Q1. A sample of 2.18 g of oxygen gas has a volume of 1870 cm^3 at a pressure of 101 kPa.

What is the temperature of the gas?
The gas constant is R = 8.31 J K^{-1} mol^{-1}.

A 167 K ⬭

B 334 K ⬭

C 668 K ⬭

D 334 000 K ⬭

(Total 1 mark)

Q2. In an experiment to identify a Group 2 metal (X), 0.102 g of X reacts with an excess of aqueous hydrochloric acid according to the following equation.

$$X + 2HCl \longrightarrow XCl_2 + H_2$$

The volume of hydrogen gas given off is 65 cm^3 at 99 kPa pressure and 303 K.
The gas constant is R = 8.31 J K^{-1} mol^{-1}.

Which is X?

A Barium ⬭

B Calcium ⬭

C Magnesium ⬭

D Strontium ⬭

(Total 1 mark)

Q3. When heated, iron(III) nitrate (M_r = 241.8) is converted into iron(III) oxide, nitrogen dioxide and oxygen.

$$4Fe(NO_3)_3(s) \longrightarrow 2Fe_2O_3(s) + 12NO_2(g) + 3O_2(g)$$

A 2.16 g sample of iron(III) nitrate was completely converted into the products shown.

(a) (i) Calculate the amount, in moles, of iron(III) nitrate in the 2.16 g sample.

Give your answer to 3 significant figures.

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(1)

(ii) Calculate the amount, in moles, of oxygen gas produced in this reaction.

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(1)

(iii) Calculate the volume, in m^3, of **nitrogen dioxide** gas at 293 °C and 100 kPa produced from 2.16 g of iron(III) nitrate.
The gas constant is $R = 8.31\ JK^{-1}\ mol^{-1}$.

(If you have been unable to obtain an answer to part (i), you may assume the number of moles of iron(III) nitrate is 0.00642. This is **not** the correct answer.)

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(b) Suggest a name for this type of reaction that iron(III) nitrate undergoes.

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(1)

(c) Suggest why the iron(III) oxide obtained is pure.
Assume a complete reaction.

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(1)
(Total 8 marks)

Q4. The metal lead reacts with warm dilute nitric acid to produce lead(II) nitrate, nitrogen monoxide and water according to the following equation.

$$3Pb(s) + 8HNO_3(aq) \longrightarrow 3Pb(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

(a) In an experiment, an 8.14 g sample of lead reacted completely with a 2.00 mol dm^{-3} solution of nitric acid.

Calculate the volume, in dm^3, of nitric acid required for complete reaction.
Give your answer to 3 significant figures

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(3)

(b) In a second experiment, the nitrogen monoxide gas produced in the reaction occupied 638 cm^3 at 101 kPa and 298 K.
Calculate the amount, in moles, of NO gas produced.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(Extra space) .....

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(3)

(c) When lead(II) nitrate is heated it decomposes to form lead(II) oxide, nitrogen dioxide and oxygen.

(i) Balance the following equation that shows this thermal decomposition.

.....$Pb(NO_3)_2(s)$ ⟶ ..... $PbO(s)$ + ...$NO_2(g)$ + ...$O_2(g)$

(1)

(ii) Suggest **one** reason why the yield of nitrogen dioxide formed during this reaction is often less than expected.

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(1)

(iii) Suggest **one** reason why it is difficult to obtain a pure sample of nitrogen dioxide from this reaction.

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(1)

(Total 9 marks)

Q5. (a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.

$$B_2O_3(s) + 3C(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g) + 3CO(g)$$

A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine. The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(5)

(b) Boron trichloride can also be prepared from its elements.

Write an equation for this reaction.
Explain why boron trichloride has a trigonal planar shape with equal bond angles.

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(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.

$$BCl_3(g) + 3H_2O(l) \longrightarrow H_3BO_3(aq) + 3HCl(aq)$$

Calculate the concentration, in mol dm^{-3}, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm^3 of solution. Give your answer to 3 significant figures.

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(ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water.
Write an equation for this reaction.

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(1)

(d) Boron trichloride can be reduced by using hydrogen to form pure boron.

$$BCl_3(g) + 1\tfrac{1}{2}\,H_2(g) \longrightarrow B(s) + 3HCl(g)$$

Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

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(e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

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(Total 20 marks)

Q6. Ammonia is used to make nitric acid (HNO_3) by the Ostwald Process.
Three reactions occur in this process.

Reaction **1** $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

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

Reaction **3** $3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$

(a) In one production run, the gases formed in Reaction **1** occupied a total volume of 4.31 m^3 at 25 °C and 100 kPa.

Calculate the amount, in moles, of NO produced.
Give your answer to 3 significant figures.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(4)

(b) In another production run, 3.00 kg of ammonia gas were used in Reaction **1** and all of the NO gas produced was used to make NO_2 gas in Reaction **2**.

(i) Calculate the amount, in moles, of ammonia in 3.00 kg.

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(2)

(ii) Calculate the mass of NO_2 formed from 3.00 kg of ammonia in Reaction **2** assuming an 80.0% yield.
Give your answer in kilograms.
(If you have been unable to calculate an answer for part (b)(i), you may assume a value of 163 mol. This is **not** the correct answer.)

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(c) Consider Reaction **3** in this process.

$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

Calculate the concentration of nitric acid produced when 0.543 mol of NO_2 is reacted with water and the solution is made up to 250 cm^3.

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(Extra space) .....

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(2)

(d) Suggest why a leak of NO_2 gas from the Ostwald Process will cause atmospheric pollution.

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(1)

(e) Give **one** reason why excess air is used in the Ostwald Process.

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(1)

(f) Ammonia reacts with nitric acid as shown in this equation.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

Deduce the type of reaction occurring.

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(1)

(Total 14 marks)