OCR
Oxford Cambridge and RSA

Tuesday 10 June 2025 – 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 page 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

Section A

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

Write your answer to each question in the box provided.

1 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?

A **W** and **X**

B **X** and **Y**

C **X** and **Z**

D **Y** and **Z**

Your answer [ ] **[1]**

2 11.895 g of hydrated cobalt(II) chloride, $CoCl_2 \bullet \mathbf{x}H_2O$, 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**?

A 3

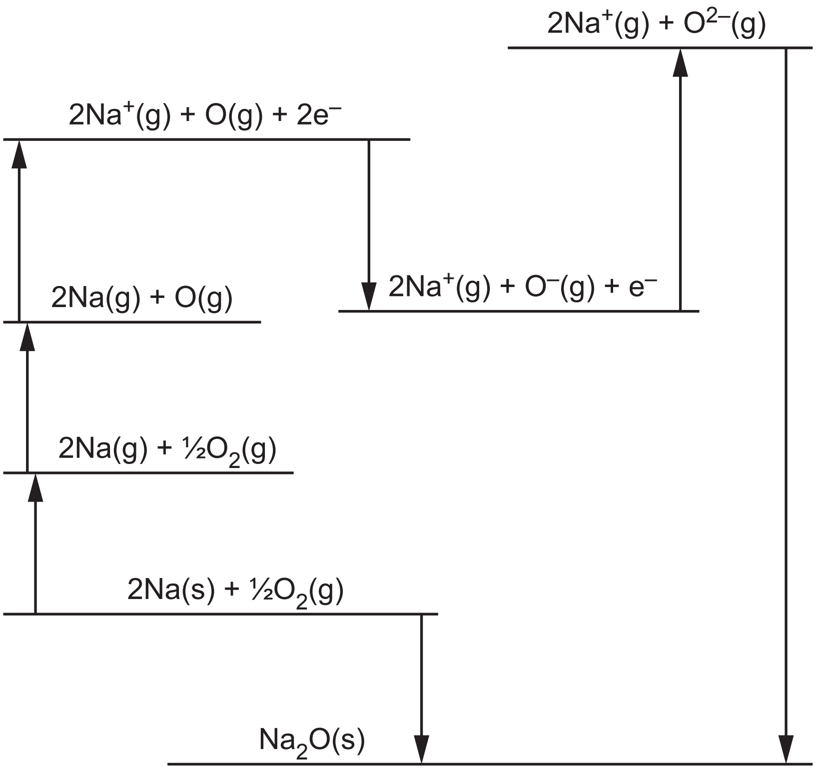
B 5

C 6

D 7

Your answer [ ] **[1]**

3 The diagram shows the Born-Haber cycle for sodium oxide, Na_2O.



Why is the value for the second electron affinity of oxygen positive?

A An electron is added to a high energy orbital.

B An electron is added to a negative ion.

C An electron is removed from a gaseous atom.

D An electron is removed from a positive ion.

Your answer ☐ **[1]**

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

$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

A 5.75

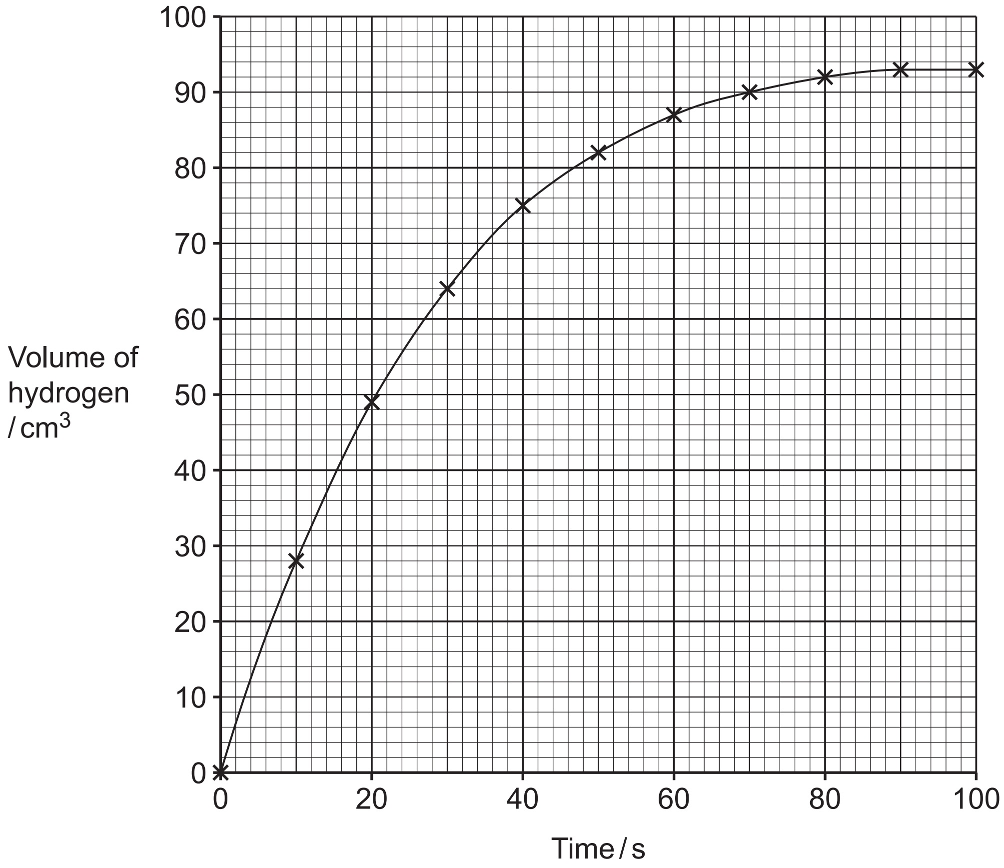
B 11.50

C 23.00

D 54.35

Your answer ☐ **[1]**

5 The graph shows the volume of hydrogen released over time in a chemical reaction.



What is the rate of reaction, in $cm^3\,s^{-1}$, at 30 seconds?

A 0.8

B 1.2

C 2.1

D 2.4

Your answer [ ] **[1]**

6 Methane reacts with oxygen as shown in the equation:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ $\Delta_r H = -730\,kJ\,mol^{-1}$

The table shows some bond enthalpies.

Bond	O–H	O=O	C=O
Bond enthalpy / kJ mol^{-1}	+464	+498	+805

What is the bond enthalpy, in kJ mol^{-1}, of the C–H bond in methane?

A +109

B +367

C +435

D +568

Your answer ☐ **[1]**

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

Hydrogen halide	**Boiling point / K**
HC*l*	188
HBr	206
HI	238

What is the best explanation for the trend in boiling points from HC*l* to HI?

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.

Your answer ☐ **[1]**

8 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 ±0.05 cm^3.

What is the percentage uncertainty of the titre?

A 0.17%

B 0.19%

C 0.34%

D 0.37%

Your answer ☐ **[1]**

9 Hydrogen reacts with iodine monochloride, ICl, as shown in the equation:

$H_2 + 2ICl \rightarrow 2HCl + I_2$

The mechanism for the reaction is:

$H_2 + ICl \rightarrow HCl + HI$ slow step

$HI + ICl \rightarrow HCl + I_2$ fast step

What is the rate equation for the reaction between H_2 and ICl?

A rate = $k[HI]\,[ICl]$

B rate = $k[H_2]\,[ICl]$

C rate = $k[H_2]\,[ICl]^2$

D rate = $k[H_2]\,[HI]\,[ICl]^2$

Your answer ☐ **[1]**

10 The overall equation for a hydrogen–oxygen fuel cell is:

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$

The half-equation at the negative electrode is:

$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$

What is the half-equation at the positive electrode?

A $\frac{1}{2}O_2(g) + H_2(g) \rightarrow 2H_2O(l) + 2e^-$

B $\frac{1}{2}O_2(g) + H_2O(l) \rightarrow 2OH^-(aq) + 2e^-$

C $\frac{1}{2}O_2(g) + H_2O(l) + 2e^- \rightarrow 2OH^-(aq)$

D $O_2(g) + 2OH^-(aq) + H_2(g) + 2e^- \rightarrow 2H_2O(l)$

Your answer ☐ **[1]**

11 Two redox systems are shown below.

$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$ $E^\ominus = -2.37\,V$

$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$ $E^\ominus = -0.13\,V$

Which species is the strongest reducing agent?

A $Mg^{2+}(aq)$

B $Mg(s)$

C $Pb^{2+}(aq)$

D $Pb(s)$

Your answer ☐ **[1]**

12 The rate constant, k, for a first order reaction is $6.19 \times 10^{-3}\,s^{-1}$.

What is the half-life, in s, for the reaction?

A 4.29×10^{-3}

B 49

C 112

D 323

Your answer ☐ **[1]**

13 A mixture of ethanoic acid and ethanol is left to reach equilibrium.

A student determines the amount of ethanoic acid remaining in the equilibrium mixture by titrating the mixture with a solution of sodium hydroxide.

Which row of the table shows a suitable indicator for the titration?

	pH range of the indicator
A	1.2 – 2.8
B	4.8 – 6.0
C	9.4 –10.6
D	12.0 –13.4

Your answer ☐ **[1]**

14 Barium is in Group 2 of the periodic table.

Which statement(s) about barium is / are correct?

1 Its outer shell electrons are in an s-orbital.

2 It reacts more vigorously with water than magnesium.

3 It has a higher first ionisation energy than magnesium.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

15 Chromium forms the complex ions $[Cr(NH_3)_6]^{3+}$ and $[Cr(OH)_6]^{3-}$.

Which statement(s) about the complexes is / are correct?

1 Chromium is in the same oxidation state in each complex ion.

2 The complex ions are different colours.

3 The complex ions have different coordination numbers.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

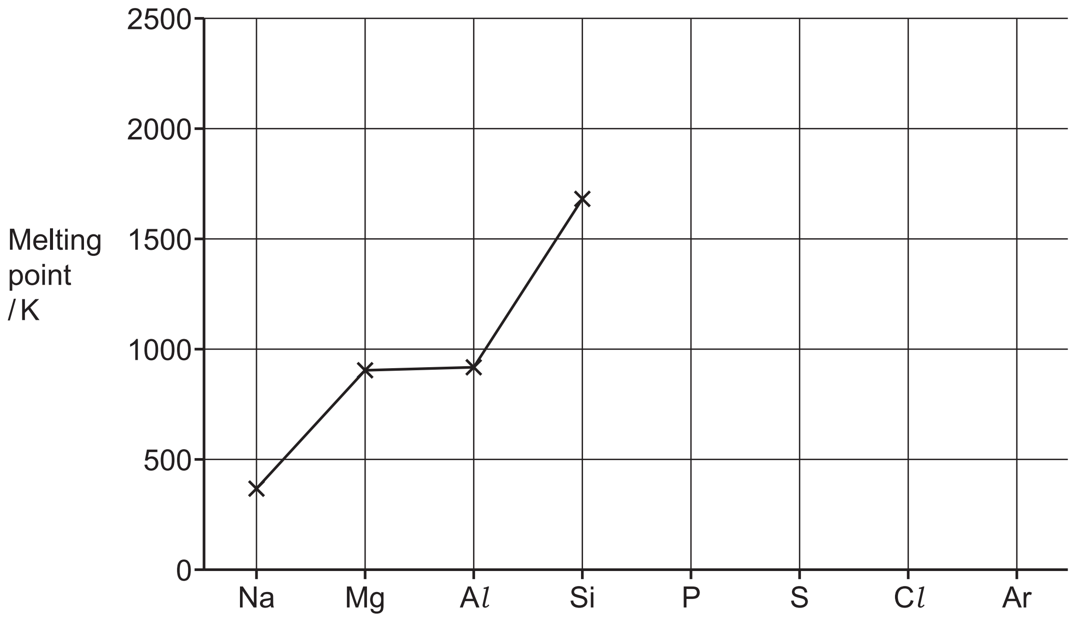
D Only 1

Your answer ☐ **[1]**

Section B

16 This question is about trends in the periodic table.

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



(i) Complete the graph to show approximate melting points for P, S, Cl and Ar. **[2]**

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

Use ideas about structure and bonding in your answer.

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.... **[3]**

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

Element	Na	Mg	A*l*	Si	P	S	C*l*	Ar
First ionisation energy / kJ mol^{-1}	496	738	578	789	1012	1000	1251	1521

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

.... **[1]**

(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.

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.... **[2]**

(c) A student adds an aqueous solution of bromine, $Br_2(aq)$, to two test tubes.

The student adds aqueous sodium iodide, $NaI(aq)$, to the $Br_2(aq)$ in one test tube, and aqueous sodium chloride, $NaCl(aq)$, to the $Br_2(aq)$ 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**
$Br_2(aq) + NaI(aq)$	....
$Br_2(aq) + NaCl(aq)$	....

Ionic equation(s) ....

....

.... **[3]**

(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.

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Additional answer space if required.

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17 This question is about carbon monoxide and carbon as reducing agents in industry.

(a) Iron(III) oxide, Fe_2O_3, can be reduced by carbon monoxide to form iron.

$Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g)$ **Equilibrium 17.1**

Some standard enthalpy change of formation, $\Delta_f H^{\ominus}$, and standard entropy, $S^{\ominus}$, values are shown in the table.

Substance	**Fe_2O_3(s)**	**CO(g)**	**Fe(s)**	**CO_2(g)**
$\Delta_f H^{\ominus}$ / kJ mol^{-1}	–824	–111	0	–394
$S^{\ominus}$ / J K^{-1} mol^{-1}	87	198	To calculate in part **(a)(iv)**	214

(i) Explain why the standard enthalpy change of formation of Fe has a value of 0 kJ mol^{-1}.

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.... **[1]**

(ii) Calculate the enthalpy change, $\Delta_r H$, for the forward reaction in **Equilibrium 17.1**.

ΔH = ... kJ mol^{-1} **[2]**

(iii) Explain why the standard entropy of CO_2 is greater than the standard entropy of Fe_2O_3.

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.... **[2]**

(iv) The standard entropy change, $\Delta S^{\ominus}$, for the forward reaction in **Equilibrium 17.1** has a value of $+15\,J\,K^{-1}\,mol^{-1}$.

Use data from the table to calculate the standard entropy, $S^{\ominus}$, of Fe.

$S^{\ominus}$ = ... $J\,K^{-1}\,mol^{-1}$ **[2]**

(b) Carbon can also reduce $Fe_2O_3(s)$ to iron as shown in **Equilibrium 17.2**.

$Fe_2O_3(s) + 3C(g) \rightleftharpoons 3CO(g) + 2Fe(s)$

Equilibrium 17.2
$\Delta H = +491\,kJ\,mol^{-1}$
$\Delta S = +543\,J\,K^{-1}\,mol^{-1}$

The forward reaction is only feasible at high temperatures.

- Show that the forward reaction is **not** feasible at 100 °C.
- Calculate the minimum temperature, in K, for the forward reaction to be feasible.

Give the minimum temperature to the nearest whole number.

T = ... K **[3]**

(c) Steam can be reduced by carbon monoxide in a reversible reaction.

$H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$ **Equilibrium 17.3**
$\Delta H = -39.9\,kJ\,mol^{-1}$

At 700 K the value of K_p is 8.13.

(i) Explain why K_p for **Equilibrium 17.3** has no units.

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.... **[1]**

(ii) An equal number of moles of steam and carbon monoxide are left at 700 K in a sealed container until equilibrium is reached.

At equilibrium, both H_2 and CO_2 have a partial pressure of 211 kPa.

Calculate the partial pressures of H_2O and CO at equilibrium.

Partial pressure of H_2O = ... kPa

Partial pressure of CO = ... kPa
[3]

(iii) At a second temperature the value of K_p for **Equilibrium 17.3** is 129.

Explain whether the second temperature is higher or lower than 700 K.

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.... **[2]**

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Turn over for the next question

18 Nitrogen monoxide, NO, reacts with oxygen to form nitrogen dioxide, NO_2.

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ **Reaction 18.1**

(a) The rate of reaction increases in the presence of a heterogeneous platinum catalyst.

(i) Explain why platinum is an example of a *heterogeneous* catalyst for **Reaction 18.1**.

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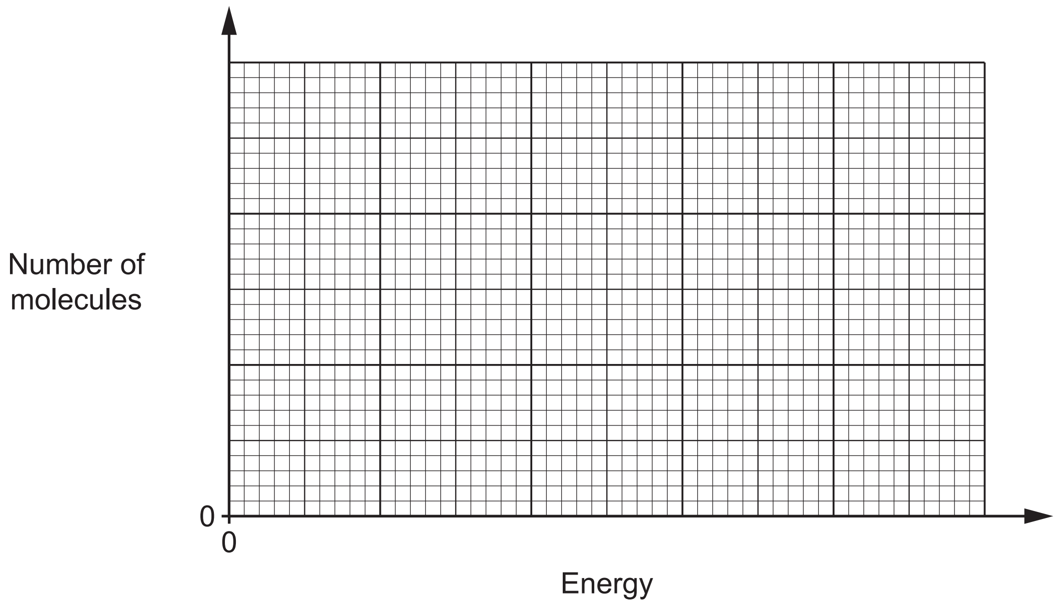
.... **[1]**

(ii) Explain how the platinum catalyst increases the rate of reaction.

Include a labelled sketch of the Boltzmann distribution on the grid.



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.... **[2]**

(iii) In industry, catalysts have great economic importance and benefits for increased sustainability.

Explain how the use of catalysts is beneficial to the environment.

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.... **[1]**

(b) The following data was obtained in a series of experiments on the rate of the reaction for **Reaction 18.1** at a constant temperature.

Experiment	**[NO] / mol dm^{-3}**	**[O_2] / mol dm^{-3}**	**rate / mol dm^{-3} s^{-1}**
1	0.040	0.035	7.45×10^{-4}
2	0.040	0.070	1.49×10^{-3}
3	0.060	0.035	1.68×10^{-3}

Determine the orders with respect to NO and O_2. Explain your reasoning.

Determine the rate equation and calculate the rate constant, *k*, including units.

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k = ... units ....

[5]

(c) The rate constant varies with temperature, according to the Arrhenius equation.

A technician determines the activation energy for **Reaction 18.1** by determining the rate constant, *k*, at different temperatures.

The table shows the technician's results.

Temperature / K	$\frac{1}{T}$ **/ K^{-1}**	***k***	**ln *k***
1500	6.7×10^{-4}	1.81×10^{3}	7.50
1750	5.7×10^{-4}	8.51×10^{4}	....
2000	5.0×10^{-4}	2.79×10^{5}	12.5
2250	4.4×10^{-4}	1.47×10^{6}	14.2
2500	4.0×10^{-4}	5.70×10^{6}	15.6

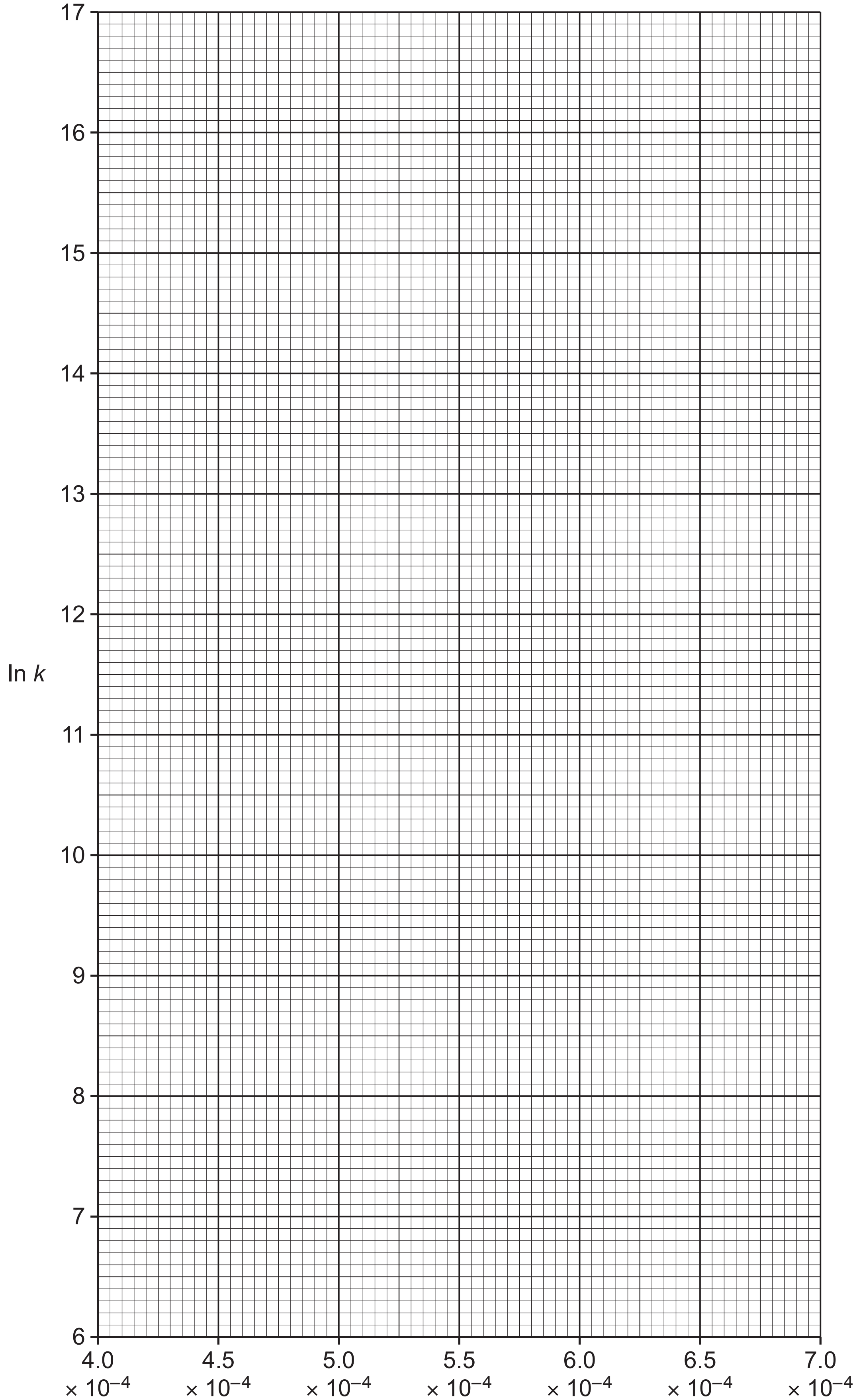
(i) Complete the table by adding the missing value of ln *k*. **[1]**

(ii) Plot a graph of ln *k* against $\frac{1}{T}$ on the grid opposite.

Use your graph to calculate the value of the activation energy, E_a, in kJ mol^{-1}.

Give your answer to **2** significant figures.

E_a = ... kJ mol^{-1} **[4]**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4.0 × 10^{-4}
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6.0 × 10^{-4}
6.5 × 10^{-4}
7.0 × 10^{-4}
$\frac{1}{T}$ / K^{-1}

19 This question is about monobasic acids and buffer solutions.

(a) Nitric acid, HNO_3, is a strong monobasic acid.

Calculate the pH of 0.150 mol dm^{-3} HNO_3.

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

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

(b)
(i) Nitrous acid, HNO_2, is a weak monobasic acid.

Predict whether the pH of 0.150 mol dm^{-3} HNO_2 is higher, lower or the same as the pH of 0.150 mol dm^{-3} nitric acid, HNO_3.

Explain your answer.

Prediction ....

Explanation ....

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.... **[2]**

(ii) When heated, aqueous HNO_2 disproportionates. The equation is shown below.

$3HNO_2(aq) \rightarrow HNO_3(aq) + 2NO(g) + H_2O(l)$

- What is meant by **disproportionation**?
- Use oxidation numbers to show that disproportionation has taken place.

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.... **[3]**

(c)* A student plans to prepare a buffer solution with a pH of 4.85 using propanoic acid, CH_3CH_2COOH, and sodium propanoate, CH_3CH_2COONa.

K_a for $CH_3CH_2COOH = 1.32 \times 10^{-5}\,mol\,dm^{-3}$.

The student mixes $125\,cm^3$ of $0.180\,mol\,dm^{-3}$ $CH_3CH_2COOH(aq)$ with a calculated mass of $CH_3CH_2COONa(s)$. The student assumes that the volume of the solution does not change.

- Calculate the mass of CH_3CH_2COONa needed to make $125\,cm^3$ of a buffer solution with a pH of 4.85.
- Explain why this solution resists changes in pH when a small amount of alkali is added.

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Additional answer space if required.

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20 Standard electrode potentials for seven redox systems are shown in the table below.

Redox system	Half-equation	$E^{\ominus}$ / V
1	$V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$	–1.18
2	$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
3	$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	–0.28
4	$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
5	$2H^+(aq) + VO^{2+}(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
6	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
7	$2H^+(aq) + VO_2^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00

(a)

(i) A student sets up a standard cell based on redox systems **2** and **4**.

Draw a labelled diagram to show how this cell could be set up to measure its standard cell potential.

Include the conditions required to measure the standard cell potential.

standard conditions ....

....

.... **[4]**

(ii) Calculate the standard cell potential of this cell.

standard cell potential = ... V **[1]**

(b) A student predicts that cobalt metal will reduce acidified VO^{2+} ions to form V^{2+} ions in two stages.

Explain why this two-stage reduction should happen in terms of electrode potentials and equilibria shifts.

Include overall equations for the predicted reactions.

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.... **[4]**

21 This question is about reactions of compounds of iron and copper.

(a)

(i) Complete the electron configuration of

an Fe atom: $1s^2$ ....

a Cu^{2+} ion: $1s^2$ ....

[2]

(ii) Solutions of iron(II) sulfate, $FeSO_4$, and copper(II) sulfate, $CuSO_4$, can be distinguished by adding aqueous sodium hydroxide.

Describe what would be observed when NaOH(aq) is added to each solution.

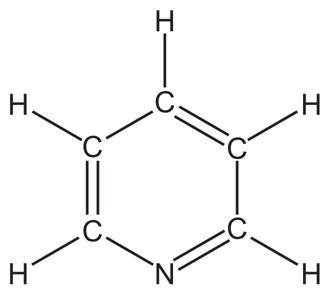
Observation with $FeSO_4$(aq) ....

Observation with $CuSO_4$(aq) ....

[2]

(b) The cyclic organic compound pyridine, C_5H_5N, can act as a monodentate ligand.

The structure of pyridine is shown below.



(i) What is meant by a **monodentate ligand**?

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.... **[1]**

(ii) An iron(II) complex contains two different ligands: C_5H_5N, and Cl^-.

The complex has a molar mass of $442.8\,g\,mol^{-1}$ and the following percentage composition by mass:

Fe, 12.6%; C, 54.3%; H, 4.5%; N, 12.6%; Cl, 16.0%

Determine the empirical formula of the iron(II) complex.

Deduce the number of C_5H_5N ligands in the complex and the coordination number of the iron(II) ion.

Empirical formula of iron(II) complex ....

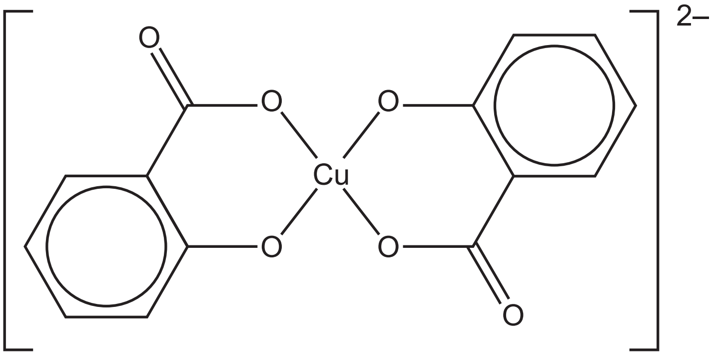
Number of C_5H_5N ligands ....

Coordination number of iron(II) ion ....

[4]

(c) Aqueous copper(II) sulfate reacts with salicylic acid to form a complex ion which has two stereoisomers.

One isomer of the complex ion is shown:



Draw the other stereoisomer of the complex.

Identify the type of stereoisomerism shown by the complexes.

Type of stereoisomerism .... **[2]**

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Question 21(d) starts on Page 30

(d) **Mixture A** is a mixture of copper(II) sulfate crystals, $CuSO_4•5H_2O$ and iron(II) sulfate crystals, $FeSO_4•7H_2O$.

A student carries out a titration to determine the percentage by mass of $CuSO_4•5H_2O$ in **Mixture A**.

The student uses the following method.

Step 1 Dissolve 9.51 g of **Mixture A** in water and make up the solution to 250.0 cm^3 in a volumetric flask.

Step 2 Pipette 25.0 cm^3 of the solution from **Step 1** into a conical flask and add an excess of aqueous potassium iodide, KI(aq).

The copper(II) ions react with iodide ions to form a precipitate of copper(I) iodide and a solution of iodine.

$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$

Step 3 Titrate the contents of the conical flask from **Step 2** with 0.0800 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$, using starch as the indicator.

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

Step 4 Repeat **Step 2** and **Step 3** to obtain concordant titres and calculate the mean titre.

Results

Mean titre = 31.15 cm^3

(i) Calculate the percentage by mass of $CuSO_4•5H_2O$ in **Mixture A**.

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

Percentage of $CuSO_4•5H_2O$ in **Mixture A** = ... % **[5]**

(ii) The student repeats their method, but after carrying out **Step 1** they leave the solution exposed to the air for a few days.
Some of the iron(II) sulfate is oxidised to iron(III) sulfate.

The student then continues with **Step 2**, **Step 3** and **Step 4** of the method.

This mean titre is greater than 31.15 cm^3.

Suggest why this mean titre is greater than 31.15 cm^3.

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.... **[1]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

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