



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	StemUp Model Solution									
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.

2
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

C

[1]

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

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

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

Your answer

C

[1]

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

- A** 7.525×10^{22}
B 4.515×10^{23}
C 3.7625×10^{23}
D 3.612×10^{24}

Your answer

B

[1]

- 4 A student titrates a standard solution of barium hydroxide, $\text{Ba}(\text{OH})_2$, with nitric acid, HNO_3 .
 25.00 cm^3 of $0.0450 \text{ mol dm}^{-3}$ $\text{Ba}(\text{OH})_2$ 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?

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

Your answer

D

[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

A

[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 X_2Y_5
- B X_2Y_3
- C X_3Y_2
- D X_5Y_2

Your answer

C

[1]

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

- A It reacts with $\text{Ba}(\text{NO}_3)_2(\text{aq})$ 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 .

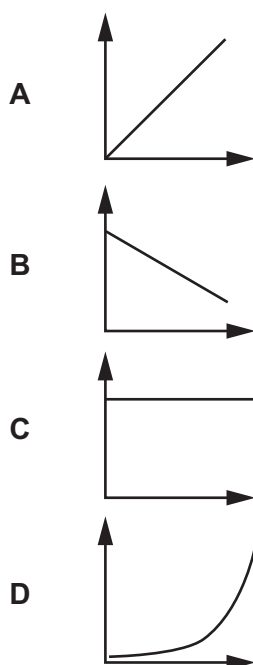
Your answer

D

[1]

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

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

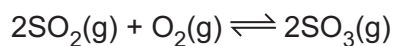


Your answer

A

[1]

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



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

B

[1]

- 10 A buffer solution is prepared by mixing 200 cm^3 of 2.00 mol dm^{-3} propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, with 600 cm^3 of 1.00 mol dm^{-3} sodium propanoate, $\text{CH}_3\text{CH}_2\text{COONa}$.

K_a for $\text{CH}_3\text{CH}_2\text{COOH} = 1.32 \times 10^{-5}\text{ mol dm}^{-3}$

What is the pH of the buffer solution?

- A 4.58
- B 4.70
- C 5.06
- D 5.18

Your answer

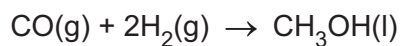
C

[1]

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

Substance	CO(g)	H ₂ (g)	CH ₃ OH(l)
$S^\ominus/\text{J mol}^{-1}\text{K}^{-1}$	197.6	130.6	239.7

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



- A -219.1
B -88.5
C +88.5
D +219.1

Your answer

A

[1]

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



What is the equation for the overall cell reaction?

- A $\text{H}_2\text{(g)} + 4\text{OH}^-\text{(aq)} \rightarrow 3\text{H}_2\text{O(l)} + \frac{1}{2}\text{O}_2\text{(g)}$
B $3\text{H}_2\text{O(l)} + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{(g)} + 4\text{OH}^-\text{(aq)}$
C $\text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)}$
D $\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O(l)}$

Your answer

D

[1]

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

B

[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

C

[1]

15 Which statement(s) is/are correct for the complex $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$?

- 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

D

[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

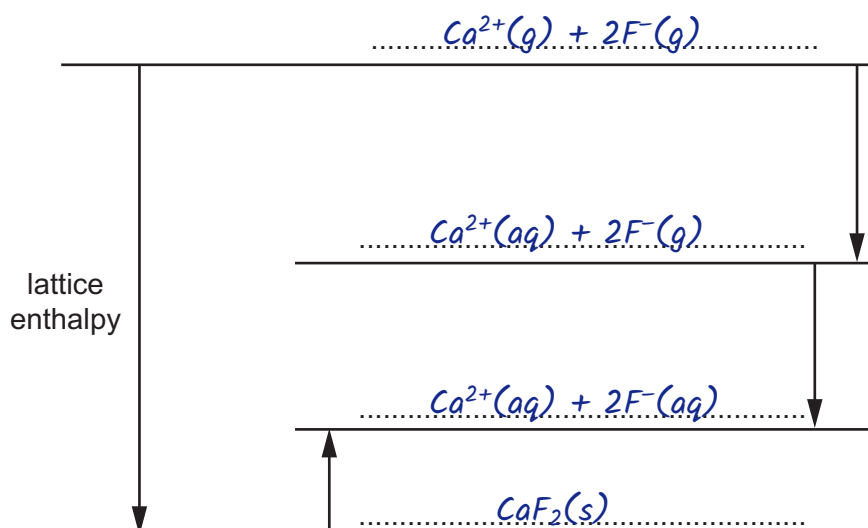
- (i) Explain what is meant by the term *enthalpy change of hydration*.

The enthalpy change when 1 mole of gaseous ions dissolves in water, i.e. gaseous ions form 1 mole of aqueous (hydrated) ions.

[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.



[4]

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

$$\text{lattice enthalpy} = \Delta_{\text{hyd}}H(\text{Ca}^{2+}) + 2\Delta_{\text{hyd}}H(\text{F}^-) - \Delta_{\text{sol}}H(\text{CaF}_2)$$

$$2\Delta_{\text{hyd}}H(\text{F}^-) = (-2630 + 13) - (-1609) = -1008 \text{ kJ mol}^{-1}$$

$$\Delta_{\text{hyd}}H(\text{F}^-) = -1008 \div 2 = -504 \text{ kJ mol}^{-1}$$

enthalpy change of hydration = ... **-504** kJ mol^{-1} [2]

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

Explain your answer.

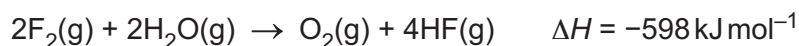
$\Delta_{\text{hyd}}H$ of F^- is more negative (more exothermic) than $\Delta_{\text{hyd}}H$ of Cl^- .

because F^- is a smaller ion than Cl^- .

So F^- has a greater attraction to the (δ^+ H atoms of) water molecules.

..... [2]

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



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*.

The energy needed to break one mole of a given type of bond in gaseous molecules, averaged over a range of different compounds.

[2]

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

$$\text{bonds broken} = 2E(\text{F-F}) + 4 \times 464 = 2E(\text{F-F}) + 1856$$

$$\text{bonds made} = 498 + 4 \times 568 = 498 + 2272 = 2770$$

$$\Delta H = \text{bonds broken} - \text{bonds made}$$

$$-598 = 2E(\text{F-F}) + 1856 - 2770$$

$$2E(\text{F-F}) = 2770 - 1856 - 598 = 316$$

$$E(\text{F-F}) = 316 \div 2 = +158 \text{ kJ mol}^{-1}$$

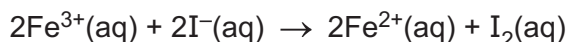
bond enthalpy = ... **+158** kJ mol^{-1} [3]

13
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17 This question is about reaction rates.

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



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

Experiment	$[\text{Fe}^{3+}(\text{aq})]$ / mol dm^{-3}	$[\text{I}^{-}(\text{aq})]$ / mol dm^{-3}	Initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$
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]

Exp 1 to 2: $[\text{Fe}^{3+}]$ doubles with $[\text{I}^{-}]$ constant, and the rate doubles (8.10×10^{-4} to 1.62×10^{-3}), so the reaction is 1st order with respect to Fe^{3+} .

Exp 1 to 3: $[\text{I}^{-}]$ doubles with $[\text{Fe}^{3+}]$ constant, and the rate increases by 4 times = 2^2 (8.10×10^{-4} to 3.24×10^{-3}), so the reaction is 2nd order with respect to I^{-} .

Rate equation: $\text{rate} = k[\text{Fe}^{3+}][\text{I}^{-}]^2$ (3rd order overall).

$k = \text{rate} \div ([\text{Fe}^{3+}][\text{I}^{-}]^2) = 8.10 \times 10^{-4} \div (4.00 \times 10^{-2} \times (3.00 \times 10^{-2})^2)$

$k = 22.5 \text{ dm}^6 \text{ mol}^{-2} \text{ s}^{-1}$

Mechanism: the slow (rate-determining) step must involve one Fe^{3+} and two I^{-} ions, to match the rate equation:

Step 1: $\text{Fe}^{3+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightarrow [\text{FeI}_2]^{+}(\text{aq})$ slow

Step 2: $[\text{FeI}_2]^{+}(\text{aq}) + \text{Fe}^{3+}(\text{aq}) \rightarrow 2\text{Fe}^{2+}(\text{aq}) + \text{I}_2(\text{aq})$ fast

Adding the two steps gives the overall equation, $2\text{Fe}^{3+} + 2\text{I}^{-} \rightarrow 2\text{Fe}^{2+} + \text{I}_2$, as the intermediate $[\text{FeI}_2]^{+}$ cancels; each step balances in species and charge.

Additional answer space if required

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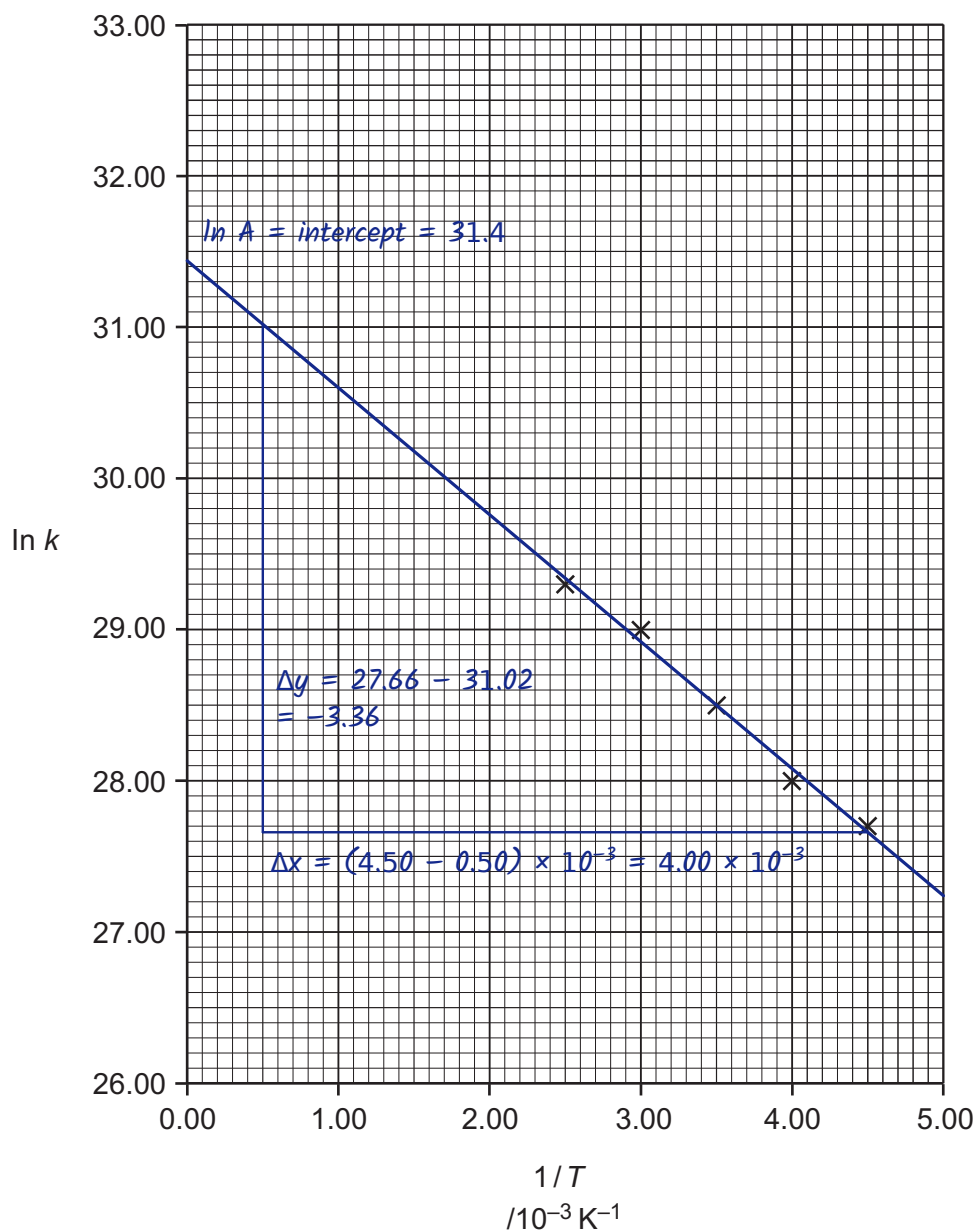
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- (b) A student carries out an investigation to find the activation energy, E_a , and the pre-exponential factor, A , of a reaction.

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.



- (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.

$$\ln k = -E_a/R \times 1/T + \ln A, \text{ so gradient} = -E_a/R$$

$$\text{gradient} = (27.66 - 31.02) \div (4.00 \times 10^{-3}) = -840 \text{ K}$$

$$E_a = -\text{gradient} \times R = 840 \times 8.314 = 6983.8 \text{ J mol}^{-1}$$

activation energy, $E_a = + \dots\dots\dots 6980 \dots\dots\dots \text{ J mol}^{-1}$ [3]

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

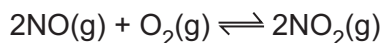
Show your working.

$$\ln A = y\text{-intercept (where } 1/T = 0) = 31.4$$

$$A = e^{31.4} = 4.33 \times 10^{13}$$

pre-exponential factor, A = $\dots\dots\dots 4.33 \times 10^{13} \dots\dots\dots$ [2]

- 18 Nitrogen monoxide, NO, and oxygen, O₂, react to form nitrogen dioxide, NO₂, in the reversible reaction shown in **equilibrium 18.1**.



Equilibrium 18.1

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

$$K_c = \frac{[\text{NO}_2]^2}{[\text{NO}]^2 [\text{O}_2]}$$

$$\text{Units} = \text{dm}^3 \text{ mol}^{-1}$$

[2]

- (b) A chemist mixes together nitrogen and oxygen and pressurises the gases so that their total gas volume is 4.0 dm³.

- The mixture is allowed to reach equilibrium at constant temperature and volume.
- The equilibrium mixture contains 0.40 mol NO and 0.80 mol O₂.
- Under these conditions, the numerical value of K_c is 45.

Calculate the amount, in mol, of NO₂ in the equilibrium mixture.

$$[\text{NO}] = 0.40 \div 4.0 = 0.10 \text{ mol dm}^{-3}$$

$$[\text{O}_2] = 0.80 \div 4.0 = 0.20 \text{ mol dm}^{-3}$$

$$K_c = [\text{NO}_2]^2 \div ([\text{NO}]^2 [\text{O}_2])$$

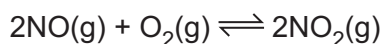
$$[\text{NO}_2]^2 = K_c \times [\text{NO}]^2 \times [\text{O}_2] = 45 \times 0.10^2 \times 0.20 = 0.090$$

$$[\text{NO}_2] = \sqrt{0.090} = 0.30 \text{ mol dm}^{-3}$$

$$\text{amount of NO}_2 = 0.30 \times 4.0 = 1.2 \text{ mol}$$

$$\text{amount of NO}_2 = 1.2 \text{ mol [4]}$$

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



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.

Exothermic, because K_p decreases as the temperature increases (the equilibrium shifts to the left). [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.

The equilibrium position shifts to the right (towards NO_2 , the side with fewer moles of gas).

$K_p = p(\text{NO}_2)^2 \div (p(\text{NO})^2 \times p(\text{O}_2))$. When the pressure increases, all partial pressures increase, but the denominator (bottom) increases more than the numerator (top), so the ratio decreases.

K_p does not change (same temperature), so more NO_2 forms; the numerator increases until the ratio increases back to K_p , restoring K_p . [3]

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 $\text{p}K_a$ value of CH_3COOH .

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

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

$$K_a = \frac{[\text{H}^+(\text{aq})] [\text{CH}_3\text{COO}^-(\text{aq})]}{[\text{CH}_3\text{COOH}(\text{aq})]}$$

[1]

(ii) Calculate the $\text{p}K_a$ value of CH_3COOH .

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

$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-2.41} = 3.89 \times 10^{-3} \text{ mol dm}^{-3}$$

$$K_a = [\text{H}^+]^2 \div [\text{CH}_3\text{COOH}] = (3.89 \times 10^{-3})^2 \div 0.870$$

$$K_a = 1.74 \times 10^{-5} \text{ mol dm}^{-3}$$

$$\text{p}K_a = -\log K_a = -\log(1.74 \times 10^{-5}) = 4.76$$

$$\text{p}K_a = \dots\dots\dots 4.76 \dots\dots\dots [3]$$

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

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

$$\% \text{ dissociation} = [\text{H}^+] \div [\text{CH}_3\text{COOH}] \times 100$$

$$= 3.89 \times 10^{-3} \div 0.870 \times 100 = 0.447\%$$

$$\text{percentage dissociation} = \dots\dots\dots 0.447 \dots\dots\dots \% [1]$$

(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 cm³.
- 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.

$$[H^+] = 10^{-13.48} = 3.31 \times 10^{-14} \text{ mol dm}^{-3}$$

$$[OH^-] = K_w \div [H^+] = 1.00 \times 10^{-14} \div 3.31 \times 10^{-14} = 0.302 \text{ mol dm}^{-3}$$

$$n(\text{NaOH}) = 0.302 \times 100.0 \div 1000 = 0.0302 \text{ mol}$$

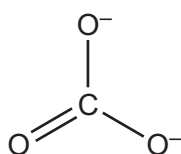
$$\text{mass of NaOH} = 0.0302 \times 40.0 = 1.21 \text{ g}$$

$$\% \text{ NaOH} = 1.21 \div 1.26 \times 100 = 95.9\%$$

percentage = ... 95.9 % [4]

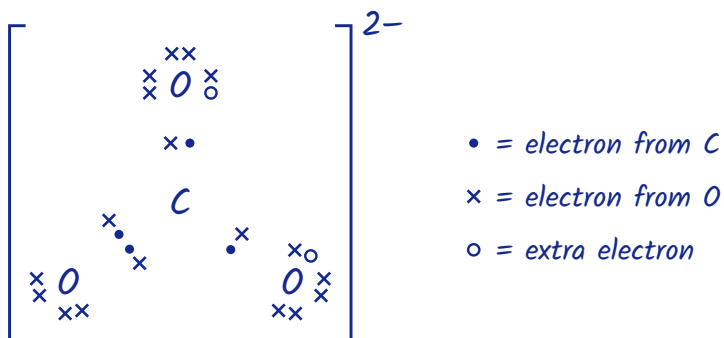
(c) Sodium carbonate, Na₂CO₃, is a base used in washing soda.

Na₂CO₃ contains the carbonate ion, CO₃²⁻, 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]

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.

Down the group, the number of electrons in each halogen molecule increases.
 So the London forces (induced dipole–dipole interactions) between the
 molecules increase (are stronger).
 So more energy is needed to break the intermolecular London forces, so the
 boiling point increases.

[3]

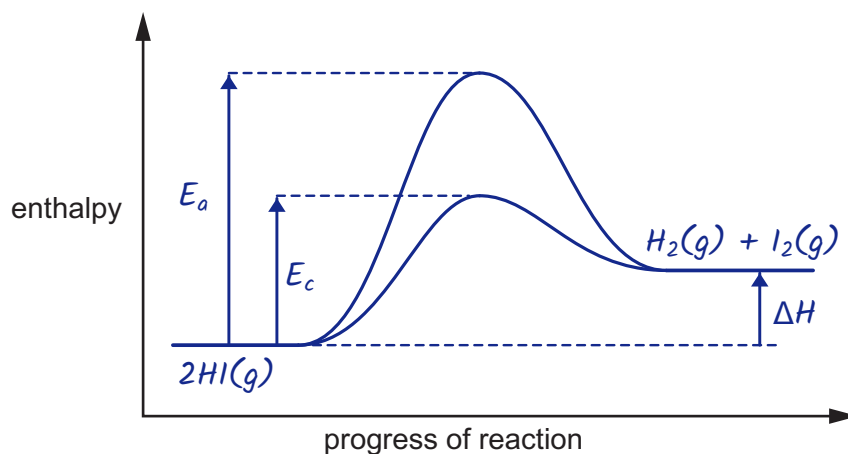
(b) Hydrogen iodide, HI, is decomposed by heat into its elements:



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.



[3]

- (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 cm³ of gas is produced.

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

Show all your working.

$$T = 100 + 273 = 373 \text{ K}; \quad p = 1.00 \times 10^5 \text{ Pa}$$

$$V = 76.0 \text{ cm}^3 = 76.0 \times 10^{-6} \text{ m}^3$$

$$n = pV \div RT = (1.00 \times 10^5 \times 76.0 \times 10^{-6}) \div (8.314 \times 373)$$

$$n = 2.45 \times 10^{-3} \text{ mol}$$

$$M = m \div n = 0.4485 \div 2.45 \times 10^{-3} = 183 \text{ g mol}^{-1}$$

$$\text{Cl}_2\text{O}_7: M = 2 \times 35.5 + 7 \times 16.0 = 183.0 \text{ g mol}^{-1}, \text{ which matches}$$

molecular formula of **A** = ... Cl₂O₇ [4]

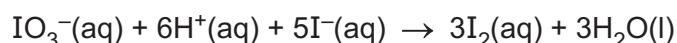
- (d) Compound **B** is an iodate(V) salt of a Group 1 metal.
The iodate(V) ion has the formula IO_3^- .

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 $\text{KI}(\text{aq})$.

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



Step 3: The resulting mixture is titrated with $0.150 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3(\text{aq})$.



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	24.00	23.40	23.75	23.85

Table 20.1

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

concordant titres 2 and 3: $(23.75 + 23.85) \div 2 = 23.80 \text{ cm}^3$

mean titre = ... **23.80** cm^3 [2]

- (ii) The uncertainty in each burette reading is $\pm 0.05 \text{ cm}^3$.

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

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

uncertainty in titre = $2 \times 0.05 = 0.10 \text{ cm}^3$

% uncertainty = $0.10 \div 23.40 \times 100 = 0.43\%$

percentage uncertainty = ... **0.43** % [1]

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

Add starch indicator near the end point (when the iodine solution is pale yellow).

The end point is when the colour changes from blue-black to colourless. [2]

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

Show your working.

$$n(S_2O_3^{2-}) = 0.150 \times 23.80 \div 1000 = 3.57 \times 10^{-3} \text{ mol}$$

$$n(I_2) = 3.57 \times 10^{-3} \div 2 = 1.785 \times 10^{-3} \text{ mol}$$

$$n(IO_3^-) \text{ in } 25.00 \text{ cm}^3 = 1.785 \times 10^{-3} \div 3 = 5.95 \times 10^{-4} \text{ mol}$$

$$\text{(i.e. } IO_3^- : S_2O_3^{2-} = 1 : 6)$$

$$n(IO_3^-) \text{ in } 250.0 \text{ cm}^3 = 10 \times 5.95 \times 10^{-4} = 5.95 \times 10^{-3} \text{ mol}$$

$$\text{relative formula mass of B} = 1.55 \div 5.95 \times 10^{-3} = 260.5$$

$$M(IO_3) = 126.9 + 3 \times 16.0 = 174.9$$

$$A_r \text{ of Group 1 metal} = 260.5 - 174.9 = 85.6$$

85.6 is closest to rubidium ($A_r = 85.5$), so B is $RbIO_3$

relative formula mass of **B** = *260.5*

formula of **B** = *RbIO₃* [5]

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.

$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^{-}$	$\rightleftharpoons$	$\text{Zn}(\text{s})$	$E^{\circ} = -0.76\text{V}$
$\text{Cr}^{3+}(\text{aq}) + \text{e}^{-}$	$\rightleftharpoons$	$\text{Cr}^{2+}(\text{aq})$	$E^{\circ} = -0.42\text{V}$
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^{-}$	$\rightleftharpoons$	$\text{Ni}(\text{s})$	$E^{\circ} = -0.25\text{V}$
$\text{I}_2(\text{aq}) + 2\text{e}^{-}$	$\rightleftharpoons$	$2\text{I}^{-}(\text{aq})$	$E^{\circ} = +0.54\text{V}$
$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-}$	$\rightleftharpoons$	$\text{Fe}^{2+}(\text{aq})$	$E^{\circ} = +0.77\text{V}$
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^{+}(\text{aq}) + 6\text{e}^{-}$	$\rightleftharpoons$	$2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	$E^{\circ} = +1.33\text{V}$
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^{+}(\text{aq}) + 2\text{e}^{-}$	$\rightleftharpoons$	$2\text{H}_2\text{O}(\text{l})$	$E^{\circ} = +1.78\text{V}$

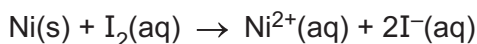
Table 21.1

(a) Complete the electron configuration of

a Ni atom: $1\text{s}^2 \dots 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^8 4\text{s}^2$

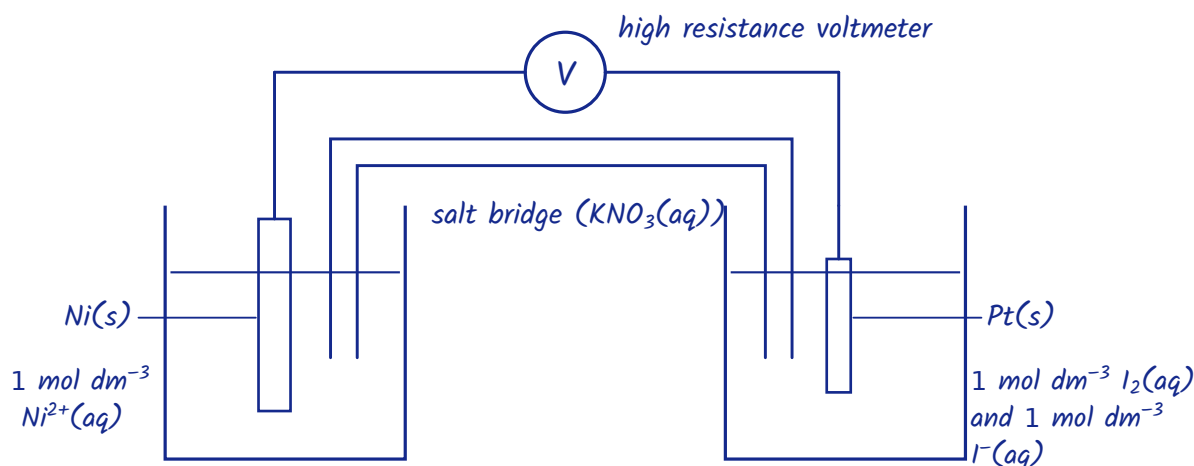
a Ni^{2+} ion: $1\text{s}^2 \dots 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^8$ [2]

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



(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 $298\text{ K } (25\text{ }^{\circ}\text{C})$

all solutions 1 mol dm^{-3} : $[\text{Ni}^{2+}] = [\text{I}_2] = [\text{I}^{-}] = 1\text{ mol dm}^{-3}$

[4]

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

standard cell potential = ... *0.79* 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 .



- (ii) Zinc reacts with acidified $\text{Cr}_2\text{O}_7^{2-}$ 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.

$E^\ominus(\text{Zn}^{2+}/\text{Zn}) = -0.76 \text{ V}$ is more negative than both $E^\ominus(\text{Cr}_2\text{O}_7^{2-}/\text{Cr}^{3+}) = +1.33 \text{ V}$ and $E^\ominus(\text{Cr}^{3+}/\text{Cr}^{2+}) = -0.42 \text{ V}$.

So the Zn^{2+}/Zn equilibrium shifts left (Zn is oxidised and loses electrons), while the $\text{Cr}_2\text{O}_7^{2-}$ equilibrium, and then the Cr^{3+} equilibrium, shift right (gain electrons).

Stage 1: $3\text{Zn}(\text{s}) + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) \rightarrow 3\text{Zn}^{2+}(\text{aq}) + 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$ ($E_{\text{cell}} = +2.09 \text{ V}$)

Stage 2: $\text{Zn}(\text{s}) + 2\text{Cr}^{3+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{Cr}^{2+}(\text{aq})$ ($E_{\text{cell}} = +0.34 \text{ V}$)

..... [4]

(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%.

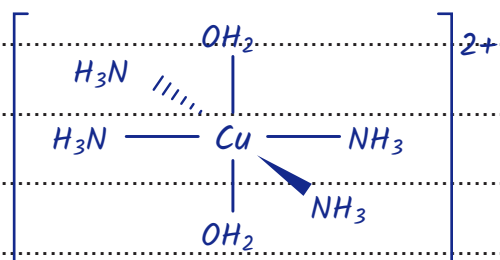
Identify **C–F** by formulae or structures, as appropriate.

Include equations, any changes in oxidation number, and working.

[6]

Reaction 1: C is $\text{trans-}[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$, formed by ligand substitution

(Cu stays +2):



trans: the two H_2O ligands are opposite (180°), octahedral



D is $\text{CuSO}_4(\text{aq})$ ($[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$, blue); E is Cu (brown solid).

Disproportionation: Cu is oxidised from +1 to +2 (CuSO_4) and reduced from +1 to 0 (Cu).



F: Cu : H : N : O = 26.29/63.5 : 2.48/1.0 : 11.59/14.0 : 59.63/16.0 = 1 :

6 : 2 : 9, so $\text{CuH}_6\text{N}_2\text{O}_9$

= $\text{Cu}(\text{NO}_3)_2 + 3\text{H}_2\text{O}$, so F is $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$

Additional answer space if required.

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END OF QUESTION PAPER

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