11. Measurement and data processing (SL)

Syllabus:

11.1 Uncertainties and errors in measurement and results

Definition of qualitative data and quantitative data.

Propagation of random errors in data processing shows the impact of the uncertainties on the final result.

Experimental design and procedure usually lead to systematic errors in measurement, which cause a deviation in a particular direction.

Repeat trials and measurements will reduce the random errors but not systematic errors.

11.2 Graphical techniques

Graphical techniques are an effective means of communicating the effect of an independent variable on a dependent variable, and can lead to determination of physical quantities.

Sketched graphs have labelled but unscaled axes, and are used to show quantitative trends, such as variables that are proportional or inversely proportional.

Drawn graphs have labelled and scaled axes, and are used in quantitative measurements.

11.3 Spectroscopic identification of organic compounds

The degree of unsaturation or index of hydrogen deficiency (IHD) can be used to determine from a molecular formula the number of rings or multiple bonds in a molecule.

Mass spectrometry (MS), proton nuclear resonance spectroscopy (^1H NMR) and infrared spectroscopy (IR) are techniques that can be used to help identify compounds and to determine their structure.

11.1 Uncertainties and errors in measurement and results

(A) Uncertainty

In the experiment, you will use different measuring apparatus. In order to measure accurately, you would choose suitable instruments. For example, you can use a 25 cm^3 volumetric flask to make up a 25 cm^3 known concentration solution.

For some analogue instrument , the degree of uncertainty is mentioned on the apparatus.
For some digital instruments such as electrical balance, the mass of the solid sample measured is 30.00g, so the uncertainty is the smallest scale division ($\pm$)0.01 g.

(B) Significant figures in measurements

Significant figures are the digits in the measurement up to and including the first uncertain digit.

For example, the significant figure in 23.0 cm^3 is 3 and 100.20 g is 5.

Measurement	**Significant figures**
100	Not specified
2×10^3	1
2.0×10^2	2
3.41×10^3	3
2.400×10^6	4

(C) Experimental errors

1. Random errors

Random errors are the chance of being too high or too low when an experiment approximates a reading.

The causes of random errors:

1. readability of the measuring instrument
2. not enough data
3. surroundings change such as temperature or air flow
4. the observer misinterpreting reading

Random errors can be reduced through repeated measurements.

2. Systematic errors

Systematic errors result from the poor experimental design or procedure.

The causes of systematic errors:

1. Overshooting the volume in the titration
2. Heat loss to the surroundings in the exothermic reaction
3. Measuring the volume of the liquid from the top of the meniscus instead of the bottom
4. Use a wrong pH indicator in the acid-base titration
5. Electrical balance was incorrectly zeroed

Systematic errors cannot be reduced by repeating the experiment.
It can be reduced by designing the experiment carefully.

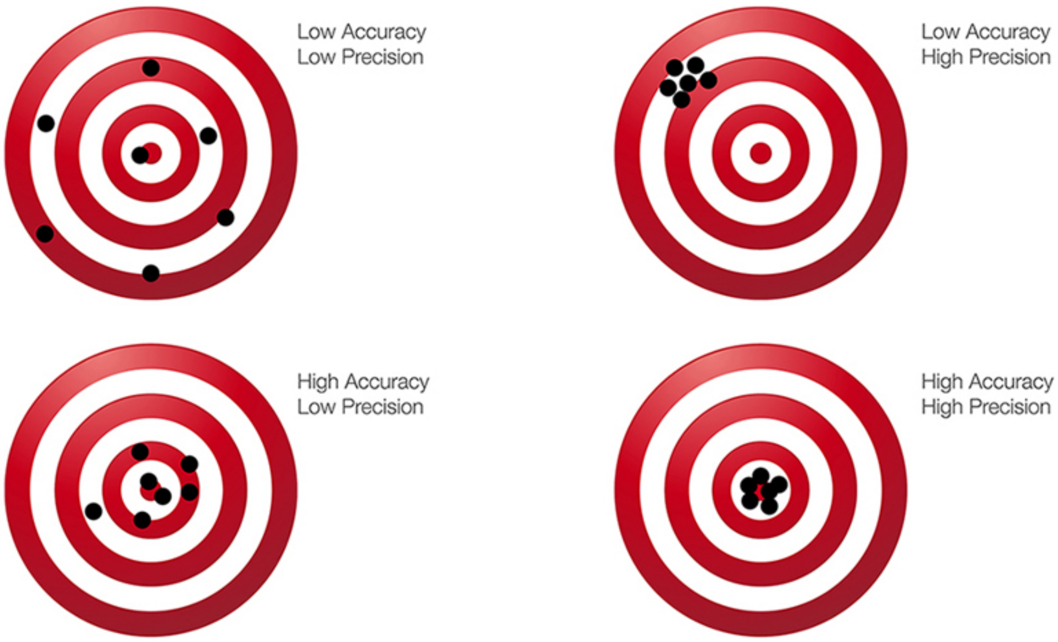
(D) Accuracy and precision

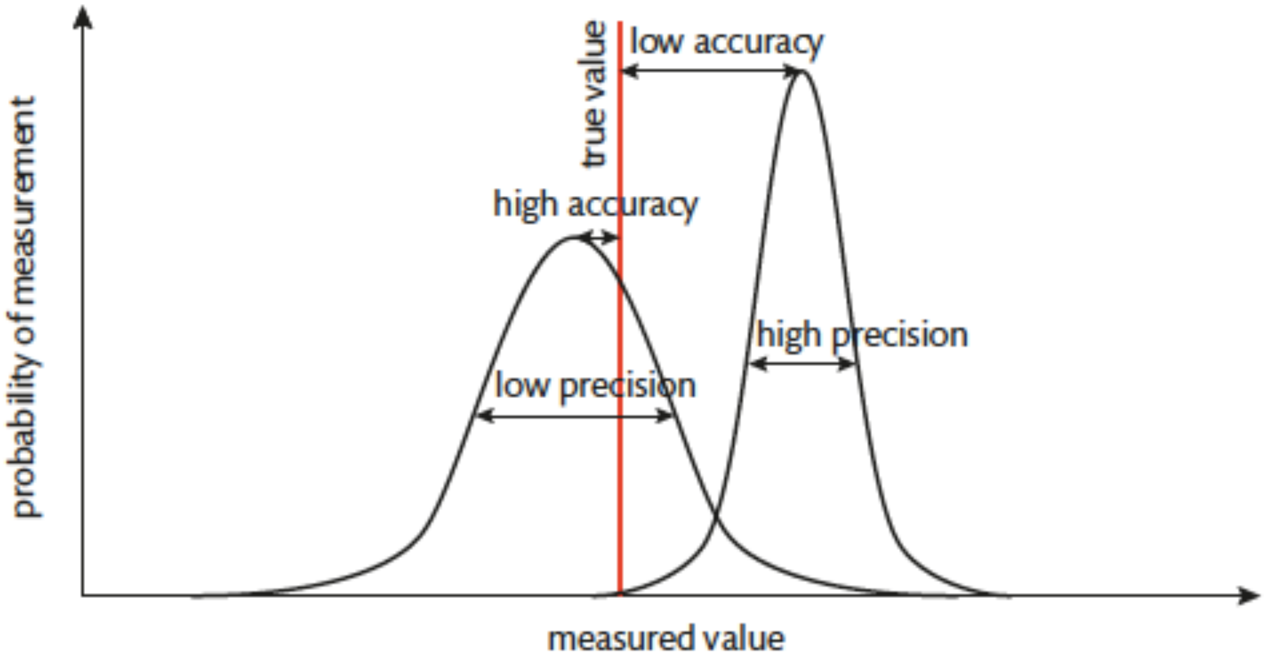
Random error leads to **imprecise**.

Systematic error leads to **inaccurate**.

Precise measurements have small random errors and are reproducible in repeated trials.

Accurate measurements have small systematic errors and give a result close to accepted value.





(E) Uncertainties and errors

$$\text{Percentage uncertainty} = \frac{\text{absolute uncertainty}}{\text{measured value}} \text{ x } 100\%$$

$$\text{Percentage error} = \frac{\text{accepted value} - \text{experimental value}}{\text{accepted value}} \text{ x } 100\%$$

(F) Propagation of uncertainties in calculated results

1. Addition and subtraction

Initial burette reading = 14.05 ± 0.05 cm^3

Final burette reading = 28.30 ± 0.05 cm^3

The volume added = 28.30 – 14.05 = 14.25 cm^3

The uncertainty of the volume added = 0.05 + 0.05 = $\pm$ 0.1

The uncertainty is the sum of the two absolute uncertainties.

2. Multiplication and division

Mass = 22.0 $\pm$ 0.5 g

Volume = 2.0 $\pm$ 0.1 cm^3

Density = $\frac{22.0}{2.0}$ = 11 g cm^{-3}

Percentage uncertainty of mass = $\frac{0.5}{22.0}$ x 100% = 2%

Percentage uncertainty of volume = $\frac{0.1}{2.0}$ x 100% = 5%

Percentage uncertainty of density = 2% + 5% = 7%

Total percentage uncertainty is the sum of the individual percentage uncertainties.

(G) Significant figures in calculations

1. Multiplication and division

Density = $\frac{5.00}{2.4}$ = 2.083333333 g cm^{-3} = 2.1 g cm^{-3}

The result show be expressed based on the measurement with the smallest number of significant figures.

2. Addition and subtraction

Initial reading = 23.20 cm^3

Final reading = 42.00 cm^3

Volume added = 42.00 – 23.20 = 18.80 cm^3

The result show be expressed based on the measurement with the smallest number of decimal places.