

OCR A-Level Chemistry A

Module 2: Foundations in chemistry

Questions only

All 106 questions in Module 2: Foundations in chemistry

Questions

106

Total marks

426

Name

Class or teacher

Date

Instructions

- Answer all questions in the spaces provided.
- Use black ink. Show your working for every calculation.
- You may use a scientific calculator and the OCR Data Sheet.
- Print the separate mark scheme when you are ready to mark your answers.

For marking

Total _____ / 426 Percentage _____ %

Questions from OCR past papers, 2017–2025, reproduced for revision. Practise these topics online, with instant marking:

whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/?topics=acids-and-redox,amount-of-substance,atoms-and-isotopes,electrons-bonding-and-structure&len=0

Questions

Acids and redox reactions, Amount of substance, Atomic structure and isotopes and Electrons, bonding and structure · 106 questions · 426 marks

Q1 · Acids and redox reactions · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q3 · [1 mark]

What is the oxidation number of Mn in K_2MnO_4 ?

Tick (✓) one box.

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

Q2 · Acids and redox reactions · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q4 · [1 mark]

Which calcium compound contains the greatest percentage by mass of calcium?

Tick (✓) one box.

- ☐ **A** calcium carbonate
- ☐ **B** calcium nitrate
- ☐ **C** calcium hydroxide
- ☐ **D** calcium sulfate
-

Q3 · Acids and redox reactions · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q2 · [1 mark]

In the compound $[ICl_2]^+ [SbCl_6]^-$, the oxidation number of chlorine is -1 .

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

Tick (✓) one box.

- ☐ **A** I: +1 · Sb: +5
- ☐ **B** I: +1 · Sb: +7
- ☐ **C** I: +3 · Sb: +5
- ☐ **D** I: +3 · Sb: +7
-

Q4 · Acids and redox reactions · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q4 · [1

mark]

This question also needs Acids, bases and buffers.

A student titrates a standard solution of barium hydroxide, Ba(OH)_2 , with nitric acid, HNO_3 .

25.00 cm^3 of $0.0450 \text{ mol dm}^{-3}$ Ba(OH)_2 are needed to neutralise 23.35 cm^3 of $\text{HNO}_3(\text{aq})$.

What is the concentration, in mol dm^{-3} , of the nitric acid?

Tick (✓) one box.

- ☐ **A** 0.0241
- ☐ **B** 0.0482
- ☐ **C** 0.0900
- ☐ **D** 0.0964

Q5 · Acids and redox reactions · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q7 · [1 mark]

Which statement about ammonium carbonate is not correct?

Tick (✓) one box.

- ☐ **A** It reacts with $\text{Ba(NO}_3)_2(\text{aq})$ to form a white precipitate.
- ☐ **B** It effervesces with dilute nitric acid.
- ☐ **C** It release an alkaline gas with warm $\text{NaOH}(\text{aq})$.
- ☐ **D** It has the formula NH_4CO_3 .

Q6 · Acids and redox reactions · June 2019 · Paper 1 (Periodic table, elements and physical chemistry) · Q5 · [1 mark]

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

Tick (✓) one box.

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

Q7 · Acids and redox reactions · June 2019 · Paper 1 (Periodic table, elements and physical chemistry) · Q6 · [1

mark]

Which reaction is a redox reaction?

Tick (✓) one box.

- ☐ **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** $3\text{CuO} + 2\text{NH}_3 \rightarrow 3\text{Cu} + 3\text{H}_2\text{O} + \text{N}_2$

Q8 · Acids and redox reactions · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q17 · [11 marks]

This question also needs Amines, amino acids and polymers and Chromatography and functional group tests.

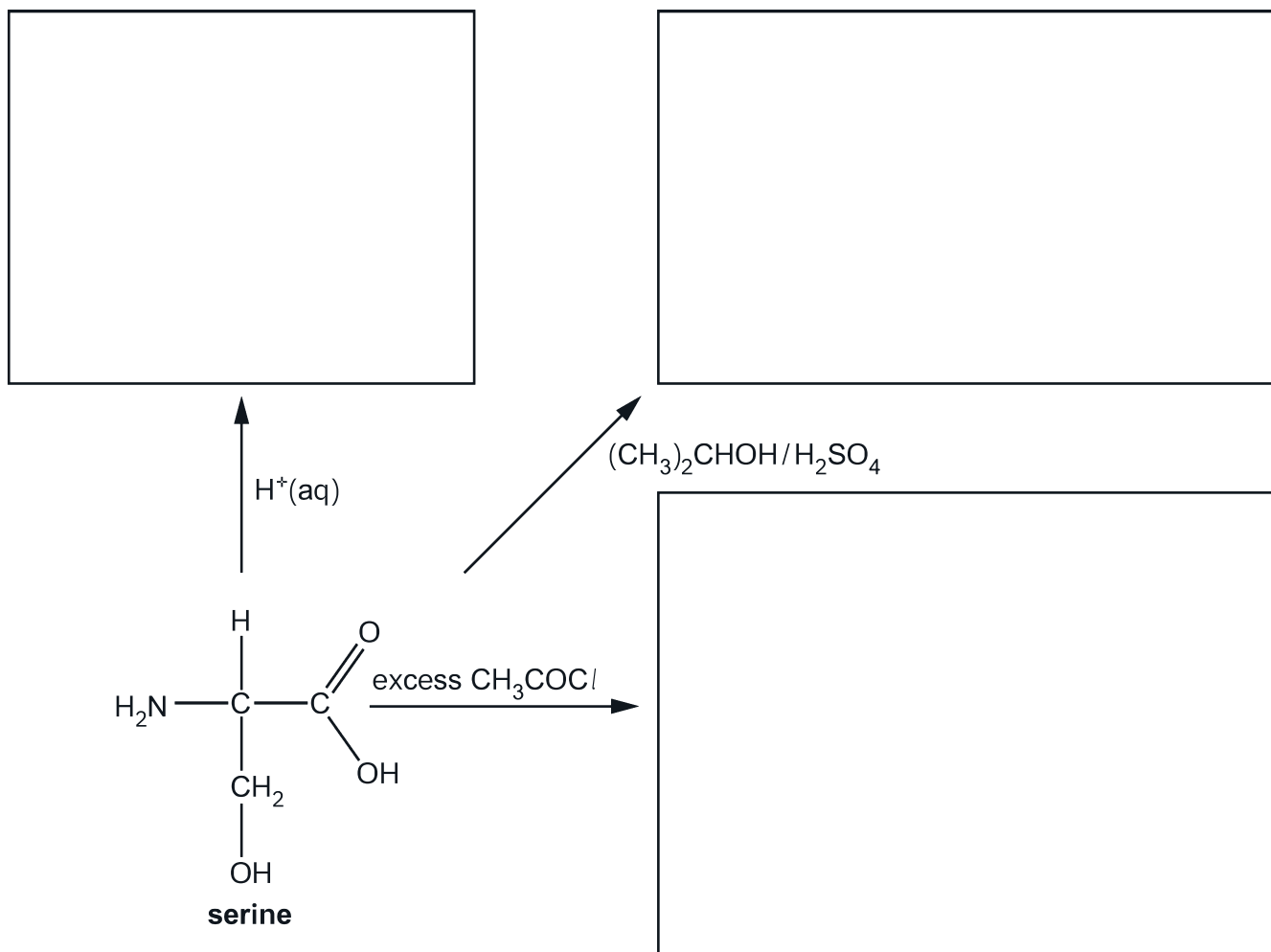
This question is about α -amino acids, $\text{RCH}(\text{NH}_2)\text{COOH}$.

Table 17.1 shows the R groups in four amino acids.

Amino acid	R group
alanine (ala)	CH_3-
serine (ser)	HOCH_2-
leucine (leu)	$(\text{CH}_3)_2\text{CHCH}_2-$
glycine (gly)	$\text{H}-$

Table 17.1

17(a)(i) In the boxes, draw the organic products for the reactions of serine shown below.



[4 marks]

Draw your answer on the figure above.

17(a)(ii) A student is provided with one of the four amino acids in Table 17.1.

A student carries out a titration with a standard solution of hydrochloric acid to identify the amino acid. The student's method is outlined below.

- The student dissolves 5.766 g of the amino acid in water and makes the solution up to 250.0 cm³ in a volumetric flask.
- The student titrates this solution with 25.0 cm³ of 0.150 mol dm⁻³ hydrochloric acid.
- 21.30 cm³ of the amino acid solution were required for complete neutralisation of the hydrochloric acid.

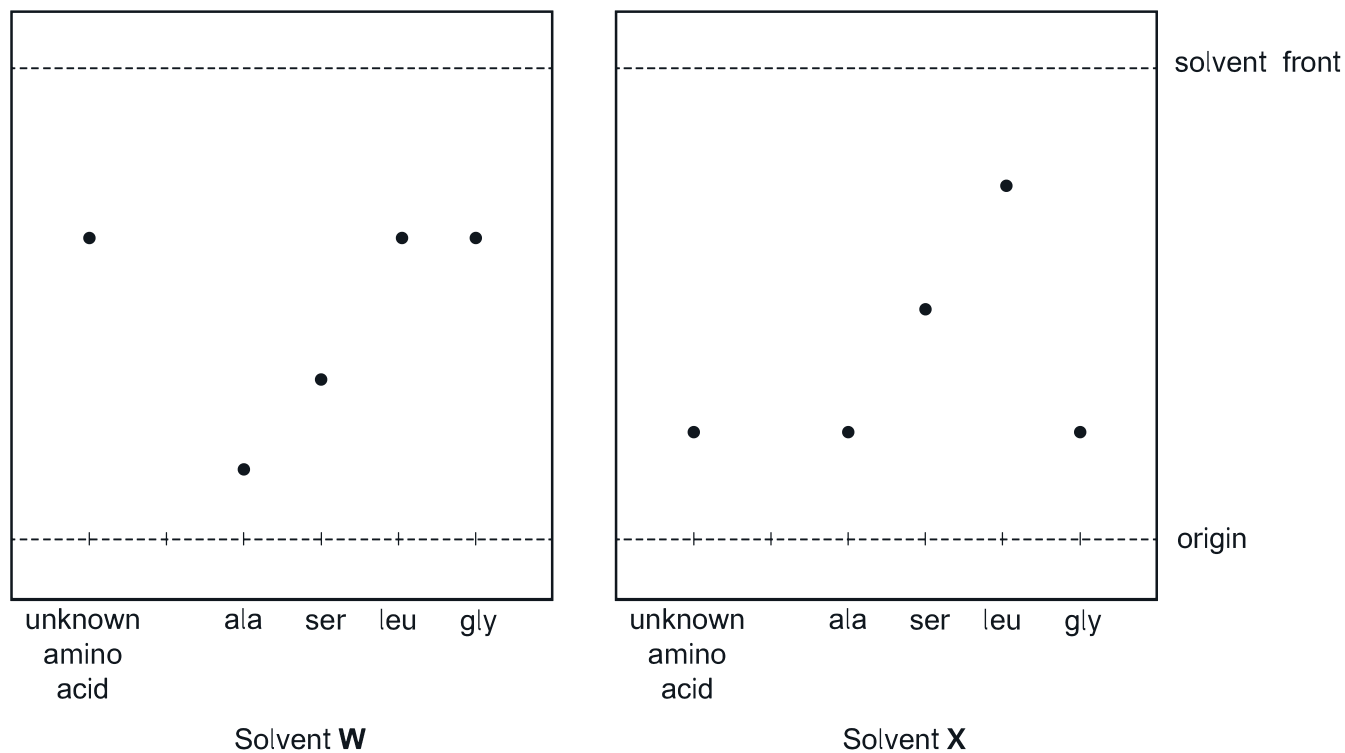
Determine which amino acid the student used.

[4 marks]

The student is provided with another amino acid.

The student attempts to identify the unknown amino acid using chromatography.

The student obtains two TLC chromatograms of the unknown amino acid and the four amino acids in Table 17.1, using two different solvents, W and X.



17(b)(i) What is the R_f value of serine (ser) in solvent W?

$R_f =$

[1 mark]

17(b)(ii) Analyse the chromatograms to identify the unknown amino acid.

Explain your reasoning.

[2 marks]

Name of unknown amino acid

Explanation

Q9 · Acids and redox reactions · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q6 · [1 mark]

Prussian blue, $\text{C}_{18}\text{Fe}_7\text{N}_{18}$, is a deep blue pigment containing Fe^{2+} , Fe^{3+} and CN^- ions.

What are the numbers of Fe^{2+} and Fe^{3+} ions in one formula unit of $\text{C}_{18}\text{Fe}_7\text{N}_{18}$?

Tick (✓) one box.

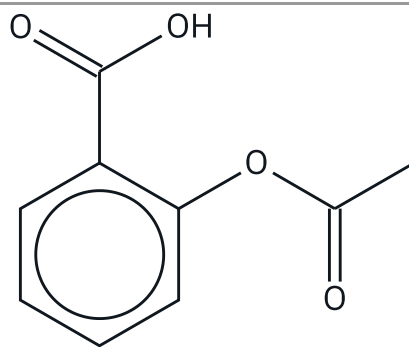
- ☐ **A** 2 Fe^{2+} and 5 Fe^{3+}
- ☐ **B** 3 Fe^{2+} and 4 Fe^{3+}
- ☐ **C** 4 Fe^{2+} and 3 Fe^{3+}
- ☐ **D** 5 Fe^{2+} and 2 Fe^{3+}
-

Q10 · Acids and redox reactions · June 2023 · Paper 3 (Unified chemistry) · Q5 · [11 marks]

This question also needs Organic synthesis, IR and mass spectra.

Aspirin tablets are used for pain relief.

The structure of aspirin is shown below.

**Aspirin**

5(a) A student uses the reaction of aspirin with cold NaOH(aq) to determine the mass of aspirin in **one** tablet.

In this reaction, 1 mol of aspirin reacts with 1 mol of cold NaOH(aq).

The student's method is outlined below.

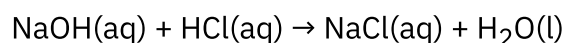
Step 1 The student reacts **three** aspirin tablets with 100 cm³ of 0.500 mol dm⁻³ NaOH(aq).

The NaOH is in excess. A colourless solution forms.

Step 2 The colourless solution from Step 1 is made up to 250.0 cm³ with distilled water.

Step 3 A 25.00 cm³ sample of the diluted solution from Step 2 is titrated with 0.200 mol dm⁻³ HCl(aq) in the burette.

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



The student repeats the titration to obtain concordant (consistent) titres.

Titration results

The trial titre has been omitted.

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

	1	2	3
Final reading / cm ³	23.10	45.40	27.40
Initial reading / cm ³	0.00	23.10	5.00

Analysis of results

From the results, the student can determine the following.

1. The amount, in mol, of excess NaOH(aq) that remains after the reaction of aspirin with NaOH(aq) .
2. The amount, in mol, of NaOH(aq) that reacted with the aspirin.

Use the results to determine the mass, in mg, of aspirin in **one** aspirin tablet.

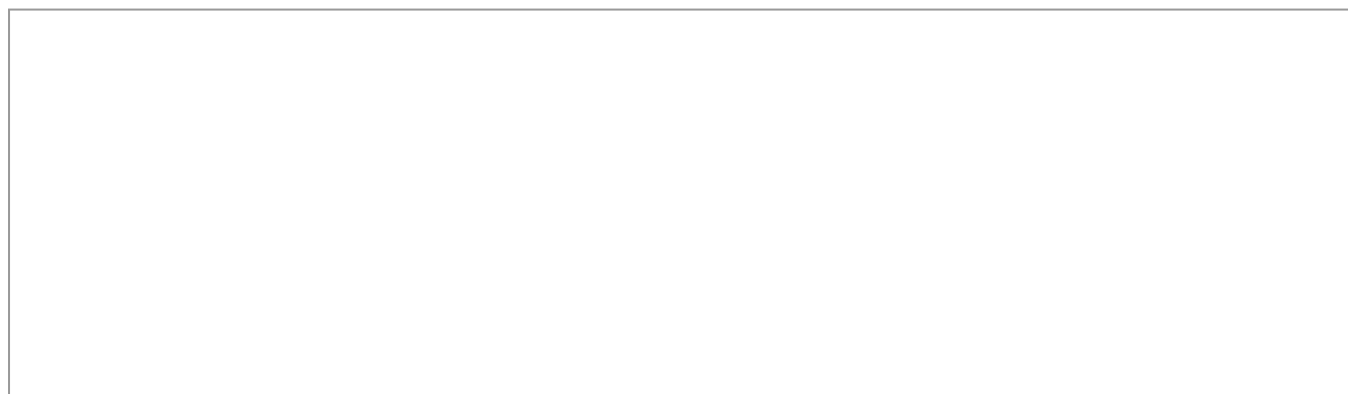
mass of aspirin in **one** tablet = mg

[6 marks]

Aspirin reacts with hot NaOH(aq) , under reflux.

5(b)(i) Draw a labelled diagram of suitable apparatus for reflux.

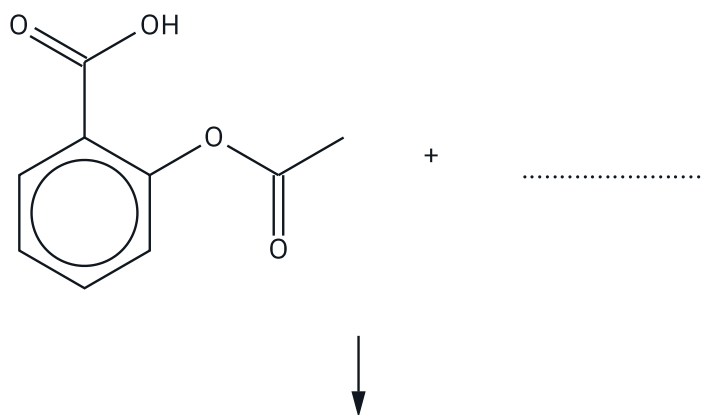
[2 marks]



5(b)(ii) In this reaction, 1 mol of aspirin reacts with 3 mol of hot NaOH(aq).

Complete the equation for the reaction of aspirin with an excess of hot NaOH(aq).

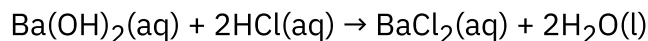
Show structures for organic compounds.



[3 marks]

Q11 · Acids and redox reactions · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q4 · [1 mark]

What volume, in cm^3 , of $0.250 \text{ mol dm}^{-3}$ barium hydroxide solution is required to exactly neutralise 25.0 cm^3 of $0.115 \text{ mol dm}^{-3}$ hydrochloric acid?



Tick (✓) one box.

- ☐ **A** 5.75
- ☐ **B** 11.50
- ☐ **C** 23.00
- ☐ **D** 54.35

Q12 · Acids and redox reactions · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q8 · [1 mark]

The burette readings from an experiment are shown:

Final reading / cm^3	29.35
Initial reading / cm^3	2.60

The burette has an uncertainty of $\pm 0.05 \text{ cm}^3$.

What is the percentage uncertainty of the titre?

Tick (✓) one box.

- ☐ **A** 0.17%
- ☐ **B** 0.19%
- ☐ **C** 0.34%
- ☐ **D** 0.37%

Q13 · Acids and redox reactions · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q1 · [1 mark]

Several students titrate 25.00 cm^3 of the same solution of sodium hydroxide, NaOH(aq) with hydrochloric acid, HCl(aq) .

One student obtains a smaller titre than the other students.

Which procedure explains the smaller titre?

Tick (✓) one box.

- ☐ **A** The burette readings are taken from the top of the meniscus instead of the bottom of the meniscus.
- ☐ **B** The conical flask is rinsed with water before carrying out the titration.
- ☐ **C** An air bubble is released from the jet of the burette during the titration.
- ☐ **D** The pipette is rinsed with water before filling with NaOH(aq) .

Q14 · Acids and redox reactions · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q18 · [12 marks]

This question also needs Acids, bases and buffers and Redox and electrode potentials.

A student carries out an experiment to determine the percentage by mass of copper in an ore containing copper in its +2 oxidation state.

The student is provided with a sample of the copper ore, 1 mol dm^{-3} potassium iodide, KI(aq) , and $0.0200 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

The student's method is outlined below.

Step 1 Add an excess of warm nitric acid to 2.50 g of the ore.

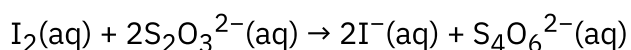
The copper(II) compounds in the ore react, forming aqueous copper(II) nitrate.

Step 2 Filter the mixture to remove the unreacted rock. Neutralise the filtrate.

Step 3 Add an excess of aqueous potassium iodide, KI(aq) .

A precipitate of copper(I) iodide and a solution of iodine, $\text{I}_2(\text{aq})$, forms.

Step 4 Titrate the mixture from Step 3 using $0.0200 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$ in the burette.



26.55 cm³ of 0.0200 mol dm⁻³ Na₂S₂O₃ are required to reach the end point.

18(a) In Step 1, the student observed that bubbles of gas were produced.

Suggest the formula of the copper(II) compound which reacted with HNO₃ to form the gas, and write a full equation for the reaction.

Formula:

Equation:

[2 marks]

18(b) Write an ionic equation, including state symbols, for the reaction in Step 3.

[1 mark]

18(c) Suggest a suitable indicator for this titration and state the colour change at the end point in Step 4.

Indicator:

Colour from to

[1 mark]

18(d) Determine the percentage, by mass, of copper in the copper ore.

Give your answer to an appropriate number of significant figures.

percentage = %

[4 marks]

Explain whether the calculated percentage by mass of copper would be higher, lower or the same if the following changes were made to the method.

18(e)(i) The potassium iodide was not in excess, in Step 3.

[1 mark]

18(e)(ii) The burette readings were read from the top of the meniscus, in Step 4.

[1 mark]

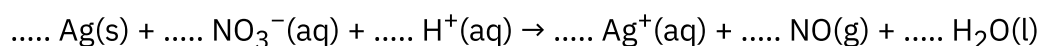
18(f) The student then modifies the method in order to obtain a more accurate value for the percentage by mass of copper in the ore. The student decides to use 25.00 g of the copper ore in Step 1.

What further modifications should the student make to produce a more accurate value for the percentage by mass of copper in the ore?

[2 marks]

Q15 · Acids and redox reactions · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q3 · [1 mark]

The unbalanced equation for the reaction of silver with concentrated nitric acid is shown below.



Which numbers for Ag and H₂O will balance the equation?

Tick (✓) one box.

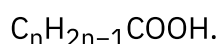
- ☐ **A** Ag(s): 1 · H₂O(l): 2
- ☐ **B** Ag(s): 2 · H₂O(l): 3
- ☐ **C** Ag(s): 3 · H₂O(l): 1
- ☐ **D** Ag(s): 3 · H₂O(l): 2

Q16 · Acids and redox reactions · November 2021 · Paper 3 (Unified chemistry) · Q3 · [12 marks]

This question also needs Acids, bases and buffers, Alkenes and addition polymers, Basic concepts of organic chemistry and Carbonyls, carboxylic acids and esters.

This question is about carboxylic acids.

Compound D is a cis stereoisomer of an unsaturated organic acid with the general formula



A student plans to analyse acid D by carrying out a titration.

3(a) A student first prepares 250.0 cm^3 of a standard solution of $0.150 \text{ mol dm}^{-3} \text{ Ba(OH)}_2$ for the titration.

The student is provided with solid Ba(OH)_2 and usual laboratory apparatus and equipment.

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

[5 marks]

3(b) The student prepares a 100.0 cm^3 solution containing 3.215 g of acid D.

The student titrates 25.0 cm^3 samples of the solution of D with $0.150\text{ mol dm}^{-3}\text{ Ba(OH)}_2(\text{aq})$ in the burette.

1 mol Ba(OH)_2 reacts with 2 mol of D.

The mean titre of $\text{Ba(OH)}_2(\text{aq})$ is 23.50 cm^3 .

Analyse the titration results to determine two possible structures for the cis stereoisomer of organic acid D.

Structures of 2 possible cis stereoisomers of acid D

[7 marks]

Q17 · Amount of substance · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q12 · [1 mark]

HA and HB are two strong monobasic acids.

25.0 cm³ of 6.0 mol dm⁻³ HA is mixed with 45.0 cm³ of 3.0 mol dm⁻³ HB.

What is the H⁺(aq) concentration, in mol dm⁻³, in the resulting solution?

Tick (✓) one box.

☐ **A** 1.9

☐ **B** 2.1

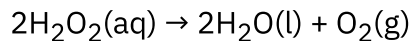
☐ **C** 4.1

☐ **D** 4.5

Q18 · Amount of substance · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q19 · [10 marks]

This question also needs Rate equations and Reaction rates and equilibrium.

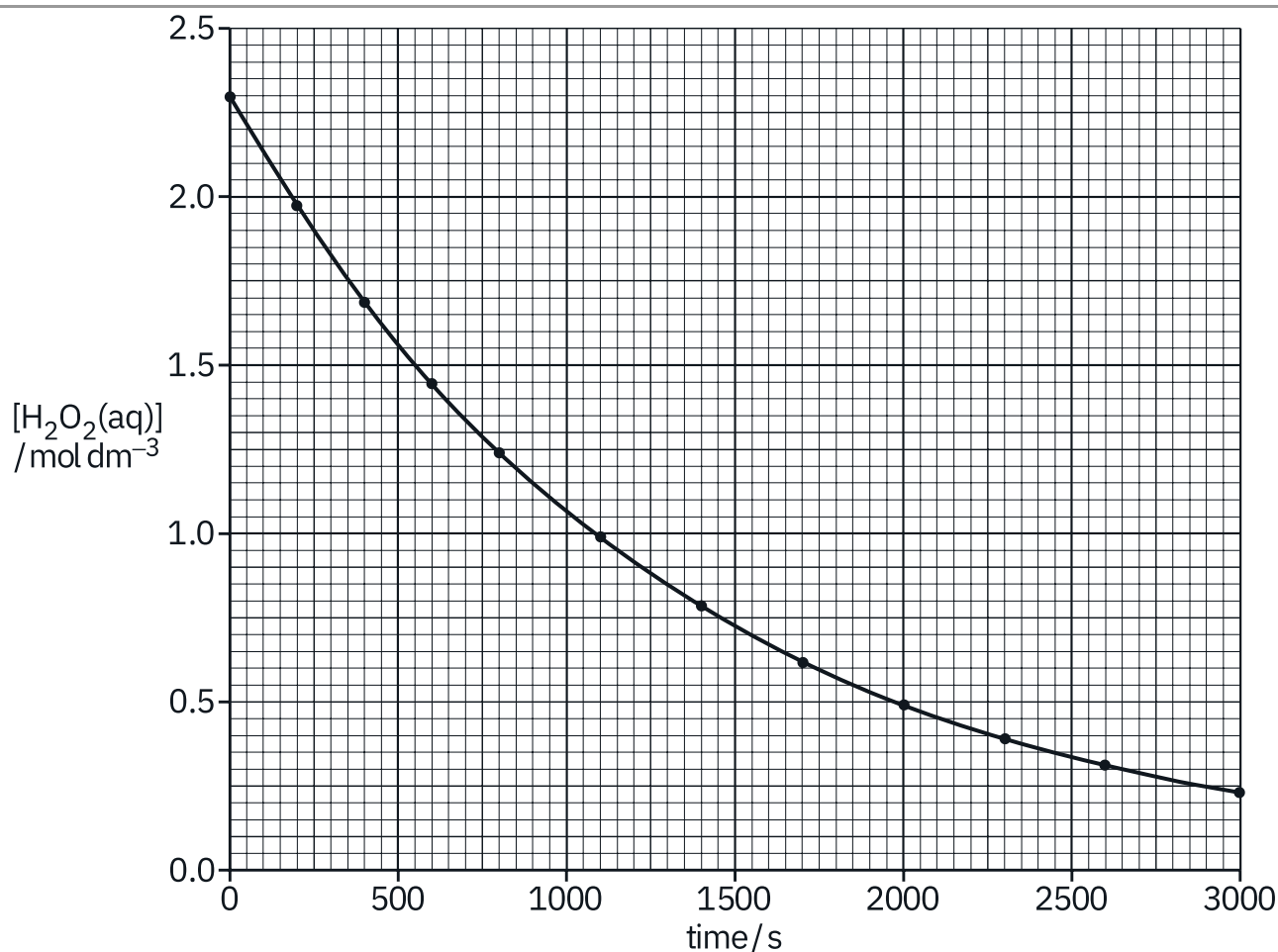
Aqueous solutions of hydrogen peroxide, H₂O₂(aq), decompose as in the equation below.



A student investigates the decomposition of H₂O₂(aq) by measuring the volume of oxygen gas produced over time. All gas volumes are measured at room temperature and pressure.

The student uses 25.0 cm³ of 2.30 mol dm⁻³ H₂O₂.

From the results, the student determines the concentration of H₂O₂(aq) at each time. The student then plots a concentration–time graph.



19(a) Determine the total volume of oxygen, measured at room temperature and pressure, that the student should be prepared to collect in this investigation.

Suggest apparatus that would allow this gas volume to be collected, indicating clearly the scale of working.

[3 marks]

19(b) Suggest a different experimental method that would allow the rate of this reaction to be followed over time.

[1 mark]

19(c) Determine the initial rate of reaction, the order with respect to H_2O_2 , and the rate constant.

Your answer must show full working on the graph and on the lines below.

[6 marks]

Q19 · Amount of substance · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q5 · [1 mark]

0.0200 mol of calcium oxide is reacted completely with 2.00 mol dm^{-3} HCl.

What is the volume, in cm^3 , of 2.00 mol dm^{-3} HCl required for this reaction?

Tick (✓) one box.

- ☐ **A** 15
- ☐ **B** 20
- ☐ **C** 30
- ☐ **D** 60

Q20 · Amount of substance · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q6 · [1

mark]

How many electrons are removed from 2.02×10^{-2} g of Ne(g) atoms to form $\text{Ne}^+(\text{g})$ ions?

Tick (✓) one box.

☐ A 3.36×10^{-26}

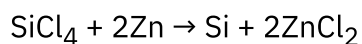
☐ B 1.66×10^{-27}

☐ C 6.02×10^{20}

☐ D 1.22×10^{22}

Q21 · Amount of substance · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q7 · [1 mark]

Silicon can be made by heating silicon tetrachloride, SiCl_4 , with zinc.



8.50 g of SiCl_4 is reacted with an excess of zinc. The percentage yield of silicon is 90%.

What is the mass of silicon made?

Tick (✓) one box.

☐ A 1.26 g

☐ B 1.31 g

☐ C 1.40 g

☐ D 1.55 g

Q22 · Amount of substance · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q12 · [1 mark]

0.1 mol of $\text{HOOCCH}_2\text{COOH}$ are reacted with 0.1 mol of aqueous NaOH.

How many molecules of water are formed?

Tick (✓) one box.

☐ A 6.02×10^{22}

☐ B 3.01×10^{22}

☐ C 6.02×10^{23}

☐ D 3.01×10^{23}

Q23 · Amount of substance · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q3 · [1 mark]

Complete combustion of an organic compound forms 40 cm^3 of carbon dioxide and 40 cm^3 of water vapour, under the same conditions of temperature and pressure.

Which molecular formula could the organic compound have?

Tick (✓) one box.

- ☐ **A** C_3H_8
- ☐ **B** $\text{C}_2\text{H}_2\text{O}$
- ☐ **C** $\text{C}_2\text{H}_4\text{O}$
- ☐ **D** $\text{C}_2\text{H}_3\text{N}$

Q24 · Amount of substance · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q5 · [1 mark]

This question also needs Alcohols and haloalkanes.

Which type of reaction has the greatest atom economy?

Tick (✓) one box.

- ☐ **A** Substitution
- ☐ **B** Hydrolysis
- ☐ **C** Elimination
- ☐ **D** Addition

Q25 · Amount of substance · June 2017 · Paper 3 (Unified chemistry) · Q1 · [11 marks]

Within the permafrost in Arctic regions of the Earth, large amounts of methane are trapped within ice as ‘methane hydrate’, $\text{CH}_4 \cdot x\text{H}_2\text{O}$. Methane makes up about 13.4% of the mass of ‘methane hydrate’.

Scientists are concerned that global warming will melt the permafrost, releasing large quantities of methane into the atmosphere.

1(a) The H–O–H bond angle in ice is about 109° but about 105° in gaseous H_2O .

Explain why there is this difference.

[3 marks]

1(b) Why are scientists concerned about the release of methane into the atmosphere?

[1 mark]

1(c) Determine the formula of 'methane hydrate', $\text{CH}_4 \cdot x\text{H}_2\text{O}$.

In the formula, show the value of x to two decimal places.

formula =

[2 marks]

1(d) Calculate the volume of methane, in dm^3 , that would be released from the melting of each 1.00 kg of 'methane hydrate' at 101 kPa and 0 °C.

Give your answer to three significant figures.

volume = dm^3

[4 marks]

1(e) Suggest why some industries are interested in the presence of 'methane hydrate' in regions of the Earth.

[1 mark]

Q26 · Amount of substance · June 2017 · Paper 3 (Unified chemistry) · Q4 · [19 marks]

This question also needs Acids, bases and buffers, Basic concepts of organic chemistry, Carbonyls, carboxylic acids and esters and 2 other topics.

This question is about weak acids.

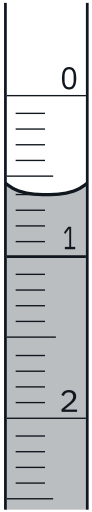
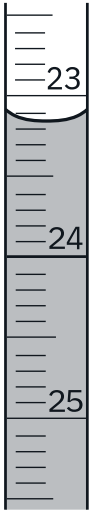
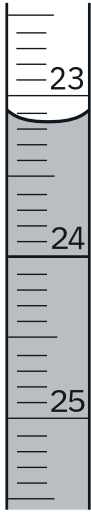
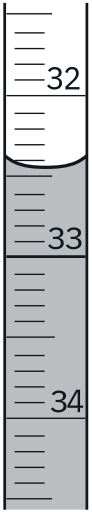
Compound A is a weak monobasic acid.

A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of A.

The student titrates 25.0 cm^3 samples of this solution with $0.0840 \text{ mol dm}^{-3}$ NaOH in the burette.

The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three further titrations.

All burette readings are measured to the nearest 0.05 cm^3 .

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

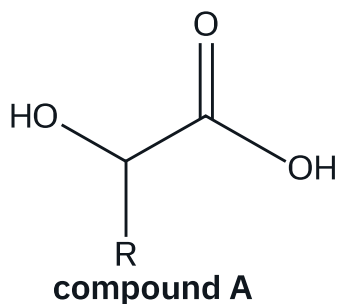
4(a)(i) Record the student's readings and the titres in an appropriate format.

Calculate the mean titre that the student should use for analysing the results.

mean titre = cm³

[4 marks]

4(a)(ii) The structure of compound A is shown below.



Compound A has four optical isomers.

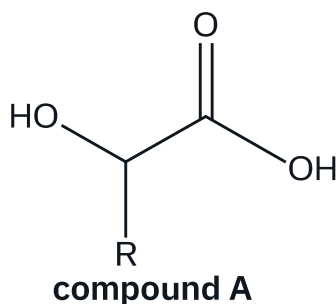
Using this information and the student's results, answer the following.

- Determine the molar mass of A and the formula of the alkyl group R.
- Draw the structure of compound A and label any chiral carbon atoms with an asterisk*.

Show all your working.

[6 marks]

The structural formula of compound A is repeated below.



Two reactions of compound A are carried out.

Suggest an equation for each reaction and state the type of reaction.

In your equations, draw structures for organic compounds.

You can use R for the alkyl group.

4(b)(i) Magnesium ribbon is added to a solution of compound A.

Gas bubbles are seen and the magnesium slowly dissolves.

[3 marks]

Equation

Type of reaction

4(b)(ii) Compound A is heated with a few drops of concentrated sulfuric acid as a catalyst.

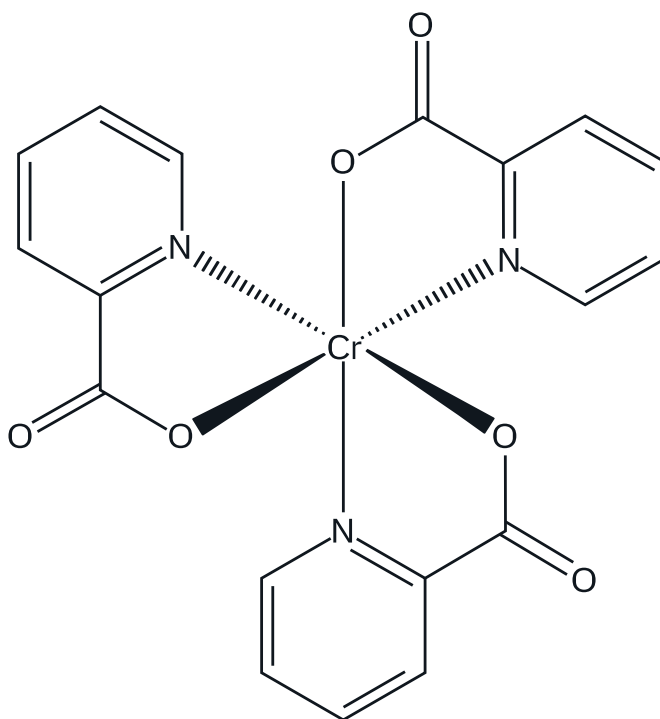
A cyclic 'dimer' of compound A forms.

[3 marks]

Equation

Type of reaction

Chromium(III) picolinate, shown below, is a neutral complex that can be prepared from the weak acid, picolinic acid.



Chromium(III) picolinate is used in tablets as a nutritional supplement for chromium.

4(c)(i) Draw the structure of the ligand in chromium(III) picolinate.

[1 mark]

4(c)(ii) A typical tablet of chromium(III) picolinate contains 200 μg of chromium.

Calculate the mass, in g, of chromium(III) picolinate in a typical tablet.

$$1 \mu\text{g} = 10^{-6} \text{ g.}$$

Give your answer to three significant figures.

mass = g

[2 marks]

Q27 · Amount of substance · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q3 · [1 mark]

What is the number of hydrogen atoms in 0.125 mol of $\text{C}_2\text{H}_5\text{OH}$?

Tick (✓) one box.

☐ **A** 7.525×10^{22}

☐ **B** 4.515×10^{23}

☐ **C** 3.7625×10^{23}

☐ **D** 3.612×10^{24}

Q28 · Amount of substance · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q7 · [1 mark]

This question also needs Alcohols and haloalkanes.

Ethanol can be prepared by different reactions.

Which reaction has the lowest atom economy?

Tick (✓) one box.

- ☐ **A** $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$
- ☐ **B** $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$
- ☐ **C** $\text{C}_2\text{H}_5\text{Br} + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH} + \text{HBr}$
- ☐ **D** $\text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH} + \text{CH}_3\text{COOH}$

Q29 · Amount of substance · June 2019 · Paper 1 (Periodic table, elements and physical chemistry) · Q3 · [1 mark]

One molecule of a gas has a mass of 2.658×10^{-23} g.

What is a possible formula of the gas?

Tick (✓) one box.

- ☐ **A** CH_4
- ☐ **B** O_2
- ☐ **C** SO_2
- ☐ **D** SO_3

Q30 · Amount of substance · June 2019 · Paper 1 (Periodic table, elements and physical chemistry) · Q4 · [1 mark]

In the laboratory, acid spills can be cleaned up and made safe by spreading anhydrous sodium carbonate over the spill to neutralise the acid.

A student accidentally spills 50.0 cm^3 of 2.00 mol dm^{-3} HCl(aq) on the bench.

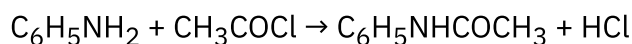
What is the minimum mass of anhydrous sodium carbonate required to neutralise the acid?

Tick (✓) one box.

- ☐ **A** 4.15 g
- ☐ **B** 5.30 g
- ☐ **C** 8.30 g
- ☐ **D** 10.6 g

Q31 · Amount of substance · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q11 · [1 mark]

A student reacts 4.50 g of $\text{C}_6\text{H}_5\text{NH}_2$ with excess CH_3COCl in the reaction below.



$$M_r = 93.0 \quad M_r = 135.0$$

The reaction produces 3.25 g of $\text{C}_6\text{H}_5\text{NHCOCH}_3$.

What is the percentage yield of $\text{C}_6\text{H}_5\text{NHCOCH}_3$?

Tick (✓) one box.

- ☐ **A** 49.8
- ☐ **B** 68.9
- ☐ **C** 72.2
- ☐ **D** 95.4

Q32 · Amount of substance · June 2019 · Paper 3 (Unified chemistry) · Q1 · [9 marks]

This question also needs Acids, bases and buffers, Equilibrium constants K_c and K_p and NMR spectroscopy.

These short questions are from different areas of chemistry.

1(a) Explain why a CF_4 molecule has polar bonds but does not have an overall dipole.

[2 marks]

1(b) Explain why a small proportion of molecules in water have a relative molecular mass of 20.

[1 mark]

1(c) What is the partial pressure of O_2 (in Pa) in a gas mixture containing 21% O_2 by volume and with a total pressure of 1.0×10^5 Pa?

partial pressure of O_2 = Pa

[1 mark]

1(d) What mass of carbon dioxide (in g) is formed by the complete combustion of 42.0 m^3 (measured at RTP) of propane?

mass = g

[2 marks]

1(e) A reaction is first order with respect to H^+ . At a pH of 1, the initial rate is $2.4 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$.

What is the initial rate at a pH of 3?

initial rate = $\text{mol dm}^{-3} \text{ s}^{-1}$

[1 mark]

1(f) What is the number of oxygen atoms in 4.26 g of P_2O_5 ?

number of oxygen atoms =

[2 marks]

Q33 • Amount of substance • June 2019 • Paper 3 (Unified chemistry) • Q2 • [8 marks]

This question also needs Organic synthesis, IR and mass spectra and Redox and electrode potentials.

Benzoic acid, $\text{C}_6\text{H}_5\text{COOH}$, is added to some foods as a preservative.

A student prepares benzoic acid as outlined below.

Step 1 The student mixes 4.00 cm^3 of phenylmethanol, $\text{C}_6\text{H}_5\text{CH}_2\text{OH}$, (density = 1.04 g cm^{-3}) with sodium carbonate and aqueous potassium manganate(VII), as an oxidising agent.

The mixture is heated under reflux.

Step 2 The resulting mixture is cooled and then acidified with concentrated HCl.

Impure crystals of benzoic acid appear.

Step 3 The student recrystallises the impure crystals to obtain 1.59 g of pure benzoic acid.

2(a) In Step 1, sodium carbonate, Na_2CO_3 , makes the reaction mixture alkaline.

Write an ionic equation to show how carbonate ions form an alkaline solution in water.

[1 mark]

2(b) In Step 2, explain why the mixture must be acidified so that crystals of benzoic acid appear.

[1 mark]

2(c) Write the overall equation for the preparation of benzoic acid from phenylmethanol.

Use [O] for the oxidising agent.

[1 mark]

2(d) Calculate the percentage yield of benzoic acid.

Give your answer to 3 significant figures.

percentage yield = %

[3 marks]

2(e) In Step 3, describe how the student can recrystallise the impure crystals to obtain pure benzoic acid.

[2 marks]

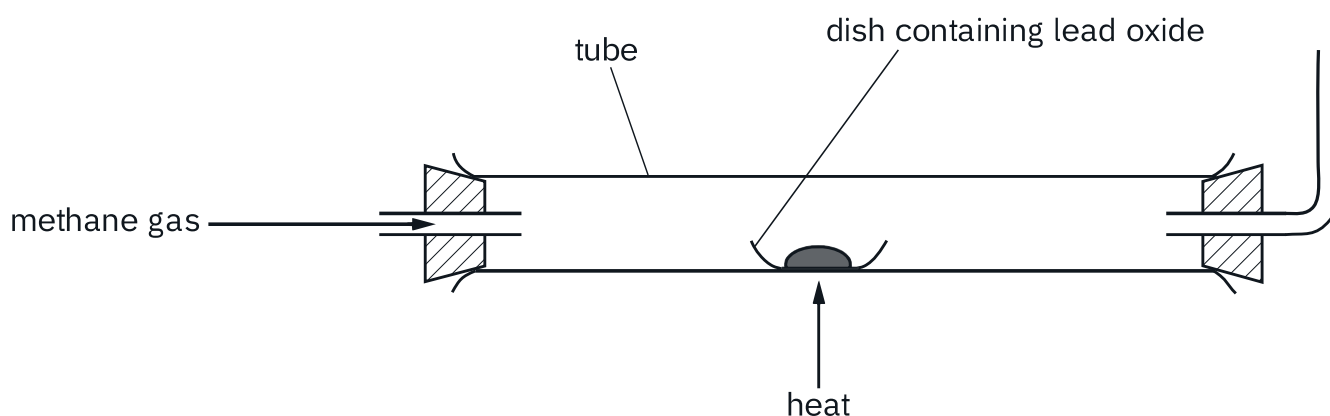
Q34 · Amount of substance · June 2019 · Paper 3 (Unified chemistry) · Q3 · [10 marks]

This question is about elements and compounds in Group 14 (Group 4) of the periodic table.

There are four oxides of lead: PbO , PbO_2 , Pb_2O_3 and Pb_3O_4 .

A student carries out an experiment to identify an unknown lead oxide, which is one of the four oxides of lead shown above.

The student plans to reduce the unknown lead oxide to lead by heating the lead oxide in a stream of methane gas, CH_4 . The apparatus is shown below.



Student's method

- Weigh an empty dish. Add the lead oxide to the dish and reweigh.
- Set up the apparatus and pass methane gas through the tube as shown. Heat the dish for 10 minutes.
- Pass cold air through the tube to cool the dish and contents.

- Weigh the dish and contents.

3(a)(i) Write the equation for the reduction of Pb_2O_3 with CH_4 .

[1 mark]

3(a)(ii) The student uses safety glasses and a lab coat.

State, with a reason, one other important safety precaution the student should take when carrying out this experiment.

[1 mark]

3(a)(iii) The student was not sure that all the oxygen had been removed from the lead oxide.

Suggest two modifications that the student could make to their method to be confident that all the oxygen had been removed. Explain your reasoning.

[2 marks]

1

2

3(a)(iv) The student makes suitable modifications to the method and repeats the experiment to obtain the accurate results shown below.

Mass of dish / g	8.364
Mass of dish + lead oxide / g	11.818
Mass of dish + lead at end of experiment / g	11.496

Calculate the empirical formula of the lead oxide.

empirical formula =

[2 marks]

3(b) SiO_2 and CO_2 are oxides of other Group 14 (Group 4) elements.

Solid SiO_2 melts at 2156°C . Solid CO_2 melts at -56°C .

Suggest the type of lattice structure in solid SiO_2 and in solid CO_2 and explain the difference in melting points in terms of the types of force within each lattice structure.

[4 marks]

Structure in $\text{SiO}_2(\text{s})$

Structure in $\text{CO}_2(\text{s})$

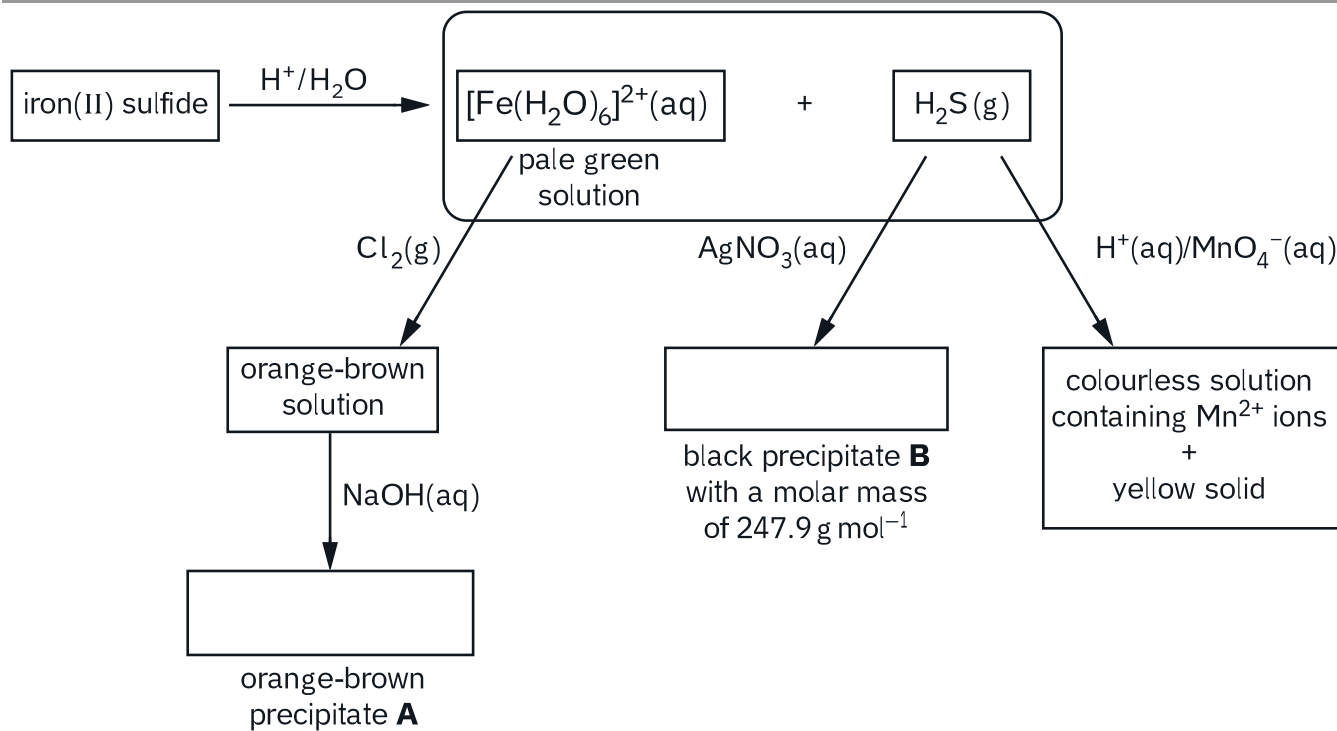
Explanation

Q35 · Amount of substance · June 2019 · Paper 3 (Unified chemistry) · Q6 · [12 marks]

This question also needs Redox and electrode potentials.

This question is about reactions of iron compounds.

A student carries out the reactions in the flowchart, starting with iron(II) sulfide.



6(a)(i) In the boxes, write the formulae of A and B.

[2 marks]

6(a)(ii) The student thinks that the reaction of iron(II) sulfide with $\text{H}^+ / \text{H}_2\text{O}$ is a redox reaction.

Explain, with reasons, whether the student is correct.

[1 mark]

6(a)(iii) Write the equation for the reaction of $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ with $\text{Cl}_2(\text{g})$.

[1 mark]

6(a)(iv) Construct an equation for the reaction of $\text{H}_2\text{S}(\text{g})$ with $\text{H}^+(\text{aq})/\text{MnO}_4^-(\text{aq})$.

[2 marks]

6(b) Compound C is a hydrated ionic compound with the empirical formula: $\text{FeH}_{18}\text{N}_3\text{O}_{18}$.

A student investigates the thermal decomposition of compound C as outlined below.

Stage 1

The student gently heats 0.00300 mol of compound C to remove the water of crystallisation.

0.486 g of water is collected, leaving 0.00300 mol of the anhydrous compound D.

Stage 2

The student strongly heats 0.00300 mol of compound D, which decomposes to form a solid oxide E (molar mass of 159.6 g mol^{-1}) and 270 cm^3 of a gas mixture, measured at RTP, containing gases F and G.

Stage 3

The student cools the 270 cm^3 gas mixture of F and G.

- Gas F is a compound that condenses to form 0.414 g of a liquid.
- Gas G remains and has a volume of 54 cm^3 , measured at RTP. Gas G is tested and it relights a glowing splint.

Determine the formulae of C, D, E, F and G.

Show all your working and equations for the reactions.

[6 marks]

mark]

20 cm³ of nitrogen gas reacts with 10 cm³ of oxygen gas to form 20 cm³ of a gaseous product.

Which equation is the most likely for the reaction?

Tick (✓) one box.

- ☐ **A** $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$
- ☐ **B** $\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$
- ☐ **C** $2\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{N}_2\text{O}(\text{g})$
- ☐ **D** $2\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g})$

Q37 · Amount of substance · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q3 · [1 mark]

0.541 g of an element X is reacted with oxygen to form 0.790 g of the oxide X₂O₃.

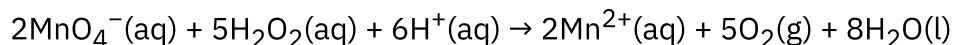
What is the element X?

Tick (✓) one box.

- ☐ **A** Al
- ☐ **B** Cr
- ☐ **C** Ga
- ☐ **D** Sc

Q38 · Amount of substance · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q4 · [1 mark]

Hydrogen peroxide, H_2O_2 , can be oxidised by manganate(VII) ions under acid conditions as shown below.



In a titration, 25.00 cm^3 of a disinfectant containing hydrogen peroxide reacts with 22.00 cm^3 of $0.125 \text{ mol dm}^{-3} \text{ KMnO}_4(\text{aq})$.

What is the concentration of H_2O_2 , in mol dm^{-3} , in the disinfectant?

Assume that KMnO_4 only reacts with H_2O_2 in the disinfectant.

Tick (✓) one box.

- ☐ **A** 0.0440
- ☐ **B** 0.110
- ☐ **C** 0.275
- ☐ **D** 0.550

Q39 · Amount of substance · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q5 · [1 mark]

The mass of 4 molecules of a substance is $2.125 \times 10^{-22} \text{ g}$.

What is the possible formula of the substance?

Tick (✓) one box.

- ☐ **A** CH_4
- ☐ **B** O_2
- ☐ **C** SO_2
- ☐ **D** I_2

Q40 · Amount of substance · June 2022 · Paper 2 (Synthesis and analytical techniques) · Q17 · [6 marks]

17 This question is about an analysis of an unknown organic Compound X.

Some properties of Compound X are shown in the table.

Molecular formula	Functional groups	Chirality
$C_xH_yF_6O$	C–F C–O–C	1 chiral carbon

At a pressure of 1.07×10^5 Pa at 30 °C, 1.327 g of Compound X is a gas with a volume of 186 cm³.

Determine the molar mass of Compound X and its molecular formula.

Draw a possible structure for a molecule of Compound X.

[6 marks]

molar mass g mol⁻¹

molecular formula

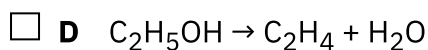
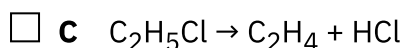
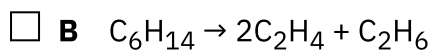
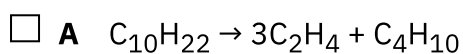
Structure of Compound X

Q41 • Amount of substance • June 2022 • Paper 2 (Synthesis and analytical techniques) • Q6 • [1 mark]

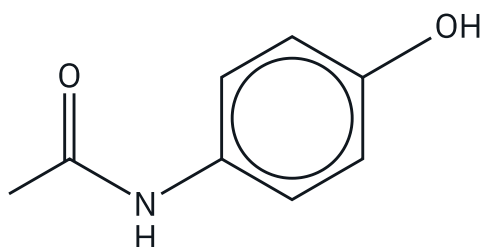
Which process has the highest atom economy for preparing ethene, C_2H_4 ?

In each process, assume that ethene is the only product that is used.

Tick (✓) one box.

**Q42 • Amount of substance • June 2022 • Paper 2 (Synthesis and analytical techniques) • Q8 • [1 mark]**

The structure of the painkiller, paracetamol, is shown below.

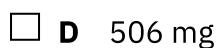
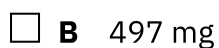
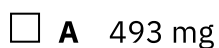


paracetamol

A tablet contains 3.31×10^{-3} mol of paracetamol.

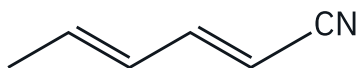
What is the mass of paracetamol in the tablet?

Tick (✓) one box.



Q43 · Amount of substance · June 2022 · Paper 2 (Synthesis and analytical techniques) · Q9 · [1 mark]

The compound below reacts with hydrogen gas to form a saturated compound.



What is the volume of hydrogen, measured at room temperature and pressure, that reacts with 0.0500 mol of the compound?

Tick (✓) one box.

☐ **A** 2.40 dm³

☐ **B** 3.60 dm³

☐ **C** 4.80 dm³

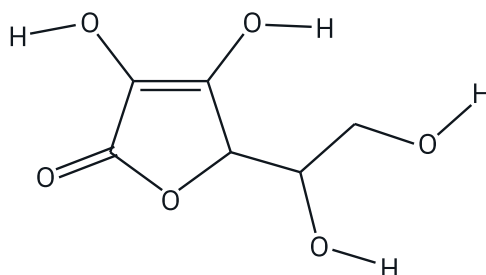
☐ **D** 6.00 dm³

Q44 · Amount of substance · June 2022 · Paper 3 (Unified chemistry) · Q6 · [13 marks]

This question also needs Acids, bases and buffers.

A student carries out an investigation on vitamin C, C₆H₈O₆.

6(a) The structure of vitamin C is shown below. Vitamin C is an optical isomer.

**Vitamin C**

What is the total number of optical isomers with the structure of vitamin C?

total number of optical isomers =

[1 mark]

Vitamin C is extremely soluble in water. This means that vitamin C is removed rapidly from the body. 'Vitamin C ester' is available in tablet form as a less soluble source of vitamin C which stays in the body for longer.

6(b)(i) Suggest why vitamin C is extremely soluble in water.

[1 mark]

6(b)(ii) A 'vitamin C ester' tablet contains an ester with the molecular formula $C_{22}H_{38}O_7$.

This ester can be prepared by reacting vitamin C with a long chain carboxylic acid, C_xH_yCOOH , in the presence of an acid catalyst.

Vitamin C and the long chain carboxylic acid react in a 1:1 molar ratio.

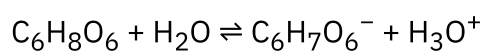
Determine x and y in the formula of this carboxylic acid.

x = y =

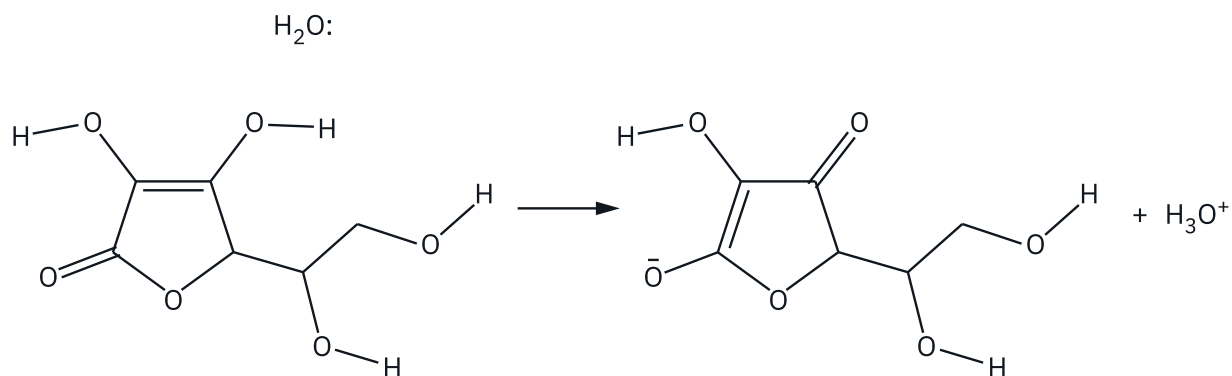
[2 marks]

Vitamin C, $\text{C}_6\text{H}_8\text{O}_6$, is a weak acid ($K_a = 7.94 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$), which is often referred to as ascorbic acid.

6(c)(i) In aqueous solution, vitamin C donates a proton to water:



Add curly arrows to the diagram to suggest the mechanism for this process.



[2 marks]

Draw your answer on the figure above.

6(c)(ii) The student dissolves 0.150 mol of vitamin C in water and makes the solution up to 250 cm^3 in a volumetric flask.

Calculate the pH of this solution of vitamin C.

Give your answer to **2** decimal places.

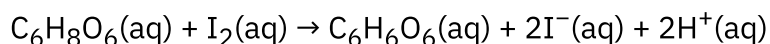
pH =

[3 marks]

6(d) The label on a carton of orange juice lists the mass of vitamin C, in mg, in a typical serving of 150 cm^3 .

The student carries out an investigation to check the vitamin C content in the orange juice.

Vitamin C can be oxidised by iodine:



The student dilutes 150 cm^3 of the orange juice with water to 250.0 cm^3 in a volumetric flask.

The student then titrates 25.0 cm^3 volume of this solution with $9.60 \times 10^{-4} \text{ mol dm}^{-3}$ iodine solution, $\text{I}_2(\text{aq})$.

The mean titre of $\text{I}_2(\text{aq})$ is 22.50 cm^3 .

Determine the mass, in mg, of vitamin C in a 150 cm^3 serving of the orange juice.

mass of vitamin C in the 150 cm^3 serving of orange juice = mg

[4 marks]

Q45 · Amount of substance · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) · Q1 · [1 mark]

Which sample contains the greatest number of molecules?

Tick (✓) one box.

- ☐ **A** 35.0 g of C_2H_2
- ☐ **B** 45.0 g of C_2H_6
- ☐ **C** 60.0 g of C_4H_{10}
- ☐ **D** 100.0 g of C_6H_6

Q46 · Amount of substance · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) · Q10 · [1 mark]

What is the percentage dissociation of a $0.015 \text{ mol dm}^{-3}$ solution of methanoic acid, HCOOH ($K_a = 1.60 \times 10^{-4} \text{ mol dm}^{-3}$)?

Tick (✓) one box.

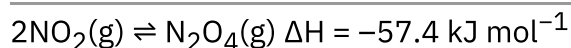
- ☐ **A** 0.016%
- ☐ **B** 1.1%
- ☐ **C** 1.82%
- ☐ **D** 10.3%

Q47 · Amount of substance · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) · Q19 · [13 marks]

This question also needs Equilibrium constants K_c and K_p .

This question is about oxides of nitrogen.

An investigation is carried out on the equilibrium system shown below.



19(a)(i) A sealed flask containing 6.00 moles of $\text{NO}_2(\text{g})$ is heated to a constant temperature and allowed to reach equilibrium.

The equilibrium mixture contains 5.40 mol of $\text{NO}_2(\text{g})$, and the total pressure is 5.00 atm.

Determine the value of K_p and give your answer to **3** significant figures.

Include an expression for K_p and the units of K_p in your answer.

$K_p =$ units

[5 marks]

19(a)(ii) The sealed flask in (a)(i) is then heated to a higher temperature at an increased pressure. The system is allowed to reach equilibrium again.

Explain why it is difficult to predict how these changes in reaction conditions affect the amount of $\text{N}_2\text{O}_4(\text{g})$ formed at equilibrium.

[3 marks]

19(b) N_2O_4 reacts fully with oxygen to form a different oxide of nitrogen, oxide A, as the only product.

Oxide A is collected and cooled to $75.0\text{ }^\circ\text{C}$ at a pressure of 101 kPa .

Under these conditions, oxide A is a gas that occupies a volume of 74.0 cm^3 and has a mass of 0.280 g .

Calculate the molar mass of oxide A and suggest its molecular formula.

molar mass = g mol^{-1}

molecular formula =

[5 marks]

Q48 • Amount of substance • June 2023 • Paper 1 (Periodic table, elements and physical chemistry) • Q2 • [1 mark]

0.688 g of an oxide of manganese is reduced by hydrogen gas to form manganese metal and 0.235 g of water.

What is the formula of the oxide of manganese?

Tick (✓) one box.

- ☐ **A** MnO
- ☐ **B** MnO_2
- ☐ **C** Mn_2O_3
- ☐ **D** Mn_3O_4

Q49 • Amount of substance • June 2023 • Paper 1 (Periodic table, elements and physical chemistry) • Q21 • [10

marks]

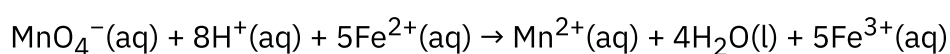
This question also needs Redox and electrode potentials.

Some grass fertilisers contain compounds of iron.

During heavy rain, a fertiliser is washed into a nearby river causing the water to be polluted with a mixture of iron(II) and iron(III) ions.

A student determines the concentration of iron(II) ions in a sample of river water by titration with potassium manganate(VII).

25.0 cm³ portions of river water are acidified with dilute sulfuric acid. Each portion is titrated with 0.00250 mol dm⁻³ potassium manganate(VII) until a colour change is seen.



21(a)(i) State the colour change seen at the end point of the titration.

from to

[1 mark]

21(a)(ii) The student's titration results are shown in the table below.

The trial titre has been omitted.

	1	2	3
Final volume / cm ³	12.65	25.60	38.35
Initial volume / cm ³	0.00	12.65	25.60
Titre volume / cm ³			

Complete the table above and calculate the mean titre that the student should use to determine the concentration of iron(II) ions in the river water.

mean titre = cm³

[2 marks]

21(a)(iii) Determine the concentration, in mol dm⁻³, of iron(II) ions in the river water.

concentration = mol dm⁻³

[3 marks]

21(b) The student modifies the experiment in (a) to determine the combined concentration of iron(II) and iron(III) ions in the river water.

The student's method is shown below.

Step 1 Add excess zinc to a 250.0 cm^3 sample of river water and warm gently.

Step 2 Cool the solution and remove excess zinc by filtration.

Step 3 Acidify 25.0 cm^3 portions of the filtrate from Step 2. Then titrate each portion with $0.00250 \text{ mol dm}^{-3}$ potassium manganate(VII) until a colour change is seen.

The table below shows information about three redox systems.

Redox system	Half-equation	$E^\ominus / \text{V}$
1	$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
2	$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
3	$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51

Use the information in the table above to explain the reasons for Step 1 and Step 2.

[4 marks]

Reason(s) for Step 1

Reason(s) for Step 2

Q50 • Amount of substance • June 2023 • Paper 1 (Periodic table, elements and physical chemistry) • Q3 • [1

mark]

How many hydrogen atoms are in 2.50 g of pharmacolite, $\text{CaHAsO}_4 \cdot 2\text{H}_2\text{O}$ ($M_r = 216.0$)?

Tick (✓) one box.

- ☐ **A** 6.97×10^{21}
- ☐ **B** 2.09×10^{22}
- ☐ **C** 2.79×10^{22}
- ☐ **D** 3.48×10^{22}

Q51 • Amount of substance • June 2023 • Paper 1 (Periodic table, elements and physical chemistry) • Q4 • [1 mark]

40.0 cm³ of 0.200 mol dm⁻³ HCl is added to 60.0 cm³ of 0.100 mol dm⁻³ NaOH.

What is the concentration of the resulting solution?

Tick (✓) one box.

- ☐ **A** 0.0200 mol dm⁻³ HCl and 0.0200 mol dm⁻³ NaCl
- ☐ **B** 0.0200 mol dm⁻³ HCl and 0.0400 mol dm⁻³ NaCl
- ☐ **C** 0.0200 mol dm⁻³ HCl and 0.0600 mol dm⁻³ NaCl
- ☐ **D** 0.0600 mol dm⁻³ HCl and 0.0200 mol dm⁻³ NaCl

Q52 • Amount of substance • June 2023 • Paper 1 (Periodic table, elements and physical chemistry) • Q7 • [1 mark]

This question also needs Rate equations.

The reaction below is first order with respect to reactant X.

$\text{X(aq)} \rightarrow \text{products}$

When the initial concentration of X is 1.0 mol dm⁻³, the half-life is 16 minutes.

What is the half-life when the initial concentration of X is 2.0 mol dm⁻³?

Tick (✓) one box.

- ☐ **A** 2 minutes
- ☐ **B** 4 minutes
- ☐ **C** 8 minutes
- ☐ **D** 16 minutes

Q53 · Amount of substance · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) · Q8 · [1 mark]

Which compound requires the most energy to convert one mole into its gaseous ions?

Tick (✓) one box.

- ☐ **A** NaF
- ☐ **B** Na₂O
- ☐ **C** MgF₂
- ☐ **D** MgO

Q54 · Amount of substance · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) · Q3 · [1 mark]

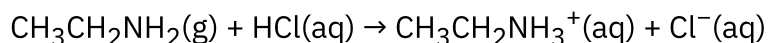
Which chemical process is the most sustainable in terms of the atom economy of the iron produced?

Tick (✓) one box.

- ☐ **A** $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
- ☐ **B** $\text{Fe}_2\text{O}_3 + 3\text{H}_2 \rightarrow 2\text{Fe} + 3\text{H}_2\text{O}$
- ☐ **C** $2\text{Fe}_2\text{O}_3 \rightarrow 4\text{Fe} + 3\text{O}_2$
- ☐ **D** $2\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_2$

Q55 · Amount of substance · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q10 · [1 mark]

1.35 g of ethylamine gas, CH₃CH₂NH₂ (M_r = 45.0), is reacted with 20 cm³ of 2.0 mol dm⁻³ hydrochloric acid forming a solution of ethylammonium chloride.



What is the concentration of ethylammonium chloride in mol dm⁻³?

Tick (✓) one box.

- ☐ **A** 0.03
- ☐ **B** 0.67
- ☐ **C** 1.50
- ☐ **D** 2.00

Q56 · Amount of substance · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q2 · [1 mark]

11.895 g of hydrated cobalt(II) chloride, $\text{CoCl}_2 \cdot x\text{H}_2\text{O}$, is heated to remove the water of crystallisation.

After heating to constant mass, the mass of the anhydrous salt was 6.495 g.

What is the value of x ?

Tick (✓) one box.

☐ **A** 3

☐ **B** 5

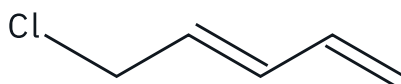
☐ **C** 6

☐ **D** 7

Q57 · Amount of substance · June 2025 · Paper 2 (Synthesis and analytical techniques) · Q2 · [1 mark]

0.0200 mol of the compound below reacts with $\text{Br}_2(\text{aq})$ to make a saturated compound.

How many grams of Br_2 are needed for this reaction?



Tick (✓) one box.

☐ **A** 3.20

☐ **B** 6.39

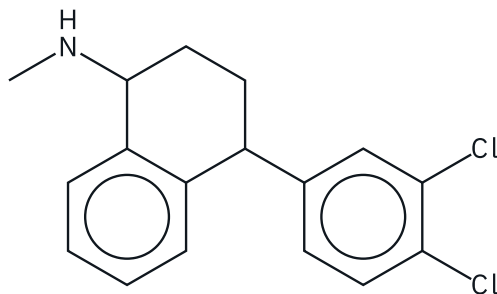
☐ **C** 7.99

☐ **D** 12.80

Q58 · Amount of substance · June 2025 · Paper 2 (Synthesis and analytical techniques) · Q3 · [1 mark]

The skeletal structure of a medicinal drug is shown below.

How many hydrogen atoms are in its molecular formula?



Tick (✓) one box.

- ☐ **A** 14
- ☐ **B** 15
- ☐ **C** 17
- ☐ **D** 19

Q59 · Amount of substance · June 2025 · Paper 2 (Synthesis and analytical techniques) · Q5 · [1 mark]

0.200 mol of $\text{HOOCCH}_2\text{CH}_2\text{COOH}$ is reacted with 0.300 mol NaOH .

How many water molecules are formed?

Tick (✓) one box.

- ☐ **A** 1.204×10^{23}
- ☐ **B** 1.806×10^{23}
- ☐ **C** 2.408×10^{23}
- ☐ **D** 3.612×10^{23}

Q60 · Amount of substance · June 2025 · Paper 2 (Synthesis and analytical techniques) · Q6 · [1 mark]

Propene can be prepared using the reactions shown.

Which reaction has the **lowest** atom economy?

Tick (✓) one box.

- ☐ **A** $\text{C}_3\text{H}_7\text{Br} \rightarrow \text{C}_3\text{H}_6 + \text{HBr}$
- ☐ **B** $\text{C}_{12}\text{H}_{26} \rightarrow 2\text{C}_3\text{H}_6 + \text{C}_6\text{H}_{14}$
- ☐ **C** $\text{C}_8\text{H}_{18} \rightarrow \text{C}_3\text{H}_6 + \text{C}_5\text{H}_{12}$
- ☐ **D** $\text{C}_3\text{H}_7\text{OH} \rightarrow \text{C}_3\text{H}_6 + \text{H}_2\text{O}$

Q61 · Amount of substance · June 2025 · Paper 3 (Unified chemistry) · Q2 · [14 marks]

This question also needs Acids, bases and buffers.

This question is about different compounds that each contain O and H atoms covalently bonded together.

The alcohol 2,3-dimethylhexan-1-ol has the molecular formula $\text{C}_8\text{H}_{18}\text{O}$.

2(a)(i) Draw the skeletal formula of 2,3-dimethylhexan-1-ol.

[1 mark]

2(a)(ii) What is the number of H atoms in 8.45 g of 2,3-dimethylhexan-1-ol?

Give your answer to **3** significant figures and in standard form.

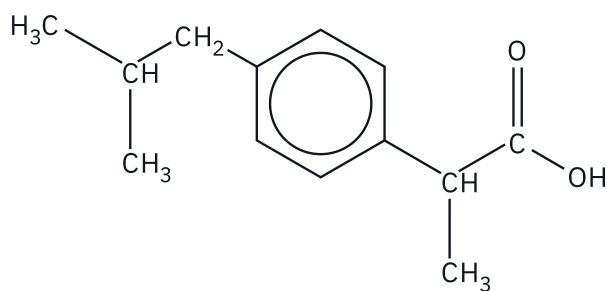
Number of H atoms =

[3 marks]

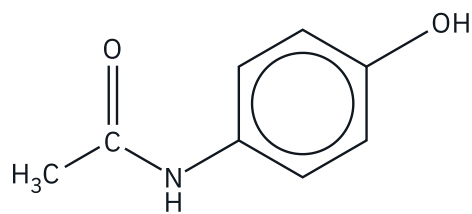
Nuromol tablets are used to relieve pain.

Nuromol tablets contain a mixture of ibuprofen and paracetamol.

The structures of ibuprofen and paracetamol are shown.



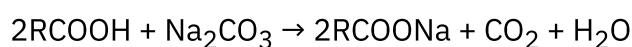
Ibuprofen



Paracetamol

A student carries out an investigation to determine the mass of ibuprofen and the mass of paracetamol in one nuromol tablet.

- Ibuprofen reacts with aqueous sodium carbonate, $\text{Na}_2\text{CO}_3(\text{aq})$, to produce a gas.



- Paracetamol does **not** react with $\text{Na}_2\text{CO}_3(\text{aq})$.

2(b)(i) Why does paracetamol **not** react with $\text{Na}_2\text{CO}_3(\text{aq})$?

[1 mark]

2(b)(ii) The student uses the reaction of nuromol tablets with $\text{Na}_2\text{CO}_3(\text{aq})$ to determine the mass of ibuprofen and the mass of paracetamol in one nuromol tablet.

The student's method is outlined below.

- Weigh **four** nuromol tablets.
- Add the tablets to an excess of aqueous sodium carbonate.
- Collect the gas produced and measure its volume.

Results

Mass of four nuromol tablets = 2.80 g

Volume of gas collected at RTP = 48.0 cm³

Assume that ibuprofen is the only compound in nuromol tablets that reacts with $\text{Na}_2\text{CO}_3(\text{aq})$.

Determine the mass of ibuprofen and the mass of paracetamol, in mg, in **one** nuromol tablet.

Mass of ibuprofen = mg

Mass of paracetamol = mg

[4 marks]

2(c) Barium hydroxide, $\text{Ba}(\text{OH})_2$, is an alkali.

A student is supplied with a solution of $\text{Ba}(\text{OH})_2$ with a concentration of 46.80 g dm^{-3} at 25°C .

The student dilutes 20.0 cm^3 of this solution of $\text{Ba}(\text{OH})_2$ with water and the solution is made up to 100.0 cm^3 at 25°C .

Calculate the pH of the diluted solution of $\text{Ba}(\text{OH})_2$ at 25°C .

Give your answer to **2** decimal places.

pH =

[5 marks]

Q62 · Amount of substance · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q2 · [1 mark]

Which statement gives the numerical value of the Avogadro constant?

Tick (✓) one box.

- ☐ **A** The number of moles in 12 g of carbon-12.
- ☐ **B** The number of electrons lost by 20.05 g of calcium when it reacts with oxygen.
- ☐ **C** The number of molecules in 16.0 g of oxygen.
- ☐ **D** The number of atoms in 1 mole of chlorine molecules.

Q63 · Amount of substance · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q3 · [1 mark]

0.80 g of element X is reacted with 0.40 g of O₂ to form an oxide with the formula X₂O₃.

What is the identity of element X?

Tick (✓) one box.

- ☐ **A** Aluminium
- ☐ **B** Titanium
- ☐ **C** Germanium
- ☐ **D** Molybdenum

Q64 · Amount of substance · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q4 · [1 mark]

This question also needs Group 2 and the halogens.

Phosphoric acid is a tribasic acid.

What is the mass of Ca(OH)₂ that completely neutralises 100 cm³ of 0.100 mol dm⁻³ phosphoric acid?

Tick (✓) one box.

- ☐ **A** 0.49 g
- ☐ **B** 0.74 g
- ☐ **C** 1.11 g
- ☐ **D** 2.22 g

Q65 · Amount of substance · November 2020 · Paper 2 (Synthesis and analytical techniques) · Q11 · [1 mark]

Complete combustion of 1.00 g of a hydrocarbon gives 3.38 g carbon dioxide.

What is the empirical formula of the hydrocarbon?

Tick (✓) one box.

- ☐ **A** CH
- ☐ **B** CH₂
- ☐ **C** C₂H₅
- ☐ **D** C₃H₈

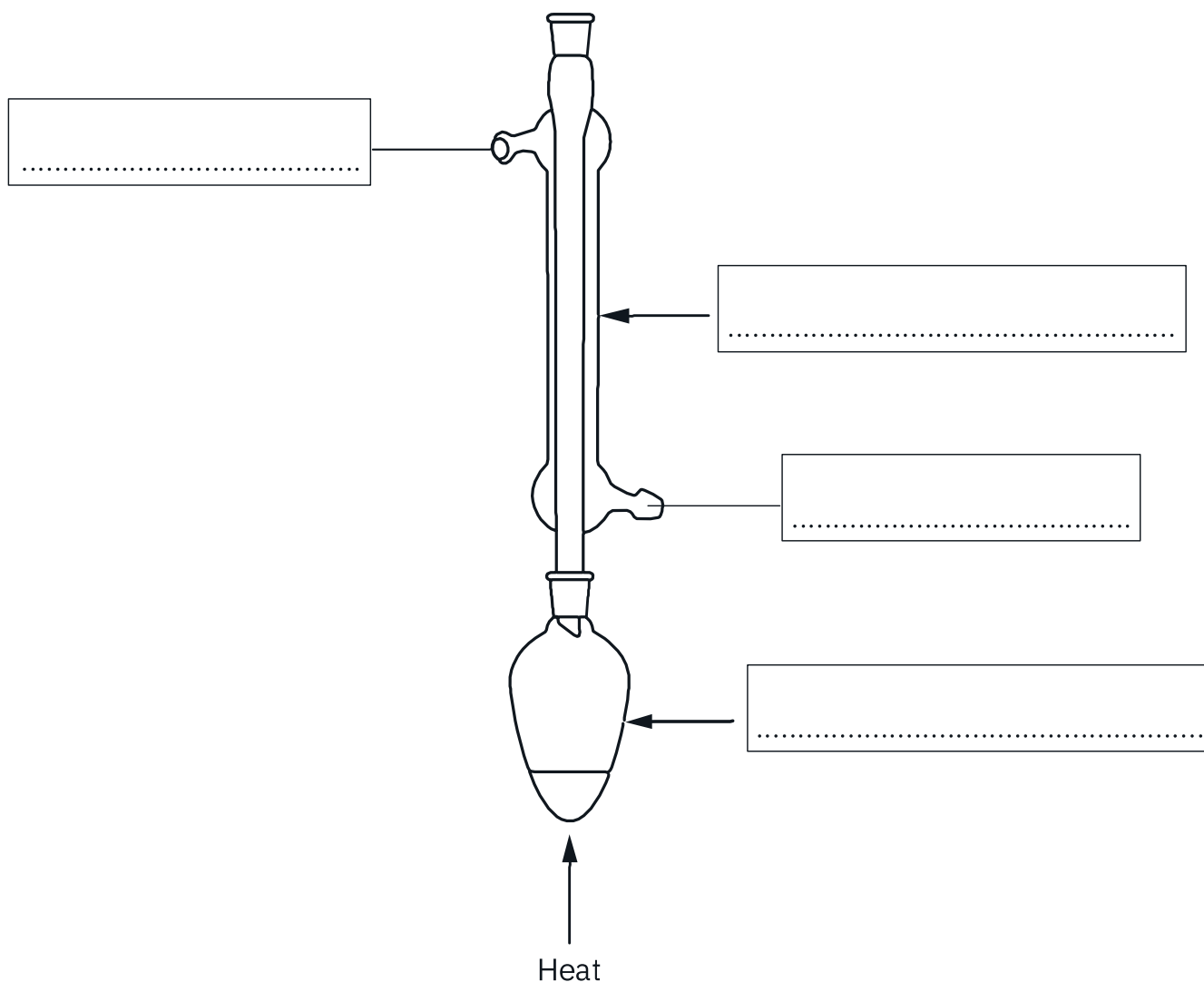
Q66 · Amount of substance · November 2020 · Paper 3 (Unified chemistry) · Q1 · [16 marks]

This question also needs Alkanes, Amines, amino acids and polymers, Basic concepts of organic chemistry and 3 other topics.

This question is about organic chemistry.

This part is about two practical techniques used in organic preparations.

1(a)(i) Complete the missing labels on the diagram and name the technique.



Name of technique:

[2 marks]

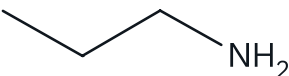
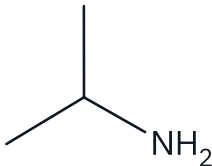
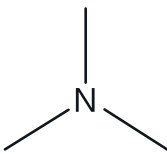
Draw your answer on the figure above.

1(a)(ii) Draw a labelled diagram to show apparatus set up for filtration under reduced pressure (vacuum filtration).

[2 marks]

This part is about amines.

1(b)(i) The table shows the structures and boiling points of three amines, which are structural isomers of C_3H_9N .

Amine	$CH_3CH_2CH_2NH_2$	$(CH_3)_2CHNH_2$	$(CH_3)_3N$
Skeletal formula			
Boiling point/ $^{\circ}C$	48–49 $^{\circ}C$	33–34 $^{\circ}C$	3–4 $^{\circ}C$

Explain the difference in the boiling points of the three amines.

[4 marks]

1(b)(ii) Amine A is a liquid at room temperature and pressure.

When vaporised, 0.202 g of the amine produces 72.0 cm³ of gas at 1.00×10^5 Pa and 100 °C. The ¹³C NMR spectrum of amine A has 3 peaks.

Determine the molecular formula of A and suggest a possible structure for amine A.

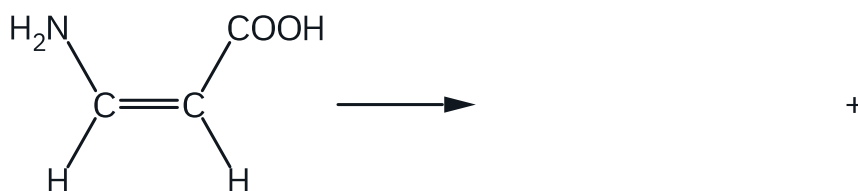
[6 marks]

Molecular formula of A

Structure of A

1(c) The amino acid Z-H₂NCH=CHCOOH can react to form a cyclic compound with the molecular formula C₃H₃NO and one other product.

Complete the equation for this reaction.



[2 marks]

Draw your answer on the figure above.

Q67 · Amount of substance · November 2020 · Paper 3 (Unified chemistry) · Q4 · [19 marks]

A student carries out an investigation to identify two metals, M and X, by two different methods.

The student is provided with a sample of 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 cm^3 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.

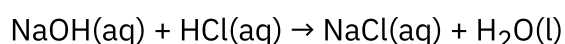
Stage 2

The resulting solution from Stage 1 is made up to 250.0 cm^3 with distilled water.

Stage 3

A 25.00 cm^3 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 cm^3 .

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

4(a)(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.

[3 marks]

Overall equation

Oxidation half-equation

Reduction half-equation

4(a)(ii) In Stage 1, suggest two observations that would confirm that all of metal M has reacted.

[2 marks]

1

2

4(a)(iii) In Stage 3, write the ionic equation for the reaction taking place in the titration.

[1 mark]

4(a)(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.

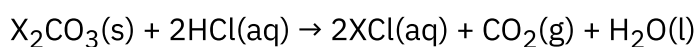
Analyse the results to identify metal M.

Metal M =

[6 marks]

The student is provided with the carbonate of an unknown metal, X_2CO_3 .

The student measures the mass loss when the X_2CO_3 is reacted with an excess of hydrochloric acid. The equation is shown below.



The reaction is carried out using this method:

Step 1 Add 100 cm^3 $HCl(aq)$ to a conical flask and weigh.

Step 2 Add X_2CO_3 to the conical flask and immediately reweigh.

Step 3 After 5 minutes, reweigh the conical flask and contents.

Results

Mass of conical flask + $HCl(aq)$	172.93 g
Mass of conical flask + X_2CO_3 + $HCl(aq)$ before reaction	187.50 g
Mass of conical flask + contents after 5 minutes	184.75 g

4(b)(i) Calculate the amount, in mol, of CO_2 released in the reaction.

Amount of CO_2 = mol

[1 mark]

4(b)(ii) Calculate the molar mass of X_2CO_3 and identify metal X.

Molar mass of X_2CO_3 = g mol⁻¹ Metal X =

[3 marks]

After analysing the results, the student was told that their molar mass of X_2CO_3 was incorrect.

The student evaluated the experiment for possible reasons for the incorrect result.

4(c)(i) The student wondered whether the reaction was complete when the mass was recorded after 5 minutes (Step 3).

How could the student modify the experimental procedure to be confident that the reaction was complete?

[1 mark]

4(c)(ii) The student finds out that carbon dioxide is slightly soluble in water.

State and explain how the solubility of CO_2 would affect the calculated molar mass of X_2CO_3 .

[2 marks]

Q68 · Amount of substance · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q10 ·

[1 mark]

This question also needs Acids, bases and buffers.

An aqueous solution of ethanoic acid, CH_3COOH , has a concentration of 0.50 mol dm^{-3} . pK_a for $\text{CH}_3\text{COOH} = 4.76$ at 25°C .

What is the pH of the ethanoic acid solution at 25°C ?

Tick (✓) one box.

- ☐ **A** 2.53
- ☐ **B** 2.68
- ☐ **C** 4.91
- ☐ **D** 5.06

Q69 · Amount of substance · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q2 · [1 mark]

A chlorate(VII) ion has a 1– charge.

What is the formula for sodium chlorate(VII)?

Tick (✓) one box.

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

Q70 · Amount of substance · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q4 · [1 mark]

Which sample contains the greatest number of molecules?

Tick (✓) one box.

- ☐ **A** 140.0 g C_2H_2
- ☐ **B** 180.0 g C_2H_6
- ☐ **C** 240.0 g C_4H_{10}
- ☐ **D** 400.0 g C_6H_6

Q71 · Amount of substance · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q5 · [1 mark]

Chromium(III) oxide, Cr_2O_3 , is reduced to chromium by heating with magnesium.

What is the minimum mass of Mg required to reduce 11.4 g of chromium(III) oxide?

Tick (✓) one box.

- ☐ **A** 0.61 g
- ☐ **B** 0.91 g
- ☐ **C** 3.65 g
- ☐ **D** 5.47 g

Q72 · Amount of substance · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q6 · [1 mark]

A student is supplied with 100.0 cm^3 of a solution of $0.400 \text{ mol dm}^{-3}$ magnesium iodide, MgI_2 .

A student plans to dilute this solution so that the iodide concentration is $0.250 \text{ mol dm}^{-3}$.

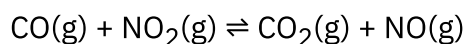
What volume of water, in cm^3 , does the student need to add?

Tick (✓) one box.

- ☐ **A** 60.0
- ☐ **B** 160.0
- ☐ **C** 220.0
- ☐ **D** 320.0

Q73 · Amount of substance · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q9 · [1 mark]

An equilibrium system is shown below.



Different amounts of CO, NO₂, CO₂ and NO are added to four containers, as shown below.

Which container would have the largest concentration of CO(g) at equilibrium?

Tick (✓) one box.

☐ **A** CO / mol: 1 · NO₂ / mol: 1 · CO₂ / mol: 0 · NO / mol: 0

☐ **B** CO / mol: 1 · NO₂ / mol: 0 · CO₂ / mol: 1 · NO / mol: 1

☐ **C** CO / mol: 1 · NO₂ / mol: 1 · CO₂ / mol: 1 · NO / mol: 0

☐ **D** CO / mol: 0 · NO₂ / mol: 1 · CO₂ / mol: 1 · NO / mol: 1

Q74 · Amount of substance · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q3 · [1 mark]

Which sample contains the greatest number of carbon atoms?

Tick (✓) one box.

☐ **A** 20.0 g C₆H₅OH

☐ **B** 30.0 g C₂H₅COOH

☐ **C** 40.0 g CH₃CHO

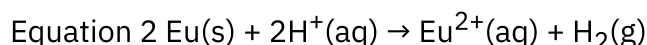
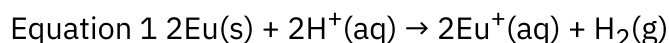
☐ **D** 50.0 g CH₃OH

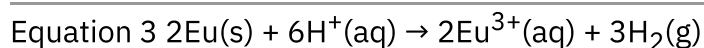
Q75 · Amount of substance · November 2021 · Paper 3 (Unified chemistry) · Q2 · [9 marks]

This question also needs Reaction rates and equilibrium.

Europium ($A_r = 152.0$) reacts with dilute aqueous acid in a redox reaction, forming a solution and hydrogen gas.

A student proposed three possible ionic equations for this reaction, forming europium ions with different charges:





The student plans to carry out an investigation to determine which equation is correct.

Hydrochloric acid is used as the source of $\text{H}^+(\text{aq})$ ions.

The student's method is outlined below.

Step 1 Using a 3 decimal place balance, weigh a suitable container for the reaction.

Add about 1 g of europium to the container and reweigh.

Step 2 Set up apparatus for gas collection.

Add an excess of dilute hydrochloric acid to the europium.

Step 3 Measure the volume of gas produced.

Results

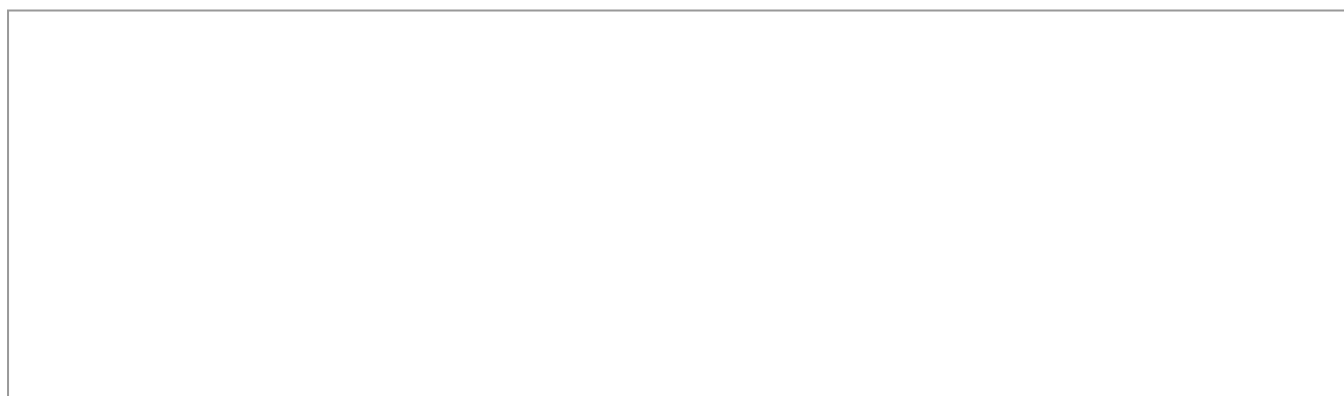
Mass of container = 32.795 g

Mass of container + europium = 33.783 g

Volume of gas collected = 152 cm³

2(a) Draw a labelled diagram of suitable apparatus for this investigation.

[2 marks]



2(b) Analyse the student's results to conclude which of Equation 1 or 2 or 3, is supported by the experimental results.

Assume that the conditions in the laboratory are 'room temperature and pressure' (RTP).

correct equation (1, 2, or 3) =

[3 marks]

2(c) The student repeats the experiment but adds concentrated hydrochloric acid instead of dilute hydrochloric acid. The apparatus gets hot during the reaction.

Predict how the hot apparatus would change the student's results and the conclusion in (b).

Explain your answer.

[2 marks]

2(d) The student modifies their method as outlined below:

- 1.52 g (0.01 mol) of europium is reacted with an excess of dilute hydrochloric acid.
- An excess of aqueous sodium hydroxide is added to the reaction mixture.
- A precipitate forms which is collected, dried and weighed.

Explain how the mass of precipitate formed would allow the student to conclude which of Equation 1 or 2 or 3 is correct.

[2 marks]

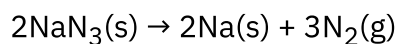
Q76 · Amount of substance · November 2021 · Paper 3 (Unified chemistry) · Q5 · [20 marks]

This question also needs Acids, bases and buffers, Amines, amino acids and polymers, Carbonyls, carboxylic acids and esters and Organic synthesis, IR and mass spectra.

This question is about nitrogen and its compounds.

Sodium azide, NaN_3 , has been used in car airbags.

The airbag inflates when the NaN_3 decomposes to form nitrogen gas:



5(a)(i) This is a redox reaction.

Write half-equations for the reduction and oxidation processes that take place.

[2 marks]

Reduction

Oxidation

5(a)(ii) A 16.0 dm^3 airbag is inflated at 17.0°C .

The pressure in the inflated airbag is $1.20 \times 10^5 \text{ Pa}$.

Calculate the mass of NaN_3 that has decomposed.

Give your answer to 3 significant figures.

mass of $\text{NaN}_3 = \text{g}$

[5 marks]

Hydrazoic acid, HN_3 , is a weak acid ($K_a = 2.51 \times 10^{-5} \text{ mol dm}^{-3}$).

5(b)(i) Calculate the pH of $0.125 \text{ mol dm}^{-3}$ hydrazoic acid.

Give your answer to 2 decimal places.

pH =

[2 marks]

5(b)(ii) When added to water, hydrazoic acid forms an equilibrium mixture containing conjugate acid–base pairs.

Complete the equation for this equilibrium and label the conjugate acid–base pairs as:

A1, B1 and A2, B2.

Equation $\text{HN}_3 + \rightleftharpoons +$

Acid-base pairs

[2 marks]

5(b)(iii) In the Schmidt reaction, hydrazoic acid, HN_3 , reacts with carboxylic acids to form primary amines.

For example, HN_3 reacts with RCOOH to form RNH_2 and two gases that are found in the atmosphere.

Write the equation for the reaction of HN_3 with 2-methylbutanoic acid.

Show structures for organic compounds.

[3 marks]

5(c) This question is about two reactions of ammonia.

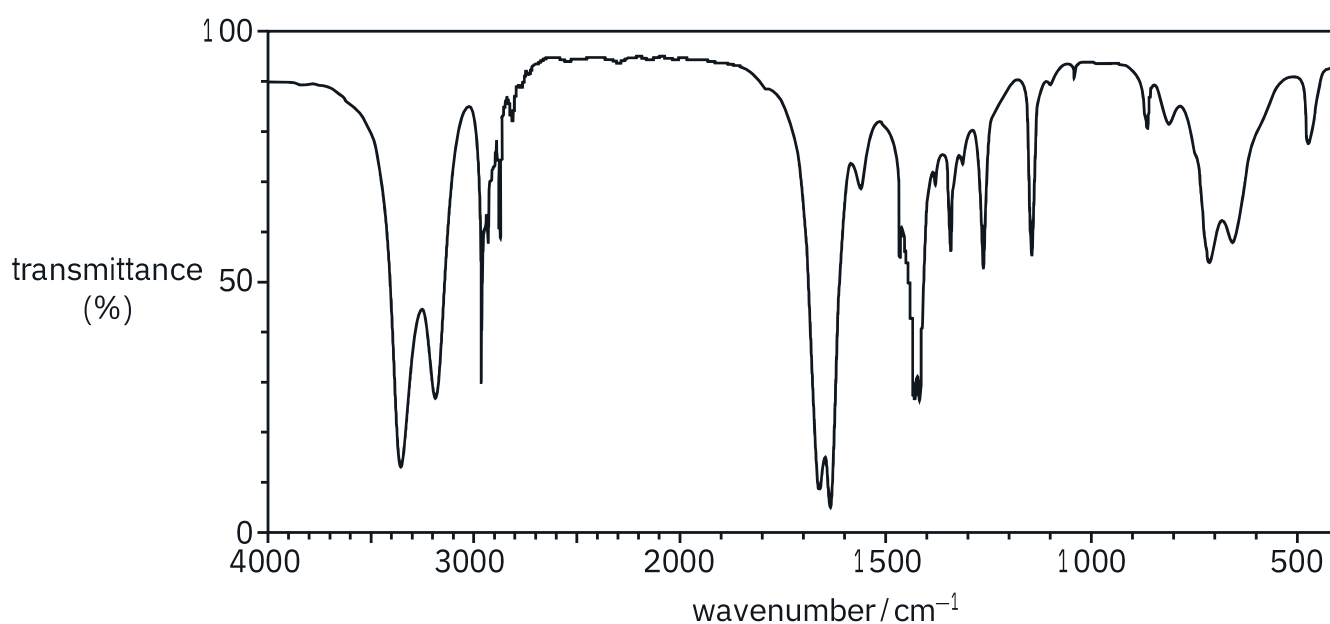
Reaction 1

Excess ammonia is reacted with 4.77 g of copper(II) oxide. The reaction produces 3.81 g of solid E, liquid F and 0.560 g of gas G, which has a volume of 480 cm³ at RTP.

Reaction 2

Ammonia reacts with compound H to form compound I, C₂H₅NO, and chloride salt J.

The IR spectrum of I is shown below.



Identify E, F, G, H, I and J, and write equations for the two reactions.

Show your reasoning.

[6 marks]

• [1 mark]

Which atom is not an isotope of iodine?

Tick (✓) one box.

- ☐ **A** Number of neutrons: 72 · Mass number: 125
- ☐ **B** Number of neutrons: 74 · Mass number: 127
- ☐ **C** Number of neutrons: 75 · Mass number: 128
- ☐ **D** Number of neutrons: 77 · Mass number: 129

Q78 · Atomic structure and isotopes · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q1
• [1 mark]

A sample of boron contains the isotopes ^{10}B and ^{11}B .

The relative atomic mass of the boron sample is 10.8.

What is the percentage of ^{11}B atoms in the sample of boron?

Tick (✓) one box.

- ☐ **A** 8.0%
- ☐ **B** 20%
- ☐ **C** 80%
- ☐ **D** 92%

Q79 · Atomic structure and isotopes · June 2022 · Paper 3 (Unified chemistry) · Q1 · [16 marks]

This question also needs NMR spectroscopy and Transition elements.

These questions are from different areas of chemistry.

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

1(a)(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 marks]

1(a)(ii) Two students discuss the oxidation numbers in ammonium nitrate, NH_4NO_3 .

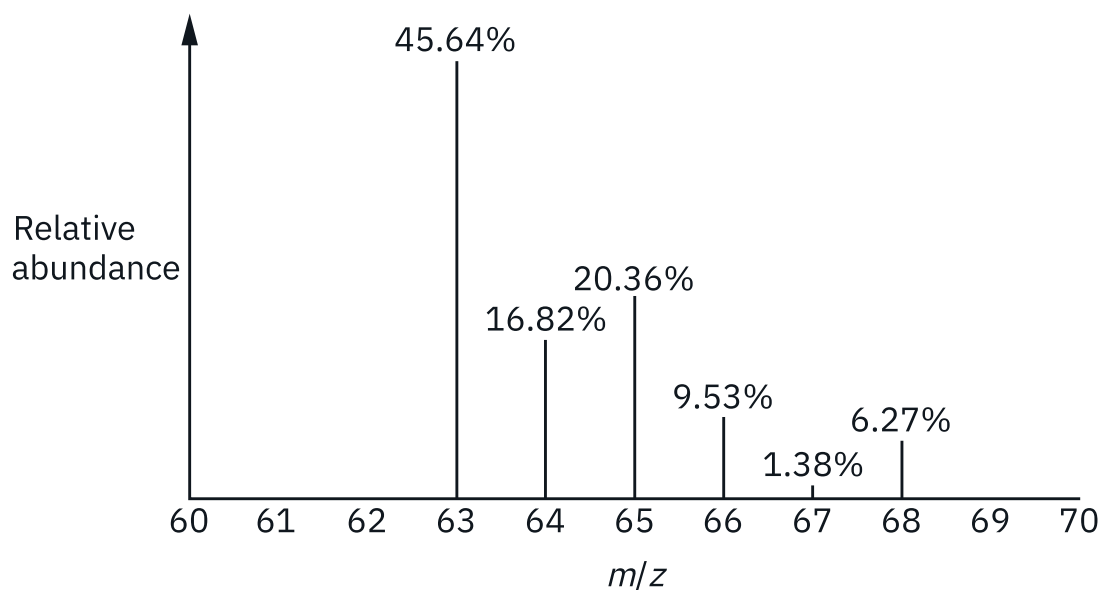
One student claims that the two nitrogen atoms have the same oxidation number. The other student disagrees and claims that the nitrogen atoms have different oxidation numbers.

Explain with reasons which student is correct.

[1 mark]

Brass is an alloy of copper and zinc.

The mass spectrum of a sample of brass is shown below.



The peaks at $m/z = 63$ and $m/z = 65$ are from the ^{63}Cu and ^{65}Cu isotopes of copper.

The remaining four peaks are from isotopes of zinc.

1(b)(i) What are the percentage compositions of copper and zinc in the brass sample?

Cu = % Zn = %

[1 mark]

1(b)(ii) Calculate the relative atomic mass of zinc in the sample of brass.

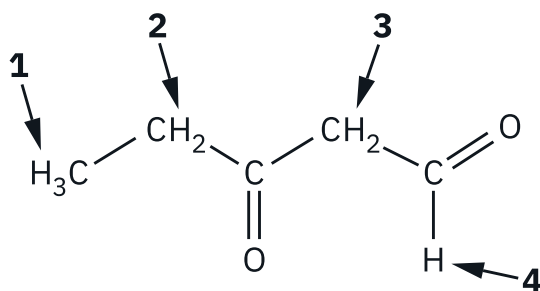
Give your answer to **2** decimal places.

relative atomic mass =

[2 marks]

The structure of an organic compound is shown below.

The protons are in four different environments, which are labelled **1–4**.



1(c)(i) Fill in the table to predict the splitting patterns in the **proton** NMR spectrum of the organic compound.

Proton environment	Splitting pattern
1	
2	
3	
4	

[2 marks]

1(c)(ii) The table shows the chemical shifts for the peaks in the **proton** NMR spectrum at proton environments **2** and **3**.

Proton environment	2	3
Chemical shift, δ	2.5 ppm	3.6 ppm

Suggest why the peaks for proton environments **2** and **3** have the chemical shifts which are shown in the table.

[2 marks]

Glycine, $\text{H}_2\text{NCH}_2\text{COOH}$, is an α -amino acid.

1(d)(i) Glycine reacts with NaOH to form the salt $\text{H}_2\text{NCH}_2\text{COONa}$.

Glycine reacts with HCl to form the salt $\text{HOOCCH}_2\text{NH}_3\text{Cl}$.

The salts have different $\text{H}-\text{N}-\text{H}$ bond angles.

State the different $\text{H}-\text{N}-\text{H}$ bond angles and explain why they are different.

$\text{H}_2\text{NCH}_2\text{COONa}$ $\text{H}-\text{N}-\text{H}$ bond angle = $^\circ$

$\text{HOOCCH}_2\text{NH}_3\text{Cl}$ $\text{H}-\text{N}-\text{H}$ bond angle = $^\circ$

explanation

[3 marks]

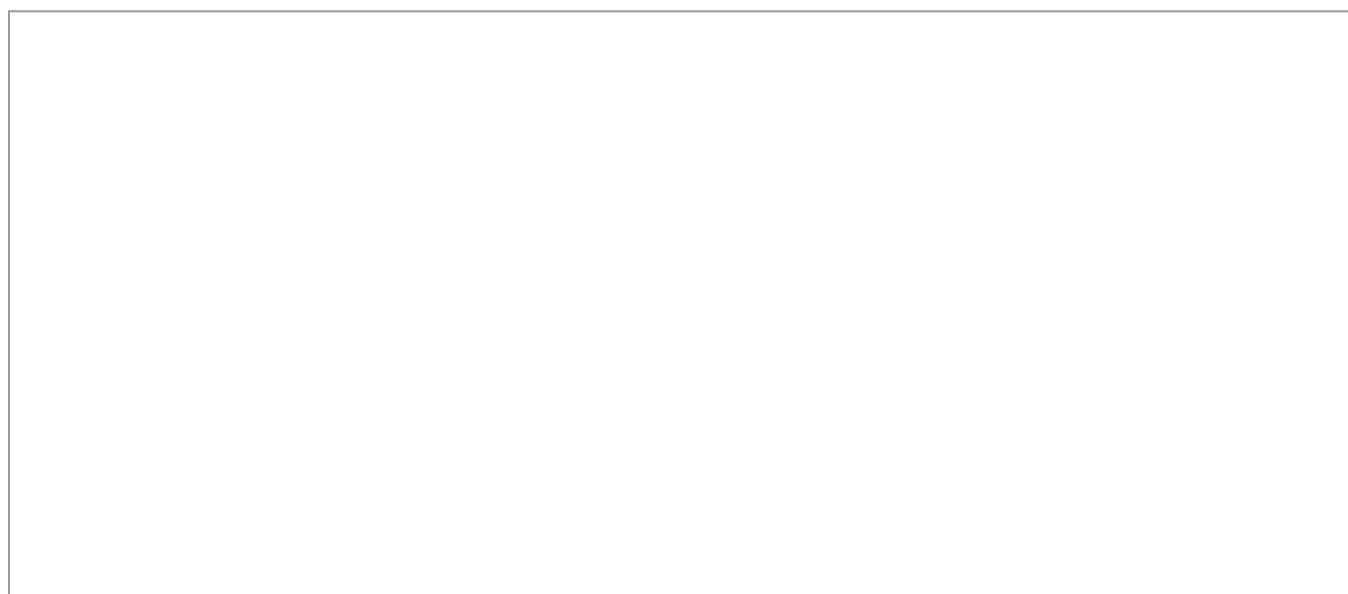
1(d)(ii) Glycine reacts with aqueous copper(II) ethanoate to form copper(II) glycinate, $\text{Cu}(\text{H}_2\text{NCH}_2\text{COO})_2$, and ethanoic acid. Copper(II) glycinate is a complex which exists as two square planar isomers.

Write an equation for this reaction and draw the structures of the two square planar isomers of the complex $\text{Cu}(\text{H}_2\text{NCH}_2\text{COO})_2$.

[3 marks]

equation

structures



• [1 mark]

The table shows the number of protons and neutrons in four different atoms.

Atom	Number of protons	Number of neutrons
W	17	18
X	18	18
Y	19	18
Z	18	19

Which two atoms are isotopes of the same element?

Tick (✓) one box.

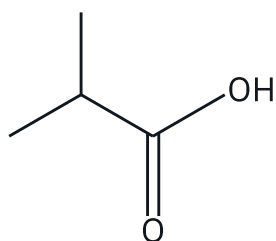
- ☐ **A** W and X
- ☐ **B** X and Y
- ☐ **C** X and Z
- ☐ **D** Y and Z

Q81 • Atomic structure and isotopes • June 2025 • Paper 2 (Synthesis and analytical techniques) • Q11 • [1 mark]

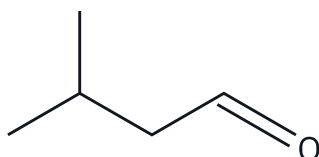
Which molecule does **not** produce a mass spectrum containing a peak at $m/z = 29$?

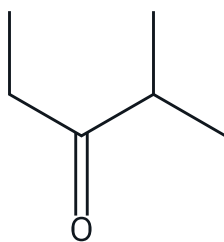
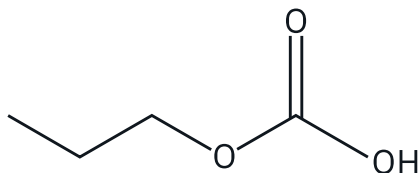
Tick (✓) one box.

☐ **A**



☐ **B**



☐ C☐ D**Q82 · Atomic structure and isotopes · June 2025 · Paper 3 (Unified chemistry) · Q1 · [8 marks]**

This question also needs NMR spectroscopy.

This question is about spectra.

The mass spectrum for Br₂ has peaks at m/z values of 79, 81, 158, 160 and 162.

The peaks at m/z 79 and 81 have virtually the same relative abundance.

1(a)(i) Complete the table to show the number of protons, neutrons and electrons in the particles that cause the peaks at m/z 79 and 81.

m/z	Number of protons	Number of neutrons	Number of electrons
79			
81			

[2 marks]

1(a)(ii) Explain why there are peaks with m/z values of 158, 160 and 162 and predict their relative abundances.

[3 marks]

Explanation

Relative abundances

1(b) This question looks at proton NMR spectra of dibromoalkanes.

Predict the following.

Compound	Number of peaks	CH_2 splitting pattern(s)
$\text{BrCH}_2\text{CH}_2\text{Br}$		
$\text{BrCH}_2\text{CH}_2\text{CH}_2\text{Br}$		

[3 marks]

Q83 · Electrons, bonding and structure · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q15 · [1 mark]

Which electron configuration(s) is/are correct?

1 Cr atom: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$

2 Cu atom: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$

3 Fe^{2+} ion: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$

Tick (✓) one box.

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

Q84 · Electrons, bonding and structure · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q16 · [7 marks]

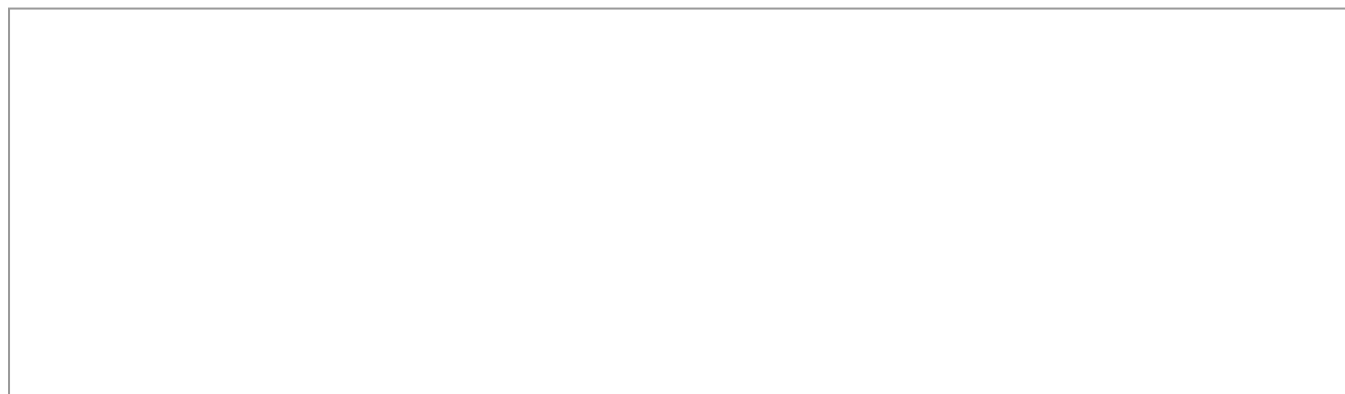
This question is about ions and compounds containing hydrogen.

16(a) Lithium aluminium hydride, $LiAlH_4$, contains the AlH_4^- ion.

Draw a 'dot-and-cross' diagram to show the bonding in an AlH_4^- ion.

Show outer electrons only.

[1 mark]



16(b) Nitrogen forms NH_4^+ and NH_2^- ions.

Predict the name of the shape of, and H–N–H bond angle in, NH_4^+ and NH_2^- .

Ion	Name of shape	H–N–H bond angle
NH_4^+		
NH_2^-		

[2 marks]

Nitrogen, phosphorus and arsenic are in Group 15 (5) of the periodic table.

The boiling points of their hydrides are shown below.

Element	Hydride	Boiling point / °C
N	NH_3	–33
P	PH_3	–88
As	AsH_3	–55

16(c)(i) Explain why the boiling point of PH_3 is lower than the boiling point of NH_3 .

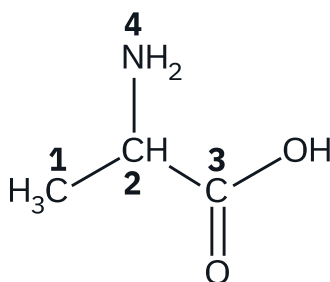
[2 marks]

16(c)(ii) Explain why the boiling point of PH_3 is lower than the boiling point of AsH_3 .

[2 marks]

Q85 · Electrons, bonding and structure · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q6 · [1 mark]

Four atoms, 1–4, are labelled in the structure below.



Which atom has a trigonal planar arrangement of bonds around it?

Tick (✓) one box.

- ☐ **A** Atom 1
- ☐ **B** Atom 2
- ☐ **C** Atom 3
- ☐ **D** Atom 4

Q86 · Electrons, bonding and structure · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q5 · [1 mark]

Which molecule is not planar?

Tick (✓) one box.

- ☐ **A** C_2H_4
- ☐ **B** C_2H_6
- ☐ **C** H_2CO
- ☐ **D** HCN

Q87 · Electrons, bonding and structure · June 2019 · Paper 1 (Periodic table, elements and physical chemistry) ·

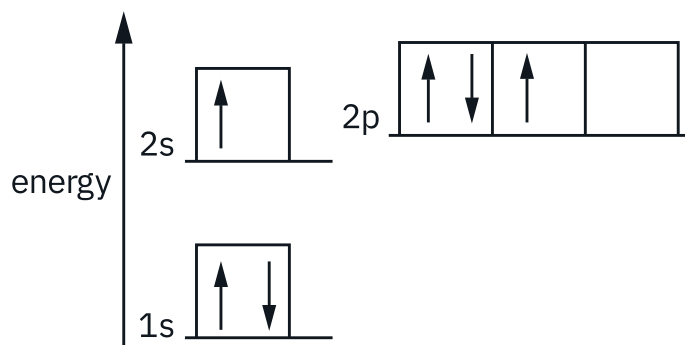
Q1 · [1 mark]

In the diagrams below, each box represents an orbital and each electron is shown as an arrow.

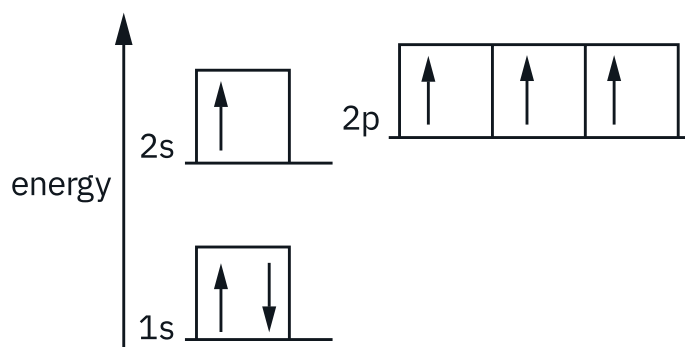
Which diagram shows the correct arrangement of electrons in an atom of carbon?

Tick (✓) one box.

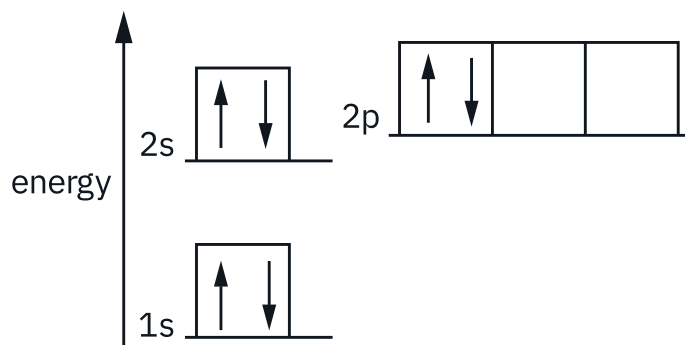
☐ **A**



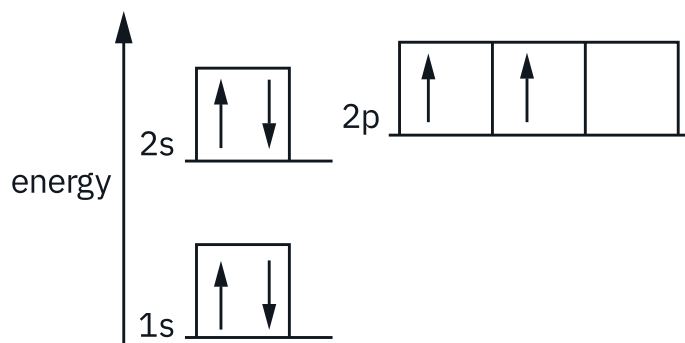
☐ **B**



☐ **C**



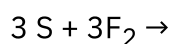
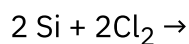
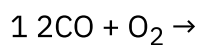
☐ **D**



Q14 · [1 mark]

The three reactions below each form one product only.

Which reaction(s) form(s) a product with non-polar molecules?

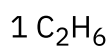


Tick (✓) one box.

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

Q89 · Electrons, bonding and structure · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) · Q13 · [1 mark]

Which substance(s) has/have induced dipole–dipole interactions (London forces) in the solid state?



Tick (✓) one box.

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

Q90 · Electrons, bonding and structure · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) ·

Q5 · [1 mark]

Which compound has polar molecules?

Tick (✓) one box.

☐ **A** HCN

☐ **B** BCl₃

☐ **C** CO₂

☐ **D** C₂F₄

Q91 · Electrons, bonding and structure · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q15 · [1 mark]

Which ion(s) contain(s) bond angles of approximately 120°?

1 CH₃COO⁻

2 C₆H₅O⁻

3 (CH₃)₃C⁺

Tick (✓) one box.

☐ **A** 1, 2 and 3

☐ **B** Only 1 and 2

☐ **C** Only 2 and 3

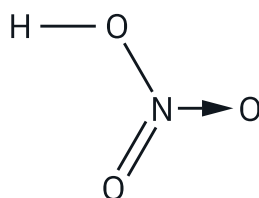
☐ **D** Only 1

Q92 · Electrons, bonding and structure · June 2023 · Paper 3 (Unified chemistry) · Q6 · [23 marks]

This question also needs Equilibrium constants K_c and K_p .

This question is about nitric acid, hydrochloric acid and sulfuric acid.

6(a) Nitric acid has 2 single covalent bonds, 1 double covalent bond and 1 dative covalent bond as shown below.



Nitric acid

Predict the H–O–N and O–N–O bond angles in nitric acid.

Explain your reasoning.

[4 marks]

Dilute nitric acid reacts with aluminium oxide to form a solution of aluminium nitrate.

6(b)(i) Write an equation for this reaction.

[2 marks]

6(b)(ii) The solution contains nitrate ions, NO_3^- .

Draw a 'dot-and-cross' diagram for the NO_3^- ion.

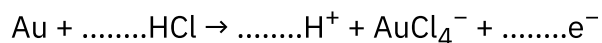
Use a different symbol for the extra electron.

[2 marks]

A mixture of concentrated nitric and hydrochloric acid is called 'aqua regia'. Aqua regia can dissolve gold.

The reaction of aqua regia with gold is a redox reaction which forms chlorauric acid, HAuCl_4 .

6(c)(i) Balance the half-equation for the oxidation process in this reaction.



[1 mark]

6(c)(ii) In the reduction process in this reaction, HNO_3 and H^+ react together to form 2 oxides: X ($M_r = 30$) and Z ($M_r = 18$).

Determine the formulae of X and Z and write the half-equation for this reduction.

X =

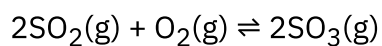
Z =

half-equation

[3 marks]

6(d) In the UK, most sulfuric acid, H_2SO_4 , is manufactured by the Contact process.

One stage in the Contact process involves the equilibrium between sulfur dioxide, oxygen and sulfur trioxide.



This equilibrium is investigated:

Step 1	5.82×10^{-2} mol of SO_2 is mixed with 7.40×10^{-2} mol of O_2 in a 2.00 dm^3 container.
Step 2	The container is sealed and allowed to reach equilibrium at constant temperature.
Step 3	At equilibrium, 5.20×10^{-2} mol of SO_3 is formed.

Determine the equilibrium concentrations and calculate K_c , including units.

$K_c =$ units

[5 marks]

6(e) Three reactions involving sulfuric acid are shown below.

Reaction 1

Dilute sulfuric acid is reacted with nickel(II) hydroxide to form a green solution.

The solvent is allowed to evaporate leaving hydrated crystals of compound D, with the percentage composition by mass: Ni, 22.33%; S, 12.20%; O, 60.87%; H, 4.60%.

Reaction 2

Concentrated sulfuric acid is reacted with hydrogen bromide, HBr, to form three products:

- an element which exists as diatomic molecules
- a gaseous compound E
- a liquid.

At RTP, 1.00 dm³ of compound E has a mass of 2.67 g.

Reaction 3

Concentrated sulfuric acid acts as a catalyst when 2-hydroxypropanoic acid reacts to form compound F ($M_r = 144$).

In this reaction, 2 mol of 2-hydroxypropanoic acid forms 1 mol of compound F and 2 mol of water.

Identify compounds D, E and F and construct equations for the reactions.

Show structures for any organic compounds.

[6 marks]

Q93 · Electrons, bonding and structure · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) · Q1 · [1 mark]

Oxygen has the electron configuration $1s^2 2s^2 2p^4$.

How are the electrons in an atom of oxygen arranged in the p-orbitals?

Tick (✓) one box.

**Q94 · Electrons, bonding and structure · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) · Q14 · [1 mark]**

Chlorine has the electron configuration $[\text{Ne}]3s^2 3p^5$.

Which statement(s) about chlorine is/are correct when it reacts in redox reactions?

- 1 It can gain one electron to form $1-$ ions.
- 2 It can lose its $3s^2$ electrons to form $2+$ ions.
- 3 It can lose its $3p^5$ electrons to form $5+$ ions.

Tick (✓) one box.

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

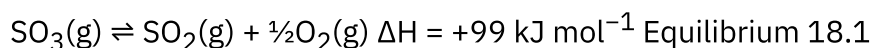
Q95 · Electrons, bonding and structure · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) ·

Q18 · [12 marks]

This question also needs Equilibrium constants K_c and K_p .

This question is about two oxides of sulfur: sulfur dioxide, SO_2 , and sulfur trioxide, SO_3 .

SO_3 decomposes to form SO_2 and O_2 , as shown in Equilibrium 18.1.



18(a)(i) 2.25 moles of SO_3 is heated to 550°C in the presence of a catalyst and the resulting mixture allowed to reach equilibrium.

The equilibrium mixture contains 0.900 mol of SO_2 and the total pressure is 2.80 atm.

Calculate the numerical value for K_p for Equilibrium 18.1 under these conditions and state the units of K_p .

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

$K_p =$

units

[5 marks]

18(a)(ii) The numerical values of K_p for Equilibrium 18.1 at temperatures T_1 and T_2 are shown below.

Temperature	K_p
T_1	3.3×10^{-5}
T_2	7.7×10^{-2}

Explain why T_2 is a higher temperature than T_1 .

[2 marks]

18(a)(iii) Suggest how the value of K_p would change if the reaction was repeated with no catalyst added and the pressure of the system increased.

Tick (✓) one box in each row.

Change	Decrease	No change	Increase
No catalyst			
Increased pressure			

[2 marks]

SO₂ and SO₃ both have molecules with sulfur in the centre and bond angles of approximately 120°.

18(b)(i) Explain why the bond angles in SO₃ are 120°.

[1 mark]

18(b)(ii) Explain why both SO₂ and SO₃ have polar bonds, but only SO₂ has polar molecules.

[2 marks]

Q96 · Electrons, bonding and structure · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) · Q2 · [1 mark]

Water has the anomalous properties below.

- Water has relatively high melting and boiling points.
- Ice is less dense than water.

Which statement explains these anomalous properties?

Tick (✓) one box.

- ☐ **A** The covalent bonding within water molecules.
- ☐ **B** The hydrogen bonding between water molecules.
- ☐ **C** The induced dipole–dipole interactions (London forces) between water molecules.
- ☐ **D** The ionic bonding between water molecules.

Q97 · Electrons, bonding and structure · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) ·

Q5 · [1 mark]

This question also needs Group 2 and the halogens.

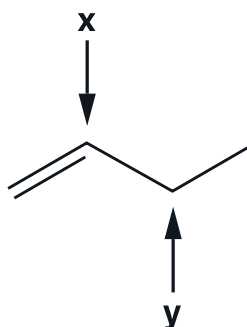
Which statement explains the trend in boiling points down the halogens group?

Tick (✓) one box.

- ☐ **A** The bond enthalpy of the covalent bonds increases.
- ☐ **B** The halogens become less electronegative.
- ☐ **C** The induced dipole–dipole interactions (London forces) become stronger.
- ☐ **D** The reactivity of the halogens decreases.

Q98 · Electrons, bonding and structure · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q4 · [1 mark]

The structure of but-1-ene is shown below.



Which row has the correct **shape** around carbon atoms labelled x and y?

Tick (✓) one box.

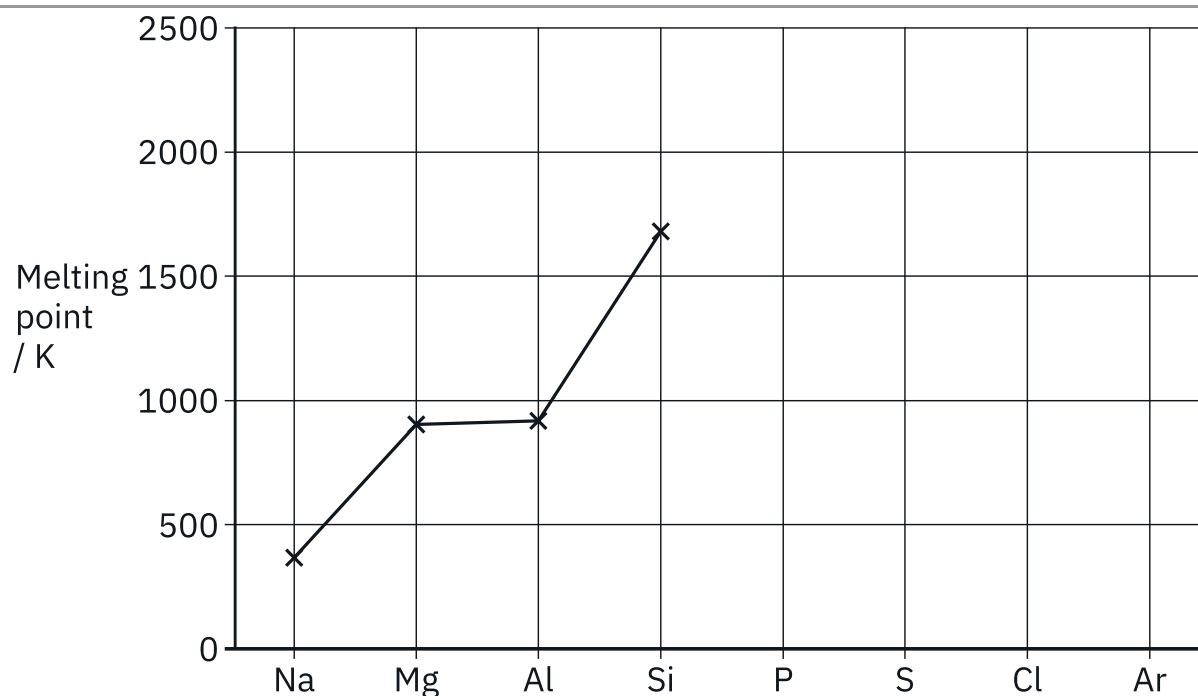
- ☐ **A** x: Tetrahedral · y: Pyramidal
- ☐ **B** x: Trigonal planar · y: Tetrahedral
- ☐ **C** x: Trigonal planar · y: Pyramidal
- ☐ **D** x: Pyramidal · y: Tetrahedral

Q99 · Electrons, bonding and structure · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q16 · [17 marks]

This question also needs Periodicity.

This question is about trends in the periodic table.

The graph shows the melting points for Period 3 elements from sodium to silicon.



16(a)(i) Complete the graph to show approximate melting points for P, S, Cl and Ar.

[2 marks]

16(a)(ii) Explain why silicon has a higher melting point than aluminium.

Use ideas about structure and bonding in your answer.

[3 marks]

The table shows the first ionisation energies for the elements in Period 3.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
First ionisation energy / kJ mol ⁻¹	496	738	578	789	1012	1000	1251	1521

16(b)(i) Write an equation to represent the first ionisation energy of sulfur. Include state symbols.

[1 mark]

16(b)(ii) The table shows that there is a general increase in first ionisation energies across Period 3, but that this trend is **not** followed by phosphorus to sulfur.

Explain why the first ionisation energy of sulfur is **lower** than the first ionisation energy of phosphorus.

[2 marks]

16(c) A student adds an aqueous solution of bromine, $\text{Br}_2(\text{aq})$, to two test tubes.

The student adds aqueous sodium iodide, $\text{NaI}(\text{aq})$, to the $\text{Br}_2(\text{aq})$ in one test tube, and aqueous sodium chloride, $\text{NaCl}(\text{aq})$, to the $\text{Br}_2(\text{aq})$ in the other test tube.

Complete the table to show the student's observations.

Write ionic equation(s) for any reaction(s) that take place.

Solutions	Observations
$\text{Br}_2(\text{aq}) + \text{NaI}(\text{aq})$	
$\text{Br}_2(\text{aq}) + \text{NaCl}(\text{aq})$	

Ionic equation(s)

[3 marks]

16(d) The hydrides of silicon, phosphorus and sulfur have simple molecular structures, but their molecules have different shapes.

Explain why molecules of SiH_4 , PH_3 and H_2S have different shapes.

Your answer should include 'dot-and-cross' diagrams (outer shells only), the names of the shapes and an explanation of why the bond angles are different.

[6 marks]

Q100 · Electrons, bonding and structure · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q7 · [1 mark]

The table below shows the boiling points of some hydrogen halides.

Hydrogen halide	Boiling point / K
HCl	188
HBr	206
HI	238

What is the best explanation for the trend in boiling points from HCl to HI?

Tick (✓) one box.

- ☐ **A** The strength of the covalent bonds increases.
- ☐ **B** The strength of the hydrogen bonds increases.
- ☐ **C** The strength of the induced dipole–dipole interactions (London forces) increases.
- ☐ **D** The strength of the permanent dipole–dipole interactions increases.

Q101 · Electrons, bonding and structure · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q16 · [19 marks]

This question also needs Enthalpy changes and Lattice enthalpy, entropy and free energy.

This question is about magnesium, bromine and magnesium bromide.

16(a) Relative atomic mass is defined as ‘the weighted mean mass compared with 1/12th mass of carbon-12’.

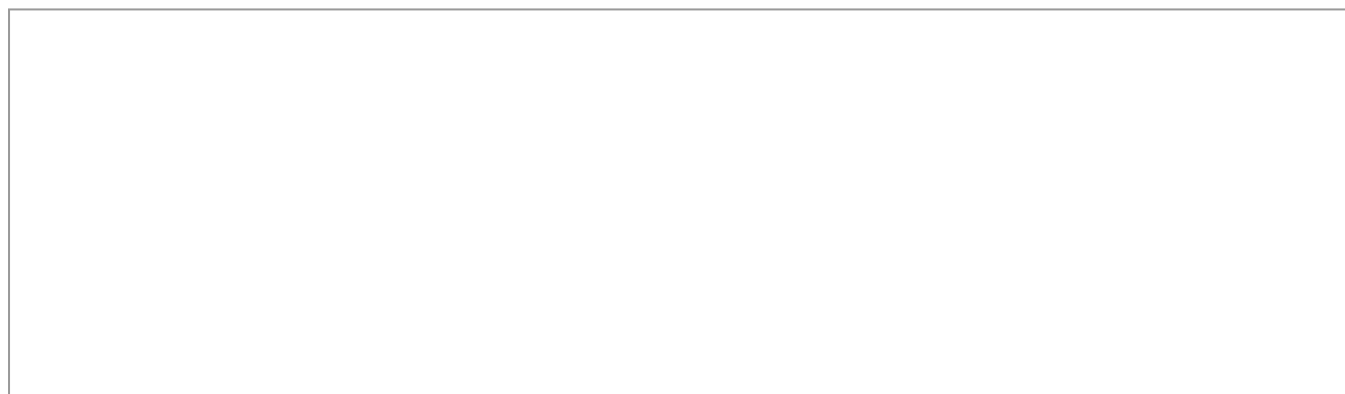
Explain what is meant by the term weighted mean mass.

[1 mark]

16(b)(i) Draw a ‘dot-and-cross’ diagram for MgBr_2 .

Show outer electron shells only.

[2 marks]



16(b)(ii) Calculate the total number of ions in 1.74 g of magnesium bromide, MgBr_2 .

Give your answer to 3 significant figures.

number of ions =

[3 marks]

16(c) Table 16.1 shows some physical properties of magnesium, bromine and magnesium bromide.

Substance	Melting point / °C	Electrical conductivity Solid	Electrical conductivity Liquid
Magnesium	711	Good	Good
Bromine	-7	Poor	Poor
Magnesium bromide	650	Poor	Good

Table 16.1

Explain the physical properties shown in Table 16.1 using your knowledge of structure and bonding.

[6 marks]

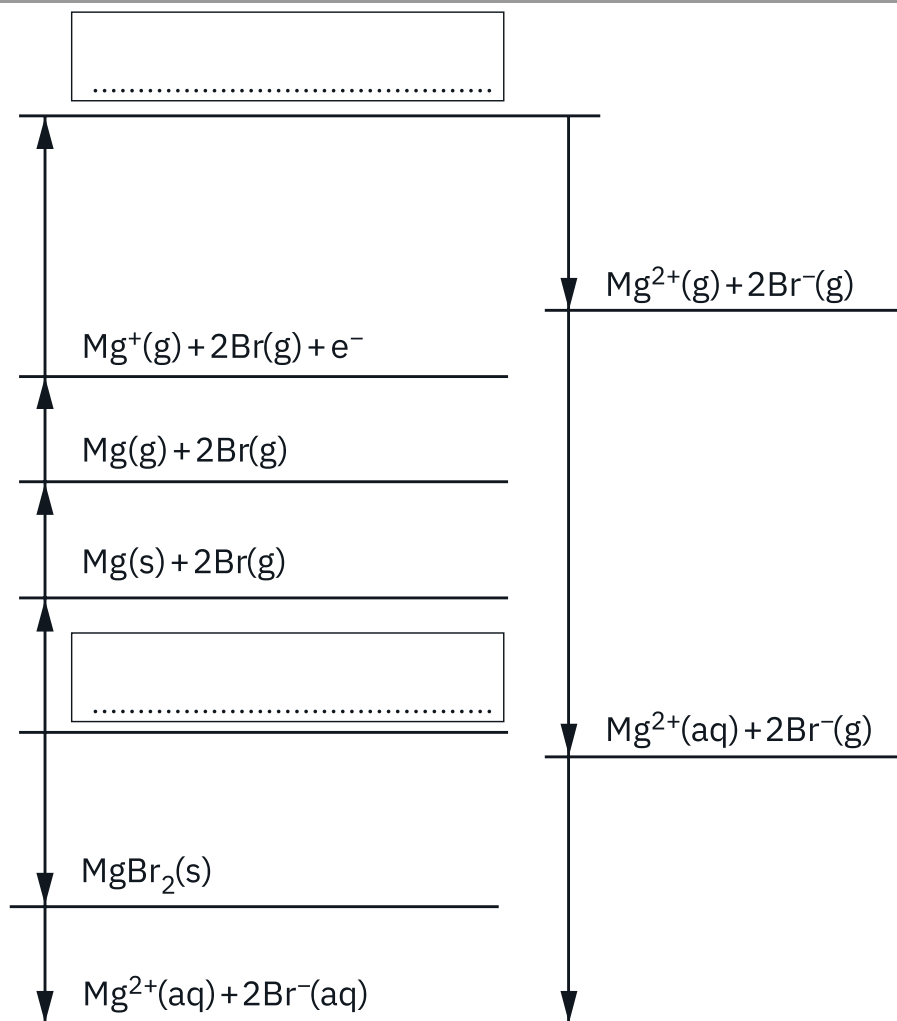
The enthalpy change of hydration of bromide ions can be determined using the enthalpy changes in Table 16.2.

Enthalpy change	Energy / kJ mol^{-1}
1st ionisation energy of magnesium	+736
2nd ionisation energy of magnesium	+1450
atomisation of bromine	+112
atomisation of magnesium	+148
electron affinity of bromine	-325
formation of magnesium bromide	-525
hydration of bromide ion	to be calculated
hydration of magnesium ion	-1926
solution of magnesium bromide	-186

Table 16.2

16(d)(i) An incomplete energy cycle based on Table 16.2 is shown below.

On the dotted lines, add the species present, including state symbols.



[2 marks]

16(d)(ii) Using your completed energy cycle in 16(d)(i), calculate the enthalpy change of hydration of bromide ions.

enthalpy change of hydration = kJ mol^{-1}

[2 marks]

16(d)(iii) Write the equation for the lattice enthalpy of magnesium bromide and calculate the lattice enthalpy of magnesium bromide.

[3 marks]

Equation

Calculation

lattice enthalpy = kJ mol^{-1}

Q102 · Electrons, bonding and structure · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q5 · [1 mark]

Which statement about elements in the d block of Period 4 of the periodic table is correct?

Tick (✓) one box.

- ☐ **A** Cr atoms have the electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$.
- ☐ **B** Cu^+ ions contain an incomplete 3d sub-shell.
- ☐ **C** Fe^{2+} ions contain 3 unpaired electrons.
- ☐ **D** Sc forms ions with different oxidation states.

Q103 · Electrons, bonding and structure · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q1 · [1 mark]

Which statement describes electronegativity?

Tick (✓) one box.

- ☐ **A** A measure of the reactivity of an element.
- ☐ **B** The ability of an atom to attract an electron to become a 1– ion.
- ☐ **C** The attraction of a bonded atom for the electrons in a covalent bond.
- ☐ **D** The attraction of an atom for a lone pair of electrons.

Q104 · Electrons, bonding and structure · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q13 · [1 mark]

This question also needs Group 2 and the halogens.

Which statement(s) explain(s) the trend in boiling points down the halogens group?

1: The induced dipole–dipole interactions (London forces) become stronger.

2: The covalent bonds become stronger.

3: The permanent dipole–dipole interactions become stronger.

Tick (✓) one box.

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

Q105 · Electrons, bonding and structure · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q14 · [1 mark]

Which statement(s) about a molecule of Cl–N=O is/are correct?

- 1: It is a polar molecule.
- 2: It contains 6 lone pairs of electrons.
- 3: It has a bond angle of 180°.

Tick (✓) one box.

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

Q106 · Electrons, bonding and structure · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q8 · [1 mark]

Which compound contains a bond angle of approximately 120°?

Tick (✓) one box.

- ☐ **A** CH₃CH₂CN
- ☐ **B** CH₃CH(OH)CH₃
- ☐ **C** CH₃COOCH₂CH₂CH₃
- ☐ **D** CH₃CH₂CH₂NH₂

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