{Radioactivity}

Some elements spontaneously emits some radiations or particles, such elements are called radioactive elements and this property of spontaneous emission of radiations or particles is called radio activity.

For example: $_{92}U^{235}$ is a radioactive element.

- Radioactive element may be proton or neutron.

→ There are three types of emission by radioactive elements as shown in the figure below:-

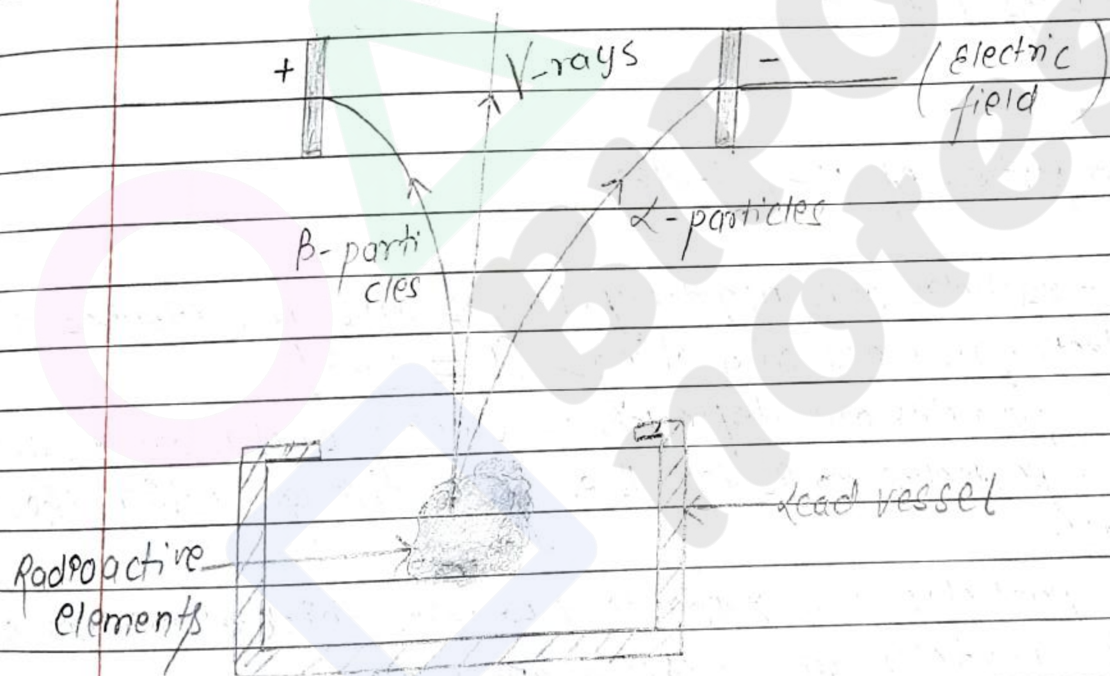

Fig:- Deflection of radioactive emission in electric field.

* propertise of α - particles:

1. α-particle is equivalent to Helium in mass and charge [$q = 2e$ and $m = 4m_p$] [$\alpha = {}_2He^4$]
2. α-particle being positively charged, is deflected in electric and magnetic fields.
3. α- particle ionize the gases through out which they pass
4. α- particle have low penetration power and can be stopped by thick sheet of paper.
5. α- particles affect photographic plates.
6. α- particles produce fluroscence on fluorescent materials like zns.
7. velocity: $\left(\frac{1}{100} c\right)$

* propertise of β - particles.

1. β- particles are negatively charged and are identical to electron in mass and charge [$\beta \equiv {}_{-1}e^0$]
2. β- particles are deflected in electric and magnetic fields
3. β - particles ionize the gases through which they pass.
4. β- particles can pentrate few mm thick alumenium sheet
5. β - particles affect photographic plates.
6. β- particles produce fluorescence on fluorescent materials like zns.
7. β - particles have high velocity of the order $10^7 ms^{-1}$ $\left(\frac{1}{10} c\right)$

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* propertise of γ-rays.

(1) γ-rays are electromagnetic waves which are electrically neutral.
(2) γ-rays are not deflected in the electric and magnetic fields as they are electrically neutral.
(3) γ-rays ionize the gases through which they pass.
(4) γ-rays have high penetration power and can penetrate 80 cm thick steel wall.
(5) γ-rays affect photographic plates.
(6) γ-rays produce fluorescence on fluorescent materials like zns.
(7) γ-rays move with velocity of light in vacuum (c).

• Notes:-

(1) Ionization power : $\alpha > \beta < \gamma$.
(2) penetration power : $\alpha < \beta < \gamma$.

* Laws of Radioactive decay:-

(1) When a nucleus radioactive neucleus emits a β- particle then the atoms number of resulting nucleus increases by 1 and the mass number is constant. (i.e it remain same as that of parent nucleus).
example:-

$$_{Z}X^{A} \xrightarrow{-\beta} {}_{(Z+1)}Y^{A} + {}_{-1}e^{0}$$

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Similarly,
When a radioactive nucleus emits an α-particles the atomic number and mass number of the resulting nucleus is decreased by 2 and 4 respectively.

Example:-

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

Imp ② The rate of decay of a radioactive sample at an instant is directly porportional to the number of its atoms present at that instant. Thus,

$$\frac{dN}{dt} \propto N$$

or, $$\frac{dN}{dt} = -\lambda N \quad ; \left[\lambda = \text{decay (or disintegeration constant)}\right]$$

$$\therefore \frac{dN}{N} = \cancel{-\lambda t} -\lambda dt \quad \text{—} (i)$$

Negative sign in eqn (i) indicates the rate of decay decrease when time increases.

Integration of eqn (1) from $t=0$ to $t=t$, we get.

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_{0}^{t} dt$$

or $$\left[\log_e N\right]_{N_0}^{N} = -\lambda [t]_0^t$$

or, $[\log_e N - \log_e N_0] = -\lambda t$

or, $\log_e \frac{N}{N_0} = -\lambda t$

or, $\frac{N}{N_0} = e^{-\lambda t}$

$\boxed{\log_{10} 1000 = 3}$ value, $\leftarrow$ power, base, $\text{base}^{\text{power}} = \text{value}$

$\therefore N = N_0 \cdot e^{-\lambda t}$ — ② where, $[\log_n n = 1]$

N_0 = Initial number of radioactive atoms.
N = Number of atoms remained after time t.
Eqn ② gives the relation between N_0 and N.

* Half life time ($T_{1/2}$):-

The time taken to decay half of the inital amount of a radioactive substance is called Half life period (or time) of that substance.

Thus, if N_0 is the intial number of radioactive atoms of a substances then after;

$t = T_{1/2}$

$N = \frac{N_0}{2}$

Therefore, eqn $N = N_0 e^{-\lambda t}$ gives;

$\frac{\cancel{N_0}}{2} = \cancel{N_0} \cdot e^{-\lambda \cdot T_{1/2}}$

or, $\frac{1}{2} = e^{-\lambda \cdot T_{1/2}}$

or, $\frac{1}{2} = \frac{1}{e^{\lambda T_{1/2}}}$

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$\therefore \boxed{2 = e^{\lambda \cdot T_{1/2}}}$

Taking $\log_e$ (or $\ln$) on both sides of above eqn; we get

$\log_e 2 = \log_e \cdot e^{\lambda \cdot T_{1/2}}$

or, $\ln 2 = \lambda \cdot T_{1/2} \cdot \log_e \cdot e$ [$\because \log m^n = n$

or, $0.693 = \lambda \cdot T_{1/2}$ ($\because \log n \cdot n = 1$]

$\therefore \boxed{T_{1/2} = \frac{0.693}{\lambda}}$ — ①

* Alternating relation between N and No:-

If $T_{1/2}$ is a half life time and No is the initial number of atom of a radioactive substance.

Then,

Number of atoms remained after 1 half life time

$= \frac{N_0}{2}$.

Similarly.

Number of atoms remained after 3 half lives

$= \left[\frac{1}{2}\right]\left[\left(\frac{1}{2}\right)^2 \cdot N_0\right] = N_0\left(\frac{1}{2}\right)^3$.

Number of atoms required after n half time life

$= N_0\left(\frac{1}{2}\right)^n$

$= N$

Then, $\boxed{N = N_0\left(\frac{2}{2}\right)^n}$

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where,
n = number of half lives
$\therefore = \frac{t}{T_{1/2}}$

Numerical:

(1) A radioactive sample has 2×10^{20} atoms. If its half life period is 10 hrs, calculate number of atoms which have decayed in 30 hours. Also calculate total energy released in 30 hours. If energy released per day is 2ev. Also find power.

⇒ soln;
here;
Initial number of radioactive atoms $(N_0) = 2\times10^{20}$ atoms.
Half life time period $(T_{1/2}) = 10$ hrs.
Total time $(t) = 30$ hrs.

(1) Number of atoms decayed in 30 hrs. $(N_0 - N) = ?$
(2) Total energy released in 30 hrs = ?
(3) Power = ?

Energy per decay = 2ev
$= 2\times1.6\times10^{-19}$ J.
$\Rightarrow 3.2\times10^{-19}$ J.

Now
No. of atoms remained (N);

$$N = N_0\left(\frac{1}{2}\right)^n \qquad \left[\begin{aligned} n &= t/T_{1/2} \\ &= \frac{30h}{10h} \Rightarrow 3 \end{aligned}\right]$$

$$= 2\times10^{20}\times\left(\frac{1}{2}\right)^3$$

$$= \frac{2\times10^{20}}{8}$$

$$= (0.25\times10^{20})\text{ atoms}$$

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(i) No. of atom decayed $= N_0 - N$
$= 2\times10^{20} - 0.25\times10^{20}$
$= 10^{20}(2-0.25)$
$= (1.75\times10^{20})$ atoms.

(ii) Total energy released ~~in 30 hrs~~ $= (N_0 - N)\times 3.2\times10^{-29}$
$= 1.75\times10^{20}\times3.2\times10^{-19}$
$= 56$ Joules.

(iii) Power(P) $= \frac{\text{Energy}}{\text{Time}} = \frac{56}{30\,hr}$
$= \frac{56}{30\times3600\,sec}$
$= \frac{56}{108000} \Rightarrow 5.18\times10^{-14}$ Watt.

(2) A radioactive sample contains mass 10 gm and has half life 100 yrs. find the mass remained after 131 years.

⇒ Soln:
Here;
Initial mass of radio active sample $(M_0) = 10\,gm$.
Half life time $(T_{1/2}) = 100$ years
Total time $(t) = 131$ years.
Mass remained after 131 years $(M) = ?$
we have,
$M = M_0 e^{-\lambda t}$
or, $M = 10\times e^{-\left(\frac{0.693}{T_{1/2}}\right)\times t}$
or, $M = 10\times e^{-\frac{0.693\times131\,yrs}{100\,yrs}}$
or, $M = 10\times e^{-0.90783}$
$\therefore \boxed{M = 4.033\,gm}$ #

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(3) find the activity of a radioactive sample having $N_0 = 2 \times 10^{20}$, $T_{1/2} = 5$ hrs after 15 hours.

⇒ Soln:
here
$N_0 = 2 \times 10^{20}$ atoms
Half life time $(T_{1/2}) = 5$ hours $= 5 \times 3600$ sec.
Total time $(t) = 15$ hours.

Now
$$\text{activity} = \left(-\frac{dN}{dt}\right) = \lambda N$$

$$= \frac{0.693}{T_{1/2}} \left[N_0 \left(\frac{1}{2}\right)^n\right]$$

$\boxed{\therefore n = t/T_{1/2} = \frac{15}{5} = 3}$

$$= \frac{0.693}{5 \times 36000 \text{ sec}} \times \left[2 \times 10^{20} \times \left(\frac{1}{2}\right)^3\right]$$

$$= \frac{7.7 \times 10^{15}}{8}$$

$$= \boxed{0.96 \times 10^{15}} \text{ decays/sec Ans.}$$

Imp (4) The activity of sodium solution injected into patient's body was 12000 decay/min. After 30hrs, the activity in 1 cm³ blood of a patient was found to be 0.5 decay/min. If $T_{1/2}$ is 15hr for Na solution then find the total volume of blood in the patient's body.

⇒ soln;

According to the question, while injecting

activity of Na solution $\left(-\frac{dN_0}{dt}\right) = \frac{1200 \text{ decay}}{\text{min}}$

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$\Rightarrow dN_0 = \frac{12000 \text{ decay}}{min}$ — ①

And,

after $t = 30$ hrs in 1 cm³ blood.

$$\text{let, } \left(-\frac{dN}{dt}\right) = \frac{0.5 \text{ decay}}{min} = dN''$$

$$\Rightarrow \frac{0.5 \text{ decay}}{min} = \left(\frac{0.693}{T_{1/2}}\right) N'$$

$$\Rightarrow \frac{0.5}{min} = \frac{0.693 \, N'}{15 \times 60 \, min} \quad \left(\because T_{1/2} = 15 \, hr = 15 \times 60 \, min\right)$$

$$\Rightarrow N' = \frac{0.5 \times 15 \times 60}{0.693}$$

$$\Rightarrow N' = 649.35 \text{ atoms}$$

Similarly

from ⑨

$$\frac{12000}{min} = dN_0$$

$$\Rightarrow \frac{12000}{min} = \frac{0.693 \, N_0}{15 \times 60 \, min}$$

$$\Rightarrow N_0 = \frac{12000 \times 15 \times 60}{0.693}$$

$$\Rightarrow N_0 = 15584415.58 \text{ atoms}$$

Now,

$$N = N_0 \left(\frac{1}{2}\right)^n \quad \left[n = t/T_{1/2} = \frac{30 \, hr}{15 \, hr} = 2 hr\right]$$

$$= 15584415.58 \times \frac{1}{4}$$

$$= 3896103.896 \text{ atoms} \quad (\text{In whole blood})$$

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Hence,

Total volume of blood $(V) = \frac{N}{N_1}$

$= \frac{3896103.896}{649.35}$

$\Rightarrow 6000\,cm^3.$

OR $\Rightarrow$ 6 litre.

Therefore, the total volume of blood in patients blood is 6 litre.

ECQ ⑤ Find the mass of ~~1g~~ U^{235} which gives activity 1 curie. $[T_{1/2} = 2\times10^9$ years$]$.

$\Rightarrow$ Here: for U^{235}

$-\frac{dN}{dt} = 1$ curie (1 Ci) $= 3.7\times10^{10}\,\frac{\text{decay}}{\text{sec}} = \lambda N$

$\Rightarrow N = \frac{3.7\times10^{10}}{\lambda}$

$\Rightarrow N = \frac{3.7\times10^{10}}{\frac{0.693}{T_{1/2}}}$

$\Rightarrow N = \frac{3.7\times10^{10}\times2\times10^9\,yr}{0.693}$

$\Rightarrow N = \frac{3.7\times10^{10}\times(2\cdot10^9\times365\times86400)\,sec}{0.693}$

$\Rightarrow \boxed{N = 3.36\times10^{27}\text{ atoms}}.$

Now

for U^{235}

Mass (m) $= \frac{235}{6.023\times10^{23}}\times N$

$= \frac{235}{6.023\times10^{23}}\times3.36\times10^{27}.$

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$= \frac{789.6 \times 10^{27}}{6.023 \times 10^{23}}$
$= (131.1 \times 10^{4})$ gm.

* Decay constant (λ):-

we know
$N = N_0 . e^{-\lambda t}$ —— (i)

Putting $t = 1/\lambda$ in eqn (i), we get.

$N = N_0 . e^{-\lambda t \times 1/\lambda}$
$\Rightarrow N = N_0 . e^{-1}$
$\Rightarrow N = \frac{N_0}{e} = \frac{N_0}{2.718}$ [standard value of $e = 2.718$]

$\Rightarrow N = 0.37 N_0$.
$\Rightarrow N = \frac{37}{100} N_0$.
$\Rightarrow \boxed{N = 37\% \text{ of } N_0}$

Thus, the decay constant of a radioactive substance or element is defined as the reciprocal of time interval after which number of atoms of radioactive elements falls to nearly 37% of its initial number.

mcq *) Units of radioactivity:-

(i) 1 Bequerrel $\Rightarrow$ 1 Bq = 1 $\frac{\text{decay}}{\text{sec}}$

(ii) 1 Rutherford $\Rightarrow$ 1 Rd = 10^6 $\frac{\text{decays}}{\text{sec}}$

(iii) 1 Curie = 1 Ci = 3.7×10^{10} $\frac{\text{decays}}{\text{sec}}$

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Note: [1 ci is equal to activity of radium]

* Radiocarbon dating:-
All the living beings and plants absorb stable (non-radioactive) C^{12} and unstable (radioactive) C^{14}. When they die, the radioactive C^{14} decays by emission of β particle according to the following nuclear reaction:-

$$_6C^{14} \xrightarrow{-1\beta^0} {}_7N^{14} + {}_{-1}\beta^0$$

If N_0 is the total no of C^{14} & C^{12} atoms. Then.
$$N_0 = N^{14} + N^{12}$$
After time t no. of C^{14} atoms remained will be
$$\text{or, } N_{14} = \left[N^{14} + N^{12}\right] e^{-\lambda t} \quad \text{or } N_{14} = N_0 \cdot e^{-\lambda t}$$
$$\text{or, } N_{14} = \frac{N^{14} + N^{12}}{e^{\lambda t}}$$
$$\text{or, } e^{\lambda t} = \frac{N^{14} + N^{12}}{N^{14}}$$
$$\text{or, } e^{\lambda t} = \left(1 + \frac{N^{12}}{N^{14}}\right)$$
Taking $\log_e$ on both sides, we get
$$\log_e e^{\lambda t} = \log_e \left(1 + \frac{N^{12}}{N^{14}}\right)$$
$$\text{or, } \lambda t \cdot \log_e e = \ln\left(1 + \frac{N^{12}}{N^{14}}\right)$$
$$\text{or, } \lambda t = \ln\left(1 + \frac{N^{12}}{N^{14}}\right) \quad (\because \log_e e = 1)$$
$$\text{or, } \therefore \boxed{t = \frac{1}{\lambda} \ln\left(1 + \frac{N^{12}}{N^{14}}\right)}$$

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where, $\lambda = \frac{0.693}{T_{1/2}}$ & $T_{1/2} = 5730$ yrs for C^{14}.

Thus, the technique of estimating the age of archaeological sample or rock through radioactive process is called radioactive dating.

* Average life (T_a):-

m.c.q

The reciprocal of decay constant of a radioactive substance is called Average life of that substance.

Thus, $T_a = 1/\lambda = \frac{1}{0.693/T_{1/2}}$

$$\Rightarrow T_a = \frac{T_{1/2}}{0.693}$$

$$\therefore \boxed{T_a = 1.44\ T_{1/2}}$$

I.Q. A nucleus has no electron yet it emits β-particle How!

Ans In β- decay, one neutron is converted into proton keeping the no of nucleons in the nucleus.

Thus,

$$_0n^1 \longrightarrow {}_1P^1 + {}_{-1}\beta^0 + \underset{\text{anti neutrino}}{\overline{\nu}}$$

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Numericals:-

1. After a certain lapse of time, the fraction of radioactive polonium decayed is found to have 12.5% of initial quantity. what is the duration of this lapse if the half time of polonium is 139 days!

Given, for polonium

$T_{1/2} = 139$ days.

$t = ?$ time taken.

$N = 12.5\%$ of N_0.

$\frac{12.5}{100} N_0$

Acc to the question

$N = \frac{12.5}{100} N_0 = \frac{1}{8} N_0$

or, $N = \left(\frac{1}{2}\right)^3 N_0$ — i)

~~or~~ ~~Al~~ we know that

$N = \left(\frac{1}{2}\right)^n N_0$ — ii)

Equating i) and ii) we get

$n = 3$

$\therefore n = 3 = \frac{t}{T_{1/2}}$ [where, $n = t/T_{1/2}$ = number of half time]

$\therefore t = 3 \times T_{1/2} = 3 \times 139 = 417$ day

Method - II

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

or $\frac{12.5}{100} \cancel{N_0} = \cancel{N_0} \cdot e^{-\lambda t}$

or $\frac{1}{8} = \frac{1}{e^{\lambda t}}$

Taking $\log_e$ on both sides of above eqn, we get

$\log_e 8 = \log_e e^{\lambda t}$

$\therefore \ln 8 = \lambda t \log_e e$ [$\because \log_e = \ln$]

or, $2.0794 = \lambda t$

$\therefore t = \frac{2.0794}{\lambda}$

$= \frac{2.0794}{\left(\frac{0.693}{T_{1/2}}\right)}$

$= T_{1/2} \times \frac{2.0794}{0.693}$

$= 417.08$ days Ans.

2. If 15% of the radioactive material decays in 5 days what would be the percentage of the material left after 28 days?

Soln

After time $(t_1) = 5$ days, fraction remained,

$\frac{N_1}{N_0} = (100-15)\% = 85\% = \frac{85}{100}$.

Now, $N_1 = N_0 e^{-\lambda t_1}$

or, $\frac{N_1}{N_0} = e^{-\lambda t_1}$

or, $\frac{N_1}{N_0} = \frac{1}{e^{\lambda t_1}}$

Putting the value of $\frac{N_1}{N_0}$

$\therefore \frac{85}{100} = \frac{1}{e^{\lambda t_1}}$

or, $\frac{100}{85} = e^{\lambda t_1}$

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or, $\frac{100}{85} = e^{5\lambda}$

$\therefore \log_e \left(\frac{100}{85}\right) = \log_e e^{\lambda 5}$

or, $\log_e \left(\frac{100}{85}\right) = 5\lambda$

$\therefore \lambda = 0.0325$

Hence, after time t_2, we have

$\frac{N_2}{N_0} = e^{-\lambda t_2}$

or, $\frac{N_2}{N_0} = e^{-0.0325 \times 25}$

or, $\frac{N_2}{N_0} = 0.443$

or, $\frac{N_2}{N_0} \simeq 0.44$

$= \frac{44}{100}$ %

$\therefore \frac{N_2}{N_0} = 44\%$

3. It is observed that 3.67×10^{10} α-particles are emitted per sec from 1 gm of R^{226}. Calculate the half life of radium.

Given,

For 1 gm of R^{226}.

$\frac{-dN}{dt} = 3.67 \times 10^{10} \frac{decay}{sec}$

$T_{1/2} = ?$

Soln:

1 mole (or 226 gm) of Ra^{226} has N_A atoms

$\therefore N_0 =$ Number of atoms of 1 gm of Ra^{226}.

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$= \frac{N_A}{2\cdot 26} = \frac{6\cdot 023 \times 10^{23}}{226}$

$= 2\cdot 665 \times 10^{21}$ atoms

Now,

$\left(\frac{-dN_0}{dt}\right) = \lambda N_0$

or $\left(\frac{-dN_0}{dt}\right) = \frac{0\cdot 693}{T_{1/2}} \times N_0$

or, $T_{1/2} = \frac{0\cdot 693 N_0}{\left(\frac{-dN_0}{dt}\right)}$

or, $T_{1/2} = \frac{0\cdot 693 \times 2\cdot 665 \times 10^{21}}{3\cdot 67 \times 10^{10}}$

or, $T_{1/2} = 5\cdot 03 \times 10^{10}$ sec.

or, $T_{1/2} = \frac{5\cdot 03 \times 10^{10}}{365 \times 24 \times 3600}$ years.

or $T_{1/2} = 1595$ yrs #

4. Measurement show that for certain isotope decay rate decreases from 8318 $\frac{\text{decay}}{\text{min}}$ to 3091 $\frac{\text{decay}}{\text{min}}$ in 4 days. what is the half life of this isotop.

Soln

$R_1 = \left(\frac{-dN}{dt}\right)_1 = 8318 \frac{\text{decay}}{\text{min}} = \lambda N_1$

after 4 days,

$R_2 = \left(\frac{dN}{dt}\right)_2 = 3091 \frac{\text{decay}}{\text{min}} = \lambda N_2$

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$$\therefore \frac{R_1}{R_2} = \frac{N_1}{N_2} = e$$

Taking $\log_e$ on both side

$$\log_e\left(\frac{8318}{3091}\right) = \log_e . e^{+4\lambda}$$

or $$\ln\left(\frac{8318}{3091}\right) = 4\lambda$$

$$\ln\left(\frac{8318}{3091}\right) = 4\left(\frac{0.693}{T_{1/2}}\right)$$

$$\ln\left(\frac{8318}{3091}\right) \times T_{1/2} = 4 \times 0.693$$

or, ~~$T_{1/2}$~~ $$T_{1/2} = \frac{4 \times 0.693}{\ln\left(\frac{8318}{3091}\right)}$$

$\therefore$ ~~$T_{1/2}$~~ $T_{1/2} = 2.8$ days.

5. At a certain instant a piece of radioactive material contains 10^{12} atoms. calculate the number of disintegrations in the first second ($T_{1/2}$ = 40 days)

Soln

$T_{1/2}$ = 40 days = 40 × 86400 sec.

$$\therefore \lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{40 \times 86400} = 2 \times 10^{7}\ sec^{-1}$$

$\therefore$ the disintegration in the first second will be

$$\left(-\frac{dN}{dt}\right) = \lambda N$$

$$= 2 \times 10^{7} \times 10^{12}$$

$$= 2 \times 10^{5}\ \frac{decay}{sec}\ \text{Ans}$$

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6\. If the half life of a radioactive substance is 2 days, after how many days will 1/64th part of substances be left behind?

Soln

Given, $T_{1/2} = 2$ days

$\frac{N}{N_0} = \frac{1}{64}$

$t = ?$

Acc to questions

$\frac{N}{N_0} = \frac{1}{64} = \left(\frac{1}{2}\right)^6$ — i)

Also $N = N_0 \left(\frac{1}{2}\right)^n$.

$\therefore \frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ — ii)

Equating 1) and 2) we get.

$n = 6$

But $n = \frac{t}{T_{1/2}}$

or, $t = n \cdot T_{1/2}$

or, $t = 6 \times 2$

$\therefore t = 12$ days Ans

7\. The initial number of atoms in a radioactive element is 6×10^{20} and its half life is 10 hrs. Calculate the number of atoms which have decayed in 30 hrs and the amount of energy liberated per atom decay is 4×10^{-13} J.

⇒ Given,

$T_{1/2} = 10$ hrs.

$t = 30$ hrs.

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i) Number of decayed atoms $(N_0 - N) = ?$
ii) Tot. energy released in 30 hrs energy per decays $= 4\times10^{-13}$ J $(E) = ?$

Soln i) Number of atom remained is

$$N = N_0\left(\frac{1}{2}\right)^n \quad \text{where, } n = \frac{t}{T_{1/2}}$$

$$= 6\times10^{20}\times(1/2)^3 \quad \therefore n = \frac{30}{10} = 3.$$

$$= 0.75\times10^{20} \text{ atoms}$$

$\therefore$ Number of decayed atom $(N_0 - N) = 6\times10^{20} - 0.75\times10^{20}$
$= 5.25\times10^{20}$ atoms.

ii) $E = (N_0 - N)\times4\times10^{-13}$ J
$= 5.25\times10^{20}\times4\times10^{-13}$
$= 21\times10^{7}$ joule.

8.

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9. A sample of Ra-226 has half life of 1620 yrs. what is the mass of the sample which undergoes 20000 disintegerations per second? (Avogador's number = 6.02×10^{23} mol^{-1})

Given,

For Ra^{226}

$T_{1/2} = 16220$ yrs $= 1620 \times 365 \times 864000$.

$N_A = 6.02 \times 10^{23}$ mol^{-1}

$m = ?$ if $\left(-\frac{dN}{dt}\right) = 20000 \frac{decays}{sec}$.

Soln

$\left(-\frac{dN}{dt}\right) = \lambda N$

or, $\left(-\frac{dN}{dt}\right) = \frac{0.693}{T_{1/2}} N$

or, $N = \frac{\left(-\frac{dN}{dt}\right) T_{1/2}}{0.693}$

$= \frac{20000 \times 1620 \times 365 \times 86400}{0.693}$

$= 1.47 \times 10^{15}$ atom

$\therefore m = \frac{226 \times N}{N_0}$

$m = \frac{226 \times 1.47 \times 10^{15}}{6.02 \times 10^{23}}$

or, $m = 5.5 \times 10^{-7}$ gm

$\therefore m = 5.5 \times 10^{-14}$ kg

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20) The C^{14} isotopes has Half life 5700 yrs. If the sample contains 1×10^{20} atoms of C^{14}, calculate the activity of the sample.

Soln

$$\text{Activity }(R) = \left(-\frac{dN}{dt}\right) = \lambda N = \frac{0.693N}{T_{1/2}}$$

$$\therefore R = \frac{0.693\times1\times10^{20}}{5700\times365\times86400} \quad \left[\because T_{1/2} = 5700\text{ yrs}\right.$$

$$= 3.85\times10^{10}\ \frac{\text{decay}}{\text{sec}} \qquad = 5700\times365\times864000$$

21. The unstable isotope of K^{40} has half life 2.4×10^{8} year. How many $\frac{\text{decays}}{\text{sec}}$ will occur in a sample having 2×10^{-6} of K^{40}?

Given,

For radioactive K^{40}.

$m = 2\times10^{-6}$ gm.

$T_{1/2} = 2.4\times10^{8}$ yrs.

$= 2.4\times10^{8}\times365\times24\times3600$ sec.

$\left(-\frac{dN}{dt}\right) = ?$

Soln:

1 mol of K^{40} has mass 40 gm and 6.023×10^{23} atom.

$\therefore$ Number of atoms in the given mass m will be

$$N = \frac{mN_a}{40} = \frac{2\times10^{-6}\times6.023\times10^{23}}{40}$$

$$= 3.01\times10^{6}\text{ atoms.}$$

$$\therefore \left(-\frac{dN}{dt}\right) = \lambda N$$

$$= \frac{0.693N}{T_{1/2}} = \frac{0.693\times3.01\times10^{16}}{2.4\times10^{8}\times365\times24\times36} = 2.756\ \frac{\text{decay}}{\text{sec}}$$

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1) A radioactive source ($T_{1/2} = 130$ days) contain 1×10^{20} atom and energy released per day is 8×10^{-13} J. Calculate the activity after 260 days and total energy released.

Soln;

i) Number of atoms remained after 260 day.

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$= 1 \times 10^{20} \times \left(\frac{1}{2}\right)^2 \quad \left[\text{where } n = \frac{t}{T_{1/2}} = \frac{268}{130} = 2\right.$$

$$= 0.25 \times 10^{20} \text{ atoms.}$$

$$\therefore \text{Activity} = \left(\frac{-dN}{dt}\right) = \lambda N = \frac{0.693}{T_{1/2}} N$$

$$= \frac{0.693 \times 0.25 \times 10^{20}}{130 \times 24 \times 3600}$$

$$= 1.54 \times 10^{12} \frac{\text{decay}}{\text{sec}}$$

ii) Total energy released

$$= (N_0 - N) \times \text{energy released per decay}$$

$$= (1 \times 10^{20} - 0.25 \times 10^{20}) \times 8 \times 10^{-13}$$

$$= (6 \times 10^{7}) \text{ joule.}$$

13) A radioactive source has decayed to one-tenth of one percent of initial activity in 100 days. What is the half life?

Given,

$$\left(\frac{-dN}{dt}\right) = \frac{1}{10} \times \frac{1}{100} \left(\frac{-dN_0}{dt}\right) \text{ in } t = 100 \text{ day}$$

$$T_{1/2} = ?$$

Acc to question

$$\left(\frac{-dN}{dt}\right) = \frac{1}{10} \times \frac{1}{100} \left(\frac{-dN_0}{dt}\right)$$

Ultra white A4 Teacher's Signature........

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$\therefore \Delta N = \frac{1}{1000} \Delta N_0$

or, $N = \frac{1}{1000} N_0$ —— (i)

Also,

$N = N_0 e^{-\lambda t}$ —— (ii)

equating (i) and (ii)

$\frac{\cancel{N_0}}{1000} = \cancel{N_0} e^{-\lambda t}$

or, $\frac{1}{1000} = \frac{1}{e^{\lambda t}}$

Taking $\log_e$ on both side

$\log_e e^{\lambda t} = \log_e 1000$

or, $\lambda t \cdot \log_e e = \ln 1000$

or, $\lambda t = \ln 1000$

or, $\frac{0.693 \times 100}{T_{1/2}} = \ln 1000$

or, $T_{1/2} = \frac{0.693 \times 100}{\ln 1000}$

$\therefore T_{1/2} = 10$ days.

14) 4 gm of radioactive material of half life period 10 yrs decays. find out the mean life of given sample.

soln

Mean life $= T_{av} = \frac{1}{\lambda} = \frac{1}{\left(\frac{0.693}{T_{1/2}}\right)} = \frac{T_{1/2}}{0.693}$

$= \frac{10}{0.693} = 14.43$ yrs.

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15. Find the half life of U^{238} if 1 gm of it emits 1.24×10^4 α-particles per sec [$N_A = 6.025 \times 10^{23}\ mol^{-1}$]

Soln,

N = Number of atoms in 1 gm of U^{238}

$= \frac{1\,gm}{238\,gm} \times N_A = \frac{6.025 \times 10^{23}}{238} = 2.53 \times 10^{21}$

$\therefore \left(\frac{-dN}{dt}\right) = \lambda N = \frac{0.693}{T_{1/2}} N.$

$T_{1/2} = \frac{0.693 N}{\left(\frac{-dN}{dt}\right)} = \frac{0.693 \times 2.53 \times 10^{21}}{1.24 \times 10^4}$

$= 1.41 \times 10^{17} sec$

$= \frac{1.41 \times 10^{17}}{(365 \times 24 \times 3600)} yrs$

$= 4.49 \times 10^9$ yrs.

16. The isotope Ra^{226} undergoes α-decay with a half life of 1620 yrs. What is the activity of 1 gm of Ra^{226}? [$N_A = 6.023 \times 10^{23}$]

Soln

Number of atoms of Ra^{226} in 1 gm

$= \frac{1\,gm}{226\,gm} N_A$

$= \frac{6.023 \times 10^{23}}{226}$

$= 2.67 \times 10^{21}$

$\therefore$ Activity $= \left(\frac{-dN}{dt}\right) = \lambda N = \frac{0.693}{T_{1/2}} N$

$= \frac{0.693 \times 2.67 \times 10^{21}}{1620 \times 365 \times 86400}$

$= 1.32 \times 10^{13}$ decay/sec

17. calculate the mass in gms of a radioactive sample Pb^{214} having an activity of 3.7×10^{4} decay/sec and half life 26.8 minutes [$N_A = 6.02\times10^{23}$]

Soln

$$-\frac{dN}{dt} = \text{activity} = 3.7\times10^{4}\ \frac{\text{decay}}{\text{sec}} = \lambda N$$

$$\text{or, } N = \frac{3.7\times10^{4}}{\lambda} = \frac{3.7\times10^{4}}{\left(\frac{0.693}{T_{1/2}}\right)}$$

$$= \frac{T_{1/2}\times 3.7\times10^{4}}{0.693}$$

$$\text{or, } N = \frac{26.8\times60\times3.7\times10^{4}}{0.693}$$

$T_{1/2} = 26.8$ min
$= 26.8\times60$ sec

$$= 8.585\times10^{7}\ \text{atoms}$$

$$\therefore m = \frac{214\times N}{N_A}$$

{$\because$ mass of 1 mole of Pb^{214} is 214 gm
$N_A = 6.023\times10^{23}\ mol^{-1}$}

$$= \frac{214\cdot 8.585\times10^{7}}{6.02\times10^{23}}$$

$$= 215\times10^{-8}\ gm$$

$$= 2.15\times10^{-11}\ kg.$$

— 12th Mangsir / 28th November, Sunday.

Geiger Muller counter (G.M counter In 1928 A.D)

Geiger Muller counter (G.M counter) (In 1928 AD)

GM counter is an instrument to detect the presen-ce of radioactive substance and to find out the rate of radiation. Fig (1) below shows the basic diagram of a GM cou-nter.

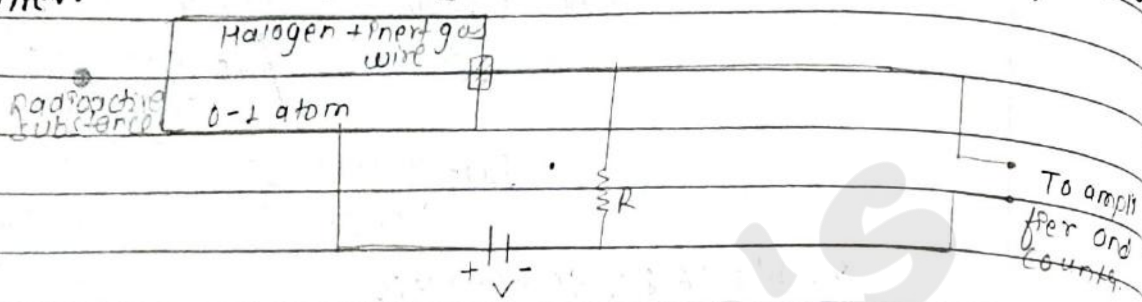

fig:- (1)

It has a metal tube having a metal wire along its axis insulated from the tube. The tube contain a mixture of halogen gas and some inert gas at very low pressure (about 0.1 atm). A ~~inert gas at very~~ potential difference V is established between metal tube and wire. Value of potential difference V is slightly less than the ionizational potential (I.p) of halogen gas in the tube. The radioactive substances is placed infront of the window of the tube. The radiation from radioactive substance ionize the halogen gas in the tube by collision and the negative and positive ion drift (आँधु) toward the opposite electrodes. In their path the ions ionize more and more gas molecules by collision due to this current flows through the wire which create the potential difference (I×R) in the resistance. This potential difference is amplified. and fed to the counter which reads the number of radiation entering the tube in the given time.

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Radio isotopes :-

The unstable isotopes of an element are called radio isotopes. for example phosphorous is a radioactive isotopes having time period life 8.5 minutes. It is converted to silicon $_{14}Si^{30}$

$$_{15}P^{30} \longrightarrow {}_{14}Si^{30} + {}_{+1}e^{0}$$

positron.

Medical uses of nuclear radioactive

(A) In diagonosis:-

1. Some radio isotopes are used to determine the volume of blood in patient's body.
2. γ-rays scanning is used to detect brain tumours.
3. Radioactive (Hg-203) is used to check the functioning of liver and kidney.
4. Similarly, Radioactive iodine (I-131) is used to study of functioning of thyroid gland.
5. Radio isotopes (Cr-51) is used to find the location of haemorrhage in the body.

(B) In therapy:-

1. Control explosure of γ-rays emitted from (Co-60) are used to destroy the cancer cells.
2. Iodine (I-131) is used to destroy over active thyroid gland.
3. Leukemia (blood cancer) can be cured or control by radioactive phosphorous and radiogold.
4. Radioactive (Bi-83) is used to treat general diseases.

Radiation hazard

Radiation like α, β and beam of neutrons caused harm by ionizing complex organic molecules of living matter and animals. The danger explosure of these radiations is called radiation hazard. These radiations are so dangerous that even they can produce soil pollution and the crops in such soil may harm the people and cattle.

Safety precaution from radiation hazard.

The effect of radiation health hazard can be minimized by.

i) By placing radioactive materials in thick walled called lead vessels which absorbs radiations.

ii) Radioactive substances are controlled by remote control system.

iii) Sheet of lead is fixed at the doors of room where X-ray some machine or cobalt plant is established.

iv) Radioactive contamination inside the working area should be avoided.

v) The workers and doctors must wear lead aprons and gloves.

Comparison betn Natural radioactivity & Artifical radio activity

Natural radioactivity	Artifical radioactivity
1) It is spontaneous process occuring in naturally found radio active elements.	1) It is artifically prepared radio active elements.
2) It is usually shown by heavy nuclei.	2) It is usually shown by light nuclei.
3) In natural radioactivity radio active substances decays either by α and β- emmission.	3) In artifical radioactivity the radio active ~~substance~~ elements decay by the emission of positron.

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4. In this case, the radioactive nucleus is already unstable and finally turns into stable nucleus.

4. In this case, the stable nucleus turns into unstable nucleus.