9.1 Physical Quantities & Units

In physical units we distinguish:

- basic unit;
- derived units;
- multiple and submultiple units;
- sub-units.

Basic quantities and their units

Name	Unit
Length	Meter (m)
Weight	Kilogram (kg)
Time	Second (s)
Electric current	Ampere (A)
Thermodynamic temperature	Kelvin (K)
Amount of substance	Mol (mol)
Luminosity	Candela (cd)

Derived quantities and units

Name	Unit
surface area	square Meter (m^2)
volume	cubic Meter (m^3)
frequency	Hertz (Hz)
rotation frequency	reciprocal Second (s^{-1})

Derived units of MECHANICAL quantities

Name	Unit
Density	Kilogram per cubic Meter ($kg.m^{-3}$)
Velocity	Meter per Second ($m.s^{-1}$)
Acceleration	Meter per square Second ($m.s^{-2}$)
Force, Gravitation	Newton (N), ($kg.m.s^{-2}$)
Pressure	Pascal (Pa), ($kg.m^{-1}.s^{-2}$)
Tension (mechanical)	Pascal (Pa), ($kg.m^{-1}.s^{-2}$)
Dynamic viscosity	Pascal Second (Pa.s), ($kg.m^{-1}. s^{-1}$)
Kinematic viscosity	Square Meter per Second ($m^2.s^{-1}$)
Surface tension	Newton per Meter ($N.m.^{-1}$), ($kg.s^{-2}$)
Work, Energy	Joule (J), ($kg.m^2.s^{-3}$)
Power	Watt (W), ($kg.m^2.s^{-2}$)

Derived units of ACOUSTIC quantities

Name	Unit
Period	Second (s)
Wave intensity	Watt per square Meter ($W.m^{-2}$)
Acoustic pressure	Pascal ($kg.m^{-1}.s^{-2}$)
Sound pressure level L_p	Decibel (dB)
Acoustic Energy	Joule (J), ($kg.m^2.s^{-2}$)
Acoustic Power	Watt (W), ($kg.m^2.s^{-3}$)
Sound intensity	Watt per square meter ($W.m^{-2}$)
Acoustic intensity level, L_J	Decibel (dB)
Volume level	Phon (Ph)
Volume	Son (son)
Hearing loss	Decibel (dB)

Derived units of THERMAL quantities

Name	Unit
Heat	Joule (J), ($kg.m^2.s^{-2}$)
Thermic flux	Watt (W), ($kg.m^2.s^{-3}$)
Density of heat flux	Watt per square Meter ($W.m^{-2}$)
Thermal capacity	Joule per Kelvin ($J.K^{-1}$)
Specific heat	Joule per Kg per Kelvin ($J.kg^{-1}.K^{-1}$)
Specific state heat	Joule per kilogram ($J.kg^{-1}$), ($m^2.s^{-2}$)
Entropy	Joule per Kelvin ($J.K^{-1}$), ($kg.m^2.s^{-}$)
Absolute air humidity	Kilogram per cubic Meter ($kg.m^{-3}$)
Relative air humidity	---------, 1

Derived units of MOLECULAR quantities

Name	Unit
Avogadro's constant	Reciprocal mol (mol^{-1})
Relative nuclide mass	----------, 1
Relative atom mass	----------, 1
Relative molecule mass	----------, 1
Molecular mass	Kilogram per Mol, ($kg.mol^{-1}$)
Atom mass	Kilogram per Mol, $kg.mol^{-1}$
Mol volume	Cubic Meter per Mol ($m^3.mol^{-1}$)
Substance concentration	Mol per cubic Meter ($mol.m^{-3}$)
Mass concentration	Kilogram per cubic Meter ($kg.m^{-3}$)

Derived units of ELECTRIC quantities

Name	Unit
Electric charge	Coulomb (C), (A.s)
Intensity of electric field	Volt per Meter ($V.m^{-1}$)
Electric potential	Volt (V)
Electric voltage	Volt (V)
Electric resistance	Ohm ($V.A^{-1}$)
Electric conductance	Siemens (S), ($A.V^{-1}$)
Electric capacity	Farad (F)
Electro-chemical equivalent	Kilogram per Coulomb ($kg.A^{-1}.s^{-1}$)
Power of electric current	Watt (W), ($kg.m^2.s^{-3}$)
Inductance	Henry (H)
Magnetic flux	Weber (Wb)
Magnetic induction	Tesla (T)

Derived units of OPTIC quantities

Name	Unit
Radiant flux	Watt (W, $kg.m^2.s^{-3}$)
Power (radian flux) density	Watt per square Meter ($W.m^{-2}$)
Radiation intensity	Watt per square Meter ($W.m^{-2}$)
Luminosity	Watt per steradian ($kg.m^2.sr^{-1}.s^{-3}$)
Luminous flux	Lumen (lm), ($cd.sr^{-1}$)
Illumination	Lux (lx), ($lm.m^{-2}$), ($cd.sr^{-1}.m^{-2}$)
Exposure	Luxsecond (lx.s), ($cd.s.sr^{-1}.m^{-2}$)
Brightness	Candela per square Meter ($cd.m^{-2}$)
Focal distance	Meter (m)
Optical power	Diopter (D), (m^{-1})

Derived units of quantities in ATOMIC PHYSICS and RADIOLOGY

Name	Unit
Frequency	Reciprocal Second (s-1)
Decay constant	Reciprocal Second (s-1)
Decay Halftime	Second (s)
Activity	Becquerel (Bq), (s-1)
Dose	Gray (Gy), (J.kg-1), (m2.s-2)
Absorbed dose rate	Gray per Second (Gy.s-1), (m2.s-3)
Exposure	Coulomb per kilogram (C.kg-1)
Exposure power	Amper per kilogram (A.kg-1)
Dose equivalent	Sievert (Sv), (J.kg-1), (m2.s-2)
Energy flux density	- (W.m-2), (kg.s-3)
Flux density	- (m-2.s-1)
Dose rate	D (Gy.s-1), (m2s-3)
Exposure rate	X (A.kg-1)
Absorbed dose	D (Gy), (m2.s-2)
Maximum dose depth	R100 (m)
Half dose depth	R50 (m)
Therapeutic range	R80 (m)
Surface dose	D (Gy), (m2.s-2)

9.1.1 Definition of quantities and units in RADIOLOGY

- **Activity**

The basic variable in radiochemistry is activity. Activity A, body of a radioactive element (isotope), is defined as the ratio of the differential radioactive transformations of N and time t

$$A = \frac{dN}{dt}$$

The main unit is: 1 becquerel = 1 Bq = 1 reciprocal second = 1 s-1.

Former unit is: 1 curie = 1 Ci = 3.7 * 1010 Bq.

- **Half-life (of conversion) (T1/2)**

Half-life (half-life of conversion) T1/2 mean median length of time for which any initial quantity of homogeneous atoms (nuclides) radioactive decay spontaneously just half of this:

T1/2 is the mean median length of time which any initial quantity of homogeneous atoms (nuclides) take to radioactively spontaneously decay to just half of their initial volume/amount/quantity:

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

(where) λ denotes the radioactive decay constant of the reference sample.

- **Decay constant (λ)**

Decay constant λ is understood as the variable characterizing the temporal instability of the radioactive element (isotope). It is the constant of proportionality between time (t) decrease in the number of atoms (N) radionuclide - dN/dt caused by spontaneous transformation, and the total number N of atoms of the same nuclide, which are still radioactively nondecayed. This begins with the time of the act of spontaneous radioactive decay and is defined as

$$\frac{dN}{dt} = -\lambda N$$

Time-dimension is 1, then the reciprocal of the second unit, ie s-1.

Decay constant is a variable specific activity of the element relative to the total number N of nuclides in the sample. It is therefore also intended by the following formula:

$$\lambda = \frac{A}{N}$$

Relationship with a median life indicates the relationship

$$\lambda = \frac{1}{\tau}$$

Even in this context, recall the statistical validity of the law of decay

$$N = N_0 . e^{-\lambda t}$$

where N0 is the number of atoms in the initial nondecayed time tracking, and N nondecayed loss after time t. Decay constant for the unit Becquerel (Bq) is not used, is intended solely activity and units derived from it.

- **Current density of particles**

Particle current density J is the mean proportion of N particles that pass for some time t An a flat surface (perpendicular to the direction of motion of particles) and the size of the area and the time interval. In vector notation:

$$\vec{J} = \frac{\partial^2 N}{\partial A_n^0 \partial t} \vec{A}_n^0$$

Unit is the reciprocal square meter per second, ie m-2s-1.

- **Linear attenuation coefficient**

Linear attenuation coefficient μ is the mean rate of decline in current density

J particle depends on the length of x in its path to the substance according to the relations:

$$J = J_0 . e^{-\mu x} \quad \Rightarrow \quad \mu = -\frac{1}{J} \frac{dJ}{dx}$$

The main unit of the linear attenuation coefficient is reciprocal meter, ie, m-1.

The inversion of the linear attenuation coefficient (1 / μ) thickness means a substance in which the current density particles are attenuated from the initial value to the value J0 = J / e ≈ 0.368 J0.

- **Half-thickness**

Half-thickness d1/2 is the mean layer thickness reducing the current density J of particle beam to half its original value. For the exponential absorption

$$d_{1/2} = \frac{\ln 2}{\mu}$$

where μ is the linear attenuation coefficient. The layer thickness is the same in the direction towards the current density particles.

- **Mean lifetime**

Mean lifetime of radioactive element τ means the average time necessary for the decreasing of the number N0 of atoms or nuclei of a species, which exist in a particular state to a number equivalent to the value of:

N = N0 / e

where e is the base of natural logarithms (e ≈ 2.718282). Size is 1 s.

- **The total flux of particles**

Total particle flux (emission sources) Φp is the ratio of the number ΔN of particles emitted by a source and time t in which the particles passed through the selected area of a certain size.

$$\Phi_p = \frac{\Delta N}{\Delta t}$$

Dimension is time-1, the main unit is s-1.

- **Shutter speed**

Shutter speed (exposure power, before irradiation also speeds) mean rate of change of X irradiation

$$\dot{X} = \frac{\Delta X}{\Delta t}$$

where ΔX denotes the mean irradiance increasing in the time interval t. The main unit of exposure rate is ampere per kilogram, A .kg-1.

Links

- The Fundamental Law of Radioactive Decay