Section 1: PREAMBLE

This section presents different units used in general and in atomic and nuclear physics and a brief resume of the basic definition of terms describing the structure of matter pertaining to atoms and nuclei

Units

There is an internationally agreed scheme of units: **Système Internationale** (**SI**). It comprises:

- **SI units (**3 types: **base, supplementary** and **derived)**
- **SI prefixes.**

SI base units

There are seven SI base units:

Quantity	Symbol	Unit	Abbreviation
length	l	metre	m
mass	m	kilogram	kg
time	t	second	s
electric current	I	ampere	A
temperature	T	kelvin	K
luminous intensity	I_v	candela	cd
amount of substance	n	mole	mol

Supplementary units

Quantity	Unit	Abbreviation
plane angle	radian	rad
solid angle	steradian	sr

Derived units

SI base units are used to derive other units.
Some have special names:

Quantity	Symbol	Unit	Abbreviation
area	A	square metre	m^2
volume	V	cubic metre	m^3
speed, velocity	v	metre per second	$m\ s^{-1}$
speed of light	c	metre per second	$m\ s^{-1}$
angular velocity	ω	radian per second	$rad\ s^{-1}$
acceleration	a	metre per second^2	$m\ s^{-2}$
density	ρ	kilogram per metre^3	$kg\ m^{-3}$
momentum	p	kilogram metre per second	$kg\ m\ s^{-1}$
angular momentum	I, l	kilogram metre^2 per second	$kg\ m^2\ s^{-1}$

Quantity	Unit symbol	Unit	Expression in base units	Expression in derived units
energy	J	joule	m^2 kg s^{-2}	N m
force	N	newton	m kg s^{-2}	J m^{-1}
pressure	Pa	pascal	m^{-1} kg s^{-2}	N m^{-2}
power	W	watt	m^2 kg s^{-3}	J s^{-1}
electric charge	C	coulomb	s A	
electric potential	V	volt	m^2 kg s^{-3} A^{-1}	W A^{-1}
frequency	Hz	hertz	s^{-1}	

SI Prefixes.

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{18}	exa	E	10^{-1}	deci	d
10^{15}	peta	P	10^{-2}	centi	c
10^{12}	tera	T	10^{-3}	milli	m
10^{9}	giga	G	10^{-6}	micro	μ
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p
10^{2}	hecto	h	10^{-15}	femto	f
10	deca	da	10^{-18}	atto	a

Table 1.6 Prefixes for binary multiples.

Factor	Name	Symbol	Origin	Derivation
2^{10}	kibi	Ki	kilobinary $(2^{10})^1$	kilo $(10^3)^1$
2^{20}	mebi	Mi	megabinary $(2^{10})^2$	mega $(10^3)^1$
2^{30}	gibi	Gi	gigabinary $(2^{10})^3$	giga $(10^3)^1$
2^{40}	tebi	Ti	terabinary $(2^{10})^4$	tera $(10^3)^1$
2^{50}	pebi	Pi	petabinary $(2^{10})^5$	peta $(10^3)^1$
2^{60}	exbi	Ei	exabinary $(2^{10})^6$	exa $(10^3)^1$

Table 1.7 Examples and comparisons of binary prefixes with SI units.

1 kibibit = 1024 bit	1 Kibit = 2^{10} bit	1 kilobit = 1000 bit	1 kbit = 10^3 bit
1 mebibyte = 1048576 B	1 MiB = 2^{20} B	1 megabyte = 1000000 B	1 MB = 10^6 B
1 gibibyte = 1073741824 B	1 GiB = 2^{30} B	1 gigabyte = 1000000000 B	1 GB = 10^9 B

Conventions

How units and symbols are expressed in the literature.

- Symbols for physical quantities should be printed in italic (sloping) type: e.g. *T* for temperature.
- Symbols for units should be in roman (upright) type: e.g. K for kelvin.
- Symbols for vector quantities should be in bold italic type: e.g. ***F*** for force.
- Names of all units are in lower case: e.g. newton.
- Symbols for units that derive from a proper name should begin with a capital letter: e.g. V (for volt), N (for newton) etc.
- The symbol for a unit should not be followed by a full stop except at the end of a sentence and should remain unaltered in the plural. Thus, 6 cm **not** 6 cms.

Structure of Matter

Compounds, Elements, Atoms and Molecules

Matter consists of mixtures of **substances**, e.g. salt in water. Salt and water are examples of **compounds**.

- **A <u>compound</u> can be decomposed into simpler substances by ordinary chemical means**.

Salt is a compound of sodium and chlorine, which are **elements**

- **An <u>element</u> cannot be further decomposed by ordinary chemical means.**

All substances are composed of **atoms**.

- **An <u>atom</u> is the smallest quantity of a substance that can exist**.

There are 112 different atomic species known today.

These are the **elements**. Single, free atoms are not always stable and combine with other atoms chemically to form **molecules**.

A <u>molecule</u> is the smallest chemical unit of a substance capable of independent existence.

Element	Atomic symbol	Molecular symbol
Hydrogen	H	H_2
Carbon	C	C
Oxygen	O	O_2, O_3 (ozone)

Nitrogen	N	N_2
Iron	Fe	Fe
Copper	Cu	Cu

Molecules of compounds consist of two or more different atomic species

Compound	Molecular symbol
Water	H_2O
Carbon dioxide	CO_2
Carbon monoxide	CO
Methane	CH_4

Units used in atomic and nuclear physics

Energy: SI unit: joule J

In atomic and nuclear physics: **electron volt (eV)**

- energy gained by an electron passing through a potential difference of one volt.

$$1 \text{ eV} = 1.602\times10^{-19} \text{ J}$$

Multiples: keV (10^3 eV) MeV (10^6 eV) GeV (10^9 eV)

Size:

Ångstrom (Å): 1 Å = 10^{-10} m. Conveniently sized for the atom.

Fermi or femtometre (fm): 1 fm = 10^{-15} m. Nuclear sizes are commonly quoted in fermis.

Micron: 1 μm = 10^{-6} m.

Barn (b): A unit of **area** 1 b = 10^{-28} m^2 = 10^{-24} cm^2 It is a measure of the **probability** that a nuclear reaction will take place.

One barn ≈ cross-sectional area of a nucleus with A = 100

Reaction probabilities (cross sections) very much greater and very much smaller than one barn are common.

Molecular weight and atomic size

Molecular weight *M*

Mean mass (in u) of 1 molecule of a substance = sum of the atomic weights of the atoms in the molecule.

- For example, the molecular weight of H_2 is 2.0160 (2×1.0080).
- The molecular weight of H_2O is 18.051 (2×1.008 + 15.999).

Definitions:

For a pure substance, consisting of a compound of molecular weight M,

1 **mole** = M g 1 **kg-mole** = M kg of that substance.

Avogadro's hypothesis

The number of molecules in 1 mole of any substance is the same. It is referred to as Avogadro's number

$$N_A = 6.022\times10^{23} \text{ per mole} = 6.022\times10^{26} \text{ per kg-mole.}$$

Thus, the mass of 1 **molecule** of molecular weight, M is $M/N_A = M/(6.022\times10^{26})$ kg.

The mass of 1 **atom** of atomic weight A is A/N_A. Hence, 1 u = 1/ N_A.

Atomic size (estimate)

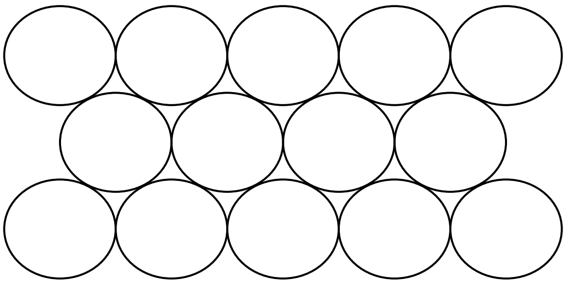
An element of atomic mass A has N_A/A atoms per kg.

or, $\rho N_A/A$ atoms per unit volume (ρ = density)

e.g. ^{12}C contains N_A atoms per mole (12g) or $N_A/0.012$ atoms per kg.

The mean volume occupied by one atom is $\boxed{V = A/\rho N_A}$

Consider a solid, and assume that the atoms are closely packed spheres with no space between them:



The mean volume of one atom $$V_A = \frac{4}{3}\pi r^3 \approx V = \frac{A}{\rho N_A}$$

where r = atomic radius. Therefore, $$r \approx \left(\frac{3A}{4\pi N_A \rho}\right)^{1/3}$$

e.g. carbon, $\rho = 2.265\times10^3$ kg m^{-3} and $A = 12.01$, therefore;

$$r \approx \left(\frac{3\times12.01}{4\pi\times6.022\times10^{26}\times2.265\times10^{3}}\right)^{1/3} = 1.28\times10^{-10}\text{ m} = 1.28 \text{ Å.}$$

This is typical of the size of an atom, which is a few Å.