Worked example 2 – Chapter 11

This worked example illustrates the principle that a percentage uncertainty does not change when multiplying or dividing by a pure number.

Sulfuric acid of concentration 0.100 ± 0.002 mol dm^{-3} is used to neutralise a sodium hydroxide solution. 0.0250 ± 0.0002 dm^3 of sulfuric acid is required to neutralise 0.0340 ± 0.0002 dm^3 of sodium hydroxide. What is the concentration of the sodium hydroxide solution?

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

The equation to work out the number of moles is:

no. moles = volume × concentration

no. moles sulfuric acid = 0.0250 × 0.100 = 0.00250 mol

To work out the uncertainty in the number of moles, work out the percentage uncertainties:

$$\text{volume percentage uncertainty} = \frac{0.0002}{0.0250} \times 100 = 0.8\%$$

$$\text{concentration percentage uncertainty} = \frac{0.002}{0.100} \times 100 = 2\%$$

We are multiplying two numbers, so the percentage uncertainties need to be added:

total percentage uncertainty = 0.9 + 2 = 2.8%

The number of moles of sodium hydroxide is twice the number of moles of sulfuric acid. 2 is a pure number (it has no uncertainty), so the percentage uncertainty stays the same when multiplying the number of moles of sulfuric acid:

no. moles of sodium hydroxide = 0.00250 mol ± 2.8% × 2 = 0.00500 mol ± 2.8%

Finally, we calculate the concentration of sodium hydroxide

$$\text{concentration of sodium hydroxide} = \frac{\text{no. moles}}{\text{volume}} = \frac{0.00500}{0.0340} = 0.1470588 \text{ mol dm}^{-3}$$

$$\text{percentage uncertainly of volume} = \frac{0.0002}{0.0340} \times 100 = 0.06\%$$

total percentage uncertainly in the concentration = 2.8 + 0.6 = 3.4%

This can be converted to an absolute uncertainty by multiplying by the final value of the concentration:

$$\text{absolute uncertainty} = \frac{3.4}{100} \times 0.1470588 = 0.005 \text{ mol dm}^{-3}$$

The uncertainty is in the third decimal place, so the final value for the concentration should be quoted to three significant figures:

0.147 ± 0.005 mol dm^{-3}

This is consistent with the fact that all the original values given are to three significant figures.