31.2 Radiation Units

Measure of the number of nuclear transformations (disintegrations) which occur in a certain time period

There are four radiation measurements used in different applications:

1. **Source activity** — نشاط المصدر
2. **Exposure** — التعرض
3. **Absorbed dose** — جرعة الامتصاص
4. **Biological equivalent dose** — الجرعة المكافئة للإنسان

source activity (*A*) is the disintegration rate of a radioactive material or the rate of decrease in the number of radioactive nuclei present .

We can not measure the number of nuclei directly, but we can measure the rate of disintegrations per unit time.

It is measured in *curies*

1curies=1Ci

$=3.7\times10^{10}$ disintegrations per second

The unit of radioactivity is Curie (Ci)

1 gram of radium (226) has approximately 3.7 x 10^{10} disintegrations per second, ➡ 1 Ci of radium has a mass of about 1 g.

source activity

$$A = \frac{-\Delta N}{\Delta t} = \lambda N = \frac{0.693}{T} N$$

The minus sign is needed because ΔN is the change in the number of nuclei present and is negative, while the disintegration rate or activity is positive.

Becquerel (Bq): is one disintegration per second (SI unit)

1 Bq = 1 decay/sec
1 Ci = 3.7×10^{10} Bq

If there are n moles in the sample, then the number of atoms is

$$N = n N_A$$

where N_A = Avogadro's number = 6.02×10^{23} is the number of particles in a mole.

The activity of n moles of a sample is then:

$$A = \frac{0.693}{T} n N_A \Rightarrow A \propto \frac{1}{T}$$

(31-14)

What is the mass of 1 microcurie (10^{-6} Ci) ^{131}I source? (The half-life ^{131}I is 8.1 days)

$$A = 10^{-6}\,Ci,\ T = 8.1\,days$$

$$A = \lambda N = \frac{0.693}{T} n N_A \longrightarrow n = \frac{AT}{(0.693)N_A}$$

$$= \frac{10^{-6} \times (8.1 \times 3600 \times 24)}{(0.693) \times (6.02 \times 10^{23})} = 6.23 \times 10^{-13}\,mole$$

$$m = 131 \frac{g}{mole} \times 6.23 \times 10^{-13}\,mole = 8.17 \times 10^{-11}\,g$$

Look example 31.2 and (31-16)

More Example

A sample of ^{60}CO with a half-life of 5.27 years = 1.66 x 10^{8} s contains 3×10^{16} radioactive nuclei. What is its activity (in Ci) after 15.78 yr?

$N_o = 3\times10^{16}$ nucleus , T = 5.27 years = 1.66 x 10^{8} s , t = 15.78 yrs = 4.99×10^{8} s

$$A = N_o \lambda e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{T} = \frac{0.693}{1.66 \times 10^{8}} = 4.17 \times 10^{-9}\,decay/\sec$$

$$\therefore A = (3 \times 10^{16})(4.17 \times 10^{-9})\, e^{-(4.17\times10^{-9})(4.99\times10^{8})}$$

$$A = 12.51 \times 10^{7}(0.125) = 15.6 \times 10^{6}\,decay/s = 15.6 \times 10^{6}\,Bq$$

$1\ Ci = 3.7\times10^{10}\ Bq$

$A = 4.22\times10^{-4}\ Ci$

Exposure and Absorbed Dose

Exposure ➡ the amount of radiation reaching a material,

Absorbed dose ➡ the energy absorbed in the material from the beam.

- The absorbed dose depends on the properties of the material and the beam.
- The exposure depends on the characteristics of the beam alone.

The conventional unit is **1 roentgen = 1 R**

= 2.58×10^{-4} coulomb/kg

Thus 1 roentgen of X rays will produce 2.58×10^{-4} C of positive ions in a kg of air at STP, and an equal amount of negative ions.

The *absorbed dose* is the energy imparted by ionizing radiation to a unit mass of absorbing tissue. It is measured in radiation absorbed dose *(rads)*, where

$$1 \text{ rad} = 10^{-2} \text{ J/kg}$$

In SI units; use Gray where;

$$1 \text{ Gy} \equiv 1 \text{ J/kg} = 100 \text{ rad}$$

Biological Quantities

The absorbed dose refers to a physical effect: the transfer of energy to a material. The effects of radiation on biological systems also depend on the type of radiation and its energy

The quality factor (QF) of a particular radiation is defined by comparing its effects to those of a standard kind of radiation, which is usually taken to be 200-keV X rays.

$$QF = \frac{Dose\ of\ x\ or\ \gamma - rays}{Dose\ of\ any\ radiation}$$

The QF varies with the radiation type and energy, with the animal species, and the biological effect under consideration

The *rem* and the millirem = 10^{-3} rem are the units used in discussions of biological effects.

Dose in (rem) = Dose in (rad) × QF

In S.I. units, the biologically equivalent dose in sieverts (Sv) equals the dose in grays times the QF.

Dose in (Sv) = Dose in (Gy) × QF

Read Example 31.4

Example 31.5

(31-23)

A ^{60}Co source produces an absorbed dose of 4000 rads per hour in tissue. The QF is 0.7 for cobalt gamma ray.
(a) How much time is required for an absorbed dose of 300 rads?

$$Dose \ \text{in rad} = 4000 \ \text{in 1 hour} \qquad t = ? \quad \text{to absorb 300 rad}$$

$$\therefore t = \frac{300}{4000} = 0.075 hour = 4.5 \min$$

(b) How much time is required for a biologically equivalent dose of 300 rems?

Rem = rad × QF   300 = rad × 0.7   rad=428.6

$$Dose \ \text{in rad} = 300 \ \text{in 4.5 min} \qquad t = ? \quad \text{to absorb 428.6 rad}$$

$$\therefore t = \frac{428.6 \times 4.5}{300} = 6.43 \min$$

(31-24)

A mouse receives an absorbed dose of 200 rads of 10MeV protons, Which have a QF of 2.What is the biologically equivalent dose?

Rem = rad × QF
=200 × 2
=400 rems

Summary

Amount	For what?	Unit	SI unit
Activity	**disintegration rate**	**Ci**	**Bq**
Exposure	**Amount of radiation**	**R**	**C/kg**
Absorbed dose	**Energy absorbed**	**rad**	**Gy**
equivalent dose	**Biological effect**	**rem**	**Sv**

مع تمنياتي لكن بالتوفيق و النجاح

Good luck for every 145 phys students

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