CHAPTER 1

Experimental Design

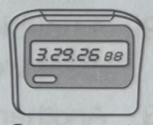
NOTES

1.1 Physical Quantities

Different apparatus and SI units are used to measure different physical quantities.

(A) Time

1. The SI unit of time is **second (s)**.
2. Other units such as minute (min) and hour (h) can be used to record longer periods of time.
3. Time is measured using a stopwatch.



Stopwatch

(B) Temperature

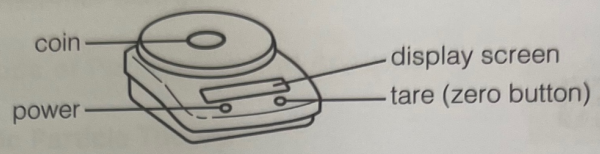
1. Two measurements for temperature are **degree Celsius (°C)** and **Kelvin (K)**.
2. Kelvin (K) is the SI unit for temperature.
3. Degree Celsius (°C) is more commonly used in everyday life.
4. Thermometers are used to measure temperature.
5. There are various types of thermometers such as the mercury-in-glass thermometer, alcohol-in-glass thermometer and digital thermometer.
6. A temperature sensor connected to a data logger can also be used to measure temperature.

Temperature in K = Temperature in °C + 273.15

$\Delta 1\ K = \Delta 1°C$

(C) Mass

1. The SI unit of mass is **kilogram (kg)**.
2. Mass can be measured using a beam balance or an electronic balance.



Electronic balance

1 kg = 1000 g = 1 000 000 mg

(D) Volume

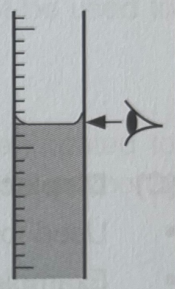
1. The SI unit of volume is **cubic metre (m^3)**.
2. As cubic metre (m^3) is a large unit of measurement, volume is usually measured in **cubic centimetre (cm^3)**.
3. Another commonly-used unit is **cubic decimetre (dm^3)**.

1 dm^3 = 1000 cm^3 1 m^3 = 1 000 dm^3 = 1 000 000 cm^3

4. Volume of a gas can be measured using a gas syringe.
5. Volume of a liquid can be measured using various apparatus. The apparatus, arranged in order of increasing accuracy, are the beaker, measuring cylinder, pipette and burette.
6. The beaker is used to measure **approximate volumes**.
7. The measuring cylinder, pipette and burette are used to **measure exact volumes**.
8. The pipette measures **fixed volumes** of liquids.
9. The burette measures **varying volumes** of liquids.

Practical Tips

1. Know the purpose and the precision of each apparatus in the lab so as to use the appropriate one for measuring different physical quantities.
2. For titration (Chapter 8) experiments, take note of the accuracy of the burette and pipette in the recording of results. Volumes recorded should be in **1 decimal place for pipettes** and **2 decimal places for burettes**.
3. Place the measuring cylinder on a flat surface before reading.
4. To avoid parallax error when measuring volumes of liquids, position the eye parallel to the liquid level and take reading from the bottom of the meniscus. Only take reading from the top of the meniscus for mercury.



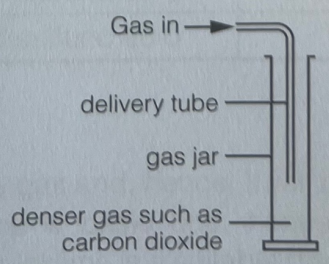
1.2 Collection of Gases

The methods of gas collection depend on:

1. The density of the gas compared to air
2. The solubility of the gas in water

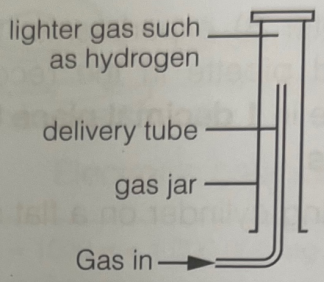
(A) Downward delivery

- Used for gases that are denser than air
- Examples are carbon dioxide (CO_2) and chlorine gas (Cl_2)
- Gas will travel downwards as it is denser than the air.



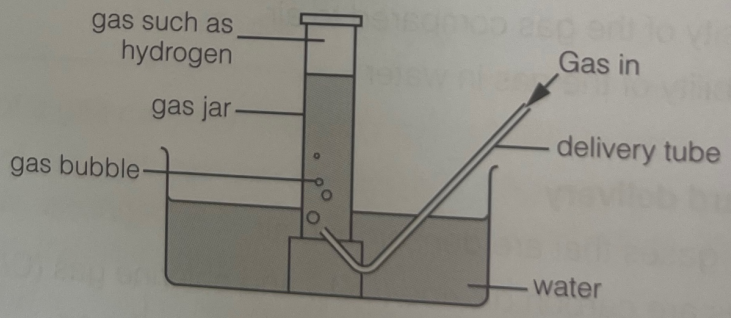
(B) Upward delivery

- Used for gases that are less dense than air
- Examples are hydrogen (H_2) and ammonia gas (NH_3)
- Gas will travel upwards as it is less dense than the air.



(C) Displacement of water

- Used for gases that are insoluble or slightly soluble in water
- Examples are hydrogen, nitrogen (N_2), oxygen (O_2) and carbon dioxide
- Gas is bubbled through water into a jar as the gas does not dissolve or only slightly dissolves in water.



1.3 Methods for Dying Gases

To dry a gas, we may pass the gas through suitable drying agents:

(a) Concentrated sulfuric acid

Note that ammonia is an alkaline gas and will react with an acid. Hence, concentrated sulfuric acid cannot be used to dry ammonia.

(b) Quicklime (Calcium oxide)

Quicklime is a base which will react with acidic gases such as sulfur dioxide and hydrogen chloride. Hence, quicklime cannot be used to dry acidic gases.

(c) Fused calcium chloride

Fused calcium chloride is calcium chloride that has been heated to remove water. It can be used to dry most gases except for ammonia as it reacts to form a complex.

Worked Examples

1. Ammonia can be made in the laboratory by heating a mixture of an alkali and an ammonium salt. A laboratory technician wants to prepare dry ammonia. What method of drying and method of gas collection should he use?

	Method of drying	Method of gas collection
A	Quicklime	Upward delivery
B	Quicklime	Displacement of water
C	Concentrated sulfuric acid	Displacement of water
D	Concentrated sulfuric acid	Upward delivery

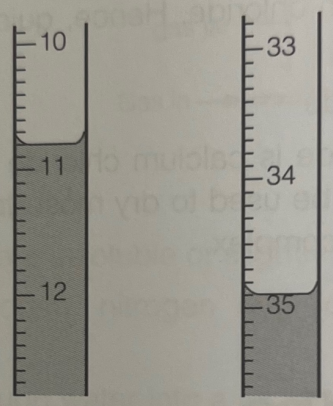
Explanation:

Ammonia is an alkaline gas and, hence, it will react with concentrated sulfuric acid. Quicklime is basic and, hence, it will not react with ammonia. Therefore, quicklime is a suitable drying agent for ammonia.

Ammonia is very soluble in water. Having a small molecular mass of 17, ammonia is less dense than air and, hence, it will float on air. Therefore, the upward delivery is a suitable method to collect ammonia.

Answer: A

2. Solution **M** is added into a piece of apparatus.



Initial reading Final reading

Solution **M** is added to 25.0 cm^3 of solution **K** for complete reaction.

(a) (i) Name the piece of apparatus used to measure solution **M**. [1]

(ii) Name the piece of apparatus used to measure out solution **K**. [1]

(b) Write down the initial reading and final reading. Hence, calculate the volume of solution **M** used to completely react with solution **K**. [2]

Solution:

(a) (i) Burette [1]

(ii) Pipette [1]

(b) Initial reading = 10.80 cm^3

Final reading = 34.90 cm^3

Volume of solution M used

= final reading – initial reading

= 34.90 – 10.80 [1]

= 24.10 cm^3 (2 d.p.) [1]

Let's Map It

Experimental Chemistry

measures

Physical Quantities

such as

Time
- SI unit: second (s)
- apparatus: stopwatch

Temperature
- SI unit: kelvin (K)
- apparatus: thermometer

Length
- SI unit: metre (m)
- apparatus: metre rule, measuring tape

Mass
- SI unit: kilogram (kg)
- apparatus: electronic balance

Volume
- SI unit: cubic metre (m^3)
- apparatus: burette, pipette, measuring cylinder, gas syringe

of

Liquids

Gases

collected by

Displacement of water

Displacement of air

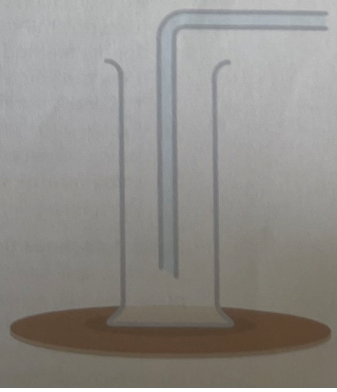
through

Upward delivery

Downward delivery

can be used to separate

Solid–solid mixtures
- magnetic attraction
- sieving
- using suitable solvents
- sublimation

Solid–liquid mixtures
- filtration
- evaporation to dryness
- crystallisation
- simple distillation

Liquid–liquid mixtures
- separating funnel
- chromatography
- fractional distillation