1
Measurements in Chemistry

1.1 INTRODUCTION

If you ask an Indian man his weight, he might say '70 kilograms'. If the same question is repeated to an American, he might say '150 pounds'. These answers will leave you in the dark about who is heavier. If the American had used the units 'kilograms' instead of 'pounds' he would have replied '68 kilograms'. Without any effort now you can see who is heavier. Similarly it is not easy to compare the volume of the petrol sold in India and America. In America it is sold in gallons whereas in India it is sold in litres. We can see that the measurements made by different people across the world can be easily compared when a quantity is measured in the same unit. Various international bodies such as CGPM(*) have been defining and redefining units of measurement from time to time.

In 1793, the French National Academy of Sciences devised the metric system. The metric system is a decimal system. India adopted the metric system in 1957. In 1960, The International Bureau of Weights and Measures adopted the International System of Units. It is known as the 'SI' Units (derived from French name 'System Internationale d' Units). The SI system is a revision and extension fo the metric system. Throughout the world, the scientists are now being urged to use the SI System of Units in all their scientific measurements. All the world over efforts are going on to change to SI Units particularly in commerce and businesses. So it becomes desirable for everyone to be familiar with the SI Systems of measurements.

1.2 OBJECTIVES

After reading this lesson, you would be able to

- recognise that metric system is decimal system of units.
- define seven base units for the seven basic physical quantities.
- list the symbols/notations for the units of the seven basic physical quantities.

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* ('Conference Generale des poido et Measures' which is commonly known as General Conference on weights and Measures)

- use the prefixes for very large or small values of units.
- derive other units from the base units in the form of 'derived units."

1.3 METRIC SYSTEM

The scientific measurements are often expressed in metric units. The metric system is decimal system and is based on a standard of length called a *Metre (m)*. Several multiple and submultiple units are used for expressing a measured physical quantity. For example

– *kilo* means 1,000 times the base unit.

– *centi* means 1/100 times the base unit.

– *milli* means 1/1000 times the base unit.

Mass: The quantity of matter in an object is defined by mass. Originally the *kilogram* (kg) was defined as the mass of 1000 cm^3 of water at 4°C and 1 atmospheric pressure. The current standard is the mass of a certain platinum iridium cylinder kept at International Bureau of Weights and Measures.

Weight: It is described as the force of gravity on an object. Mathematically:
(weight) = m (mass) × g (acceleration due to gravity)

The mass of an object does not change with the change of place. However, its weight changes because g (acceleration due to gravity) varies from one point on earth to another. In outer space the object becomes weightless because g becomes very small, while its mass remains unchanged.

Volume: Volume is not a fundamental property because it varies with temperature and pressure. The metric unit of volume is cubic metre (m^3).

1.4 THE SI SYSTEM

There are seven basic units in the SI System. The seven basic physical quantities and their units are defined as following:

i) *Length:* The basic unit of length is the *metre* (m). The length corresponding to *one metre* is defined as the distance travelled by light in vacuum during a time interval of 1/299,792,458 of a second.

ii) *Time:* The basic unit of time is the *second* (s). One second is defined as the duration of 9,192,631,770 pulses of a particular radiation emitted by caesium-133 atom.

iii) *Mass:* The basic unit of mass is the *kilogram* (kg). It has not been defined in terms of a *natural constant*. Thus, it remains as the mass of a certain platinum-iridium cylinder kept at International Bureau of Weights and Measures. One kilogram is very nearly equal to mass of 1000 cubic centimetres of water at 3.98°C.

iv) *Temperature:* The *Kelvin* is the unit of thermodynamic temperature. It is denoted by the symbol K. It has relationship with celsius temperature as following:

$$T/(K) = t/(°C) + 273.15$$

v) *Amount of Substance:* The SI Unit of the amount of the substance is *mole*. It is the amount of the substance which contains as many entities as there are atoms in 0.012 kg of carbon-12. Its symbol is 'mol'

vi) *Electric current:* The SI unit of electric current is the *amperes*. It is denoted by symbol 'A'.

vii) *Light intensity:* In the SI unit light intensity is measured in terms of *candela*. It is denoted by 'cd'.

All the seven basic physical quantities and the base units in which they are measured are summarised in the Table 1.1

Table 1.1

Physical quantity	Name of the Unit	Symbol for the Unit
Length	metre	m
Time	second	s
Mass	kilogram	kg
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A
Light intensity	candela	cd

1.4.1 PREFIXES FOR SI UNITS

Sometimes physical quantities are either very small or very large and to use the base SI unit for such physical quantities is very inconvenient. To solve this problem, multiples and fractions of the units are indicated by using the prefixes as shown in the Table 1.2.

Table 1.2

Multiple/Fraction	Prefix	Prefix symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

For example 4×10^{-9} m is written as 4 nm

INTEXT QUESTIONS 1.1

1. Match the physical quantities in column I with their SI units in Column II.

Column I	*Column II*
1. Time	(i) mol
2. Temperature	(ii) A
3. Electric current	(iii) kg
4. Mass	(iv) K
5. Amount of substance	(v) s

2. Write down the symbols for the following prefixes.

   i) tera

   ....

   ii) micro

   ....

   iii) pico

   ....

   iv) deka

   ....

   v) nano

   ....

1.5 DERIVED SI UNITS

In the SI system, the units of all the physical quantities other than the base quantities are derived from the basic units, e.g., area is a derived physical quantity. In the SI system length is the basic physical quantity and its unit is the *metre*. With the length of the sides in metres the area has the units of square metres. There are some derived units which are named after the names or the scientists. Normally such units are written in capital letters. Derived units normally used in your classes are provided in Tables 1.3 and 1.4

Table 1.3

SI Dervied Units with special names and symbols

Physical quantities	Name of SI Units	Symbol for SI Units	Expression in terms of SI base units
Force	Newton	N	$m\ kg\ s^{-2}$
Pressure	Pascal	Pa	$Nm^{-2} = m^{-1}\ kg\ s^{-2}$
Energy, work, heat	Joule	J	$Nm = m^2\ kg\ s^{-2}$
Electric Charge	Coulombs	C	As
Electric potential	Volt	V	$JC^{-1} = m^2\ kg\ s^{-3}\ A^{-1}$
Electric resistance	Ohm	Ω	$VA^{-1} = m^2\ kg\ s^{-3}\ A^{-2}$
Electric conductance	Siemens	S	$\Omega^{-1} = m^{-2}\ kg^{-1}\ s^3\ A^2$
Frequency	Hertz	Hz	s^{-1}

Table 1.4
SI derived units for other quantities

Physical Quantities	Symbol	Expression in terms of SI base units
Area	A or S	m^2
Volume	V	m^3
Velocity	v	ms^{-1}
Acceleration	a	ms^{-2}
Density	ρ	$kg\ m^{-3}$
Surface tension	γ or σ	Nm^{-1}, Jm^{-2}
Viscosity	η	Pa s
Molar conductivity	m	$Sm^2\ mol^{-1}$
Electric dipole moment of a molecule	μ	C m
Wave length	λ	m
Wave number in vacuum	$\bar{\upsilon}\left(=\frac{1}{\lambda}\right)$	m^{-1}

1.6 SOME GENERAL RULES FOR WRITING UNITS OF PHYSICAL QUANTIES

Symbols for units should be printed (written) in Roman (upright type). They should remain unaltered in plural and should not be followed by full stop at the end. Symbols for different units should be separated by blank space and not written in continuation. However there should be no gap between a prefix and the symbol of the unit.

Example: radius r = 18 cm, not Cm, or cms.

Symbol for units should be written in lower case letters, unless they are derived from a personal name when they should begin with a capital letter.

Example : m(metre), s(second) but J(joule), Hz(hertz)

Decimal-multiples and submultiples of units may be indicated by the use of prefixes.

Example: nm (nanometre), kHz (kilohertz), Mg (mega gram)

Newton, N = m kg s^{-2}, but not $mkgs^{-2}$

In order to avoid ambiguity, use of brackets is essential Example: It is better to write J/K mol as J/(K mol)

Two prefixes are avoided in expressing units.

Example: It is wrong to write k kg.. It should be written as Mg (Mega gram)

INTEXT QUESTIONS 1.2

1. What is the derived SI Unit for
   i) Force
   ii) Pressure

Write their expression in terms of SI base units

1.7 WHAT YOU HAVE LEARNT?

- The physical quantities can be compared only when the quantities are expressed in the same units.
- The scientific measurements are often expressed in the SI system which is the extension of metric system.
- SI units are coherent in nautre.
- There are seven base physical quantities and their units.
- The other physical quantitites and their units are derived from these base quantities and units.
- Prefixes are used to express the multiples or fractions of SI units.

1.8 TERMINAL EXERCISE

1. List the seven base physical quantities as specified by the SI system. How are all other physical quantities treated in this system.
2. Choose the largest unit from each group.
   (a) cm, pm or km
   (b) MV, mV or nV
   (c) TJ, kJ or μJ
   (d) cm^3, dm^3 or km^3
3. Write each of the following values using a prefix symbol.
   (a) 0.000001 V
   (b) 13500 Pa
   (c) 0.0000000005 m
4. Write down the units which can be used to express :
   (a) mass
   (b) energy
   (c) length
   (d) volume
   (d) temperature

1.9 CHECK YOUR ANSWERS

Intext Question 1.1

1. 1 – (v)
   2 - (iv)
   3 – (ii)

4 – (i)

5 – (iii)

2. i) 10^{12}

   ii) 10^{-6}

   iii) 10^{-12}

   iv) 10^{1}

   v) 10^{-9}

INTEXT QUESTION 1.2

(i) Force = Mass × acceleration

$= kg \times m\,s^{-2}$

$= kg\,m\,s^{-2}$

(ii) Pressure $= \dfrac{\text{Force}}{\text{Area}}$

Foree = Mass × acceleration

$= kg\,m\,s^{-2}$

Area = (Length) × (Length)

$m \times m = m^2$

Pressure $= \dfrac{\text{Force}}{\text{Area}} = \dfrac{kg\,m\,s^{-2}}{m^2} = kg\,m^{-1}\,s^{-2}$

TERMINAL EXERCISE

1. Length, mass, time, electric current, temperature, luminous intensity and amount of the substance. The others are derived from the base units

2. a) km
   b) MV
   c) TJ
   d) km^3

3. a) 1 μV
   b) 13.5 kPa
   c) 500 pm

4. a) kg b) $kg\,m^2\,s^{-2}$ c) m d) m^3 e) K