SL HL Error & uncertainty

As part of the assessment for your Individual Scientific Investigation you will need to take errors and uncertainties into account. You should know (or be able to estimate) the uncertainty associated with each piece of apparatus you use or any secondary data you obtain and have an awareness of which might significantly affect the result of your investigation. You should also have an awareness of uncertainties due to any assumptions you have made. For example, have all the chemicals reacted? How pure are the chemicals? Are there other products formed or side-reactions taking place, etc.? You are expected to be able to work out the percentage error by comparing your result with the 'literature' or data book value. You are also expected to be able to work out the total uncertainty by summing all the individual uncertainties and express your findings accordingly.

Error

The error is the difference between the result obtained and the generally accepted 'correct' result found in the data book or other literature. If the 'correct' result is available it should be recorded and the percentage error calculated and commented upon in the conclusion. Without the 'correct ' value no useful comment on the error can be made.

The percentage error is equal to:

$$\frac{\text{(the difference between the value obtained and the literature value)}}{\text{the literature value}} \times 100$$

Uncertainty

Uncertainty occurs due to the limitations of the apparatus itself and the taking of readings from scientific apparatus.

When recording uncertainties the uncertainty should correspond to the last significant figure of the reading to show the range of precision. For example if a thermometer is accurate to ± 0.5 °C a temperature reading of 27.21 °C should be recorded as 27.2 ± 0.5 °C, **not** as 27.21 ± 0.50 °C.

For many experiments more than one piece of apparatus is used to take measurements. During a titration, for example, there may be four separate pieces of apparatus used, each of which contributes to the uncertainty.

For example, when using a balance that weighs to ± 0.001 g the uncertainty in weighing 1.500 g will equal

(0.001 ÷ 1.500) x 100 = 0.0667%

Similarly a pipette measures 25.00 cm^3 ± 0.04 cm^3.

The uncertainty due to the pipette is thus (0.04 ÷ 25.00) x 100 = 0.16%

Assuming the uncertainties due to the burette and the volumetric flask are 0.50% and 0.10% respectively the overall uncertainty is obtained by summing all the individual uncertainties:

Overall uncertainty = 0.067 + 0.16 + 0.50 + 0.10 = 0.83% ≈ 1.0%

Hence if the answer is 0.750 mol dm^{-3} then the uncertainty is 1.0% of 0.750 mol dm^{-3}

The answer should be given as 0.750 ± 0.008 mol dm^{-3} or, even better, as 7.50 ± 0.08 x 10^{-1} mol dm^{-3}

Sometimes it is not possible to give precise percentage uncertainties. For example, in a titration the end-point taken could vary according to the person carrying out the titration. In such cases you should state the colour change taken (e.g. until a faint permanent pink colour was obtained). Any assumptions made which can add to the uncertainty (e.g. the specific heat capacity of the solution was taken to be the same as that for pure water) should also be stated.

You should be able to recognize when the uncertainty of one of the measurements is much greater than that of the others. This will then have the major effect on the uncertainty of the final result, and the approximate uncertainty can be taken as being due to that quantity alone. This is often the case whenever a traditional thermometer (rather than a probe) is used. Compared with an analytical balance, or accurate and precise volumetric apparatus, the percentage uncertainty in the temperature readings will be much greater, particularly when the temperature difference is relatively small.

Consider an experiment to measure the heat required to raise the temperature of 500 g of water by 6.0 ^{o}C.

If the uncertainty in the mass of water is ± 1 g then the percentage uncertainty in the mass is only ± 0.2%. However if the thermometer reads to ± 0.5 °C, and two readings were taken to measure the 6.0 ^{o}C temperature rise, then the absolute uncertainty is ± 1.0 °C. This gives a percentage uncertainty for the temperature rise of 16.7%, which is much higher than any of the other uncertainties inherent in the experiment. You need to bear this in mind when considering realistic suggestions to improve your experimental method.