Error Analysis in Chemistry: All data collection involves errors.

Systematic Errors

- These errors are due to identifiable causes.
- They are likely to give results which are consistently too high or consistently too low.
- Sources of systematic errors can sometimes be identified.
- Systematic errors **can** in principle be reduced by modifications to the experiment.
- They <u>cannot</u> be expressed as a ± value.

Random Errors

- These errors generally arise from the limit of <u>accuracy</u> of the apparatus.
- They arise from fluctuations that cause on average half the measurements to be too high and about half to be too low. Thus, repeated measurements ideally cancel random errors.
- Sources of random errors cannot always be identified.
- Random errors cannot generally be reduced without using different apparatus
- Random errors can be quantified, expressed as a ± value.

The random error is equivalent to the <u>uncertainty</u> in measurement. This is usually given by the manufacturer of the equipment and expressed as ± a certain value. If this information is not available, a good guideline is:

a) for analogue equipment the uncertainty = ± half the smallest scale division
b) for digital equipment the uncertainty = ± the smallest measure

Note when the uncertainty is recorded, it should be to the same decimal place as the measured value.

Significant Figures

Significant figures are defined as all of the known digits plus one estimated digit.
When you are reading a measurement that someone else has recorded:

- All non-zero digits are significant.
- Zeros between non-zero digits are significant.
- Zeros to the left of the first non-zero digit are not significant. They indicate magnitude only.
- Zeros to the right of a decimal point are significant if they are at the end of a number.
- Trailing zeroes are ambiguous when there is no decimal place.

When you are recording a measurement:

- On digital equipment: record every digit given to you, including trailing zeroes.
- On analogue equipment: record every digit that you know, plus one estimated digit. In other words, you always estimate one digit in between the lines.
- When a number without a decimal place ends in a zero or zeros, use scientific notation to indicate the significant digits.

Significant Figures in calculations:

<u>Adding and Subtracting:</u> the answer can only have as many numbers after the decimal point as the value with the least numbers after the decimal.

<u>Multiplying and Dividing:</u> the answer can only have as many significant digits as the number with the least number of significant digits.

Propagation of uncertainties in calculations:

The principle is that the overall uncertainty is the sum of the absolute uncertainties.

Adding and Subtracting: the uncertainties associated with them must be added together:

> initial temperature = 20.13 ± 0.03˚C
> final temperature = 27.90 ± 0.03 ˚C
> ⇒ temperature change = 7.77 ± 0.06 ˚C

Multiplying and Dividing: the absolute uncertainties must be expressed as percentage uncertainties. These can then be added together, and finally converted back into absolute uncertainties.

> Using the equation: heat = mass* the specific heat constant* temperature change
>
> mass reading = 5.45g ± 0.01 (% uncertainty = 0.2%)
> temperature = 7.77˚C ± 0.06 (% uncertainty = 0.8%)
>
> ⇒ total uncertainty = sum of % uncertainties = 1%
>
> The calculated heat 177 J, then the total uncertainty = 1%
> Therefore final answer = 177J ± 2J

Notes:

- Unless otherwise noted, you can assume that constants have zero uncertainty and can be ignored for the propagation of error.
- Uncertainties (both absolute and %) should generally only have one significant figure.
- We will simply use the given uncertainty for averaged data.
- Absolute uncertainties should be included in all data tables, usually in the column headers. They should also always be discussed in the conclusion portion of a lab write-up.

Experimental error: percent difference

The difference between the experimental and theoretical (looked up or calculated) results.

$$\% \text{ error} = \frac{\text{experimental} - \text{theoretical}}{\text{theoretical}} \times 100$$

If the experimental error is larger than the calculated uncertainty (the ±), then random error alone cannot explain the discrepancy and systematic errors must be involved.