UNIT 3

AMOUNT OF SUBSTANCE

PART 1 – INTRODUCTION TO PRACTICAL CHEMISTRY AND MEASUREMENTS




Contents

Key words: quantitative analysis, base quantity, base unit, derived quantity, derived unit, mass balance, stop-clock, thermometer, measuring cylinder, pipette, burette, volumetric flask, gas syringe, density

Units which must be completed before this unit can be attempted:
Unit 1 – Atomic Structure and the Periodic Table
Unit 2 – Particles, Structure and Bonding

1) Introduction

Chemistry is a practical subject. Practical skills are needed in order to:

- Prepare, extract and purify substances (**synthesis**)
- Identify substances (**qualitative analysis**)
- Determine how much of a substance is present (**quantitative analysis**)

When carrying out practical work in Chemistry, it is important to recognise that many chemicals are hazardous and can cause harm when they come into contact with skin, eyes or even clothes. **Safety precautions** are therefore very important when carrying out practical work in Chemistry.

Quantitative Analysis requires you to make measurements of various quantities. When making measurements, it is important to:

- Appreciate that most measurable quantities have **units**; understand what these units are and how the units can be interconverted
- Appreciate that measuring requires the use of specific **instruments**; understand what these instruments are and how they should be used
- Appreciate that no measuring instrument is perfect and that **errors** can arise both from the instruments themselves and how they are used

2) Safety Precautions in the Laboratory

Here is a summary of the most important safety precautions and the reasons for them:

PRECAUTION	WHEN	REASON
Wear a lab coat	Always	To prevent your clothes from coming into contact with harmful chemicals
Avoid shorts or short skirts and avoid open footwear	Always	To prevent legs and feet from coming into contact with harmful chemicals
Wear safety goggles	Whenever you or anyone else is dealing with any chemicals	To protect your eyes from harmful chemicals
Wear disposable gloves	Whenever you or anyone else is dealing with chemicals known to be harmful to skin	To protect your hands form harmful chemicals
If you have long hair, wear it tied back	Always	To prevent hair from coming into contact with harmful chemicals or open flames
Don't eat or drink	Always	To prevent food contamination
Label all containers you are using to store chemicals	Whenever you are using chemicals	To ensure you don't get the chemicals mixed up
Follow all instructions and don't do anything you are not instructed to do	Always	To ensure you don't put yourself or anyone else in danger
Report all accidents, breakages and spillages to the teacher in charge immediately	As soon as you have an accident or break or spill someone	To allow the teacher to ensure that any injuries can be dealt with immediately, and that anything unsafe can be removed from the laboratory
Don't leave any fragile apparatus in a place where it might roll off or be knocked off the bench	Whenever you are using fragile apparatus, especially glassware	To avoid breaking fragile apparatus, which can be both dangerous and expensive
Always leave Bunsen burners on safety flame if not in active use	Whenever you are using Bunsen burners	Safety flames are more visible and give out less heat
Always rinse all glassware, leave it to dry and wipe all surfaces after use	After any practical work	To ensure that the glassware and work surfaces contain no harmful chemical after use
Keep the lab free of clutter	Always	So that people have more space in which to work and move around safely
Never take any chemicals or equipment out of the laboratory	Always	They are not designed to be used outside the laboratory and are not safe to use anywhere else

3) Quantities, Units and Measuring Instruments

(a) Base and Derived Quantities and Units

There are seven **base quantities** in science. Each of these quantities has a unit as agreed by the international system of units (SI) called a **base unit**:

Base quantity (symbol)	Base SI unit	Used in Chemistry	Other units commonly used in Chemistry
Length (l)	metre (m)	No	
Mass (m)	kilogram (kg)	Yes	gram (g) (1000 g = 1 kg)
Time (t)	second (s)	Yes	
Temperature (T)	Kelvin (K)	Yes	degrees celcius (^oC) T (K) = T (^oC) + 273
Amount of substance (n)	mole (mol)	Yes	
Current (I)	Amp (A)	No	
Luminous Intensity	Candela (cd)	No	

All other quantities are known as **derived quantities** - they depend on at least one of the base quantities and can be calculated if the base quantities are known. The units for derived quantities are called **derived units** and can be expressed in terms of the base units.
The derived quantities which may need to be measured or used in Chemistry are:

Quantity (symbol)	Derived SI unit	Expressed in base units	Other units commonly used in Chemistry
Volume (V)	cubic metre (m^3)	m^3	cubic centimetre (cm^3) (or ml) cubic decimetre (dm^3) (or L) 1000000 cm^3 = 1000 dm^3 = 1 m^3
Pressure (P)	Pascal (Pa)	$kgm^{-1}s^{-2}$	atmosphere (atm) kilopascal (kPa) 1 kPa = 1000 Pa
Energy (E) (or H)	Joule (J)	kgm^2s^{-2}	kilojoule (kJ)
Voltage (V) (or pd) (or emf)	Volt (V)	$kgm^2s^{-3}A^{-1}$	
Charge (q)	Coulomb (C)	As	Faraday (F)

Test Your Progress: Topic 3 Part 1 Exercise 1

1. Express the following quantities in g:
   (a) 25 kg (b) 3.2 kg (c) 0.34 kg
2. Express the following quantities in m^3:
   (a) 25 cm^3 (b) 3.2 dm^3 (c) 0.34 dm^3 (d) 150 cm^3 (e) 120 dm^3
3. Express the following quantities in dm^3:
   (b) 0.25 m^3 (b) 3.2 m^3 (c) 25 cm^3 (d) 150 cm^3 (e) 6.2 cm^3
4. Express the following quantities in cm^3:
   (c) 0.25 m^3 (b) 3.2 m^3 (c) 0.40 dm^3 (d) 0.015 dm^3 (e) 6.2 dm^3
5. Express the following quantities in K:
   (d) 25 ^oC (b) 100 ^oC (c) -273 ^oC
6. Express the following quantities in ^oC:
   (e) 345 K (b) 600 K (c) 100 K

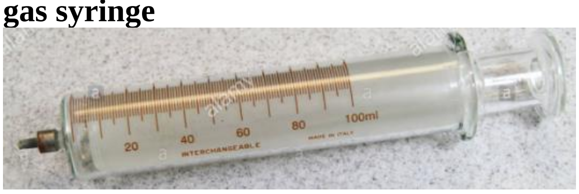
(b) Measuring Instruments in Chemistry

Special instruments are available for measuring quantities in Chemistry. Each instrument has a specific purpose and comes with a given measurement error. The smaller the error, the more precise the measurement that the instrument can make.

These are some of the most important measuring instruments in Chemistry:

Quantity	Instrument	Details
Mass (g)	mass balance 	Mass balances measure mass to 1 dp or 2 dp, depending on the balance. Typical error: ±0.1 g (if 1 dp), ±0.01 g (if 2 dp)
Temperature (°C)	Thermometer 	Thermometers usually measure temperature to the nearest 0.5 °C Typical error: ±0.5 °C
Time (s)	stop-clock 	Stop-clocks can measure time to the nearest 0.01 s, but human reaction times are much longer than that, so human error is usually the limiting factor

The quantity most frequently measured in Chemistry is **volume**. There are lots of different instruments available to measure volume. Each instrument serves a slightly different purpose:

Instrument	Details	Typical error
measuring cylinder 	Measuring cylinders are convenient, but not accurate, ways of measuring volume. They should only be used when an approximate volume measurement only is required. They are most commonly found in sizes of 10 cm^3, 25 cm^3, 50 cm^3 and 100 cm^3.	for 10 cm^3: ± 0.2 cm^3 for 25 cm^3: ± 0.5 cm^3 for 50 cm^3: ± 1 cm^3 for 100 cm^3: ± 2 cm^3
Pipette 	Most pipettes can only measure a single volume, usually 25 cm^3. However they can measure this volume very accurately. They are designed to deliver the measured volume when emptied under gravity, so they actually hold a slightly greater volume than this. They should only be used with a **pipette filler**.	for 25 cm^3: ± 0.05 cm^3
Burette 	Burettes are designed to deliver any volume up to 50 cm^3. They are more accurate than measuring cylinders but less accurate than pipettes. The volume delivered can be deduced by subtracting the initial measurement from the final measurement. They need to be used with a stand, clamp and boss and they are mainly used in titrations.	± 0.15 cm^3
volumetric flask 	Volumetric flasks are designed to measure a single, specific volume very accurately. They are not designed to deliver this volume. Most volumetric flasks are designed to contain 250 cm^3. They are mainly used to prepare standard solutions.	± 0.2 cm^3
gas syringe 	Gas syringes are used to collect and measure gas volumes. They have a similar accuracy to measuring cylinders	± 1 cm^3

4) Measuring Densities

The density of a substance is its mass per unit volume. The SI units of density are kgm^{-3}, but in the laboratory it is more common to measure density in gcm^{-3}.

DENSITY = MASS/VOLUME
(gcm^{-3}) (g) (cm^3)

Practical: measure the density of a small piece of rock

1) Select a piece of rock small enough to fit inside a measuring cylinder
2) Weigh the rock on a mass balance and record its mass
3) Add some water to a measuring cylinder until it is approximately half-full, and record the volume of water inside (this is the initial volume)
4) Drop the piece of rock into the measuring cylinder, and record the final volume
5) Determine the volume of the rock by subtracting the initial volume from the final volume
6) Use your results from step (2) and step (5) to calculate the density of the rock

Practical: comparing the densities of pure water and salt water

1) Weigh an empty 100 cm^3 measuring cylinder and record its mass (this is the initial mass)
2) Add 50 cm^3 of distilled water to the measuring cylinder
3) Weigh the measuring cylinder again, this time with the water in it (this is the final mass)
4) Determine the mass of the water in the measuring cylinder by subtracting the initial mass from the final mass
5) Hence calculate the density of the pure water
6) Repeat steps (2) to (5) using a saturated solution of sodium chloride.

Questions:

(a) The density of pure water is 1.0 gcm^{-3}. How did this compare to your calculation?
(b) Salty water is more dense than pure water. Is this what you discovered? Why do you think this is so?