GCSE AQA Chemistry: Topic 3

AQA Chemistry Topic 3: Quantitative Chemistry

Mark Scheme

Q1. Relative atomic mass

(a) Define Ar:

- The weighted average mass of one atom of an element compared with 1/12 the mass of a carbon-12 atom (1)
- Unitless / no units (1)

(b) Ar of oxygen = **16** (1)
Total: 3 marks

Q2. Sodium

(a) Ar = 23 means:

- Average mass of one atom of sodium relative to 1/12 the mass of carbon-12 (1)
- Number is relative, not in grams (1)

(b) Number of protons in sodium = **11** (1)
Total: 3 marks

Q3. Carbon dioxide

(a) Formula: **CO_2** (1)

(b) Relative formula mass (Mr) = 12 + (16 × 2) = 44 (1)
Total: 3 marks

Q4. Calculating Mr

(a) H_2O: 1 × 2 + 16 = **18** (1)

(b) NaOH: 23 + 16 + 1 = **40** (1)
Total: 2 marks

Q5. Conservation of mass

(a) Law: Mass is neither created nor destroyed in a chemical reaction (1)

- Total mass of reactants = total mass of products (1)

(b) Mass CO_2 = 12 + 32 = **44 g** (1)
Total: 3 marks

Q6. Apparent mass changes

(a) Mass increases: magnesium reacts with oxygen from air → mass of product (magnesium oxide) includes oxygen (1)

(b) Mass decreases: gas (e.g., CO_2 from heating metal carbonate) escapes → less mass remains (1)
Total: 4 marks

Q7. Moles

(a) Number of moles = mass ÷ Mr (1)

(b) Moles NaOH = 20 ÷ 40 = **0.5 mol** (1)
Total: 3 marks

Q8. Balanced equations

(a) Big number in front = **mole ratio of substances** (1)

(b) Balanced: $2H_2 + O_2 \rightarrow 2H_2O$ (1)
Total: 2 marks

Q9. Moles and Avogadro

(a) One mole contains **6.02×10^{23} particles** (atoms/molecules/ions) (1)

(b) Atoms in one mole of carbon = 6.02×10^{23} (1)
Total: 2 marks

Q10. Reacting masses

(a) Balanced: $2H_2 + O_2 \rightarrow 2H_2O$ (1)

(b) Mass of water:

- 2 mol H_2 → 18 g H_2O
- 4 g H_2 → 4 × 18 ÷ 4 = **36 g**? Wait carefully.

Step-by-step:

- Moles H_2: 4 ÷ 2 = 2 mol H_2 (check: H = 1, so H_2 = 2 g/mol → 4 g ÷ 2 g/mol = 2 mol H_2) ✅
- Mole ratio H_2 : H_2O = 2 : 2 → 2 mol H_2 produces 2 mol H_2O
- Mass H_2O = 2 mol × 18 g/mol = **36 g** ✅

Total: 3 marks

Q11. Limiting reactants

(a) Limiting reactant = substance completely used up first in a reaction (1)

(b) Important because it **determines how much product is made** (1)
Total: 4 marks

Q12. Concentration

(a) Concentration = mass ÷ volume (g/dm³) (1)

(b) Concentration = 10 ÷ 0.2 = **50 g/dm³** (1)
Total: 3 marks

Q13. Percentage yield

(a) % yield = (actual ÷ theoretical) × 100 (1)

(b) % yield = 15 ÷ 20 × 100 = **75%** (1)
Total: 4 marks

Q14. Atom economy

(a) Atom economy = (Mr of desired product ÷ Mr of all products) × 100 (1)

(b) High atom economy → **less waste, more sustainable, cost effective** (1)
Total: 3 marks

Q15. Balanced equations

(a) Importance:

- To obey the law of conservation of mass (1)
- To ensure correct stoichiometric ratios for reacting substances (1)

(b) Balanced: $4Al + 3O_2 \rightarrow 2Al_2O_3$ (1)
Total: 3 marks

Q17. Relative formula masses

(a) $Ca(OH)_2$:

- Mr = 40 + (16 + 1) × 2 = 40 + 34 = **74** (2)

(b) Al_2O_3:

- Mr = (27 × 2) + (16 × 3) = 54 + 48 = **102** (2)
  Total: 4 marks

Q18. Number of moles

(a) Moles = mass ÷ Mr (1)

(b) Moles CO_2 = 11 ÷ 44 = **0.25 mol** (2)
Total: 3 marks

Q19. Magnesium oxide

(a) Balanced: $2Mg + O_2 \rightarrow 2MgO$

- Mr Mg = 24, Mr O = 16 → MgO = 24 + 16 = 40 g/mol
- Moles Mg = 12 ÷ 24 = 0.5 mol
- Moles MgO = 0.5 mol → mass MgO = 0.5 × 40 = **20 g** (3)

(b) Mass increases because **oxygen from air combines with magnesium to form MgO** (2)
Total: 5 marks

Q20. Calcium carbonate decomposition

(a) Mass decreases: **CO_2 gas escapes** (1)

- Only solid CaO remains (1)

(b) Mass CaO = 50 × (56 ÷ 100) = 28 g (3)
Total: 5 marks

Q21. Balanced equations

(a) $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$ (1)

(b) Equations must be balanced to **obey the law of conservation of mass** and **show correct mole ratios** (2)
Total: 3 marks

Q22. Limiting reactants

(a) Limiting reactant: **substance completely used up first in a reaction** (1)

(b) Important because it **determines the maximum amount of product formed** (1)
Total: 4 marks

Q23. Titration

(a) HCl + NaOH → NaCl + H_2O (balanced 1:1) (2)

(b) Apparatus: **burette** (1)
Total: 3 marks

Q24. Concentration

(a) Concentration = moles ÷ volume (in dm^3) (1)

(b) Moles = 0.5 mol, volume = 250 cm^3 = 0.25 dm^3 → concentration = 0.5 ÷ 0.25 = **2 mol/dm^3** (2)
Total: 3 marks

Q25. Potassium hydroxide solution

(a) Moles KOH = 28 ÷ 56 = 0.5 mol, Volume = 500 cm^3 = 0.5 dm^3 → Concentration = 0.5 ÷ 0.5 = **1 mol/dm^3** (3)

(b) Safety precaution: **Wear gloves and eye protection** (1)
Total: 4 marks

Q26. Percentage yield

(a) % yield = (actual ÷ theoretical) × 100 (2)

(b) % yield = 48 ÷ 60 × 100 = **80%** (2)
Total: 4 marks

Q27. Atom economy

(a) Atom economy = (Mr desired ÷ Mr all products) × 100 (1)

(b) Atom economy = 40 ÷ 100 × 100 = **40%** (2)

(c) High atom economy → **less waste, more sustainable, cost effective** (2)
Total: 5 marks

Q28. Moles from concentration

(a) Volume = 25 cm^3 = 0.025 dm^3
Moles HCl = 2.0 × 0.025 = **0.05 mol** (2)

(b) Conversion: 25 cm^3 ÷ 1000 = **0.025 dm^3** (1)
Total: 3 marks

Q29. Titration with indicator

(a) Balanced: $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ (2)

(b) Indicator shows **end-point of neutralisation** (2)
Total: 4 marks

Q30. Gas volumes

(a) 1 mole of gas = **24 dm^3 at rtp** (1)

(b) Volume = 0.25 × 24 = **6 dm^3** (2)
Total: 3 marks

Q31. Electrolysis of water

(a) $2H_2O \rightarrow 2H_2 + O_2$

- $H_2 : O_2 = 2 : 1 \rightarrow V\ O_2 = 120 \div 2 =$ **60 cm^3** (3)

(b) Volume ratio is halved because **oxygen produced is half the volume of hydrogen** (2)
Total: 5 marks

Q32. Haber process

(a) 1 mol N_2 produces 2 mol NH_3 (1)

(b) Mass NH_3 = 2 mol × (14×1 + 1×3) = 2 × 17 = **34 g**
Check: Mass N_2 = 28 g → 2 mol H_2? Wait: 1 mol N_2 → 2 mol NH_3 = 2 × 17 = 34 g ✅ (3)
Total: 4 marks

Q33. Solution moles

(a) Moles = 0.2 × 0.5 = **0.1 mol** (3)

(b) Convert 500 cm³ → 0.5 dm³ (1)
Total: 4 marks

Q34. Poor yields

(a) Reasons: **side reactions**, **incomplete reactions** (2)

(b) Improving yield → **more product, less waste, cost effective** (2)
Total: 4 marks

Q35. Industrial processes

(a) Both % yield and atom economy important → **efficiency, cost, sustainability** (4)

(b) Low atom economy may be used if **process is faster, cheaper, or product in demand** (2)
Total: 6 marks

Q36. Measuring hydrogen gas

Planning an experiment (6 marks):

- **Apparatus**: Conical flask, delivery tube, gas syringe, balance, clamp stand (1)
- **Method**: React magnesium ribbon with excess HCl in conical flask, connect flask to gas syringe to collect gas (2)
- **Measurements**: Measure volume of gas in gas syringe at set intervals; ensure no gas escapes; repeat for accuracy (3)

Total: 6 marks

Q36. Magnesium and hydrochloric acid

(a) Mg reacts with HCl because:

- Magnesium **displaces hydrogen from the acid** (metal + acid → salt + hydrogen)
- Produces **magnesium chloride and H_2 gas** (3)

(b) Moles H_2 = 1.12 ÷ 24 = 0.0467 mol
Moles Mg = moles H_2 = 0.0467 mol
Mass Mg = 0.0467 × 24 = **1.12 g** (3)
Total: 6 marks

Q37. Calcium carbonate and hydrochloric acid

(a) Mass $CaCO_3$ = 11.2 × (100 ÷ 44) = **25.45 g** (3)

(b) Gas syringe measures volume **directly and accurately** without gas loss; allows repeatable readings (2)
Total: 5 marks

Q38. Sodium hydroxide

(a) Moles = mass ÷ Mr (1)

(b) Moles NaOH = 80 ÷ 40 = **2 mol** (2)

(c) Safety precaution: **Wear gloves/eye protection** (1)
Total: 4 marks

Q39. Concentration

(b) 250 cm^3 = 0.250 dm^3 (1)

(a) Concentration = moles ÷ volume = 0.5 ÷ 0.25 = **2 mol/dm^3** (3)
Total: 4 marks

Q40. Gas volumes

(a) Volume = 0.2 × 24 = **4.8 L** (2)

(b) Gas syringe gives **accurate measurement, reduces gas loss**, easy to read (2)
Total: 4 marks

Q41. Magnesium sulfate

(a) $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$
Moles Mg = 24 ÷ 24 = 1 mol

Mr $MgSO_4$ = 24 + 32 + (16×4) = 120 g/mol
Mass $MgSO_4$ = 1 × 120 = **120 g** (3)

(b) Hydrogen is produced because **Mg reacts with acid to displace H^+ ions** (2)
Total: 5 marks

Q42. Percentage yield

(a) % yield = (actual ÷ theoretical) × 100 (2)

(b) % yield = 40 ÷ 50 × 100 = **80%** (2)

(c) Yield < 100% due to **side reactions, incomplete reaction, or loss during handling** (2)
Total: 6 marks

Q43. Atom economy

(a) Atom economy = (Mr desired ÷ Mr all products) × 100 (2)

(b) Atom economy = 40 ÷ 100 × 100 = **40%** (2)

(c) High atom economy → **less waste, cheaper, more sustainable** (2)
Total: 6 marks

Q44. Hydrogen and oxygen in water

(a) Balanced: $2H_2 + O_2 \rightarrow 2H_2O$ (1)

(b) 2 moles H_2 → 2 moles H_2O (2)

(c) Ratio 2:1 because **water contains 2 H atoms for every O atom in its molecule** (2)
Total: 5 marks

Q45. Aluminium oxide

(a) $4Al + 3O_2 \rightarrow 2Al_2O_3$
Moles Al = 54 ÷ 27 = 2 mol
Moles Al_2O_3 = 2 ÷ 2 × 2 = 2 mol
Mr Al_2O_3 = 102 g/mol → mass = 2 × 102 = **204 g** (3)

(b) Balancing ensures **law of conservation of mass and correct mole ratios** (2)
Total: 5 marks

Q46. Preparing HCl solution

(a) 0.25 mol ÷ 0.500 dm³ = **0.5 mol/dm³** (3)

(b) Volumetric flask ensures **accurate total volume, precise concentration** (2)
Total: 5 marks

Q47. Limiting reactants

(a) Limiting reactant = **reactant used up first** (2)

(b) Knowing it allows calculation of **maximum product mass possible** (3)
Total: 5 marks

Q48. Gas syringe

(a) Gas syringe collects gas; **volume read directly**, prevents escape (2)

(b) Volume = 0.1 × 24 = **2.4 L** (3)
Total: 5 marks

Q49. Copper(II) oxide and sulfuric acid

(a) $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$ (2)

(b) Reaction produces $CuSO_4$ and H_2O because **CuO reacts with acid to form salt + water** (2)

(c) Mass $CuSO_4$:
Mr CuO = 63.5 + 16 = 79.5 g/mol → moles = 80 ÷ 79.5 ≈ 1 mol
Mr $CuSO_4$ = 63.5 + 32 + (16×4) = 159.5 g/mol → mass = 1 × 159.5 ≈ **160 g** (3)
Total: 7 marks

Q50. Experiment to measure hydrogen gas

Planning (6 marks):

- **Apparatus**: Conical flask, delivery tube, gas syringe, balance, clamp stand (1)

- **Method**: Add magnesium to HCl in conical flask; connect to gas syringe to collect H_2 (2)

- **Measurements**: Measure volume of gas in gas syringe over time; ensure **no leaks**, repeat readings for accuracy (3)

Total: 6 marks