Oxford Cambridge and RSA

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

Tuesday 5 June 2018 – Afternoon

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry A (sent with general stationery)

You may use:
- a scientific or graphical calculator

First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

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

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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.

Answer **all** the questions.

1 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?

A 8.0%

B 20%

C 80%

D 92%

Your answer ☐ **[1]**

2 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?

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

Your answer ☐ **[1]**

3 What is the number of hydrogen atoms in 0.125 mol of C_2H_5OH?

A 7.525×10^{22}

B 4.515×10^{23}

C 3.7625×10^{23}

D 3.612×10^{24}

Your answer ☐ **[1]**

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

$25.00\,cm^3$ of $0.0450\,mol\,dm^{-3}$ $Ba(OH)_2$ are needed to neutralise $23.35\,cm^3$ of $HNO_3(aq)$.

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

A 0.0241

B 0.0482

C 0.0900

D 0.0964

Your answer ☐ **[1]**

5 Which statement best explains why nitrogen has a larger first ionisation energy than oxygen?

A N atoms have less repulsion between p-orbital electrons than O atoms.

B N atoms have a smaller nuclear charge than O atoms.

C N atoms lose an electron from the 2s subshell, while O atoms lose an electron from the 2p subshell.

D N atoms have an odd number of electrons, while O atoms have an even number.

Your answer ☐ **[1]**

6 In the Periodic Table, element **X** is in Group 2 and element **Y** is in Group 15 (5).

What is the likely formula of an ionic compound of **X** and **Y**?

A $\mathbf{X_2Y_5}$

B $\mathbf{X_2Y_3}$

C $\mathbf{X_3Y_2}$

D $\mathbf{X_5Y_2}$

Your answer ☐ **[1]**

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7 Which statement about ammonium carbonate is **not** correct?

A It reacts with $Ba(NO_3)_2(aq)$ to form a white precipitate.

B It effervesces with dilute nitric acid.

C It release an alkaline gas with warm NaOH(aq).

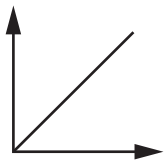
D It has the formula NH_4CO_3.

Your answer ☐ **[1]**

8 A reaction is first order with respect to a reactant **X**.

Which rate–concentration graph for reactant **X** is the correct shape?

A



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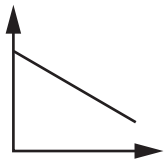

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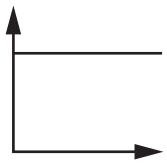

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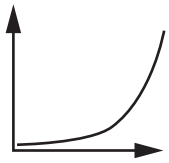

Your answer ☐ **[1]**

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9 The reversible reaction of sulfur dioxide and oxygen to form sulfur trioxide is shown below.

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

An equilibrium mixture contains 2.4 mol SO_2, 1.2 mol O_2 and 0.4 mol SO_3.
The total pressure is 250 atm.

What is the partial pressure of SO_3?

A 15 atm

B 25 atm

C 100 atm

D 200 atm

Your answer ☐ **[1]**

10 A buffer solution is prepared by mixing 200 cm^3 of 2.00 mol dm^{-3} propanoic acid, CH_3CH_2COOH, with 600 cm^3 of 1.00 mol dm^{-3} sodium propanoate, CH_3CH_2COONa.

K_a for CH_3CH_2COOH = 1.32×10^{-5} mol dm^{-3}

What is the pH of the buffer solution?

A 4.58

B 4.70

C 5.06

D 5.18

Your answer ☐ **[1]**

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11 The table below shows standard entropies, $S^{\ominus}$.

Substance	$CO(g)$	$H_2(g)$	$CH_3OH(l)$
$S^{\ominus}$ / J mol^{-1} K^{-1}	197.6	130.6	239.7

What is the entropy change, $\Delta S^{\ominus}$, in J mol^{-1} K^{-1}, for the following reaction?

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$$

A –219.1

B –88.5

C +88.5

D +219.1

Your answer ☐ **[1]**

12 The redox equilibria for a hydrogen–oxygen fuel cell in alkaline solution are shown below.

$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$ $E^{\ominus} = -0.83\,V$

$^1/_2O_2(g) + H_2O(l) + 2e^- \rightleftharpoons 2OH^-(aq)$ $E^{\ominus} = +0.40\,V$

What is the equation for the overall cell reaction?

A $H_2(g) + 4OH^-(aq) \rightarrow 3H_2O(l) + {}^1/_2O_2(g)$

B $3H_2O(l) + {}^1/_2O_2 \rightarrow H_2(g) + 4OH^-(aq)$

C $H_2O(l) \rightarrow H_2(g) + {}^1/_2O_2(g)$

D $H_2(g) + {}^1/_2O_2(g) \rightarrow H_2O(l)$

Your answer ☐ **[1]**

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13 Which enthalpy change(s) is/are endothermic?

1 The bond enthalpy of the C–H bond

2 The second electron affinity of oxygen

3 The standard enthalpy change of formation of magnesium

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

14 Which statement(s) explain(s) why reaction rates increase as temperature increases?

1 The activation energy is less.

2 Collisions between molecules are more frequent.

3 A greater proportion of molecules have energy greater than the activation energy.

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 Which statement(s) is/are correct for the complex $Pt(NH_3)_2Cl_2$?

1 One of its stereoisomers is used as an anti-cancer drug.

2 It has bond angles of 109.5°.

3 It has optical isomers.

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

Answer **all** the questions.

16 This question is about enthalpy changes.

(a) **Table 16.1** shows enthalpy changes that can be used to determine the enthalpy change of hydration of fluoride ions, F^-.

Enthalpy change	**Energy / kJ mol^{-1}**
Hydration of Ca^{2+}	–1609
Solution of CaF_2	+13
Lattice enthalpy of CaF_2	–2630

Table 16.1

(i) Explain what is meant by the term *enthalpy change of hydration*.

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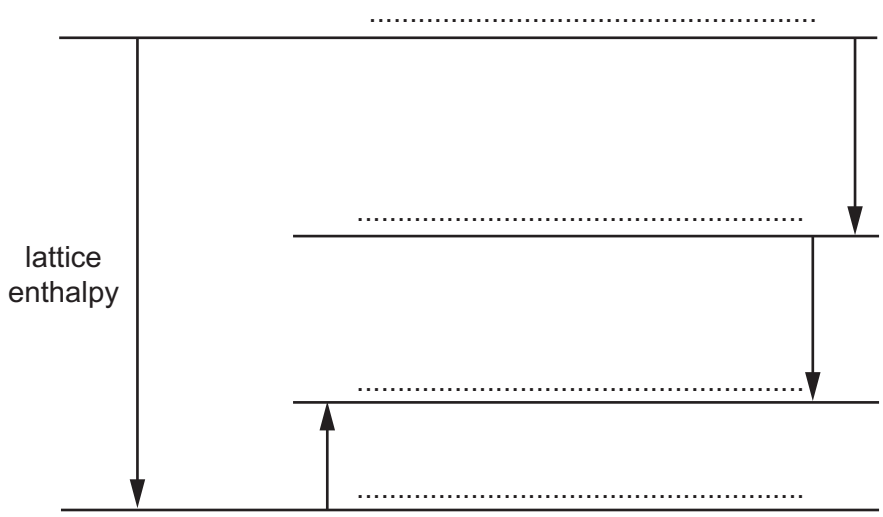
..... **[2]**

(ii) The enthalpy change of hydration of F^- can be determined using the enthalpy changes in **Table 16.1** and the incomplete energy cycle below.

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



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(iii) Calculate the enthalpy change of hydration of fluoride ions, F^-.

enthalpy change of hydration = ... kJ mol^{-1} **[2]**

(iv) Predict how the enthalpy changes of hydration of F^- and Cl^- would differ.

Explain your answer.

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

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(b) Fluorine reacts with steam as shown in the equation below.

$$2F_2(g) + 2H_2O(g) \rightarrow O_2(g) + 4HF(g) \qquad \Delta H = -598\,kJ\,mol^{-1}$$

Average bond enthalpies are shown in the table.

Bond	**Average bond enthalpy / kJ mol^{-1}**
O–H	+464
O=O	+498
H–F	+568

(i) Explain what is meant by the term *average bond enthalpy*.

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

(ii) Calculate the bond enthalpy of the F–F bond.

bond enthalpy = ... kJ mol^{-1} **[3]**

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17 This question is about reaction rates.

Aqueous iron(III) ions, $Fe^{3+}(aq)$, react with aqueous iodide ions, $I^{-}(aq)$, as shown below.

$$2Fe^{3+}(aq) + 2I^{-}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$$

A student carries out three experiments to investigate how different concentrations of $Fe^{3+}(aq)$ and $I^{-}(aq)$ affect the initial rate of this reaction. The results are shown below.

Experiment	$[Fe^{3+}(aq)]$ / mol dm^{-3}	$[I^{-}(aq)]$ / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	4.00×10^{-2}	3.00×10^{-2}	8.10×10^{-4}
2	8.00×10^{-2}	3.00×10^{-2}	1.62×10^{-3}
3	4.00×10^{-2}	6.00×10^{-2}	3.24×10^{-3}

(a)* Determine the rate constant and a possible two-step mechanism for this reaction that are consistent with these results. **[6]**

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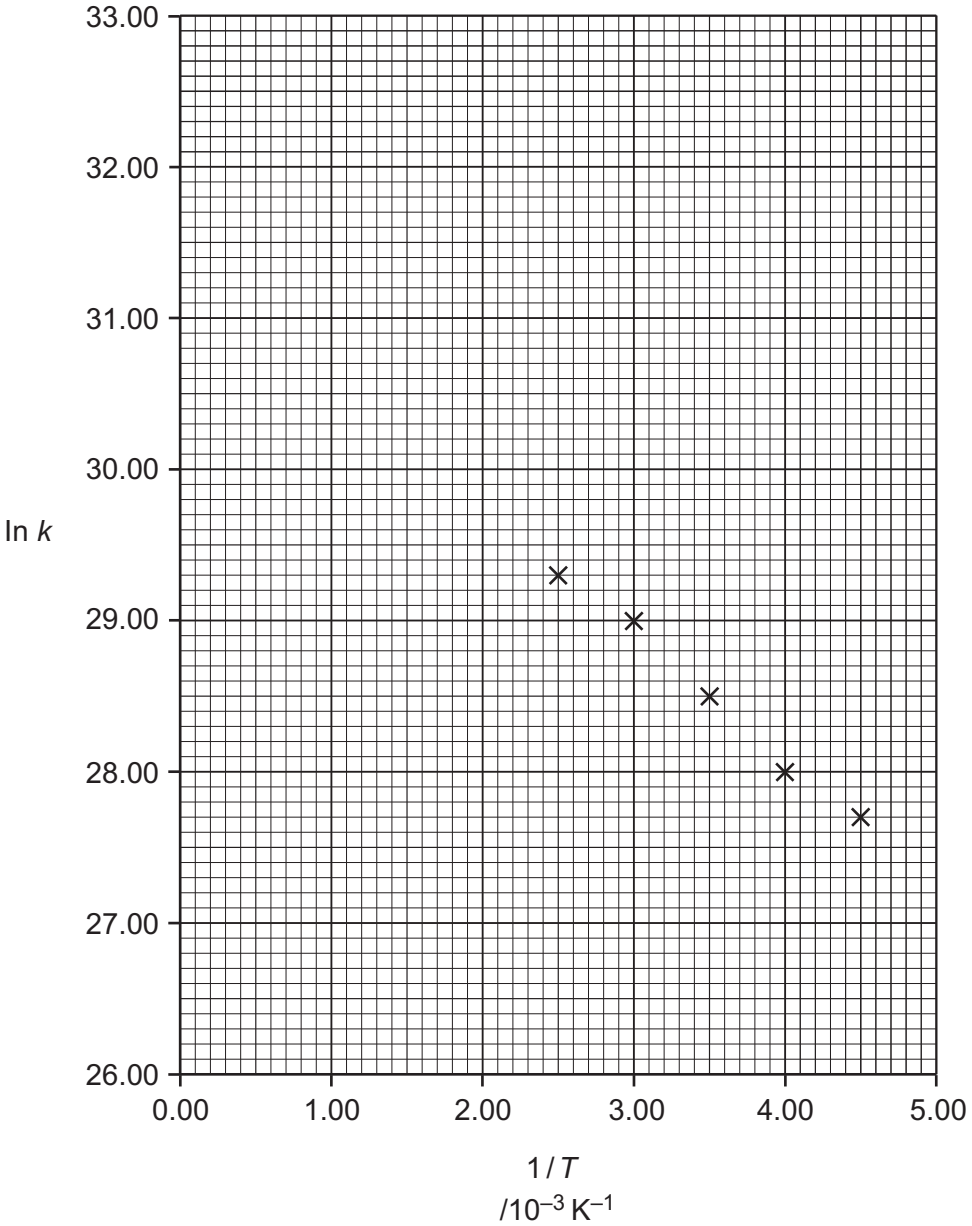
(b) A student carries out an investigation to find the activation energy, E_a, and the pre-exponential factor, A, of a reaction.

The student determines the rate constant, k, at different temperatures, T.
The student then plots a graph of $\ln k$ against $1 / T$ as shown below.



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(i) Draw a best-fit straight line and calculate the activation energy, in $J\,mol^{-1}$.
Give your answer to **three** significant figures.

Show your working.

activation energy, E_a = + ... $J\,mol^{-1}$ **[3]**

(ii) Use the graph to calculate the value of the pre-exponential factor, *A*.

Show your working.

pre-exponential factor, *A* = ... **[2]**

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18 Nitrogen monoxide, NO, and oxygen, O_2, react to form nitrogen dioxide, NO_2, in the reversible reaction shown in **equilibrium 18.1**.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$ **Equilibrium 18.1**

(a) Write an expression for K_c for this equilibrium and state the units.

K_c =

Units = ... **[2]**

(b) A chemist mixes together nitrogen and oxygen and pressurises the gases so that their total gas volume is 4.0 dm^3.

- The mixture is allowed to reach equilibrium at constant temperature and volume.
- The equilibrium mixture contains 0.40 mol NO and 0.80 mol O_2.
- Under these conditions, the numerical value of K_c is 45.

Calculate the amount, in mol, of NO_2 in the equilibrium mixture.

amount of NO_2 = ... mol **[4]**

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(c) The values of K_p for **equilibrium 18.1** at 298 K and 1000 K are shown below.

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ **Equilibrium 18.1**

Temperature / K	**K_p / atm^{-1}**
298	$K_p = 2.19 \times 10^{12}$
1000	$K_p = 2.03 \times 10^{-1}$

(i) Predict, with a reason, whether the forward reaction is exothermic or endothermic.

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

(ii) The chemist increases the pressure of the equilibrium mixture at the same temperature.

State, and explain in terms of K_p, how you would expect the equilibrium position to change.

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

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19 This question is about acids and bases found in the home.

(a) Ethanoic acid, CH_3COOH, is the acid present in vinegar.

A student carries out an experiment to determine the pK_a value of CH_3COOH.

- The concentration of CH_3COOH in the vinegar is $0.870\,mol\,dm^{-3}$.
- The pH of the vinegar is 2.41.

(i) Write the expression for the acid dissociation constant, K_a, of CH_3COOH.

[1]

(ii) Calculate the pK_a value of CH_3COOH.

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

pK_a = ... **[3]**

(iii) Determine the percentage dissociation of ethanoic acid in the vinegar.

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

percentage dissociation = ... % **[1]**

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(b) Many solid drain cleaners are based on sodium hydroxide, NaOH.

- A student dissolves 1.26 g of a drain cleaner in water and makes up the solution to 100.0 cm^3.
- The student measures the pH of this solution as 13.48.

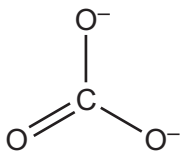
Determine the percentage, by mass, of NaOH in the drain cleaner.

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

percentage = ... % **[4]**

(c) Sodium carbonate, Na_2CO_3, is a base used in washing soda.

Na_2CO_3 contains the carbonate ion, CO_3^{2-}, shown below.



Draw the '*dot-and-cross*' diagram for the carbonate ion.

Show outer electrons only and use different symbols for electrons from C and O, and any 'extra' electrons.

[2]

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20 This question is about the halogen group of elements and some of their compounds.

(a) The halogens show trends in their properties down the group.

The boiling points of three halogens are shown below.

Halogen	Boiling point / °C
Chlorine	–35
Bromine	59
Iodine	184

Explain why the halogens show this trend in boiling points.

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

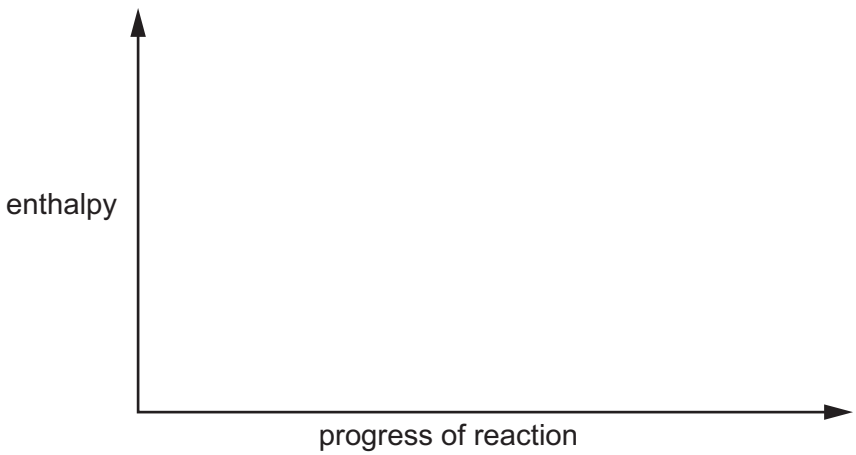
(b) Hydrogen iodide, HI, is decomposed by heat into its elements:

$$2HI(g) \rightarrow H_2(g) + I_2(g) \qquad \Delta H = +9.5\,kJ\,mol^{-1}$$

The decomposition is much faster in the presence of a platinum catalyst.

Complete the enthalpy profile diagram for this reaction using formulae for the reactants and products.

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



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(c) Compound **A** is an oxide of chlorine that is a liquid at room temperature and pressure and has a boiling point of 83 °C.

When 0.4485 g of **A** is heated to 100 °C at 1.00×10^5 Pa, 76.0 cm^3 of gas is produced.

Determine the molecular formula of compound **A**.

Show all your working.

molecular formula of **A** = ... **[4]**

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(d) Compound **B** is an iodate(V) salt of a Group 1 metal.
The iodate(V) ion has the formula IO_3^-.

A student carries out a titration to find the formula of compound **B**.

Step 1: The student dissolves 1.55 g of **B** in water and makes up the solution to 250.0 cm^3 in a volumetric flask.

Step 2: The student pipettes 25.00 cm^3 of the solution of **B** into a conical flask, followed by 10 cm^3 of dilute sulfuric acid and an excess of KI(aq).

The iodate(V) ions are reduced to iodine, as shown below.

$$IO_3^-(aq) + 6H^+(aq) + 5I^-(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

Step 3: The resulting mixture is titrated with 0.150 mol dm^{-3} $Na_2S_2O_3(aq)$.

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

The student repeats **step 2** and **step 3** until concordant titres are obtained.

Titration readings

Titration	**Trial**	**1**	**2**	**3**
Final burette reading / cm^3	24.00	47.40	23.75	47.05
Initial burette reading / cm^3	0.00	24.00	0.00	23.20
Titre / cm^3				

Table 20.1

(i) Complete **Table 20.1** and calculate the mean titre that the student should use for analysing the results.

mean titre = ... cm^3 **[2]**

(ii) The uncertainty in each burette reading is ±0.05 cm^3.

Calculate the percentage uncertainty in the titre obtained from **titration 1**.

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

percentage uncertainty = ... % **[1]**

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(iii) Describe and explain how the student should determine the end point of this titration accurately.

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.....

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

(iv) Determine the relative formula mass and formula of the Group 1 iodate(V), **B**.

Show your working.

relative formula mass of **B** = ...

formula of **B** = ... **[5]**

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21 This question is about some reactions of d block elements and their ions.

Table 21.1 shows standard electrode potentials which will be needed within this question.

$Zn^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Zn(s)$	$E^\ominus = -0.76\,V$
$Cr^{3+}(aq) + e^-$	$\rightleftharpoons$	$Cr^{2+}(aq)$	$E^\ominus = -0.42\,V$
$Ni^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Ni(s)$	$E^\ominus = -0.25\,V$
$I_2(aq) + 2e^-$	$\rightleftharpoons$	$2I^-(aq)$	$E^\ominus = +0.54\,V$
$Fe^{3+}(aq) + e^-$	$\rightleftharpoons$	$Fe^{2+}(aq)$	$E^\ominus = +0.77\,V$
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$	$\rightleftharpoons$	$2Cr^{3+}(aq) + 7H_2O(l)$	$E^\ominus = +1.33\,V$
$H_2O_2(aq) + 2H^+(aq) + 2e^-$	$\rightleftharpoons$	$2H_2O(l)$	$E^\ominus = +1.78\,V$

Table 21.1

(a) Complete the electron configuration of

a Ni atom: $1s^2$ .....

a Ni^{2+} ion: $1s^2$ ..... **[2]**

(b) A standard cell is set up in the laboratory with the cell reaction shown below.

$$Ni(s) + I_2(aq) \rightarrow Ni^{2+}(aq) + 2I^-(aq)$$

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

Include details of apparatus, solutions and the standard conditions required.

Standard conditions .....

.....

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

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

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

(c) Use the information in **Table 21.1** to help you answer both parts of this question.

(i) Write the overall equation for the oxidation of Fe^{2+} by acidified H_2O_2.

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

(ii) Zinc reacts with acidified $Cr_2O_7^{2-}$ ions to form Cr^{2+} ions in two stages.

Explain why this happens in terms of electrode potentials and equilibria.

Include overall equations for the reactions which occur.

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(d)* Three different reactions of copper compounds are described below.

Reaction 1: Aqueous copper(II) sulfate reacts with excess aqueous ammonia in a ligand substitution reaction. A deep-blue solution is formed, containing an octahedral complex ion, **C**, which is a *trans* isomer.

Reaction 2: Copper(I) oxide reacts with hot dilute sulfuric acid in a disproportionation reaction. A blue solution, **D**, and a brown solid, **E** are formed.

Reaction 3: Copper(II) oxide reacts with warm dilute nitric acid in a neutralisation reaction, to form a blue solution. Unreacted copper(II) oxide is filtered off, and the solution is left overnight in an evaporating basin.
A hydrated salt, **F**, crystallises, with the percentage composition by mass:
Cu, 26.29%; H, 2.48%; N, 11.59%; O, 59.63%.

Identify **C**–**F** by formulae or structures, as appropriate.

Include equations, any changes in oxidation number, and working. **[6]**

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