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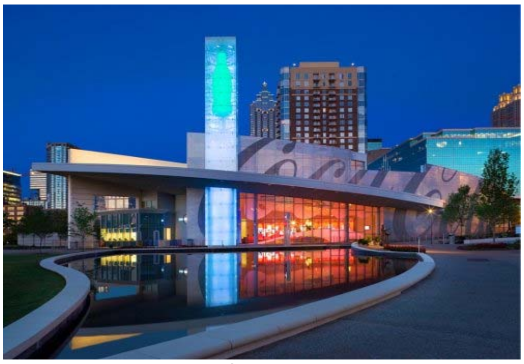
Chem Lectures

1. Measurement and Experimental Techniques

Secrets of Coca-Cola

The Coca-Cola Company is an American MNC, best known for the flag ship product Coca-Cola. The secret formula was invented in 1886 by John Stith Pemberton, a pharmacist. Till today, the exact formula of Coca-Cola is still a tightly guarded secret. The original writings containing the secret formula is held in a vault in the 'World of Coca-Cola' museum in downtown Atlanta.



Left: Bank vault at 'World of Coca-Cola' containing the secret formula
Right: World of Coca-Cola Museum in Atlanta

While we may not have the secret formula, there have been many attempts by people to recreate the signature Coca-Cola taste. Here's one such recipe:

Flavouring	Concentrate
• 3.50 ml orange oil	• 10 ml flavouring
• 1.00 ml lemon oil	• 17.5 ml 75% citric acid or phosphoric acid
• 1.00 ml nutmeg oil	• 2.28 l water
• 1.25 ml cinnamon oil	• 2.36 kg white sugar
• 0.25 ml coriander oil	• 2.50 ml caffeine
• 0.25 ml neroli oil	• 30 ml caramel colour
• 2.75 ml lime oil	
• 0.25 ml lavender oil	
• 10.0 g food-grade gum arabic	
• 3.00 ml water	

<u>Directions</u>

Part I: Making the Flavouring

1. Mix the oils together.
2. Add gum arabic and mix completely.
3. Add water and mix well.

Part II: Making the Acid Solution from Powder

1. Measure 13 g of the acid powder and place it in a small glass jar.
2. Boil a small amount of water and add 4.5 ml of hot water to the powdered acid, enough to bring the total mass up to 17.5 g.
3. Swirl the solution for about 5 minutes until the powder is completely dissolved.

Part III: Making the Concentrate

1. Mix 10 ml of the flavouring with the phosphoric acid or citric acid.
2. Mix the water and sugar and add caffeine if desired.
3. Pour the acid and flavouring mixture slowly into the water/sugar mixture
4. Add caramel and mix completely

Part IV: Making the Cola

1. Mix 1 part concentrate with five parts water.
2. Carbonate the beverage.

If you were to follow this recipe to prepare the Cola, ***what apparatus would you need to use***? Can you simply use normal kitchen apparatus? Or would you need more specialised apparatus?

Learning Outcomes

1. Name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes, measuring cylinders and gas syringes
2. Suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases and measurement of rates of reaction

1. Physical Quantities and Apparatus

<table>
<tr><th>Physical Quantities</th><th>Units</th><th>Apparatus of Choice</th></tr>
<tr><td>Mass</td><td>

- **kilogram** (**kg**) - SI unit
- gram (g)

<u>Note</u>

- 1 kg = 1000 g

</td><td>

- **Beam balance**

Figure 1.1 Beam balance

- **Electronic balance** (Fast, easy to use, measure smaller quantity of mass quickly)

Figure 1.2 Electronic balance

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<tr><td>Volume</td><td colspan="2">

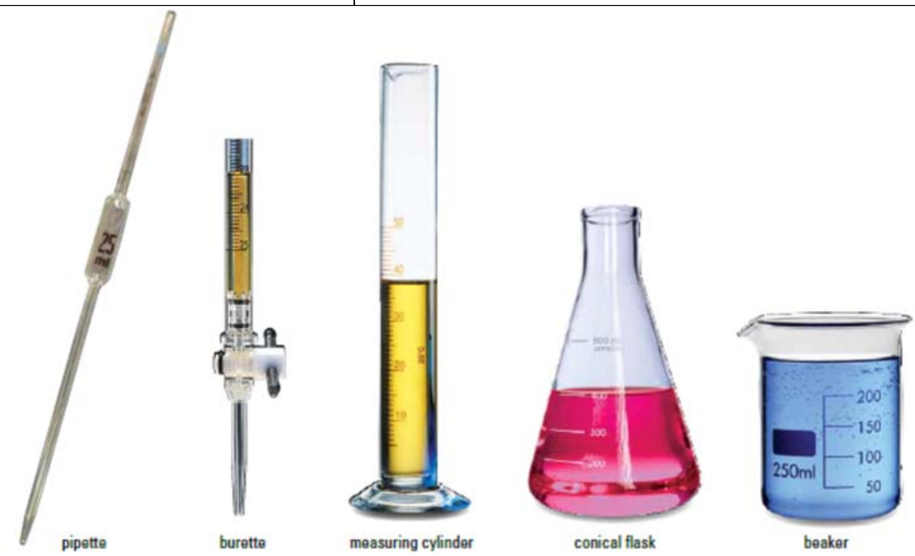

Figure 1.3 Common glassware in the laboratory

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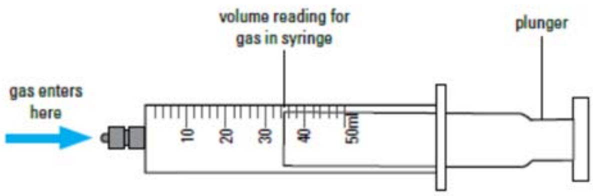
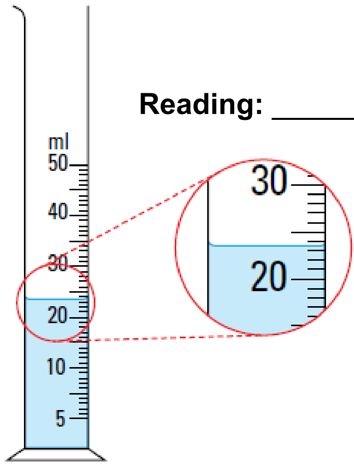
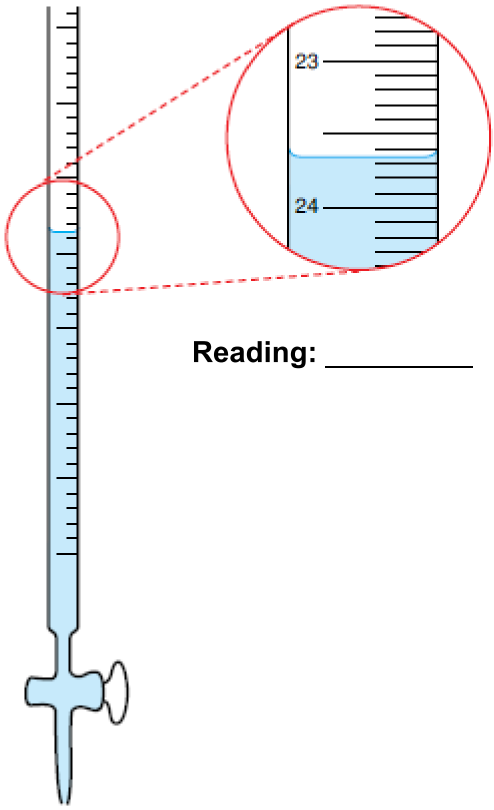
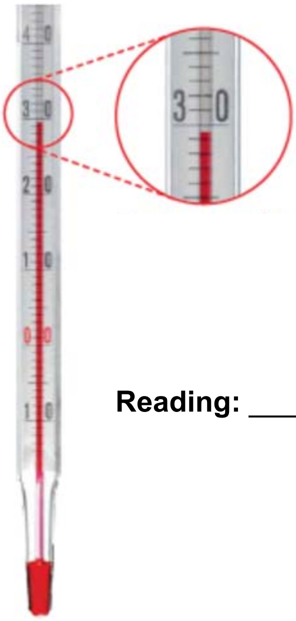
Physical Quantities	Units	Apparatus of Choice
	• **cubic meter (m^3) - SI unit** • cubic decimeter (dm^3) • cubic centimeter (cm^3) • litre (l) • millilitre (ml) <u>Note</u> • 1 m^3 = 1000 dm^3 • 1 dm^3 = 1000 cm^3 • 1 l = 1000 cm^3	<u>**For approximate measurement**</u> • **Measuring cylinder** - measuring anything from 1 cm^3 to 1000 cm^3 or more <u>**For accurate measurement**</u> • **Burette** - to measure variable volumes of liquids (accurate to the nearest 0.05 cm^3) • **Pipette** - to measure fixed volumes of liquids, e.g., 25.0 cm^3 (very accurate) • **Volumetric flask** - to measure fixed volumes of liquids, e.g., 25.0 cm^3, 250.0 cm^3, 500.0 cm^3, usually used in the preparation of standard solutions where exact concentrations need to be prepared  **Figure 1.4** 500.0 cm^3 volumetric flask • **Small syringe** - to measure small volume of liquids • **Large (gas) syringe** - to measure volumes of liquid or gases (should be gas-tight)  **Figure 1.5** Gas syringe <u>**Taking a reading**</u> • Liquids should be read at the bottom of the meniscus (with the exception of mercury which is read from the top of the meniscus)

Physical Quantities	Units	Apparatus of Choice
		 **Reading:** __________ **Figure 1.6** Measuring cylinder  **Reading:** __________ **Figure 1.7** Burette
Time	• **Second (s) - SI unit** • Hour (h) • Minute (min) <u>Note</u> • 1 h = 60 min	• **Stopwatch** • Stopclock

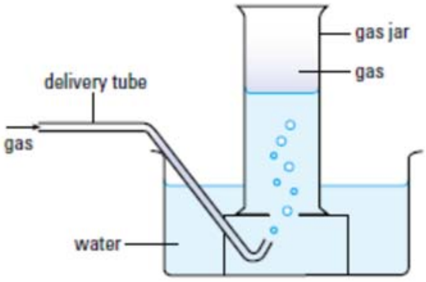
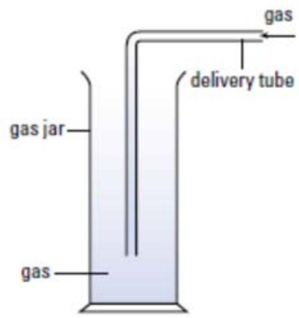
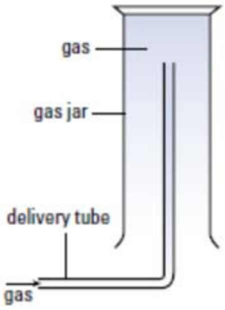
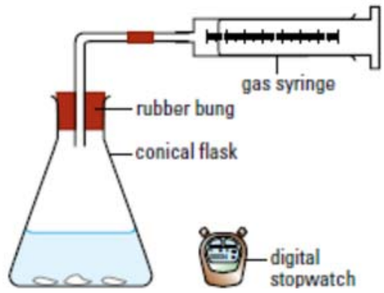
Physical Quantities	Units	Apparatus of Choice
	• 1 min = 60 s • 1 h = 3600 s	
Temperature	• **Kelvin (K) - SI unit** • Degree Celsius (^{o}C) Note • K = ^{o}C + 273	• Mercury-in-glass thermometer • Alcohol-in-glass thermometer  **Reading:** __________ **Figure 1.8** Alcohol-in-glass thermometer • Electronic Thermometer

2. Experimental Set-Ups

2.1 Collection of Gases

- The method of collecting a gas depends on two physical properties of the gas:
  - Density (compared to air)
  - Solubility (in water)

1. Displacement of water	2. Downward delivery

• For gases which are insoluble in water • E.g., hydrogen, oxygen, carbon dioxide  **Figure 2.1.1** Displacement of water	• For gases which are denser than air (and soluble in water) • E.g., chlorine  **Figure 2.1.2** Downward delivery
3. Upward delivery • For gases which are less dense than air (and soluble in water) • E.g., hydrogen, ammonia  **Figure 2.1.3** Upward delivery	**4. Using a gas syringe** • When there is a need to monitor the rate of evolution of a gas, i.e., how much gas was produced in the reaction within a certain duration  **Figure 2.1.4** Collection with gas syringe

2.2 Collecting a Dry Sample of Gas

- Gases can be dried by passing them through a drying agent.

(a) Concentrated sulfuric acid - used to dry acidic gases or gases which do not react with acids

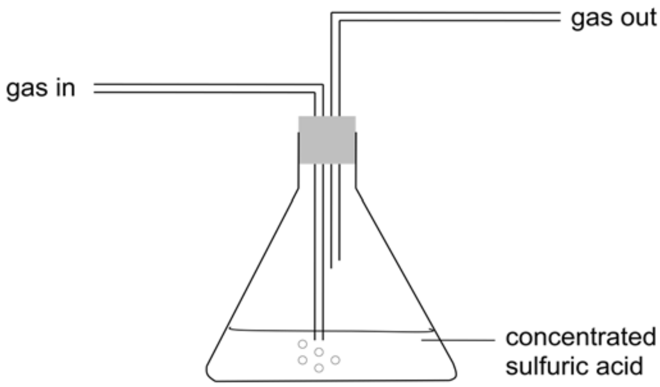


Figure 2.2.1 Drying with conc. H_2SO_4

(b) Calcium oxide - used to dry alkaline gases, e.g, ammonia

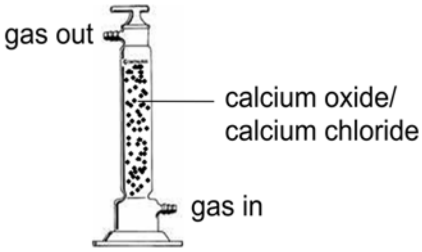


Figure 2.2.2 Drying tower containing calcium oxide

(c) Fused calcium chloride - dry most gases, e.g., hydrogen

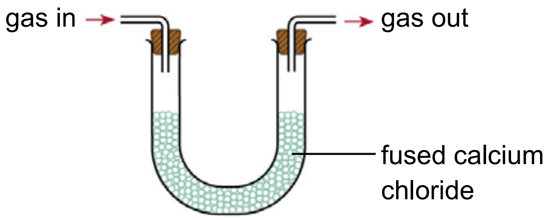


Figure 2.2.3 U-tube containing fused calcium chloride

Did you know?

The Thirsty Hippo brand of dehumifiers contain calcium chloride. The calcium chloride pellets absorb water vapour from the air.

2.3 Properties of Common Gases

Gas	Formula	Colour	Density (compared to air)	Solubility in water
Ammonia	NH_3	Colourless		
Carbon dioxide	CO_2	Colourless		
Chlorine	Cl_2	Greenish- yellow	Denser	Soluble
Hydrogen	H_2	Colourless	Less dense	Insoluble
Hydrogen Chloride	HCl	Colourless	Denser	Very soluble
Oxygen	O_2	Colourless		
Carbon monoxide	CO	Colourless	Slightly denser	Slightly soluble
Nitrogen	N_2	Colourless		
Sulphur dioxide	SO_2	Brownish		
Helium	He	Colourless	Less dense	Insoluble

Checkpoint 1

Draw a labelled set up to collect a sample of dry ammonia gas, produced from the reaction of aqueous sodium hydroxide and solid ammonium chloride in a conical flask.

2.4 Measuring Change in Mass During a Reaction

- Consider the following reaction between calcium carbonate and dilute hydrochloric acid:

$$CaCO_3(s) + HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

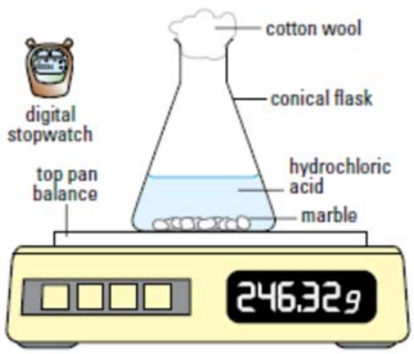


Figure 2.4.1 Measuring rate of change of mass of a reaction mixture

- During the reaction:
  - Carbon dioxide formed will escape
  - Mass reading on the electronic balance will decrease

- We can collect this information in a table as follows:

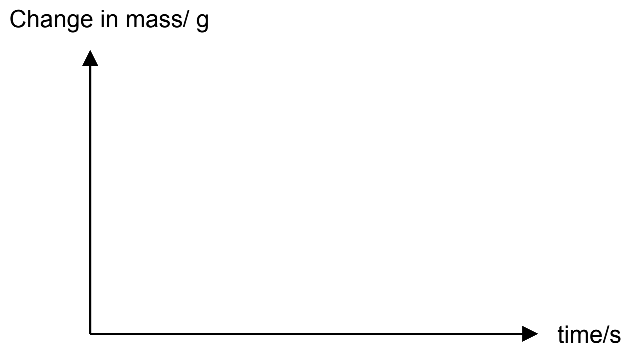
Initial mass = m_i g

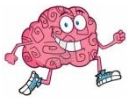
Time/ s	Mass reading, m_f/ g	Change in mass, m_i - m_f/ g
0	100	0
10	90	10
20	80	20
30	75	25
40	73	27
50	70	30
60	70	30
70	70	30

- We can then plot a graph as follows:

(a) Plotting mass reading against time

(b) Plotting change in mass against time





Rack-your-brains

Q. Why is there a plug of cotton wool at the mouth of the conical flask?

A.

Checkpoint 2

Draw a labelled diagram of an experimental setup to measure the rate of evolution of hydrogen gas during the reaction of magnesium and dilute hydrochloric acid in a conical flask.

Making a Cola

What apparatus would you use to measure the respective ingredients in the Cola recipe?

Flavouring	Apparatus
• 3.50 ml orange oil	• Burette
• 1.00 ml lemon oil	• Burette
• 1.00 ml nutmeg oil	• Burette
• 1.25 ml cinnamon oil	• Burette
• 0.25 ml coriander oil	• Burette
• 0.25 ml neroli oil	• Burette
• 2.75 ml lime oil	• Burette
• 0.25 ml lavender oil	• Burette
• 10.0 g food-grade gum arabic	• Electronic balance
• 3.00 ml water	• Burette

Concentrate	Apparatus
• 10 ml flavouring	
• 17.5 ml 75% citric acid or phosphoric acid	
• 2.28 l water	
• 2.36 kg white sugar	
• 2.50 ml caffeine	
• 30 ml caramel colour	