OCR A | Year 12 chemistry

Amount of substance

Questions & answers

53 original questions | 307 marks. Questions start on page 2. Work in the dotted spaces, then check the answers at the back. Use the values supplied in each question.

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Relative masses & the mole

Question 1 | OCR A | 4 marks

(a) State the definition of relative isotopic mass. [2 marks]

(b) State the definition of relative atomic mass, A_r. [2 marks]

Question 2 | OCR A | 6 marks

Use H = 1.0, C = 12.0, N = 14.0, O = 16.0 and Mg = 24.3.

(a) Calculate M_r of C_2H_5OH. [2 marks]

(b) Calculate the relative formula mass of $Mg(NO_3)_2$. [3 marks]

(c) State why neither answer has a unit. [1 mark]

Question 3 | OCR A | 5 marks

Use Ca = 40.1, O = 16.0 and H = 1.0 for calcium hydroxide, $Ca(OH)_2$.

(a) Calculate its relative formula mass. [2 marks]

(b) State its molar mass, including the unit. [1 mark]

(c) Explain why the two numerical values are equal but the units are different. [2 marks]

Question 4 | OCR A | 4 marks

(a) State the symbol and unit for amount of substance. (2 marks)

(b) Explain the difference between a mole and the Avogadro constant. (2 marks)

Mass, moles & particles

Question 5 | OCR A | 6 marks

(a) Name the entity represented by each of Fe, O_2 and NaCl. (3 marks)

(b) Calculate the amount in moles of oxygen atoms represented by 0.120 mol O_2. (1 mark)

(c) Calculate the amounts in moles of chloride ions and of all ions represented by 0.0800 mol $MgCl_2$. (2 marks)

Question 6 | OCR A | 6 marks

(a) Calculate the amount in moles of HCl in 7.30 g. M(HCl) = 36.5 g mol^{-1}. (2 marks)

(b) Calculate the mass of 0.0750 mol Na_2CO_3. M = 106 g mol^{-1}. (2 marks)

(c) A pure liquid has density 0.800 g cm^{-3} and molar mass 60.0 g mol^{-1}. Calculate the number of moles in 15.0 cm^3 of liquid. (2 marks)

Question 7 | OCR A | 4 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1} where needed.

(a) Calculate the number of $MgCl_2$ formula units in 0.0350 mol $MgCl_2$. [2 marks]

(b) Calculate the amount in moles of Ne represented by 9.03×10^{22} Ne atoms. [2 marks]

Question 8 | OCR A | 5 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1}.

A sample contains 0.240 mol ethanol, C_2H_5OH.

(a) Calculate the number of ethanol molecules. (2 marks)

(b) Calculate the number of oxygen atoms. (1 mark)

(c) Calculate the total number of atoms. (2 marks)

Question 9 | OCR A | 5 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1}.

A sample contains 0.0200 mol $Al_2(SO_4)_3$.

(a) Calculate the number of sulfate ions. (2 marks)

(b) Calculate the total number of ions. (2 marks)

(c) Explain why a sulfate ion counts as one ion. (1 mark)

Question 10 | OCR A | 4 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1}.

A sample contains 0.0150 mol Al^{3+} ions. Aluminium has atomic number 13.

(a) Determine the number of electrons in one Al^{3+} ion. (1 mark)

(b) Calculate the amount in moles of electrons represented by the sample. (1 mark)

(c) Calculate the number of electrons represented by the sample. (2 marks)

Question 11 | OCR A | 3 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1}.

Calculate the number of sulfate ions represented by 3.42 g $Al_2(SO_4)_3$. M = 342 g mol^{-1}. (3 marks)

Question 12 | OCR A | 5 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1}.

Separate 5.00 g samples of NaCl and $MgCl_2$ are compared. M(NaCl) = 58.5 g mol^{-1}; M($MgCl_2$) = 95.3 g mol^{-1}. Determine which sample represents more chloride ions. Support your conclusion with calculations. (5 marks)

Question 13 | OCR A | 4 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1} where needed.

A sample contains 3.01×10^{22} carbon dioxide molecules. M(CO_2) = 44.0 g mol^{-1}.

(a) Calculate the amount in moles of CO_2. [2 marks]

(b) Calculate the mass of the sample. [2 marks]

Question 14 | OCR A | 4 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1} where needed.

A 4.40 g sample of molecular substance X contains 6.02×10^{22} molecules.

(a) Calculate the amount in moles of X. [2 marks]

(b) Calculate the molar mass of X, including the unit. [2 marks]

Question 15 | OCR A | 8 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1}.

A 15.96 g sample of X_2O_3 represents 1.806×10^{23} oxygen atoms. Use $A_r(O) = 16.0$.

(a) Calculate the amount in moles of oxygen atoms. (2 marks)

(b) Calculate the amount in moles of X_2O_3. (1 mark)

(c) Calculate its molar mass. (2 marks)

(d) Calculate $A_r(X)$ and identify X. Use A_r: Mg 24.3, Al 27.0, Ca 40.1, Fe 55.8, Zn 65.4. (3 marks)

Question 16 | OCR A | 6 marks

Use $N_A = 6.02 \times 10^{23}$ mol^{-1}.

A student writes the following calculation for the number of molecules in 2.50 g CO_2: N = (2.50/44.0)/(6.02 × 10^{23}). M(CO_2) = 44.0 g mol^{-1}.

(a) Identify the error and calculate the correct number of molecules. (3 marks)

(b) Explain why intermediate values should not be rounded, and give an appropriate final precision here. (2 marks)

(c) Express 0.0003045 mol in standard form. (1 mark)

Equations & reacting masses

Question 17 | OCR A | 5 marks

(a) Balance Al + Cl_2 → $AlCl_3$, including state symbols for the solid metal, gaseous chlorine and solid product. (2 marks)

(b) Balance $KClO_3$ → KCl + O_2, including state symbols for the two solids and gaseous oxygen. (2 marks)

(c) Explain why subscripts must not be changed when balancing an equation. (1 mark)

Question 18 | OCR A | 8 marks

Aqueous barium nitrate reacts with aqueous sodium carbonate to form solid barium carbonate and aqueous sodium nitrate. The barium ion is Ba^{2+}.

(a) Write the balanced full equation, including state symbols. (2 marks)

(b) Write the ionic equation, including state symbols. (2 marks)

(c) Name both spectator ions. (1 mark)

(d) Write the formulae of zinc hydroxide, silver sulfate and ammonium nitrate. (3 marks)

Question 19 | OCR A | 4 marks

Aluminium reacts with chlorine: $2Al + 3Cl_2 \rightarrow 2AlCl_3$.

(a) State the mole ratio n(Al) : n(Cl_2) : n($AlCl_3$). [1 mark]

(b) Calculate the number of moles of $AlCl_3$ formed from 0.240 mol Cl_2 when aluminium is in excess. [2 marks]

(c) Explain why the coefficients 2 : 3 must not be used as a mass ratio. [1 mark]

Question 20 | OCR A | 3 marks

Iron reacts with excess oxygen: $4Fe + 3O_2 \rightarrow 2Fe_2O_3$. Calculate the mass of Fe_2O_3 formed from 8.37 g Fe. M(Fe) = 55.8 and M(Fe_2O_3) = 159.6 g mol^{-1}. (3 marks)

Question 21 | OCR A | 3 marks

Sodium hydrogencarbonate decomposes: $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$. Calculate the mass of $NaHCO_3$ needed to form 3.18 g Na_2CO_3. M($NaHCO_3$) = 84.0 and M(Na_2CO_3) = 106.0 g mol^{-1}. (3 marks)

Limiting reactants

Question 22 | OCR A | 3 marks

Sodium reacts with chlorine: $2Na + Cl_2 \rightarrow 2NaCl$. A mixture contains 4.60 g Na and 5.68 g Cl_2. M(Na) = 23.0 and M(Cl_2) = 71.0 g mol^{-1}. Identify the limiting reactant, showing your reasoning. (3 marks)

Question 23 | OCR A | 4 marks

For $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$, a mixture contains 7.98 g Fe_2O_3 and 4.20 g CO. $M(Fe_2O_3)$ = 159.6, M(CO) = 28.0 and M(Fe) = 55.8 g mol^{-1}. Determine whether either reactant remains after complete reaction, and calculate the mass of iron formed. (4 marks)

Question 24 | OCR A | 6 marks

Iron reacts with chlorine: $2Fe + 3Cl_2 \rightarrow 2FeCl_3$. A mixture contains 8.37 g Fe and 14.20 g Cl_2. M(Fe) = 55.8, $M(Cl_2)$ = 71.0 and $M(FeCl_3)$ = 162.3 g mol^{-1}. Determine the limiting reactant, the maximum mass of $FeCl_3$ and the mass of reactant remaining. (6 marks)

Empirical & molecular formulae

Question 25 | OCR A | 4 marks

A compound contains 0.486 g magnesium and 1.420 g chlorine. Determine its empirical formula. Use A_r(Mg) = 24.3 and A_r(Cl) = 35.5. Show your working. (4 marks)

Question 26 | OCR A | 6 marks

A 1.674 g sample of iron reacts completely with oxygen to form 2.314 g of an oxide. Determine the empirical formula of the oxide. Use A_r(Fe) = 55.8 and A_r(O) = 16.0. Show how you obtain the mass of oxygen. (6 marks)

Question 27 | OCR A | 6 marks

A molecular compound is 55.8% C, 7.0% H and 37.2% O by mass. Its M_r is 86.0. Use A_r: C 12.0, H 1.0, O 16.0.

(a) Determine its empirical and molecular formulae. (5 marks)

(b) Another compound has empirical formula C_2H_4O and M_r = 44.0. State its molecular formula. (1 mark)

Question 28 | OCR A | 8 marks

Complete combustion of 0.440 g of a compound containing only C, H and O produces 0.880 g CO_2 and 0.360 g H_2O. Its M_r is 88.0. Use $M(CO_2) = 44.0$ and $M(H_2O) = 18.0$ g mol^{-1}; A_r: C 12.0, H 1.0, O 16.0.

(a) Determine its empirical and molecular formulae. (7 marks)

(b) Explain why the oxygen atoms in the combustion products cannot all be assigned to the original compound. (1 mark)

Hydrated salts

Question 29 | OCR A | 5 marks

(a) State what is meant by an anhydrous salt. [1 mark]

(b) State what is meant by water of crystallisation. [2 marks]

(c) Explain the meaning of the dot and the 7 in $MgSO_4 \cdot 7H_2O$. [2 marks]

Question 30 | OCR A | 4 marks

$CoCl_2 \cdot xH_2O$ contains 45.4% water by mass. Determine x and the full formula. $M(CoCl_2) = 129.9$ and $M(H_2O) = 18.0$ g mol^{-1}. (4 marks)

Question 31 | OCR A | 10 marks

$FeSO_4 \cdot xH_2O$ is heated. Only water is lost. Empty crucible = 24.850 g; crucible + hydrate = 27.629 g. Successive heat–cool readings are 26.455, 26.371, 26.369 and 26.369 g. $M(FeSO_4) = 151.9$ and $M(H_2O) = 18.0$ g mol^{-1}.

(a) Determine x and the full formula, explaining the final mass chosen and why heating, cooling and weighing are repeated. (8 marks)

(b) Explain why the solid is heated gently at first and cooled before weighing. (2 marks)

Question 32 | OCR A | 7 marks

A student calculates x from the water lost and the anhydrous salt left when a hydrate is heated. For each error, state the effect on the calculated x and explain it.

(a) Some water remains after the final heating. (2 marks)

(b) Solid is lost by spitting and all mass loss is treated as water. (2 marks)

(c) The residue absorbs water before weighing. (2 marks)

(d) Explain why constant mass alone does not prove that no salt decomposed. (1 mark)

Concentration & dilution

Question 33 | OCR A | 7 marks

A solution contains 0.0850 mol Na_2CO_3 in a final volume of 250.0 cm^3. M(Na_2CO_3) = 106.0 g mol^{-1}.

(a) Calculate its concentration in mol dm^{-3}. (2 marks)

(b) Calculate its concentration in g dm^{-3}. (2 marks)

(c) Calculate the volume of this solution that contains 0.0170 mol solute. Give your answer in cm^3. (2 marks)

(d) Explain why dissolving the solute in 250.0 cm^3 of water would not necessarily produce the stated concentration. (1 mark)

Question 34 | OCR A | 6 marks

25.00 cm^3 of 0.8000 mol dm^{-3} NaOH is diluted to 250.0 cm^3.

(a) Calculate the concentration of the diluted NaOH solution in mol dm^{-3}. (2 marks)

(b) Calculate the volume, in cm^3, of 0.500 mol dm^{-3} stock solution needed to prepare 100.0 cm^3 of 0.0400 mol dm^{-3} solution. (2 marks)

(c) Name the two pieces of volumetric apparatus needed for the dilution in part (a). (2 marks)

Question 35 | OCR A | 10 marks

A student prepares 250.0 cm^3 of 0.0600 mol dm^{-3} Na_2CO_3 from pure anhydrous solid. M = 106.0 g mol^{-1}.

(a) Calculate the mass needed. (2 marks)

(b) Describe an accurate preparation from the weighed solid to a uniform solution of the required volume. (6 marks)

(c) State what should be done if the solution is warm, or if the calibration mark is overshot. (2 marks)

Acids & neutralisation

Question 36 | OCR A | 8 marks

(a) Write the formulae of hydrochloric acid, nitric acid, ethanoic acid and ammonia. (4 marks)

(b) State the ion characteristic of acids and the ion produced by alkalis in aqueous solution. (2 marks)

(c) Explain, using an equation, how aqueous ammonia produces hydroxide ions. (2 marks)

Question 37 | OCR A | 5 marks

(a) Explain the difference between a strong acid and a weak acid. (2 marks)

(b) Explain why diluting hydrochloric acid does not turn it into a weak acid. (1 mark)

(c) Equal volumes of equally concentrated HCl and CH_3COOH are separately neutralised completely by NaOH. Compare the amounts in moles of NaOH needed and explain your answer. (2 marks)

Question 38 | OCR A | 11 marks

Write balanced full equations, including state symbols, for the following aqueous-acid reactions.

(a) Sulfuric acid with potassium hydroxide solution. (2 marks)

(b) Nitric acid with magnesium oxide. (2 marks)

(c) Ethanoic acid with sodium hydroxide solution. (2 marks)

(d) Hydrochloric acid with calcium carbonate. (2 marks)

(e) Nitric acid with aqueous ammonia. (2 marks)

(f) Write the net ionic equation for H^+ reacting with OH^-. (1 mark)

Titrations & practical skills

Question 39 | OCR A | 9 marks

Describe how to carry out an accurate acid–base titration using a burette and a volumetric pipette. Include preparation of the apparatus, detection of the end point and how reliable results are obtained. (6 marks)

Name a suitable indicator for each titration: strong acid with a strong alkali; ethanoic acid with NaOH; strong acid with aqueous ammonia. (3 marks)

Question 40 | OCR A | 8 marks

A student calculates the concentration of NaOH placed in the conical flask from a titration with 0.1000 mol dm^{-3} HCl in the burette. For each error, state whether the calculated NaOH concentration is too high, too low or unchanged, and explain why.

(a) The burette is rinsed only with water before it is filled with HCl. [2 marks]

(b) The pipette is rinsed only with water before the NaOH aliquot is measured. [2 marks]

(c) The conical flask is rinsed with deionised water immediately before use. [2 marks]

(d) An air bubble in the burette tip is expelled during the titration. [2 marks]

Question 41 | OCR A | 7 marks

A rough titre is 24.30 cm^3. Four accurate titres are 24.05, 24.00, 24.45 and 24.05 cm^3. Use a concordance tolerance of 0.10 cm^3. A 25.00 cm^3 Na_2CO_3 sample is titrated with 0.1000 mol dm^{-3} HCl. $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$. Each burette reading has uncertainty ±0.05 cm^3.

(a) Select the concordant accurate titres. (1 mark)

(b) Calculate the mean titre. (1 mark)

(c) Calculate the carbonate concentration in mol dm^{-3}. (3 marks)

(d) Calculate the percentage uncertainty of a titre at this mean volume. (2 marks)

Question 42 | OCR A | 4 marks

25.00 cm^3 KOH is neutralised by 19.60 cm^3 of 0.1250 mol dm^{-3} HNO_3.

(a) Write the balanced equation. (1 mark)

(b) Calculate the KOH concentration. (3 marks)

Question 43 | OCR A | 4 marks

Citric acid reacts as shown: $C_6H_8O_7 + 3NaOH \rightarrow Na_3C_6H_5O_7 + 3H_2O$. A 25.00 cm^3 sample of citric acid solution requires 24.80 cm^3 of 0.1500 mol dm^{-3} NaOH solution for complete neutralisation. $M(C_6H_8O_7)$ = 192.1 g mol^{-1}. Calculate the acid concentration in mol dm^{-3} and g dm^{-3}. (4 marks)

Question 44 | OCR A | 5 marks

A 1.100 g impure NaOH sample contains an impurity that does not react with sulfuric acid. The sample is made up to 250.0 cm^3. A 25.00 cm^3 aliquot of this solution requires 12.50 cm^3 of 0.1000 mol dm^{-3} H_2SO_4 solution for complete neutralisation. $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$. M(NaOH) = 40.0 g mol^{-1}. Calculate the percentage purity by mass of NaOH in the sample. (5 marks)

Question 45 | OCR A | 5 marks

5.00 cm^3 of stock H_2SO_4 is diluted to 250.0 cm^3. A 25.00 cm^3 aliquot of the diluted sulfuric acid solution requires 22.60 cm^3 of 0.1500 mol dm^{-3} NaOH solution for complete neutralisation. $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$. $M(H_2SO_4) = 98.1$ g mol^{-1}. Calculate the original acid concentration in mol dm^{-3} and g dm^{-3}. (5 marks)

Question 46 | OCR A | 6 marks

A 3.000 g mineral contains $CaCO_3$ and material that does not react with nitric acid. It is treated with 50.00 cm^3 of 1.200 mol dm^{-3} HNO_3. After the reaction, all the excess nitric acid is completely neutralised by 18.50 cm^3 of 0.4000 mol dm^{-3} NaOH solution. $CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$. $M(CaCO_3) = 100.1$ g mol^{-1}. Calculate the percentage by mass of $CaCO_3$. (6 marks)

Gas calculations

Question 47 | OCR A | 5 marks

Use a molar gas volume of 24.0 dm^3 mol^{-1} at RTP.

(a) Calculate the volume of 0.0375 mol gas at RTP, in cm^3. (2 marks)

(b) Calculate the amount in moles of gas in 360 cm^3 at RTP. (2 marks)

(c) For $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$, determine the oxygen volume needed to react with 40.0 cm^3 CO. All volumes are measured at the same temperature and pressure. (1 mark)

Question 48 | OCR A | 5 marks

A 1.250 g limestone sample contains $CaCO_3$ and inert material. It reacts completely with excess hydrochloric acid, releasing 254 cm^3 CO_2 at RTP. Use $M(CaCO_3) = 100.1$ g mol^{-1} and molar gas volume 24.0 dm^3 mol^{-1}. Determine the percentage by mass of $CaCO_3$. (5 marks)

Question 49 | OCR A | 6 marks

A gas occupies 1.25 dm^3 at 96.0 kPa and 20.0 °C. Use R = 8.314 J mol^{-1} K^{-1} and T/K = temperature in °C + 273.

(a) Calculate the amount in moles of gas. (4 marks)

(b) State two conditions under which a real gas is more closely approximated by the ideal-gas model. (2 marks)

Question 50 | OCR A | 8 marks

A 0.823 g sample of gas occupies 420 cm^3 at 98.5 kPa and 315 K. Use R = 8.314 J mol^{-1} K^{-1}.

(a) Calculate the molar mass. (4 marks)

(b) Explain one reason why collecting a gas over water may underestimate the gas volume. (1 mark)

(c) Some gas escapes, while the mass used in the calculation remains unchanged. Explain the effect on the calculated molar mass. (2 marks)

(d) State one apparatus check needed for reliable gas-volume measurement with a gas syringe. (1 mark)

Yield & atom economy

Question 51 | OCR A | 9 marks

$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$. Heating 8.40 g $NaHCO_3$ gives 4.70 g Na_2CO_3. $M(NaHCO_3) = 84.0$ and $M(Na_2CO_3) = 106.0$ g mol^{-1}.

(a) Calculate the theoretical Na_2CO_3 mass. (3 marks)

(b) Calculate the percentage yield. (2 marks)

(c) Give two reasons for a yield below 100%, and one reason for an apparent yield above 100%. (3 marks)

(d) Another experiment gives 4.24 g product at 80.0% yield. Calculate the theoretical mass of product in g. (1 mark)

Question 52 | OCR A | 6 marks

50.0 cm^3 of 0.800 mol dm^{-3} H_2O_2 decomposes: $2H_2O_2 \rightarrow 2H_2O + O_2$. The actual O_2 volume is 435 cm^3 at 102 kPa and 323 K. Use R = 8.314 J mol^{-1} K^{-1}. Calculate the percentage yield. (6 marks)

Question 53 | OCR A | 8 marks

Ethanol can be made by Route 1: $C_2H_4 + H_2O \rightarrow C_2H_5OH$; or Route 2: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$. Use M_r: C_2H_4 28, H_2O 18, C_2H_5OH 46, $C_6H_{12}O_6$ 180.

(a) Calculate the atom economy for ethanol in each route. (4 marks)

(b) Explain whether obtaining only 80% yield changes the atom economy calculated for a route. (2 marks)

(c) Give one sustainability benefit of high atom economy and one other factor that should influence the route chosen. (2 marks)

Answers & marking points

Equivalent correct chemistry and working are acceptable. Use the question number to find the matching answer.

Relative masses & the mole

Question 1 | OCR A | 4 marks

(a) Relative isotopic mass: the mass of an atom of an isotope compared with one-twelfth of the mass of an atom of carbon-12: atom of an isotope [1]; carbon-12 comparison [1].

(b) Relative atomic mass: the weighted mean mass of an atom of an element compared with one-twelfth of the mass of an atom of carbon-12: weighted mean [1]; carbon-12 comparison [1].

Marking note: For A_r, average on its own is not enough. OCR requires weighted mean. Do not attach a unit to either relative mass.

Question 2 | OCR A | 6 marks

Relative molecular/formula mass = sum of the A_r contributions of every atom

(a) $M_r(C_2H_5OH) = (2 \times 12.0) + (6 \times 1.0) + 16.0$ [1] = 46.0 [1].

(b) Relative formula mass of $Mg(NO_3)_2 = 24.3 + (2 \times 14.0) + (6 \times 16.0)$ [2] = 148.3 [1].

(c) Relative masses are comparison values, so they have no unit. [1]

Question 3 | OCR A | 5 marks

(a) Relative formula mass = $40.1 + (2 \times 16.0) + (2 \times 1.0)$ [1] = 74.1 [1].

(b) $M(Ca(OH)_2) = 74.1$ g mol^{-1}. [1]

(c) The numerical value is the same because one mole has a mass in grams equal to the relative formula mass [1]. Relative formula mass is unitless, whereas molar mass is mass per mole in g mol^{-1} [1].

Question 4 | OCR A | 4 marks

(a) Symbol n [1]; unit mol. [1]

(b) The mole is the unit for amount of substance. [1] The Avogadro constant is the number of specified entities per mole and has unit mol^{-1}. [1] Its exact value is $6.02214076 \times 10^{23}$ mol^{-1}; the OCR A calculation value, 6.02×10^{23} mol^{-1}, is rounded. The exact numerical value is not required for these questions.

Mass, moles & particles

Question 5 | OCR A | 6 marks

(a) Fe: atoms [1]; O_2: molecules [1]; NaCl: formula units. [1]

(b) Moles of oxygen atoms = moles of O_2 × oxygen atoms per molecule
n(O atoms) = $2 \times 0.120 = 0.240$ mol. [1]

(c) Moles of chloride ions = moles of $MgCl_2$ × chloride ions per formula unit
$n(Cl^-) = 2 \times 0.0800 = 0.160$ mol [1]; Total moles of ions = moles of $MgCl_2$ × total ions per formula unit
n(all ions) = $(1 + 2) \times 0.0800 = 0.240$ mol. [1]

Question 6 | OCR A | 6 marks

(a) n = m/M
n = 7.30/36.5 [1] = 0.200 mol. [1]

(b) m = n × M
m = 0.0750 × 106 [1] = 7.95 g. [1]

(c) m = density × volume = 0.800 × 15.0 = 12.0 g. [1] n = m/M
n = 12.0/60.0 = 0.200 mol. [1]

Question 7 | OCR A | 4 marks

(a) $N = nN_A = 0.0350 \times 6.02 \times 10^{23}$ [1] = 2.11×10^{22} $MgCl_2$ formula units [1].

(b) $n(Ne) = N/N_A = (9.03 \times 10^{22})/(6.02 \times 10^{23})$ [1] = 0.150 mol Ne [1].

Question 8 | OCR A | 5 marks

(a) $N = nN_A$
$N = 0.240 \times 6.02 \times 10^{23}$ [1] = 1.44×10^{23} molecules. [1]

(b) One O atom per molecule, so 1.44×10^{23} oxygen atoms. [1]

(c) Each molecule contains 2 + 6 + 1 = 9 atoms. [1] Total number of atoms = number of C_2H_5OH molecules × total atoms per molecule
N(all atoms) = $9 \times 1.4448 \times 10^{23} = 1.30 \times 10^{24}$ atoms. [1]

Question 9 | OCR A | 5 marks

(a) Moles of sulfate ions = moles of $Al_2(SO_4)_3$ × sulfate ions per formula unit
$n(SO_4^{2-}) = 3 \times 0.0200 = 0.0600$ mol [1]; N = 3.61×10^{22} ions. [1]

(b) Total moles of ions = moles of $Al_2(SO_4)_3$ × total ions per formula unit
n(all ions) = (2 + 3) × 0.0200 = 0.100 mol [1]; N = 6.02×10^{22} ions. [1]

(c) SO_4^{2-} is one polyatomic ion with one overall charge; its constituent atoms are not five separate ions. [1]

Question 10 | OCR A | 4 marks

(a) 13 − 3 = 10 electrons. [1]

(b) n(electrons) = electrons per ion × n(ions)
n(electrons) = 10 × 0.0150 = 0.150 mol. [1]

(c) $N(electrons) = nN_A$
N(electrons) = $0.150 \times 6.02 \times 10^{23}$ [1] = 9.03×10^{22} electrons. [1]

Question 11 | OCR A | 3 marks

n(salt) = m/M
n(salt) = 3.42/342 = 0.0100 mol. [1] Moles of sulfate ions = moles of $Al_2(SO_4)_3$ × sulfate ions per formula unit
$n(SO_4^{2-}) = 3 \times 0.0100 = 0.0300$ mol. [1] $N = nN_A$
N = $0.0300 \times 6.02 \times 10^{23} = 1.81 \times 10^{22}$ sulfate ions, to 3 significant figures. [1]

Question 12 | OCR A | 5 marks

NaCl: n = m/M
n = 5.00/58.5 = 0.0854701... mol, so n(Cl^-) = 0.0854701... mol. [1] N(Cl^-) = 5.15×10^{22} ions. [1]

$MgCl_2$: n = m/M
n = 5.00/95.3 = 0.0524659... mol, so Moles of chloride ions = moles of $MgCl_2$ × chloride ions per formula unit
n(Cl^-) = 2 × 0.0524659... = 0.104932... mol. [1] N(Cl^-) = 6.32×10^{22} ions. [1] The $MgCl_2$ sample represents more chloride ions. [1]

Question 13 | OCR A | 4 marks

(a) n(CO_2) = N/N_A = $(3.01 \times 10^{22})/(6.02 \times 10^{23})$ = 0.0500 mol. [2]

(b) m = nM = 0.0500 × 44.0 = 2.20 g CO_2. [2]

Question 14 | OCR A | 4 marks

(a) n(X) = $(6.02 \times 10^{22})/(6.02 \times 10^{23})$ = 0.100 mol. [2]

(b) M(X) = m/n = 4.40/0.100 = 44.0 g mol^{-1}. [2]

Question 15 | OCR A | 8 marks

(a) n(O atoms) = $(1.806 \times 10^{23})/(6.02 \times 10^{23})$ = 0.300 mol. [2]

(b) Moles of X_2O_3 = moles of oxygen atoms ÷ oxygen atoms per formula unit
n(X_2O_3) = 0.300/3 = 0.100 mol. [1]

(c) M = m/n
M = 15.96/0.100 = 159.6 g mol^{-1}. [2] Retain the calculator value for identification. A final value of 160 g mol^{-1} to three significant figures is also appropriate.

(d) $2A_r(X) + 3(16.0) = 159.6$ [1]; $A_r(X) = 55.8$ [1]; X is Fe. [1]

Question 16 | OCR A | 6 marks

(a) Multiply by N_A when converting moles to particle number. [1] n = m/M
n = 2.50/44.0 = 0.05681818... mol [1]; $N = nN_A$
N = 0.05681818... × 6.02×10^{23} = 3.42×10^{22} molecules. [1]

(b) Keeping the calculator value avoids an extra rounding error in subsequent operations. [1] Give the final answer to 3 significant figures, matching the supplied data. [1]

(c) 3.045×10^{-4} mol. [1]

Equations & reacting masses

Question 17 | OCR A | 5 marks

(a) $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$: coefficients [1]; states [1].

(b) $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$: coefficients [1]; states [1].

(c) Changing a subscript changes a substance's chemical formula and identity. [1]

Question 18 | OCR A | 8 marks

(a) $Ba(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow BaCO_3(s) + 2NaNO_3(aq)$: formulae and coefficients [1]; states [1].

(b) $Ba^{2+}(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s)$: reacting species and balance [1]; states [1].

(c) Sodium ions and nitrate ions. [1] Both remain unchanged in solution.

(d) $Zn(OH)_2$ [1]; Ag_2SO_4 [1]; NH_4NO_3. [1]

Question 19 | OCR A | 4 marks

(a)

$n(Al) : n(Cl_2) : n(AlCl_3) = 2 : 3 : 2$ [1]

(b)

$n(AlCl_3)$ = n(known substance) × coefficient(target)/coefficient(known substance)
$n(AlCl_3) = 0.240 \times 2 \div 3$ [1]

$n(AlCl_3) = 0.160$ mol [1]

(c)

Coefficients compare amounts in moles; particle masses differ, so they are not a mass ratio [1]

Question 20 | OCR A | 3 marks

$n(Fe) = m/M$
$n(Fe) = 8.37/55.8 = 0.150$ mol. [1] $n(Fe_2O_3)$ = n(known substance) × coefficient(target)/coefficient(known substance)
$n(Fe_2O_3) = 0.150 \times 2/4 = 0.0750$ mol. [1] $m = n \times M$
$m = 0.0750 \times 159.6 = 11.97$ g, or 12.0 g to 3 significant figures. [1]

Question 21 | OCR A | 3 marks

$n(Na_2CO_3) = m/M$
$n(Na_2CO_3) = 3.18/106.0 = 0.0300$ mol. [1] $n(NaHCO_3)$ = n(known substance) × coefficient(target)/coefficient(known substance)
$n(NaHCO_3) = 2 \times 0.0300 = 0.0600$ mol. [1] $m = n \times M$
$m = 0.0600 \times 84.0 = 5.04$ g. [1]

Limiting reactants

Question 22 | OCR A | 3 marks

Quantity	Na	Cl_2
Mass / g	4.60	5.68
M / g mol⁻¹	23.0	71.0
Amount, n / mol	n = m/M 4.60/23.0 = 0.200	n = m/M 5.68/71.0 = 0.0800
Coefficient	2	1
n ÷ coefficient / mol	0.200/2 = 0.100	0.0800/1 = **0.0800 (smaller)**

Both mole amounts correct. [1] Both n ÷ coefficient values correct. [1] **Chlorine is limiting** because its comparison value is smaller. [1]

Question 23 | OCR A | 4 marks

$n(Fe_2O_3)$ = m/M
$n(Fe_2O_3)$ = 7.98/159.6 = 0.0500 mol; n(CO) = m/M
n(CO) = 4.20/28.0 = 0.150 mol. [1] The two n/coefficient values are both 0.0500 mol, so both reactants are used completely; neither is in excess. [1] n(Fe) = n(known substance) × coefficient(target)/coefficient(known substance)
n(Fe) = 2 × 0.0500 = 0.100 mol [1]; m(Fe) = n × M
m(Fe) = 0.100 × 55.8 = 5.58 g. [1]

Question 24 | OCR A | 6 marks

Quantity	Fe	Cl_2	$FeCl_3$
Mass / g	8.37	14.20	m = n × M 0.133333... × 162.3 = 21.64 = **21.6** [1]
M / g mol⁻¹	55.8	71.0	162.3
Amount, n / mol	n = m/M 8.37/55.8 = 0.150	n = m/M 14.20/71.0 = 0.2000	0.066666... × 2 = 0.133333... [1]
Coefficient	2	3	2
n ÷ coefficient / mol	0.150/2 = 0.0750	0.2000/3 = **0.066666... (smaller)**	Product: not compared

Both starting mole amounts correct. [1] Chlorine is limiting because its n ÷ coefficient is smaller. [1]

Fe used = 0.066666... × 2 = 0.133333... mol. Mass used = n × M = 0.133333... × 55.8 = 7.44 g. [1] Mass remaining = 8.37 − 7.44 = **0.930 g**. [1]

Empirical & molecular formulae

Question 25 | OCR A | 4 marks

Quantity	Mg	Cl
Mass / g	0.486	1.420
M / g mol^{-1}	24.3	35.5
Amount / mol	n = m/M n(Mg) = 0.486/24.3 = 0.0200 [1]	n = m/M n(Cl atoms) = 1.420/35.5 = 0.0400 [1]
÷ smallest	0.0200/0.0200 = 1	0.0400/0.0200 = 2

The simplest whole-number ratio Mg : Cl is 1 : 2. [1] Empirical formula: $MgCl_2$. [1] No further scaling is needed.

Question 26 | OCR A | 6 marks

Mass of oxygen = mass of oxide − mass of iron
m(O) = 2.314 − 1.674 = 0.640 g. [1]

Quantity	Fe	O
Mass / g	1.674	0.640
M / g mol^{-1}	55.8	16.0
Amount / mol	n = m/M n(Fe) = 1.674/55.8 = 0.0300 [1]	n = m/M n(O atoms) = 0.640/16.0 = 0.0400 [1]
÷ smallest	0.0300/0.0300 = 1	0.0400/0.0300 = 1.333...
Multiply both by 3	1 × 3 = 3	1.333... × 3 = 4

Divide both amounts in moles by 0.0300 to obtain 1 : 1.333... [1] Multiply the complete ratio by 3 to obtain 3 : 4. [1] Empirical formula: Fe_3O_4. [1] Keep the unrounded ratio when choosing the multiplier.

Question 27 | OCR A | 6 marks

(a) For 100 g, amounts are C: 55.8/12.0 = 4.65; H: 7.0/1.0 = 7.0; O: 37.2/16.0 = 2.325 mol. [1] Dividing by 2.325 gives approximately 2 : 3 : 1, so the empirical formula is C_2H_3O. [1] Its formula mass is 43.0 [1]; 86.0/43.0 = 2 [1]; molecular formula $C_4H_6O_2$. [1]

(b) C_2H_4O, because the multiplier is 44.0/44.0 = 1. [1]

Question 28 | OCR A | 8 marks

(a) n(C) = m(CO_2)/M(CO_2)
n(C) = 0.880/44.0 = 0.0200 mol. [1] n(H) = 2m(H_2O)/M(H_2O)
n(H) = 2 × 0.360/18.0 = 0.0400 mol. [1] Masses of C and H are 0.240 and 0.0400 g, giving sample oxygen mass 0.440 − 0.240 − 0.0400 = 0.160 g. [1] n(O) = m/M
n(O) = 0.160/16.0 = 0.0100 mol. [1] Ratio 2 : 4 : 1 gives C_2H_4O. [1] Empirical-formula mass = 44.0, so the multiplier is 88.0/44.0 = 2. [1] Molecular formula $C_4H_8O_2$. [1]

(b) Some of that oxygen came from the oxygen supply used to burn the sample. [1]

Hydrated salts

Question 29 | OCR A | 5 marks

(a)

An anhydrous salt contains no water of crystallisation [1]

(b)

Water molecules incorporated into a crystal structure [1]

They occur in a fixed ratio to the salt [1]

(c)

The dot separates $MgSO_4$ from its water of crystallisation [1]

There are seven H_2O molecules per $MgSO_4$ formula unit [1]

Question 30 | OCR A | 4 marks

In 100 g, water mass = 45.4 g and anhydrous salt mass = 54.6 g. [1] n(water) = m/M
n(water) = 45.4/18.0 = 2.52222... mol; n(salt) = m/M
n(salt) = 54.6/129.9 = 0.420323... mol. [1] x = 2.52222.../0.420323... = 6.00067... ≈ 6. [1] $CoCl_2 \cdot 6H_2O$. [1]

Question 31 | OCR A | 10 marks

(a) Use 26.369 g, because two successive readings agree. [1] Anhydrous salt mass = 26.369 − 24.850 = 1.519 g. [1] Water mass = 27.629 − 26.369 = 1.260 g. [1] n(salt) = m/M
n(salt) = 1.519/151.9 = 0.0100 mol. [1] n(water) = m/M
n(water) = 1.260/18.0 = 0.0700 mol. [1] x = 7 [1]; $FeSO_4 \cdot 7H_2O$. [1] Repeated heat–cool–weigh cycles check whether further measurable mass is lost, supporting complete dehydration under the stated water-only assumption. [1]

(b) Gentle initial heating reduces spitting and loss of solid. [1] Cooling avoids convection/buoyancy effects from a hot object giving an unreliable balance reading. [1]

Question 32 | OCR A | 7 marks

(a) x is too low [1]: water loss is underestimated and the mass treated as anhydrous salt is too large. [1]

(b) x is too high [1]: apparent water loss is too large and salt remaining is underestimated. [1]

(c) x is too low [1]: reabsorbed water makes the recorded residue too heavy and the apparent water loss too small. [1]

(d) A constant reading shows no further measurable mass change under the conditions; it does not establish the chemical identity of the residue. [1]

Concentration & dilution

Question 33 | OCR A | 7 marks

(a) V = 0.2500 dm^3 [1]; c = n/V
c = 0.0850/0.2500 = 0.340 mol dm^{-3}. [1]

(b) Mass concentration = cM = 0.340 × 106.0 [1] = 36.0 g dm^{-3}. [1]

(c) V = n/c = 0.0170/0.340 = 0.0500 dm^3 [1] = 50.0 cm^3. [1]

(d) The required volume is the final solution volume, not the volume of solvent added. [1]

Question 34 | OCR A | 6 marks

(a) The solute amount is unchanged: $c_2 = c_1V_1/V_2$
c_2 = (0.8000 × 25.00)/250.0 [1] = 0.08000 mol dm^{-3}. [1]

(b) $V_1 = c_2V_2/c_1$
V_1 = (0.0400 × 100.0)/0.500 [1] = 8.00 cm^3. [1]

(c) A 25.00 cm^3 volumetric pipette [1] and a 250.0 cm^3 volumetric flask. [1]

Question 35 | OCR A | 10 marks

(a) n = cV
n = 0.0600 × 0.2500 = 0.0150 mol [1]; m = n × M
m = 0.0150 × 106.0 = 1.59 g. [1]

(b) Dissolve the weighed solid fully in deionised water in a beaker. [1] Transfer to the correct volumetric flask. [1] Rinse the beaker, rod and funnel into the flask. [1] Add water near the mark, then dropwise. [1] Read the bottom of the meniscus at eye level on the mark. [1] Stopper and invert repeatedly to mix. [1]

(c) Let a warm solution cool to room temperature before making up to the mark. [1] If the mark is overshot, prepare a fresh solution; removing mixed solution does not restore its concentration. [1]

Acids & neutralisation

Question 36 | OCR A | 8 marks

(a) HCl [1], HNO_3 [1], CH_3COOH [1], NH_3. [1]

(b) Acids: $H^+(aq)$ [1]; alkalis: $OH^-(aq)$. [1]

(c) $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$. [1] Ammonia accepts H^+ from water, leaving OH^-. [1]

Question 37 | OCR A | 5 marks

(a) A strong acid dissociates essentially completely in water [1]; a weak acid dissociates only partially. [1]

(b) Dilution reduces amount per unit volume, while strength describes extent of dissociation. [1]

(c) The same amount of NaOH is needed. [1] Equal volume and concentration give equal total acid amounts, and both acids are monoprotic, so each mole neutralises one mole of OH^-. [1]

Question 38 | OCR A | 11 marks

(a) $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$. [2]

(b) $2HNO_3(aq) + MgO(s) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$. [2]

(c) $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$. [2]

(d) $2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$. [2]

(e) $HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$. [2]

For (a)–(e), award one mark for correct formulae/products and one for balancing and states. (f) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$. [1]

Titrations & practical skills

Question 39 | OCR A | 9 marks

Rinse the burette and pipette with deionised water, then each with its own solution. [1] Fill the burette tip without an air bubble and remove the filling funnel. [1] Use a pipette filler to deliver the aliquot into a conical flask, allowing the pipette to drain without blowing out the retained drop. [1] Add a few drops of suitable indicator, using a white tile to see the change. [1] Perform a rough titration, then use fresh aliquots and add dropwise near the end point while swirling. [1] Read the meniscus at eye level; calculate titres from final minus initial readings and repeat for concordant titres (within 0.1 cm^3 of each other). [1]

Strong acid/strong alkali: methyl orange or phenolphthalein. [1] Ethanoic acid/NaOH: phenolphthalein. [1] Strong acid/ammonia: methyl orange. [1] Equivalent correct operational detail is acceptable; do not require an exact prose script.

Question 40 | OCR A | 8 marks

(a)

Calculated concentration is too high [1]

Residual water dilutes the HCl, so a larger recorded titre is required but the nominal 0.1000 mol dm^{-3} is still used [1]

(b)

Calculated concentration is too low [1]

Residual water dilutes the NaOH aliquot, so fewer moles enter the flask and a smaller titre is used [1]

(c)

Calculated concentration is unchanged [1]

Water changes the concentration in the flask but not the amount of NaOH delivered by the pipette [1]

(d)

Calculated concentration is too high [1]

Some recorded burette volume fills the tip instead of entering the flask, so the recorded titre is too large [1]

Question 41 | OCR A | 7 marks

(a) Use 24.05, 24.00 and 24.05 cm^3; exclude the rough and 24.45 cm^3. [1]

(b) Mean = (24.05 + 24.00 + 24.05)/3 = 24.03333... cm^3, recorded as 24.03 cm^3. [1]

(c) Use the unrounded mean titre in the calculation. Na_2CO_3 : HCl = 1 : 2.

Quantity	Na_2CO_3	HCl
Concentration, c / mol dm^{-3}	c = n/V 0.001201667.../0.02500 = **0.04807** [1]	0.1000
Volume, V / dm^3	25.00/1000 = 0.02500	24.03333.../1000 = 0.02403333...
Amount, n / mol	0.002403333.../2 = 0.001201667... [1]	n = cV 0.1000 × 0.02403333... = 0.002403333... [1]
Coefficient (mole ratio)	1	2

Using the recorded 24.03 cm^3 mean gives 0.04806 mol dm^{-3} and is accepted at this precision.

(d) Absolute titre uncertainty = 0.05 + 0.05 = 0.10 cm^3. [1] Percentage = (0.10/24.03333...) × 100 = 0.4161...%, or 0.42%. [1] This uses the specified two-reading convention and does not divide the apparatus uncertainty by the number of repeats.

Question 42 | OCR A | 4 marks

(a) $HNO_3 + KOH \rightarrow KNO_3 + H_2O$. [1]

Quantity	HNO_3	KOH
Concentration, c / mol dm^{-3}	0.1250	c = n/V 0.002450/0.02500 = **0.09800** [1]
Volume, V / dm^3	19.60/1000 = 0.01960	25.00/1000 = 0.02500
Amount, n / mol	(b) n = cV 0.1250 × 0.01960 = 0.002450 [1]	0.002450 (1 : 1 ratio) [1]
Coefficient (mole ratio)	1	1

Question 43 | OCR A | 4 marks

One mole of citric acid reacts with three moles of NaOH.

Quantity	Citric acid	NaOH
Concentration, c / mol dm^{-3}	c = n/V 0.001240/0.02500 = **0.04960** [1]	0.1500
Volume, V / dm^3	25.00/1000 = 0.02500	24.80/1000 = 0.02480
Amount, n / mol	0.003720/3 = 0.001240 [1]	n = cV 0.1500 × 0.02480 = 0.003720 [1]
Coefficient (mole ratio)	1	3

Mass concentration = c × M = 0.04960 × 192.1 = **9.528 g dm^{-3}**. [1]

Question 44 | OCR A | 5 marks

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$.

Quantity	H_2SO_4	NaOH aliquot
Concentration, c / mol dm^{-3}	0.1000	Not needed for purity
Volume, V / dm^3	12.50/1000 = 0.01250	25.00/1000 = 0.02500
Amount, n / mol	n = cV 0.1000 × 0.01250 = 0.001250 [1]	0.001250 × 2 = 0.002500 [1]
Coefficient (mole ratio)	1	2

Moles in full flask = moles in aliquot × flask volume/aliquot volume = 0.002500 × 250.0/25.00 = 0.02500 mol. [1]

Pure mass = n × M = 0.02500 × 40.0 = 1.00 g. [1] Percentage purity = pure mass/sample mass × 100 = 1.00/1.100 × 100 = **90.9%** (3 significant figures). [1]

Question 45 | OCR A | 5 marks

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$.

Quantity	H_2SO_4 (diluted)	NaOH
Concentration, c / mol dm^{-3}	c = n/V 0.001695/0.02500 = 0.06780 [1]	0.1500
Volume, V / dm^3	25.00/1000 = 0.02500	22.60/1000 = 0.02260
Amount, n / mol	0.003390/2 = 0.001695 [1]	n = cV 0.1500 × 0.02260 = 0.003390 [1]
Coefficient (mole ratio)	1	2

Original concentration = diluted concentration × final dilution volume/original sample volume = 0.06780 × 250.0/5.00 = **3.39 mol dm^{-3}**. [1]

Mass concentration = c × M = 3.39 × 98.1 = **333 g dm^{-3}** (3 significant figures). [1]

Question 46 | OCR A | 6 marks

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$: the back titration has a 1 : 1 ratio.

Quantity	HNO_3 added	NaOH titre	HNO_3 left
Concentration, c / mol dm^{-3}	1.200	0.4000	Not needed
Volume, V / dm^3	50.00/1000 = 0.05000	18.50/1000 = 0.01850	Not needed
Amount, n / mol	n = cV 1.200 × 0.05000 = 0.06000 [1]	n = cV 0.4000 × 0.01850 = 0.007400	Same moles as NaOH 0.007400 [1]
Coefficient (mole ratio)	Not compared	1	1

Moles of HNO_3 consumed = initial − remaining = 0.06000 − 0.007400 = 0.05260 mol. [1] $CaCO_3 : HNO_3 = 1 : 2$, so moles of $CaCO_3$ = 0.05260/2 = 0.02630 mol. [1]

Pure mass = n × M = 0.02630 × 100.1 = 2.63263 g. [1] Percentage purity = pure mass/sample mass × 100 = 2.63263/3.000 × 100 = **87.75%** (4 significant figures). [1]

Gas calculations

Question 47 | OCR A | 5 marks

(a) $V = nV_m$
$V = 0.0375 \times 24.0 = 0.900\ dm^3$ [1] $= 9.00 \times 10^2\ cm^3$. [1]

(b) $n = V(cm^3)/(1000V_m)$
n = 360/24000 [1] = 0.0150 mol. [1]

(c) $2CO + O_2 \rightarrow 2CO_2$. At the same temperature and pressure, volume follows the coefficient ratio.

Quantity	CO	O_2 required
Coefficient	2	1
Volume ÷ coefficient / cm^3	40.0/2 = 20.0	Same ratio value: 20.0
Volume / cm^3	40.0	20.0 × 1 = **20.0** [1]

Question 48 | OCR A | 5 marks

Percentage purity = (mass of pure substance ÷ mass of sample) × 100
$n(CO_2) = V(cm^3)/(1000V_m)$
$n(CO_2) = 254/24000 = 0.0105833...$ mol. [1] $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$ gives a 1:1 ratio, so $n(CaCO_3) = 0.0105833...$ mol. [1] Pure $CaCO_3$ mass = 0.0105833... × 100.1 = 1.05939... g. [1] Purity = (1.05939.../1.250) × 100 [1] = 84.8% to 3 significant figures. [1]

Question 49 | OCR A | 6 marks

(a) p = 96000 Pa; $V = 1.25 \times 10^{-3}\ m^3$; T = 293 K. [1] n = pV/(RT) [1] = $(96000 \times 1.25 \times 10^{-3})/(8.314 \times 293)$ [1] = 0.0493 mol to 3 significant figures. [1]

(b) Low pressure [1] and high temperature, well above condensation. [1]

Question 50 | OCR A | 8 marks

(a) p = 98500 Pa and V = 420 × 10^{-6} m^3. [1] n = pV/(RT) = 0.0157966... mol. [1] M = m/n
M = 0.823/0.0157966... [1] = 52.1 g mol^{-1} to 3 significant figures. [1]

(b) Some of the gas may dissolve in or react with the water. [1]

(c) Measured volume, and hence calculated n, is too low. [1] M = m/n is therefore too high for the unchanged mass. [1]

(d) Check gas-tight connections, or that the syringe plunger moves freely, or begin collection promptly without losing gas. [1]

Yield & atom economy

Question 51 | OCR A | 9 marks

(a) n($NaHCO_3$) = m/M
n($NaHCO_3$) = 8.40/84.0 = 0.100 mol. [1] n(Na_2CO_3) = 0.0500 mol. [1] Theoretical mass = 0.0500 × 106.0 = 5.30 g. [1]

Percentage yield = (actual yield ÷ theoretical yield) × 100
(b) Yield = (4.70/5.30) × 100 [1] = 88.7%. [1]

(c) Any two: incomplete reaction; competing reactions; loss in transfer, separation or purification. [2] Apparent yield above 100%: wet or impure product makes its measured mass too high. [1]

Theoretical yield = actual yield/(percentage yield/100)
(d) Theoretical yield = 4.24/(80.0/100) = 5.30 g. [1]

Question 52 | OCR A | 6 marks

Percentage yield = (actual yield ÷ theoretical yield) × 100
n(H_2O_2) = cV
n(H_2O_2) = 0.800 × 0.0500 = 0.0400 mol. [1] Theoretical n(O_2) = n(known substance) × coefficient(target)/coefficient(known substance)
n(O_2) = 0.0400/2 = 0.0200 mol. [1] p = 102000 Pa and V = 435 × 10^{-6} m^3. [1] Actual n = pV/(RT) [1] = 0.0165225... mol. [1] Yield = (0.0165225.../0.0200) × 100 = 82.6%. [1]

Question 53 | OCR A | 8 marks

(a) Route 1: 46/(28 + 18) × 100 [1] = 100%. [1] Route 2: (2 × 46)/180 × 100 [1] = 51.1%. [1]

(b) It does not change atom economy. [1] Atom economy is fixed by the balanced equation; percentage yield compares actual with theoretical recovery of the desired product. [1]

(c) High atom economy can reduce by-product waste or raw-material use. [1] Other valid factor: energy use, hazards, feedstock supply/renewability, rate, yield, purification or recycling. [1] Do not include a solvent, catalyst or arbitrary excess mass in the equation-based atom-economy calculation.