1. This question is about Group 2 and Group 17 (7).

**(a)** Barium chloride can be prepared from barium hydroxide in a neutralisation reaction.

strong acid + strong base

Write the equation for this reaction. State symbols are **not** required.

$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$ **[1]**

**(b)** The reactivity of the Group 2 elements Mg–Ba increases down the group.

Explain why.

- Atomic radii size increases
- electron sheilding increases
- nuclear attraction decreases
- Ionisation energy decreases

**[3]**

**(c)** On gently heating, the compound $KClO_3$ reacts as shown in the equation.

+1 -2 +1 -1 +1 -2

$4KClO_3(s) \rightarrow KCl(s) + 3KClO_4(s)$

+5 +7

$1 + (-2 \times 4) = -7$

$(-2 \times 3) = -5$

This reaction is an example of disproportionation.

**(i)** State what is meant by *disproportionation* and use oxidation numbers to show that disproportionation has taken place.

disproportionation: where oxidation and reduction of the same element occur simultaneously.

**[3]**

**(ii)** What is the systematic name for $KClO_4$?

potassium chlorate (VII) **[1]**

chlorine has a +7 oxidation number

**(d)** Two changes are described below.

For each change,
- write an equation, including state symbols,
- state and explain how the entropy changes.

increases if more gaseous molecules produced

**(i)** The reaction of aqueous barium nitrate with aqueous sodium sulfate.

Full equation with state symbols

$Ba(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaNO_{3(aq)}$

Explanation of entropy change entropy decreases because $BaSO_4$ (s) has less disorder

[2]

**(ii)** The change that accompanies the standard enthalpy change of atomisation of iodine.

IMPORTANT only one gaseous atom produced.

Equation with state symbols

$\frac{1}{2} I_{2(s)} \rightarrow I_{(g)}$

Explanation of entropy change entropy increases because gas has more disorder

[2]

2. 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: London forces increase because the number of electrons increases so more energy needed to break London forces (hence why boiling points increase down the group).

**[3]**

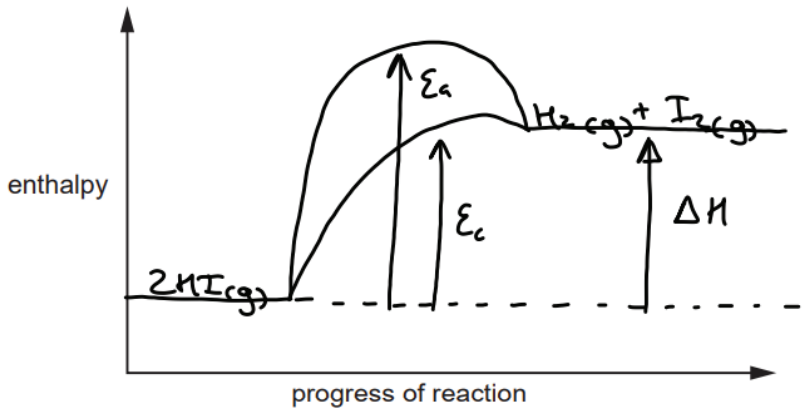
**(b)** Hydrogen iodide, HI, is decomposed by heat into its elements:

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

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 $\Delta H$ 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.

A consists only of Cl and O

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

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

$PV = nRT$

$n = \frac{PV}{RT}$

Show all your working.

$P = 1 \times 10^5$ Pa

$V = 76 \times 10^{-6}$ ← $cm^3$ → $m^3$

$n = ?$

$R = 8.314$

$T = 100 + 273 = 373$ K

$$n = \frac{1 \times 10^5 \times 76 \times 10^{-6}}{8.314 \times 373} = 2.45 \times 10^{-3} \text{ mol}$$

$\frac{\text{mass}}{\text{mol}} = \text{RFM}$ $\quad \frac{0.4485}{2.45 \times 10^{-3}} = 183$

$(35.5 \times 2) + (16 \times 7) = 183$

(RFM of Cl) (RFM of O)

molecular formula of **A** = $ClO_7$ **[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 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 / $cm^3$** | 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.

$$\frac{23.75 + 23.85}{2} = 23.80$$

mean titre = ..... 23.80 ..... $cm^3$ **[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.

$$\frac{0.05 \times 2}{23.40} \times 100 = 0.43\%$$

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

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

Add Starch

colour change: blue to colourless

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

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

Show your working.

mol of $S_2O_3^{2-}$ : $0.15 \times 23.80 \times 10^{-3} = 3.57 \times 10^{-3}$ mol

mol of $IO_3^-$ : $\frac{3.57 \times 10^{-3}}{6} = 5.95 \times 10^{-4}$ mol

$5.95 \times 10^{-4} \times 10 = 5.95 \times 10^{-3}$ mol ($25\,cm^3$) ($250\,cm^3$)

$\frac{mass}{mol}$ = RFM $\quad \frac{1.55}{5.95 \times 10^{-3}} = 260.5$

$260.5 -$ RFM of $IO_3^-$

$(126.9 + (16 \times 3)) = 174.9$

$260.5 - 174.9 = 85.6$

Closest group 1 metal with RFM near to 85.6 is Rb

So formula of B: $RbIO_3$

relative formula mass of **B** = 260.5

formula of **B** = $RbIO_3$ **[5]**

3. Which statement about the reactions of halogens with halide ions is correct?

**A** $I_2$(aq) can oxidise $Br^-$(aq).

**B** $Cl_2$(aq) can reduce $Br^-$(aq).

**C** $Br^-$(aq) can reduce $Cl_2$(aq).

**D** $Cl^-$(aq) can oxidise $I_2$(aq).

Your answer C

[1]

oxidising strength: $F_2 > Cl_2 > Br_2 > I_2$

Reducing strength: $I^- > Br^- > Cl^- > F^-$

| | $F_2$ | $Cl_2$ | $Br_2$ | $I_2$ |
|---|---|---|---|---|
| $F^-$ | X | X | X | X |
| $Cl^-$ | $F_2 + 2Cl^- \rightarrow Cl_2 + 2F^-$ | X | X | X |
| $Br^-$ | $F_2 + 2Br^- \rightarrow Br_2 + 2F^-$ | $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$ | X | X |
| $I^-$ | $F_2 + 2I^- \rightarrow I_2 + 2F^-$ | $Cl_2 + I^- \rightarrow 2Cl^- + I_2$ | $Br_2 + 2I^- \rightarrow 2Br^- + I_2$ | X |

4. 3.528 g of a Group 2 metal, **M**, is reacted with an excess of chlorine. The reaction forms 9.775 g of a chloride.

What is metal **M**?

**A** magnesium

**B** calcium

**C** strontium

**D** barium

Your answer **B**


$M + Cl_2 \rightarrow MCl_2$

M = RFM of metal

$\frac{9.775}{M+(35.5\times2)} = \frac{3.528}{M}$

$9.775M = 3.528M + 246.96$

$6.247M = 246.96 \rightarrow M = \frac{246.96}{6.247} = 39.5$

[1]

5. This question is about halogens.

**(a)** A student adds a solution of bromine in an organic solvent to two test tubes.

The student adds aqueous sodium chloride to one test tube, and aqueous sodium iodide to the other test tube.

The student shakes the mixtures, allows them to settle, and records the colour of the organic layer in each mixture.

| Sodium halide | Colour of organic layer |
|---|---|
| Sodium chloride | orange |
| Sodium iodide | violet |

Explain how the student's results provide evidence for the trend in reactivity of the halogens down group 17(7) and write an ionic equation for any reaction that takes place.

Use your chemical knowledge to explain the trend in reactivity.

orange contains bromine and no reaction

violet contains iodine

$Br_2 + 2I^- \longrightarrow 2Br^- + I_2$

Down the group:

- reactivity decreases
- oxidising power decreases / gains electrons less easily / forms negative ion less easily / less energy released when electron gained / more negative electron affinity
- Greater atomic radius / more shells / more shielding so less nuclear attraction. [5]

**(b)** Chlorine is used in water treatment.

State **one** benefit and **one** risk of using chlorine in water treatment.

Benefit ...kills bacteria.....

.....

Risk ...toxic / forms chlorinated hydrocarbons / forms carcinogenic compounds.....

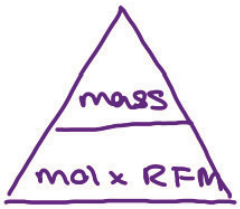
**[1]**

**(c)** Compound **A** contains bromine and fluorine only, and has a boiling point of 41 °C.

1.26 g of compound **A** is heated to 80 °C.
The volume of gas produced is 0.209 $dm^3$.

Under the conditions used, 1 mol of gas molecules has a volume of 29.0 $dm^3$.

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




$\frac{0.209}{29} = 0.00721$ mol of A

similar to 24 $dm^3$ equation: $mol = \frac{vol\ (dm^3)}{24}$

Br = 79.9
F = 19

$\frac{1.26}{0.00721} = 174.8$ RFM of A

174.8 - 79.9 = 94.9
94.9 - 79.9 = 15 ← can't have more than one Br
94.9 ÷ 19 = 5

molecular formula = ...$BrF_5$..... **[3]**