01 Experimental Chemistry



1 Measuring Physical Quantities

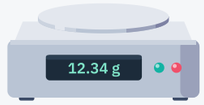
1.1 Quantities, units and apparatus

Quantity	SI unit	Apparatus	Other units
time	second, s	_____	minute (min), hour (h)
temperature	_____	thermometer	degree Celsius (°C)
length	metre, m	metre rule, measuring tape	cm, dm, mm
mass	kilogram, kg	_____	gram (g), tonne (t)
volume	cubic metre, m^3	burette, pipette, measuring cylinder, gas syringe	cm^3, dm^3



stopwatch

thermometer



electronic balance

- A **digital** stopwatch reads to ±0.01 s and an analogue stopwatch to ±0.1 s.
- Laboratory thermometers are alcohol, mercury or digital. A temperature probe joined to a **data logger** collects readings automatically.
- An electronic balance reads to about ±0.01 g.

1.2 Converting units

Time
1 min = 60 s 1 h = 60 min = 3600 s

Temperature
temperature in K = temperature in °C + _____

Length
1 m = 10 dm = 100 cm = 1000 mm

Mass
1 kg = 1000 g 1 g = 1000 mg

Volume
1 dm^3 = 1000 cm^3 = 1 litre

Volume
1 m^3 = _____ dm^3

NOTE 1 m = 10 dm, but 1 m^3 is not 10 dm^3. A cube of side 10 dm has a volume of 10 × 10 × 10 = 1000 dm^3.

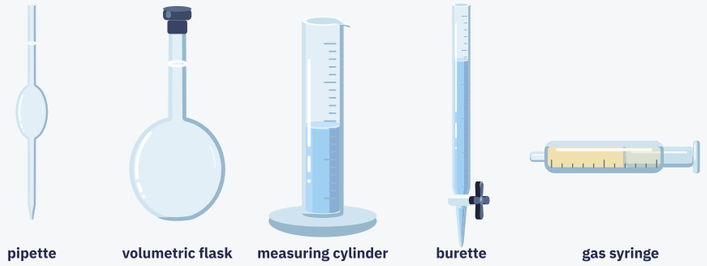
WORKED EXAMPLE Convert 250 cm^3 to dm^3.

1 dm^3 = 1000 cm^3

250 ÷ 1000 = **0.250 dm^3**

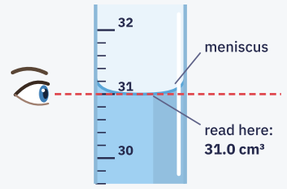
1 Measuring Physical Quantities (continued)

1.3 Measuring volume



pipette | **volumetric flask** | **measuring cylinder** | **burette** | **gas syringe**

Apparatus	What it measures
pipette	an accurate _____ volume, e.g. 10.0 cm^3 or 25.0 cm^3
volumetric flask	an accurate fixed larger volume, e.g. 100 cm^3 or 250 cm^3
measuring cylinder	a range of volumes, to the nearest 0.5 cm^3, e.g. 31.5 cm^3
burette	a range of volumes, to the nearest _____ cm^3, e.g. 23.00 cm^3
gas syringe	the volume of a _____, up to 100 cm^3

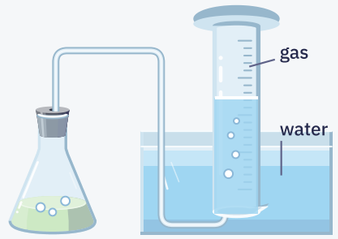


- Place your eye level with the **meniscus** to avoid parallax error.
- For water, read the _____ of the meniscus.

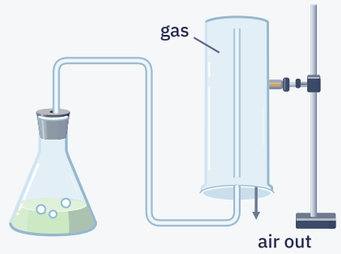
2 Collecting and Drying Gases

2.1 Methods of collecting gases

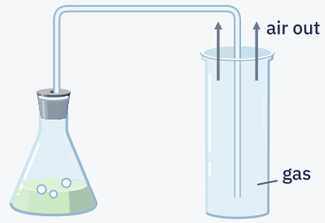
The method depends on how _____ the gas is in water and how _____ it is compared with air.



Water displacement
insoluble or slightly soluble gases



Upward delivery
gases less dense than air



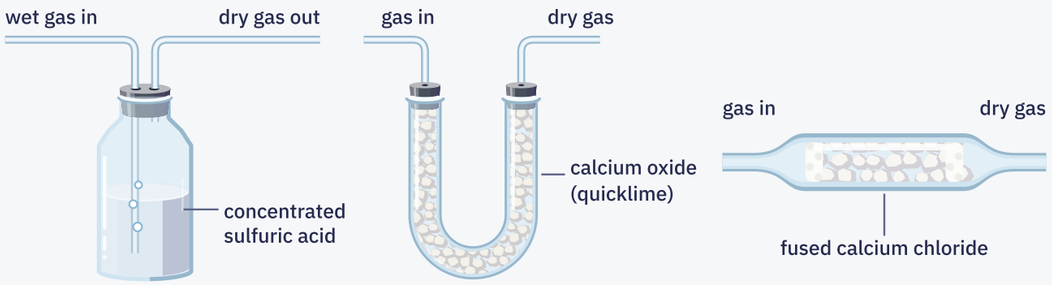
Downward delivery
gases denser than air

Method	Solubility in water	Density	Examples
water displacement	insoluble or slightly soluble	any	hydrogen, oxygen, carbon dioxide
upward delivery	soluble or insoluble	_____ than air	ammonia
downward delivery	soluble or insoluble	_____ than air	chlorine, hydrogen chloride, sulfur dioxide

NOTE To decide if a gas is denser than air, compare its M_r with the average M_r of air, about 29. A gas with M_r above 29 is **denser** than air (e.g. Cl_2, 71). A gas with M_r below 29 is **less dense** (e.g. NH_3, 17).

2 Collecting and Drying Gases (continued)

2.2 Drying agents for gases



Drying agent	Use it for	Do not use it for
concentrated sulfuric acid	most gases, e.g. chlorine and hydrogen chloride	gases that react with it, e.g. _____
calcium oxide (quicklime)	_____	gases that react with it, e.g. carbon dioxide
fused calcium chloride	most gases	ammonia

NOTE Calcium oxide and calcium chloride absorb water from the air, so they must be freshly heated before use.

3 Separation and Purification

3.1 Choosing a method

A mixture has two or more substances that are _____ chemically combined. Each is separated using a difference in a physical property: particle size, solubility, melting or boiling point, or magnetism.

What is in the mixture?

- **solid + solid**
  - one solid is magnetic → **magnet**
  - different particle sizes → **sieving**
  - only one solid dissolves → **dissolve, filter, evaporate**
  - one solid sublimes → **sublimation**
- **solid + liquid**
  - solid does not dissolve → **filtration**
  - solid dissolved, solid wanted → **evaporation to dryness**
  - crystals wanted, or solid decomposes → **crystallisation**
  - the liquid is wanted → **simple distillation**
- **liquid + liquid**
  - liquids do not mix (immiscible) → **separating funnel**
  - miscible, boiling points differ → **fractional distillation**
  - dissolved coloured substances → **paper chromatography**

NOTE **Key terms.** A **solute** dissolves in a **solvent** to make a solution. **Miscible** liquids mix completely, while **immiscible** liquids form separate layers. The **filtrate**, **residue**, **distillate** and **sublimate** are what each method collects.

3 Separation and Purification (continued)

3.2 Solid and solid mixtures

Magnetic attraction

A magnet removes _____ solids (iron, cobalt, nickel), e.g. iron filings from sulfur.

Sieving

Separates solids with different _____.

A suitable solvent

If only one solid dissolves, add the solvent and filter. For sand and salt, the salt solution is the filtrate and the sand is the residue.

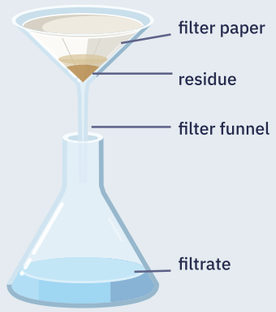
Sublimation

A solid that changes straight to a gas, e.g. _____ or naphthalene, is warmed and collected as the **sublimate** on a cold surface.



3.3 Solid and liquid mixtures

Filtration



Separates an _____ solid from a liquid. The liquid that passes through is the **filtrate**. The solid left on the paper is the **residue**.

Evaporation to dryness



Separates a _____ solid from its solvent by heating until all the solvent has boiled off.

Crystallisation

Used for a solid that _____ on strong heating, or to obtain pure crystals of a salt.

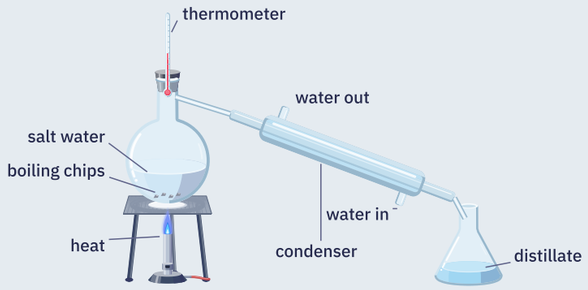
1. Heat the solution until it is _____. Stop before all the solvent evaporates.
2. Cool the solution so that crystals form.
3. Filter, wash the crystals with a little cold distilled water, and dry them between filter papers.

Why crystals form: hot water holds more solute than cold. 100 g of water holds 55 g of copper(II) sulfate at 80 °C but only 21 g at 20 °C, so on cooling the other 34 g comes out as crystals.

3 Separation and Purification (continued)

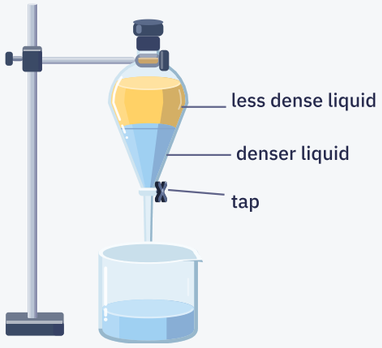
3.3 Solid and liquid mixtures (continued)

Simple distillation



- Separates a pure _____ from a solution, e.g. pure water from salt water. The solvent is collected as the **distillate**.
- The thermometer bulb is level with the **side arm**, to measure the temperature of the vapour entering the condenser.
- Cold water enters the condenser at the _____, so the condenser stays full of water and cools the vapour efficiently.
- Boiling chips give smooth boiling.

3.4 Liquid and liquid mixtures



Separating funnel

Separates _____ liquids. The less dense liquid forms the upper layer.

1. Run off the lower layer into a beaker.
2. Close the tap just as the boundary reaches it.
3. Run the upper layer into a second beaker.

WORKED EXAMPLE A mixture contains W and X, two immiscible liquids with X denser, Y, a solid that dissolves in W but not in X, and Z, a solid that is insoluble in both liquids. Outline how to separate all four.

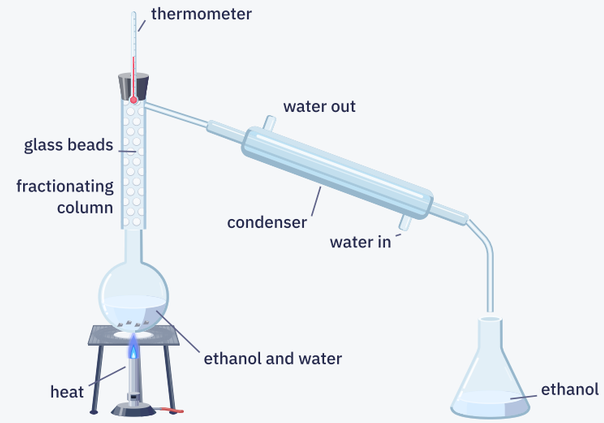
Remove the insoluble solid Z by **filtration**.

Use a **separating funnel** to run off liquid X, the lower layer.

Obtain solid Y from its solution in W by **evaporation** or **crystallisation**.

3 Separation and Purification (continued)

3.4 Liquid and liquid mixtures (continued)



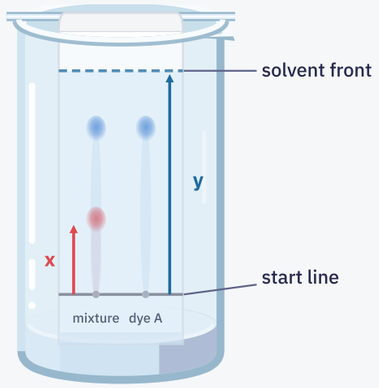
Fractional distillation

- Separates _____ liquids with different boiling points, e.g. ethanol (78 °C) and water (100 °C).
- The **glass beads** give a large surface area for the vapour to condense and boil again.
- The liquid with the _____ boiling point distils first. When the temperature rises, change the receiver.

NOTE Fractional distillation separates crude oil into fractions and liquid air into nitrogen, oxygen and argon.

3.5 Chromatography

Chromatography separates a mixture of substances that have _____ in a given solvent.



- Draw the start line in **pencil**, as graphite does not dissolve in the solvent.
- The solvent level must be _____ the start line, so the spots do not dissolve into the solvent.
- The more soluble a substance, the further it travels. A spot that matches a known pure substance is probably that substance.
- Colourless substances are shown with a **locating agent** or _____ light.

$$R_f = \frac{\text{distance moved by the } \square}{\text{distance moved by the } \square}$$ both from the **start line**

4 Purity

4.1 Pure substances and mixtures

Pure substance

Melts and boils at one _____ temperature. Gives **one spot** on a chromatogram.

Mixture

Melts and boils over a _____ of temperatures. Impurities lower the melting point and raise the boiling point.

Purity matters in medicines and food: impurities in a medicine may cause harmful side effects.

EXAM TIP To show a sample is pure, state that it has a sharp, fixed melting point that matches the known value.