Unit 2

Radioactivity

1. In every atom, the positive charge and mass are densely concentrated at the center of the atom forming its nucleus. More than 99.9% mass of the atom is concentrated in the nucleus.

2. Atomic Mass Unit (amu) The unit to express atomic masses is called atomic mass

unit. Atomic mass unit is defined as 1/12 th of the mass of carbon atom (C12).

3. Composition of Nucleus The composition of a nucleus can be described by using the following terms and symbols.

(i) Atomic Number Z Atomic number of an element is the number of protons present inside the nucleus of an atom of the element.

Atomic number = Number of protons = Number of electrons

(ii) Mass Number A Mass number of an element is the total number of protons and neutrons inside the atomic nucleus of the element.

Mass number = Number of protons + Number of neutrons = Number of electrons + Number of neutrons i.e. A=Z.+ N

Radioactivity It is the phenomenon of spontaneous disintegration of the nucleus of an atom with emission of one or more radiations like α-particle, β-particle or γ-rays.

4. **Radioactive Decay** It is a nuclear transformation process in which the radioactive rays are emitted from the nucleus of the atom. This process cannot be accelerated and slow down by any physical or chemical process.

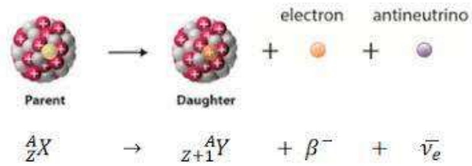
α- Decay In α-decay, the mass number of the product nucleus is four less than that of decaying nucleus while the atomic number decreases by two.

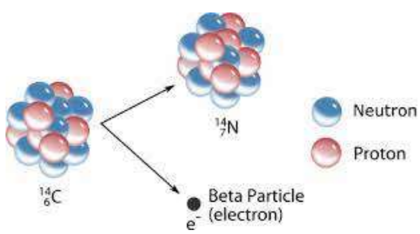
$$ {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He $$

β-Decay In β-decay, the mass number of product nucleus remains same but atomic number increases or decreases by one.

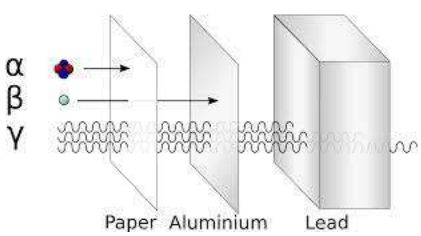
In beta-minus decay (β–),an electron and an antineutrino are created and emitted from the nucleus.

In beta-plus decay (β+), a positron and a neutrino are created and emitted from the nucleus





γ-Decay :A γ- ray is emitted when a or β-decay results in a daughter nucleus in an excited state. Atom then returns to ground state by a single photon transition or successive transitions involving more than one photon.



Name	Symbol	What is it?	Penetration depth in air	What blocks it?	Charge	Deflected by Magnetic Field?
Alpha	α or ${}^4{}_2He$	Helium nucleus: 2 protons and 2 neutrons	8cm	paper	Positive	Yes, less than beta particles because they have a higher mass
Beta	${}^{0}_{-1}\beta$ or e^-	High energy electron	1m	3mm aluminium	Negative	Yes, more than alpha, and in the opposite direction because they have the opposite charge
Gamma	γ	Part of the Electromagnetic Spectrum	Forever	Several m of concrete or lead	None	No

Radioactivity Decay Law According to this law, the rate of decay of radioactive atoms at any instant is proportional to the number of atoms present at that instant.

$\Delta N/\Delta t \propto N$

Where,

N: the total number of nuclei in the sample Δ

N: number of nuclei that undergoes decay

Δt: unit time

$\Delta N/\Delta t = \lambda N$

Where,

λ: radioactive decay constant also known as disintegration constant.

Decay Constant The radioactive decay constant may be defined as the reciprocal of the time during which the number of atoms in a radioactive substance reduces to 36.8% of their initial number.

In other words,

$\ln(N/N_0) = -\lambda t$

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

Half-life Half-life of a radioactive element is defined as the time during which half the number of atoms present initially in the sample of the element decay.

The relationship between the half-life, $T_{1/2}$, and the decay constant is given by $T_{1/2} = 0.693/\lambda$.

Solved Problems

1. If the half-life if Iridium-182 is 15 minutes, how much of a 1 gram sample is

left after 45 minutes?

Half lives = total time of decay = 45min = 3

Half-life 15min

After 3 half lives, it has been reduced by 1 /2x 1 /2x 1/2 = 1/8

So after 45 minutes, 1/8 x 1 gram = 0.125 grams remains

2.A radioactive substance has a half-life of 1 year. The fraction of this material that would remain after 5 years will be

(A) 1/32

(B) 1/5

(C) 1/2

(D) 4/5

Solution:

The substance has half-life of 1 year. Let N

0 be the initial quantity of material and N be the new quantity.

Then N/N0 = (1/2)n

Hence, N = 1/32 × N0

= 1/32. Hence, (A) is the correct option.

3. The half-life of a radioactive substance is 3.6 days. How much of 20 mg of that radioactive substance will remain after 40 days?

(A) 2.68×10^3 mg

(B) 4.31×10^{-2} mg

(C) 6.20×10^{-3} mg

(D) 9.76×10^{-3} mg

Solution:

The half-life of the radioactive substance is given to be 3.6 days.

40/3.6=11.11 half life

So, after 40 days, the quantity of substance remaining is given by

$1/ 2^{11.11}$ x $20=9.76 \times 10^{-3}$ mg

Hence, this gives (D) as the correct option.

4 .A substance reduces to 1/16th of its original mass in 2 hours. The half-life period of the substance will be:

(A) 15 min

(B) 30 min

(C) 60 min

(D) 120 min

Solution:

Let N0 be the original quantity and N be the new quantity then,

N / N0 = 1/2t/T = 1/16 = 1/24

t/T = 4 => T = t/4 = 120 / 4 = 30 min

This gives (B) as the correct option.

5. Pd-100 has a half-life of 3.6 days. If one had 6.02×10^{23} atoms at the start, how many atoms would be present after 20.0 days?

Solution:

20.0 / 3.6 = 5.56 half-lives

$(1/2)^{5.56} = 0.0213$ (the decimal fraction remaining after 5.56 half-lives)

(6.02×10^{23}) $(0.0213) = 1.28 \times 10^{22}$ atoms remain