1 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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(Extra space) ....

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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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(Extra space) ....

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(3)

(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)

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

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

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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(Extra space) ....

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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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(Extra space) ....

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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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(Extra space) ....

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(4)

(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.

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

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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(Extra space) ....

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(3)

(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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(Extra space) ....

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(4)
(Total 20 marks)

3 During a titration a chemist may rinse the inside of the conical flask with distilled or deionised water. The water used for rinsing remains in the conical flask.

(a) Explain why this rinsing can improve the accuracy of the end-point.

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(1)

(b) Explain why the addition of water during rinsing does **not** give an incorrect result.

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(1)
(Total 2 marks)

4 Potassium carbonate can also occur as a hydrated compound, $K_2CO_3.xH_2O$.
Analysis of this hydrated compound showed that it contained 11.5% by mass of water.
Determine the value of x. Show your working.

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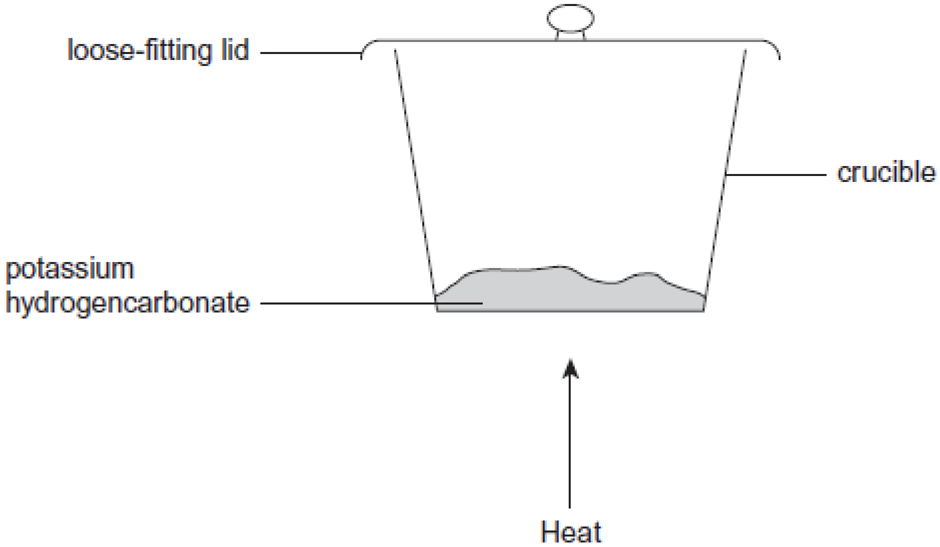
(Total 2 marks)

5 (a) Potassium carbonate can also be prepared by the decomposition of potassium hydrogencarbonate. The equation for the reaction is shown below with a diagram of the apparatus used.

$$2KHCO_3 \longrightarrow K_2CO_3 + CO_2 + H_2O$$



A student was asked to check the purity of a sample of potassium hydrogencarbonate. The student weighed a clean, dry crucible, and transferred 1.00 g of the potassium hydrogencarbonate to the crucible. A lid was placed on the crucible and the crucible was then heated for a few minutes. After cooling, the mass of the crucible and its contents was recorded.

(i) Explain why the use of a wet crucible would give an inaccurate result.

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(1)

(ii) Give **one** reason why the use of a lid improves the accuracy of the experiment.

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(1)

(iii) State **one** reason why the use of a very small amount of potassium hydrogencarbonate could lead to a less accurate result.

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(1)

(b) In another experiment, the decomposition of a 1.00 g sample of pure potassium hydrogencarbonate gave 0.81 g of solid in the crucible.

(i) Calculate the mass of potassium carbonate that can be formed from 1.00 g of potassium hydrogencarbonate.
Show your working.

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(3)

(ii) In this experiment the mass of solid remaining in the crucible was greater than expected. Suggest **one** reason for this result.

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(1)
(Total 7 marks)

6 A student calculated that a value for the enthalpy change of neutralisation is –51.2 kJ mol^{-1}.

The design of a possible hand-warmer using hydrochloric acid and sodium hydroxide was discussed. It was proposed that 500 cm^3 of hydrochloric acid should be used in a flexible, sealed plastic container with a breakable tube of solid sodium hydroxide also in the container. On breaking the tube, the sodium hydroxide would be released, react with the acid and produce heat.
A 40 °C temperature rise was thought to be suitable.

(a) Calculate the heat energy, in J, required to raise the temperature of the reaction mixture by 40 °C. Assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}.
Assume that all of the heat energy given out is used to heat the reaction mixture.

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(2)

(b) Use your answer from part (a) and the value for the enthalpy change of neutralisation of –51.2 kJ mol^{-1} to calculate the minimum amount, in moles, and hence the minimum mass of sodium hydroxide required in the breakable tube.
(If you could not complete the calculation in part (a) assume that the heat energy required was 77 400 J. This is **not** the correct answer).

Show your working.

Moles of NaOH ....

....

Mass of NaOH ....

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(3)

(c) Use the amount, in moles, of sodium hydroxide from part (b) to calculate the minimum concentration, in mol dm^{-3}, of hydrochloric acid required in the 500 cm^3 of solution used in the sealed container.

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(1)

(d) Suggest **one** possible risk to a person who uses a hand-warmer containing sodium hydroxide and hydrochloric acid.

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(1)

(e) A commercial hand-warmer uses powdered iron sealed in a plastic container.
A valve allows air to enter the container, and oxygen in the air reacts slowly with the iron to form solid iron(III) oxide. The heat released warms the container.

(i) Write an equation for this reaction between iron and oxygen to form iron(III) oxide.

....

(1)

(ii) One version of an iron-oxygen hand-warmer advertises that it is designed to stay warm for up to four hours.
Other than by increasing the amount of iron in the container, state **one** change to the iron in the hand-warmer that would increase this time.
Explain why this change to the iron might **not** be an advantage.

Change to the iron ....

....

Explanation ....

....

....

(3)

(f) Another type of hand-warmer uses sodium thiosulfate. Sodium thiosulfate is very soluble in water at 80 °C but is much less soluble at room temperature.
When a hot, concentrated solution of sodium thiosulfate is cooled it does not immediately crystallise. The sodium thiosulfate stays dissolved as a stable 'super-saturated' solution until crystallisation is triggered.
Heat energy is then released when the sodium thiosulfate crystallises.

(i) This type of hand-warmer is re-usable.
Suggest **one** environmental advantage that a sodium thiosulfate hand-warmer has over the other two types.

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(1)

(ii) Describe the **two** steps that you would take to make the sodium thiosulfate hand-warmer ready for re-use.

Step 1 ....

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Step 2 ....

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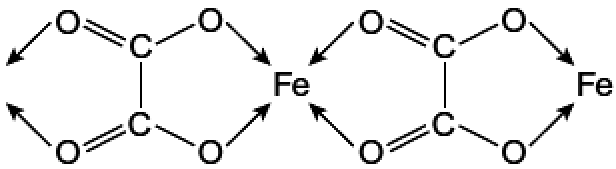
(2)
(Total 14 marks)

7 Solid iron(II) ethanedioate dihydrate ($FeC_2O_4.2H_2O$) has a polymeric structure.
Two repeating units in the polymer chain are shown.



Each iron ion is also bonded to two water molecules. These are **not** shown in the diagram.

(a) Name the type of bond that is represented by the arrows.

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(1)

(b) In terms of electrons explain how the water molecules, **not** shown in the diagram, form bonds to the iron.

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(2)

(c) Predict the value of the bond angle between the two bonds to iron that are formed by these two water molecules.

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(1)

(d) Iron(II) ethanedioate dihydrate can be analysed by titration using potassium manganate(VII) in acidic solution. In this reaction, manganate(VII) ions oxidise iron(II) ions and ethanedioate ions.

A 1.381 g sample of impure $FeC_2O_4.2H_2O$ was dissolved in an excess of dilute sulfuric acid and made up to 250 cm^3 of solution.
25.0 cm^3 of this solution decolourised 22.35 cm^3 of a 0.0193 mol dm^{-3} solution of potassium manganate(VII).

(i) Use the half-equations given below to calculate the reacting ratio of moles of manganate(VII) ions to moles of iron(II) ethanedioate.

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \longrightarrow Fe^{3+} + e^-$$

$$C_2O_4^{2-} \longrightarrow 2CO_2 + 2e^-$$

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(1)

(ii) Calculate the percentage by mass of $FeC_2O_4.2H_2O$ in the original sample.

(If you have been unable to answer part (d)(i) you may assume that three moles of manganate(VII) ions react with seven moles of iron(II) ethanedioate. This is **not** the correct ratio.)

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(5)
(Total 10 marks)

8 A student was given a task to determine the percentage purity of a sample of salicylic acid. The method used by the student to prepare a solution of salicylic acid is described below.

- 0.500 g of an impure sample of salicylic acid was placed in a weighing bottle.
- The contents were tipped into a beaker and 100 cm^3 of distilled water were added.
- Salicylic acid does not dissolve well in cold water so the beaker and its contents were heated gently until all the solid had dissolved.
- The solution was poured into a 250 cm^3 graduated flask and made up to the mark with distilled water.

(a) Give **two** additional instructions that would improve this method for making up the salicylic acid solution.

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(2)

(b) The pH of this solution was measured and a value of 2.50 was obtained.
Calculate the concentration of salicylic acid in this solution.
Assume that salicylic acid is the only acid in this solution. The K_a for salicylic acid is 1.07×10^{-3} mol dm^{-3}. You may represent salicylic acid as HA.
Show your working.

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(3)

(c) Use your answer to part (b) to calculate the mass of salicylic acid (M_r = 138.0) present in the original sample.
(If you were unable to complete the calculation in part (b), assume that the concentration of salicylic acid is 8.50×10^{-3} mol dm^{-3}. This is **not** the correct answer.)

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(2)

(d) Use your answer to part (c) to calculate the percentage purity of the salicylic acid used to make the solution.
(If you were unable to complete the calculation in part (c), assume that the mass of salicylic acid is 0.347 g. This is **not** the correct answer.)

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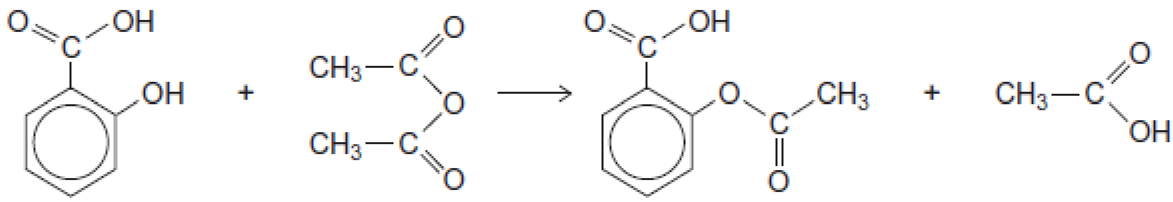
(1)
(Total 8 marks)

9 Aspirin can be made by reacting salicylic acid with ethanoic anhydride as outlined below.



(a) In an experiment, after purification by recrystallisation, 1.76 g of aspirin (M_r = 180.0) were produced from 2.00 g of salicylic acid.
Calculate the percentage yield for this experiment.

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(2)

(b) Suggest **one** practical reason why the yield of purified aspirin is less than 100%.

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(1)
(Total 3 marks)

10 (a) The iron(II) ions in well-water can be removed by oxidation using potassium manganate(VII) in **alkaline** solution. A mixture containing solid iron(III) hydroxide and solid manganese(IV) oxide is formed. These solid products can be removed by filtration under reduced pressure.

(i) Draw a diagram of the apparatus used for this filtration. Do **not** include the apparatus used to reduce the pressure.

(2)

(ii) An equation representing the oxidation reaction is given below.

$$3Fe^{2+}(aq) + KMnO_4(aq) + 5OH^-(aq) + 2H_2O(l) \longrightarrow 3Fe(OH)_3(s) + MnO_2(s) + K^+(aq)$$

Calculate the mass, in grams, of $KMnO_4$ required to react with the iron(II) ions in 1.00 dm^3 of well-water that has an iron(II) concentration of 0.225 mol dm^{-3}.
Give your answer to the appropriate precision.
Show your working.

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(3)

(iii) In practice, a slight excess of potassium manganate(VII) is used to treat the well-water.
Although this treated water is safe to drink, this excess of potassium manganate(VII) is undesirable. Suggest **one** reason, other than colour, why the excess is undesirable.

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(1)

(b) Suggest **one** reason why the colour of potassium manganate(VII) solution can be a source of error when using a volumetric (graduated) flask to prepare a standard solution.

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(1)
(Total 7 marks)

11 The slowing down of chemical processes is important in food storage. Over time, fats may become rancid. This involves the formation of compounds that have unpleasant odours and flavours within the food.
Hydrolysis of fats is one way in which rancid flavours are formed. Fats break down to long-chain carboxylic (fatty) acids and glycerol.

(a) Complete the right-hand side of the equation below to show how hydrolysis affects the molecule of fat shown.

$$\begin{array}{l} CH_3(CH_2)_{14}COOCH_2 \\ \qquad\qquad\qquad\quad | \\ CH_3(CH_2)_{14}COOCH \quad + \ 3H_2O \ \rightarrow \ 3 \ \ldots\ldots\ldots\ldots \ + \ \ldots\ldots\ldots\ldots \\ \qquad\qquad\qquad\quad | \\ CH_3(CH_2)_{14}COOCH_2 \end{array}$$

(2)

(b) Other than by cooling, suggest **one** method that would decrease the rate of hydrolysis of fats.

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(1)

(c) Food can also acquire unpleasant flavours when the fatty acids, produced by hydrolysis of fats, are oxidised by air. This oxidation occurs by a free-radical mechanism.
Chemicals called anti-oxidants can be added to food to slow down the oxidation.
Suggest why anti-oxidants are **not** regarded as catalysts.

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(2)

(d) A student investigated the extent of hydrolysis in an old sample of the fat in part (a).
The carboxylic acid extracted from a 2.78 g sample of this fat (M_r = 806.0) reacted with 24.5 cm^3 of a 0.150 mol dm^{-3} solution of NaOH.
Calculate the percentage of the fat that had hydrolysed.
Show your working.

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(4)
(Total 9 marks)

12 The element nitrogen forms compounds with metals and non-metals.

(a) Nitrogen forms a nitride ion with the electron configuration $1s^2\ 2s^2\ 2p^6$
Write the formula of the nitride ion.

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(1)

(b) An element forms an ion **Q** with a single negative charge that has the same electron configuration as the nitride ion.
Identify the ion **Q**.

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(1)

(c) Use the Periodic Table and your knowledge of electron arrangement to write the formula of lithium nitride.

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(1)

(d) Calcium nitride contains 81.1% by mass of the metal.
Calculate the empirical formula of calcium nitride.
Show your working.

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(3)

(e) Write an equation for the reaction between silicon and nitrogen to form silicon nitride, Si_3N_4

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(1)
(Total 7 marks)

13 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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(Extra space) ....

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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.

$$\text{........}Pb(NO_3)_2(s) \longrightarrow \text{.......}\ PbO(s) + \text{.......}NO_2(g) + \text{.......}O_2(g)$$

(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)

14 Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

(a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

(i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

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(1)

(ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

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(1)

(iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

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(2)

(iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

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(1)

(b) Norgessaltpeter decomposes on heating as shown by the following equation.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

A sample of Norgessaltpeter was decomposed completely.

The gases produced occupied a volume of 3.50×10^{-3} m^3 at a pressure of 100 kPa and a temperature of 31 °C.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(i) Calculate the total amount, in moles, of gases produced.

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(3)

(ii) Hence calculate the amount, in moles, of oxygen produced.

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(1)

(c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

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(3)
(Total 12 marks)

15 (a) A student investigated the acid content of a different crater-lake solution. The student used a 50.0 cm^3 burette to measure out different volumes of this crater-lake solution. Each volume of crater-lake solution was titrated with a 0.100 mol dm^{-3} sodium hydroxide solution. Each titration was repeated. The results are shown below.

Volume of crater-lake solution / cm^3		10.0	20.0	30.0	40.0	50.0
Volume of sodium hydroxide solution / cm^3	Experiment 1	5.85	17.00	20.00	26.50	32.45
	Experiment 2	6.15	13.00	19.90	26.50	32.55
Average titre / cm^3		6.00	15.00	19.95	26.50	32.50

(i) On the graph paper below, plot a graph of average titre (y-axis) against volume of crater-lake solution. Both axes must start at zero.

(3)

(ii) Draw a line of best fit on the graph.

(1)

(iii) Use the graph to determine the titre that the student would have obtained using a 25.0 cm^3 sample of crater-lake solution.

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(1)

(iv) Excluding any anomalous points, which average titre value would you expect to be the least accurate value? Give **one** reason for your choice.

Least accurate average titre ....

Reason ....

....

(2)

(b) Another 100 cm^3 sample of crater-lake solution was reacted with an excess of powdered limestone. The gas produced was collected in a gas syringe. The equation for the reaction between the sulfuric(IV) acid in the crater-lake solution and the calcium carbonate in the powdered limestone is shown below.

$$H_2SO_3 + CaCO_3 \longrightarrow CaSO_3 + H_2O + CO_2$$

The volume of gas collected from the reaction of the sulfuric(IV) acid in 100 cm^3 of crater-lake solution with an excess of powdered limestone was 81.0 cm^3 at 298 K and 1.00 $\times 10^5$ Pa.

(i) State the ideal gas equation.

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(1)

(ii) Use the ideal gas equation to calculate the amount, in moles, of carbon dioxide formed.
Show your working.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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....

(3)

(iii) Use the equation for the reaction and your answer from part (b)(ii) to calculate the minimum mass of calcium carbonate needed to neutralise the sulfuric(IV) acid in 1.00 dm^3 of crater-lake solution.
Show your working.

(If you could not complete the calculation in part (b)(ii) assume that the amount of carbon dioxide is 1.25×10^{-2} mol. This is **not** the correct value.)

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(3)

(iv) The percentage by mass of calcium carbonate in the powdered limestone was 95.0%. Calculate the minimum mass of this powdered limestone needed to neutralise the sulfuric(IV) acid in 1.00 dm^3 of this crater-lake solution.

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(2)

(v) Give **one** reason, other than cost, why limestone rather than solid sodium hydroxide is often used to neutralise acidity in lakes.

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(1)
(Total 17 marks)

16 (a) A solution of barium hydroxide is often used for the titration of organic acids. A suitable indicator for the titration is thymol blue. Thymol blue is yellow in acid and blue in alkali. In a titration a solution of an organic acid was added from a burette to a conical flask containing 25.0 cm^3 of a barium hydroxide solution and a few drops of thymol blue.

(i) Describe in full the colour change at the end-point of this titration.

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(1)

(ii) Thymol blue is an acid. State how the average titre would change if a few cm^3, rather than a few drops, of the indicator were used by mistake in this titration.

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(1)

(iii) Barium hydroxide is toxic. Suggest **one** safety precaution you would take to minimise this hazard when wiping up a spillage of barium hydroxide solution.

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(1)

(iv) Suggest **one** reason why a 250 cm^3 conical flask is preferred to a 250cm^3 beaker for a titration.

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(1)

(v) Suggest **one** reason why repeating a titration can improve its reliability

....

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(1)

(b) Solubility data for barium hydroxide and calcium hydroxide are given in the table below.

Compound	Solubility at 20 °C / g dm^{-3}
barium hydroxide	38.9
calcium hydroxide	1.73

(i) Use the data given in the table to calculate the concentration, in mol dm^{-3}, of a saturated solution of calcium hydroxide (M_r = 74.1) at 20°C.

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(1)

(ii) Suggest **one** reason why calcium hydroxide solution is **not** used in the titration of a 0.200 mol dm^{-3} solution of an acid.

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(1)
(Total 7 marks)

17 In an experiment to determine its solubility in water, solid barium hydroxide was added to 100cm^3 of water until there was an excess of the solid. The mixture was filtered and an excess of sulfuric acid was added to the filtrate. The barium sulfate produced was obtained from the reaction mixture, washed with cold water and dried. The mass of barium sulfate was then recorded.

(a) Explain why the mixture was filtered before the addition of sulfuric acid.

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(1)

(b) State how the barium sulfate produced was obtained from the reaction mixture.

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(1)

(c) Explain why the barium sulfate was washed before it was dried.

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(1)

(d) Write an equation for the reaction between barium hydroxide and sulfuric acid.

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(1)

(e) In an experiment, 4.25 g of barium sulfate were formed when an excess of sulfuric acid was added to 100 cm^3 of a saturated solution of barium hydroxide.

(i) Use data from the Periodic Table to calculate the M_r of barium sulfate. Give your answer to one decimal place.

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(1)

(ii) Calculate the amount, in moles, of $BaSO_4$ in 4.25 g of barium sulfate.

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(1)

(iii) Use your answer from part (ii) to calculate the mass of barium hydroxide (M_r = 171.3) present in 1 dm^3 of saturated solution. Show your working.

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(2)

(f) Barium sulfate is taken by mouth by patients so that an outline of a human digestive system can be viewed using X-rays. Explain why patients do **not** suffer any adverse effects from barium sulfate when it is known that solutions containing barium ions are toxic.

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(1)
(Total 9 marks)

18 A chemist was asked to prepare a standard solution of sodium carbonate. The chemist dissolved an accurately known mass of sodium carbonate in a small amount of water in a conical flask. The chemist then poured the solution into a 250 cm^3 graduated flask and made the solution up to the mark. Suggest **one** improvement to the chemist's procedure.

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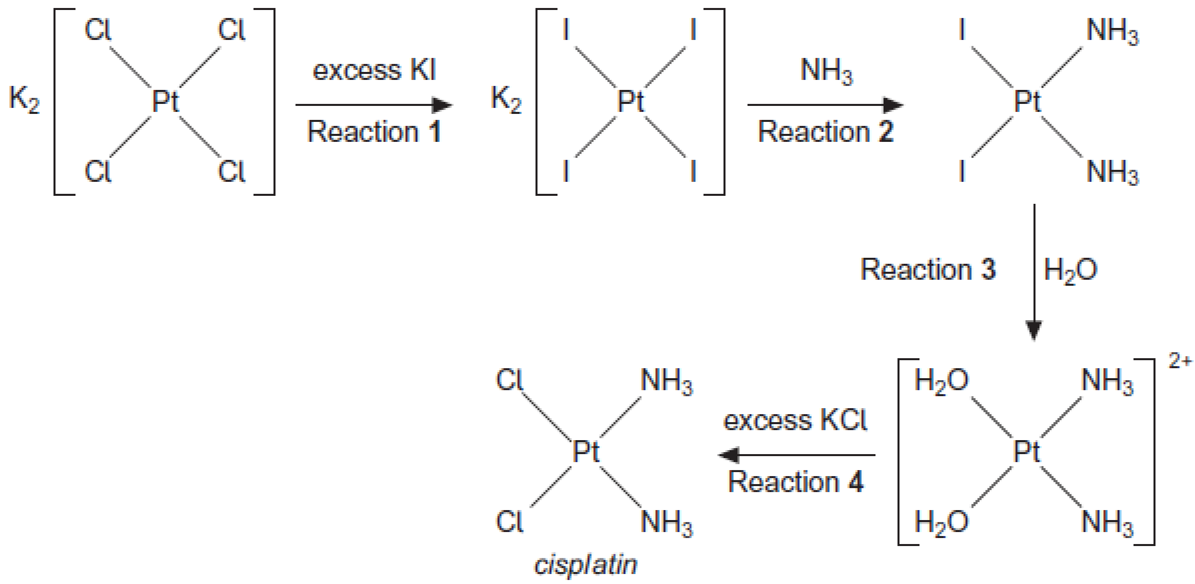
(Total 1 mark)

19 Complexes containing transition elements have a wide variety of uses including acting as dyestuffs like *Prussian Blue*.

Cisplatin is a platinum-based chemotherapy drug used to treat various types of cancers. It was the first member of a class of anti-cancer drugs that react with DNA in tumour cells.

Cisplatin is prepared from K_2PtCl_4 according to the following scheme.

All the reactions shown are reversible.



(a) Name the type of reaction occurring in all four steps of the scheme.

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(1)

(b) Explain why an excess of potassium iodide is used in Reaction **1**.

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(2)

(c) (i) Write an equation for Reaction **1**.

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(1)

(ii) Calculate the percentage atom economy for the formation of K_2PtI_4 in Reaction **1**. Show your working.

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(2)

(d) In Reaction **3**, silver nitrate solution is added to improve the yield of product.

(i) Write the **simplest ionic** equation for the reaction of iodide ions with silver nitrate.

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(1)

(ii) Suggest why addition of silver nitrate improves the yield of product from Reaction **3**.

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....

(1)

(e) Suggest two reasons, other than poor practical technique, why the overall yield of *cisplatin* in this synthesis may be low.

Reason 1 ....

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Reason 2 ....

....

(2)

(f) The *cisplatin* formed in Reaction **4** is impure. Outline how the impure solid is purified by recrystallisation.

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(3)

(g) Platinum compounds are highly toxic.

(i) State why *cisplatin* is used in cancer treatment despite its toxicity.

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(1)

(ii) Suggest a suitable precaution that should be taken by medical staff when using *cisplatin*.

....

(1)
(Total 15 marks)

20 (a) Some metal ions are toxic to humans. A substance that can be used to treat such poisoning contains the ion $EDTA^{4-}$.

$EDTA^{4-}$ forms very stable complexes with metal ions. These complexes are **not** toxic.

(i) Write an equation for the reaction of $EDTA^{4-}$ with aqueous copper(II) ions, $[Cu(H_2O)_6]^{2+}$.

....

(1)

(ii) A solution containing $EDTA^{4-}$ can also be used in a titration to determine the concentration of metal ions in solution.

A river was polluted with copper(II) ions. When a 25.0 cm^3 sample of the river water was titrated with a 0.0150 mol dm^{-3} solution of $EDTA^{4-}$, 6.45 cm^3 were required for complete reaction.

Calculate the concentration, in mol dm^{-3}, of copper(II) ions in the river water.
Show your working.

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(2)

(b) The determination of the concentration of copper(II) ions in a single sample of river water gives an unreliable value for the copper(II) ion pollution in the river.
Give one reason why this value is unreliable.

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(1)

(c) Silver complexes can be used to identify a particular organic functional group.
Give **one** example of a silver complex that can be used in this way and state the organic functional group it identifies.

Silver complex ....

Organic functional group ....

(2)
(Total 6 marks)

21 Steel rods are cleaned before they are painted. The rods are cleaned by passing them through a bath of dilute sulfuric acid. This process produces large quantities of iron(II) sulfate.

(a) Write an equation for the reaction between iron and dilute sulfuric acid.

....

(1)

(b) State **one** chemical hazard in this process and suggest an appropriate safety precaution for this hazard.

Hazard ....

Precaution ....

(2)
(Total 3 marks)

22 Indium is in Group 3 in the Periodic Table and exists as a mixture of the isotopes ^{113}In and ^{115}In.

(a) Use your understanding of the Periodic Table to complete the electron configuration of indium.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$ ....

(1)

(b) A sample of indium must be ionised before it can be analysed in a mass spectrometer.

(i) State what is used to ionise a sample of indium in a mass spectrometer.

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(1)

(ii) Write an equation, including state symbols, for the ionisation of indium that requires the minimum energy.

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(1)

(iii) State why more than the minimum energy is **not** used to ionise the sample of indium.

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(1)

(iv) Give two reasons why the sample of indium must be ionised.

Reason 1 ....

Reason 2 ....

(2)

(c) A mass spectrum of a sample of indium showed two peaks at *m/z* = 113 and *m/z* = 115. The relative atomic mass of this sample of indium is 114.5

(i) Give the meaning of the term *relative atomic mass*.

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(2)

(ii) Use these data to calculate the ratio of the relative abundances of the two isotopes.

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(2)

(d) State and explain the difference, if any, between the chemical properties of the isotopes ^{113}In and ^{115}In

Difference in chemical properties ....

Explanation ....

(2)

(e) Indium forms a compound **X** with hydrogen and oxygen. Compound **X** contains 69.2% indium and 1.8% hydrogen by mass.
Calculate the empirical formula of compound **X**.

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(3)
(Total 15 marks)

23 (a) An unknown metal carbonate reacts with hydrochloric acid according to the following equation.

$$M_2CO_3(aq) + 2HCl(aq) \rightarrow 2MCl(aq) + CO_2(g) + H_2O(l)$$

A 3.44 g sample of M_2CO_3 was dissolved in distilled water to make 250 cm^3 of solution. A 25.0 cm^3 portion of this solution required 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid for complete reaction.

(i) Calculate the amount, in moles, of HCl in 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid. Give your answer to 3 significant figures.

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(1)

(ii) Calculate the amount, in moles, of M_2CO_3 that reacted with this amount of HCl. Give your answer to 3 significant figures.

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(1)

(iii) Calculate the amount, in moles, of M_2CO_3 in the 3.44 g sample. Give your answer to 3 significant figures.

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(1)

(iv) Calculate the relative formula mass, M_r, of M_2CO_3 Give your answer to 1 decimal place.

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(1)

(v) Hence determine the relative atomic mass, A_r, of the metal M and deduce its identity.

A_r of M ....

Identity of M ....

(2)

(b) In another experiment, 0.658 mol of CO_2 was produced. This gas occupied a volume of 0.0220 m^3 at a pressure of 100 kPa.
Calculate the temperature of this CO_2 and state the units.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(3)

(c) Suggest **one** possible danger when a metal carbonate is reacted with an acid in a sealed flask.

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(1)

(d) In a different experiment, 6.27 g of magnesium carbonate were added to an excess of sulfuric acid. The following reaction occurred.

$$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + CO_2 + H_2O$$

(i) Calculate the amount, in moles, of $MgCO_3$ in 6.27 g of magnesium carbonate.

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(2)

(ii) Calculate the mass of $MgSO_4$ produced in this reaction assuming a 95% yield.

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(3)
(Total 15 marks)

24 Hydrogen peroxide is used as an oxidising agent in the preparation of transition metal complexes.

(a) Consider the following reaction scheme. All the complexes are in aqueous solution.

$$[Co(H_2O)_6]^{2+} \xrightarrow{\text{Reaction } \mathbf{1}} \text{cobalt(II) complex} \xrightarrow[H_2O_2]{\text{Reaction } \mathbf{2}} [Co(NH_3)_6]^{3+}$$

(i) Identify a reagent for Reaction **1** and describe the colour change that occurs.

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(3)

(ii) State the colour of the final solution formed in Reaction **2**.

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(1)

(b) Consider the following reaction scheme. All the complexes are in aqueous solution.

$$[Cr(H_2O)_6]^{3+} \xrightarrow[\text{Excess NaOH(aq)}]{\text{Reaction } \mathbf{3}} \text{chromium(III) complex} \xrightarrow[H_2O_2]{\text{Reaction } \mathbf{4}} CrO_4^{2-}$$

(i) For Reaction **3**, state the colour of the initial and of the final solution and write an equation for the reaction.

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(4)

(ii) Write a half-equation for the reduction of hydrogen peroxide to hydroxide ions.

Deduce an overall equation for Reaction **4** and state the colour of the final solution.

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(4)

(c) The concentration of a hydrogen peroxide solution can be determined by titration with acidified potassium manganate(VII) solution. In this reaction the hydrogen peroxide is oxidised to oxygen gas.

A 5.00 cm^3 sample of the hydrogen peroxide solution was added to a volumetric flask and made up to 250 cm^3 of aqueous solution. A 25.0 cm^3 sample of this diluted solution was acidified and reacted completely with 24.35 cm^3 of 0.0187 mol dm^{-3} potassium manganate(VII) solution.

Write an equation for the reaction between acidified potassium manganate(VII) solution and hydrogen peroxide.
Use this equation and the results given to calculate a value for the concentration, in mol dm^{-3}, of the original hydrogen peroxide solution.
(If you have been unable to write an equation for this reaction you may assume that 3 mol of $KMnO_4$ react with 7mol of H_2O_2. This is **not** the correct reacting ratio.)

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(5)
(Total 17 marks)

25 In this question give all your answers to three significant figures.

Magnesium nitrate decomposes on heating to form magnesium oxide, nitrogen dioxide and oxygen as shown in the following equation.

$$2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) Thermal decomposition of a sample of magnesium nitrate produced 0.741 g of magnesium oxide.

(i) Calculate the amount, in moles, of MgO in 0.741 g of magnesium oxide.

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(2)

(ii) Calculate the total amount, in moles, of gas produced from this sample of magnesium nitrate.

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(1)

(b) In another experiment, a different sample of magnesium nitrate decomposed to produce 0.402 mol of gas. Calculate the volume, in dm^3, that this gas would occupy at 333 K and 1.00×10^5 Pa.
(The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$)

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(3)

(c) A 0.0152 mol sample of magnesium oxide, produced from the decomposition of magnesium nitrate, was reacted with hydrochloric acid.

$$MgO + 2HCl \rightarrow MgCl_2 + H_2O$$

(i) Calculate the amount, in moles, of HCl needed to react completely with the 0.0152 mol sample of magnesium oxide.

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(1)

(ii) This 0.0152 mol sample of magnesium oxide required 32.4 cm^3 of hydrochloric acid for complete reaction. Use this information and your answer to part (c) (i) to calculate the concentration, in mol dm^{-3}, of the hydrochloric acid.

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(1)
(Total 8 marks)

26 There are several oxides of nitrogen.

(a) An oxide of nitrogen contains 25.9% by mass of nitrogen. Determine the empirical formula of this oxide.

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(3)

(b) Give **one** reason why the oxide NO is a pollutant gas.

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(1)

(c) The oxide NO reacts with oxygen to form nitrogen dioxide. Write an equation for this reaction.

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(1)

(d) Explain how NO is produced in the engine of a motor vehicle.

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(2)

(e) Write an equation to show how NO is removed from the exhaust gases in motor vehicles using a catalytic converter.

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(1)
(Total 8 marks)

27 (a) Define the term *relative atomic mass*.

An organic fertiliser was analysed using a mass spectrometer. The spectrum showed that the nitrogen in the fertiliser was made up of 95.12% ^{14}N and 4.88% ^{15}N

Calculate the relative atomic mass of the nitrogen found in this organic fertiliser.
Give your answer to two decimal places.

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(4)

(b) In a mass spectrometer, under the same conditions, $^{14}N^+$ and $^{15}N^+$ ions follow different paths. State the property of these ions that causes them to follow different paths.

State **one** change in the operation of the mass spectrometer that will change the path of an ion.

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(2)

(c) Organic fertilisers contain a higher proportion of ^{15}N atoms than are found in synthetic fertilisers.

State and explain whether or not you would expect the chemical reactions of the nitrogen compounds in the synthetic fertiliser to be different from those in the organic fertiliser. Assume that the nitrogen compounds in each fertiliser are the same.

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(2)
(Total 8 marks)

28 (a) The manufacturer of vinegar buys concentrated ethanoic acid as a 15.0 mol dm^{-3} solution. In case of an accidental spillage of this ethanoic acid the manufacturer always has sodium carbonate readily available to neutralise the acid. The equation for this reaction is shown below.

$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + H_2O + CO_2$$

(i) Calculate the amount, in moles, of ethanoic acid in 10.0 cm^3 of a 15.0 mol dm^{-3} solution.

....

(1)

(ii) Use your answer from part (i) to calculate the amount, in moles, of sodium carbonate needed to react completely with this amount of ethanoic acid.

....

(1)

(iii) Use data from the Periodic Table to calculate the relative formula mass of sodium carbonate. Give your answer to the appropriate precision.

....

(1)

(iv) Use your answers from parts (ii) and (iii) to determine the minimum mass of sodium carbonate needed to react completely with 10.0 cm^3 of the 15.0 mol dm^{-3} solution of ethanoic acid.

....

(1)

(b) State **one** hazard when using concentrated ethanoic acid and **one** safety precaution you would take to minimise this hazard.

Hazard ....

Precaution ....

....

(1)
(Total 5 marks)

29 (a) Sodium hydrogencarbonate ($NaHCO_3$) can also be used to neutralise ethanoic acid spillages. The equation for this reaction is shown below.

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

State the ideal gas equation.

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(1)

(b) There are several methods by which ethanoic acid is synthesised on an industrial scale. One method is the oxidation of butane in the presence of metal ion catalysts. Balance the equation given below which summarises this reaction.

$$..........C_4H_{10} + ...O_2 \longrightarrow ....CH_3COOH + ...H_2O$$

(1)

(c) A second method by which ethanoic acid is synthesised involves the oxidative fermentation of ethanol in the presence of bacteria. The equation representing this reaction is given below.

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

In a small scale experiment using this second method it was found that 23.0 g of ethanol produced only 4.54 g of ethanoic acid. Calculate the percentage yield for this experiment.

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(2)
(Total 4 marks)

30 The manufacturer supplying concentrated ethanoic acid for the production of vinegar also supplied other acids. The label had come off a batch of one of these other acids.
A sample of this unknown acid was analysed and found to contain 54.5% of carbon and 9.10% of hydrogen by mass, the remainder being oxygen.

(a) Use these data to calculate the empirical formula of the unknown acid.
Show your working.

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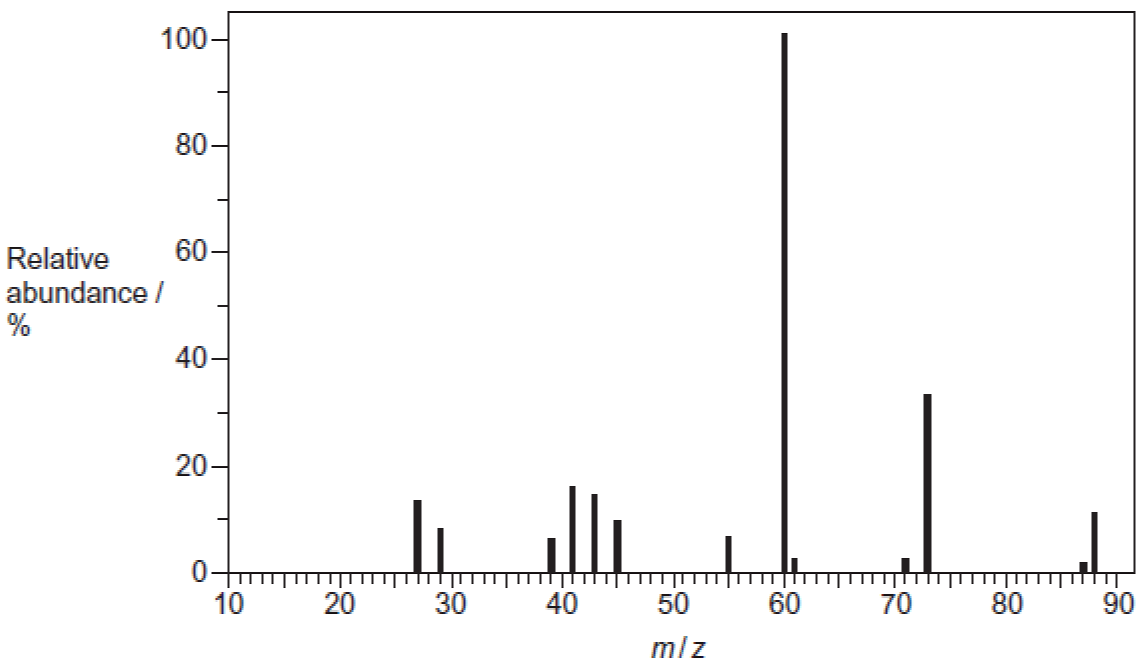
(3)

(b) A sample of the unknown acid was analysed in a mass spectrometer. The mass spectrum obtained is shown below.



Use the mass spectrum to determine the M_r of the unknown acid.

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(1)

(c) Use your answers from parts (a) and (b) to determine the molecular formula of the unknown acid.
(If you could not answer part (b), you should assume that the M_r of the acid is 132.0 but this is **not** the correct value.)
Show your working.

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(2)
(Total 6 marks)

31 Desalination is a technique for making drinking water by the removal of salts from sea water. It is used in parts of the world where fresh water is in short supply. A problem with this technique is the increase in the concentration of salts, particularly of sodium chloride, in the effluent (the solution returned to the sea).

Desalination uses a process called reverse osmosis. In this process, sea water under high pressure is passed over a special membrane which allows only pure water to pass through it.

The owners of a desalination plant have asked for the effluent to be analysed at different operating pressures. This is needed to find an **approximate** value for the maximum operating pressure that gives an effluent that has a minimum harmful effect on the environment.

A chemist sampled the effluent at different pressures. For each pressure, a 250 cm^3 sample of effluent was taken in a measuring cylinder and poured into a weighed beaker. The water was evaporated by heating and the beaker reweighed. The following results were obtained.

Experiment	**1**	**2**	**3**	**4**	**5**	**6**
Pressure / MPa	0.1	0.5	1.0	2.5	4.0	8.0
Beaker mass before heating / g	55.3	55.5	55.0	55.1	55.3	56.3
Beaker mass after heating / g	62.5	64.9	65.3	66.6	67.5	69.4
Mass of solid in beaker / g						

(a) Complete the table above to determine the mass of solid that remains in the beaker at each pressure.

Plot a graph of mass of solid (y-axis) against pressure on the graph paper.

Draw a smooth curve through the points.

(4)

(b) To minimise harmful effects on the environment, the concentration of sodium chloride in the effluent should not exceed 44.0 g dm^{-3}. Use your graph to find a value for the pressure, in MPa, that the chemist should advise to be the maximum operating pressure.

Assume that all the solid left in the beaker is sodium chloride.

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(1)

(c) In Experiment **1** the 250 cm^3 sample of the effluent contained the same amount of sodium chloride as the original sea water. Calculate the concentration, in mol dm^{-3}, of sodium chloride in sea water.

Assume that all the solid left in the beaker is sodium chloride.
Show your working.

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(2)

(d) For the measuring cylinder and the balance, the maximum total errors are shown below. These errors take into account multiple measurements.

250 cm^3 measuring cylinder	±1.0 cm^3
balance	±0.1 g

Estimate the maximum percentage error in using these pieces of apparatus, and hence estimate their combined error.

You should use the mass of the solid in the beaker in Experiment **1** to estimate the percentage error in using the balance.
Show your working.

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(2)

(e) Consider your graph.

(i) Is the curve good enough to use with confidence to predict the intermediate values? Explain your answer.

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(1)

(ii) Identify the anomalous results, if any.

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(1)

(f) Give **one** reason why the owners of the plant were satisfied with the maximum operating pressure determined in part (b) despite the combined errors you have calculated in part (d).

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(1)

(g) (i) Suggest **one** harmful effect that effluent with a high concentration of sodium chloride might have if it is returned to the sea.

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....

(1)

(ii) Suggest **one** low cost method of treating the effluent so that this harmful effect could be reduced.

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....

(1)

(h) Bromine can be obtained by reacting the bromide ions in the concentrated sea water using chlorine gas in a displacement reaction. Write an equation for this reaction.

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(1)

(i) The solid obtained by the chemist after heating the effluent to dryness was treated with concentrated sulfuric acid. A vigorous reaction resulted, including the formation of a purple vapour of iodine. Give **one** reason why this procedure could **not** be adapted to be an economic method for producing iodine from sea water on an industrial scale.

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(1)

(j) Sea water contains some organic material. After removing all the water, by heating the effluent samples strongly, it was noticed that the solid formed contained black particles. These particles are insoluble in water.

On heating very strongly in air these particles burned to give a colourless gas.

(i) Identify these black particles.

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(1)

(ii) Suggest how these black particles are formed by heating the effluent strongly.

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....

(1)

(iii) Suggest how a sample of the black particles could be separated from the solid formed.

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(2)

(k) The water produced by some desalination plants is acidic due to the presence of hydrochloric acid. Lime, $Ca(OH)_2$, is added to neutralise this acid. Write an equation for this reaction.

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(1)

(l) Lime is used because it is relatively inexpensive and available in large quantities. Identify **one** other large-scale use of lime.

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(1)
(Total 22 marks)

32 Ammonium salts such as ammonium nitrate are used in fertilisers. The ammonium nitrate content of a fertiliser can be determined by heating a sample of the fertiliser with an excess of sodium hydroxide solution. An equation for this reaction is shown below.

$$NH_4NO_3 + NaOH \longrightarrow NH_3 + NaNO_3 + H_2O$$

Heating ensures that all of the ammonia produced is given off as a gas. The unreacted sodium hydroxide remaining in the solution can be determined by a titration with standard hydrochloric acid.

(a) Explain why it is necessary to remove all of the ammonia before titrating the unreacted sodium hydroxide.

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(1)

(b) Suggest why it is important to test samples from more than one batch of the fertiliser.

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(1)

(c) Ammonium nitrate decomposes when heated to form water and one other product. Write an equation for this reaction.

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(1)

(d) The table below shows some information about three salts that could be used in fertilisers.

Salt	Nitrogen content by mass / %	Price per tonne / £
Ammonium chloride	26.2	134
Ammonium nitrate	35.0	175
Ammonium sulfate	21.2	111

(i) Use the data in the table to determine the salt that offers the best value for money, based on nitrogen content. Show your working.

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(2)

(ii) Ammonium nitrate is very soluble in water. Suggest **one** disadvantage of its high solubility when ammonium nitrate is used in a fertiliser.

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(1)

(e) A saturated solution of ammonia contains 300 g of ammonia in 1.00 dm^3 of solution. Calculate the concentration, in mol dm^{-3}, of ammonia in this solution.

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(1)
(Total 7 marks)

33 In an experiment to determine the concentration of a solution of sodium hydroxide, 25.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid were transferred to a conical flask. An indicator was added to the flask. The solution of sodium hydroxide was then added to the flask from a burette.

(a) State a suitable amount of indicator solution that should be added to the flask.

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(1)

(b) State why it is important to fill the space below the tap in the burette with alkali before beginning the titration.

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(1)
(Total 2 marks)

34 The electrons transferred in redox reactions can be used by electrochemical cells to provide energy.

Some electrode half-equations and their standard electrode potentials are shown in the table below.

Half-equation	***E*⦵/V**
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

(a) Describe a standard hydrogen electrode.

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(4)

(b) A conventional representation of a lithium cell is given below.
This cell has an e.m.f. of +2.91 V

$Li(s) \mid Li^{+}(aq) \parallel Li^{+}(aq) \mid MnO_2(s) , LiMnO_2(s) \mid Pt(s)$

Write a half-equation for the reaction that occurs at the positive electrode of this cell.

Calculate the standard electrode potential of this positive electrode.

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(2)

(c) Suggest what reactions occur, if any, when hydrogen gas is bubbled into a solution containing a mixture of iron(II) and iron(III) ions. Explain your answer.

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(2)

(d) A solution of iron(II) sulfate was prepared by dissolving 10.00 g of $FeSO_4.7H_2O$ (M_r = 277.9) in water and making up to 250 cm^3 of solution. The solution was left to stand, exposed to air, and some of the iron(II) ions became oxidised to iron(III) ions. A 25.0 cm^3 sample of the partially oxidised solution required 23.70 cm^3 of 0.0100 mol dm^{-3} potassium dichromate(VI) solution for complete reaction in the presence of an excess of dilute sulfuric acid.

Calculate the percentage of iron(II) ions that had been oxidised by the air.

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(6)
(Total 14 marks)

35 (a) When a solution containing iron(II) ions is treated with a slight excess of a solution containing ethanedioate ions a bright yellow precipitate of hydrated iron(II) ethanedioate, $FeC_2O_4.2H_2O$, is formed. The precipitate is filtered off, washed with propanone and then allowed to dry. A typical yield of the solid is 95%.

(i) Propanone boils at 56 °C and is miscible with water in all proportions. Suggest **two** reasons why washing with propanone is an effective method for producing a pure, dry precipitate.

Reason 1 ....

....

Reason 2 ....

....

(2)

(ii) By suggesting a simple test tube reaction, state how the filtrate could be tested to show that all of the iron(II) ions have been removed from the solution. State what you would observe.

Test ....

Observation ....

(2)

(iii) Suggest **one** reason why the typical yield of iron(II) ethanedioate is less than 100%.

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(1)

(iv) Calculate the mass of hydrated iron(II) ethanedioate, $FeC_2O_4.2H_2O$ that can be formed from 50.0 cm^3 of a 0.50 mol dm^{-3} solution of iron(II) sulfate when the yield of the reaction is 95%. Show your working.

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(3)

(v) The identity of the precipitate can be confirmed by dissolving it in sulfuric acid and titrating the mixture with potassium manganate(VII).

Deduce the number of moles of iron(II) ethanedioate that would react with one mole of potassium manganate(VII) in acidic solution.

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(1)

(b) Ethanedioate ions can be used to remove calcium ions from blood plasma. A precipitate of calcium ethanedioate is formed. Write an ionic equation for the reaction of ethanedioate ions with calcium ions.

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(1)

(c) Ethanedioic acid is used to clean marble, a form of calcium carbonate. Suggest **one** reason why the reaction between ethanedioic acid and marble stops after a short time.

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(1)

(d) Tea leaves contain ethanedioic acid. Suggest **one** reason why tea drinkers do **not** suffer from ethanedioic acid poisoning.

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(1)

(e) Ethanedioic acid is produced by the oxidation of carbon monoxide in a multi-step process. The equation which summarises the reactions taking place is shown below.

$$4CO + 4NaOH + O_2 + 4HCl \rightarrow 2H_2C_2O_4 + 4NaCl + 2H_2O$$

Calculate the percentage atom economy for the formation of ethanedioic acid in this reaction. Show your working.

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(2)
(Total 14 marks)

36 Hydrogen peroxide is sold commercially as an aqueous solution containing approximately 60 g dm^{-3} of hydrogen peroxide.

(a) Use data from the Periodic Table to calculate the M_r of hydrogen peroxide. Give your answer to the appropriate precision.

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(1)

(b) Calculate the concentration, in mol dm^{-3}, of a solution containing 60.0 g dm^{-3} of hydrogen peroxide.

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(1)

(c) The concentration of hydrogen peroxide in a hair bleach is 0.050 mol dm^{-3}. Use your answer from (b) to calculate the dilution factor needed to make the commercial hydrogen peroxide solution suitable for use in this hair bleach. Show your working.

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(2)
(Total 4 marks)

37 Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \rightarrow 2NH_3(g) + Na_2SO_4(aq) + 2H_2O(l)$$

(a) A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm^3 of a sodium hydroxide solution.

(i) Calculate the amount, in moles, of $(NH_4)_2SO_4$ in 3.14 g of ammonium sulfate.

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(2)

(ii) Hence calculate the amount, in moles, of sodium hydroxide which reacted.

....

(1)

(iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution used.

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(1)

(b) Calculate the percentage atom economy for the production of ammonia in the reaction between ammonium sulfate and sodium hydroxide.

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(2)

(c) Ammonia is manufactured by the Haber Process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Calculate the percentage atom economy for the production of ammonia in this process.

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(1)

(d) A sample of ammonia gas occupied a volume of 1.53×10^{-2} m^3 at 37 °C and a pressure of 100 kPa.

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

Calculate the amount, in moles, of ammonia in this sample.

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(3)

(e) Glauber's salt is a form of hydrated sodium sulfate that contains 44.1% by mass of sodium sulfate. Hydrated sodium sulfate can be represented by the formula $Na_2SO_4.xH_2O$ where x is an integer. Calculate the value of x.

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(3)
(Total 13 marks)

38 A mass spectrometer can be used to investigate the isotopes in an element.

(a) Define the term *relative atomic mass* of an element.

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(2)

(b) Element **X** has a relative atomic mass of 47.9

Identify the block in the Periodic Table to which element **X** belongs and give the electron configuration of an atom of element **X**.

Calculate the number of neutrons in the isotope of **X** which has a mass number 49

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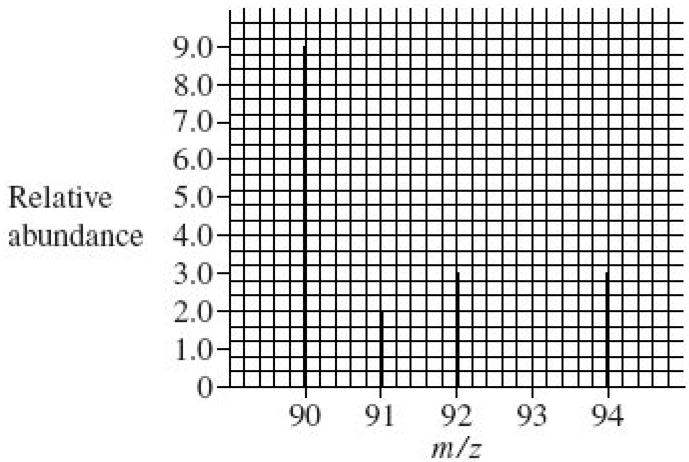
(3)

(c) The mass spectrum of element **Z** is shown below.

Use this spectrum to calculate the relative atomic mass of **Z**, giving your answer to one decimal place.

Identify element **Z**.



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(4)

(d) State how vaporised atoms of **Z** are converted into **Z**$^+$ ions in a mass spectrometer.

State and explain which of the **Z**$^+$ ions formed from the isotopes of **Z** in part (c) will be deflected the most in a mass spectrometer.

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(4)

(e) Explain briefly how the relative abundance of an ion is measured in a mass spectrometer.

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(2)
(Total 15 marks)

39 (a) State and explain the trend in electronegativities across Period 3 from sodium to sulfur.

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(4)

(b) Explain why the oxides of the Period 3 elements sodium and phosphorus have different melting points. In your answer you should discuss the structure of and bonding in these oxides, and the link between electronegativity and the type of bonding.

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(6)

(c) A chemical company has a waste tank of volume 25 000 dm^3. The tank is full of phosphoric acid (H_3PO_4) solution formed by adding some unwanted phosphorus(V) oxide to water in the tank.

A 25.0 cm^3 sample of this solution required 21.2 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution for complete reaction.

Calculate the mass, in kg, of phosphorus(V) oxide that must have been added to the water in the waste tank.

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(5)
(Total 15 marks)

40 Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

$$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

A 0.0732 g sample of magnesium was added to 36.4 cm^3 of 0.265 mol dm^{-3} nitric acid. The acid was in excess.

(a) (i) Calculate the amount, in moles, of magnesium in the 0.0732 g sample.

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(1)

(ii) Hence calculate the amount, in moles, of nitric acid needed to react completely with this sample of magnesium.

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(1)

(iii) Calculate the amount, in moles, of nitric acid originally added to this sample of magnesium.

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(1)

(iv) Hence calculate the amount, in moles, of nitric acid that remains unreacted.

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(1)

(b) In a second experiment, 0.512 mol of hydrogen gas was produced when another sample of magnesium reacted with dilute nitric acid. Calculate the volume that this gas would occupy at 298 K and 96 kPa. Include units in your final answer.

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

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(3)

(c) Concentrated nitric acid reacts with magnesium to form an oxide of nitrogen which contains 30.4% by mass of nitrogen.

Calculate the empirical formula of this oxide of nitrogen. Show your working.

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(3)
(Total 10 marks)

41 (a) (i) Define the term *relative atomic mass* (A_r) of an element.

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(2)

(ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

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(4)

(b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

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(6)

(c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

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(3)

(d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

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(5)
(Total 20 marks)

42 In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

$2KBr + MnO_2 + 2H_2SO_4 \rightarrow MnSO_4 + K_2SO_4 + 2H_2O + Br_2$

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

(a) Write a half-equation for the conversion of MnO_2 in acid solution into Mn^{2+} ions and water.
In terms of electrons, state what is meant by the term *oxidising agent* and identify the oxidising agent in the overall reaction.

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(3)

(b) Write an equation for Extraction Process **2** and an equation for Extraction Process **3**. Calculate the percentage atom economy for the extraction of bromine from potassium bromide by Extraction Process **3**. Suggest why Extraction Process **3** is the method in large-scale use today.

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(5)

(c) Bromine has been used for more than 70 years to treat the water in swimming pools. The following equilibrium is established when bromine is added to water.

$$Br_2 + H_2O \rightleftharpoons HBrO + HBr$$

Give the oxidation state of bromine in HBr and in HBrO

Deduce what will happen to this equilibrium as the HBrO reacts with micro-organisms in the swimming pool water. Explain your answer.

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(4)
(Total 12 marks)

43 Some antacid tablets contain sodium hydrogencarbonate, sucrose and citric acid.

(a) Analysis of a pure sample of citric acid showed that it contained 37.50% of carbon and 4.17% of hydrogen by mass, the remainder being oxygen. Use these data to show that the empirical formula of the acid is $C_6H_8O_7$.

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(3)

(b) When the antacid tablet is added to water, sodium hydrogencarbonate and citric acid react together to form a gas. Identify this gas.

....

(1)

(c) A weighed portion of this antacid was added to water. The gas formed was collected and its volume measured.

(i) Draw a diagram to show how this experiment could have been carried out to collect and measure the volume of the gas.

(ii) The experiment was repeated with further weighed portions of the same antacid.

The results are shown below.

Experiment	1	2	3	4	5
Mass of antacid / g	2.60	1.17	0.88	2.31	1.80
Volume of gas collected / cm^3	168	86	57	149	116

1 On the graph paper below, plot a graph of mass of antacid (*x*-axis) against volume of gas collected.

(3)

2 Draw a line of best fit on the graph, ignoring any anomalous points.

(1)

3 Use the graph to determine the volume of gas which would have been collected using 2.00 g of antacid.

Volume of gas collected ....

(1)

(d) Suggest **one** reason why the presence of sodium hydrogencarbonate in the stomach may cause a person to suffer some extra discomfort for a short time.

....

(1)

(e) Explain why the value for the M_r of citric acid does not need to be an exact value to deduce the molecular formula of citric acid from its empirical formula.

....

....

(2)

(f) Apart from misreading the gas volume, suggest **two** reasons why the volumes of gas collected may be lower than the volumes of gas produced.

Reason 1 ....

....

Reason 2 ....

....

(2)

(g) Explain why it is important to record the temperature and pressure when measuring the volume of a gas.

....

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(1)

(h) Suggest why, in an analysis of an antacid, it is important to test samples from more than one bottle of the antacid.

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(1)

(i) In the industrial production of sodium hydrogencarbonate, ammonia and carbon dioxide are bubbled through a saturated solution of sodium chloride. The equation for this reaction, and some solubility data, are shown below.

$$NaCl(aq) + NH_3(aq) + CO_2(g) + H_2O(l) \rightarrow NaHCO_3(s) + NH_4Cl(aq)$$

Compound	Solubility in water at 20 °C / g dm^{-3}
sodium chloride	360
sodium hydrogencarbonate	96
ammonium chloride	370

(i) Suggest **one** reason why sodium hydrogencarbonate precipitates from the reaction mixture at this temperature.

....

(1)

(ii) Explain how this reaction could be used to remove carbon dioxide from the gases formed when fossil fuels are burned.

....

....

(1)

(j) The thermal decomposition of sodium hydrogencarbonate produces sodium carbonate. The other products are water and carbon dioxide. Write an equation for this thermal decomposition.

....

(1)

(k) Sodium carbonate is produced on an industrial scale by a multi-step process. The equation which summarises the reactions taking place is shown below.

$$CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$$

Calculate the percentage atom economy for the production of sodium carbonate by this reaction.

....

(1)
(Total 20 marks)

44 Magnesium carbonate, $MgCO_3$, can occur as the anhydrous compound, or as hydrates with 2, 3 or 5 molecules of water of crystallisation. All types of magnesium carbonate can be decomposed to form magnesium oxide, an important starting material for many processes. This decomposition reaction can be used to identify the type of magnesium carbonate present in a mineral.

A chemist was asked to identify the type of magnesium carbonate present in a mineral imported from France. The chemist weighed a clean dry crucible, and transferred 0.25 g of the magnesium carbonate mineral to the crucible. The crucible was then heated for a few minutes. The crucible was then allowed to cool, and the crucible and its contents were reweighed. This process was repeated until the crucible and its contents had reached constant mass. The mass of the crucible and its contents was then recorded.

The experiment was repeated using different masses of the magnesium carbonate mineral.

For each experiment the chemist recorded the original mass of the mineral and the mass of magnesium oxide left after heating to constant mass. The chemist's results are shown in the table below.

Experiment	1	2	3	4	5	6
Mass of mineral / g	1.60	1.17	0.74	1.31	1.80	1.34
Mass of magnesium oxide / g	0.54	0.39	0.24	0.44	0.61	0.49

(a) Plot a graph of the mass of the mineral (*x*-axis) against the mass of magnesium oxide on the grid below.

Draw a straight line of best fit on your graph.

(4)

(b) Use the graph to determine the mass of the mineral which would have formed 0.50 g of magnesium oxide.

Mass of the mineral ....

(1)

(c) Calculate the amount, in moles, of MgO present in 0.50 g of magnesium oxide.

....

....

(1)

(d) Use your answers from part (b) and from part (c) to calculate the M_r of the magnesium carbonate present in the mineral.

....

....

....

(1)

(e) Use your answer from part (d) to confirm that this mineral is $MgCO_3.2H_2O$

(If you could not complete the calculation in part (d), you should assume that the experimental M_r value is 122.0 This is not the correct answer.)

....

....

....

(1)

(f) Explain why it was **not** necessary to use a more precise balance in this experiment.

....

....

(1)

(g) Consider your graph and comment on the results obtained by the chemist. Identify any anomalous results.

Comment ....

....

Anomalous results ....

....

(2)

(h) Explain why it was necessary for the chemist to heat the crucible and its contents to constant mass.

....

(1)

(i) Suggest **one** reason in each case why

(i) small amounts of the mineral, such as 0.10 g, should **not** be used in this experiment.

....

....

(1)

(ii) large amounts of the mineral, such as 50 g, should **not** be used in this experiment.

....

....

(1)

(j) Analysis of a different hydrated magnesium carbonate showed that it contained 39.05% by mass of water. Determine the formula of this hydrated magnesium carbonate.

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(2)

(k) Magnesium oxide is produced by the thermal decomposition of magnesium carbonate and by the thermal decomposition of magnesium hydroxide. The equations for the reactions taking place are shown below.

Reaction 1	$MgCO_3$	$\rightarrow$	$MgO + CO_2$
Reaction 2	$Mg(OH)_2$	$\rightarrow$	$MgO + H_2O$

Show that Reaction 2 has the greater atom economy for the production of magnesium oxide.

....

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(2)

(l) Apart from cost, suggest **one** advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

....

....

(1)
(Total 19 marks)

45 Titanium(IV) oxide (TiO_2, M_r = 79.9) is used as a white pigment in some paints. The pigment can be made as shown in the following equation.

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(aq)$$

(a) (i) Calculate the percentage atom economy for the formation of TiO_2

....

....

....

(2)

(ii) In view of the low atom economy of this reaction, suggest how a company can maximise its profits without changing the reaction conditions or the production costs.

....

....

(1)

(b) In an experiment 165 g of $TiCl_4$ were added to an excess of water.

(i) Calculate the amount, in moles, of $TiCl_4$ in 165 g.

....

....

....

(2)

(ii) Calculate the maximum amount, in moles, of TiO_2 which can be formed in this experiment.

....

....

(1)

(iii) Calculate the maximum mass of TiO_2 formed in this experiment.

....

....

(1)

(iv) In this experiment only 63.0 g of TiO_2 were produced. Calculate the percentage yield of TiO_2

....

....

....

(1)
(Total 8 marks)

46 A metal carbonate MCO_3 reacts with hydrochloric acid as shown in the following equation.

$$MCO_3 + 2HCl \rightarrow MCl_2 + H_2O + CO_2$$

A 0.548 g sample of MCO_3 reacted completely with 30.7 cm^3 of 0.424 mol dm^{-3} hydrochloric acid.

(a) (i) Calculate the amount, in moles, of HCl which reacted with 0.548 g MCO_3

....

....

(1)

(ii) Calculate the amount, in moles, of MCO_3 in 0.548 g.

....

....

(1)

(iii) Calculate the relative formula mass of MCO_3

....

....

(1)

(b) Use your answer from part (a)(iii) to deduce the relative atomic mass of metal M and suggest its identity.
(If you have been unable to calculate a value for the relative formula mass of MCO_3 you should assume it to be 147.6 but this is not the correct answer.)

Relative atomic mass ....

....

....

Identity of M ....

(2)
(Total 5 marks)

47 (a) Nitromethane, CH_3NO_2, is used as an 'energy rich' fuel for motor-racing. It burns in oxygen forming three gases.

$$2CH_3NO_2(l) + 1\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) + N_2(g)$$

(i) A 1.00 mol sample of nitromethane was burned in oxygen forming the products shown in the equation above. Calculate the total volume of gases produced at 298 K and 100 kPa (assume that the water is gaseous).

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(ii) This combustion reaction is very exothermic and reaches a temperature of 1000 K. Determine the total volume of gases when the temperature is raised to 1000 K at a constant pressure.

(If you have been unable to determine a volume in your answer to part (a)(i), you may assume it to be 8.61×10^{-4} m^3 but this is not the correct answer).

....

....

(5)

(b) It has been suggested that, instead of releasing it into the atmosphere, the carbon dioxide gas evolved during a combustion reaction can be absorbed by sodium hydroxide solution, as shown by the following equation.

$$2NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$$

(i) Give two reasons why this reaction might not be suitable for the removal of carbon dioxide from the exhaust gases of an engine.

Reason 1 ....

Reason 2 ....

(ii) The sodium hydroxide solution for this reaction can be made on an industrial scale, together with chlorine gas and hydrogen gas, by electrolysis of a dilute solution of sodium chloride. Suggest one commercial advantage and one environmental disadvantage of this industrial process.

Commercial advantage ....

....

Environmental disadvantage ....

....

(4)

(c) Nitrogen forms several different oxides. Calculate the empirical formula of an oxide of nitrogen which contains 26% of nitrogen by mass.

....

....

....

....

(3)

(d) Another oxide of nitrogen, N_2O, decomposes on warming to produce nitrogen and oxygen. Write an equation for the decomposition reaction.

....

(1)

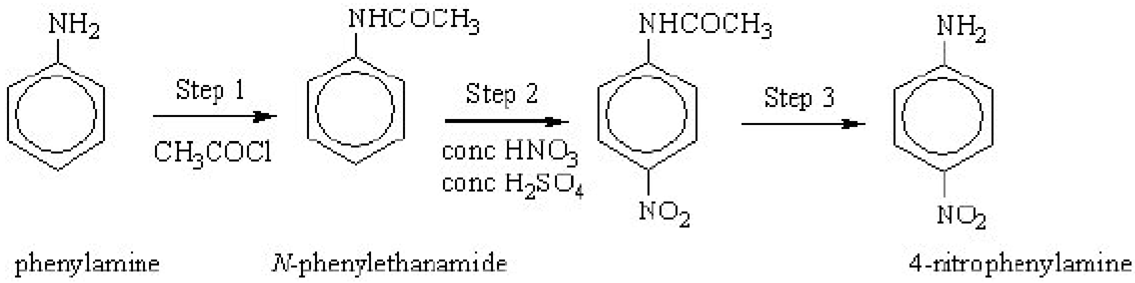
(e) Internal combustion engines burn fuels in air. Suggest one advantage of using air mixed with N_2O for this purpose.

....

(1)
(Total 14 marks)

48 Synthetic dyes can be manufactured starting from compounds such as 4-nitrophenylamine.

A synthesis of 4-nitrophenylamine starting from phenylamine is shown below.



(a) An equation for formation of *N*-phenylethanamide in Step 1 of the synthesis is shown below.

$$2C_6H_5NH_2 + CH_3COCl \rightarrow C_6H_5NHCOCH_3 + C_6H_5NH_3Cl$$

N-phenylethanamide

(i) Calculate the % atom economy for the production of *N*-phenylethanamide (M_r = 135.0).

(ii) In a process where 10.0 kg of phenylamine are used, the yield of *N*-phenylethanamide obtained is 5.38 kg.

Calculate the percentage yield of *N*-phenylethanamide.

(iii) Comment on your answers to parts (i) and (ii) with reference to the commercial viability of the process.

(7)

(b) Name and outline a mechanism for the reaction in Step 1.

(5)

(c) The mechanism of Step 2 involves attack by an electrophile. Write an equation showing the formation of the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

(4)
(Total 16 marks)

49 CH_2O is the empirical formula of

A methanol

B methyl methanoate

C ethane-1,2-diol

D butanal

(Total 1 mark)

50 When $TiCl_4$ is reduced with hydrogen under certain conditions, a new compound is produced which contains 68.9% chlorine by mass. Which one of the following could be the formula of the new compound?

A TiH_2Cl_2

B TiCl

C $TiCl_2$

D $TiCl_3$

(Total 1 mark)

Mark schemes

1 (a) P = 100 000 Pa and T = 298 K

Wrong conversion of V or incorrect conversion of P / T lose M1 + M3

1

$n = \frac{PV}{RT}$ or $\frac{100\ 000 \times 4.31}{8.31 \times 298}$

If not rearranged correctly then cannot score M2 and M3

1

n(total) = 174(.044)

1

n (NO) = <u>69.6</u>

Allow student's M3 × 4 / 10 but must be to 3 significant figures

1

(b) (i) $\frac{3000}{17}$

Allow answer to 2 significant figures or more

1

176.5

Allow 176 − 177
But if answer = 0.176 − 0.18 (from 3 / 17) then allow 1 mark

1

(ii) 176.47 × 46 = 8117.62

M1 is for the answer to (b)(i) × 46. But lose this mark if 46 ÷ 2 at any stage
However if 92 ÷ 2 allow M1

1

$8117.62 \times \frac{80}{100}\ (= 6494\ g)$

M2 is for M1 × 80 / 100

1

$$\frac{6494}{1000} = 6.5$$

M3 is for the answer to M2 ÷ 1000 to min 2 significant figures (kg)

OR

If 163 mol used:
163 × 46 = 7498 (1)

$$7498 \times \frac{80}{100} = 5998.4\,g(1)$$

6.00 kg (1)

1

(c) $0.543 \times \frac{2}{3} (= 0.362)$

if not $\times \frac{2}{3}$ CE = 0/2

1

$$0.362 \times \frac{1000}{250} = 1.45 \left(mol\,dm^{-3}\right)$$

Allow 1.447 − 1.5 (mol dm^{-3}) for 2 marks

1

(d) NO_2 contributes to acid rain / is an acid gas / forms HNO_3 / NO_2 is toxic / photochemical smog

Ignore references to water, breathing problems and ozone layer.
Not greenhouse gas

1

(e) Ensure the ammonia is used up / ensure complete reaction or combustion

OR

Maximise the yield of nitric acid or products

1

(f) Neutralisation

Allow acid vs alkali or acid base reaction

1

[14]

2 (a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list Allow 100 (kPa) and 5 (dm^3) for M1.

1

$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= <u>2.81</u> (g)

M5 is for their answer to 3 sig figures.

2.81 (g) gets 5 marks.

1

(b) $B + 1.5\ Cl_2 \rightarrow BCl_3$

Accept multiples.

1

<u>3</u> bonds

1

Pairs repel <u>equally</u>/ by the <u>same amount</u>

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= <u>2.20 to 2.22</u> mol dm^{-3}

Allow 2.2

Allow 2 significant figures or more

1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.

Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

(d) $\frac{10.8}{120.3} (\times 100)$

Mark is for both M_r *values correctly as numerator and denominator.*

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

B Cl

$\frac{13.2}{10.8}$ $\frac{86.8}{35.5}$

B *Cl*

$\frac{21.6}{10.8}$ $\frac{142}{35.5}$

1

1.22 2.45 or ratio 1:2 or BCl_2

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

Do not allow $(BCl_2)_2$

1

[20]

3 (a) (Returns) reagent on the sides of the flask to the reaction mixture (to ensure that all of the acid / alkali reacts)

Do not allow 'to get a better result' without qualification.

Do not allow 'to ensure that all of the acid / alkali reacts' without qualification.

1

(b) Water is not a reagent / water one of the products / does not change the number of moles of reagents

Do not allow 'water does not affect the titration' without qualification.

1

[2]

4 Ratios 88.5 / 138.2 and 11.5 / 18

Correct answer without working scores one mark only.

1

$x = 1$

Allow $K_2CO_3.H_2O$ / 1:1 ratio / one molecule of water of crystallisation.

M2 can be awarded for a correct method using incorrect ratios.

Allow correct answer if integer or decimal number.

1

[2]

5 (a) (i) Mass loss would be too large / water would be lost when heating (so mass incorrect)

Do not allow 'to improve accuracy' without qualification.

Do not allow 'water is a product of the reaction'.

Do not allow 'mass of crucible incorrect / too high'.

1

(ii) Prevents loss of solid / potassium carbonate / potassium hydrogencarbonate (from the crucible)

Do not allow 'to improve accuracy' without qualification.

Do not allow 'stops anything escaping'.

1

(iii) Errors in weighing are too high / percentage errors in (obtaining) the mass are too high

Do not allow 'hard to / can't weigh very small amounts' without further qualification.

1

(b) (i) M_r of $KHCO_3$ is 100(.1)

Do not penalise precision.

1

moles $K_2CO_3 = 1 / (M_r \times 2) = 0.005$

If factor of 2 missing can only score first mark (M1).

Allow consequential answer on incorrect M_r of $KHCO_3$

1

mass of K_2CO_3 = 0.005 × 138.2 = 0.69(0)

Correct mass without working scores one mark only (M3).

1

(ii) Reaction / decomposition incomplete

Do not allow 'a wet crucible was used'.

Ignore references to impurity and / or experimental errors.

1

[7]

6 (a) q = 500 × 4.18 × 40

Do not penalise precision.

1

= 83600 J

Accept this answer only.

Ignore conversion to 83.6 kJ if 83600 J shown.

Unit not required but penalise if wrong unit given.

Ignore the sign of the heat change.

An answer of 83.6 with no working scores one mark only.

An answer of 83600 with no working scores both marks.

1

(b) Moles (= 83.6 / 51.2) = 1.63

Using 77400 alternative gives 1.51 mol

Allow (a) in kJ / 51.2

Do not penalise precision.

1

Mass = 1.63 × 40(.0) = 65.2 (g)

Allow 65.3 (g)

Using 77400 alternative gives 60.4 to 60.5

Allow consequential answer on M1.

1 mark for M_r (shown, not implied) and 1 for calculation.

Do not penalise precision.

2

(c) Molarity = 1.63 / 0.500 = 3.26 mol dm–3

Allow (b) M1 × 2

Using 1.51 gives 3.02

1

(d) Container splitting <u>and</u> releasing irritant / corrosive chemicals

Must have reference to both aspects; splitting or leaking (can be implied such as contact with body / hands) ***and*** *hazardous chemicals.*

Allow 'burns skin / hands' as covering both points

Ignore any reference to 'harmful'.

Do not allow 'toxic'.

1

(e) (i) $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Allow fractions / multiples in equation.

Ignore state symbols.

1

(ii) Iron powder particle size could be increased / surface area lessened

Decrease in particle size, chemical error = 0 / 3

Change in oxygen, chemical error = 0 / 3

1

Not all the iron reacts / less reaction / not all energy released / slower release of energy / lower rate of reaction

Mark points M2 and M3 independently.

1

Correct consequence of M2

An appropriate consequence, for example

- *too slow to warm the pouch effectively*
- *lower temperature reached*
- *waste of materials*

1

(f) (i) Conserves resources / fewer disposal problems / less use of landfill / fewer waste products

Must give a specific point.

Do not allow 'does not need to be thrown away' without qualification.

Do not accept 'no waste'.

1

(ii) Heat to / or above 80 °C (to allow thiosulfate to redissolve)

Accept 'heat in boiling water'.

If steps are transposed, max 1 mark.

1

Allow to cool before using again

Reference to crystallisation here loses this mark.

1

[14]

7 (a) Co-ordinate / dative / dative covalent / dative co-ordinate

Do not allow covalent alone

1

(b) (lone) pair of electrons on <u>oxygen/O</u>

If co-ordination to O^{2-}, CE=0

1

forms co-ordinate bond with <u>Fe</u> / donates electron pair to <u>Fe</u>

'Pair of electrons on O donated to Fe' scores M1 and M2

1

(c) 180° / 180 / 90

Allow any angle between 85 and 95

Do not allow 120 or any other incorrect angle

Ignore units eg °C

1

(d) (i) 3 : 5 / 5 FeC_2O_4 reacts with 3 MnO_4^-

Can be equation showing correct ratio

1

(ii) **M1** Moles of MnO_4^- per titration = 22.35 × 0.0193/1000 = <u>4.31 × 10^{-4}</u>

Method marks for each of the next steps (no arithmetic error allowed for M2):

Allow <u>4.3 × 10^{-4}</u> (2 sig figs)

Allow other ratios as follows:

eg from given ratio of 7/3

1

M2 moles of FeC_2O_4= ratio from (d)(i) used correctly × 4.31 × 10^{-4}

M2 *= 7/3 × 4.31 × 10^{-4} = 1.006 × 10^{-3}*

1

M3 moles of FeC_2O_4 in 250 cm^3 = M2 ans × 10

M3 *= 1.006 × 10^{-3} × 10 = 1.006 × 10^{-2}*

1

M4 Mass of $FeC_2O_4.2H_2O$ = M3 ans × 179.8

M4 *= 1.006 × 10^{-2} × 179.8 = 1.81 g*

1

M5 % of $FeC_2O_4.2H_2O$ = (M4 ans/1.381) × 100

M5 *= 1.81 × 100/1.381 = 131 % (130 to 132)*

1

(OR for M4 max moles of $FeC_2O_4.2H_2O$ = 1.381/179.8 (= 7.68 × 10^{-3})
for M5 % of $FeC_2O_4.2H_2O$ = (M3 ans/above M4ans) × 100)
eg using correct ratio 5/3:

Moles of FeC_2O_4 = 5/3 × 4.31 × 10^{-4} = 7.19 × 10^{-4}

Moles of FeC_2O_4 in 250 cm^3 = 7.19 × 10^{-4} × 10 = 7.19 × 10^{-3}

Mass of $FeC_2O_4.2H_2O$ = 7.19 × 10^{-3} × 179.8 = 1.29 g
% of $FeC_2O_4.2H_2O$ = 1.29 × 100/1.381 = 93.4 (allow 92.4 to 94.4)
Note correct answer (92.4 to 94.4) scores 5 marks

Allow consequentially on candidate's ratio

eg ***M2*** *= 5/2 × 4.31 × 10^{-4} = 1.078 × 10^{-3}*

M3 *= 1.0078 × 10^{-3} × 10 = 1.078 × 10^{-2}*

M4 *= 1.078 × 10^{-2} × 179.8 = 1.94 g*

M5 *= 1.94 × 100/1.381 = 140 % (139 to 141)*

Other ratios give the following final % values

1:1 gives 56.1% (55.6 to 56.6)

5:1 gives 281% (278 to 284)

5:4 gives 70.2% (69.2 to 71.2)

[10]

8 (a) Any **two** from:

Weigh by difference or rinse weighing bottle <u>and</u> add to beaker

Rinse beaker <u>and</u> add washings to graduated flask

Invert flask several times to ensure uniform solution

Use a funnel to transfer to the flask <u>and</u> rinse the funnel

Use a stirrer to prepare the solution <u>and</u> rinse the stirrer

If more than two answers apply the list rule.

Max 2

(b) $K_a = [H^+]^2 / [HA]$

Allow any correct expression relating K_a, $[H^+]$ and [HA]

1

$[HA] = (10^{-2.50})^2 / 1.07 \times 10^{-3}$

M2 also scores M1

1

$= 9.35 \times 10^{-3}$ (mol dm^{-3})

Do not allow 9.4 (answer is 9.346).

Correct answer only scores 1 mark.

Do not penalise precision but must be to at least two significant figures.

1

(c) (b) × 138.0 / 4

1

= 0.322

Using 8.50×10^{-3} gives 0.293

Correct answer scores M1 and M2.

Do not penalise precision but must be to at least two significant figures.

1

(d) (c) × 100 / 0.500 = 64.5%

Using 0.293 from (c) gives 58.7%

Using 0.347 gives 69.4%

Do not penalise precision.

1

[8]

9 (a) Theoretical mass produced = 180 × 2 / 138 = 2.61 g

Using 1.76 × 100 / 2 is a chemical error (CE), scores 0 / 2

1

Percentage yield = 1.76 × 100 / 2.61 = 67.5%

Correct answer scores M1 and M2.

Accept 67.4%

Do not penalise precision but answers must be to at least two significant figures.

1

(b) Crystals lost when filtering or washing / some aspirin stays in solution / other reactions occurring

Ignore references to impurities.

1

[3]

10 (a) (i) Flask with side arm

1

Buchner funnel <u>and</u> horizontal filter paper

Allow Hirsch funnel and horizontal filter paper.

Do not allow standard Y-shaped funnel.

If there is not a clear air-tight seal (labelled or drawn) between the funnel and the flask maximum 1 mark.

1

(ii) M_r $KMnO_4$ = 158(.0)

1

Mass = 0.225 × 158 / 3 = 11.9 (g)

Lose M2 if no working shown.

Allow consequential mark on an incorrect M_r for $KMnO_4$

1

Precision mark: three significant figures

Allow if mass incorrect.

1

(iii) (Unpleasant) taste

Ignore smell.

1

(b) Difficult to see meniscus / line on graduated flask

Do not allow reference to over filling.

1

[7]

11 (a) $CH_3(CH_2)_{14}COOH$

Allow molecular formulae.

1

$CH_2OHCHOHCH_2OH$

Allow one mark only if formulae are swapped in position.

1

(b) Keeping the foodstuff dry

Allow an answer which refers to removal of water from the environment.

Do not allow dehydration / removal of water from the fat.

1

(c) They (antioxidants) react with free radicals

1

And they are used up in the reaction / do not remain behind after reaction

Lose one mark for any reference to 'catalysts can't slow down a reaction'.

1

(d) Mol of fat = (2.78 / 806 =) 3.45×10^{-3}

Mol of NaOH = 3.68×10^{-3} = mol of fatty acid

1

Mol of NaOH = 3.68×10^{-3}

Mol of fat hydrolysed = 1.23×10^{-3}

1

Mol of fat hydrolysed = (3.68×10^{-3} / 3 =) 1.23×10^{-3}

Mass of fat hydrolysed = 0.987 g

1

Percentage hydrolysed = 35.5 – 35.7

Percentage hydrolysed = 35.5 – 35.7

Do not penalise precision at any point.

Since there are a variety of approaches to this calculation, award four marks for a correct answer but it must be clear that there is some relevant working.

The answer alone gets M4 only.

Any incorrect use of the 3:1 ratio is CE – lose M3 and M4.

1

[9]

12 (a) N^{3-} / N^{-3}

1

(b) F^{-}/ fluoride

Ignore fluorine/F

Penalise Fl

1

(c) Li_3N / NLi_3

1

(d) $\frac{81.1}{40.1}$ $\frac{18.9}{14}$

M1 for correct fractions

1

(=2.02 = 1.35)

1.5 1 or 3 : 2

M2 for correct ratio

1

Ca_3N_2

If Ca_3N_2 shown and with no working award 3 marks

If Ca_3N_2 obtained by using atomic numbers then lose M1

1

(e) $3\ Si + 2\ N_2 \rightarrow Si_3N_4$

Accept multiples

1

[7]

13 (a) Mol Pb = 8.14 / 207(.2) (= 0.0393 mol)

M1 and M2 are process marks

1

Mol HNO_3 = 0.0393 × 8 / 3 = 0.105 mol

Allow mark for M1 × 8/3 or M1 × 2.67

1

Vol HNO_3 = 0.105 / 2 = 0.0524 (dm^3)

Accept range 0.0520 to 0.0530

No consequential marking for M3

Answer to 3 sig figs required

1

(b) 101000 (Pa) and 638×10^{-6} (m^3)

1

n = pV/RT $\left(= \frac{101000 \times 638 \times 10^{-6}}{8.31 \times 298}\right)$

Can score M2 with incorrect conversion of p and V

If T incorrect lose M1 and M3

1

<u>0.026</u>(0) (mol)

If answer correct then award 3 marks

Allow answers to 2 sig figs or more

26.02 = 1

If transcription error lose M3 only

1

(c) (i) $2Pb(NO_3)_2(s) \rightarrow 2\ PbO(s) + 4NO_2(g) + (1)O_2(g)$

Allow multiples

Allow fractions

1

(ii) Decomposition not complete / side reactions / by-products / some (NO_2) escapes / not all reacts / impure $Pb(NO_3)_2$

Ignore reversible / not heated enough / slow

1

(iii) Hard to separate O_2 from NO_2 / hard to separate the 2 gases

Allow mixture of gases

Not 'all products are gases'

1

[9]

14 (a) (i) <u>0.0212</u>

Need 3 sig figs

Allow correct answer to 3 sig figs eg 2.12×10^{-2}

1

(ii) 0.0106

Mark is for (a)(i) divided by 2 leading to correct answer 2 sig figs

1

(iii) M_r = <u>100.1</u>

1.06 g

Allow 100.1 as 'string'

Need 3 sig figs or more

Consequential on (a)(ii) x 100(.1)

2

(iv) Neutralisation or acid / base reaction

Allow acid / alkali reaction

Apply list principle

1

(b) (i) T = 304(K) and P = 100 000 (Pa)

Only T and P correctly converted

1

$$\frac{100\,000 \times 3.50 \times 10^{-3}}{8.31 \times 304} \text{ OR } n = \frac{PV}{RT}$$

1

0.139 (mol)

Allow <u>0.138 – 0.139</u>

1

(ii) 0.0276 – 0.0278(mol)

Allow answer to (b)(i) divided by 5 leading to a correct answer

Allow 0.028

1

(c) 4.20 g $Ca(NO_3)_2$

1

$Ca(NO_3)_2$ H_2O

$\frac{4.20}{164(.1)}$ $\frac{1.84}{18}$

Mark is for dividing by the correct Mr values

M2 and M3 dependent on correct M1

0.0256 0.102

M2 can be awarded here instead

1 : 3.98

$x = 4$

If $Ca(NO_3)_2.4H_2O$ seen with working then award 3 marks

Credit alternative method which gives $x = 4$

1

[12]

15 (a) (i) Volume of crater-lake solution on *x*-axis

Do not penalise missing axes labels.

If axes unlabelled use data to decide.

Lose this mark if axes mis-labelled.

1

Sensible scales

*Lose this mark if **plotted points** do not cover at least half the paper or plot goes off the squared paper.*

1

All points plotted correctly +/– one square

1

(ii) Draws appropriate line of best fit, omitting point at 20 cm^3 / 15 cm^3

Lose this mark if the line deviated towards the anomalous result.

Lose this mark if the candidate's line is doubled or kinked.

Candidate does not have to extrapolate to the origin.

1

(iii) 16.5 cm^3 +/– 0.5 cm^3

Accept this answer only.

Do not mark consequentially on candidate's graph.

1

(iv) Value corresponding to 10 cm^3 crater-lake solution / 6.00 cm^3

Must have correct identity for explanation mark.

Accept results aren't concordant.

1

Greatest % error from use of burette

Accept difficult to be accurate with small volumes (owtte).

1

(b) (i) pV = nRT

Accept any correct rearrangement.

Ignore case.

1

(ii) $V = 81.0 \times 10^{-6}$ or 8.1×10^{-5}

1

$n = (1 \times 10^5 \times 81.0 \times 10^{-6}) / (8.31 \times 298)$

Mark consequentially on candidate's volume.

1

$n = 3.27 \times 10^{-3}$ (mol)

Correct answer without working scores one mark only.

Allow consequential mark using incorrect conversion.

Incorrect units lose this mark.

1

(iii) M_r $CaCO_3$ = 100.1 (M1)

Accept 100 (can score this mark in calculation for M2 and M3).

1

Moles $CaCO_3$ = $(3.27 \times 10^{-3} \times 10) = 3.27 \times 10^{-2}$ (M2)

Do not penalise lack of units.

Allow b(ii) × 10

Allow $1.25 \times 10^{-3} \times 10$

1

Mass $CaCO_3$ = M1 × M2 (= 3.27 g)

Correct mass without working scores one mark only.

Allow $1.25 \times 10^{-2} \times 10 \times 100.1 = 12.5$ g

1

(iv) (3.27 / 95) × 100

Accept (b(iii) / 95) × 100.

Do not penalise precision.

1

3.44 g

Do not penalise lack of units.

Using 12.5 g gives 13.2 g

Correct answer without working scores 2 marks.

1

(v) Abundant / readily available

Accept not caustic or alkaline.

Non-corrosive

Accept insoluble so safe to add in excess (owtte).

1

[17]

16 (a) (i) Blue to green

Accept blue to yellow.

1

(ii) Decrease / less acid needed

Ignore references to rate

1

(iii) Gloves **or** avoid skin contact

Allow 'if reagent contacts skin wash off (immediately)' or answers to that effect.

Do not accept 'wash' only.

Ignore 'eye protection' or 'lab coat' or 'use of fume cupboard' or 'don't ingest'.

1

(iv) Less chance of losing liquid on swirling / liquid doesn't splash on swirling

Do not accept 'easier to swirl' on its own.

Do not accept 'easier to stir'.

1

(v) Idea that a single titration could be flawed / anomalous

Allow an indication that the first titration is a rough titration.

Do not allow 'to improve accuracy' without qualification.

Do not allow vague references to 'outliers'.

1

(b) (i) $2.3(3) \times 10^{-2}$

Do not penalise additional significant figures, but do not allow 0.02

1

(ii) Dilution of acid needed / may react with carbon dioxide in air

Accept 'poor end-point' or 'no suitable indicator' or 'a large volume (of calcium hydroxide) will be needed'.

Ignore references to low solubility or concentration too low.

1

[7]

17

(a) Remove undissolved barium hydroxide / <u>excess</u> solid

Do not accept 'remove impurities'.

1

(b) Filtration

Do not accept 'decanting' or 'sieving'.

Ignore references to heating or drying.

1

(c) Remove (excess) sulfuric acid

1

(d) $Ba(OH)_2 + H_2SO_4 \rightarrow BaSO_4 + 2H_2O$

Accept multiples.

Accept $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Ignore state symbols.

1

(e) (i) 233.4

Accept 233

1

(ii) 0.018(2)

Do not penalise additional significant figures, but do not allow 0.02

Allow consequential answer from (i).

1

(iii) 0.018(2) × 171.3 = 3.12

Do not penalise precision.

If 0.018 used, answer = 3.08

1

× 10 = 31.2

Do not penalise precision.

Allow this mark if 0.18(2) used directly.

Correct answer without working scores one mark only.

Allow consequential answer on (ii)

1

(f) Barium sulfate / it is insoluble

Do not accept answers based on small amount ingested.

Do not accept barium.

1

[9]

18

Include washings or words to that effect / mix contents

Accept 'use distilled / deionised water'.

Allow 'weigh directly into flask' if washing included.

1

[1]

19 (a) (ligand) substitution

Allow 'ligand exchange'.

1

(b) To display <u>the equilibrium</u> to the right

To ensure reaction goes to completion.

1

To improve the yield

Allow 'to replace all chlorines'.

1

(c) (i) $K_2PtCl_4 + 4KI \rightarrow K_2PtI_4 + 4KCl$

Allow correct ionic equations $PtCl_4^{2-} + 4I^- \rightarrow PtI_4^{2-} + 4Cl^-$

Allow multiples and fractions.

1

(ii) = (780.9) × 100 / (415.3 + 664)

Working must be clearly shown.

Allow one mark for correct relationship even if M_r *values are incorrect eg using values from ionic equation.*

1

= 72.4

Allow 72%

1

(d) (i) $Ag^+ + I^- \rightarrow AgI$

Ignore state symbols even if incorrect.

This equation only.

1

(ii) Stops the reverse reaction / equilibrium displaced to the right

1

(e) Number of steps in the process

Allow 'equilibrium may lie on the reactant side' / side reactions / isomer formation.

1

Losses at each stage of the synthesis

Equilibrium losses or practical losses or yield not 100% for each step.

1

(f) Minimum amount of hot solvent

Accept 'small' for minimum.

Accept water.

1

Cool / crystallise

1

Filter

1

(g) (i) Small amounts are more likely to kill cancer cells rather than the patient

1

(ii) Wear gloves / wash hands after use

Ignore masks.

Apply the list principle if more than one answer.

1

[15]

20 (a) (i) $EDTA^{4-} + [Cu(H_2O)_6]^{2+} \rightarrow [Cu(EDTA)]^{2-} + 6H_2O$

1

(ii) (Mol EDTA = (6.45/1000) × 0.015 =)9.68×10^{-5} mol Cu(II)

1

Conc. Cu(II) = ((9.68×10^{-5}) / 0.025 =) 0.00387 mol dm^{-3}

Correct answer without working gains M2 only.

1

(b) Samples may not be consistent throughout the river
OR
Concentration may vary over time

Ignore comments on technique.

1

(c) $[Ag(NH_3)_2]^+$

Accept name eg diamminesilver(I) ion.

1

aldehyde

Allow CHO.

1

[6]

21 (a) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

Accept multiples.

Ignore state symbols, even if incorrect.

1

(b) Hazard acid corrosive **or**
hydrogen flammable / explosive

Accept 'iron(II) sulfate / sulfuric acid an irritant'.

1

Precaution gloves or eye protection **or** avoid naked flames / spark

Allow 'if reagent contacts skin wash off immediately' or answers to that effect instead of gloves.

Do not allow 'wipe up spillages'.

Ignore 'lab coat' or 'use of fume cupboard' or 'do not ingest chemicals'.

1

[3]

22 (a) $4d^{10}\ 5s^{2}\ 5p^{1}$ in any order

Allow subscripts for numbers

Allow capitals

1

(b) (i) Using an electron gun/(beam of) high energy/fast moving electrons

Ignore 'knocks out an electron'

1

(ii) $In(g) + e^{-} \rightarrow In^{+}(g) + 2e^{-}$

OR

$In(g) \rightarrow In^{+}(g) + e^{-}$

$In(g) - e^{-} \rightarrow In^{+}(g)$

The state symbols need not be present for the electron - but if they are they must be (g)

No need to show charge on electron

If I CE = 0

Ignore any equations using M

1

(iii) So no more than 1 electron is knocked out/so only one electron is knocked out/prevent further ionisation

Allow stop 2+ and 3+/other ions being formed

Not to get wrong m/z

1

(iv) Any two processes from

- Accelerate (owtte)
- Deflect (owtte)
- Detect (owtte)

Ignore wrong causes of process

2 max

(c) (i) Average/mean mass of (1) atom(s) (of an element)

1

1/12 mass of one atom of ^{12}C

1

OR

(Average) mass of one mole of atoms

1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes

1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12 on a scale in which an atom of C-12 has a mass of 12

Not average mass of 1 molecule

Allow the wording Average mass of 1 atom of an element compared to 1/12 mass atom of ^{12}C (or mass 1/12 atom of ^{12}C)

Allow if moles of atoms on both lines

Accept answer in words

Can have top line × 12 instead of bottom line ÷12

If atoms/moles mixed, max = 1

(ii) $$\frac{113x + 115y}{x + y} = 114.5$$

Allow idea that there are 4 × 0.5 divisions between 113 and 115

1

ratio (113:115) = 1:3 **OR** 25:75 **OR** 0.5:1.5 etc

Correct answer scores M1 and M2

If 1:3 for In(115):In(113), max = 1

1

(d) None

1

Same no of electrons (in the outer shell)/same electron configuration)

Ignore electrons determine chemical properties/ignore protons

M2 dependent on M1 being correct

1

(e) 29.0%/29% O

If no O calculated, allow M2 if In and H divided by the correct A_r

1

$\frac{69.2}{114.8/114.5}$ $\frac{1.8}{1}$ $\frac{29.0}{16}$

1

or

0.603 1.8 1.81

1 3 3

EF = In H_3O_3

Allow $In(OH)_3$

Do not allow last mark just for ratio 1:3:3

If InO_3H_3 given with no working then allow 3 marks

If I not In, lose M3

1

[15]

23 (a) (i) $\underline{4.98 \times 10}^{-3}$

1

Only

(ii) 2.49×10^{-3}

Allow answer to (a)(i) ÷ 2

Allow answers to 2 or more significant figures

1

(iii) 2.49×10^{-2}

Allow (a)(ii) × 10

Allow answers to 2 or more significant figures

1

(iv) 138.2

3.44 divided by the candidate.s answer to (a)(iii)

138.2 or 138.1 (i.e. to 1 d.p.)

1

(v) (138 – 60) ÷ 2 = 39.1

Allow 39 – 39.1

Allow ((a)(iv) – 60) ÷ 2

1

K/potassium

Allow consequential on candidate's answer to (a)(iv) and (a)(v) if a group 1 metal

Ignore + sign

1

(b) PV = n RT or rearranged

If incorrectly rearranged CE = 0

1

$$T = \frac{0.022 \times 100000}{0.658 \times 8.31}$$

Correct M2 also scores M1

1

402(.3) K (or 129 °C)

allow 402-403K

or 129-130 °C

do not penalise °K

M3 must include units for mark

1

(c) Pressure build up from gas/may explode/stopper fly out/glass shatters/breaks

Penalise incorrect gas

1

(d) (i) M_r = 84.3

If 84 used, max 1

1

$\frac{6.27}{84.3}$ = 0.074(4)

CE if not 84 or 84.3

Allow answers to 2 or more significant figures

M2 = 0.074-0.075

1

(ii) M1 M_r $MgSO_4$ = 120(.4)

allow 120.3 and 120.1

CE if wrong Mr

1

M2 Expected mass $MgSO_4$ = 0.074(4) × 120(.4) = 8.96 g

Allow 8.8 – 9.0 or candidate's answer to (d)(i) × 120(.4)

1

M3 95% yield = $\frac{8.96 \times 95}{100}$ = 8.51 g

Allow 8.3 – 8.6

M3 dependent on M2

Alternative method

M2 0.074(4) × 95/100 = 0.0707

M3 0.0707 × 120(.4) = 8.51 g

Allow (d)(i) × 95/100

Allow 8.3 – 8.6

M3 dependent on M2

1

[15]

24 (a) (i) Ammonia

If reagent is missing or incorrect cannot score M3

1

Starts as a pink (solution)

1

Changes to a yellow/straw (solution)

Allow pale brown

Do not allow reference to a precipitate

1

(ii) (dark) brown

Do not allow pale/straw/yellow-brown (i.e. these and other shades except for dark brown)

1

(b) (i) Ruby/red-blue/purple/violet/green

Do not allow red or blue

If ppt mentioned contradiction/CE =0

1

Green

If ppt mentioned contradiction/CE =0

1

$[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$

1

Formula of product

Can score this mark in (b) (ii)

1

(ii) $H_2O_2 + 2e^- \rightarrow 2OH^-$

1

$2[Cr(OH)_6]^{3-} + 3H_2O_2 \rightarrow 2CrO_4^{2-} + 8H_2O + 2OH^-$

Allow 1 mark out of 2 for a balanced half-equation such as Cr(III) → Cr(VI) + 3e⁻

or $Cr^{3+} + 4H_2O \rightarrow CrO_4^{2-} + 8H^+ + 3e^-$ *etc*

also for $2Cr(III) + 3H_2O_2 \rightarrow 2CrO_4^{2-}$ *(unbalanced)*

2

Yellow

Do not allow orange

1

(c) $2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

if no equation and uses given ratio can score M2, M3, M4 & M5

1

Moles MnO_4^- = (24.35/1000) × 0.0187 = $\underline{4.55 \times 10^{-4}}$

Note value must be quoted to at least 3 sig. figs.

M2 is for 4.55×10^{-4}

1

Moles H_2O_2 = (4.55×10^{-4}) $\underline{\times\ 5/2}$ = 1.138×10^{-3}

M3 is for × 5/2 (or 7/3)

Mark consequential on molar ratio from candidate's equation

1

Moles H_2O_2 in 5 cm^3 original

M4 is for × 10

1

= (1.138×10^{-3}) <u>× 10</u> = 0.01138

Original $[H_2O_2]$ = 0.01138 <u>× (1000/5)</u> = 2.28 mol dm^{-3}

(allow 2.25-2.30)

M5 is for consequentially correct answer from (answer to mark 4) × (1000/5)

Note an answer of between 2.25 and 2.30 is worth 4 marks)

If candidate uses given ratio 3/7 max 4 marks:

***M1**: Moles of MnO_4^- = <u>4.55×10^{-4}</u>*

***M2**: Moles H_2O_2 = (4.55×10^{-4}) <u>× 7/3</u> = 1.0617×10^{-3}*

***M3**: Moles H_2O_2 in 5 cm^3 original*

= $(1.0617 \times 10^{-3}) \times 10$ = 0.01062

M4: Original $[H_2O_2]$ = 0.01062 × (1000/5) = 2.12 mol dm^{-3}

(allow 2.10 to 2.15)

1

[17]

25 (a) (i) M_r MgO = 40.3

If used 40 then penalise this mark but allow consequential M2 (0.0185)

1

0.741/40.3 = 0.0184

0.018 with no M_r shown = 0
Penalise if not 3 sig figs in this clip only

1

(ii) 0.0184 × <u>5/2</u> = 0.0460

Allow 0.0459 to 0.0463
Allow their (a)(i) × 5/2 ie allow process mark of × 5/2 but insist on a correct answer being written down
Ignore sig figs

1

(b) pV = nRT

1

$(V = \frac{0.402 \times 8.31 \times 333)}{100\,000})$

If rearranged incorrectly then lose M1
If this expression correct then candidate has scored first mark

0.0111

1

Ignore units

11.1 (dm^3)

3 marks for 11.1 (dm^3)
However if 11.1 m^3 or cm^3 allow 2 (ie penalise wrong units in final answer)
Ignore sig figs- but must be 2 sig figs or greater

1

(c) (i) 0.0152 × 2 = 0.0304
Allow 0.03

1

(ii) 0.938 mol dm^{-3}
Allow range 0.92 – 0.94
Minimum 2 sig figs
Allow consequential marking from (c)(i)
Ignore units even if wrong

1

[8]

26 (a) O = 74.1%

1

$\frac{25.9}{14}$ $\frac{74.1}{16}$

If atomic numbers or molecular masses are used lose M2

1

1.85 4.63
1 2.5
N_2O_5

1

This ratio alone will not score the final mark. (It would get 2)
Allow 3 marks for N_2O_5

(b) Toxic/poisonous/forms an acidic gas/forms NO_2 which is acidic/ respiratory irritant/forms HNO_3 when NO reacts with water and oxygen/ triggers asthma attacks/greenhouse gas/photochemical smog/ contributes to global warming/formation of acid rain

ignore NO is an acidic gas or NO is acidic in water
Not references to ozone layer

1

(c) $2NO + O_2 \rightarrow 2NO_2$

Accept multiples or fractions of equation
Ignore wrong state symbols

1

(d) Nitrogen/N_2 and oxygen/O_2 combine/react

QWC (not N and O combine)
Not nitrogen in fuel
Allow $N_2 + O_2 \rightarrow 2NO$ for M1 only

1

spark/high temperature/2500-4000 °C

1

(e) $2NO + 2CO \rightarrow N_2 + 2CO_2$

OR

$2NO \rightarrow N_2 + O_2$

Accept multiples or fractions of equation
Ignore wrong state symbols
Allow $C_8H_{18} + 25NO \rightarrow 8CO_2 + 12.5N_2 + 9H_2O$

1

[8]

27 (a) Average/mean mass of (1) atom(s) (of an element)

1

1/12 mass of one atom of ^{12}C

Accept answer in words
Can have top line × 12 instead of bottom line ÷ 12

1

OR

<u>(Average) mass of one mole of atoms</u>
1/12 mass of one mole of ^{12}C

OR

<u>(Weighted) average mass of all the isotopes</u>
1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12
on a scale in which an atom of C-12 has a mass of 12

$$\frac{(95.12 \times 14) + (4.88 \times 15)}{100}$$

Allow 95.12 + 4.88 instead of 100

1

= 14.05

If not to 2 d.p. then lose last mark
Not 14.04

1

(b) ^{15}N is heavier/^{15}N has a bigger m/z/different m/z values

Not different no's of neutrons
Not ionisation potential

1

Electromagnet/electric field/magnet/accelerating
potential or voltage/electric current

1

(c) No difference

1

Same no of electrons (in outer orbital/shell/sub shell)/same electron configuration

M2 dependent on M1
Not just electrons determine chemical properties
Ignore protons

1

[8]

28 (a) (i) 0.150

Accept 0.15

1

(ii) 0.0750

Accept 0.75

Accept consequential answer from (i)

1

(iii) 106.0

Must have M_r to 1 d.p. to score mark.

Only penalise once in paper

Do not penalise correct answer in g.

Ignore wrong units.

1

(iv) 7.95

Accept consequential answer from (ii) and (iii).

1

(b) Hazard: (acid) corrosive
Precaution: eye protection / gloves

Both hazard and appropriate precaution needed for 1 mark.

Do not accept 'toxic' as hazard.

Accept 'irritant <u>vapour</u>' and 'fume cupboard'.

Do not accept 'ingest'.

1

[5]

29 (a) pV = nRT

Do not penalise incorrect use of capitals / lower case letters.

Accept correct rearrangement of equation.

1

(b) $\mathbf{2}C_4H_{10} + \mathbf{5}O_2 \rightarrow \mathbf{4}CH_3COOH + \mathbf{2}H_2O$

Accept any correct combination of multiples, including fractions.

1

(c) 23.0 g ethanol produces 30.0 g ethanoic acid

1

15.1% (4.54 × 100 / 30)

Do not penalise precision.
15.1% scores 2 marks.

Accept consequential answer on wrong mass of ethanoic acid for second mark only.

1

[4]

30 (a) Percentage of oxygen is 36.4%

% of oxygen stated or shown in calculation.

1

Correct calculation of ratios (C 4.54, H 9.10, O 2.28)

Mark is for correct method, dividing % by A_r

1

Empirical formula C_2H_4O

Allow consequential answer from wrong percentage of oxygen (max 2 marks).

1

(b) 88

Accept 88.0

Do not penalise correct answer in g.

1

(c) Ratio MF / EF of 2 (88 / 44.0 = 2)

If use 132 / 44 = 3, molecular formula $C_6H_{12}O_3$ scores 2 marks.

1

Molecular formula is $C_4H_8O_2$

Accept consequential answers from (a) and (b)

1

[6]

31 (a) Correct completion of table
(7.2 – 9.4 – 10.3 – 11.5 – 12.2 – 13.1)

Any error loses the mark.

1

Appropriate scales for axes

No penalty for missing labels but the graph must cover at least half of the available area.

1

All points plotted correctly

Allow ±1 small square.

1

Line of best fit acceptable

Must be a reasonably smooth curve but make allowance for freehand drawing passing within one small square of each point.

Do not penalise minor doubling of line.

1

(b) Maximum mass at (44.0 / 4) = 11.0 g
giving a max. pressure of 1.7 ± 0.1 MPa

Allow this pressure range only.

Check that candidate's answer matches graph.

1

(c) 7.2 g of NaCl in 250 cm^3 represents 28.8 g dm^{-3}

Allow 0.49 but not 0.5; otherwise do not penalise precision of answer

1

Molarity = 0.492 mol dm^{-3}

Conseq. to their graph value for 100 kPa to 2 or 3 sig.

1

(d) Measuring cylinder = (1 / 250) × 100 = 0.4%
Balance = (0.1 / 7.2) × 100 = 1.4%

Both values correct for the first mark.

Balance error conseq. on their 100 kPa mass value.

Ignore precision of answers.

1

Combined error 1.8%

*When error being calculated is **not** stated, allow **if** the calculations are in the same order as in the question (measuring cylinder, balance).*

If only combined error given then 1 mark only.

1

(e) (i) The points are good enough to be able to draw a smooth curve because the line passes through / close to all points.

Mark consequentially on candidate's graph

1

(ii) There are no anomalous points

Mark consequentially on candidate's graph

1

(f) The experiment only seeks an approximate figure for the maximum pressure

Allow words to that effect.

1

(g) (i) Toxic (to marine life)

Allow phrasing which implies a detrimental effect on marine ecology.

1

(ii) Mixing the effluent with (sea) water to dilute it

Penalise any method which removes the salt or which implies storage.

1

(h) $2Br^- + Cl_2 \rightarrow 2Cl^- + Br_2$

Allow NaBr or KBr

1

(i) The cost of removing water / heating would be too high

Discount answers based on toxicity or speed of reaction.

Allow answers based on cost of using sulfuric acid.

1

(j) (i) Carbon

Allow C, soot, graphite, coal.

1

(ii) Formed by the decomposition of organic material / living organisms in the sea water

Allow 'erosion of coal beds'.

1

(iii) Dissolve the solid formed in water

Do not allow melting of the solid.

1

Filter off the insoluble particles

1

(k) $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

Allow $Ca(OH)_2 + 2H^+ \rightarrow Ca^{2+} + 2H_2O$

Allow multiples.

1

(l) In agriculture / to raise the pH of soil / (Lime-based) mortars in construction

Allow words to that effect.

1

[22]

32 (a) Ammonia is an alkali / would react with HCl

Do not allow 'fair test' or 'to improve accuracy' without further qualification

1

(b) Batches may vary / batch might be contaminated

Do not allow 'fair test', 'to improve accuracy', 'reliable' or 'reproducible' without further qualification

1

(c) $NH_4NO_3 \rightarrow N_2O + 2H_2O$

Accept multiples

1

(d) (i) ammonium chloride 134 / 26.2 = 5.11 £ per %

ammonium nitrate 175 / 35 = 5.00 £ per %

ammonium sulphate 111 / 21.2 = 5.24 £ per %

Must have some evidence of working to score this mark
Accept calculations of nitrogen content per pound

1

ammonium nitrate

Accept name or correct formula
Allow consequential answer from candidate's results

1

(ii) Washed / dissolved / leached from soil by rainwater / eutrophication

Allow root damage due to temperature drop when salt dissolves

1

(e) 17.6

Ignore precision of answer
Ignore units
Do not allow 18

1

[7]

33 (a) 2-6 drops / 0.1-0.3 cm^3

Accept 'a few drops'

1

(b) Incorrect volume recorded / space will fill during titration / produces larger titre value

Do not accept 'to give an accurate result' without further qualification
Do not accept references to contamination

1

[2]

34 (a) Hydrogen/H_2 <u>gas/bubbles</u>

1

1.0 mol dm^{-3} HCl/H^+

1

At 298K and 100kPa

Allow 1 bar instead of 100 kPa
Do not allow 1 atm

1

Pt (electrode)

1

(b) $Li^+ + MnO_2 + e^- \rightarrow LiMnO_2$

Ignore state symbols

1

–0.13(V)

1

(c) Fe^{3+} ions reduced to Fe^{2+}

Can score from equation/scheme

1

Because $E(Fe^{3+}(/Fe^{2+})) > E(H^+/H_2)/E$(hydrogen)

Allow emf/E_{cell} +ve/0.77V
Allow Fe^{3+} better oxidising agent than H^+
Allow H_2 better reducing agent than Fe^{2+}
Only award this explanation mark if previous mark given

1

(d) Moles $Cr_2O_7^{2-}$ = $\underline{23.7 \times 0.01/1000}$ = 2.37×10^{-4}

1

1 mol $Cr_2O_7^{2-}$ reacts with 6 mol Fe^{2+} so moles
Fe^{2+} in 25 cm^3 = $6 \times 2.37 \times 10^{-4} = 1.422 \times 10^{-3}$

1

M1 × 6

Moles Fe^{2+} in 250 cm^3 = 1.422×10^{-2}

M2 × 10 or M4/10

1

Original moles Fe^{2+} = $\underline{10.00/277.9}$ = 0.0360

Independent mark

1

Moles Fe^{2+} oxidised = 0.0360 – 0.0142 = 0.0218

M4 – M3

1

% oxidised = (0.0218 × 100)/0.0360 = 60.5%

(M5 × 100)/M4
Allow 60 to 61
Note Max 3 if mol ratio for M2 wrong
eg 1:5 gives 67.1%
1:1 gives 93.4%
Note also, 39.5% (39-40) scores M1, M2, M3 and M4 (4 marks)

1

[14]

35 (a) (i) Propanone evaporates (or similar)

1

Removes water (from the precipitate)

Accept 'removes impurities / excess reagents'.
Accept 'salt insoluble in propanone'.

1

(ii) Add NaOH / NH_3 / Na_2CO_3

1

No green ppt

Accept 'no visible change'.
Must have correct reagent to score this mark.

1

(iii) Some salt dissolves (in propanone) **or** some lost in filtration **or** some Fe^{2+} gets oxidised (to Fe^{3+} in air)

Do not accept 'reaction reversible' or 'incomplete reaction' or similar.

1

(iv) Moles $Fe^{2+} = 2.50 \times 10^{-2}$

Accept 2.5×10^{-2}

1

M_r of salt = 179.8

Allow 180

Allow if 179.8 or 180 appears in a calculation.

1

Mass of salt = $179.8 \times 2.5 \times 10^{-2} \times 0.95 = 4.27$ (g)

Correct answer with no working scores this mark only.

Allow range 4.2 to 4.3 (g)

1

(v) 1.67 mol or correct ratio of $5FeC_2O_4 : 3MnO_4^-$

1

(b) $Ca^{2+} + C_2O_4^{2-} \rightarrow CaC_2O_4$

Accept multiples.

1

(c) (Insoluble) calcium ethanedioate coats surface

Allow 'calcium ethanedioate is insoluble'.

Do not allow answers based on ethanedioic acid being a weak acid.

Do not accept 'acid used up' or 'reaction very fast'.

1

(d) Small amount of tea used **or** concentration of the acid in tea is low

Accept 'high temperature decomposes the acid'.

Accept 'calcium ions in milk form a precipitate with the acid'.

Do not accept 'do not drink tea often' or similar.

1

(e) Mass of acid = 180.0 and mass of reagents = 450.0

Accept 180 and 450.

1

(180 / 450 × 100 =) 40.0%

Do not penalise precision.

Correct answer without working scores this mark only.

1

[14]

36 (a) 34.0

Penalise precision once

1

(b) 1.76 mol dm^{-3}

1

(c) answer to (b) divided by 0.05

35(.3) on correct figures

1

Shows working

Correct answer only scores this mark

Lose this mark if any units are given for the factor

1

[4]

37 (a) (i) M_r = 132.1

1

132

0.0238

Allow 0.024
Allow 0.0237
Penalise less than 2 sig fig once in (a)

1

(ii) 0.0476

1

0.0474-0.0476
Allow (a) (i) × 2

(iii) 1.21

Allow consequential from (a) (ii)
ie allow (a) (ii) × 1000/39.30
Ignore units even if wrong

1

(b) $\frac{34 \times 100}{212.1}$

Allow mass or Mr of desired product times one hundred divided by total mass or Mr of reactants/products
If 34/212.1 seen correctly award M1

1

= 16.0(3)%

Allow 16%
16 scores 2 marks

1

(c) 100(%)

Ignore all working

1

(d) PV = nRT or $n = \frac{PV}{RT}$

If rearranged incorrectly lose M1 and M3

1

$n = \frac{100000 \times 1.53 \times 10^{-2}}{8.31 \times 310}$

M2 for mark for converting P and T into correct units in any expression

1

= 0.59(4)

Allow 0.593
M3 consequential on transcription error only not on incorrect P and T

1

(e) (Na_2SO_4) H_2O
(44.1%) 55.9%

M1 is for 55.9

1

44.1/142.1 55.9/18
0.310 3.11
= 1 = 10

Alternative method gives180 for water part = 2 marks

1

x = 10

X = 10 = 3 marks
10.02 = 2 marks

1

[13]

38 (a) Average/mean mass of (1) atom(s) (of an element)

1/12 mass of one atom of ^{12}C

1

If moles and atoms mixes Max = 1

1

OR

(Average) mass of one mole of atoms

1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes

1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12 on a scale in which an atom of C-12 has a mass of 12

This expression = 2 marks

(b) d block

Allow 3d/D
Other numbers lose M1
Ignore transition metals

1

[Ar] $3d^2 4s^2$

1

Can be written in full
Allow subscripts
$3d^2$ and $4s^2$ can be in either order

27

1

(c) $\frac{(90 \times 9) + (91 \times 2) + (92 \times 3) + (94 \times 3)}{17}$

(= 1550)

1

(or ∑ their abundances)

If one graph reading error lose M1 and allow consequential M2 and M3.
If 2 GR errors penalise M1 and M2 but allow consequential M3
If not 17 or ∑ their abundances lose M2 and M3

1

= 91.2

91.2 = 3 marks provided working shown.

1

Zr/Zirconium

M4 -allow nearest consequential element from M3
accept Zr in any circumstance

1

(d) High energy electrons/bombarded or hit with electrons

accept electron gun

1

knocks out electron(s) (to form ions)

1

Z^+ = <u>90</u> deflected most

If not 90 lose M3 and M4
If charge is wrong on 90 isotope lose M3 only
Accept any symbol in place of Z

1

since lowest mass/lowest m/z

Allow lightest

1

(e) (ions hit detector and) cause current/(ions) accept electrons/cause electron flow

QWC

1

bigger current = more of that isotope/current proportional to abundance

Implication that current depends on the number of ions

1

[15]

39 (a) Electronegativity increases

1

Proton number increases (increase in nuclear charge)

1

Same number of electron shells/levels

Or same radius or Shielding of outer electrons remains the same

1

Attraction of bond pair to nucleus increases

Allow 'electrons in bond' instead of 'bond pair'

1

(b) Big difference in electronegativity leads to ionic bonding, smaller covalent

Lose a mark if formula incorrect

1

Sodium oxide ionic lattice

1

Strong forces of attraction between ions

1

P_4O_{10} covalent molecular

Must have covalent and molecular (or molecules)

1

Weak (intermolecular) forces between molecules

Or weak vdW, or weak dipole–dipole between molecules

1

melting point Na_2O greater than for P_4O_{10}

Or argument relating mpt to strength of forces

1

(c) Moles NaOH = 0.0212 × 0.5 = 0.0106

M1 moles of NaOH correct

1

Moles of H_3PO_4 = 1/3 moles of NaOH (= 0.00353)

M2 is for 1/3

1

Moles of P in 25000 l = 0.00353 × 10^6 = 3.53 × 10^3

M3 is for factor of 1,000,000

1

Moles of P_4O_{10} = 3.53 × 10^3/4

M4 is for factor of 1/4 (or 1/2 if P_2O_5)

1

Mass of P_4O_{10} = 3.53 × 10^3/4 × 284 = 0.251 × 10^6 g
= 251 kg

(Or if P_2O_5 3.53 × 10^3/2 × 142)
M5 is for multiplying moles by M_r with correct units
allow conseq on incorrect M4
(allow 250-252)

1

[15]

40 (a) (i) 0.00301/ 3.01 × 10^{-3};

Penalise < 3sf in (a)(i);

Allow 3.01 × 10^{-3} – 3.05 × 10^{-3}.
(for candidates who have used Mg as 24)

1

(ii) 0.00602

Allow correct answer a(i) × 2.

1

(iii) 0.00965/ 9.65 × 10^{-3};

Allow 0.009646/ 0.0096-0.0097.

1

(iv) 0.00363 moles;

Allow range 0.0035 to 0.0037.
Allow (a)(iii) – 2 (a)(ii) (must be positive).

1

(b) PV = nRT;

Allow all capitals/ lower case.

1

$$V = \frac{0.512 \times 8.31 \times 298}{96000};$$

M2 Mark is for all numbers correct.

If units in answer are in dm^3 allow this expression with 96 in denominator.

1

0.0132 m^3/ 13.2 dm^3;

M3 Must have correct units/

allow 13200 cm^3.

Allow min 2 sig figs in answer.

1

(c) O = 69.6 (%);

1

$\frac{30.4}{14}$ $\frac{69.6}{16}$ 2.17 : 4.35

Use of 7/8 CE then M1 only.

1

(1 : 2) NO_2

Mark for formula not ratio.
If NO_2 and no working shown then allow 1 mark.
If 69.6% + NO_2 only = 2.
Need to see evidence of M2 working.
Allow M2 conseq on the wrong M1 (ie max 1).

1

[10]

41 (a) (i) Average/mean mass of 1 atom (of an element);

Average mass of 1 atom × 12.

1

Mass 1/12 atom of ^{12}C;

Mass 1 atom of ^{12}C.
QWC.

1

(ii) Other isotope = 46.0%;

1

$$107.9 = \frac{(54 \times 107.1) + (46 \times ?)}{100};$$

M2 whole expression.

1

108.8;

Answer 108.8 (3 marks).
Answer min 1 d.p..

1

Same electronic configuration/ same number of electrons (in outer shell)/ both have 47 electrons;

Ignore protons and neutrons unless incorrect.
Not just electrons determine chemical properties.

1

(b) Ionisation;

1

high energy electrons fired at sample;

Allow electron gun /blasted with electrons.

1

Acceleration;

1

With electric field/accelerating potential/potential difference;

Allow by negative plate.

1

Deflection;

1

With electromagnet/ magnet/ magnetic field;

M2 dependent on M1.
M4 dependent on M3.
M6 dependent on M5.

1

(c) (Silver) metallic (bonding);

Vdw/molecules CE=0.

1

Regular arrangement of same sized particles;

1

+ charge in each ion;

Ignore multiple positive charges.
Candidates do not need to show delocalised electrons.

1

(d) Ionic (bonds);

1

Minimum 4 ions shown in 2D square arrangement placed Correctly;

Do not allow multiple charges on ions.

1

Further 3 ions shown correctly in a cubic lattice;

1

Strong (electrostatic) forces/bonds;

If vdw/molecules/covalent mentioned CE = 0 for M4 and M5.

1

Between <u>+ and – ions</u>;

Accept between <u>oppositely charged ions</u>.

1

[20]

42 (a) **M1** $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$

1

OR multiples

M2 An oxidising agent is an <u>electron acceptor</u> OR <u>receives / accepts / gains electrons</u>

Ignore state symbols

M2 NOT an "electron pair acceptor"

1

M3 MnO_2 is the oxidising agent

Ignore "takes electrons" or "takes away electrons"

1

(b) **M1** Formation of SO_2 and Br_2 (could be in an equation)

1

M2 Balanced equation

Several possible equations

$\mathbf{2}KBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}KHSO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$

OR

$\mathbf{2}KBr + 2H_2SO_4 \rightarrow K_2SO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$

1

M3 $\mathbf{2}KBr + Cl_2 \rightarrow \mathbf{2}KCl + Br_2$

M2 Could be ionic equation with or without K^+

$\mathbf{2}Br^- + \mathbf{6}H^+ + \mathbf{3}SO_4^{2-} \rightarrow Br_2 + \mathbf{2}HSO_4^- + SO_2 + \mathbf{2}H_2O$

$(\mathbf{3}H_2SO_4)$

$\mathbf{2}Br^- + \mathbf{4}H^+ + SO_4^{2-} \rightarrow Br_2 + SO_2 + \mathbf{2}H_2O$

$(\mathbf{2}HBr + H_2SO_4)$

Accept HBr and H_2SO_4 *in these equations as shown or mixed variants that balance.*

Ignore equations for KBr reacting to produce HBr

M3 Could be ionic equation with or without K^+

$\mathbf{2}Br^- + Cl_2 \rightarrow \mathbf{2}Cl^- + Br_2$

1

M4 % atom economy of bromine

$$= \frac{Br_2}{2KBr + Cl_2} \times 100 = \frac{(2 \times 79.9)}{238 + 71} \times 100 = \frac{159.8}{309} \times 100$$

= **51.7%** OR **52%**

M4 Ignore greater number of significant figures

1

M5 One from:

- High atom economy
- Less waste products
- Cl_2 is available on a large-scale
- No SO_2 produced
- Does not use concentrated H_2SO_4
- (Aqueous) KBr or bromide (ion) in seawater.
- Process 3 is simple(st) or easiest to carry out

M5 Ignore reference to cost

Ignore reference to yield

1

(c) **M1** HBr **–1**

1

M2 HBrO **(+)1**

1

M3 Equilibrium will shift to the right
OR
L to R
OR
Favours forward reaction
OR
Produces more HBrO

1

M4 **Consequential on correct M3**
OR
to oppose the loss of HBrO
OR
replaces (or implied) the HBrO (that has been used up)

1

[12]

43 (a) percentage of oxygen is 58.33

1

correct calculation of ratios (C 3.125, H 4.17, O 3.645)

1

clearly relates ratios to formula eg
simplifies ratios (C 1, H 1.29, O 1.17) or for H then 3.125 × 8 / 6 = 4.17% etc

1

Notes
* *correct percentage of oxygen can be stated or shown clearly in a calculation*
* *to score final mark must **clearly** show how ratios relate to $C_6H_8O_7$*
* *allow full credit to candidate who correctly finds*
percentage of oxygen
calculates M_r
shows percentage of H is 8 divided by M_r

(b) carbon dioxide / CO_2

1

(c) (i) suitable reaction vessel
eg sealed flask or test-tube with side arm or
eg tube in bung

1

suitable collection method
eg gas syringe / over water in measuring
eg cylinder

1

Notes
* *collection vessel must allow measurement of gas*
* *if apparatus would leak lose second mark*
* *ignore heating*
* *can draw tubing as single line*
* *accept 2D or 3D diagrams*
* *do not need labels, and ignore mis-labelling*

(ii) (1) mass on x-axis

1

Notes
* *If axes unlabelled use data to decide that mass is on the x-axis*

sensible scales

1

Notes
* *lose this mark if the* ***plotted points*** *do not cover at least half of the paper*
* *lose this mark if the graph plot goes off the squared paper*

plots points correctly ± one square

1

(2) draws appropriate straight line of best fit, omitting point at 1.17g / 86 cm^3

Notes
* *lose this mark if the line deviates towards the point at 1.17g / 86 cm^3*
* *candidates does not have to extrapolate the line to the origin to score this mark*
* *when checking for best fit, candidate's line* ***must*** *go through the origin ± one square. Extend candidate's line if necessary*

1

(3) 129 ± 1 cm^3

Notes
* *accept this answer* ***only***

1

(d) CO_2 / gas formed distends stomach / produces wind / increases pressure in stomach

1

(e) molecular formula has to be a simple multiple of the empirical formula

1

so approximate M_r value will distinguish between the options or equivalent wording

1

(f) gas escapes before bung inserted any 2 × 1 for

syringe sticks

carbon dioxide soluble in water

Notes
* *do **not** accept 'operator error' / 'inaccurate equipment' / 'equipment leaks'*

2

(g) volume depends on pressure and temperature

Notes
* *do **not** accept 'to get a more accurate result' or equivalent wording without qualification*

1

(h) Tablets could vary between samples or equivalent wording

Notes
* *do **not** accept 'to get a more accurate / reliable result' or 'to make a fair test' without qualification*

1

(i) (i) $NaHCO_3$ **least** soluble

1

(ii) exhaust gases passed into mixture of NaCl and NH_3

1

(j) $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Notes
* *accept multiples*

1

(k) 106.0 divided by 217.1 × 100 = 48.8%

Notes
* *ignore precision of answer*

1

[22]

44 (a) Mass of mineral on *x*-axis;

If axes unlabelled use data to decide if mass of mineral is on the x-axis.

1

Sensible continuous scales;

*Lose this mark if the **plotted points** do not cover at least 9 squares by 7.*
Lose this mark if the graph plot goes off the squared paper.
The graph does not have to start at the origin.

1

Plots points correctly ± one square;

Award this mark if the line is close to your line.

1

Draws a best fit straight line

Award this mark if best fit line is consistent with candidate's plotted points.
Lose this mark if line is kinked or doubled.

1

(b) 1.48 or 1.49 or 1.50 or 1.5 (g);

*Accept these answers **only***
Ignore precision of answer.
Allow range 1.48 – 1.5

1

(c) 0.0124 (mol);

Accept 0.012, 0.0125.
Allow answer without working.

1

(d) (1.49 / 0.0124) = 119.4 – 125.0;

Must divide answer to part (b) by answer to part (c) to score first mark.
Allow consequential answer from part (b).
Allow answer without working.
Ignore precision of answer.

1

(e) Answer to part (e) close to 120.3;

Allow consequential answer from part (d).
Allow correct calculation of x

1

(f) $\underline{x}$ must be a whole number;

1

(g) Good / straight line so results good / reliable;

Allow consequential answers from candidate's graph
Do not allow 'so results are accurate'.

1

Anomaly at 1.34 g;

Allow anomaly clearly indicated on the graph.

1

(h) Ensure reaction / decomposition goes to completion;

Do not allow 'to make fair test' or 'improve reliability'
Accept to 'remove all carbon dioxide <u>and</u> water'.

1

(i) (i) Percentage errors too high / errors in weighing too high;

Do not allow 'to make fair test' or 'improve reliability'
Do not allow 'errors' on its own.

1

(ii) Incomplete decomposition or words to that effect;

Do not allow 'to make fair test' or 'improve reliability'
Do not allow 'takes too long' or 'wastes chemicals'
Do not allow 'not all of the water removed'.

1

(j) 39.05 / 18 = 2.170 and 60.95 / 84.3 = 0.723;

Allow M_r of $MgCO_3.H_2O$ = 138.3

1

$MgCO_3.3H_2O$;

54 / 138.3 + 39.05%
$MgCO_3.3H_2O$ without working scores 1 mark.

1

(k) Atom economy for Reaction 1 is (40.3 / 84.3) x 100 = 47.8%

Maximum 1 mark if no working.
Ignore precision of answers.

1

Atom economy for Reaction 2 is (40.3 / 58.3) x 100 = 69.1%

1

(l) No gas produced <u>in stomach</u> / won't cause wind;

Do not allow 'gas produced' on its own.

1

[19]

45 (a) (i) $\frac{79.9}{225.9} \times 100$;

Whole expression
Ignore >3 sig figs

1

= 35.37(%) allow 35.0 – 35.4%;

Allow 35%
Allow 2 marks if correct %

1

(ii) Sell the HCl or sell the other product or sell the acid (formed in the reaction);

Need a financial gain

1

(b) (i) $\frac{165}{189.9}$ = 0.869;

One mark for M_r = 189.9

allow 0.86 – 0.87;;

Ignore units

2

(ii) 0.869

Accept same value as in (i)

1

(iii) 0.869 × 79.9 = 69.4;

Allow 68.7 – 70;

Accept answer to (ii) × 79.9

1

(iv) $\frac{63}{69.4}$ × 100;

Accept 63 × 100 /answer to (iii)

= 90.75%;

If > 100% lose this mark

Accept 90.6 to 92%

1

[8]

46 (a) (i) 0.013;

1

(ii) 0.0065;

Answer to (i) ÷ 2

1

(iii) $\frac{0.548}{0.0065}$ = 84.3;

Allow 0.548 ÷ answer to (ii)
Allow 84.1 – 84.4

1

(b) 84.3 – 60 = 24.3;

1 mark for -60

1

Mg;

If 147.6 used the answer is 87.6 (1)
And this is Sr (1)

Allow consequential metal from their calculated A
Answer has got to be a metal to score M2

1

[5]

47 (a) (i) Moles of gas produced = 3

1

PV = nRT

1

V = nRT/P = 3 × 8.31 × 298/100000

1

= 7.43×10^{-2} m^3

1

(ii) $7.43 \times 10^{-2} \times 1000/298 = 0.249$ m^3

1

(b) (i) any two from:

exhaust gases hot so would boil the solution away
solution would splash
reaction might be too slow
would need continuous supply of solution and/or replacement of products

2

(ii) *Commercial advantage* could sell chlorine and/or hydrogen

1

environmental disadvantage generation of electricity likely to lead to release of CO_2 (or chlorine toxic)

1

(c) % O = 74%

1

N:O = 26/14:74/16

1

= 1.86: 4.63 = 1:2.5 therefore formula is N_2O_5

1

(d) $2N_2O \rightarrow 2N_2 + O_2$

1

(e) Proportion of O_2 increased leading to higher T (or more complete combustion)

1

[14]

48

Mark Range	The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor
4-5	– claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2-3	– claims partially supported by evidence – good use of information or ideas about chemistry given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	– valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

(a) (i) M_r of $C_6H_5NH_2$ = 93 M_r of CH_3COCl = 78.5
total M_r of reagents = 264.5 **1**

% atom economy = $\frac{M_r \text{ of wanted product}}{\text{total } M_r \text{ of all reagents}}$ × 100 QWC **1**

= $\frac{135}{264.5}$ × 100 = 51.0 % **1**

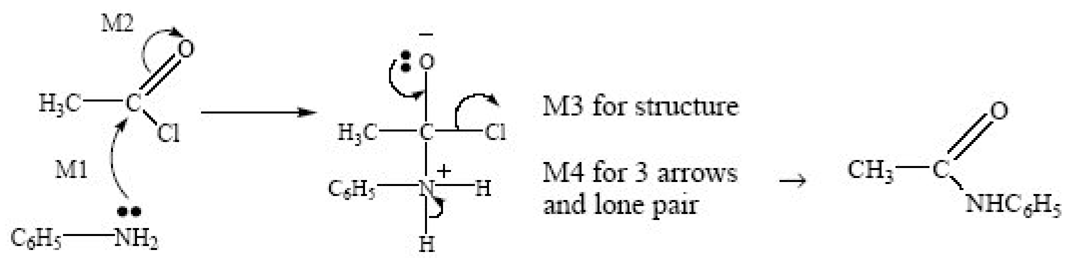
(ii) expected yield = $\frac{10}{93} \times 0.5 \times 135 = 7.26$ kg 1

% yield = $\frac{5.38}{7.26} \times 100 = 74.1$ % 1

(iii) Although yield appears satisfactory (74%) % atom economy is only 51% QWC 1

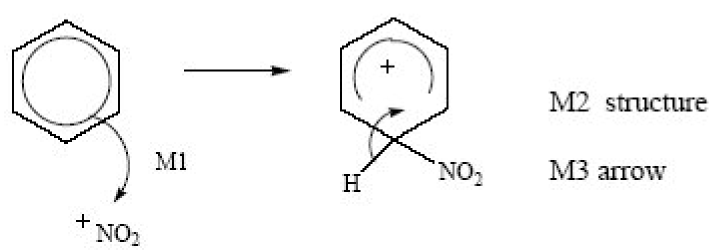
nearly half of the material produced is waste and must be disposed of QWC 1

(b) (nucleophilic) addition-elimination 1



QWC (2) 4

(c) $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ 1



3 **[16]**

49 B **[1]**

50 D **[1]**