

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Methane has five atoms per molecule. Its molar mass is 16 g mol^{-1} .

$$n = \frac{m}{M} = \frac{10 \text{ g}}{16 \text{ g mol}^{-1}} = 0.625 \text{ mol}$$

$$N_{\text{atoms}} = 5nL = 5 \times 0.625 \text{ mol} \times 6.02 \times 10^{23} \text{ mol}^{-1} = 1.88 \times 10^{24}$$

Molecule count alone does not answer this question.

2.2 $\text{C}_4\text{H}_{10} + 6.5\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O}$. Oxygen amount follows the 1:6.5 coefficient ratio.

$$n(\text{O}_2) = 6.5n(\text{C}_4\text{H}_{10}) = 6.5 \times 0.25 \text{ mol} = 1.625 \text{ mol}$$

$$V(\text{O}_2) = nV_m = 1.625 \text{ mol} \times 24 \text{ dm}^3 \text{ mol}^{-1} = 39 \text{ dm}^3$$

2.3 The balanced desired-product mass contribution divided by the sum of balanced mass contributions of all products, $\times 100 \%$.

3.1 $\text{H}_2\text{SO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$. One mole of ammonium sulfate releases two moles of ammonia, which consume one mole of sulfuric acid.

$$n(\text{H}_2\text{SO}_4) = cV = 0.250 \text{ mol dm}^{-3} \times 0.0480 \text{ dm}^3 = 0.0120 \text{ mol}$$

Thus $n((\text{NH}_4)_2\text{SO}_4) = 0.0120 \text{ mol}$.

$$m = nM = 0.0120 \text{ mol} \times 132 \text{ g mol}^{-1} = 1.584 \text{ g}$$

$$\text{mass percentage} = \frac{m(\text{salt})}{m(\text{sample})} \times 100\% = \frac{1.584 \text{ g}}{2.50 \text{ g}} \times 100\% = 63.4\%$$

The salt mass is smaller than the sample mass, as required.

3.2 $\text{CuO} + 2\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O}$. Nitric acid is assumed in excess. The oxide and salt have a 1:1 mole ratio.

$$n(\text{CuO}) = \frac{m}{M} = \frac{4.0 \text{ g}}{80 \text{ g mol}^{-1}} = 0.050 \text{ mol}$$

Hence $n(\text{Cu}(\text{NO}_3)_2) = 0.050 \text{ mol}$.

$$m(\text{Cu}(\text{NO}_3)_2) = nM = 0.050 \text{ mol} \times 188 \text{ g mol}^{-1} = 9.4 \text{ g}$$

Both product coefficients are one.

$$\text{atom economy} = \frac{M(\text{salt})}{M(\text{salt}) + M(\text{water})} \times 100\% = \frac{188}{188 + 18} \times 100\% = 91.3\%$$

3.3 The volume and density give the mass; the water formula then identifies the number of oxygen atoms per molecule.

$$m = \rho V = 1.0 \text{ g cm}^{-3} \times 0.050 \text{ cm}^3 = 0.050 \text{ g}$$

$$n = \frac{m}{M} = \frac{0.050 \text{ g}}{18.0 \text{ g mol}^{-1}} = 2.78 \times 10^{-3} \text{ mol}$$

$$N = nL = 2.78 \times 10^{-3} \text{ mol} \times 6.02 \times 10^{23} \text{ mol}^{-1} = 1.7 \times 10^{21} \text{ molecules}$$

There is one oxygen atom per molecule, so $N(\text{O}) = N(\text{H}_2\text{O}) = 1.7 \times 10^{21}$.