+ on O</p> <p>Examiner's Comments</p>



					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°. 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	
20		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 'CuSO ₄ ' ALLOW one mark two electrons gained and lost for each species but oxidation/reduction is incorrect or is omitted



					<p>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)</p> <p>ALLOW 'two' electrons transferred from magnesium to copper</p> <p>Examiner's Comments</p> <p>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.</p>
		ii	<p>$\text{Mg(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Mg(OH)}_2\text{(aq)} + \text{H}_2\text{(g)}$ Correct reactants and products ✓ Balance and state symbols ✓</p>	2	<p>ALLOW multiples ALLOW $\text{Mg(OH)}_2\text{(s)}$ ALLOW $\text{Mg(s)} + \text{H}_2\text{O(g)}$ OR $\text{H}_2\text{O(l)}$ $\text{MgO(s)} + \text{H}_2\text{(g)}$ including state symbols for one mark</p> <p>Examiner's Comments</p> <p>The equation for the reaction between magnesium and water was well known – but many erroneously assumed MgO was formed.</p>
			Total	4	
21			C	1	<p>ALLOW +5 OR 5+ in box</p> <p>Examiner's Comments</p> <p>Generally scored well.</p>
			Total	1	
22		i	<p>$\text{NiO} + 2\text{HNO}_3 \rightarrow \text{Ni(NO}_3)_2 + \text{H}_2\text{O}$ ✓</p>	1	<p>ALLOW multiples</p> <p>IGNORE state symbols (even if wrong)</p> <p>Examiner's Comments</p> <p>This part was surprisingly poorly answered. Common errors included incorrect formulae for nickel(II) oxide</p>



			AND 1 'extra' electron with different symbol		proved to be more difficult, with many omitting to show the 'extra electron'.
			Total	3	
23			Element oxidised: aluminium/Al 0 to +3 ✓ Element reduced: hydrogen/H/H ⁺ +1 to 0 ✓	2	<p>MAX 1 mark if no '+' sign for oxidation number</p> <p>ALLOW 3+</p> <p>ALLOW 1+</p> <p>ALLOW H₂ for hydrogen</p> <p>ALLOW 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around</p> <p>IGNORE numbers around equation <i>i.e. treat as rough working</i></p> <p><u>Examiner's Comments</u></p> <p>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.</p>
			Total	2	
24			C	1	
			Total	1	
25			D	1	
			Total	1	
26			C	1	ALLOW +6 in the box
			Total	1	
27		i	sodium nitrate(III)	1	ALLOW sodium nitrite OR sodium nitrite(III)



					<p>Examiner's Comment: This part was very poorly answered, the most common answer being sodium nitrate. The examiners were expecting sodium nitrate(III) but the mark scheme was extended to also allow sodium nitrite.</p> <p>Sodium(III) nitrate was sometimes seen, indicating that candidates are not fully conversant with rules for showing oxidation states in names.</p>
		ii	<p>Sodium / Na oxidised from 0 to +1 ✓</p> <p>Nitrogen / N reduced from +3 to 0 ✓</p>	2	<p>ALLOW 1+ for +1 and 3+ for +3</p> <p>ALLOW N₂ for nitrogen</p> <p>ALLOW 1 mark for elements AND all oxidation numbers correct, but N on oxidised line and Na on reduced line</p> <p>'+' is required in +3 and +1 oxidation numbers</p> <p>Examiner's Comment: This part was generally answered well although a significant number of candidates managed to get one of the oxidation numbers wrong, usually for N. It was rare to see the sign for an oxidation number omitted.</p>
		iii	<p>$2\text{NaNO}_2 + 6\text{Na} \rightarrow 4\text{Na}_2\text{O} + \text{N}_2$ ✓</p> <p>IGNORE state symbols</p>	1	<p>ALLOW multiples, e.g. $\text{NaNO}_2 + 3\text{Na} \rightarrow 2\text{Na}_2\text{O} + \frac{1}{2}\text{N}_2$ ✓</p> <p>Examiner's Comment: The examiners were impressed with the responses for this part with just over half the candidates producing a correct balanced equation for this unfamiliar reaction. Most used whole numbers for balancing but it was common to also see the half-multiple version including $\frac{1}{2}\text{N}_2$.</p>
			Total	4	
28		i	<p>$2\text{Al(s)} + 6\text{CH}_3\text{COOH(aq)} \rightarrow 2(\text{CH}_3\text{COO})_3\text{Al(aq)} + 3\text{H}_2(\text{g})$ ✓</p>	1	<p>ALLOW multiples, e.g. $\text{Al(s)} + 3\text{CH}_3\text{COOH(aq)} \rightarrow (\text{CH}_3\text{COO})_3\text{Al(aq)} + \frac{1}{2}\text{H}_2(\text{g})$</p>



					<p>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.</p>
		ii	<p>Element oxidised: aluminium/Al 0 to +3 ✓</p> <p>Element reduced: hydrogen/H +1 to 0 ✓</p>	2	<p>ALLOW 3+ for +3 and 1+ for +1</p> <p>ALLOW H₂ for hydrogen</p> <p>ALLOW 1 mark for elements AND all oxidation numbers correct, but H in oxidised line and Al in reduced line</p> <p>'+' is required in +3 and +1 oxidation numbers</p> <p>IGNORE numbers around equation (<i>treat as rough working</i>)</p> <p>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.</p>
			Total	3	
29		i	<p><i>Disproportionate:</i> oxidation and reduction of the same element ✓</p> <p><i>Redox:</i> Cl is oxidised from +5 (in KClO₃) to +7 (in KClO₄) ✓</p> <p>Cl is reduced from +5 (in KClO₃) to -1 (in KCl) ✓</p>	3	<p>ALLOW 'chlorine' OR 'Cl' for same element</p> <p>IGNORE 'species' for 'element'</p> <p>ALLOW after number, e.g. 5+</p> <p>IGNORE ionic charges, e.g. Cl⁵⁺</p> <p>IGNORE '5' (signs required)</p> <p>IGNORE any reference to electron loss / gain (even if wrong)</p> <p>ALLOW one redox mark if oxidation numbers are correct but reduction / oxidation is incorrectly assigned</p>



					<p>Examiner's Comments The question asked candidates to state what disproportionation meant. Many candidates failed to give this statement, despite correctly identifying the change in oxidation number and correctly assigning the redox terms.</p>
		ii	potassium chlorate(VII) ✓	1	<p>Brackets required</p> <p>Examiner's Comments It was apparent that the idea of systematic naming of compounds was not known by many candidates. Of those who realised that Roman numerals were required, many showed uncertainty of the identity of the Roman numeral to be used or positioned the numeral at an inappropriate place within the name of the compound.</p>
			Total	4	
30		i	<p>Disproportionation Oxidation AND reduction of same element/iodine</p> <p>OR Iodine has been oxidised and iodine has been reduced ✓</p> <p>Oxidation from 0 to +1 in HIO ✓</p> <p>Reduction from 0 to -1 in HI ✓</p>	3	<p>ALLOW I or I₂ for iodine IGNORE numbers around equation for oxidation states</p> <p>ALLOW 1- for -1 AND 1+ for +1</p> <p>NOTE (for iodine/I₂) from 0 only needs to be seen once, does not need to be stated twice</p> <p>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</p> <p>ALLOW 1 mark for species missing: Iodine oxidised (from 0) to +1 AND iodine reduced (from 0) to -1</p> <p>Examiner's Comments</p>



					<p>Most candidates were aware of disproportionation but lost marks by not stating the species or whether the process was oxidation or reduction.</p> <p>Exemplar 2</p> <p>(i) Iodine reacts with water as shown below.</p> $\overset{-1}{\text{I}}_2 + \text{H}_2\text{O} \rightleftharpoons \overset{-1}{\text{I}}\text{H} + \overset{+1}{\text{I}}\text{HO}$ <p>Using oxidation numbers, explain why this reaction is a disproportionation.</p> <p><i>Disproportionation is when the same element is both oxidised and reduced in the same reaction. Iodine is reduced to form HI and oxidised to +1 in HIO.</i></p> <p>[3]</p>
		ii	<p>Chlorine is toxic/poisonous OR forms halogenated hydrocarbons OR forms carcinogens/toxic compounds ✓</p>	1	<p>ALLOW (reacts with hydrocarbons to) form carcinogens/toxic compounds</p> <p>IGNORE</p> <ul style="list-style-type: none"> chlorine causes cancer harmful/dangerous chlorine causes breathing problems <p>Examiner's Comments</p> <p>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</p>
			Total	4	
31			C	1 (AO 2.2)	<p>Examiner's Comments</p> <p>The majority of candidates showed a good understanding of oxidation number and gave the correct answer.</p>
			Total	1	
32		i	Hydrogen/H ✓	1	<p>ALLOW H₂</p> <p>Examiner's Comments</p> <p>Most candidates were credited this</p>

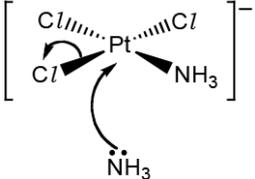
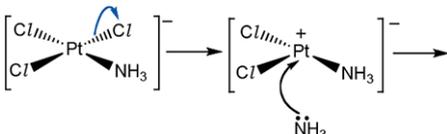
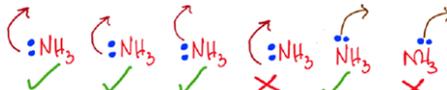


					<p>straightforward mark and identified that hydrogen would gain an electron to form a 1⁻ ion. Some candidates opted for lithium, able to form an ion with the same electron configuration as helium, but with a 1⁺ rather than a 1⁻ charge.</p> <p>Candidates are recommended to look closely at the requirements of the question set.</p>
		ii	Helium/He ✓	1	<p><u>Examiner's Comments</u></p> <p>This part required candidates to recall their knowledge of trends in first ionisation energy. Candidates found this part harder than 1(a)(i) with only the higher ability candidates choosing the correct response of 'helium'.</p> <p>Many candidates instead chose another noble gas, with neon and argon commonly seen. Other common incorrect responses were hydrogen and fluorine.</p>
		iii	Magnesium/Mg ✓	1	<p><u>Examiner's Comments</u></p> <p>Most candidates did correctly select magnesium, but many other elements were seen, especially aluminium, silicon, beryllium and calcium.</p> <p>To identify the element's group, candidates needed to analyse the data to find the large increase in ionisation energy corresponding to a change in shell. From the responses, some candidates did not make use of 'Period 3' in the stem.</p>
		iv	Sulfur/S ✓	1	<p>ALLOW sulphur; S₈</p> <p><u>Examiner's Comments</u></p> <p>Most candidates selected sulfur as the correct response, recalling their knowledge of molecular shapes encountered early in the course. There was no real pattern for incorrect responses, suggesting that they were guesses.</p>



		v	Chlorine/C/ OR fluorine/F ✓	1	<p>ALLOW Cl₂ OR F₂</p> <p><u>Examiner's Comments</u></p> <p>Most candidates chose the correct response of chlorine, although hydrogen was a common incorrect response, presumably by linking to the acidic properties of H⁺ ions. Other candidates focused on 'reacts with water' and chose sodium (which does form a solution with water, but on that is alkaline rather than acidic).</p>
		vi	Phosphorus/P ✓	1	<p>ALLOW P₄</p> <p><u>Examiner's Comments</u></p> <p>Almost all candidates correctly responded with phosphorus and this was the easiest part of 1(a).</p>
		vii	Carbon/C ✓	1	<p>ALLOW silicon/Si</p> <p><u>Examiner's Comments</u></p> <p>Most candidates correctly selected carbon. From their A Level studies, candidates would expect hydrogen to have an oxidation number of +1 and to form compounds with carbon (CH₄) and silicon (SiH₄) in which the element has an oxidation number of -4. Although hydrogen is actually slightly less electronegative than carbon, hydrogen is slightly more electronegative than silicon. Therefore, in the case of SiH₄, silicon has an oxidation number of +4. A response of silicon still indicates a correct understanding of oxidation number rules and was also credited</p>
		viii	Oxygen/O ✓	1	<p>ALLOW O₂</p> <p><u>Examiner's Comments</u></p> <p>This proved to be the hardest part of 1(a) with only the higher ability candidates selecting oxygen. Sulfur proved to be the key distractor, having the same molar mass as O₂. Most candidates did not consider that the</p>



					element was gaseous and could not be sulfur.
			Total	8	
33	i	+2 Sign required		1	<p>ALLOW 2+ OR +II ALLOW Pt²⁺</p> <p>Examiner's Comments</p> <p>Almost all candidates responded with the correct oxidation number of +2. Incorrect responses were 0 (the overall charge of the complex), +4 or 2 (with no sign).</p> <p>Candidates are reminded on the importance of the sign in assigning oxidation numbers.</p>
	ii	 <p>Curly arrow from lone pair on NH₃ to Pt ✓</p> <p>[PtCl₃(NH₃)]⁻ drawn with 1 Pt, 3 Cls and 1 NH₃ AND Curly arrow from any Pt-Cl bond in the complex ✓</p> <p>ALLOW S_N1 mechanism:</p>  <p>Mark curly arrows as above for S_N2 Requires + on platinum intermediate</p>		2	<p>For [PtCl₃(NH₃)]⁻ :</p> <ul style="list-style-type: none"> • IGNORE dipoles • IGNORE absence of – charge • IGNORE – charge shown on atoms <p>ALLOW any 4 coordinate shape for [PtCl₃(NH₃)]⁻,</p> <p style="text-align: center;"> </p> <p>e.g. tetrahedral; </p> <p>1st curly arrow must</p> <p>go to Pt AND</p> <ul style="list-style-type: none"> • start from, OR be traced back to any point across width of lone pair on N of NH₃  <p>DO NOT ALLOW charge on NH₃ nucleophile, e.g. NH₃⁻</p> <p>2nd curly arrow must start from, OR be traced back to, any part of Pt–Cl bond and go to one of the 3 Cl atoms</p>



				<p>Examiner's Comments</p> <p>This part required candidates to apply their knowledge and understanding of the nucleophilic substitution mechanism in a novel context.</p> <p>This part discriminated extremely well with able candidates drawing the correct initial complex and showing precisely positioned curly arrows, dipoles and the role of the NH_3 lone pair, as shown in Exemplar 7.</p> <p>Lower ability candidates often showed imprecise curly arrows or placed a negative charge on NH_3, as shown in Exemplar 8.</p> <p>Exemplar 7</p> <p>Exemplar 8</p>
			Total	3
34		C		<p>ALLOW +6</p> <p>Examiner's Comments</p> <p>Nearly all candidates responded with the correct response of C. Candidates seem to have a very good understanding of applying oxidation number rules.</p>



			Total	1	
35			D	1	<p>Examiner's Comments</p> <p>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.</p>
			Total	1	
36	i		<p>Oxidised AND (Mg) transfers/loses/donates 2 electrons ✓</p> <p style="text-align: right;">2 essential</p>	1	<p>ALLOW Mg loses 6 electrons: <i>3 Mg in equation</i> ALLOW $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$</p> <p>IGNORE oxidation numbers (even if wrong)</p> <p>Examiner's Comments</p> <p>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.</p>
	ii		<p>FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 2.26 (3 SF) award 3 marks</p> <p>-----</p> <p>--</p> $n(\text{H}_3\text{PO}_4) = \frac{1.24 \times 50.0}{1000} = 0.062(0) \text{ (mol)} \checkmark$ $n(\text{Mg}) = \frac{3}{2} \times 0.062(0) = 0.093(0) \text{ (mol)} \checkmark$ <p>mass of Mg = $0.0930 \times 24.3 = 2.26$ (g) ✓</p> <p style="text-align: right;">3 SF required</p>	3	<p>At least 3SF needed throughout BUT ALLOW no trailing zeroes (e.g. 0.062 for 0.0620)</p> <p>ALLOW ECF from $n(\text{H}_3\text{PO}_4)$</p> <p>ALLOW ECF from $n(\text{Mg})$</p> <p>-----</p> <p>COMMON ERRORS for 2 marks 3:2 ratio omitted → $n(\text{Mg}) = 0.062(0)$ → 1.51 (g) Inverted 2:3 ratio → $n(\text{Mg}) = 0.0413$</p>



				<p>→ 1.00 (g)</p> <p>Examiner's Comments</p> <p>Most candidates are competent at answering questions based on the mole. Almost all candidates were able to calculate the amount of H₃PO₄ 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.</p> <p>Exemplar 1</p> <p>(ii) The student plans to add magnesium to 50.0 cm³ of 1.24 mol dm⁻³ H₃PO₄. Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid. Give your answer to three significant figures. $n = cv$</p> <p>$50 \text{ cm}^3 = 0.05 \text{ dm}^3$</p> <p>$1.24 \times 0.05 = 0.062 \text{ mol}$</p> <p>$0.062 \times 24.3 = 1.5066$</p> <p>$M = n \times m$</p> <p>mass of Mg = 1.51 g [3]</p>
	iii	<p>Separation of solid</p> <p>Filter to obtain solid/precipitate ✓</p> <p><i>Requires realisation that solid is filtered off.</i></p> <p><i>Solid may be stated within in 'removal of water'</i></p> <p>Removal of water</p> <p>Dry (solid) OR Evaporate (water/solution/liquid) ✓</p>	2	<p>ALLOW</p> <p>Removal of water</p> <p>Evaporate/ distil water/solution/liquid ✓</p> <p>IGNORE 'distil' if product OR H₂ is distilled</p> <p>Collection of remaining solid ✓</p> <p><i>Requires realisation that solid remains</i></p> <p>IGNORE 'Leave to crystallise' (already solid)</p> <p>Examiner's Comments</p> <p>Candidates often struggle with questions based on practical work. There were many random responses</p>



					to this question, with relatively few candidates identifying that solid magnesium phosphate could be obtained by filtration, followed by drying.
					<p>In equation: NO ECF from incorrect formula ALLOW multiples IGNORE state symbols (even if incorrect)</p> <p>Soluble Mg salts include MgCl₂, MgSO₄, Mg(NO₃)₂, MgBr₂, MgI₂ If unsure, check with TL e.g. 3MgCl₂ + 2H₃PO₄ → Mg₃(PO₄)₂ + 6HCl</p> <p>Examiner's Comments</p> <p>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.</p> <p>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 3MgO + 2H₃PO₄ → Mg₃(PO₄)₂ + 3H₂O [2]</p>
		iv	<p>Formula</p> <p>MgO OR Mg(OH)₂ OR MgCO₃ OR soluble Mg salt ✓</p> <p>Equation</p> <p>3MgO + 2H₃PO₄ → Mg₃(PO₄)₂ + 3H₂O OR 3Mg(OH)₂ + 2H₃PO₄ → Mg₃(PO₄)₂ + 6H₂O OR 3MgCO₃ + 2H₃PO₄ → Mg₃(PO₄)₂ + 3CO₂ + 3H₂O</p>	2	
			Total	8	
37		B		1 (AO 1.2)	<p>Examiner's Comments</p> <p>The correct answer B required candidates to assign correct oxidation numbers to Mg and O. The most common error was option A (+2),</p>



					obtained by candidates thinking that O has an oxidation number of -1
			Total	1	
38			D	1 (AO 1.2)	<p><u>Examiner's Comments</u></p> <p>This was generally well answered. The key to candidates quickly arriving at the correct answer (D) was to focus on the first compound in each equation. Good candidates could see clearly that the CuO in option D had been reduced to Cu. Some candidates lost time here by working out oxidation numbers for all the elements in all the equations.</p>
			Total	1	
39			D	1 (AO1.2)	
			Total	1	
40			Element oxidised: Oxygen/O Change from: -2 to 0 ✓ Element reduced: Nitrogen/N Change from +5 to +4 ✓	2(AO2.2×2)	<p>MAX 1 mark if no '+' sign for oxidation number</p> <p>ALLOW 2-</p> <p>ALLOW 5+ AND 4+</p> <p>ALLOW O₂ for oxygen</p> <p>ALLOW 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around</p> <p>IGNORE numbers around equation <i>i.e. treat as rough working</i></p> <p><u>Examiner's Comments</u></p> <p>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.</p>
			Total	2	
41			A	1 (AO1.2)	<p><u>Examiner's Comments</u></p> <p>Candidates performed well with this</p>



					question. Most successful candidates wrote the oxidation numbers beneath the equation to work out that Cl is both oxidised and reduced. This is a good strategy.
			Total	1	
42			B	1 (AO1.2)	<u>Examiner's Comments</u> Candidates found this question difficult with less than half choosing B, FeO_4^{2-} , as the correct response. There was no obvious key distractor, with A, C and D all being chosen by candidates.
			Total	1	
43			Oxidised AND nickel has lost/donated two electrons ✓	1 (AO2.1)	IGNORE reference to oxidation numbers (even if incorrect) <u>Examiner's Comments</u> A considerable number of candidates did not score the mark here despite knowing that it was an oxidation reaction. They either omitted to give the number of electrons lost or gave their justification using oxidation numbers. This question highlights the importance of reading the question carefully and answering the question asked, not one that may have been seen previously.
			Total	1	
44		i	Sodium bromate(V) ✓	1 (AO2.5×1)	<u>Examiner's Comments</u> Very few candidates scored this mark. Although a number of candidates did give sodium bromate as the answer (with the omission of the oxidation state), many other answers were seen suggesting candidates are not aware of naming conventions for inorganic compounds.
		ii	Br is oxidised AND reduced OR Br oxidation number is increased and decreased ✓	3 (AO1.1×1)	ALLOW same element is both oxidised and reduced ALLOW 1 mark if all 3 oxidation numbers are correct (even if



			Br is oxidised from 0 to +5 ✓ Br is reduced from 0 to -1 ✓	(AO2.2×2)	oxidation/reduction incorrectly assigned) Examiner's Comments This is the first time in a reformed chemistry AS paper that the question space has been left unstructured for oxidation number changes. The highest-attaining candidates set out their responses clearly, dealing with changes for oxidation and reduction separately, and giving the correct oxidation numbers. Some struggled to obtain an oxidation state of Br in NaBrO ₃ as +5, suggesting +1 instead.
			Total	4	
45	i		Overall equation AND state symbols: $\begin{array}{l} \text{M(s)} + \\ 2\text{HCl(aq)} \\ \rightarrow \\ \text{MCl}_2\text{(aq)} \\ + \text{H}_2\text{(g)} \checkmark \end{array}$ STATE SYMBOLS required in overall equation ONLY Half equations: Oxidation $\text{M} \rightarrow \text{M}^{2+} + 2\text{e}^- \checkmark$ Reduction $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ OR $\text{H}^+ + \text{e}^- \rightarrow \frac{1}{2}\text{H}_2 \checkmark$	3 (AO 2.6×3)	All 3 marks are independent. IGNORE charges/oxidation numbers shown around overall <i>equation</i> . <i>Treat as rough working</i> ALLOW overall equation shown with some or all ions that are present e.g. (with state symbols) $\text{M} + 2\text{H}^+ \rightarrow \text{M}^{2+} + \text{H}_2$ $\text{M} + 2\text{HCl} \rightarrow \text{M}^{2+} + 2\text{Cl}^- + \text{H}_2$ $\text{M} + 2\text{H}^+ + 2\text{Cl}^- \rightarrow \text{M}^{2+} + 2\text{Cl}^- + \text{H}_2$ In half equations, IGNORE state symbols even is wrong BUT half equations MUST only have species that change. For charges on half equations, ALLOW M ⁺² for M ²⁺ OR H ⁺¹ for H ⁺ ALLOW M - 2e ⁻ → M ²⁺ If BOTH half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations Examiner's Comments This question required candidates to write an overall equation and half equations for oxidation and reduction. Many candidates made errors within one or more equations. The overall equation was often written without



					<p>state symbols, despite the question instruction 'with state symbols'. The oxidation half equation was more likely to be correct than the reduction half equation, which often used Cl instead of H⁺. When H⁺ was used, the half equation was often unbalanced or electrons had been omitted.</p> <p>It is recommended that candidates carefully use the chemical information in the question.</p>
		ii	<p>Bubbles/effervescence/fizzing stops ✓</p> <p>M/metal/solid has disappeared/dissolved ✓</p>	<p>2 (AO 3.3×2)</p>	<p>Responses must imply that all fizzing has stopped and that all the solid has dissolved i.e. 'metal disappears' is not quite enough. 'All the metal disappears' is enough</p> <p>IGNORE constant mass IGNORE no increase in temperature</p> <p><u>Examiner's Comments</u></p> <p>Most candidates identified that all the metal would have reacted when it had all disappeared and that gas bubbles from the reaction would have stopped. Some responses did not emphasise that these observations would have stopped and this prevented credit being given.</p>
		iii	<p>H⁺ + OH⁻ → H₂O ✓</p>	<p>1 (AO 2.5)</p>	<p>ALLOW multiples e.g. 2H⁺ + 2OH⁻ → 2H₂O</p> <p>IGNORE state symbols, even if wrong</p> <p><u>Examiner's Comments</u></p> <p>The ionic equation for neutralisation of an acid with an alkali was well known and this question was answered correctly by most candidates.</p>
		iv	<p>Mean titre 1 mark = $\frac{(27.30 + 27.20)}{2} = 27.25 \text{ (cm}^3\text{)} \checkmark$</p> <p>Analysis of results 5 marks</p>	<p>6 (AO 2.8×5)</p>	<p><i>FULL ANNOTATIONS MUST BE USED</i></p> <p>-----</p> <p>-----</p> <p>Common error: Incorrect mean from all 3 titres =</p>



	<p> $n(\text{NaOH}) = 27.25 \times \frac{0.320}{1000} = 8.72 \times 10^{-3} \text{ (mol) } \checkmark$ $n(\text{HCl}) \text{ in } 25.0 \text{ cm}^3 = n(\text{NaOH})$ $n(\text{HCl}) \text{ in } 250 \text{ cm}^3$ $= 8.72 \times 10^{-3} \times 10 = 8.72 \times 10^{-2}$ $\text{(mol) } \checkmark$ </p> <p> $n(\text{HCl}) \text{ that reacted with M}$ $= 0.210 - 8.72 \times 10^{-2} = 0.1228 \text{ (mol)}$ \checkmark </p> <p> $n(\text{M}) \text{ that reacted} = \frac{0.1228}{2} = 0.0614 \text{ (mol) } \checkmark$ $A_r \text{ of M} = \frac{6.90}{0.0614} = 112.4 \text{ AND M} = \text{cadmium/Cd } \checkmark$ </p> <p>COMMON ERRORS:</p> <p>Mean of 27.35 (use of all 3 titres)</p> <p>→ $8.752 \times 10^{-3} \rightarrow 8.752 \times 10^{-2} \rightarrow$ 0.12248 → 0.06124 → 112.7 AND Cd: 5 marks</p> <p>No ÷2 to obtain $n(\text{M})$</p> <p>→ 56.2 AND Fe (from 27.25) 5 marks</p> <p>→ 56.3 AND Fe (from 27.35) 4 marks</p> <p>No subtraction from 0.210</p> <p>$A_r \text{ of M} = \frac{6.90}{0.0614} = 112.4 \text{ AND M} = \text{cadmium/Cd } \checkmark$ → 158.2 to 158.3 AND Tb 5 marks</p> <p>No ×10 to obtain $n(\text{HCl})$ in 250 cm³ 5 marks</p> <p>0.210 – $8.72 \times 10^{-3} = 0.20128$ OR 0.201 $n(\text{M}) = 0.20128/2 = 0.10064$ $A_r = 6.90/0.10064 = 68.56 \rightarrow \text{Zn}$</p> <p>No ×10 and no ÷ 2 4 marks</p> <p>0.210 – $8.72 \times 10^{-3} = 0.20128$ $A_r = 6.9/0.20128 = 34.28 \rightarrow \text{Ca}$</p> <p>Omitting initial titration calculation Zero marks</p> <p>0.210/2 = 0.105 → 6.9/0.105 = 65.71 → Zn</p>	<p>(AO 3.2)</p>	<p>27.35 cm³</p> <p>Use ECF throughout Intermediate values for working to at least 3 SF.</p> <p>TAKE CARE: Value written down may be truncated calculator value. Depending on rounding, either can be credited.</p> <p>ALLOW 0.123 (mol) i.e. 3SF</p> <p>ALLOW 0.0615 (mol) IF 0.1228 rounded to 0.123</p> <p>ALLOW 112.2 from 0.0615 AND Cd</p> <p>ALLOW A_r to nearest whole number ALLOW ECF for metal closest to calculated A_r</p> <p>DO NOT ALLOW Ga OR Sc (Form 3+ ions only)</p> <p>Examiner's Comments</p> <p>Candidates were presented with information about a back titration, a technique that they would be unlikely to have encountered during their course. The question stem to (iv) suggested a three-step strategy. Many candidates followed this guidance and were credited with many of the available marks. Marks were given for a correct method (by error carried forward) even if there was an error or omission in the multi-step calculation. This emphasises the importance of clear working.</p> <p>Most candidates determined the correct mean titre of 27.25 cm³. A few candidates did take the mean of all three titres rather than the closest. Most calculated that 8.72×10^{-3} mol of NaOH reacted with the same number of moles of HCl in the titration</p>
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					<p>and then scaled up the HCl by a factor of 10 to 8.72×10^{-2} mol in the 250 cm³ volumetric flask. These steps are standard for many titration calculations and gave a route to three of the six available marks. The more difficult back titration steps then followed and the higher-attaining candidates recognised the need to subtract this amount of HCl from the original amount of HCl used to react with metal M. These candidates then divide this value by two to find the moles of M that reacted (from the 1 : 2 stoichiometry of M : HCl). The correct calculation then gave a relative atomic mass of M as 112 and its identity as cadmium. It was common for candidates to omit the division by two and to arrive at a relative atomic mass of 56 for iron. The mark scheme shows the variety of metals that candidates identified from their calculations, the errors made, and the error carried forward marks that resulted.</p> <p>Many lower-attaining candidates did not follow the 3 steps in the stem, using only the original amount of HCl and ignoring the titration. This approach was not credited with marks.</p> <p>A large range of marks was seen, and the question discriminated extremely well.</p>
			Total	12	
46			C	1 (AO 2.6)	
			Total	1	
47			Equation: $\text{Mg} + 2\text{CH}_3\text{COOH} \rightarrow (\text{CH}_3\text{COO})_2\text{Mg} + \text{H}_2 \checkmark$ Oxidation: Mg from 0 to +2 \checkmark	3 (AO 2.6) (AO 1.2)	ALLOW $\text{Mg}(\text{CH}_3\text{COO})_2$ ALLOW multiples IGNORE Oxidation numbers in formulae IGNORE state symbols Mark independently from equation



			Reduction: H from +1 to 0 ✓	(AO 1.2)	ALLOW 1 mark for correct oxidation numbers but incorrectly linked to redox.
			Total	3	
48		i	$\text{Ni} : \text{S} : \text{N} = \frac{16.26}{58.7} : \frac{35.36}{32.1} : \frac{31.0}{14}$ OR 0.277 : 1.10 : 2.21 OR 1 : 4 : 8 ✓ $x = 4$ ✓ $2 + x + y = 8$ $y = 2$ ✓	3 (AO 3.1×1) (AO 3.2×2)	ALLOW any correct method ALLOW NiS ₄ N ₈ for ratio ALLOW ECF for y from incorrect x
		ii	+2 ✓	1 (AO 2.1)	+ required ALLOW 2+
			Total	4	
49			Element oxidised : Chlorine/Cl Change from: -1 to 0 ✓ Element reduced : Manganese/Mn Change from +4 to +2 ✓	2 AO1.2×2	MAX 1 mark if no '+' sign for oxidation number ALLOW Cl ₂ for chlorine ALLOW 1- ALLOW 4+ AND 2+ ALLOW 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around IGNORE numbers around equation i.e. treat as rough working
			Total	2	
50			B	1 (AO1.2)	
			Total	1	
51		i	Mn is oxidised from +6 (in MnO ₄ ²⁻) to +7 (in MnO ₄ ⁻) ✓ Mn is reduced from +6 (in MnO ₄ ²⁻) to +4 (in MnO ₂) ✓	2 (AO2.1×2)	IGNORE '6' (signs required) ALLOW after number, e.g. 5+ ALLOW 1 mark for correct oxidation numbers but not linked to oxidation/reduction. IGNORE any reference to electron loss/gain (even if wrong) Examiner's Comments Most candidates were able to construct the equation for the overall cell reaction and to use oxidation numbers to explain disproportionation.



		ii	<p><i>Explanation using E° values</i> $(E^\circ$ of) system 3 ($\text{MnO}_4^-/\text{MnO}_4^{2-}$) is less positive / more negative than system 5 ($\text{MnO}_4^{2-}/\text{MnO}_2$) ✓</p> <p><i>Equilibrium shift related to E° values</i> system 3 ($\text{MnO}_4^-/\text{MnO}_4^{2-}$) shifts left AND system 5 ($\text{MnO}_4^{2-}/\text{MnO}_2$) shifts right ✓</p>	2 (AO3.1×2)	<p>IGNORE 'lower/higher' ALLOW reverse argument: System 5 more positive than system 3, etc Must be comparative ALLOW response in terms of E_{cell} $E = (+)1.14 \text{ V}$ for system 5 – system 3</p> <p>Shift dependent on systems 3 and 5 correctly identified</p> <p>Examiner's Comments Only a few candidates were able to link the electrode potentials and equilibrium shifts. Many candidates did not clarify which redox system they were referring to and only stated one of the ions. Often only one equilibrium shift was mentioned, and it was not linked to any redox system. Centres should advise candidates to use the redox system numbers found within the question to aid communication. Candidates should avoid using the terms 'higher/lower' to compare the E_{cell} values.</p> <p> OCR support</p> <p>Further guidance on electrode potentials can be found in our delivery guide: Delivery Guide for OCR AS/A Level Chemistry A</p>
		Total		4	
52		i	<p>Structure and bonding NH_3 is (simple) molecular/simple covalent/ /has intermolecular forces AND NH_4NO_3 is ionic ✓</p> <p>Comparison of strength Ionic bonds are stronger than intermolecular bonds / forces between molecules OR Ionic bonds need more energy to break than intermolecular bonds ✓</p>	2 (2× AO1.1)	<p>For intermolecular bonds/forces ALLOW hydrogen bonds OR London Forces/induced dipole forces/permanent dipole forces OR van der Waals' forces</p> <p>ALLOW NH_4NO_3 has molecular ions NH_4^+ and NO_3^- are molecular ions</p> <p>ORA</p> <p>ALLOW: Intermolecular bonds are weak</p>



				<p>AND ionic bonds are strong ✓</p> <p><u>Examiner's Comments</u></p> <p>Candidates found the explanation difficult, and the responses showed some misconceptions. For example, many suggested that NH_3 and NH_4NO_3 both have hydrogen bonds. Those identifying that NH_4NO_3 has ionic bonding usually compared the greater strength of ionic bonding over intermolecular forces in NH_3. Unfortunately, many candidates described the ionic bonds as acting between molecules.</p> <p>This question proved to be one of the most difficult on the paper.</p> <p> Misconception</p> <p>A good understanding of structure and bonding continues to be difficult for candidates, demonstrated by many incorrect explanations for the different boiling points. This is a key misconception.</p> <p>Understanding could be improved by first considering the following.</p> <ul style="list-style-type: none">• What is the type of bonding?• What are particles in the structure? <p>Candidates need to be very careful when describing the two types of structure containing covalent bonds:</p> <ul style="list-style-type: none">• Simple molecular with strong covalent bonds within the molecules and weaker intermolecular bonds between the molecules in the structure <p>Giant covalent with strong covalent bonds between the atoms in the</p>
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				structure. Exemplar 1 <i>NH₃ and NH₄NO₃ both have hydrogen bonding, however NH₄NO₃ has many more H bonds due to size of compound. This means more energy is required to break bonds.</i> Exemplar 1 is typical of many, suggesting that NH ₄ NO ₃ has hydrogen bonding, which is either stronger than in NH ₃ , or that NH ₄ NO ₃ has more hydrogen bonds. This response was given 0 marks.
		ii	(NH ₄ ⁺) nitrogen has oxidation number of -3 AND (NO ₃ ⁻) nitrogen has oxidation number of +5 ✓ <i>i.e. nitrogens are -3 AND +5 gets the mark</i> BOTH signs essential	1 (AO1.2) Statement that one student is correct is NOT required. <i>Implicit in answer</i> ALLOW 3- AND 5+ Examiner's Comments Considering the large number of candidates describing NH ₄ NO ₃ as molecular in Question 1 (a) (i), most candidates identified here that NH ₄ NO ₃ contains NH ₄ ⁺ and NO ₃ ⁻ ions. Most then went on to show that the nitrogen atoms in the ions have different oxidation numbers: -3 and +5 respectively. Candidates were only given marks if both signs had been included and this was usually the case. -4 and +6 were common incorrect responses, presumably by ignoring the charges on the ions. Comparatively few candidates grouped the nitrogen atoms together and suggested that they had the same oxidation number.
			Total	3
53		i	FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 2.19 × 10⁻³ award 3 marks ----- -----	3 (3 × AO2.2) Use of ideal gas equation for all 3 marks provided 'sensible' <i>p</i> and <i>T</i> used: e.g. from 101 kPa and 298 K → <i>n</i> = 17.122 → 2.14 × 10 ⁻³ from 100 kPa and 298 K → <i>n</i> = 16.952 → 2.12 × 10 ⁻³ Examples of 'sensible'



		$n(\text{Cl}_2) = 420/24 = 17.5 \text{ (mol)} \checkmark$ $n(\text{Ca}(\text{ClO})_2) = \frac{17.5}{2} = 8.75 \text{ (mol)} \checkmark$ $\text{Concentration Ca}(\text{ClO})_2 = \frac{8.75}{4 \times 1000}$ $= 2.19 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>3SF AND standard form</p>	$p = 100 \text{ kPa, } 101 \text{ kPa, } 101,325 \text{ Pa}$ $T = 273 - 298 \text{ K}$ ALLOW ECF <p>-----</p> <p>Common errors</p> $4.38 \times 10^{-3} \text{ (no } \div 2) \rightarrow 2 \text{ marks}$ $2.19 \times 10^n \rightarrow 2 \text{ marks}$ $4.38 \times 10^n \rightarrow 1 \text{ mark}$ $2.2 \times 10^{-3} \rightarrow 2 \text{ marks}$ <i>not appropriate SF</i> <p>Examiner's Comments</p> <p>Most candidates calculated the amounts of Cl_2 and $\text{Ca}(\text{ClO})_2$ correctly as 17.5 mol and 8.75 mol respectively. Only the least successful did not use the equation's stoichiometry to halve 17.5 to 8.75. For the final step in the calculation, candidates needed to convert 4.00 m³ into 4000 dm³ and to then determine the concentration to an appropriate number of significant figures and standard form. As all the data had been provided to 3 significant figures, the final answer was also required to 3 significant figures, as $2.09 \times 10^{-3} \text{ mol dm}^{-3}$. Answers such as 2.2×10^{-3}, 2.1875×10^{-3} and 2.19×10^{-6} and 0.00219 illustrate errors in these areas.</p>
	ii	<p>Equation</p> $3 \text{ Ca}(\text{ClO})_2 \rightarrow 2 \text{ CaCl}_2 + \text{Ca}(\text{ClO}_3)_2$ <p>✓</p> <p>Reduction</p> <p>Cl reduced from +1 to -1 ✓</p> <p>Oxidation</p> <p>Cl oxidised from +1 to +5 ✓</p> <p>+1 starting oxidation number seen once Cl required for both explanation</p>	<p>3 (AO2.6) (2 × AO1.2)</p> <p>ALLOW multiples ALLOW $3 \text{ ClO}^- \rightarrow 2 \text{ Cl}^- + \text{ClO}_3^-$</p> <p>ALLOW 1 out of 2 redox marks if oxidation number changes are BOTH correct ...BUT reduction/oxidation is incorrectly assigned, i.e. Cl is oxidised from +1 to -1 Cl is reduced from +1 to +5</p> <p>ALLOW 1 out of 2 redox marks if oxidation changes correct but red and</p>



		<p>marks</p> <p>IGNORE oxidation numbers shown below/above equation (<i>treat as rough working</i>)</p> <p>BUT If no oxidation numbers in explanation, <i>look at equation for oxidation numbers</i></p>	<p>ox not stated C/ changes from +1 to -1 C/ changes from +1 to +5</p> <p>----- -----</p> <p>General: ALLOW number before sign in ox no, e.g. 1- for -1</p> <p>IGNORE ionic charges, e.g. C^{5+} IGNORE '1' (signs required)</p> <p>IGNORE references to electron loss/gain (even if wrong)</p> <p><u>Examiner's Comments</u></p> <p>Candidates were required to write a balanced equation from provided reactants and products and to use oxidation numbers to illustrate disproportionation.</p> <p>In the equation, the reactants and products were sometimes unbalanced, or incorrectly balanced. A common error was to balance the equation after first adding O_2 as an extra reactant.</p> <p>Illustrating disproportionation proved to be easier with the oxidation number changes from the initial +1 being required.</p> <p>Otherwise, more successful responses sometimes missed out on marks if they omitted detail. For example, the oxidation number changes were stated but the candidate omitted to state which change was oxidation and which was reduction. The best responses identified $Ca(ClO_3)_2$ as the oxidation product and $CaCl_2$ as the reduction product.</p> <p>One unexpected error on many scripts was for calcium to be identified as the element undergoing</p>
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					disproportionation, with oxidation number changes from +6 to +14 and +2. It was difficult to see why this happened, with Ca forming +2 compounds, but the error was common.
			Total	6	
54		i	$\text{Sr} + 2\text{H}_2\text{O} \rightarrow \text{Sr}(\text{OH})_2 + \text{H}_2$ All formulae and balancing correct ✓	1 (AO2.6)	<p>IGNORE STATE SYMBOLS</p> <p>ALLOW multiples</p> <p>IGNORE state symbols (even if wrong)</p> <p><u>Examiner's Comments</u></p> <p>Around half of all candidates did not score this mark. The most common error was giving SrO as the product rather than the hydroxide. Other errors included incorrect balancing (missing 2 on H₂O, SrOH as the formula of the hydroxide and no hydrogen formed (often giving H₂O instead)).</p> <p> Assessment for learning</p> <p>Regular practice writing formulae and balancing chemical equations will help to consolidate these concepts, avoiding basic errors such as giving formula of group 2 hydroxide as SrOH.</p>
		ii	<p>Oxidation Sr from 0 to +2 ✓</p> <p>Reduction H from +1 to 0 ✓</p>	2 (AO 2.1 × 2)	<p>ALLOW 2+ for +2 and 1+ for +1 '+' is required in +2 and +1 oxidation numbers</p> <p>ALLOW H₂ for hydrogen</p> <p>ALLOW 1 mark for elements AND all</p>



				<p>oxidation numbers correct but oxidation and reduction wrong way round OR not given.</p> <p>IGNORE numbers around equation in (i) (<i>treat as rough working</i>)</p> <p><u>Examiner's Comments</u></p> <p>Most candidates managed to score at least 1 mark for this question. The most common reason for losing a mark, despite demonstrating a good understanding of redox, was stating that H changed from +2 to 0 (need to give oxidation number per atom). Other errors seen included only giving change for Sr, descriptions in terms of electrons rather than oxidation numbers, Sr change from 0 to +1 (linked to SrOH), oxygen being reduced rather than H and mixing up oxidation/reduction or not specifying.</p>
	iii	<p><i>Atomic radius</i> Ca has smaller atomic radius OR fewer shells ✓</p> <p><i>Effect of nuclear charge/shielding</i> Ca has less/decreased shielding ✓</p> <p><i>Nuclear attraction</i> Ca has greater nuclear attraction (for electrons) OR Ca has a higher ionisation energy OR more energy is required to lose the outer electrons ✓</p>	<p>3 (AO 1.2) (AO 1.2) (AO 1.2)</p>	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ORA in terms of Sr Comparison needed for each mark.</p> <p>ALLOW 'fewer energy levels' ALLOW 'electrons closer to nucleus'</p> <p>IGNORE fewer orbitals OR fewer sub-shells OR different shell</p> <p>ALLOW more electron repulsion from inner shells</p> <p>IGNORE nuclear charge/effective nuclear charge ALLOW 'less nuclear pull' OR 'electrons held less tightly'</p>



					<p><u>Examiner's Comments</u></p> <p>Most candidates gained some marks here although a significant proportion were unable to score all 3 marks covering atomic radius, shielding, nuclear attraction/IE. The mark most often missed was for shielding. Some candidates did not answer the question asked and gave the trend down the group so could not be given marks unless they made it clear Sr is below Ca in the group. Care must be taken to answer question asked not similar questions they have seen before. The best responses were those with direct comparative statements, e.g. "Ca has a smaller atomic radius than Sr". It is worth noting that harder/easier to lose electrons didn't gain marks, but was seen fairly frequently, as response needs to be in terms of energy required or linked to nuclear attraction.</p>
			Total	6	
55		i	<p>Ca fizzes faster AND Ca dissolves/disappears more quickly ✓</p>	1 (AO2.3)	<p>CARE Both needed for 1 mark.</p> <p>ORA ALLOW AW</p> <p>IGNORE finishes first IGNORE more bubbles (need idea of rate) IGNORE exothermic</p> <p><u>Examiner's Comments</u></p> <p>Very few candidates made two valid statements where both clearly indicated an idea of relative rate – in almost all cases one of the descriptions would be about quantity of gas rather than rate of gas production. Some candidates identified a precipitate being formed, colour change, or gave a general</p>



					answer of the reaction happening quicker.												
		ii	<p>Oxidation $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^- \checkmark$</p> <p>Reduction $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$</p> <p>OR $\text{H}^+ + \text{e}^- \rightarrow \frac{1}{2}\text{H}_2 \checkmark$</p>	2 (AO2.6×2)	<p>In half equations, ALLOW the use of e for e⁻</p> <p>ALLOW $\text{Mg} - 2\text{e}^- \rightarrow \text{Mg}^{2+}$</p> <p>IGNORE state symbols even is wrong BUT half equations MUST only have species that change.</p> <p>For charges on half equations, ALLOW Mg^{+2} for Mg^{2+}</p> <p>OR H^{+1} for H^+</p> <p>If BOTH half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations</p> <p><u>Examiner's Comments</u></p> <p>Some candidates coped well with this question which was based on the AS part of the specification and gained both marks. More candidates gained 1 mark through writing one half equation, usually the oxidation of magnesium. Common errors were for chlorine to featuring in the reduction half equation and the lack of electrons in their answers. Very few candidates mixed up the oxidation and reduction equations.</p>												
			Total	3													
56			<table border="1"> <thead> <tr> <th>Name of oxyanion</th> <th>Ionic charge</th> <th>Formula of oxyanion</th> </tr> </thead> <tbody> <tr> <td>Bromate(III) ✓</td> <td>1-</td> <td>BrO_2^-</td> </tr> <tr> <td>Sulfate(VI)</td> <td>2-</td> <td>SO_4^{2-}</td> </tr> <tr> <td>Phosphate(V)</td> <td>3-</td> <td>$\text{PO}_4^{3-} \checkmark$</td> </tr> </tbody> </table>	Name of oxyanion	Ionic charge	Formula of oxyanion	Bromate(III) ✓	1-	BrO_2^-	Sulfate(VI)	2-	SO_4^{2-}	Phosphate(V)	3-	$\text{PO}_4^{3-} \checkmark$	2 (AO3.1 ×2)	<p>ALLOW PO_4^{-3}</p> <p><u>Examiner's Comments</u></p> <p>Although this question included important clues within the table, these were usually ignored by candidates and this item did not score as well as expected. The bromate(III) was poorly</p>
Name of oxyanion	Ionic charge	Formula of oxyanion															
Bromate(III) ✓	1-	BrO_2^-															
Sulfate(VI)	2-	SO_4^{2-}															
Phosphate(V)	3-	$\text{PO}_4^{3-} \checkmark$															



					identified, with many candidates missing the oxidation state of the bromine. Many candidates wrote bromide, bromate without (III), bromide (III), bromate (VI) and other oxidation numbers. The phosphate ion was more familiar with many candidates identifying its formula as PO_4^{3-} . A common error was the inclusion of the wrong number of oxygen atoms in the ion, such as PO_5 with various charges.
			Total	2	
57		i	Oxidation and reduction of the same element ✓ 'Atom' is insufficient for element	1 (AO1.1 ×1)	ALLOW 'chlorine' OR 'Cl' for same element IGNORE 'species' for 'element' Examiner's Comments Candidates answered this question well and most were given the mark. Where candidates didn't receive credit, it was mainly because they used the term 'same atom' instead of 'same element'. Some less successful responses responded with completely incorrect chemistry and had clearly not learnt this specification content.
		ii	Equation $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaClO} + \text{NaCl} + \text{H}_2\text{O}$ ✓ Redox: Cl is oxidised from 0 (in Cl_2) to +1 in NaClO ✓ Cl is reduced from 0 (in Cl_2) to -1 in NaCl/HCl ✓ IGNORE oxidation numbers shown in equation (<i>treat as rough working</i>) BUT If no oxidation numbers in explanation, <i>look at equation for oxidation numbers</i>	3 (AO2.6×1) (AO2.1×2)	DO NOT ALLOW $\text{Cl}_2 + \text{NaOH} \rightarrow \text{NaClO} + \text{HCl}$ ALLOW ECF from HCl in equation ALLOW 1 out of 2 redox marks if NaClO AND NaCl omitted, i.e. Cl is oxidised from 0 to +1 AND Cl is reduced from 0 to -1 ALLOW 1 out of 2 redox marks if oxidation number changes are BOTH correct ... BUT reduction/oxidation is incorrectly assigned, i.e. Cl is reduced from 0 (in Cl_2) to +1 in NaClO Cl is oxidised from 0 (in Cl_2) to -1 in NaCl/HCl General: ALLOW number before sign in ox no, i.e. 1+ for +1 1- for -1 IGNORE ionic charges, e.g. Cl^{1+} IGNORE '1' (signs required) IGNORE references to electron



				<p>loss/gain (even if wrong)</p> <p><u>Examiner's Comments</u></p> <p>Candidates found the equation hard, despite this reaction being specification content and the inclusion in the earlier part of the stem of 'NaClO' as one product. The correct response required candidates to realise that NaCl would be a product and to balance the resulting equation. Some did not add the balancing '2' before NaOH, and many selected HCl as the second product, a compound that would react further with NaOH to produce NaCl. The explanation worked the same whether NaCl or HCl had been identified as the second product. There were some excellent responses, providing the correct oxidation number changes, linking these to the species involved and identifying the changes as either oxidation or reduction. Two explanation marks were available with marks not being given for omission of one of the three features described above.</p> <p>Exemplar 2</p> <p>Equation $\text{Cl}_2 + \text{NaOH} \rightarrow \text{NaClO} + \text{HCl}$</p> <p>Explanation The way I wrote the disproportionation has been done because Cl has gone from 0 to +1 in NaClO and has gone from 0 to -1 in HCl (so it has been oxidised and reduced)</p> <p>[3]</p> <p>This exemplar has been included to emphasise the points made above. It was only possible to award this response 1/3 marks. The equation shows the common error of the second chlorine-containing product being HCl and not NaCl: 0 marks The candidate has identified the oxidation number changes and has linked these to the correct species. The last statement in brackets is correct but the candidate has not communicated which oxidation number change is</p>
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				oxidation and which is reduction: 1/2 marks
			Total	4
58			<p>$C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓</p> <p>$2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓</p> <p>H₂O AND CO₂ ✓</p> $ \begin{array}{c} H \\ \\ H_2N - C - COONa \\ \\ CH_2 \\ \\ COONa \end{array} $ <p>Correct formula of salt: ✓</p>	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>IGNORE state symbols and use of equilibrium sign</p> <p>ALLOW KC_2H_5COO</p> <p>DO NOT ALLOW a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but IGNORE for next equations.</p> <p>For salts, ALLOW $C_2H_5COO^-K^+$ OR $C_2H_5COO^- + K^+$</p> <p>DO NOT ALLOW $-COO-K$ (covalent bond) the 1st time seen but IGNORE for next equations.</p> <p>FOR $CO_2 + H_2O$ ALLOW H_2CO_3</p> <p>4 (AO2.6×4)</p> <p>Examiner's Comments</p> <p>This question proved challenging for candidates. The first equation was often answered correctly, although some candidates used sodium hydroxide rather than potassium hydroxide in their response. The second equation was frequently incorrect. Candidates frequently missed a hydrogen from the structure for methanoic acid or did not recognise that hydrogen was a product. Many candidates did not account for magnesium having a 2+ charge when working out the product. For the third equation, the majority of candidates identified that carbon dioxide and water would be produced</p>



					but were unable to give the correct formula of the salt as they did not interpret the information given regarding the R group.
			Total	4	
59	i	Titanium (IV) oxide ✓		1 (AO2.5)	<p>DO NOT ALLOW titanium dioxide</p> <p>Examiner's Comments</p> <p>Very few candidates gave the correct answer for this question. The most common errors included: titanium oxide, titanium(IV) dioxide, titanium oxide(IV), titanium(II) oxide. A few also attempted to give names like those for organic compounds: 1,1-titanium dioxide or the reverse 1,1-dioxytitanium.</p> <p>How Science Works</p> <p>It is important in Chemistry to have clear communication by use of systematic and unambiguous nomenclature. This includes the use of Roman numerals to indicate the magnitude of the oxidation number when an element, such as Ti, may have different oxidation numbers in different compounds. See specification statement 2.1.5(c) and HSW8.</p>
	ii	<p>FIRST CHECK ANSWER ON ANSWER LINE If answer = 2.67 kg award 4 marks</p> <hr style="border-top: 1px dashed #00aaff;"/> <p>$n(\text{Ti}) = \frac{1000}{47.9}$ OR 20.8768... (mol) ✓</p> <p>$n(\text{Na})$ for 72% yield = 20.88×4 OR 83.5073... (mol) ✓</p> <p>$n(\text{Na})$ for 100% yield = $83.51 \times \frac{100}{72}$ OR 115.98237... (mol) ✓</p> <p>mass Na = $115.98 \times \frac{23.0}{23.0}$ = 2667.659... (g)</p>	4 (AO2.2 × 4)	<p>ALLOW ECF throughout TAKE CARE: values shown may be truncated calculator values.</p> <p>Steps can be calculated in any order which will change the intermediate answers. Marks are for the processing of the data.</p> <p>ALLOW 3SF up to calculated value throughout</p> <p>IGNORE rounding errors past 3SF</p> <p>Common Errors for 3 marks: 1.92 (missing yield) 1.38 (yield wrong way round)</p>	



= 2.67 (kg) ✓
**3 SF AND kg
 required**

0.673 (use of Mr 189.9 for TiCl_4
 instead 47.9 for Ti)

Examiner's Comments

Candidates found this calculation quite challenging, with less than a quarter achieving full marks. The most common errors are highlighted on the mark scheme. Many that struggled were often given credit for the x4 ratio mark but only if it was possible to see this in the working. Many gave multiple, often contradictory attempts at the calculation. It was not always clear how the final answer had been obtained. Clear working enables us to follow the logic and give ECF where appropriate.

Many divided 1000 g by the molar mass for TiCl_4 and then found 72% of this. It was important here to read the question carefully to ensure complete understanding.

Exemplar 1

$$\begin{aligned} \text{\% yield} &= \frac{\text{actual yield}}{\text{theoretical yield}} \\ n(\text{Ti}) &= \frac{1000}{47.9} = 20.8762\dots \\ &= \frac{20.8762\dots}{4} \times 100 = 71 \\ \text{mass (Na)} &= \frac{20.8762\dots}{4} \times 23 \\ &= (20.8762\dots \div 4) \times 23 \\ &= 119.5711\dots \text{ g} \\ &= 0.1195711\dots \text{ kg} \\ \text{mass of sodium} &= \dots 0.167 \dots \text{ kg [4]} \end{aligned}$$

This candidate achieved 3 out of the 4 possible marks. The steps in their calculation are logical and it is easy to follow their working and therefore spot the error in their calculation. They have divided by 4 rather than multiplying. It also shows the calculation can be performed in a different order to that on the mark scheme. All intermediate values are used in calculations as calculator values without rounding to ensure an accurate answer.



			<p>Add water AND filter ✓</p> <p>iii</p> <p>Ti does not dissolve OR NaCl/ does dissolve ✓</p>	<p>ALLOW dissolve in water</p> <p>ALLOW Ti is insoluble OR NaCl is soluble/aqueous</p> <p>ALLOW Ti is the residue OR NaCl is the filtrate</p> <p><u>Examiner's Comments</u></p> <p>Most candidates did not gain any credit here. However, the range of responses seen highlighted some misconceptions in their understanding of how different mixtures can be separated. Many assumed that sodium chloride was in solution/aqueous, not recognising that water was not present in this reaction. Responses such as "sodium chloride will evaporate" or "remove the water" were seen. Some gave a description of the purification method for an organic liquid - the use of a separating funnel and/or distillation were common. Some suggested the use of a magnet to remove Ti despite it being a non-magnetic metal.</p> <p> Misconception</p> <p>Understanding how to separate mixtures is covered in both KS3 and KS4 but it is important that these concepts can be applied during further study. Asking this type of problem solving question would make a good starter activity.</p> <p>Some useful activities for separating mixtures can be found in the GCSE Chemistry B (Twenty First Century Science) Chemical analysis transition guide</p>	<p>2 (AO 3.3 × 2)</p>
			Total		7



60		<p>Disproportionation</p> <p>Oxidation AND reduction of same element/chlorine</p> <p>OR</p> <p>Chlorine/Cl/Cl₂ has been oxidised AND chlorine/Cl/Cl₂ has been reduced ✓</p> <p>Oxidation</p> <p>from 0 in Cl₂ to +1 in Ca(OCl)₂ OR ClO⁻ ✓</p> <p>Reduction</p> <p>from 0 in Cl₂ to -1 in CaCl₂ OR Cl⁻ ✓</p>	<p>3 (AO 1.1) (AO 2.2) (AO 2.2)</p>	<p>IGNORE numbers around equation for oxidation numbers</p> <p>IGNORE 'species' or 'reactant' for element</p> <p>ALLOW 1+ for +1 AND 1- for -1 NOTE for chlorine/Cl₂ from 0 only needs to be seen once, does not need to be stated twice</p> <p>ALLOW 1 mark for 3 oxidation numbers correct but no mention of words oxidation/reduction: e.g.</p> <p>0 in Cl₂ AND -1 in CaCl₂ AND +1 in Ca(OCl)₂</p> <p>ALLOW 1 mark for species missing</p> <p>oxidised from 0 to +1 AND reduced (from 0) to -1</p> <p><u>Examiner's Comments</u></p> <p>Most were able to explain the term disproportionation. Some missed the mark by not stating an element or chlorine. A very common error was giving final oxidation numbers of Cl as +2 and/or -2, rather than per atom. The link between oxidation number and species was not always clearly indicated or changes not specified as oxidation/reduction (or given as the wrong way round). It is vital to set out answers clearly showing oxidation numbers, species and stating if oxidised or reduced. It is not enough to write on the equation given in the question as it often challenging to read these numbers, or they contradict the main answer. Some attempted to show that Ca has been disproportionated.</p>
		<p>Total</p>	<p>3</p>	
61		<p>B</p>	<p>1 (AO 1.2)</p>	<p><u>Examiner's Comments</u></p> <p>Most candidates corrected selected</p>



					option B. Many candidates wrote their oxidation numbers by each response with most identifying the oxidation number of S in S ₈ as being 0. The main distractors were A and C. Annotations showed that many assignments of oxidation number had the wrong sign. For example, assigning S as -2 for S (SF ₂) would result in C being chosen. This suggests that some candidates have an insufficient understanding of the rules for assigning oxidation numbers.
			Total	1	
62		i	CuO + 2HCl → CuCl ₂ + H ₂ O ✓	1 (AO2.6)	<p>ALLOW multiples IGNORE state symbols IGNORE charges, even if wrong</p> <p>Examiner's Comments</p> <p>This question required candidates to recognise the reaction as being 'acid-base' and to interpret a formula from a name containing a Roman numeral. Candidates identifying the formula of copper(II) oxide as CuO were normally able to complete the equation. A reasonably large number identified the copper compounds as CuO₂ and CuCl. Overall, most candidates produced a correct equation.</p>
		ii	<p>(NH₄)₂CO₃ + 2HNO₃ → 2NH₄NO₃ + CO₂ + H₂O</p> <p>Any 4 formulae correct ✓ All 5 formulae correct and balanced ✓</p>	2 (AO2.6 × 2)	<p>ALLOW multiples IGNORE state symbols IGNORE charges, even if wrong</p> <p>ALLOW H₂CO₃ for CO₂ + H₂O <i>Counts as 2 formulae for marking criteria</i></p> <p>Examiner's Comments</p> <p>This item was much more demanding than the equation in 22(b)(i) and was often answered incorrectly. Most were unable to work out the formula of the two ammonium compounds, with NH₃ often shown instead of NH₄. A mark was available for 4 of the 5 formulae</p>



					being correct but comparatively few were able to construct the correct balanced equation. Candidates are expected to know the formula and charge of ammonium and carbonate ions and the common acids (sulfuric, hydrochloric and nitric) and these are clearly listed in the specification.
			Total	3	
63			C	1 (AO 2.6)	<u>Examiner's Comments</u> Most candidates answered this question correctly with C.
			Total	1	
64			D	1 (AO 1.2)	<u>Examiner's Comments</u> The correct answer was D. Most candidates recognised that the complex represented cisplatin. Cisplatin has a bond angle of 90 degrees due to being square planar and shows cis/trans isomerism, but some candidates thought it showed optical isomerism too. Most could tell the oxidation number of platinum is not +4.
			Total	1	
65	i		Rubidium chlorate(VII) ✓	1 (AO 1.1)	ALLOW Rubidium(I) chlorate(VII) Rubidium chloroate(VII) IGNORE Rubidium (VII)chlorate Rubidium chlorate(IIV) Rubidium chlorate (7) Rubidium perchlorate <u>Examiner's Comments</u> Candidates had difficulty in naming a compound using Roman numerals for an element which can have different oxidation numbers. For the name of RbClO_4 , many omitted the number entirely, showing just rubidium chlorate. Many inventive names such as rubidium chlorotetraoxide were



				seen. Some candidates wrote the correct VII before chlorate and many different Roman oxidation numbers were seen. Roman numerals' use in naming compounds is part of chemical nomenclature, included in the specification.
		ii	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 54.0 OR 54.1 OR 54.2 (kJ mol⁻¹) award 3 marks</p> <hr/> <p>Energy change from mcΔT</p> <p>Energy in J OR kJ = 102 × 4.18 × 1.5 OR 639.54 (J) OR 0.63954 (kJ) ✓</p> <hr/> <p>Amount in mol of RbClO₃</p> $n(\text{RbClO}_3) = \frac{2.00}{169} \text{ OR } 0.0118\dots\dots$ <p>(mol) ✓</p> <hr/> <p>Δ_{sol}H(RbClO₃)</p> $= \frac{0.63954}{0.0118\dots\dots} = (+) \text{ 54.0 } \checkmark$ <p><i>From unrounded values, ΔH = 54.04113</i></p> <p><i>Examples of mixed acceptable intermediate rounding, e.g.</i></p> $\frac{0.640}{0.0118} \Delta H = 54.237 \rightarrow 54.2$ $\frac{0.63954}{0.01183} \Delta H = 54.06 \rightarrow 54.1$	<p>ALLOW ECF throughout</p> <p>IGNORE sign IGNORE RE and SF in 1st 2 marks</p> <p>0.01183431953 unrounded ALLOW 54 (from 54.0) CARE 54.00 is a rounding error</p> <hr/> <p>COMMON ERRORS</p> <p>52.98 OR 53.14 2 marks</p> <p>100 instead of 102: Energy = 100 × 4.18 × 1.5 = 627 J</p> <p style="text-align: center;">3 (AO 2.8 × 3)</p> <p>From unrounded <i>n</i>,</p> $\Delta H = \frac{0.627}{0.0118\dots\dots} = \text{ 52.98 } \text{ kJ mol}^{-1}$ <p style="text-align: right;">OR 53.0 (3SF) OR 53</p> <p>From rounded 0.0118,</p> $\Delta H = \frac{0.627}{0.0118} = 53.14 \text{ OR } 53.1$ <hr/> <p>0.02078 OR 0.0208 1 mark</p> <p>102 and 2 swapped: Energy = 2 × 4.18 × 1.5 = 12.54 J</p>



$$n = \frac{102}{169} = 0.60355\dots$$

$$\text{ECF } \Delta H = \frac{0.01254}{0.60355\dots} = \mathbf{0.0208} \text{ kJ mol}^{-1}$$

1.06

2 marks

102 for n instead of 2.00:

$$n = \frac{102}{169} = 0.60355\dots$$

$$\Delta H = \frac{0.63954}{0.60355\dots} = \mathbf{1.06} \text{ kJ mol}^{-1}$$

OR

2 for energy instead of 102

$$\text{Energy} = 2 \times 4.18 \times 1.5 = 12.54 \text{ J}$$

$$\Delta H = \frac{0.01254}{0.0118\dots} = \mathbf{1.06} \text{ kJ mol}^{-1}$$

107.4 – 107.7

2 marks

8.314 for c instead of 4.18:

$$\text{Energy} = 102 \times 8.314 \times 1.5 = 1272 \text{ J}$$

$$\text{Energy} = 102 \times 8.31 \times 1.5 = 1271.4 \text{ J}$$

$$\Delta H = \mathbf{107.4 - 107.7} \text{ kJ mol}^{-1}$$

depends on intermediate rounding

CHECK

Apply **ECF** for any other comparable responses. If in doubt contact TL

Examiner's Comments

This question was a good discriminator, producing marks across the whole 3 mark range. More successful candidates correctly calculated the energy change, moles of RbC/O_3 and enthalpy change of solution. However, there were pitfalls for many including the following:



					<ul style="list-style-type: none"> calculating the energy change using the mass of water rather than the mass of the solution. This was despite the supplied information that the specific heat capacity of the solution is the same as for water. Candidates should understand that m in $mc\Delta T$ is the mass of the substance that produces ΔT calculating an incorrect value for the molar mass of RbC/O_3. Instead of 169, this was often seen as 120.5 (using the atomic number of 37 for Rb, rather than the mass number of 85.5) and 185 (for RbC/O_4) using values of m at the wrong stages in the calculation. e.g. 2 g with the energy change and 102 g or 100 g with the moles calculation calculating the correct numerical value for the enthalpy change of solution, but then placing a '-' sign in front of the value, despite ΔT being for a decrease in temperature. <p>Finally, as with all multi-step calculations, candidates are advised to use calculator values throughout. Any intermediate rounding introduces rounding errors in the final value. The final value can be rounded either to the significant figures demanded by the question or to the lowest number of significant figures used in the provided data.</p>
			Total	4	
66		i	Ca loses 2 electrons AND Oxidised✓ H gains 1 electron (per atom) AND Reduced✓	2	ALLOW H gains an electron OR gains electrons OR gains 2 electrons ALLOW 1 mark for Ca is oxidised AND H is reduced



				<p>ALLOW 1 mark for Ca loses electron(s) AND H gains electron(s)</p> <p>IGNORE oxidation numbers even if incorrect</p> <p><u>Examiner's Comments</u></p> <p>Explaining redox reactions is a common question in exam papers, however here candidates needed to do it 'in terms of electron transfer'. Subsequently, many lost a mark as they identified oxidation and reduction in terms of oxidation numbers only. However, many gave responses both in terms of oxidation numbers and electrons.</p> <p>It was necessary to be specific here and say Ca had lost 2 electrons, so a few lost the mark by only referring to 'Ca losing electrons'. Some lost marks for only describing oxidation of Ca and not reduction of H.</p> <p>There was some evidence that candidates were not sure of Cl's role in the reaction (i.e. as a spectator ion) with some stating it was reduced and/or accepted electrons from Ca but then gave them to H.</p>
		ii	<p>$n(\text{HCl}) = 0.012 \text{ (mol)} \checkmark$</p> <p>$n(\text{Ca})$ required to react with HCl = 0.006 (mol)</p> <p>OR</p> <p>0.0100 mol Ca would need 0.02 mol HCl to completely react \checkmark</p> <p>Ca reacts with water \checkmark</p>	<p>3</p> <p>Second mark must show recognition of the 2:1 ratio e.g. ALLOW ratio is 1:2 but here only 1:1.2 so Ca is in excess</p> <p><u>Examiner's Comments</u></p> <p>Most candidates correctly calculated the amount of HCl as 0.012 mol. However, many struggled with demonstrating that Ca is in excess. Responses often highlighted misconceptions here in terms of candidates' understanding about excess and limiting reagents. For example, 'Ca has a lower</p>

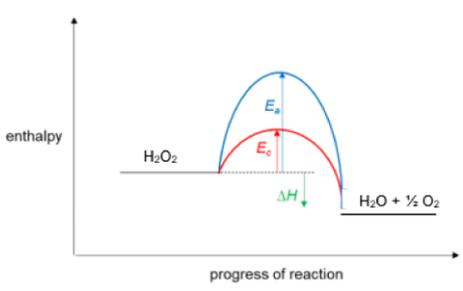


				<p>concentration than HCl so becomes the limiting reagent' and 'Not all the HCl had reacted'</p> <p>Many compared moles of HCl calculated (i.e. 0.012) directly to moles of Ca (i.e. 0.01) saying that HCl was in excess, despite being told otherwise in the question. Some had the 2:1 ratio of HCl to Ca the wrong way around. Some attempted to calculate mass of Ca and HCl to use for comparison.</p> <p>Only a small proportion of candidates were able to access the third mark and correctly suggest that Ca was also reacting with water. Some other suggestions that were seen included:</p> <ul style="list-style-type: none">• 'Ca reacted with oxygen or was impure'. In both cases this would mean that we would expect solid to remain• 'Higher concentration of HCl added', or 'HCl is a strong acid', or 'acid acts as a catalyst'.• 'H₂ evolved' or 'Ca reacts with hydrogen formed'.• 'Human error', 'didn't weigh Ca correctly', 'measured volume of HCl incorrectly'. <p> Misconception</p> <p>Candidates often struggle to understand the concepts around limiting reagents and those in excess. Using a simple baking analogy can help to relate this to everyday life.</p> <p>For example:</p> <p>To make 10 pancakes you need 100 g flour, 2 eggs and 300 ml milk</p>
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					How many pancakes can I make if I have only 50 g flour, 2 eggs and 300 ml milk? Which is the limiting ingredient and which are in excess? The number of pancakes we can make is the theoretical yield.
			Total	5	
67			D	1	<p><u>Examiner's Comments</u></p> <p>The correct answer was D. This proved a more challenging question. Successful candidates often presented oxidation numbers above the equations to identify the element that was simultaneously oxidised and reduced. Most candidates recognised that A and B could be ruled out, with C being the most common error.</p>
			Total	1	
68	a	i	<p>FIRST CHECK ANSWER ON ANSWER LINE If answer = -117 kJ mol^{-1}, award 4 marks.</p> <p>----- -----</p> $\Delta H = -286 - (-188)$ $= -98 \text{ kJ mol}^{-1} \checkmark$ $\Delta S = 70 + \frac{1}{2}(205) - 110 = 62.5 \text{ (J K}^{-1} \text{ mol}^{-1})$ $\text{or } 0.0625 \text{ (kJ K}^{-1} \text{ mol}^{-1}) \checkmark$ $\Delta G = \Delta H - T\Delta S$ $= -98 - (298 \times 0.0625) \checkmark$ $\Delta G = -117 \text{ kJ mol}^{-1} \text{ (3SF)} \checkmark$	4	<p>ALLOW ECF throughout</p> <p>ALLOW $-98000 - (298 \times 62.5)$</p> <p>Common Errors for ΔG 3 marks -18700 (ΔS not converted to kJ) -493 ($\Delta H = -286 + (-188) = -474$) -147 ($\Delta S = 165$: not halving 205) -99.6 (T not converted to K) -18.7 (ΔH not converted J but ΔS J $\text{K}^{-1} \text{ mol}^{-1}$) $(+79.4$ ($-188 - (-286) = +98$)</p> <p>2 marks $(+117$ (incorrect signs for ΔH and ΔS)</p> <p>Final Answer MUST BE 3 SF</p> <p><u>Examiner's Comments</u></p> <p>Almost all candidates had a good attempt at this calculation, with many gaining full marks. Most were able to calculate the entropy change. Almost</p>



					<p>all could reproduce the equation for free energy. Of those who did not get the correct final answer, the most common error was not converting the entropy value into kJ and / or the temperature to K. There were a few candidates who did not manipulate the equation correctly. A few candidates incorrectly calculated ΔS, obtaining the value of $165 \text{ J K}^{-1} \text{ mol}^{-1}$ or ΔH, obtaining -474 kJ mol^{-1}. Candidates were given ECF in these cases.</p>
	ii	(Rate of reaction) slow OR Activation energy high ✓	1	<p>ALLOW ΔG takes no account of rate of reaction</p> <p>ALLOW molecules do not have sufficient energy to equal or exceed the activation energy.</p> <p>IGNORE molecules do not have sufficient energy to react.</p> <p>DO NOT ALLOW there is not enough activation energy</p> <p>Examiner's Comments</p> <p>Lots of good answers from candidates were seen for this question. A few candidates attempted the explanation via a $\Delta G / \Delta S$ argument and misinterpreted the comment within the question.</p>	
b	i	 <p>H_2O_2 on LHS AND $\text{H}_2\text{O} + \frac{1}{2} \text{O}_2$ on RHS AND ΔH labelled with product line below reactant line</p>	3	<p>Care enthalpy profile must match ΔH sign in 16 a) i) – check calculation</p> <p>ALLOW endothermic profile as ECF from $+\Delta H$ calculated in 16 a) i) for all three marks</p> <p>State symbols not required</p> <p>ΔH DO NOT ALLOW $-\Delta H$</p> <p>DO NOT ALLOW double headed arrow on ΔH</p>	



		<p>AND Arrow downwards ✓</p> <p>E_a correctly labelled ✓</p> <p>E_c <u>correctly labelled</u> with $E_c < E_a$ ✓</p>	<p>ALLOW ΔH arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line.</p> <p>E_a and E_c ALLOW no arrowhead or arrowheads at both end of E_a or E_c lines E_a or E_c lines must reach maximum (or near to maximum) on curve</p> <p>ALLOW overlapping lines OR lines on side reaching maximum</p> <p>For E_a, ALLOW AE OR A_E OR E_{act} OR suitable alternatives</p> <p>ALLOW ECF marks for E_a and E_c for correctly labelled endothermic diagram from a $-\Delta H$ value (from 16 a i))</p> <p><u>Examiner's Comments</u></p> <p>This question proved more difficult for candidates with lots of inaccuracies. The profile was dependent on the calculation for ΔH in Question 16 (a) (i). The arrowhead for ΔH needs to be pointing from the reactants to the products. The activation energies, again, need to start at the reactant line and go to the maximum level of the curve. Those that needed to draw an endothermic profile were far more likely to make an error with the E_a and E_c arrows, often starting from the product line or even from the base line of the graph. A significant number of candidates did not add arrows and instead labelled the curves E_a and E_c. Some candidates drew a Boltzmann distribution curve scoring 0 marks.</p> <p>Exemplar 1</p>
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					<p>The candidate has the correct exothermic profile but has the incorrect starting point for the activation energy going from the product line.</p>
	ii	<p>(MnO₂) is in different phase/state (to the reactant / H₂O₂)</p> <p>OR</p> <p>catalyst is a <u>solid</u> AND reactant is <u>liquid</u> ✓</p>	1	<p>ASSUME 'it' is MnO₂</p> <p>ALLOW 'species in the reaction'</p> <p>IGNORE references to products</p> <p>Examiner's Comments</p> <p>This was a well answered question. A few candidates, incorrectly, suggested that it was heterogeneous due to the reactants and products being in different states, and did not mention the catalyst.</p>	
	iii	<p>Mn is +2 AND +3</p> <p>OR</p> <p>Mn is +1 AND +6 ✓</p>	1	<p>+ required</p> <p>ALLOW 2+ and 3+</p> <p>DO NOT ALLOW Mn²⁺ Mn³⁺</p> <p>DO NOT ALLOW + 4 (this is the oxidation state in MnO₂)</p> <p>Examiner's Comments</p> <p>This question proved more challenging for candidates. Candidates stating +4 was the most common error; this is the oxidation state in MnO₂. Some candidates stated fractions, negative values and gave the state symbol instead i.e. solid and liquid.</p>	
		Total	10		
69		A	1		

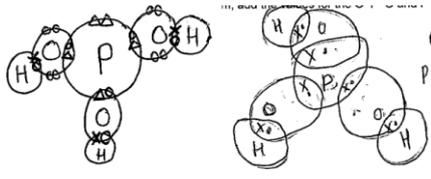


					<p>Examiner's Comments</p> <p>About half of the candidates chose A correctly. Most candidates wrote oxidation numbers below the chlorine in the equations, which is good practice, with C proving to be the main distractor. Note also the point made in Question 6 about underlining the word 'not'.</p>
			Total	1	
70	i	iron(III) oxide ✓		1	<p>IGNORE iron(3) oxide, iron(III) dioxide, etc i.e. MUST be systematic</p> <p>ALLOW no brackets</p> <p>Examiner's Comments</p> <p>This question required candidates to work out a systematic name from a formula. Transition elements can have different oxidation numbers in their compounds and the systematic name needs to contain a Roman numeral. Approximately half the candidates were able to write the correct name as iron(III) oxide. An array of incorrect names were seen, commonly iron(II) oxide, presumably from the number of iron atoms in Fe₂O₃.</p> <p> Misconception</p> <p>A systematic name may contain the oxidation number, not the number of atoms in the formula. So Fe₂O₃ is iron(III) oxide and not iron(II) oxide.</p>
	ii	Fe ₂ O ₃ + 3 CO → 2 Fe + 3 CO ₂ ✓		1	<p>ALLOW multiples e.g. 2 Fe₂O₃ + 6 CO → 4 Fe + 6 CO₂</p> <p>ALLOW 1 Fe₂O₃ but NOT 0 Fe₂O₃</p> <p>Examiner's Comments</p>



					Most candidates were able to balance this straightforward equation.
			Total	2	
71	a	i	<p>In (Equilibrium) 1,</p> <p>H_2PO_4^-/It acts as a base AND accepts/gains H^+/a proton OR H_2PO_4^- forms H_3PO_4 ✓</p> <p>In (Equilibrium) 2,</p> <p>H_2PO_4^-/It acts as an acid, AND donates/loses H^+/a proton OR H_2PO_4^- forms HPO_4^{2-} ✓</p>	2	<p>ALLOW description for 1 or 2 as long as unambiguous, e.g. Equation 1, etc</p> <p>IGNORE missing charge on H_2PO_4^- throughout</p> <p>IGNORE reference to $\text{H}_2\text{PO}_4^{2-}$ acting as an acid/base OR Equilibrium 3 <i>Question is about H_2PO_4^-</i></p> <p>ALLOW 'dissociates into H^+ and $\text{H}_2\text{PO}_4^{2-}$' IGNORE 'partially'</p> <p><u>Examiner's Comments</u></p> <p>Candidates were expected to link proton-transfer behaviour in acids and bases to the provided equilibria. The question differentiated between candidates well.</p> <p>Some candidates just stated that an acid is a proton donor and a base a proton acceptor without referring to the provided equilibria. This was the answer to a much simpler question and could not be given marks.</p> <p>The best responses demonstrated excellent understanding within the context of the equilibria. Such candidates clearly explained how H_2PO_4^- behaves as an acid in the forward reaction of Equilibrium 2 and as a base in the reverse reaction of Equilibrium 1.</p>
		ii	<p>Diagram showing all bonds correctly ✓</p>	3	<p>IGNORE geometry</p> <p>ALLOW dot and cross diagram showing 2 shared electrons for each bond and IGNORE any lone pairs e.g.</p>



		<ul style="list-style-type: none"> • 3 bonds only around each P • 2 bonds only around each O • Each O bonded to an H <p>Bond angles</p> <p>O-P-O = 107° ✓ P-O-H = 104.5° ✓</p>		 <p>Unambiguous bond angles may be shown on dot and cross diagram</p> <p>ALLOW 106-108°</p> <p>ALLOW 104-105°</p> <p><u>Examiner's Comments</u></p> <p>Most candidates used the information in the question to draw a correct displayed formula of H₃PO₃. Another acceptable approach was to show a 'dot-and-cross' diagram.</p> <p>Candidates usually chose 104.5° for the P-O-H bond angles although a significant number suggested 180°. The O-P-O bond angle proved to be more difficult. Many suggested 120° by ignoring the lone pair of electrons on the P atom. The shape was analogous with NH₃ giving a bond angle of 107°.</p> <p>Overall, candidates answered this question well. Candidates are advised to assess the number of bonded pairs and lone pairs around each atom when suggesting bond angles. This would have reduced the number of incorrect bond angles such as 180° for P-O-H and 120° for O-P-O.</p>
	iii	<p>phosphoric(III) acid ✓ Oxidation number MUST be in correct place</p>	1	<p>DO NOT ALLOW phosphoric acid (III)</p> <p>DO NOT ALLOW phosphorous acid</p> <p><u>Examiner's Comments</u></p> <p>Most candidates wrote the correct systematic name of phosphorus(III)</p>



				<p>acid and the clue given in the question for the name of H_3PO_4 should have helped.</p> <p>Common errors included phosphorus(IV) acid, the same as for H_3PO_4, and the (III) oxidation number being placed after 'acid' in the name. The commonest error though, was hydrogen phosphate.</p> <p>Candidates are advised to use any information provided in the question, which often contains clues. This certainly would have prevented hydrogen phosphate as a response.</p>
b	i	$4\text{PH}_3 + 8\text{O}_2 \rightarrow \text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \checkmark$	1	<p>ALLOW multiples</p> <p>ALLOW $2\text{PH}_3 + 4\text{O}_2 \rightarrow \text{P}_2\text{O}_5 + 3\text{H}_2\text{O}$</p> <p>IGNORE state symbols, even if wrong</p> <p><u>Examiner's Comments</u></p> <p>Candidates found this question quite challenging, with only about one-third writing a correct equation. The question gave the reactants and products with only the formula of phosphorus(V) oxide having to be worked out.</p> <p>The actual reaction does produce P_4O_{10} but P_2O_5 was shown in almost all equations, and this was acceptable.</p> <p>Various incorrect formulae were seen for phosphorus(V) oxide including PO, PO_2, P_5O, HPO, etc. Unfortunately a significant number of candidates could not balance the equation, despite using correct formulae.</p>
	ii	$6\text{AgNO}_3 + (1)\text{PH}_3 + 3\text{H}_2\text{O} \rightarrow 6\text{Ag} + (1)\text{H}_3\text{PO}_3 + 6\text{HNO}_3 \checkmark$ <p>Ag is reduced from +1 to 0 \checkmark</p>	3	<p>ALLOW equation with '1' omitted, i.e. $6\text{AgNO}_3 + \text{PH}_3 + 3\text{H}_2\text{O} \rightarrow 6\text{Ag} + \text{H}_3\text{PO}_3 + 6\text{HNO}_3 \checkmark$</p> <p>BUT DO NOT ALLOW '0'</p> <p>ALLOW 1 mark for BOTH correct</p>



		<p>P is oxidised from -3 to +3 ✓</p> <p>IGNORE oxidation numbers written around equation <i>Treat as rough working</i></p> <p>IGNORE reference to electrons <i>Question states oxidation numbers</i></p>	<p>oxidation number changes with 'reduced' and 'oxidised' omitted</p> <p>OR 'oxidised and reduced the wrong way round</p> <p>+ signs required for +1 and +3</p> <p>For oxidation numbers, ALLOW 1+, 3- and 3+</p> <p><u>Examiner's Comments</u></p> <p>This question generated a wide range of responses, testing many important chemical skills.</p> <p>Candidates often used oxidation numbers correctly to show that silver is reduced and phosphorus oxidised, with silver being the easier. Hydrogen was sometimes incorrectly chosen for oxidation.</p> <p>The oxidation number change of +1 to 0 for silver was usually correct although +9 and +11 were common errors for silver in AgNO_3, presumably by choosing the oxidation number of nitrogen as -3 or -5.</p> <p>Candidates usually recognised that phosphorus started with an oxidation number of -3 but the oxidation number of +5 was a common error in H_3PO_3.</p> <p>Balancing the equation was the most difficult part of this question with numbers being added almost at random. It is easier to balance equations for redox reactions by balancing the oxidation number changes first.</p> <p> Assessment for learning</p>
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				<p>Ag⁺ and NO₃⁻ are among the common ions that students should know (see also Question 4 (c) (i)).</p> <p>For a NO₃⁻ ion to have a charge of 1-, the oxidation number of nitrogen must be +5. By choosing -5, the charge on NO₃ would be -11 and silver would have an oxidation number of +11. This is completely unrealistic and should be rejected as it points to a serious error.</p> <p>The specification states the following: <i>2.1.5 (a) rules for assigning and calculating oxidation number for atoms in elements, compounds and ions.</i></p> <p>This section will have been studied at the start of the two-year course and forms part of the backbone of chemical literacy.</p> <p>For success in chemistry, the ions should be learnt and the rules for assigning oxidation numbers need to be mastered.</p>
			Total	10