Measurement and Experimental Techniques

Experimental Techniques

Experimental Techniques

What do you see? (Part 1)

- Girls.
- Chemistry.
- Cheerful.
- Interested.
- Collaboration.

Experimental Techniques

What do you see? (Part 2)

- 4 students.
- Average mass = 42.5 kg.
- Average height = 1.62 m.
- Average grade for Chemistry = 73.5%.
- Average amount of sleep each night = 5.75 h.

Experimental Techniques

What is the difference between qualitative and quantitative data?

Experimental Techniques

- **Qualitative Data:**

→ Deals with descriptions.

→ Data can be observed, but not measured.

e.g. appearance, colour, smell, taste, texture.

- **Quantitative Data:**

→ Deals with numbers.

→ Data can be measured.

e.g. length, mass, temperature, time, volume.

Experimental Techniques

- **Qualitative Data:**

→ Green solution.

→ Nickel(II) sulfate.

- **Quantitative Data:**

→ 100 cm^3.

→ 25 °C.

→ 1.50 mol/dm^3.

Experimental Techniques

Why is it important to make measurements in science?

Experimental Techniques

Experimental Techniques

- A Boeing 767 airplane flying for Air Canada on 23rd July 1983 consumed its complete supply of fuel only an hour into its flight. It was headed to Edmonton from Montreal, but it received low fuel pressure warnings in both fuel pumps at an altitude of 12, 500 m; engine failures followed soon after. Fortunately, the captain was an experienced glider pilot and the first officer knew of an unused air force base about 20 kilometres away. Together, they landed the plane on the runway, and only a few passengers sustained minor injuries.

www.chemwiki.ucdavis.edu/analytical_chemistry/quantifying_nature

Experimental Techniques

- This incident was due partially to the airplane's fuel indication system, which had been malfunctioning. Maintenance workers resorted to manual calculations in order to fuel the craft. They knew that 22,300 kg of fuel was needed, and they wanted to know what volume in litres should be pumped. They used 1.77 as their density ratio in performing their calculations. However, 1.77 was given in *pounds* per litre, not *kilograms* per litre. The correct number should have been 0.80 *kilograms* per litre; thus, their final figure accounted for less than half of the necessary volume of fuel.

www.chemwiki.ucdavis.edu/analytical_chemistry/quantifying_nature

Experimental Techniques

Experimental Techniques

- Tokyo Disneyland's Space Mountain roller coaster came to a sudden halt just before the end of a ride on 5th December, 2003. This startling incident was due a broken axle. The axle in question fractured because it was smaller than the design's requirement. Because of the incorrect size, the gap between the bearing and the axle was over 1 mm – when it should have been a mere 0.2 mm. The accumulation of excess vibration and stress eventually caused it to break.

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Experimental Techniques

- Though the coaster derailed, there were no injuries. Once again, unit systems caused the accident. In September 1995, the specifications for the coaster's axles and bearings were changed to *metric units*. In August 2002, however, the *imperial units* (English units) plans prior to 1995 were used to order *44.14 mm* axels instead of the needed *45.00 mm* axels.

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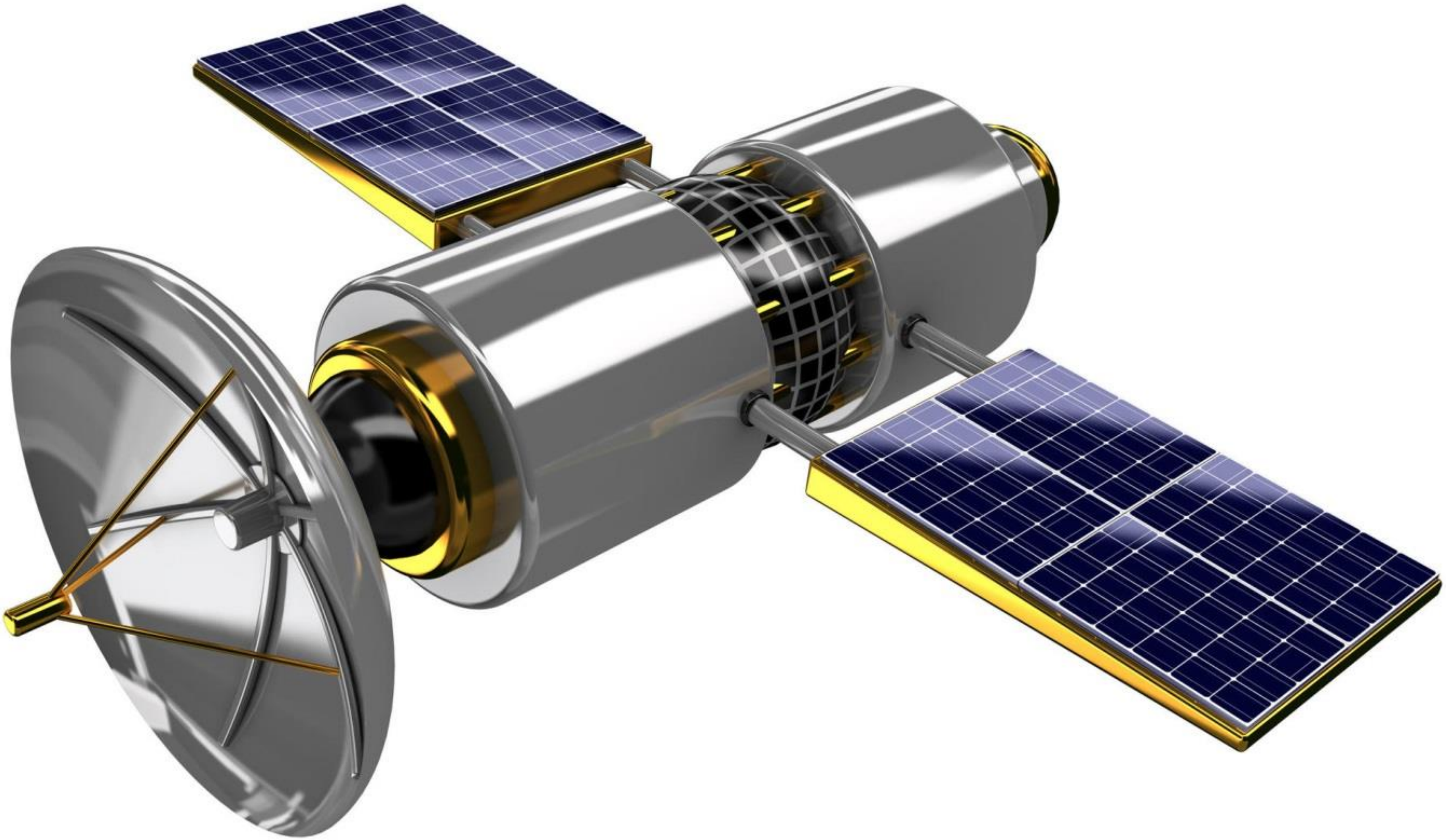
Experimental Techniques



Experimental Techniques

- The Mars Climate Orbiter, meant to help relay information back to Earth, is one notable example of the unit system struggle. The orbiter was part of the Mars Surveyor ’98 program, which aimed to better understand the climate of Mars. As the spacecraft journeyed into space on September 1998, it should have entered orbit at an altitude of 140 - 150 km above Mars, but instead went as close as 57km.

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Experimental Techniques

- This navigation error occurred because the software that controlled the rotation of the craft's thrusters was not calibrated in SI units. The spacecraft expected *newtons*, while the computer, which was inadequately tested, worked in *pound forces*; 1.00 *pound force* is equal to about 4.45 *newtons*. Unfortunately, friction and other atmospheric forces destroyed the Mars Climate Orbiter. The project cost US$ 327.6 million in total.

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Experimental Techniques

Measurements:

Science is based on measurements.

All measurements have:

a) Magnitude.

b) Uncertainty.

c) Units.

Numbers:

Mathematics is based on numbers.

Exact numbers are obtained by:

a) Counting.

b) Definition.

Experimental Techniques

"Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it."

H. James Harrington

Born 1929

Author, Engineer, Entrepreneur

Experimental Techniques

Enduring Understandings

- Interactions with the environment need to be quantified.
- Matter and energy need to be measured / quantified in order to be understood.
- Measurement has uncertainties.

Experimental Techniques

Essential Questions

- Is precision always possible / necessary?
- In what ways do scientists influence what they are measuring?
- Can everything in the natural world be measured?

Experimental Techniques

What is accuracy and what is precision? Are they the same?

Experimental Techniques

Accuracy

Accuracy is how *close* to the *true value* a given measurement is.

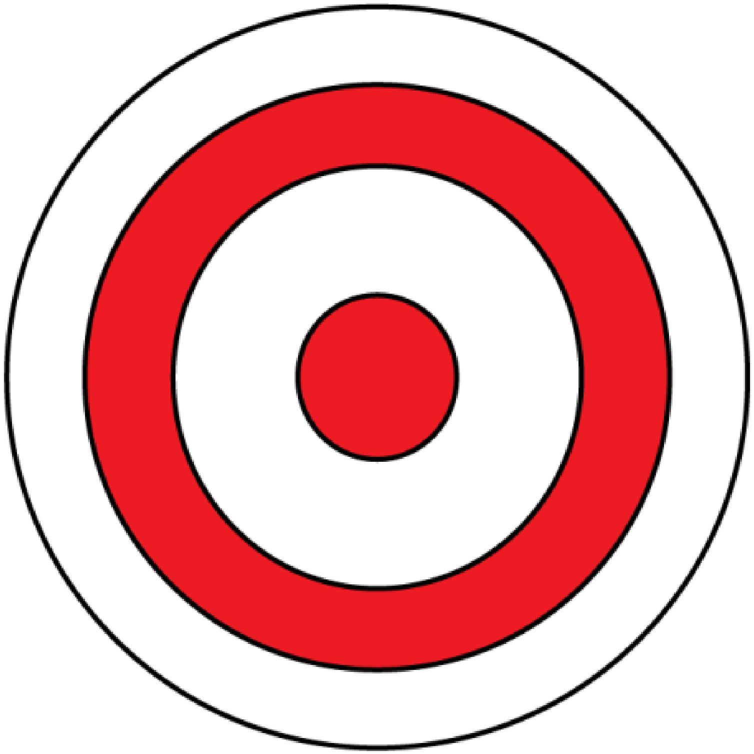
Experimental Techniques

Precision

Precision is how *closely* two measurements of the same quantity *come to each other*.

Experimental Techniques

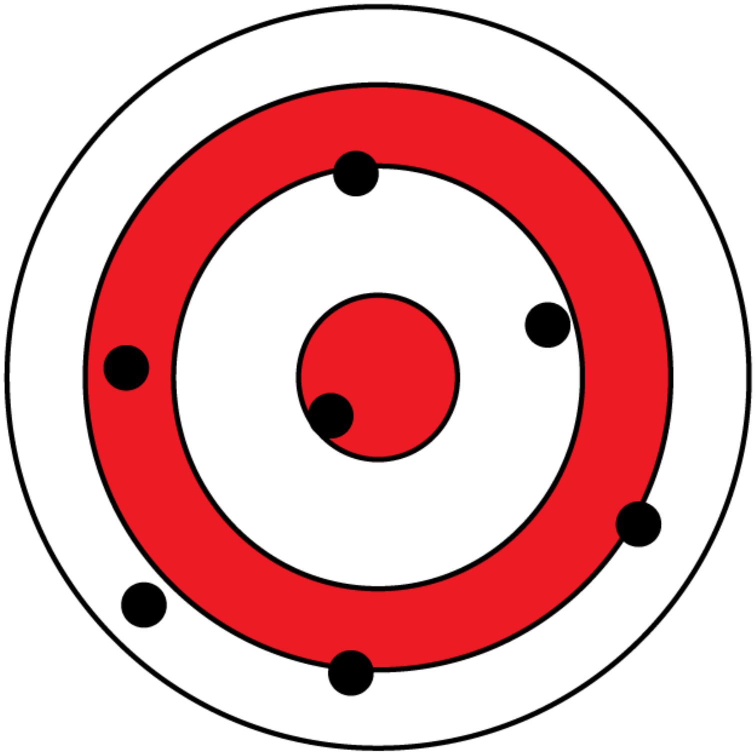
- Low Accuracy
- Low Precision



- If you had seven arrows and you fired them at the target with *low accuracy* and *low precision*, what would it look like?

Experimental Techniques

- Low Accuracy
- Low Precision



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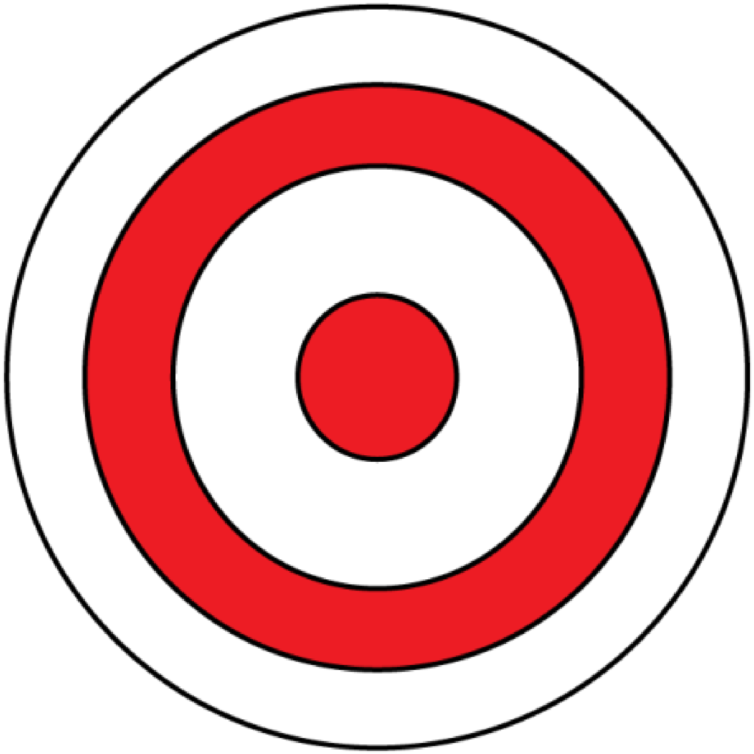
Experimental Techniques

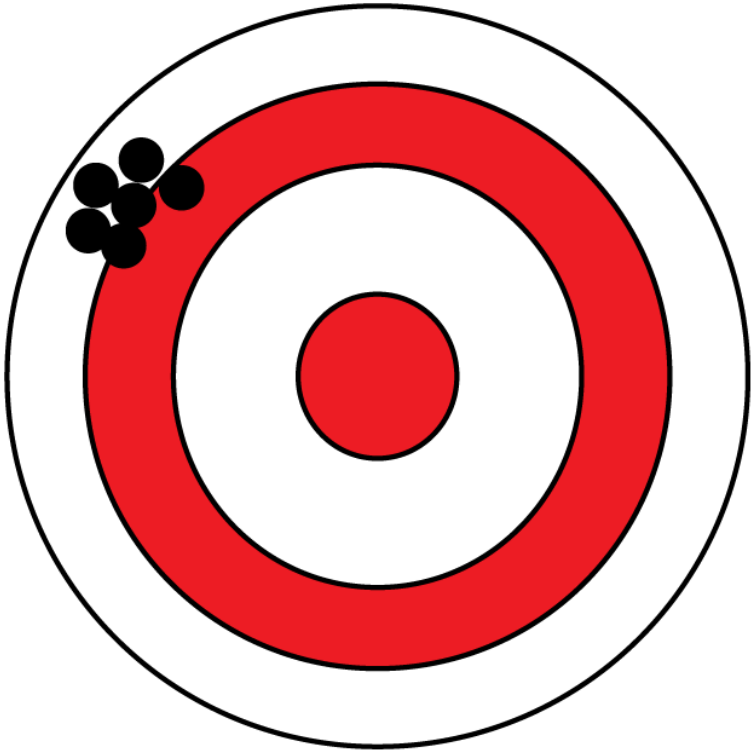
- Low Accuracy
- High Precision



- If you had seven arrows and you fired them at the target with *low accuracy* and *high precision*, what would it look like?

Experimental Techniques

- Low Accuracy
- High Precision



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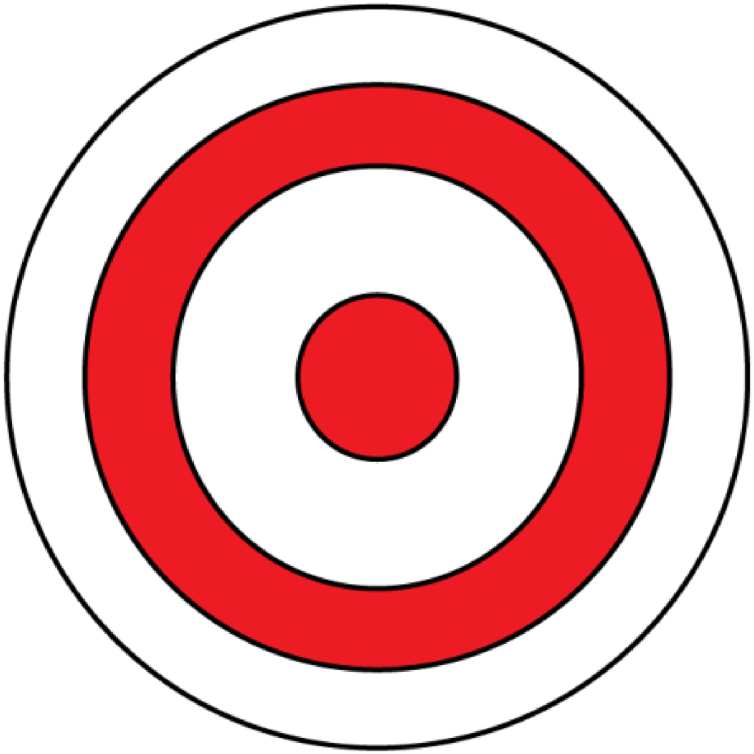
Experimental Techniques

- High Accuracy

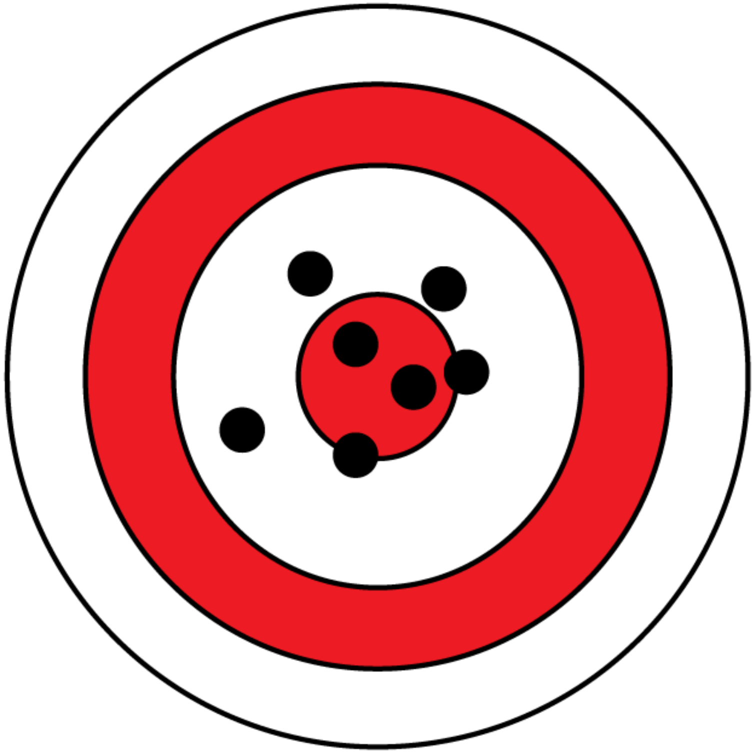
- Low Precision



- If you had seven arrows and you fired them at the target with *high accuracy* and *low precision*, what would it look like?

Experimental Techniques

- High Accuracy
- Low Precision



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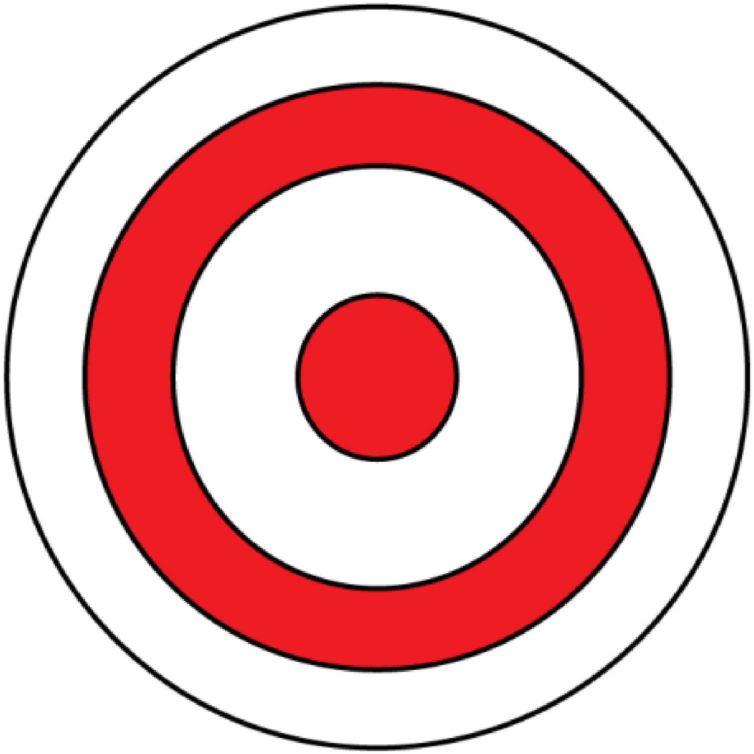

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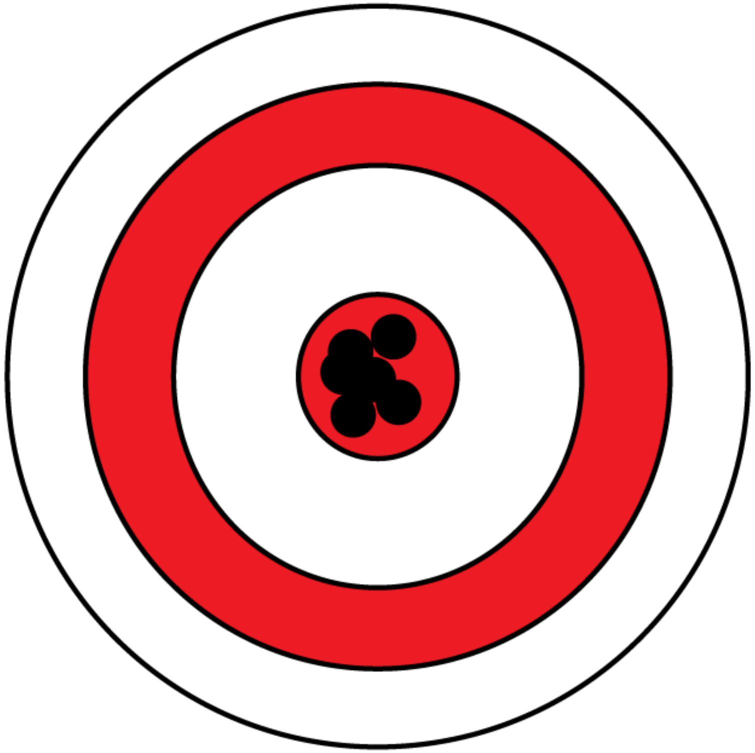


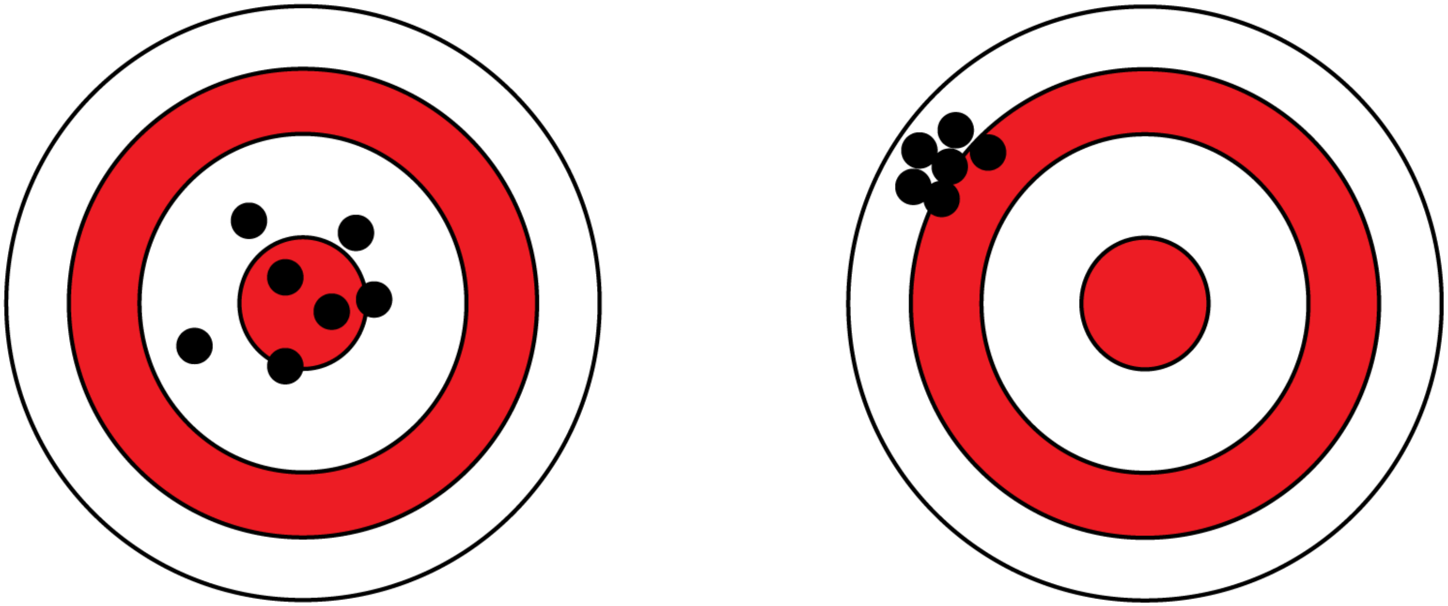
- If you had seven arrows and you fired them at the target with *high accuracy* and *high precision*, what would it look like?

Experimental Techniques

In science, is it more important to be accurate or precise?

Experimental Techniques

- It is better to be accurate rather than precise.



- It is better to be close to the true value…

…rather than have lots of similar values that are misleading.

Experimental Techniques

What units should I use when I record my measurements?

Experimental Techniques

Variable	SI Unit	Common Unit
Amount of Substance	mole mol	mole mol
Concentration	moles per decimetre cubed mol/dm^3	moles per decimetre cubed mol/dm^3
Density	kilograms per cubic metre kg/m^3	grams per cubic centimetre g/cm^3
Length	metre m	centimetre cm
Mass	kilogram kg	grams g
Temperature	Kelvin K	degrees Celsius °C
Time	second s	second s
Volume	cubic metre m^3	cubic centimetre cm^3

Experimental Techniques

What apparatus is commonly used in the Chemistry lab to make measurements?

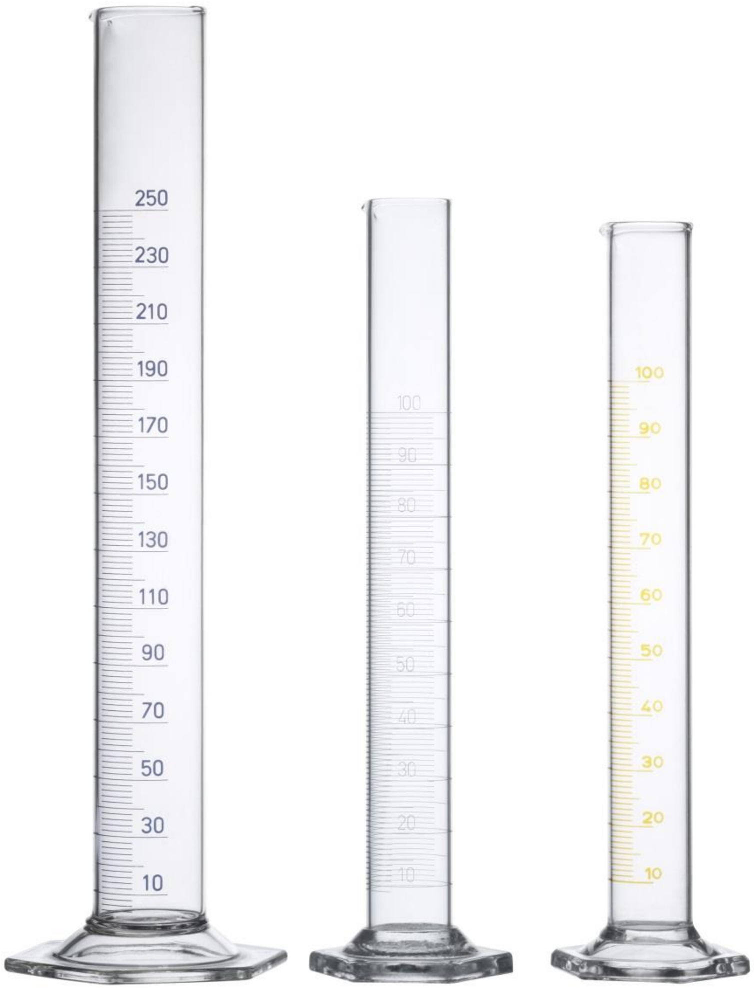
Experimental Techniques

- Electronic Balance.
- Readings taken to two decimal places.
- *e.g.*
  254.27 g
  254.28 g

Experimental Techniques

- Thermometer.
- Readings taken to $\pm$ 0.5 °C.
- e.g.
  42.0 °C
  42.5 ° C

Experimental Techniques



- Measuring Cylinder.
- Readings taken to nearest whole cm^3.
- e.g.
  57.0 cm^3
  58.0 cm^3

Experimental Techniques

- Burette
- Readings taken to ± 0.05 cm^3.
- e.g.
  26.05 cm^3
  26.10 cm^3

Experimental Techniques

- Analogue Stopwatch
- Readings taken to ± 1 s.
- e.g.
  15 s
  16 s

Experimental Techniques

- Digital Stopwatch
- Readings taken to ± 1 s.
- e.g.
  37 s
  38 s

Experimental Techniques

Which stopwatch is more accurate and precise, the analogue or the digital?

Experimental Techniques

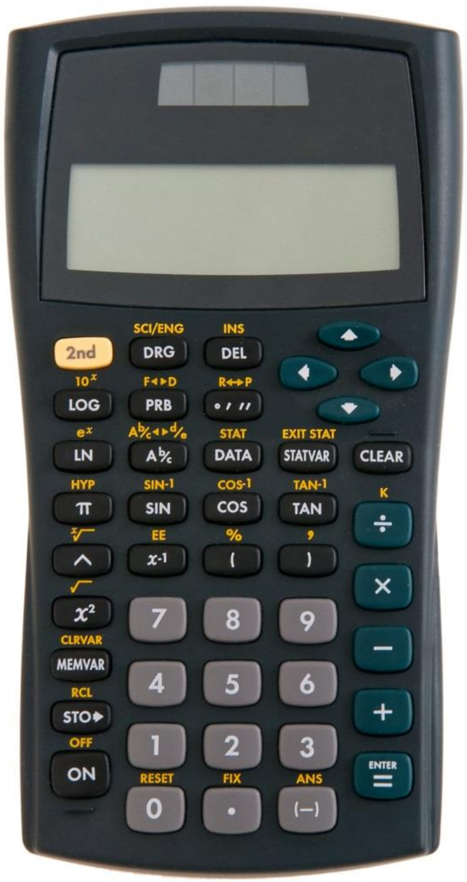
Which stopwatch is more accurate and precise, the analogue or the digital?

- It all depends upon how accurate and precise *you* are starting and stopping the stopwatch.

Experimental Techniques

What about calculations based upon the results from my experiments?

Experimental Techniques



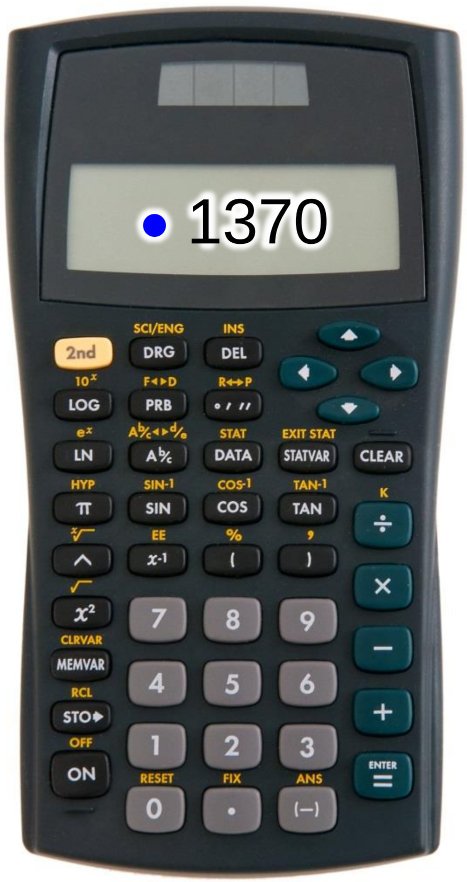
- Calculations should be done using *decimal notation*, not fractions.

- Calculated answers should be given to *three significant figures* (3 s.f.).

- **Note:** Results taken from scientific apparatus follow the number of decimal places for that particular apparatus.

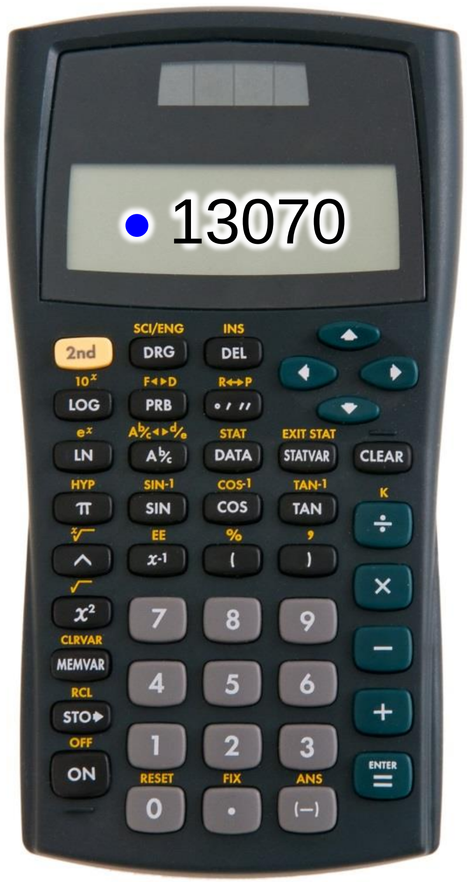
- Answers should include *units*. The only exception is an answer that comes from a ratio. Ratios do not have units.

Experimental Techniques



- This number is recorded to *three* significant figures.

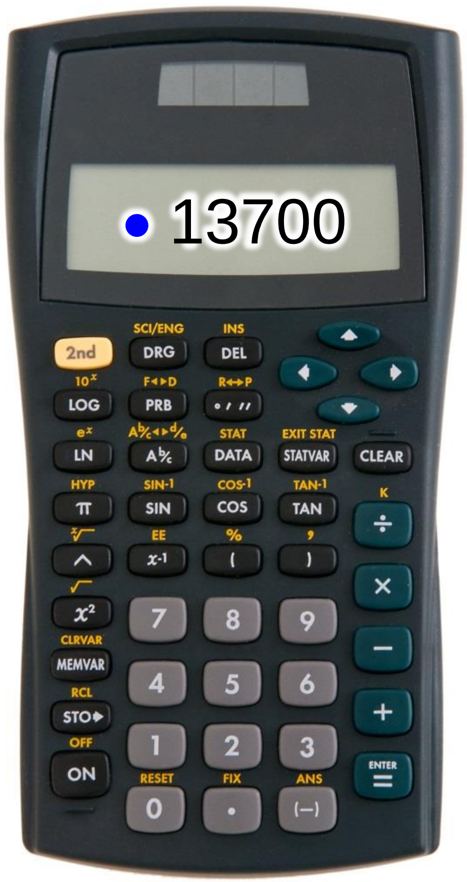
Experimental Techniques



- 13070

- This number is recorded to *four* significant figures.
- It should be recorded as *13100* to *three* significant figures.

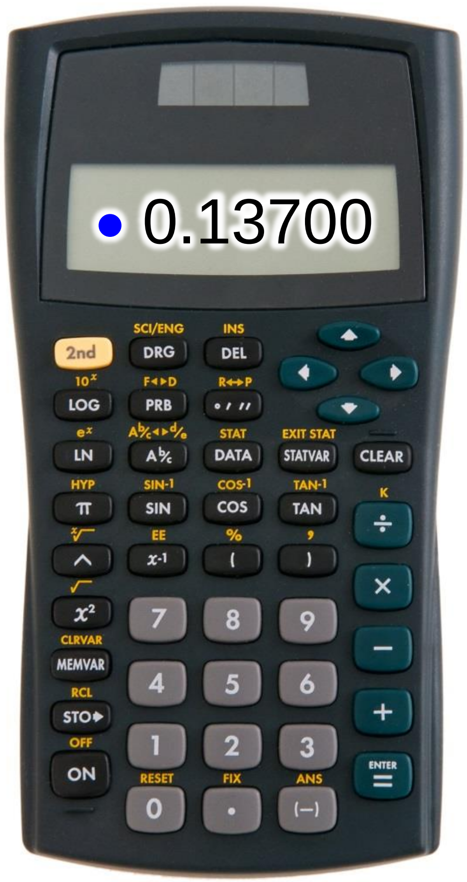
Experimental Techniques



- 13700

- This number is recorded to *three* significant figures.

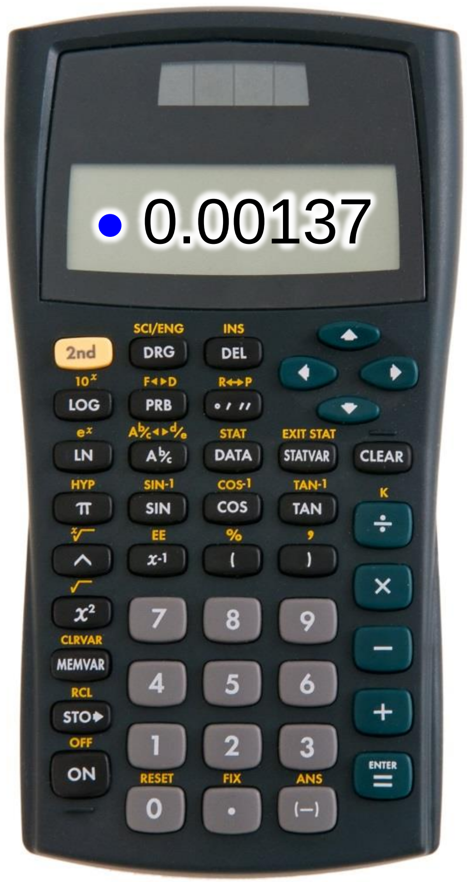
Experimental Techniques



- 0.13700

- This number is recorded to *five* significant figures.
- It should be recorded as *0.137* to *three* significant figures.

Experimental Techniques



- 0.00137

- This number is recorded to *three* significant figures.

Experimental Techniques

Can I please review some experimental techniques in Chemistry?

Experimental Techniques







Experimental Techniques

Corrosive

Dangerous to the Environment

Explosive

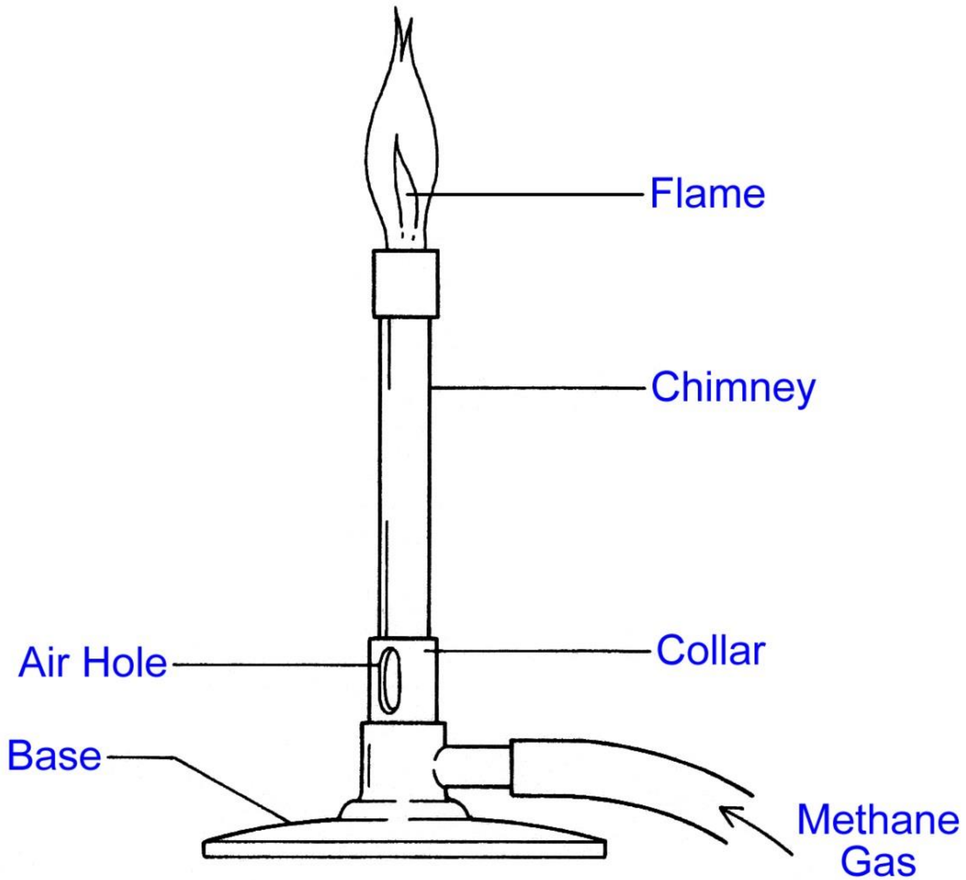
Flammable

Harmful / Irritant

Oxidising

Toxic

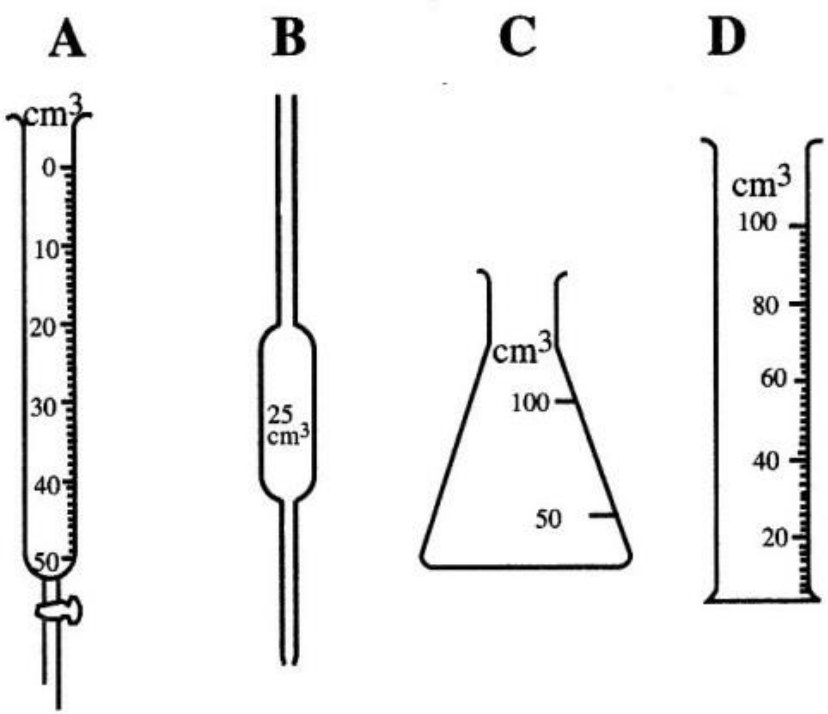
Experimental Techniques



Correct use of a Bunsen Burner:

- Before lighting the Bunsen burner, ensure that the air hole is *closed*.
- *Open* the air hole and use the non-luminous / blue flame for heating.
- *Never* use the luminous / yellow flame for heating, it is a relatively low temperature dirty / sooty flame.
- For safety, always *close the air hole* when the Bunsen burner is not in use. The luminous / yellow flame is highly visible.

Experimental Techniques



A is a *burette* which can measure between 0.0 cm^3 and 50.0 cm^3 of a solution to *$\pm$0.05 cm^3*.

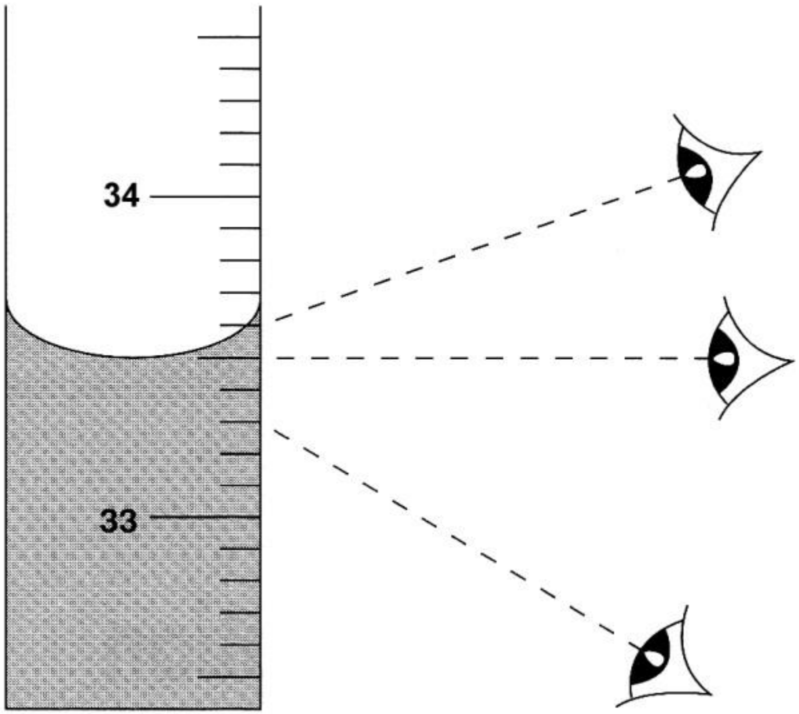
B is a *volumetric pipette* which is used to measure *exactly 25.0 cm^3* of a solution, and nothing else.

C is a *conical flask* which can be used to measure *approximately* 50 cm^3 and 100 cm^3 of a solution.

D is a *measuring cylinder* which can measure between 0 cm^3 and 100 cm^3 a solution to the *nearest whole cubic centimetre*.

Experimental Techniques

- At what level should your eyes be located when taking measurements from glassware?



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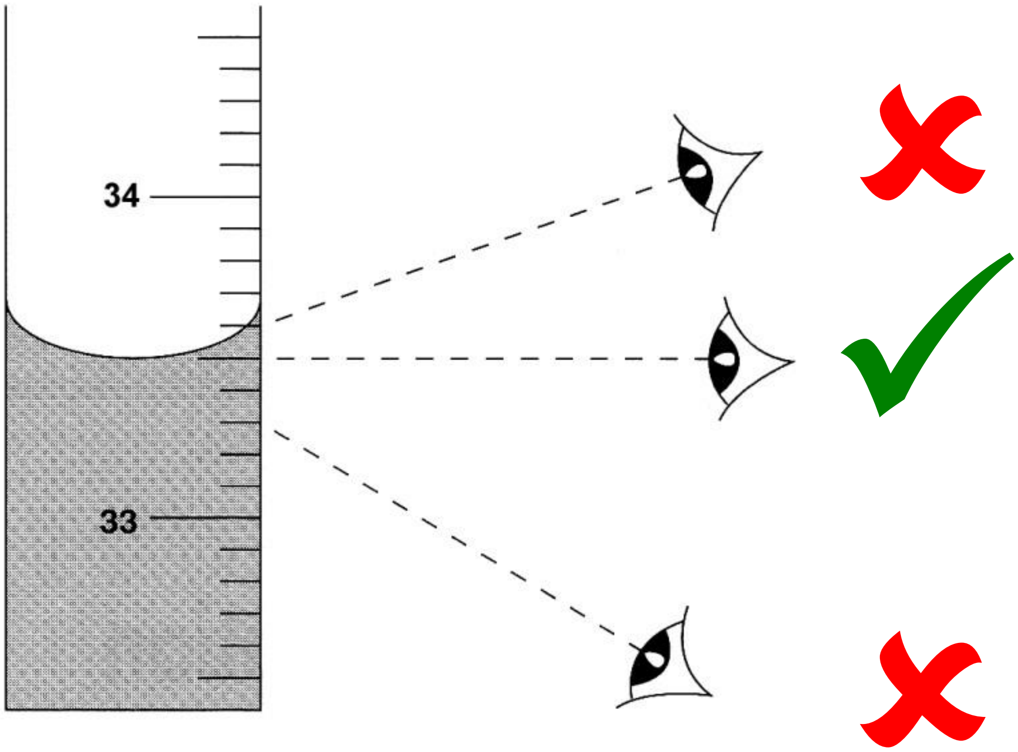
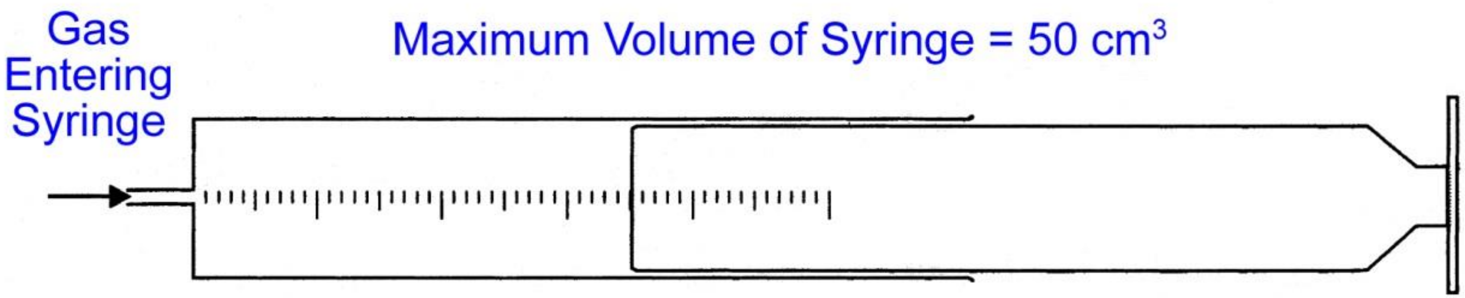


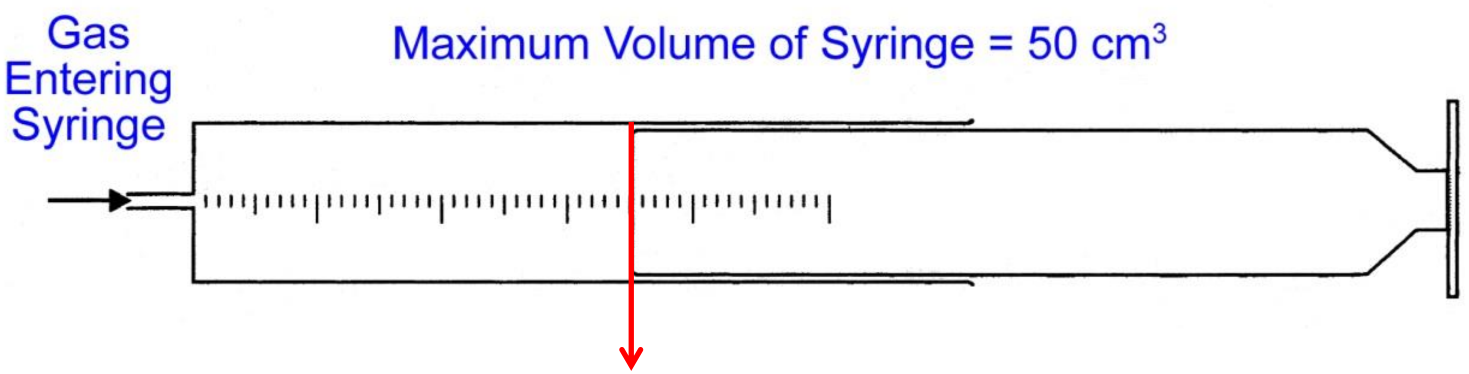
Experimental Techniques

- What volume of gas is contained inside the syringe?



Experimental Techniques

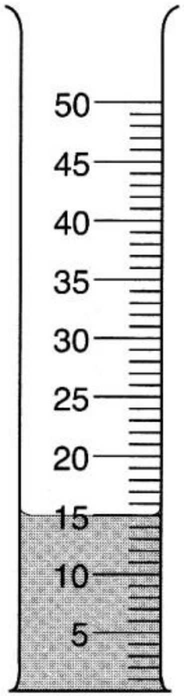
- What volume of gas is contained inside the syringe?

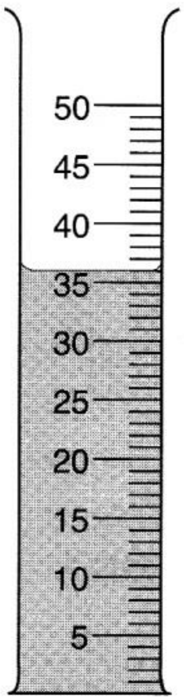


35.0 cm^3

Experimental Techniques

- What volume of solution does each of the measuring cylinders contain?





Experimental Techniques

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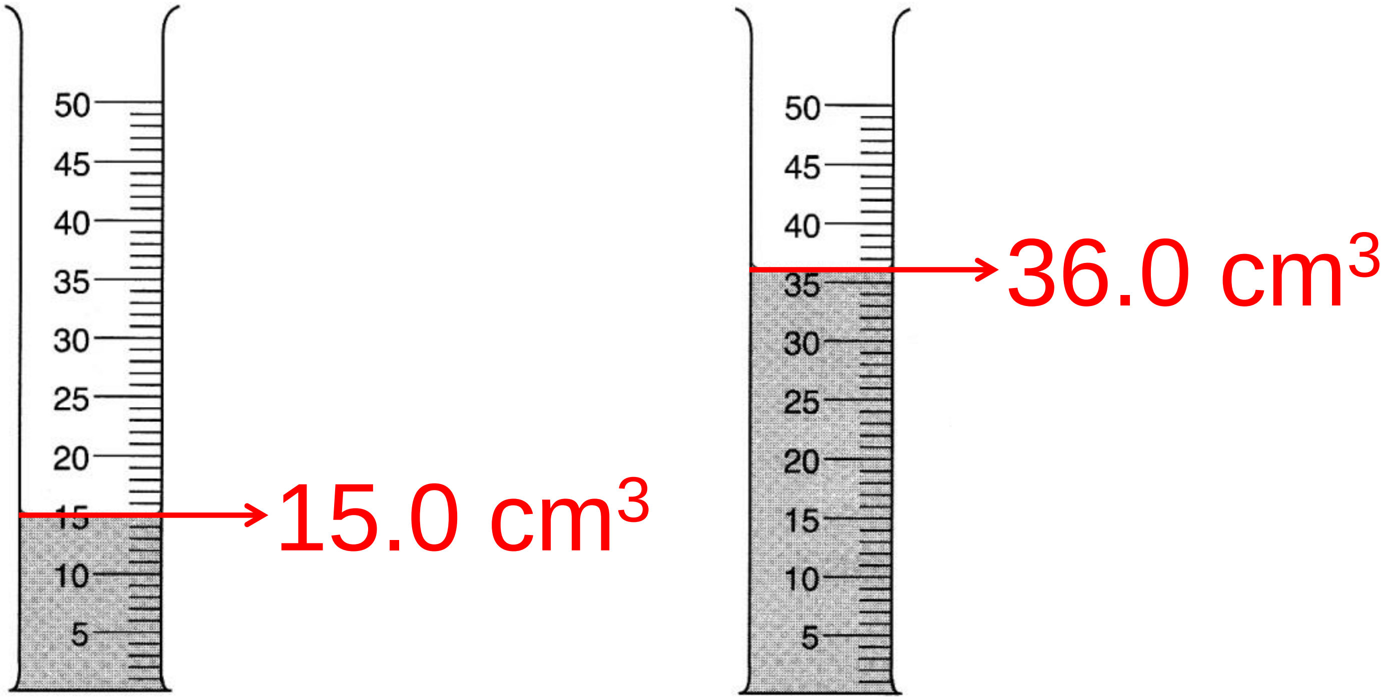


Experimental Techniques

What are dependent, independent and control variables?

Experimental Techniques

Independent Variable

- An *independent* variable is the variable that is changed or manipulated in an experimental study to explore its effects. It is called *independent* because it is not influenced by any other variables in the study.

Experimental Techniques

Dependent Variable

- A *dependent* variable is the variable that changes as a result of the *independent* variable's manipulation. It is the outcome the researcher is interested in measuring, and it *depends* on the independent variable.

Experimental Techniques

Control Variable

- A *control variable* is anything that is *kept constant* across all experiments as the *independent variable* is changed. The control variable is not of interest to the experiment's aims, but is controlled because it could influence the results.

Experimental Techniques

Example One:

- A students wants to determine how the temperature of the water affects how much salt can dissolve in it.

- Independent Variable:

- Dependent Variable:

- Control Variables:

Experimental Techniques

Example One:

- A students wants to determine how the temperature of the water affects how much salt can dissolve in it.

- Independent Variable: The temperature of the water, *e.g.* 40 °C, 50 °C and 60 °C.

- Dependent Variable: The mass in grams of salt that dissolves in the water at each given temperature.

- Control Variables: The volume of water used, the number of times the solution is stirred.

Experimental Techniques

Example Two:

- A students wants to investigate how the amount of fertiliser added to soil affects the growth of tomato plants.

- Independent Variable:

- Dependent Variable:

- Control Variables:

Experimental Techniques

Example Two:

- A students wants to investigate how the amount of fertiliser added to soil affects the growth of tomato plants.
- Independent Variable: The mass in grams of fertiliser added to the soil, *e.g.* 2.5 g, 5.0 g and 7.5 g.
- Dependent Variable: The rate at which the tomato plants grow, *e.g.* centimetres per week.
- Control Variables: The mass of soil used to grow the plants, the volume of water used to water the plants, the amount of sunlight the plants receive.

Experimental Techniques

Example Three:

- A students wants to investigate which type of material is the best conductor of heat.

- Independent Variable:

- Dependent Variable:

- Control Variables:

Experimental Techniques

Example Three:

- A students wants to investigate which type of material is the best conductor of heat.

- Independent Variable: Rods or bars made of different materials, *e.g.* copper, glass, plastic.

- Dependent Variable: Time in seconds that it takes a piece or wax at one end of the bar to melt when the opposite end of the bar is placed in boiling water.

- Control Variables: The length of the bar, diameter of the bar, temperature of the surrounding air in the laboratory.

Experimental Techniques

What are the different ways of collecting and drying gases in the laboratory?

Experimental Techniques

- In order to determine the best way of collecting and drying a gas in the laboratory, three things must first be known about the gas:

1. The *solubility* of the gas in water.

- Gases that are *very soluble* in water cannot be collected by the *downward displacement of water*.

- Gases that are very soluble in water include ammonia, NH_3(g), and hydrogen chloride, HC*l*(g).

Experimental Techniques

- In order to determine the best way of collecting and drying a gas in the laboratory, three things must first be known about the gas:

2. The *density* of the gas – relative to air.

- Air is approximately *1* % argon, *78* % nitrogen and *21* % oxygen.

The relative atomic mass of Ar(g) = *40.0*

The relative molecular mass of N_2(g) = 14.0 + 14.0 = *28.0*

The relative molecular mass of O_2(g) = 16.0 + 16.0 = *32.0*

The "relative molecular mass" of air is therefore…

$((1 \times 40) + (78 \times 28) + (21 \times 32)) \div 100 =$ *29.0 (3 s.f.)*

Experimental Techniques

- In order to determine the best way of collecting and drying a gas in the laboratory, three things must first be known about the gas:

2. The *density* of the gas – relative to air.

- The relative molecular mass of CO_2(g) = 12.0 + 16.0 + 16.0 = *44.0*

Since *44.0* > *29.0*, CO_2(g) is *more dense* than air.
CO_2(g) can be collected by *downward delivery*.

- The relative molecular mass of NH_3(g) = 14.0 + 1.0 + 1.0 + 1.0 = *17.0*

Since *17.0* < *29.0*, NH_3(g) is *less dense* than air.
NH_3(g) can be collected by *upward delivery*.

Experimental Techniques

• In order to determine the best way of collecting and drying a gas in the laboratory, three things must first be known about the gas:

3. The *acid* / *base nature* of the gas.

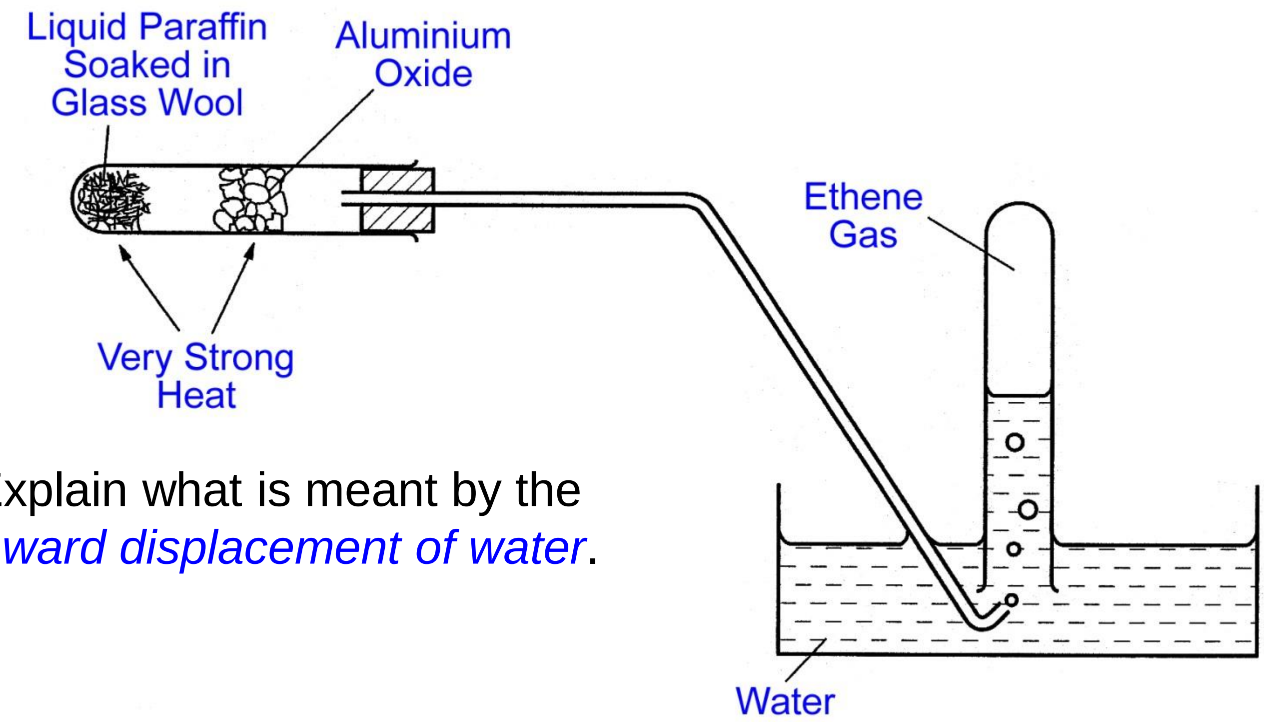
• Gases that are *acidic* in nature, *e.g.* HC*l*(g) and SO_2(g), must be dried* using an *acidic* drying agent. The most common acidic drying agent is *concentrated sulfuric acid*.

• Gases that are *basic* in nature, *e.g.* NH_3(g), must be dried* using a *basic* drying agent. The most common basic drying agent is powdered anhydrous *calcium oxide*.

***Note**: Water vapour may be an impurity that must be removed from a gas.

Experimental Techniques

- The apparatus below is used to collect a gas by the *downward displacement of water* *.

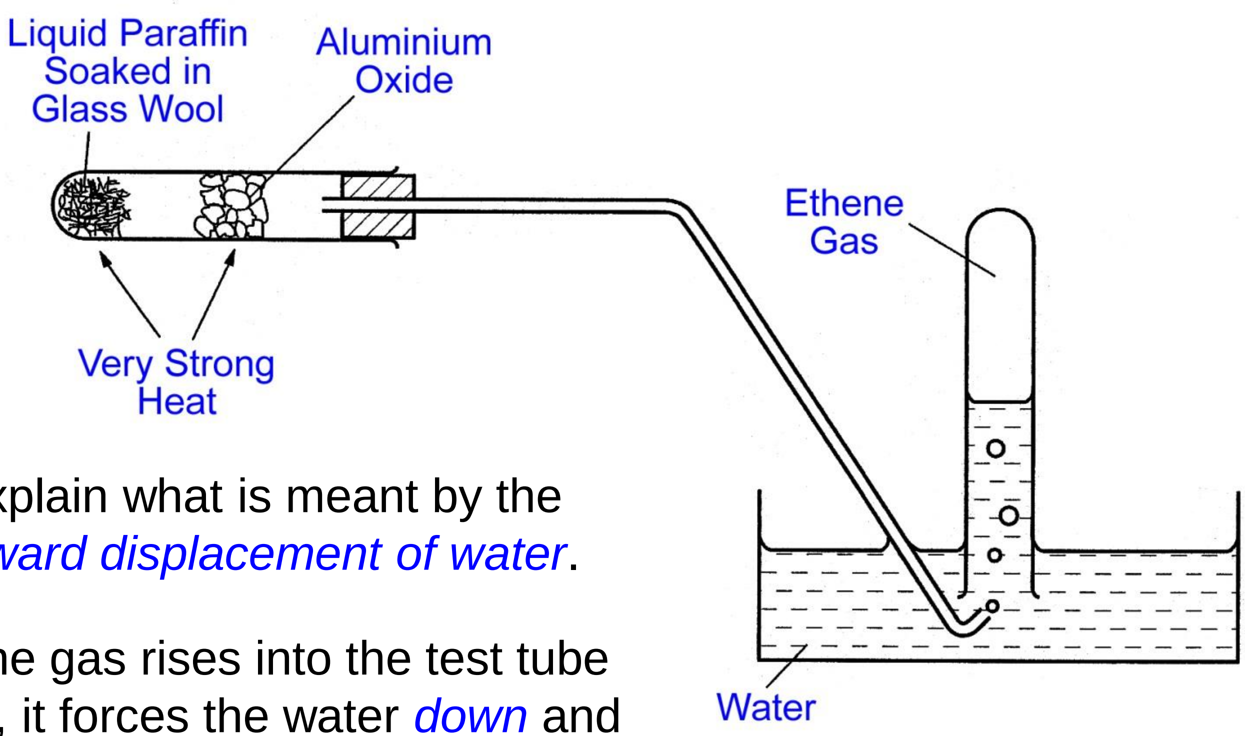


Q: Explain what is meant by the *downward displacement of water*.

***Note**: The downward displacement of water *cannot* be used to collect a gas that must be *dry*!

Experimental Techniques

- The apparatus below is used to collect a gas by the *downward displacement of water* *.



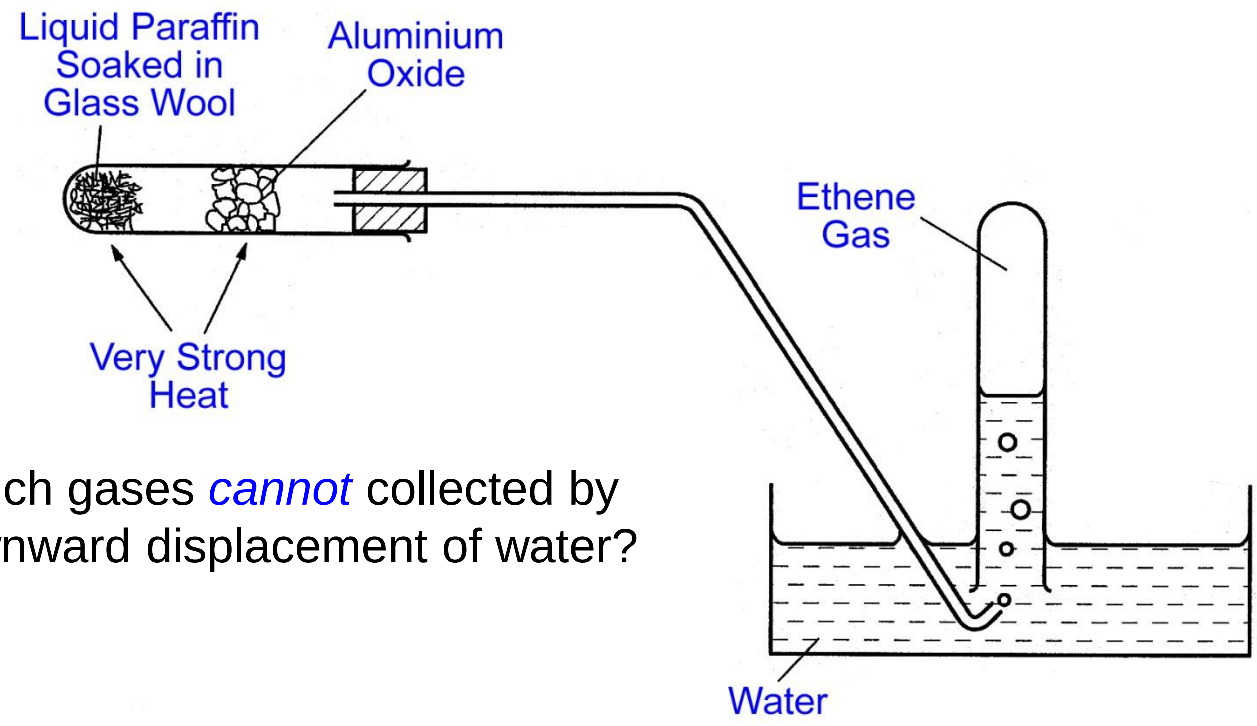
Q: Explain what is meant by the *downward displacement of water*.

A: As the gas rises into the test tube of water, it forces the water *down* and *out* of the test tube.

*__Note__: The downward displacement of water *cannot* be used to collect a gas that must be *dry*!

Experimental Techniques

- The apparatus below is used to collect a gas by the *downward displacement of water* *.



Q: Which gases *cannot* collected by the downward displacement of water?

***Note**: The downward displacement of water *cannot* be used to collect a gas that must be *dry*!

Experimental Techniques

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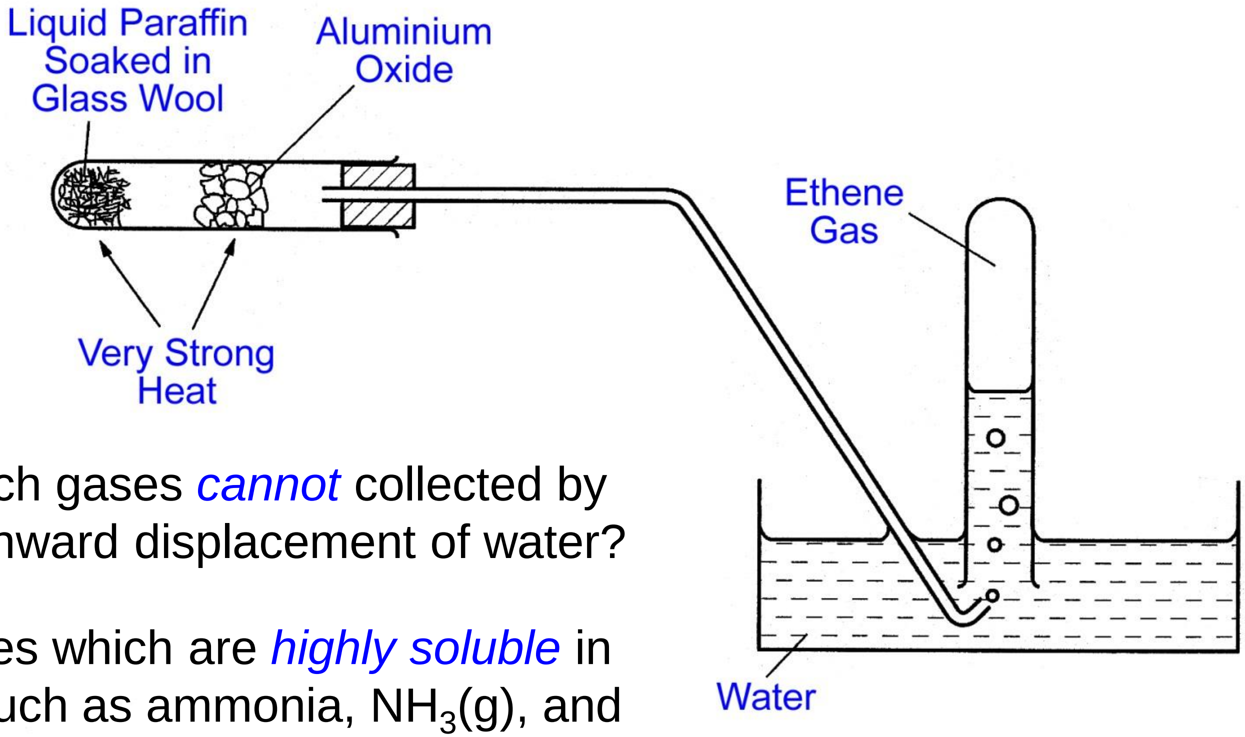


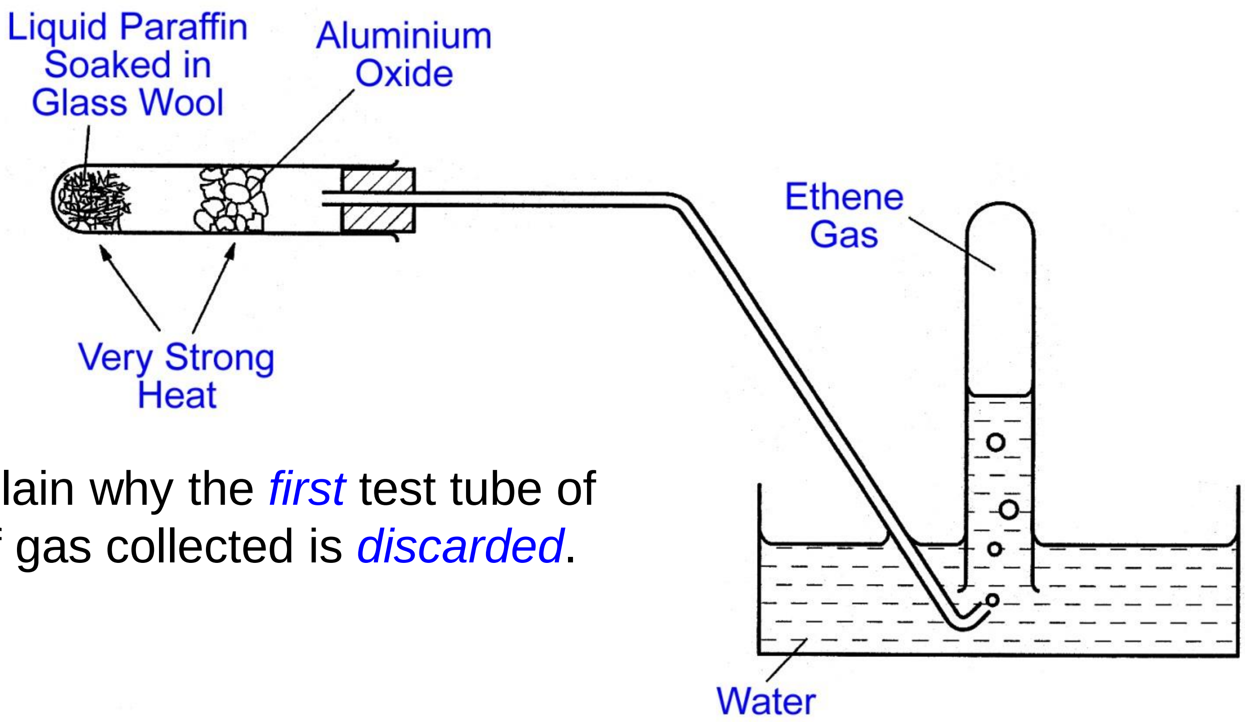
Q: Which gases *cannot* collected by the downward displacement of water?

A: Gases which are *highly soluble* in water, such as ammonia, $NH_3(g)$, and hydrogen chloride, $HCl(g)$.

***Note**: The downward displacement of water *cannot* be used to collect a gas that must be *dry*!

Experimental Techniques

- The apparatus below is used to collect a gas by the *downward displacement of water* *.

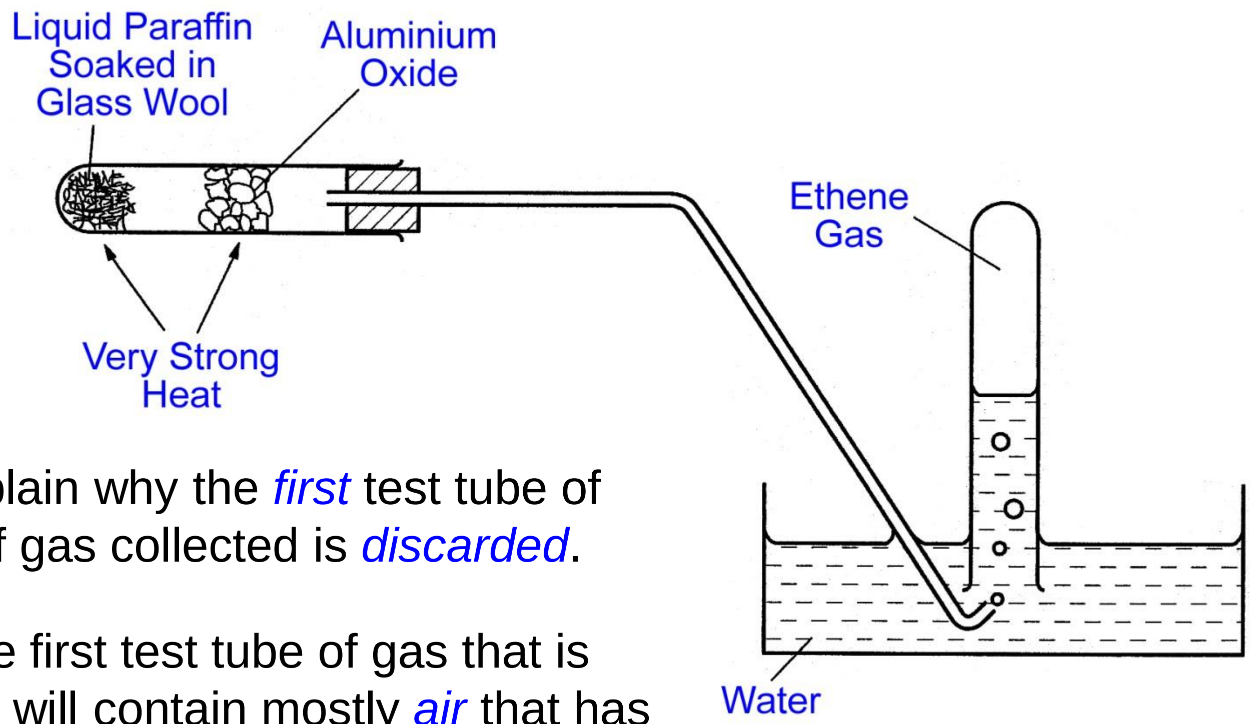


Q: Explain why the *first* test tube of gas of gas collected is *discarded*.

***Note**: The downward displacement of water *cannot* be used to collect a gas that must be *dry*!

Experimental Techniques

- The apparatus below is used to collect a gas by the *downward displacement of water* *.



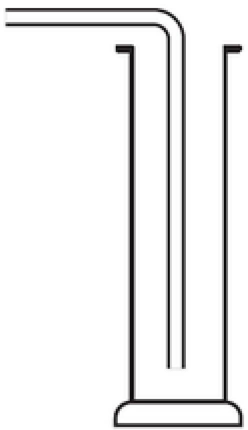
Q: Explain why the *first* test tube of gas of gas collected is *discarded*.

A: The first test tube of gas that is collected will contain mostly *air* that has been displaced from the apparatus.

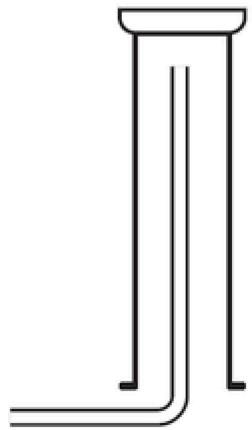
***Note**: The downward displacement of water *cannot* be used to collect a gas that must be *dry*!

Experimental Techniques

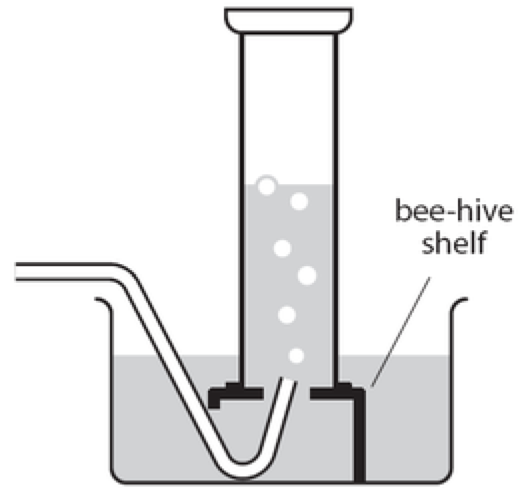
- The diagrams shown below summarise the different ways of collecting gases, based upon the properties of the gas.



downward delivery (upward displacement of air)



upward delivery (downward displacement of air)



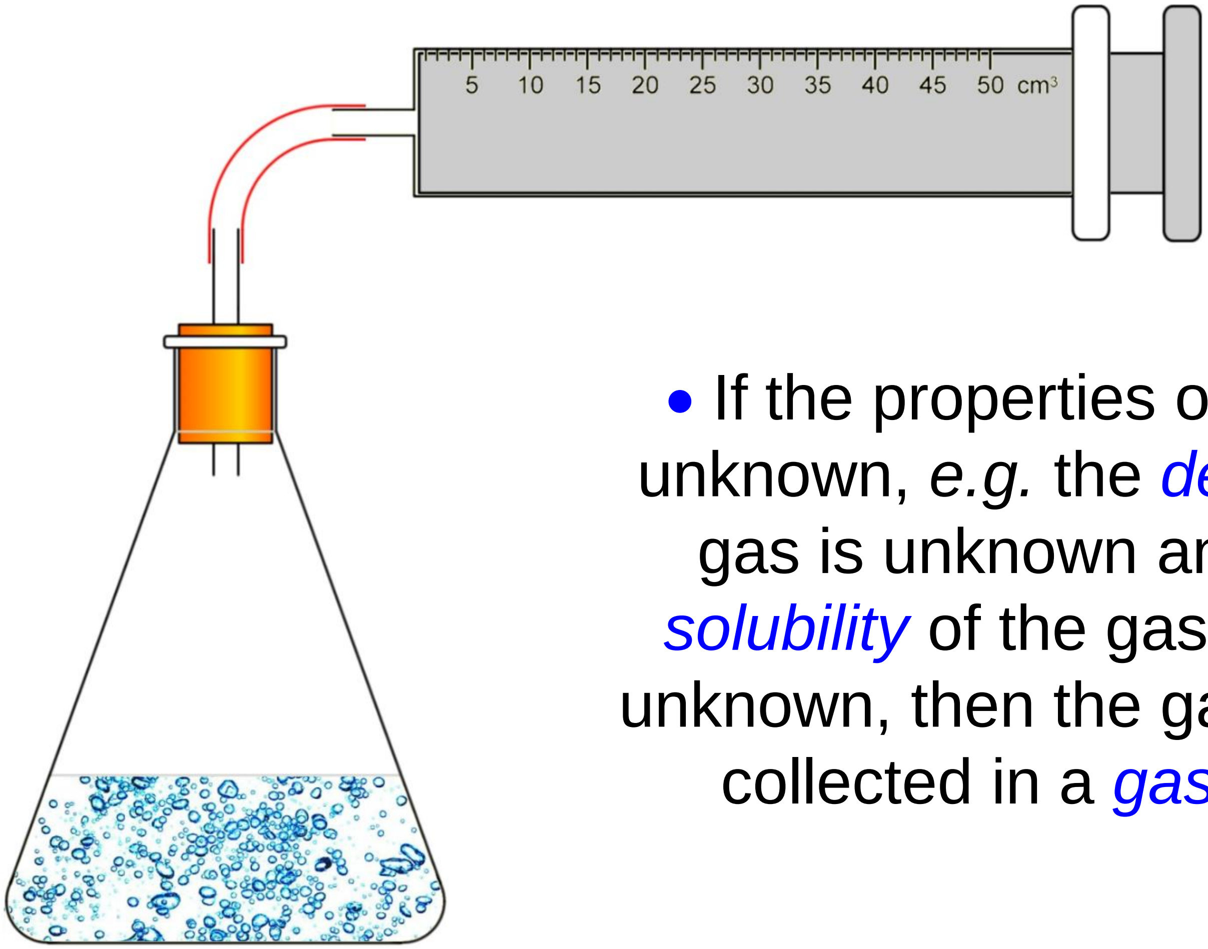
over water

- Collection of a gas that is more dense than air, *e.g.* CO_2(g).

- Collection of a gas that is less dense than air, *e.g.* H_2(g).

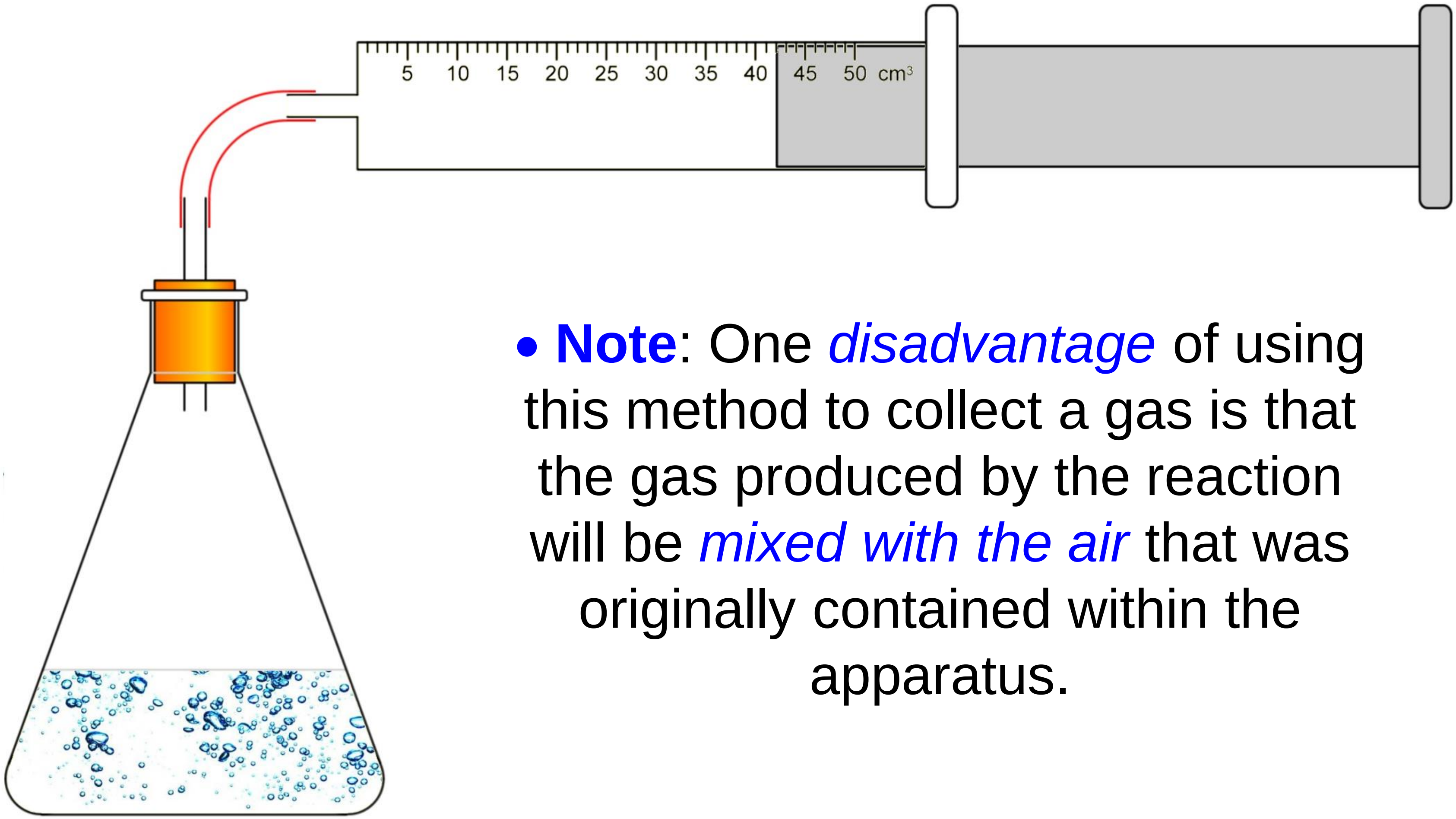
- Collection of a gas that is insoluble in water, *e.g.* CH_4(g).

Experimental Techniques



- If the properties of a gas are unknown, *e.g.* the *density* of the gas is unknown and / or the *solubility* of the gas in water is unknown, then the gas should be collected in a *gas syringe*.

Experimental Techniques



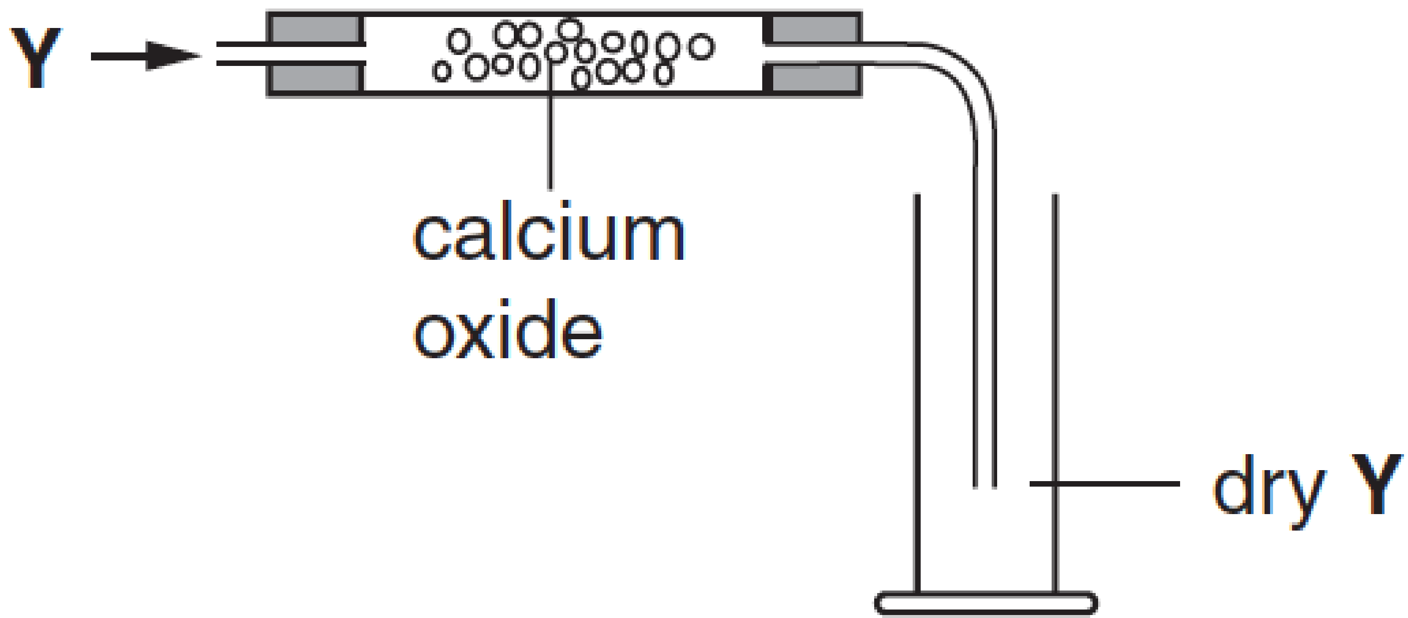
- **Note**: One *disadvantage* of using this method to collect a gas is that the gas produced by the reaction will be *mixed with the air* that was originally contained within the apparatus.

Experimental Techniques

- Essential understanding: Acids and bases (or alkalis) react together. Consequence…
- Acidic gases, *e.g.* Cl_2(g), CO_2(g), HCl(g) and SO_2(g), must be dried using the acidic drying agent concentrated sulfuric acid – H_2SO_4.
- Alkaline gases, *e.g.* NH_3(g), must be dried using the basic drying agent powdered anhydrous calcium oxide – CaO.
- Neutral gases, *e.g.* H_2(g), N_2(g) and O_2(g), can be dried using either concentrated H_2SO_4 or anhydrous CaO.
- A general, all purpose, drying agent is anhydrous calcium chloride – $CaCl_2$ (but it *cannot* be used to dry *ammonia*!)

Experimental Techniques

- What are the essential properties of gas **Y**?



Experimental Techniques

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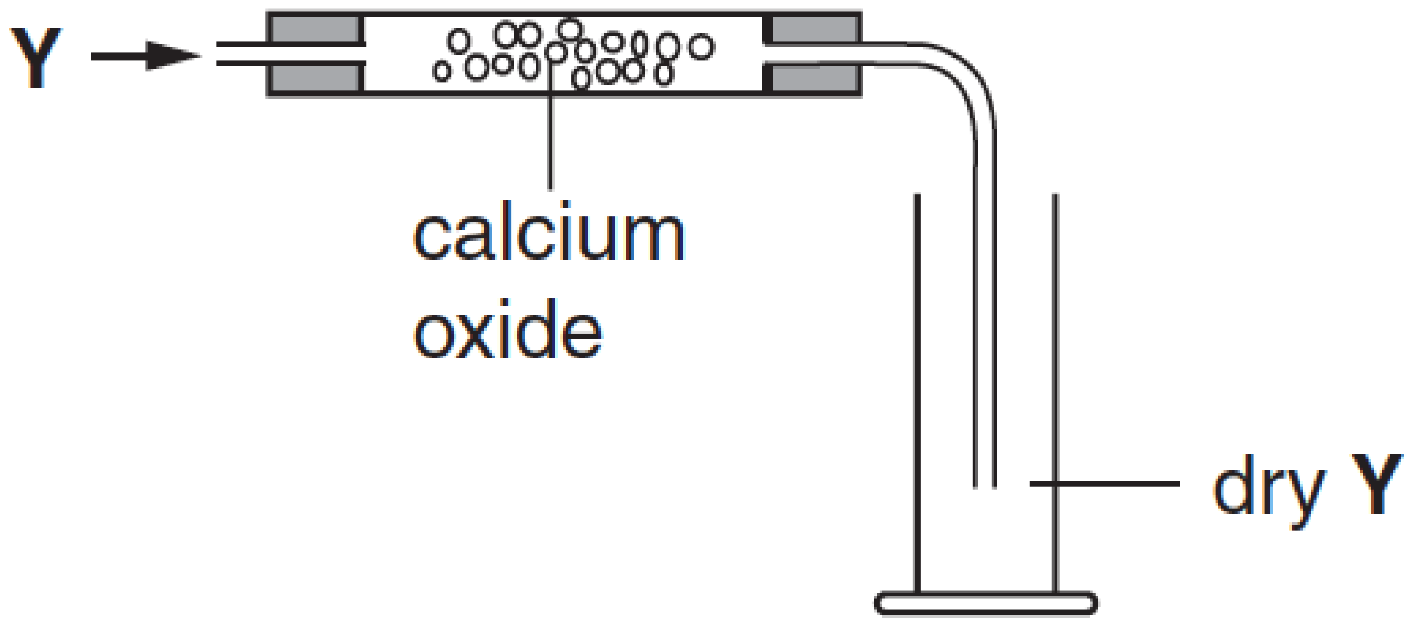

- **Y** is an *alkaline* or *neutral* gas that is *more dense* than air.

Experimental Techniques

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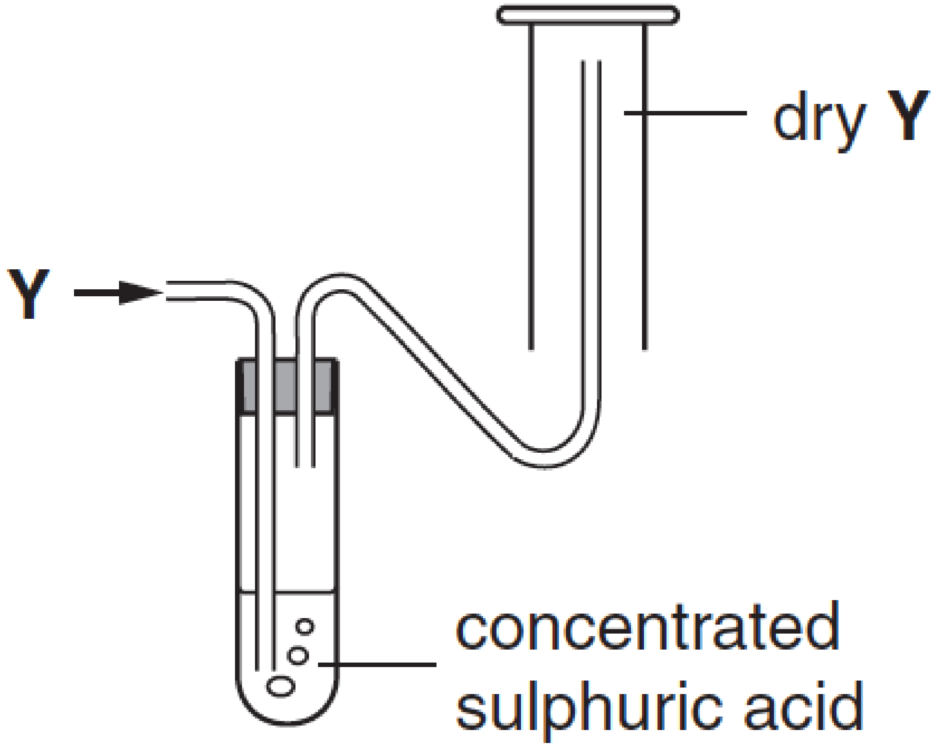

Experimental Techniques

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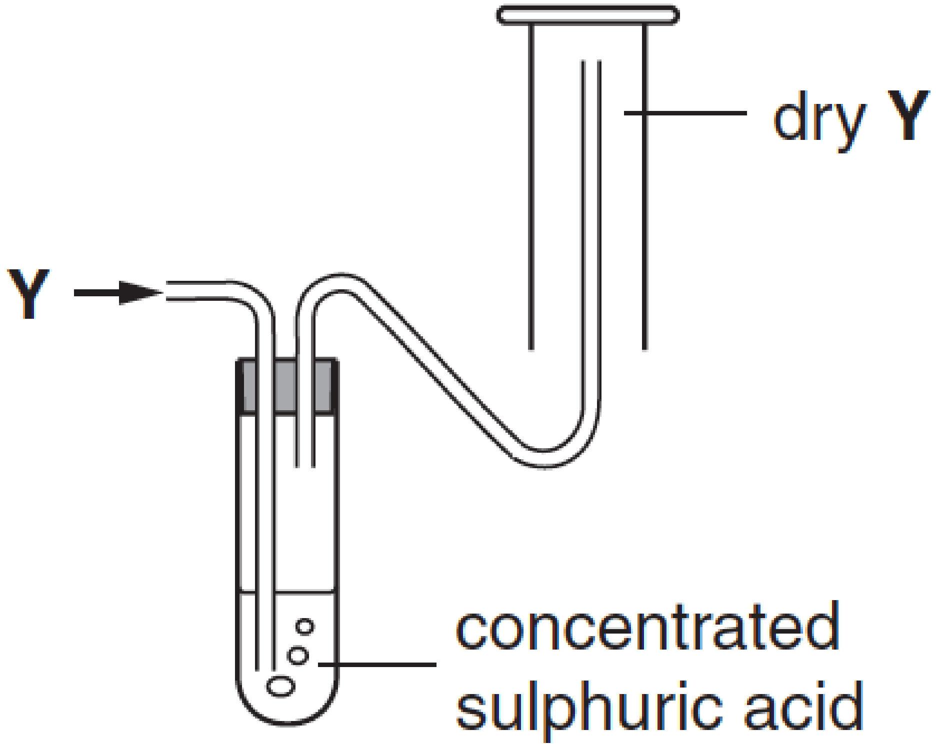

- **Y** is an *acidic* or *neutral* gas that is *less dense* than air.

Experimental Techniques

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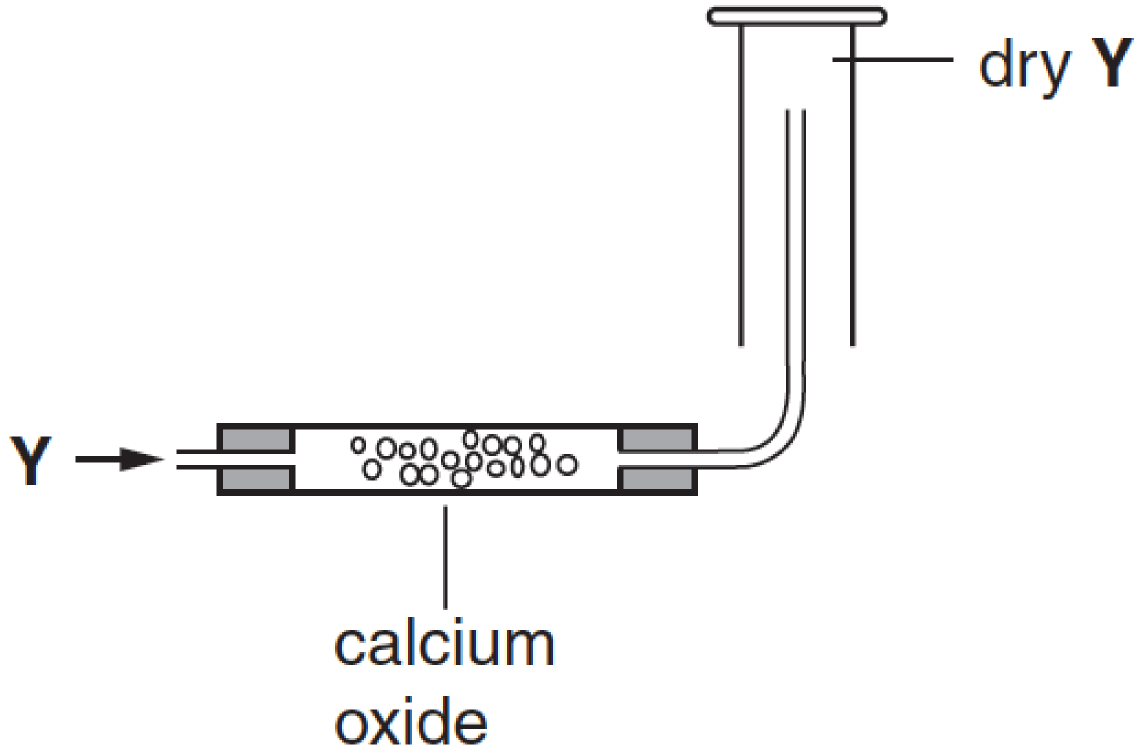

Experimental Techniques

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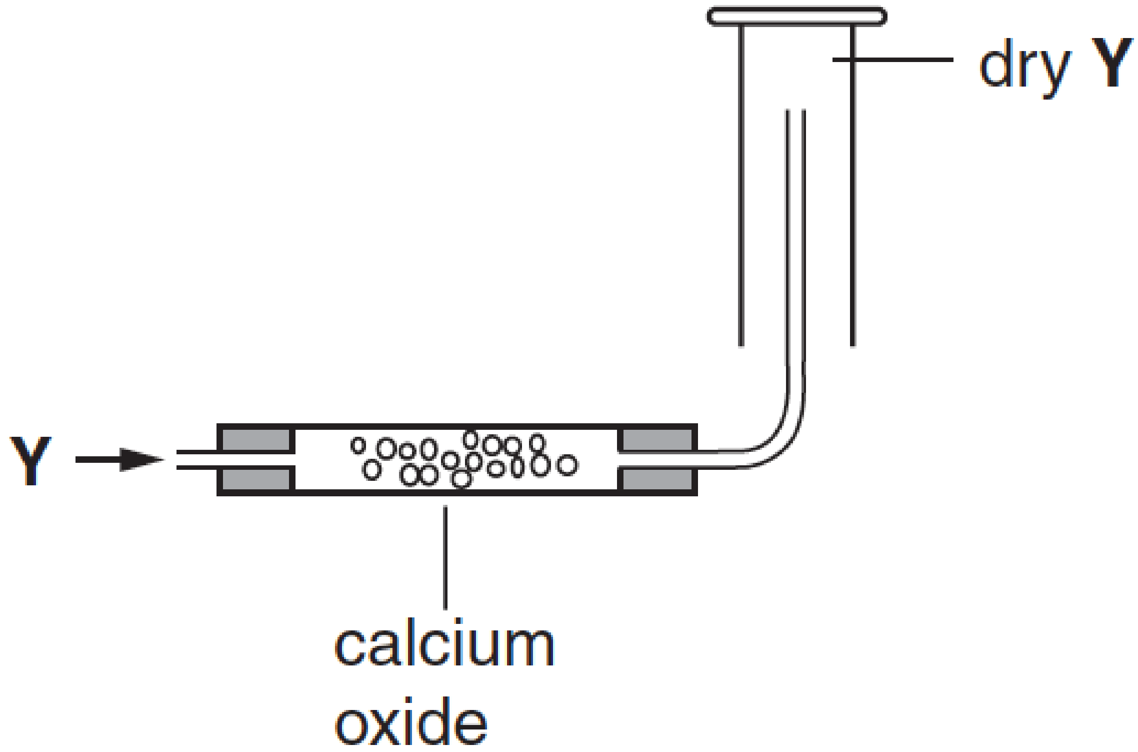
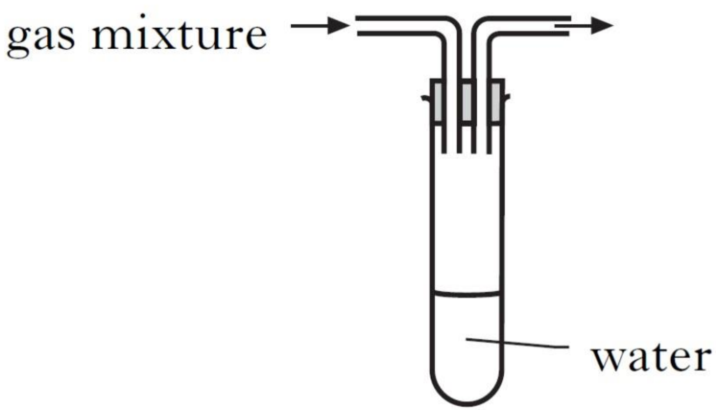
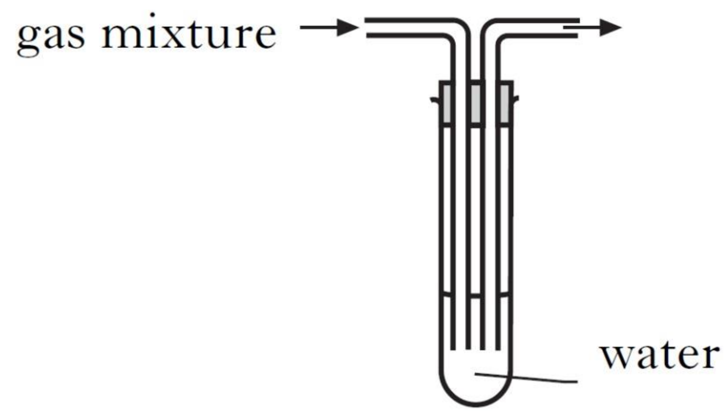


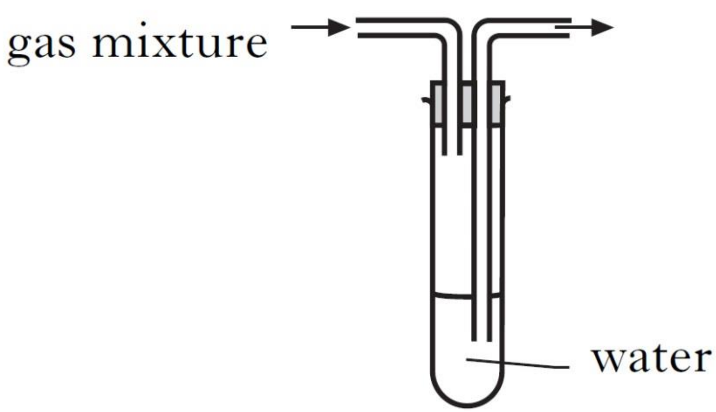
- **Y** is an *alkaline* or *neutral* gas that is *less dense* than air.

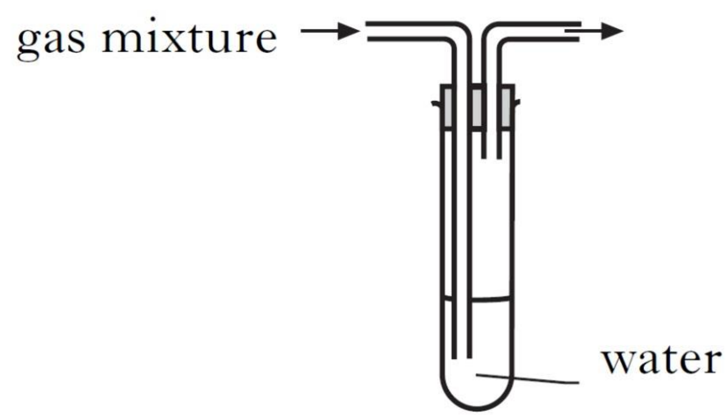
Experimental Techniques

- Which one of the following methods should be used to remove a water soluble impurity from a gaseous mixture?









Experimental Techniques

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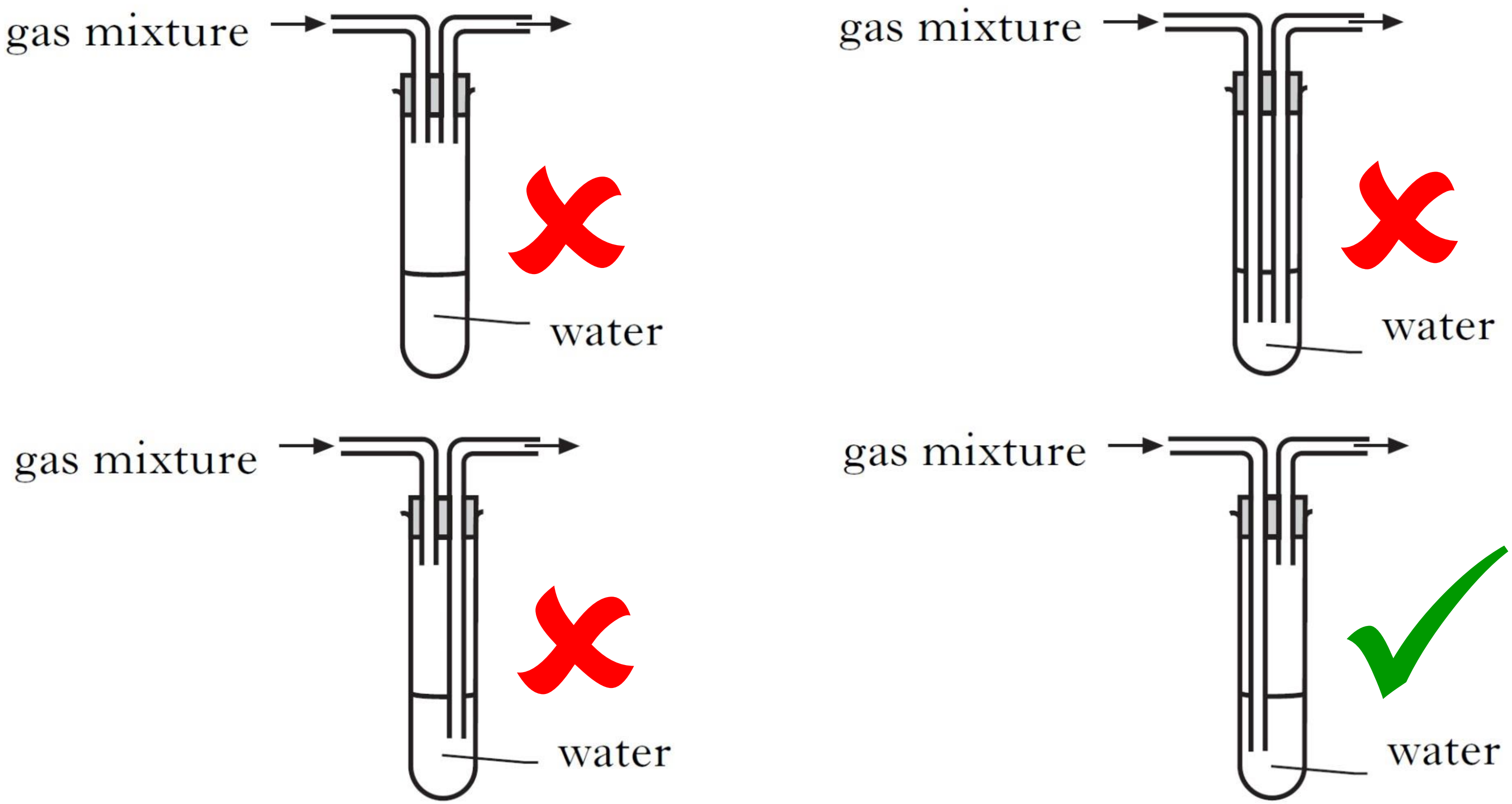
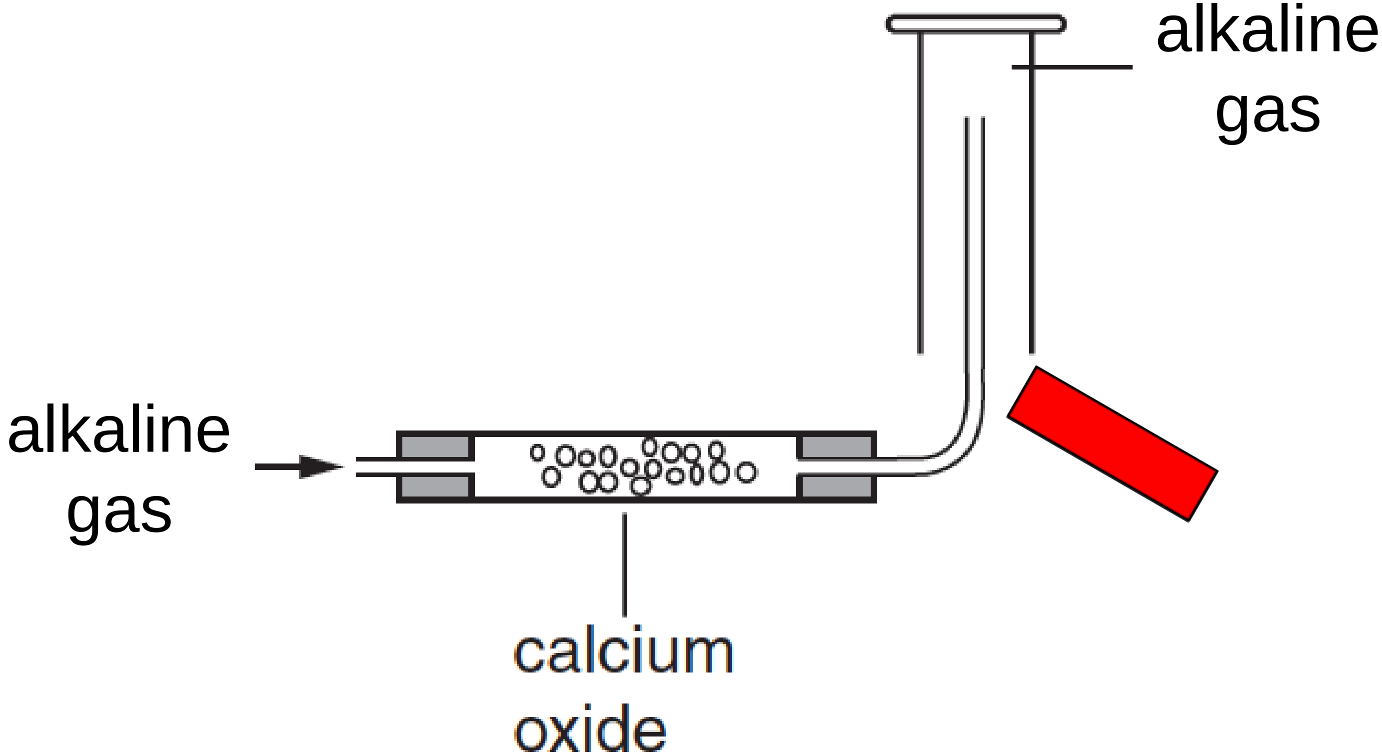


Experimental Techniques

If I collect a gas by downward or upward delivery, how can I tell when the gas jar is full?

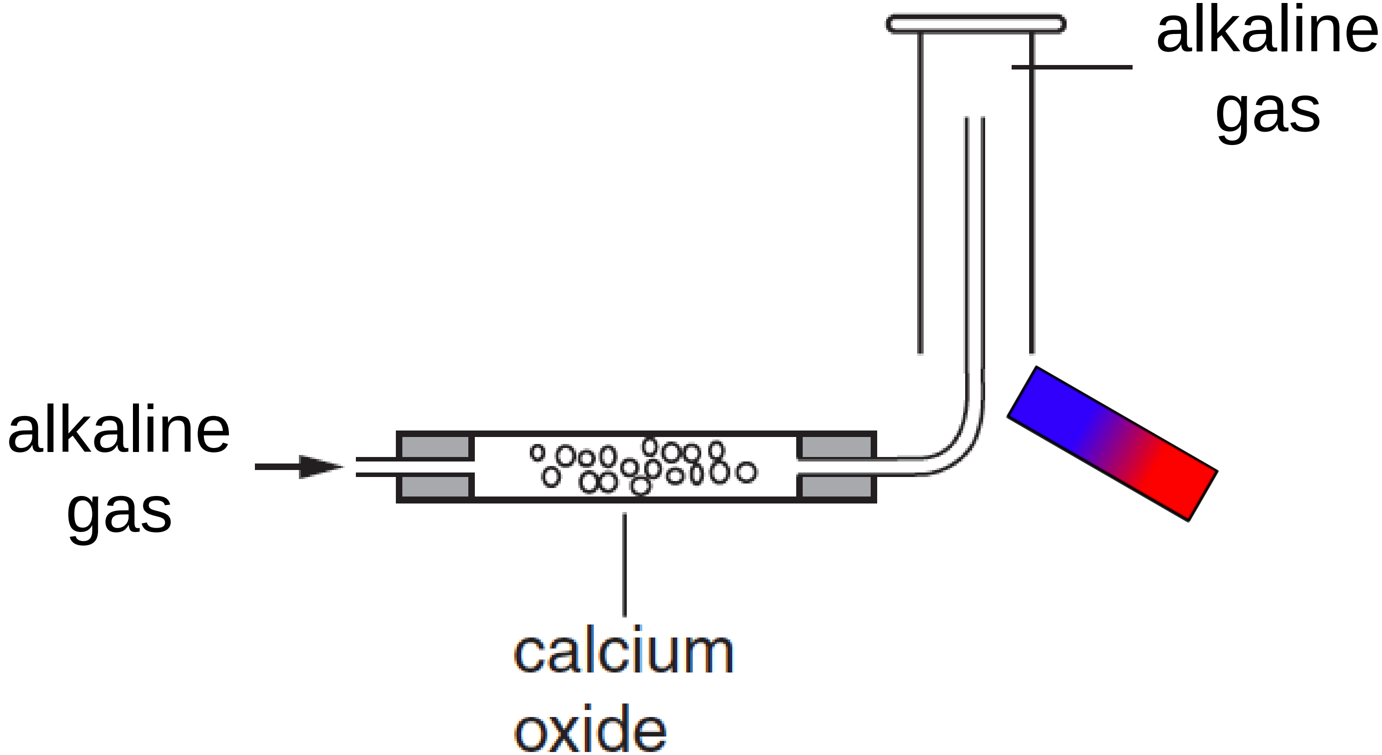
- Many gases are colourless, making it difficult to tell when the gas jar is full.

Experimental Techniques



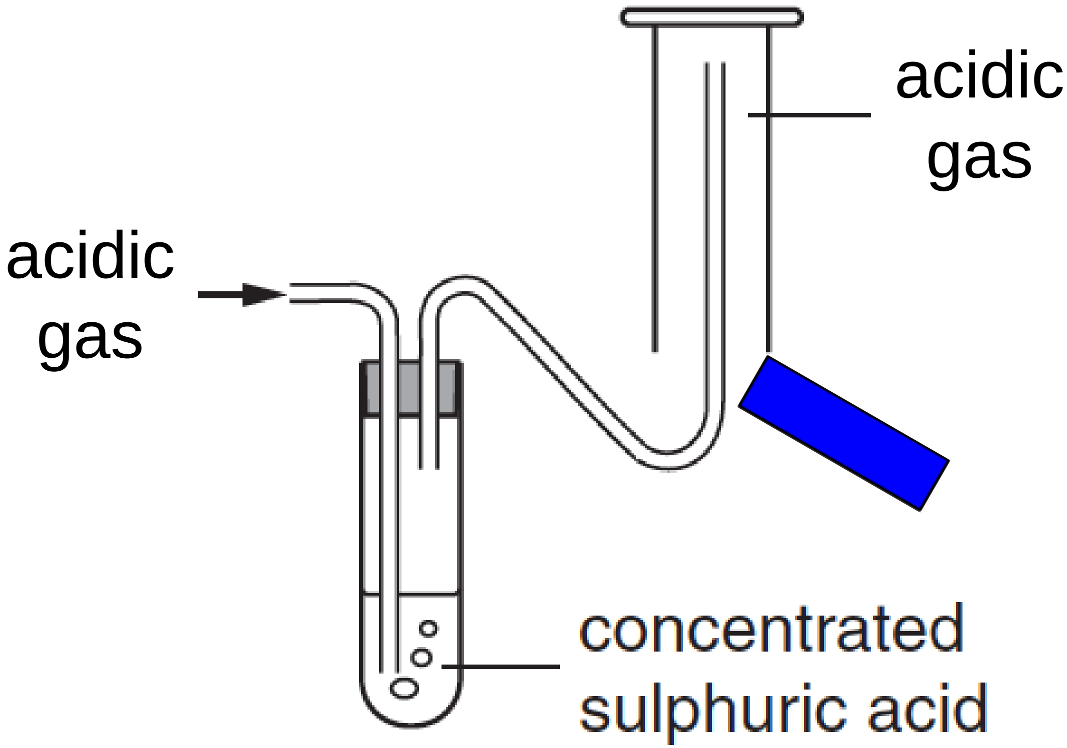
- When collecting an *alkaline gas* by downward or upward delivery, it is possible to know when the gas jar is full by holding a piece of *damp red litmus paper* in the mouth of the gas jar.

Experimental Techniques



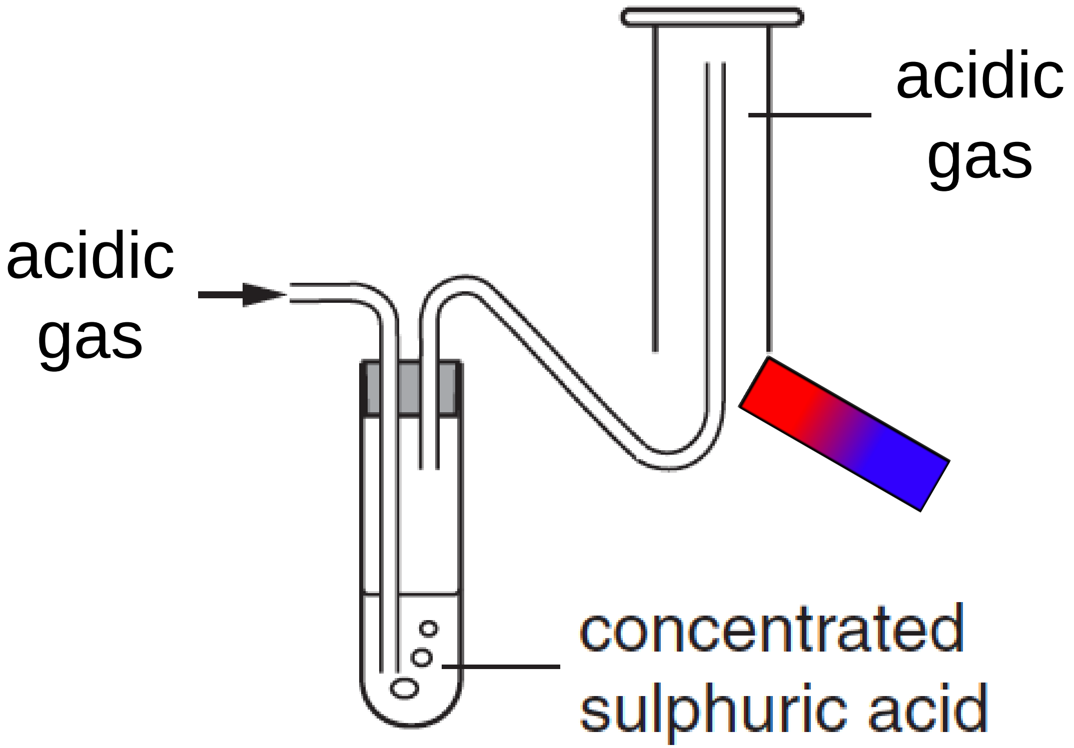
- When the gas jar is full of the alkaline gas, the gas will overflow out of the gas jar, causing the damp red litmus paper to *turn blue*.

Experimental Techniques



- When collecting an *acidic gas* by downward or upward delivery, it is possible to know when the gas jar is full by holding a piece of *damp blue litmus paper* in the mouth of the gas jar.

Experimental Techniques



- When the gas jar is full of the acidic gas, the gas will overflow out of the gas jar, causing the damp blue litmus paper to *turn red*.

Experimental Techniques

Gas	Solubility of Gas in Water	Acid / Base Nature of Gas	Density of Gas Compared to Air
ammonia, NH_3	extremely soluble	alkaline	less dense (17.0)
carbon dioxide, CO_2	slightly soluble	acidic	more dense (44.0)
chlorine, Cl_2	soluble	acidic	more dense (71.0)
hydrogen, H_2	insoluble	neutral	less dense (2.0)
hydrogen chloride, HCl	very soluble	acidic	more dense (36.5)
oxygen, O_2	slightly soluble	neutral	slightly more dense (32.0)
sulfur dioxide, SO_2	very soluble	acidic	more dense (64.0)

Experimental Techniques

Presentation on
Measurement and
Experimental Techniques
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