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Tuesday 2 June 2026 – Morning

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry A

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **32** pages.

ADVICE
- Read each question carefully before you start your answer.

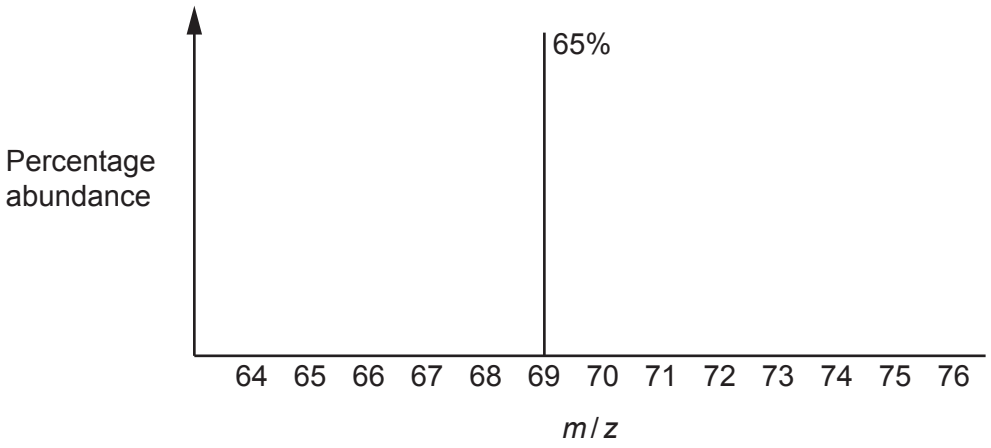
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Section A

You should spend a **maximum** of **20 minutes** on this section.

Write your answer to each question in the box provided.

1 A sample of gallium with a relative atomic mass of 69.7 has two isotopes. The mass spectrum shows the percentage abundance of one of the isotopes.



What is the mass-to-charge ratio, m/z, of the other isotope of gallium?

A 67

B 68

C 70

D 71

Your answer ☐ **[1]**

2 The reaction for the complete combustion of butane is

$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

What is the volume of oxygen, in cm^3, needed for the complete combustion of 0.0100 mol of butane at room temperature and pressure (RTP)?

A 156

B 312

C 369

D 1560

Your answer ☐ **[1]**

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3 Which increase explains the trend in the boiling points down the halogen group?

A The strength of the covalent bonds

B The strength of the hydrogen bonds

C The strength of the induced dipole–dipole interactions (London forces)

D The strength of the permanent dipole–dipole interactions

Your answer ☐ **[1]**

4 3.56 g of element **X** combines with O_2 to form 4.52 g of an oxide, **X**O_2.

Which element is **X**?

A Si

B Ge

C Sn

D Pb

Your answer ☐ **[1]**

5 25.0 cm^3 of sodium hydroxide solution is added to 25.0 cm^3 of dilute hydrochloric acid.

The maximum temperature of the mixture formed is 27 °C.

The reaction releases 1045 J of energy.

What was the initial temperature of the dilute hydrochloric acid, in °C?

(Assume the specific heat capacity, c, of the mixture is the same as for water.)

A 17

B 22

C 32

D 37

Your answer ☐ **[1]**

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6 An equilibrium equation between $N_2(g)$, $H_2(g)$ and $NH_3(g)$ is shown.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The numerical value of K_p at 600 K for this equilibrium is 1.66×10^{-3}.

A different equilibrium equation between $N_2(g)$, $H_2(g)$ and $NH_3(g)$ is shown.

$\frac{1}{2}N_2(g) + 1\frac{1}{2}H_2(g) \rightleftharpoons NH_3(g)$

What is numerical value of K_p, at 600 K, for this equilibrium equation?

A 2.76×10^{-6}

B 8.30×10^{-4}

C 3.32×10^{-3}

D 4.07×10^{-2}

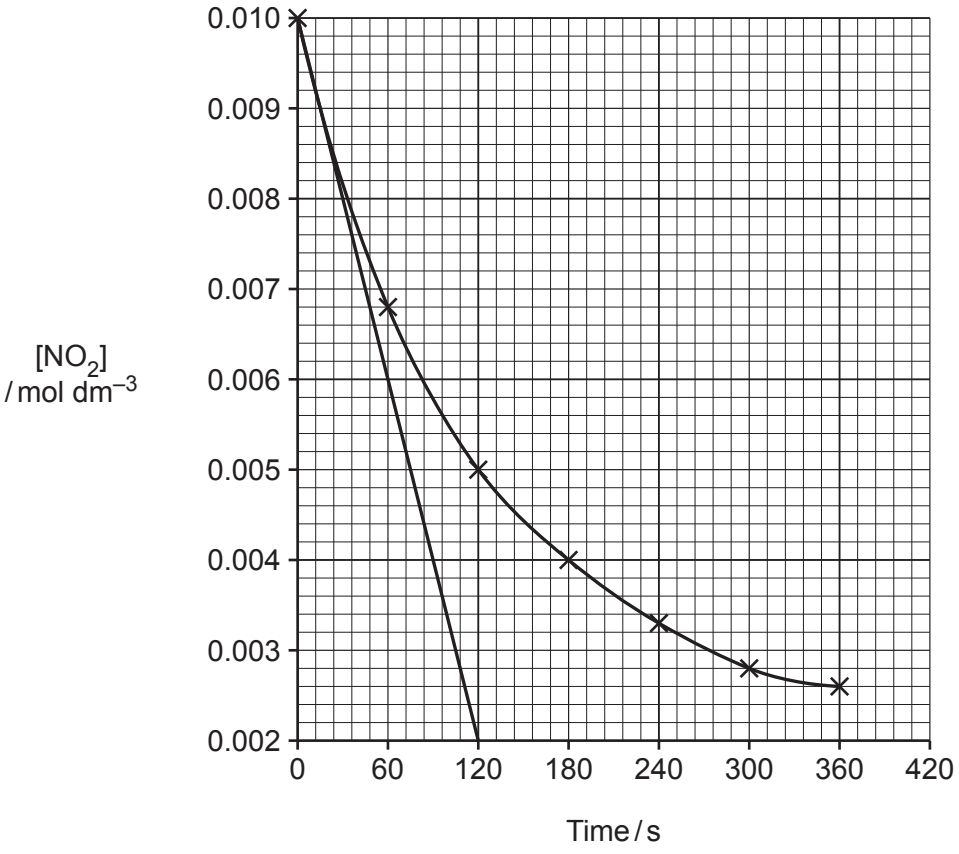
Your answer ☐ **[1]**

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7 Nitrogen dioxide, NO_2, decomposes to form nitrogen monoxide and oxygen.

The graph shows how the concentration of nitrogen dioxide changes over time during this reaction.

The tangent at $t = 0$ is also shown.



What is the initial rate of reaction, in mol dm^{-3} s^{-1}?

A 6.7×10^{-5}

B 8.3×10^{-5}

C 1.2×10^{4}

D 1.5×10^{4}

Your answer ☐ **[1]**

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8 Sulfurous acid, H_2SO_3, has two dissociation constants, as shown below.

Equation 8.1 $H_2SO_3(aq) \rightleftharpoons H^+(aq) + HSO_3^-(aq)$ $K_a = 1.20 \times 10^{-2}\,mol\,dm^{-3}$

Equation 8.2 $HSO_3^-(aq) \rightleftharpoons H^+(aq) + SO_3^{2-}(aq)$ $K_a = 6.61 \times 10^{-8}\,mol\,dm^{-3}$

Which statement is correct?

A H_2SO_3 acts as a strong acid and HSO_3^- acts as a weak acid.

B H_2SO_3 is a weaker acid than HSO_3^-.

C The percentage dissociation in **Equation 8.1** is greater than the percentage dissociation in **Equation 8.2**.

D The pK_a value for **Equation 8.1** is greater than the pK_a value for **Equation 8.2**.

Your answer ☐ **[1]**

9 A student makes a buffer solution by mixing solutions of ethanoic acid, $CH_3COOH(aq)$, and sodium hydroxide, NaOH(aq).

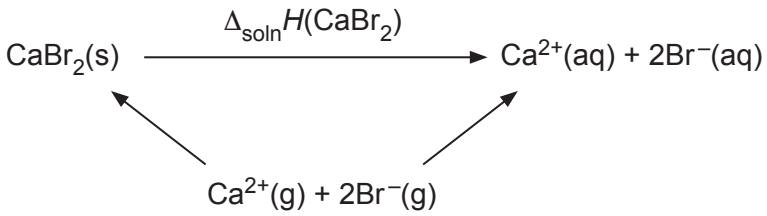
Which row in the table shows the volumes and concentrations of $CH_3COOH(aq)$ and NaOH(aq) that forms a buffer solution?

	$CH_3COOH(aq)$		**NaOH(aq)**	
	Volume / cm^3	**Concentration / $mol\,dm^{-3}$**	**Volume / cm^3**	**Concentration / $mol\,dm^{-3}$**
A	5	0.1	10	0.1
B	10	0.1	5	0.1
C	10	0.1	10	0.1
D	10	0.1	10	0.5

Your answer ☐ **[1]**

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10 The enthalpy cycle below can be used to calculate the enthalpy change of solution of calcium bromide $CaBr_2$.



Which expression is correct?

A $\Delta_{soln}H(CaBr_2) = \Delta_{LE}H(CaBr_2) + \Delta_{hyd}H(Ca^{2+}) + \Delta_{hyd}H(Br^-)$

B $\Delta_{soln}H(CaBr_2) = \Delta_{LE}H(CaBr_2) + \Delta_{hyd}H(Ca^{2+}) + 2\Delta_{hyd}H(Br^-)$

C $\Delta_{soln}H(CaBr_2) = \Delta_{hyd}H(Ca^{2+}) + \Delta_{hyd}H(Br^-) - \Delta_{LE}H(CaBr_2)$

D $\Delta_{soln}H(CaBr_2) = \Delta_{hyd}H(Ca^{2+}) + 2\Delta_{hyd}H(Br^-) - \Delta_{LE}H(CaBr_2)$

Your answer ☐ **[1]**

11 25.0 cm^3 of an iron(II) sulfate solution of unknown concentration is acidified and titrated with a 0.0200 $mol\,dm^{-3}$ potassium manganate(VII) solution.

How could the percentage uncertainty in the titre be reduced?

A Increasing the concentration of the potassium manganate(VII) solution.

B Increasing the volume of the iron(II) sulfate solution.

C Repeating the titration to obtain concordant titres.

D Using an indicator.

Your answer ☐ **[1]**

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12 Magnesium reacts with aqueous phosphoric acid as shown below.

$3Mg(s) + 2H_3PO_4(aq) \rightarrow Mg_3(PO_4)_2(aq) + 3H_2(g)$

What is the minimum mass of magnesium needed to react completely with 250 cm^3 of 0.200 $mol\,dm^{-3}$ $H_3PO_4(aq)$?

A 0.81 g

B 1.22 g

C 1.82 g

D 3.65 g

Your answer ☐ **[1]**

13 Which equation does **not** represent a disproportionation reaction?

A $3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$

B $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$

C $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

D $3BrF \rightarrow BrF_3 + Br_2$

Your answer ☐ **[1]**

14 $NH_3(aq)$ is added dropwise to three separate solutions until in excess.

Which solution(s) form(s) a precipitate which dissolves in excess $NH_3(aq)$?

1 $Cr^{3+}(aq)$

2 $Fe^{2+}(aq)$

3 $Mn^{2+}(aq)$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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15 The equilibrium mixture containing sulfur dioxide, oxygen, and sulfur trioxide is shown below.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

At 500 K, the value of K_p is 2.5×10^{10} atm^{-1}.

Which of the following changes to the equilibrium mixture would **not** affect the value of K_p?

1 Adding a catalyst

2 Changing the total pressure

3 Changing the concentration of $SO_2(g)$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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Section B

16 This question is about Period 3 elements and their ions.

(a) The table shows the first six successive ionisation energies of aluminium.

	1st	2nd	3rd	4th	5th	6th
Ionisation energy / kJ mol^{-1}	578	1817	2745	11 578	14 831	18 378

(i) Write an equation to represent the **third** ionisation energy of aluminium.

Include state symbols.

..... **[1]**

(ii) For aluminium there is:

- a gradual increase from the 1st ionisation energy to the 3rd ionisation energy, and
- a large increase from the 3rd ionisation energy to the 4th ionisation energy.

Explain why.

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

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(b) Magnesium and chlorine both take part in redox reactions.

(i) The reaction between magnesium and hydrochloric acid is an example of a redox reaction.

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

Use oxidation numbers to show which element has been oxidised and which has been reduced.

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

(ii) The reaction between chlorine gas and aqueous potassium iodide is also a redox reaction.

Write an ionic equation for the reaction and explain why this reaction takes place in terms of the reactivity of the halogens.

Ionic equation .....

Explanation .....

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[3]

Question 16(c) starts on page 12

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(c) Magnesium chloride is formed from the reaction of magnesium and chlorine.

$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$ $\Delta H^{\ominus} = -641\,kJ\,mol^{-1}$ **Equation 16.1**

(i) Most enthalpy changes are given under standard conditions and standard states.

Explain what is meant by standard conditions **and** standard state.

Standard conditions .....

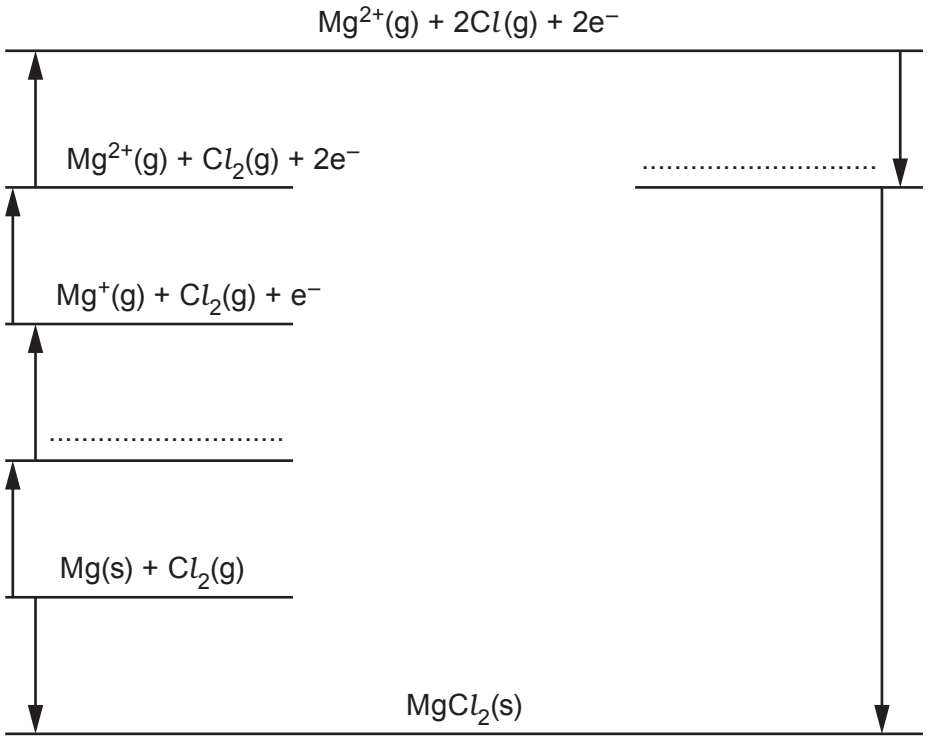
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Standard state .....

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[1]

(ii) Complete the Born-Haber cycle for the reaction.



[2]

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(iii) Some enthalpy changes are given in the table.

Energy term	**Enthalpy change / kJ mol^{-1}**
Atomisation of magnesium	+148
1st ionisation energy of magnesium	+738
2nd ionisation energy of magnesium	+1451
1st electron affinity of chlorine	–349
Lattice enthalpy of magnesium chloride	–2526

Calculate the enthalpy change of atomisation of chlorine.

Use the values in the table and the value for $\Delta H^{\ominus}$ shown in **Equation 16.1**.

Enthalpy change of atomisation of chlorine = ... kJ mol^{-1} **[2]**

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17 This question is about compounds of cobalt and copper.

Cobalt and copper are both transition elements in Period 4.

(a) What is meant by a **transition element**?

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..... **[1]**

(b) In its compounds, the common oxidation states of cobalt are +2 and +3.

(i) Complete the electron configuration of cobalt in its +2 oxidation state.

$1s^2$ ..... **[1]**

(ii) Cobalt is able to form complex ions.

The complex ion $[CoCl_4]^{2-}$ can be made by adding concentrated hydrochloric acid (as a source of chloride ions) to a solution containing $[Co(H_2O)_6]^{2+}$ ions.

Construct an ionic equation for the reaction and state the type of reaction that takes place.

Equation .....

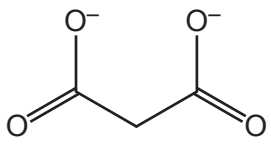
Type of reaction .....

[2]

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(iii) A chemist suggests that Co(III) ions should react with propanedioate ions to form a complex ion, $[Co(C_3H_2O_4)_3]^{3-}$.

The propanedioate ion, which is shown below, is a bidentate ligand.



The chemist predicts that the complex ion would exist as two optical isomers.

Explain how a propanedioate ion is able to act as a bidentate ligand.

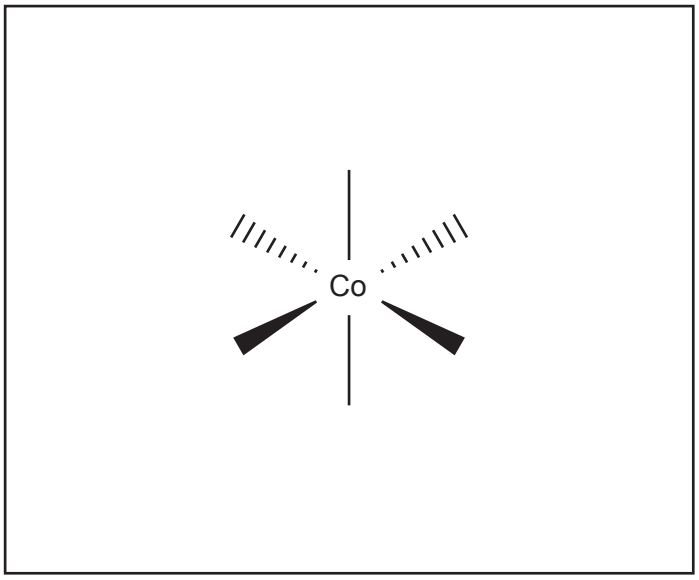
Complete the diagrams below to show the structures of the two optical isomers.

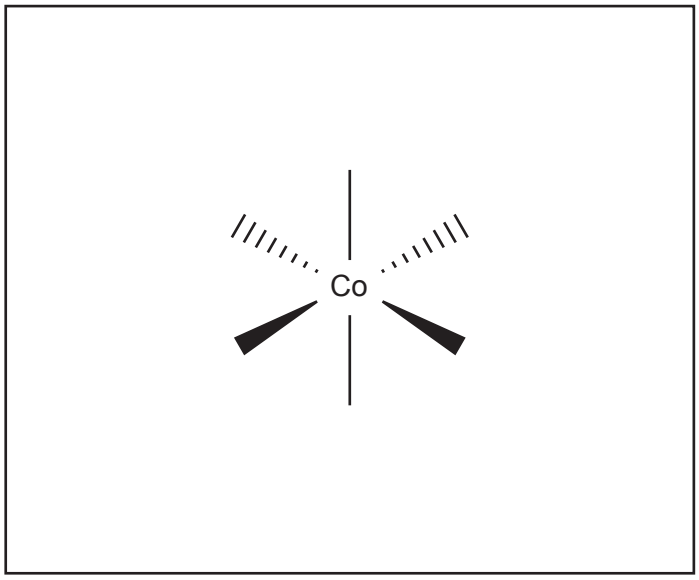
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[3]

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(c) Hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$ undergoes dehydration at 450 K as shown in the equation below.

$CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(g)$ $\quad \Delta H = +299\,kJ\,mol^{-1}$, $\Delta S = +754\,J\,K^{-1}\,mol^{-1}$

(i)* Explain why ΔH and ΔS are both positive.

Show that this reaction is feasible at 450 K and explain how changes in temperature affect the feasibility of this reaction.

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Additional answer space if required.

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(ii) A sample of $CuSO_4 \cdot 5H_2O(s)$ is heated to remove all the water of crystallisation. The mass of water lost is recorded.

The mass of water obtained is 6.05 g.

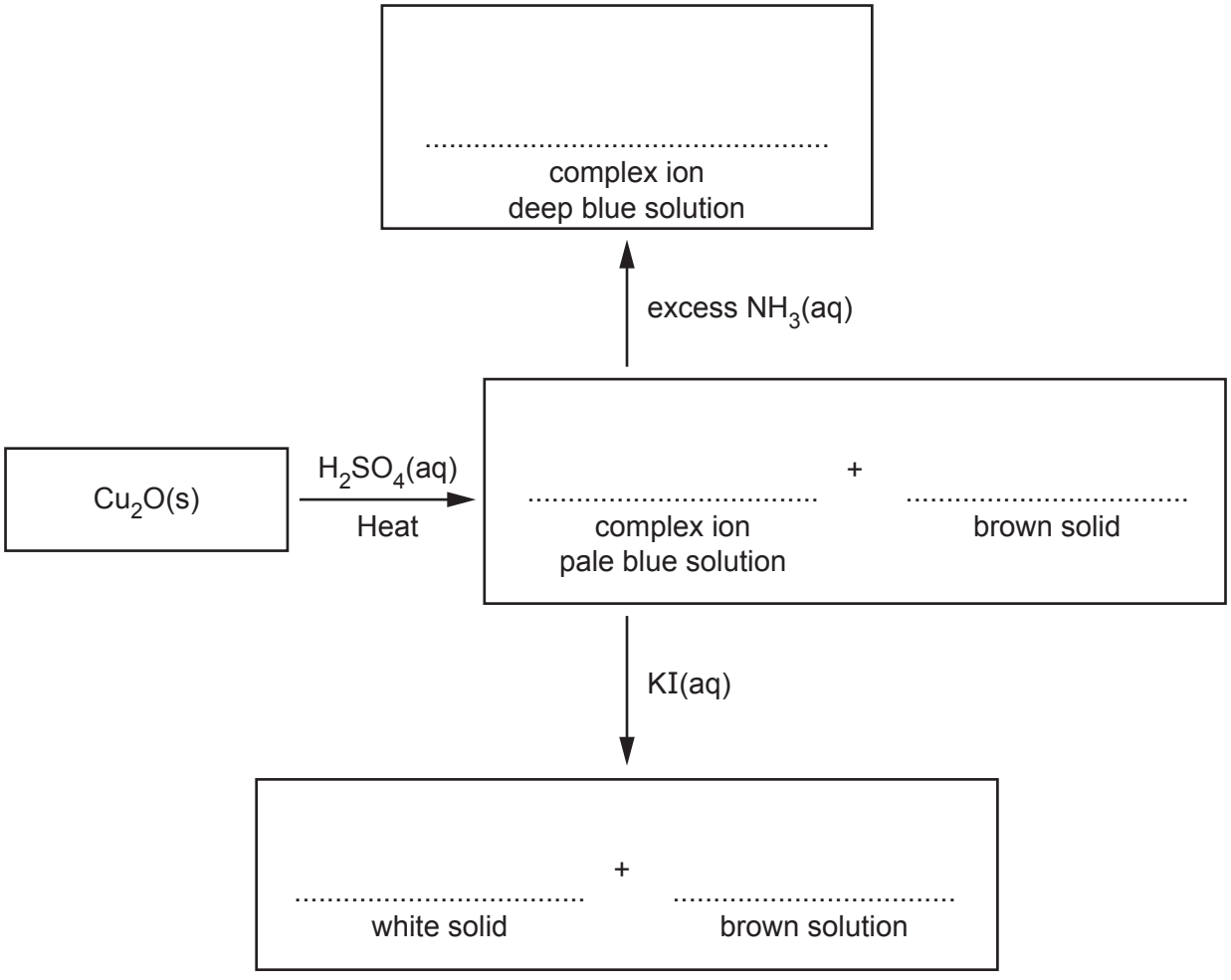
Calculate the mass of the sample of $CuSO_4 \cdot 5H_2O(s)$ that was heated.

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

Mass of $CuSO_4 \cdot 5H_2O(s)$ = ...g **[3]**

(iii) The flowchart shows reactions of copper(I) oxide, Cu_2O.

Complete the flowchart by adding the formulae of the species responsible for the observations.



[5]

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18 This question is about how observations can be used to make deductions about chemical reactions.

(a)* A double salt is a salt that contains two different cations or two different anions.

Hydrated ammonium iron(III) sulfate is a double salt with the formula $NH_4Fe(SO_4)_2 \cdot 12H_2O$. Its common name is iron alum.

Iron alum is a crystalline solid which is soluble in water. It contains two cations and one anion.

A student carries out a series of test-tube tests to identify which ions are present in iron alum.

Outline how the student would carry out the tests and describe the expected observations.

Include ionic equations for reactions which take place.

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Extra answer space if required

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Question 18(b) starts on Page 20

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(b) In its ions, vanadium is found with four common oxidation numbers from +2 to +5.

Table 18.1 shows the colours of some vanadium containing ions in aqueous solution.

Table 18.1

Oxidation number of vanadium	Ion	Colour
+2	$V^{2+}(aq)$	violet
+3	$V^{3+}(aq)$	green
+4	$VO^{2+}(aq)$	blue
+5	$VO_2^{+}(aq)$	yellow

Table 18.2 shows some standard electrode potentials $E^{\ominus}$.

Table 18.2

Redox system	Half-equation	$E^{\ominus}$ / V
1	$V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$	–1.18
2	$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
3	$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
4	$VO_2^{+}(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00

(i) Write the formulae of the strongest reducing agent and the strongest oxidising agent shown in **Table 18.2**.

Strongest reducing agent .....

Strongest oxidising agent .....

[2]

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(ii) A student adds an aqueous solution of iodine, $I_2(aq)$, **dropwise** to a solution containing $V^{2+}(aq)$ ions until there is no further colour change and the iodine is in excess.

The $I_2(aq)/2I^-(aq)$ redox system has a standard electrode potential of +0.54 V.

Predict the colour changes that the student would observe.

Use the information in **Table 18.1** and **Table 18.2** to explain your predictions in terms of electrode potentials and equilibria shifts.

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..... **[5]**

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19 Syngas is a mixture of carbon monoxide and hydrogen which is used in the chemical industry as a feedstock for a range of chemicals.

(a) Syngas can be produced by reacting methane and carbon dioxide in the presence of a suitable catalyst.

$CH_4(g) + CO_2(g) \rightleftharpoons 2CO(g) + 2H_2(g)$ $\Delta H = +247\,kJ\,mol^{-1}$ **Equilibrium 19.1**

(i) Explain, in terms of le Chatelier's principle, the conditions of pressure and temperature needed to produce a high equilibrium yield of syngas.

Explain why the operational conditions used by the chemical industry may be different.

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..... **[4]**

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(ii) 0.650 mol of CH_4 is added to 0.825 mol CO_2 in a 500 cm^3 flask and the reaction mixture is allowed to reach equilibrium at a constant temperature. At equilibrium the amount of CO present is 0.244 mol.

Calculate the value of K_c for **Equilibrium 19.1** at this temperature, including units.

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

K_c = ... units ..... **[5]**

(b)

(i) Syngas can also be produced from methane and steam.

Construct an equation for this production of syngas.

..... **[1]**

(ii) Suggest why the production of syngas from **Equilibrium 19.1** is regarded as being more beneficial to the environment than using methane and steam.

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..... **[1]**

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20 The question is about the pH of solutions at 298 K.

(a) Calculate the pH of 0.35 mol dm^{-3} nitric acid, HNO_3.

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

pH ..... **[1]**

(b)

(i) Barium hydroxide, $Ba(OH)_2$, is a strong base.

What is meant by a strong base?

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..... **[1]**

(ii) Write the equation for the reaction that takes place between HNO_3 and $Ba(OH)_2$.

..... **[1]**

(iii) A student adds 25.0 cm^3 of 0.0800 mol dm^{-3} HNO_3 to 100 cm^3 of 0.0500 mol dm^{-3} $Ba(OH)_2$.

Calculate the pH of the final solution.

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

pH = ... **[5]**

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(c) The student measures the pH of 0.100 mol dm^{-3} solutions of three bases.

- aqueous ammonia
- barium hydroxide
- potassium hydroxide

Predict the order of pH values, from lowest to highest, for the three 0.100 mol dm^{-3} solutions.

Explain your predictions.

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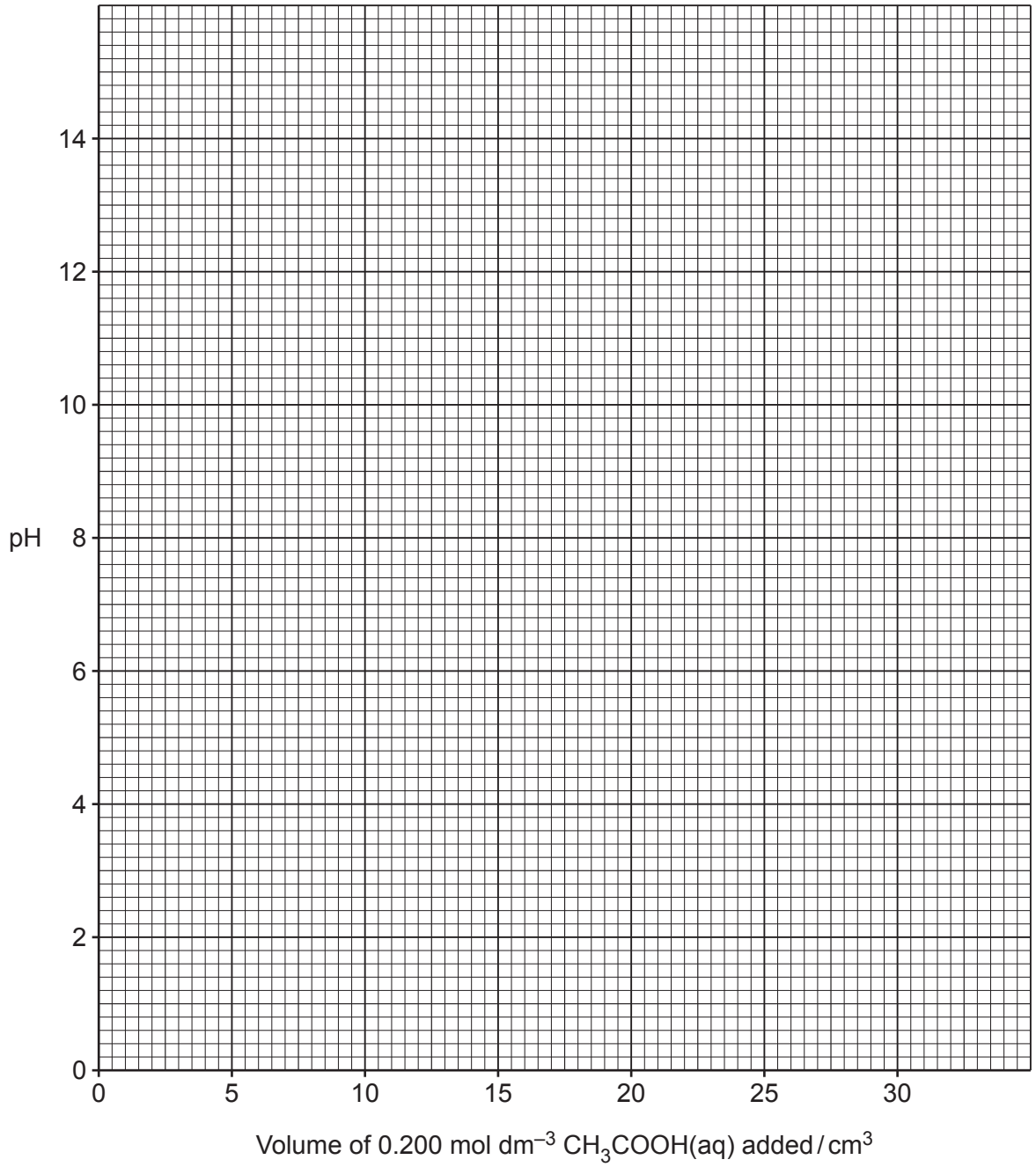
..... **[3]**

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(d)

(i) A student gradually adds 0.200 mol dm^{-3} ethanoic acid $CH_3COOH(aq)$ to 25.0 cm^3 of 0.100 mol dm^{-3} NaOH(aq) and monitors the pH throughout.
A total of 30.0 cm^3 of 0.200 mol dm^{-3} $CH_3COOH(aq)$ is added.

Use this information to sketch the pH titration curve that the student obtains.



[4]

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(ii) How could the student use the pH titration curve to identify an appropriate indicator for this reaction?

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..... **[1]**

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21 Hydrogen peroxide, H_2O_2, decomposes to form oxygen and water in the presence of manganese(IV) oxide, MnO_2, as a catalyst.

(a) A group of students carries out a series of experiments to determine the order of reaction with respect to H_2O_2.

The students use different initial concentrations of $H_2O_2(aq)$ with the MnO_2 catalyst and measure the time taken to produce $10.0\,cm^3$ of oxygen.

(i) Suggest **two** variables which must be kept constant in this series of experiments.

1 .....

2 .....

[1]

(ii) The students use their results to calculate the initial rate of reaction as shown in the table below.

Experiment	Initial $[H_2O_2]$ / mol dm^{-3}	Initial rate of reaction / $cm^3\,s^{-1}$
1	0.200	0.50
2	0.300	0.75
3	0.500	1.25

Use the values in the table to determine the order of reaction with respect to H_2O_2.

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

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(b)

(i) The rate constant, k, for the reaction is $1.2 \times 10^{-3}\ s^{-1}$ at 300 K.

Use the Arrhenius equation to calculate the activation energy of the reaction.

The value of A (the pre-exponential factor) for this reaction is $4.33 \times 10^{7}\ s^{-1}$.

E_a = ... kJ mol^{-1} **[2]**

(ii) The overall equation for decomposition of H_2O_2 is:

$2H_2O_2 \rightarrow 2H_2O + O_2$

One suggested reaction mechanism for the decomposition of H_2O_2 assumes that MnO_2 contains the Mn^{4+} ion.

Part of the suggested reaction mechanism is shown below.

Step 1 $Mn^{4+} + H_2O_2 \rightarrow H^+ + Mn^{3+} + HO_2$

Step 2 HO_2 + ... → ..... + ... + ...

Step 3 $HO + Mn^{3+} \rightarrow Mn^{4+} + OH^-$

Step 4 ..... + ... → .....

Complete the equations for Step 2 and Step 4. **[2]**

Question 21(b)(iii) starts on page 30

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(iii) MnO_2 can be made by the redox reaction between manganese(II) sulfate and acidified potassium manganate(VII).

The half equations are shown below.

$Mn^{2+} + 2H_2O \rightarrow MnO_2 + 4H^+ + 2e^-$

$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$

Construct the overall equation for the reaction.

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

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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