Chapter 1

Chemistry and Measurement

Why is it important to Study Chemistry?

- needed in every modern Science from Astronomy to Zoology
- material engineers and Technologist

  understand the chemical behavior of materials they use
- development of synthetic Fibers: nylon   Plastics: polystyrene
- creation of thousands of new products

  live longer: vaccines & drugs (prevent or cure)

  healthier: understanding of body chemistry (heart disease, high blood P)

  easier: Greater food production (fertilizers and pesticides)

  more comfortable: synthetic fibers & plastics
- Needed in cleaning up the environment
- find substitutes for scarce resources
- decisions as a voter
- help in making intelligent decisions
- chemical reactions are part of everything from breathing , eating, to thinking.

I) What is Chemistry?

Chemistry: The science that deals with the composition, structure, and properties of matter and the changes that matter undergoes.

Matter: anything that has mass and occupies space

II) Scientific Method

process of creative thinking and testing

A) Observation

- Natural phenomena
- measured events
- collection of information (data)

Two types of Observations

- **qualitative**: consisting of general observations about the system
- **quantitative**: comprising numbers obtained by various measurement of the system (most useful)

B) Hypothesis

- a tentative explanation for a set of observations
- must be testable
- can be revised

C) Experiment

- procedural steps that test a hypothesis: one variable at a time

D) Law

- a concise statement or mathematical equation about a basic relationship or regularity of nature
- example: the law of gravity is the force between two masses

E) Theory

- hypotheses that survive many experimental tests of their validity may evolve into a theory.

Scientific Method Example

(AD 130-200) Greek physician **Galen**

observed a fact

blood goes somehow from the left side of the heart to the right side

and hypothesized

must be tiny hole present in the muscular walls that separates two halves

--> believed for 1000 yrs (was not tested)

(~1600) **William Harvey**

tested **Galen's** hypothesis

dissected both human and animal hearts and blood vessels

found one way valves separating upper chambers from lower chambers

and discovered

heart is a pump, contracting and expanding (pushes blood out)

his teacher **Fabricius** observed

one way valves in veins

Harvey hypothesized

blood circulates throughout the body pumped by the heart

(~1661) Italian anatomist **Malpighi**

using a newly discovered microscope found tiny vessels, now called capillaries

III) Chemistry & Matter

recall the following definitions

Chemistry: Study of matter & its properties

changes that matter undergoes

energy associated with the change

Matter: physical material of the universe

anything that occupies space and has mass

To Investigate Matter, one must observe properties of the substance

Properties: characteristic that give each substance a unique identification

Two Types

1) Physical Property

measured without changing the basic identity of the substance

color, odor, density, melting pt, boiling pt, hardness

2) Chemical Property

describes the way a substance may change or "react" to form other substances

flammability, corrosiveness, reactivity with acids

changes a substance can undergo can be:

Two Types

1) physical change

substance alters its physical form or shape but not its chemical composition

usually reversible

e.g.: ice melts

2) chemical change (chem. rxn)

a substance is converted into a different substance with different properties than original substance

usually irreversible

e.g.: water decomposes (→) to hydrogen gas + oxygen gas

A substance is defined by its own unique set of physical and chemical properties

For example:

Which of the following observations about a substance describes a physical or chemical property?

a) color

b) melting pt

c) reactivity with water

d) boiling pt

e) state of matter under ordinary conditions

f) flammability

g) density

h) electrical conductivity

i) decomposition products upon heating

Which of the following are physical or chemical changes?

a) tarnishing of silverware

b) melting of ice

c) cutting a diamond

d) burning of gasoline

e) wine turning to vinegar

Matter is classified in two principal ways. A) Its physical state as a solid, liquid, or gas and B) but its chemical constitution as an element, compound, or mixture.

A) Physical State

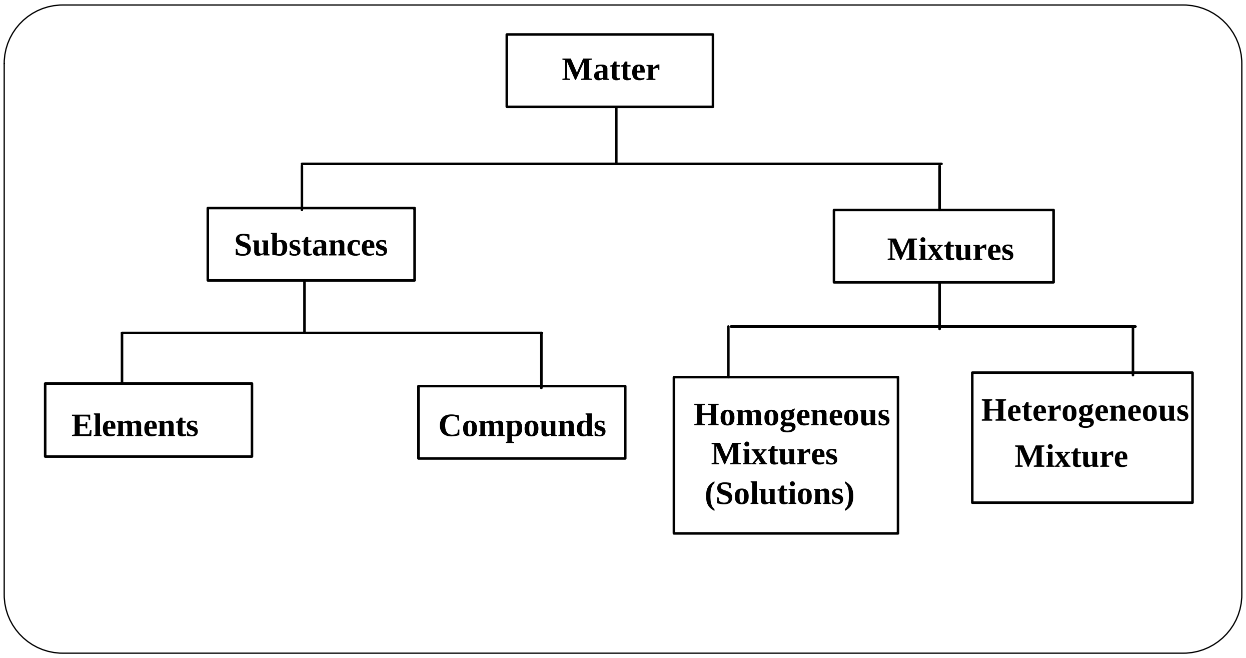
3 states of matter (physical forms)

states of matter	fluidity or rigidity	compressibility	volume and shape
solid	rigid	very low	fixed volume and shape
liquid	fluid	very low	fixed volume but no fixed shape
gas	fluid	high	no fixed volume or shape

fluidity: how easy does the substance flow and change shape in the presence of slight outside forces

rigidity: maintain their shapes when subjected to outside forces

B) Chemical constitution



Substance: consist of only one kind of matter (a kind of matter that cannot be separated into other kinds of matter by any physical change)

Element: a substance that cannot be separated into simpler substances by chemical means (copper, oxygen gas)

Compound: a substance composed of atoms of two or more elements united chemically in definite proportions by mass (table salt- NaCl)

Mixture: combination of two or more substances in which the substances retain their distinct identities

Heterogeneous mixture: a mixture that consists of physically distinct parts, each with different properties (composition is not uniform)

Homogeneous mixture: a mixture that is uniform in its properties throughout given samples (also called a solution)

IV) Measurement

Many properties of matter are **quantitative**

A) Remember the **American System**?

length 12 in = 1 ft 3 ft = 1 yd

1760 yd = 1 mile = 5280 ft

mass 16 oz = 1 lb 2000 lb = 1 ton

volume 2 cup = 1 pt 2 pt = 1 qt

4 qt = 1 gal 8 fl oz = 1 cup

temp ^{o}F

B) **Metric System**

Units of scientific measurements

SI units (*Systeme International d'Unitites's*)

There are 7 fundamental scientific quantities

quantity	unit	symbol
length	meter	m
mass	kilogram	kg
time	second	s
temperature	Kelvin	K
amount of substance	mole	mol
electric current	ampere	A
luminous intensity	candela	cd

** All other units can be derived from these seven

(i.e.) volume m^3

Metric System

is a decimal system (based on units of 10)

Multiple	prefix	prefix abbrs..
10^6	*mega*	M
10^3	*kilo*	k
10^2	hecto	h
10^1	deka	da
	base	
10^{-1}	*deci*	d
10^{-2}	*centi*	c
10^{-3}	*milli*	m
10^{-6}	*micro*	µ
10^{-9}	nano	n
10^{-10}	angstrom	Å
10^{-12}	pico	p

C) Useful conversions between American and Metric systems

length	2.54 cm = 1 in
mass	1 kg = 2.205 lb
volume	0.9464 L = 1 qt

Temperature

Celsius (^oC) metric, general science use

Kelvin (K) absolute scale

Fahrenheit (^oF) American

General observation between scales:

100 unit difference between water's boiling pt and melting point on the Celsius or Kelvin scale

180 unit difference between water's bp and mp on the Fahrenheit scale

Converting between temp. scales

Celsius to Kelvin

$$K = {}^oC + 273$$

Celsius to Fahrenheit

$$^oF = (1.8\ {}^oC) + 32$$

and Fahrenheit to Celsius

$$^oC = \frac{(^oF - 32)}{1.8}$$

Derived Units

Units derived from the seven SI base Units

volume (V)

SI cubic meter (m^3)

lab cubic decimeter (dm^3)

cubic centimeter (cm^3)

Chemist use Liter (L)

Useful volume conversions:

$1\ dm^3 = 1\ L$

1000 mL = 1 L

$1\ cm^3 = 1\ mL$

density (d)

mass per unit volume $d = \frac{m}{V}$

Example of calculatingdensity

Oil of wintergreen is a colorless liquid used a s a flavoring. A 28.1 g sample of oil of wintergreen has a volume of 23.7 mL What is the density of oil of wintergreen?

Answer: $d = \frac{m}{V} = \frac{28.1\ g}{23.7\ mL} = 1.185654008\ g/mL = 1.19\ g/mL$

V) Calculations using (Factor - label method)

Converting between units

A) Examples

A peck of apple weigh 2.31 kg.

What is this mass in mg?

$$2.31\text{ kg}\left(\frac{10^3\text{ g}}{1\text{ kg}}\right)\left(\frac{10^3\text{ mg}}{1\text{ g}}\right) = 2.31\times10^6\text{ mg}$$

What is this mass in lb?

$$2.31\text{ kg}\left(\frac{1\text{ lb}}{0.4536\text{ kg}}\right) = 5.09\text{ lb}$$

How many L of milk are in 2.5 cups?

(1 qt = 0.9464 L)

$$2.5\text{ cups}\left(\frac{1\text{ qt}}{4\text{ cups}}\right)\left(\frac{0.9464\text{ L}}{1\text{ qt}}\right)\left(\frac{10^3\text{ mL}}{1\text{ L}}\right) = 591.5 = 5.9\times10^2\text{ mL}$$

Numbers in calculations . . .

B) Precision, Accuracy and Significant Figures

Precision: a measure of how closely individual measurements agree with one another

Accuracy: how closely individual measurements agree with the correct or "true" or "accepted" value.

In measuring using a measuring device the *last digit* contains some uncertainty.

Significant figures (sig figs) in a measured number includes all certain digits and the last uncertain digit.

C) Rules for Sig Figs

1. All nonzero digits are significant

2. Zeros

a) captured zeros are significant

e.g. 8<u>00</u>1 4 sig figs

b) leading zeros are **not** significant

e.g. <u>0.00</u>431 3 sig figs

c) trailing zeros

i) right of decimal point are significant

e.g. 2.00, 20.0 3 sig figs

ii) left of decimal point may or may not be significant

e.g. 400 1, 2, or 3 sig figs

to avoid ambiguities use scientific notation

4.0×10^2 2 sig figs

4×10^2 1 sig fig

4.00×10^3 3 sig figs

D) Sig Figs in Calculations

1) Multiplying and Dividing

the answer contains same number of sig figs as the number with least number of sig figs

e.g. 54.63 x 2.0 = 109.26 = 1.1×10^2

45.00/9.53 = 4.72 = 4.72

2) Adding and Subtracting

the answer consist of the same number of decimal places as the number with least number of decimal places

e.g.

	5.24	47.5
	+ 6.3442	– 46.87
	11.5842	0.63
answer reported:	*11.58*	*0.6*

E) Rounding

What happens to last kept digit?

Look at leftmost digit to be dropped

	dropped left most digit	last retained digit	e.g.
1	< 5	remains the same	4.32|2 = *4.32*
2	≥ 5	increases by 1	64.38|54 = *64.39*

F) Measured Numbers versus exact Numbers

Measured number: determined using a measuring device

Exact Number: a counted number or defined equality

e.g. 12 eggs or 144 pencils *counted number*

4 cups = 1 qt or 1 in = 2.54 cm *defined equality*

Exact Numbers are **not** used in determining the number of sig figs in calculations

VI) Law of Conservation of Mass

Mass: the quantity of matter in a material

Matter: whatever occupies space and can be perceived by our senses

Law of conservation of mas: a law that states that the total mass remains constant during a chemical change (chemical reaction)

The mass before and after a reaction remains the same.

Note:

difference between mass and weight

mass: quantity of matter in a material

weight: force of gravity exerted on an object (matter)

Example demonstrating the law of conservation of mass:

Aluminum powder burns in oxygen to produce a substance called aluminum oxide. A sample of 2.00 grams of aluminum is burned in oxygen and produces 3.78 grams of aluminum oxide. How many grams of oxygen were used in this reaction?

$$2.00 \text{ grams Al} + \text{mass of oxygen} = 3.78 \text{ grams of } Al_2O_3$$

$$3.78 \text{ g } Al_2O_3 - 2.00 \text{ g Al} = 1.78 \text{ g } O_2$$