

3.1 Conservation of mass and equations

Name: _____ Class: _____ Date: _____

Total: 18 marks

KEY WORDS conservation of mass • relative formula mass
• uncertainty

Objective

Balance equations, use conservation of mass, Mr and percentage by mass, and handle gas mass changes. Original questions for spec statements 4.3.1.1–4.3.1.4.

1 Key knowledge and worked examples

Conservation of mass: no atoms are lost or made – mass of products = mass of reactants. Balance symbol equations in atom numbers; a **multiplier before** a formula counts units; a **subscript inside** counts atoms in the unit.

Mr = sum of the Ar's in the numbers shown: $\text{CaCO}_3 = 40 + 12 + (3 \times 16) = 100$.

Percentage by mass of element = $(\text{Ar} \times n \div \text{Mr}) \times 100$.

Apparent mass changes: metal + oxygen → oxide, mass **rises** (O_2 adds); carbonate → oxide + CO_2 , mass **falls** (CO_2 escapes). Weigh **closed** or account for the gas.

Uncertainty: repeat measurements and use the **range about the mean** as the uncertainty estimate.

Worked example (3 marks). Calculate the percentage by mass of oxygen in calcium carbonate ($\text{Ca} = 40$, $\text{C} = 12$, $\text{O} = 16$).

$\text{Mr}(\text{CaCO}_3) = 40 + 12 + 48 = 100$; mass of oxygen per formula unit = $3 \times 16 = 48$;
 $\% \text{O} = 48/100 \times 100 = 48 \%$.

2 Practice

2.1 Balance: ____ Al + ____ $\text{O}_2 \rightarrow$ ____ Al_2O_3 . [1]

2.2 Calculate the Mr of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$ (N = 14, H = 1, S = 32, O = 16). [2]

2.3 A marble chip reaction loses 2.2 g. Suggest what left the flask. [1]

3 Exam-style questions

3.1 A student heats 5.00 g of copper in air and obtains 5.63 g of black copper oxide. Explain the mass change and show it obeys conservation of mass. [4]

3.2 Calculate the percentage by mass of sulfur in sulfuric acid, H_2SO_4 (H = 1, S = 32, O = 16). [3]

3.3 Four repeated volume readings are 24.10, 24.30, 24.20 and 24.80 cm^3 . The final trial has a recorded reading error and must be excluded. Give the mean of the remaining readings and estimate uncertainty using the stated half-range convention. [3]

3.4 Three repeated masses are 2.40, 2.42 and 2.44 g. Describe their positions on a number line, calculate the mean and range, then explain why a narrow range does not prove accuracy. [4]

Solutions

2.1 $4 \text{ Al} + 3 \text{ O}_2 \rightarrow 2 \text{ Al}_2\text{O}_3$.

2.2 $2 \times (14 + 4) + 32 + 64 = 36 + 32 + 64 = 132$.

2.3 Carbon dioxide gas.

3.1 Copper combines with oxygen from the air; the oxygen's mass adds to the solid; mass gain = $5.63 - 5.00 = 0.63$ g of oxygen; total reactant mass (copper + oxygen) equals product mass – conservation of mass holds once the gas is counted.

3.2 $\text{Mr}(\text{H}_2\text{SO}_4) = 2 + 32 + 64 = 98$; sulfur contributes 32; $\%S = 32/98 \times 100 = 32.65\% \approx 32.7\%$.

3.3 The recorded-error reading 24.80 is excluded for the stated reason, not merely because it is furthest from the others; mean = $(24.10 + 24.20 + 24.30) \div 3 = 24.20 \text{ cm}^3$; uncertainty $\pm \text{range}/2 = \pm 0.10 \text{ cm}^3$.

3.4 Marks at 2.40, 2.42 and 2.44 g on an equally spaced labelled mass axis. Mean = $(2.40 + 2.42 + 2.44)/3 = 2.42$ g; range = $2.44 - 2.40 = 0.04$ g. A systematic calibration error can shift all readings together while leaving a narrow range.