Practical skills

Planning, variables, measurement and uncertainty, tables and graphs, evaluation, apparatus choice, safety, and a summary of the core practicals in Units 1 and 2 and Units 4 and 5.

Planning an investigation

A good plan states clearly:

- the **independent variable** (what you change) and its range,
- the **dependent variable** (what you measure) and how,
- the **control variables** (what you keep the same, and how),
- the apparatus, with its size and resolution,
- the **method** in enough detail to repeat, including how many repeats,
- how the results will be processed, and
- the main **hazards** and how the risk is reduced.

To improve **validity**, control the other variables and measure what you intend to measure. To improve **reliability**, repeat and check that the repeats agree.

Measurements and uncertainty

- **Resolution** is the smallest division the instrument shows.
- **Accuracy** is how close a result is to the true value. **Precision** is how close repeated results are to each other.
- **Random errors** make readings scatter either side of the true value; repeating and averaging reduces them. **Systematic errors** shift all readings the same way (for example a zero error), and repeating does not remove them.
- A **mean** should use only **concordant** results.

The **percentage uncertainty** in a measurement is $\frac{\text{absolute uncertainty}}{\text{value}} \times 100$.

> **When quantities are multiplied or divided in a calculation, add the percentage uncertainties. When they are added or subtracted, add the absolute uncertainties: a titre is the difference of two burette readings, each ±0.05 cm^3, so the titre is ±0.10 cm^3.**

To reduce the percentage uncertainty: use a larger quantity (a larger titre or mass), or apparatus with a smaller uncertainty (a balance with more decimal places).

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Presenting data

- Give a table with **headings that have quantities and units**.
- Record all raw data to the same number of decimal places, matching the instrument.
- Quote calculated results to the same number of **significant figures** as the least precise data.

Graphs

- Put the independent variable on the horizontal axis. Use a scale that fills more than half of the grid, with sensible steps, and label axes with quantity and units.
- Mark points with small crosses and draw a **best-fit line** (a smooth curve or a straight line with points either side). Do not force it through the origin unless the data show it should be there.
- The **gradient** of a line is found from a large triangle. For a curve, draw a **tangent** to give the rate at a point.
- **Anomalous** results are circled and can be left out of the line of best fit, but you should repeat them if possible.

Evaluating

For each source of error, say whether it is random or systematic, estimate its effect and suggest an **improvement** (more repeats, a bigger quantity, a more precise instrument, better insulation). Draw a **conclusion** that the data support, and say how confident you are. Compare the percentage uncertainty with the difference between results to judge whether the difference is significant.

Apparatus

Choose by the **size and resolution** needed: a measuring cylinder (±0.5 cm^3 for 25 cm^3) for rough volumes, a **pipette** (25.0 cm^3, one fixed volume, low uncertainty) and **burette** (readable to ±0.05 cm^3) for titrations, a **volumetric flask** for standard solutions, a **balance** (0.001 g) for accurate masses, and a **gas syringe** for collecting gases. Know the apparatus for reflux, distillation, filtration under reduced pressure, and a thermometer or data logger.

Safety

Identify the hazard (corrosive, toxic, flammable, oxidising, irritant) from its symbol, name the **risk** and give the **control**: eye protection, gloves, a fume cupboard for toxic or irritant vapours, no naked flames near flammable liquids, dilute solutions, small amounts, and safe disposal.

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The core practicals at a glance

No.	Practical	Key idea
1	Molar volume of a gas	$n = V/V_m$ from mass of a solid reactant and gas collected
2	Enthalpy change with Hess's law	Temperature changes in cups, combine two cycles
3	Concentration of HCl	Titration against a standard base
4	Standard solution from a solid acid	Weigh by difference; volumetric flask
5	Rates of hydrolysis of halogenoalkanes	Time to precipitate with $AgNO_3$
6	Chlorination of 2-methylpropan-2-ol	Separating funnel, wash, dry, distil
7	Oxidation of propan-1-ol	Distillation versus reflux
8	Inorganic and organic unknowns	Test-tube tests with spectra
9a, 9b	Iodine-propanone rate; iodine clock	Order of reaction
10	Activation energy	Rate against temperature, Arrhenius plot
11	K_a of a weak acid	pH of a half-neutralised solution
12	Electrochemical cells	Measuring cell potentials
13a, 13b	Redox titrations	Iron(II) with manganate(VII); thiosulfate with iodine
14	Transition metal complex	Preparation and purification
15	Unknowns	As core practical 8
16	Aspirin	Preparation and recrystallisation

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