RADIOACTIVITY

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RADIOACTIVITY:

- The process of spontaneous disintegration of unstable nucleus into stable nucleus with the emission of α-particles, $\beta -$ particles & γ-rays, is called Radioactivity.
- It is a nuclear but not atomic process
- It occurs in accordance with the law of **chance or probability.**
- The elements which exhibit radioactivity are known as radioactive elements.
- Radioactivity is a continuous, irreversible & nuclear phenomenon which is not affected by external activities like by exposing the strongest physical & chemical treatments. That is why, radioactivity is called spontaneous phenomenon.
- The elements having atomic number Z >82 are unstable, so are radioactivity**.**

Types of radioactivity:

a) Natural radioactivity: [Discovered by A.H. Becquerel in 1896A.D.]

- The process of spontaneous emission of radiation from heavy elements occurring in nature is called natural radioactivity.
- It is not affected by external factors like temperature , pressure, electric field , magnetic field, etc
- e.g. Uranium , Radium, Polonium, Thorium, Actinium, Neptunium etc are natural radioactivity

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- Penetrating power of such type of radiation (α-, β & γ-rays) are very high.
- Elements having Z >82 are Natural Radioactivity.

b)Artificial radioactivity [Discovered by Irene Joliet Curie in 1934A.D.]

- The process of spontaneous emission of radiation by artificial transmutation of element (Induced elements), is called artificial radioactivity or Induced radioactivity.
- These elements are produced in lab. by bombarding elements with α-particles, neutrons , protons ,& other particles or radiation.
- They have less penetrating power.
- e.g. N^{13}, C^{14} , Na^{24} , Al^{26} , P^{30} ,Co^{60} etc
- They emit electrons, positrons, & other particles as well as γ-rays during disintegration.

RADIOACTIVE RADIATION:

The nature of radiations emitted by radioactive substances is studied by applying Electric field (fig. a) or magnetic field (fig. b) & doing simple experiment. A radium(R) is kept at a narrow & deep cavity of Leadblock. The source emits radiations (α-particles, $\beta -$ particles & γ-rays) & come out through the hole. It is found that a narrow beam splits into three components in both cases.

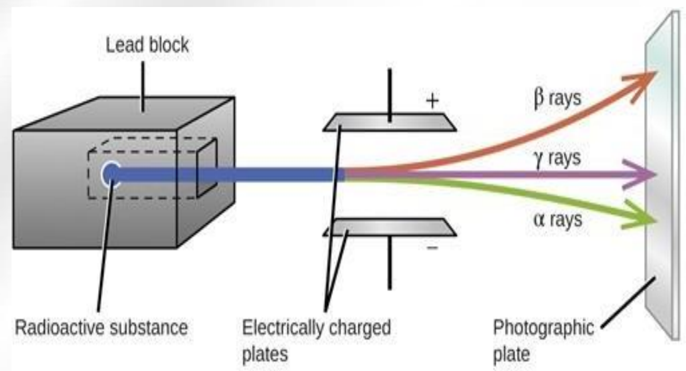
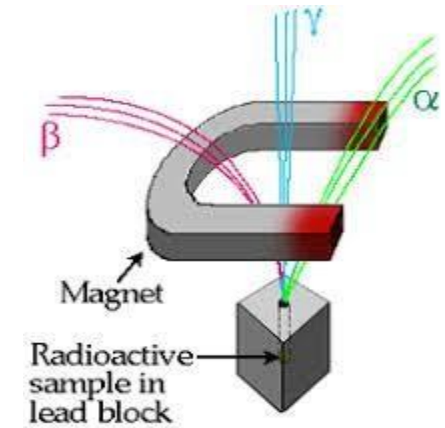


fig (a)



fig(b)

One of the components of radiations is slightly deflected towards the negative plate. These radiations contain positively charged, called $\alpha -$ particles.

Another radiation is largely deflected towards positive plate. These radiations contain negatively charged, called, $\beta -$ particles.

The Third radiation is undeflected. So these radiations don't contain charge particles but contain photons, called γ-rays.

CONCLUSION FROM ABOVE EXPERIMENTS:

- Radioactive substances emit radiations α-particles or $\beta -$ particles & γ-rays.
- $\alpha -$ particles are positively charged(show less deflection).
- $\beta -$ particles are negatively charged(show more deflection).
- The γ-rays are chargeless (shows no deflection).

Three Types of Radiation:

- Rutherford identified three types of radiation using an electric field.
  1) Positive alpha particles were attracted to the **negative** plate.
  2) Negative beta particles were attracted to the **positive** plate.
  3) Neutral gamma rays did not move towards any plate.

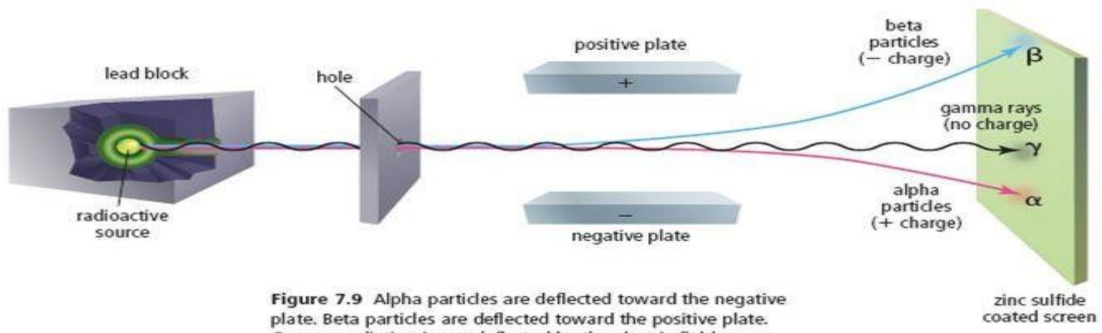


Figure 7.9 Alpha particles are deflected toward the negative plate. Beta particles are deflected toward the positive plate. Gamma radiation is not deflected by the electric field.

PROPERTIES OF RADIOACTIVE RADIATION:

PROPERTIES OF α-particles:

1) α-particles are the helium nuclei ($_2He^4$).
2) They are positively charged particles of electronic charge 2e. & having mass about four times the mass of proton(.i.e. 4 m_p)
3) They are Deflected by electric & magnetic fields.
4) They can move with velocity from $1.4X10^7$m/s to $2.0X10^7$m/s depending upon nature of radioactive substance.
5) They affect photographic plates
6) They have less penetrating power.
7) They ionize the gas through which they pass. The ionizing power of α-particles is 100 times greater than β − particles & 10000 times greater than that of γ-rays.
8) They produce heating effect when they are stopped.

9) The Energy of α-particle emitted from radioactive element is 6MeV.

10) The range of α-particle is very small. They can pass about 5cm in air at NTP.

11) They are originated from the nucleus due to different energy levels in the nuclei.

12) Its specific charge (e/m) is $4.815X10^{7}C/Kg$.

PROPERTIES OF $\beta -$ particles:

1) They are fast moving electrons (i.e. $_{-1}e^{0}$ or $_{-1}\beta^{0}$).
2) They are negatively charged particles of electronic charge (e).
3) The rest mass of $\beta -$ particle is undefined.
4) They are Deflected by electric & magnetic fields.
5) They can move with velocity from 0.33C to 0.998C depending on radioactive substance where $C=3X10^{8}m/s$
6) They affect photographic plates more strongly than α-particles.
7) The ionizing power of β-particles is 100 times lesser than $\alpha -$ particles & 100 times greater than that of γ-rays.
8) They can penetrate through a thin metal foil (Aluminum). Their penetrating power is 100 times more than that of α-particles but 100 times less than γ-rays.
9) The Energy of β-particle emitted from radioactive element is ranges from 2 to 3 MeV.
10) The range of β-particle is greater than that of α-particles. They can pass through several meters in air.
11) They are originated from nucleus by conversion of neutron into proton.
12) Its specific charge (e/m) is $1.75X10^{11}C/Kg$.

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PROPERTIES OF γ-RAYS:

1) $\gamma-$ rays are electromagnetic waves of very short wavelength even smaller than X-rays.
2) They are chargeless particles.
3) The rest mass of $\gamma-$ rays is zero.
4) They are not deflected by electric & magnetic fields.
5) They move with the velocity of light.
6) They can produce nuclear reaction.
7) They cause Photoelectric effect.
8) They affect photographic plate very strongly.
9) They ionize the gas through which they pass. The ionizing power of $\gamma-$ rays is 10,000 times lesser than that of α-particles & 100 times lesser than β-particles.
10) They can penetrate through iron plate of 30cm thickness. The penetrating power of $\gamma-$ rays is 100 times more than that of β-particles & 10,000 times greater than $\alpha-$particles.
11) $\gamma-$ rays are stream of electrically neutral particles called Photons.
12) They are used in radio therapy to destroy cancerous cells.

RADIOACTIVE TRANSFORMATION:

A radioactive element emits either an α-particles or β-particles & γ-rays.

a) **EMISSION OF α-particles(α-decay):**

The process of emission of an α-particles from a nucleus is called *α*-**decay.**

When a radioactive element emits an α-particles, then the daughter nucleus has atomic number 2 units less & mass number 4 units less than the parent's nucleus.

The emission of α-particles can be represented by

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

e.g. $_{92}U^{238} \rightarrow {}_{2}He^{4} + {}_{90}Th^{234}$

$_{88}Ra^{226} \rightarrow {}_{2}He^{4} + {}_{86}Rn^{222}$

After emission, the nucleus remains unstable & becomes stable only when there is γ-emission.

b)EMISSION OF or β-particles(β-Decay):

When a radioactive element emits *β*-**particles,** then daughter nucleus has atomic number 1 unit greater than the parent's nucleus & mass number remains unchanged.

The emission of β- particles can be represented by

$_{Z}X^{A} \rightarrow {}_{-1}\beta^{0} + {}_{Z+1}Y^{A} + \bar{\vartheta}$

e.g. $_{82}Pb^{209} \rightarrow {}_{-1}\beta^{0} + {}_{83}Bi^{209} + \bar{\vartheta}$

Here actually a neutron decays into proton along with *β*-particles & antineutrino. This can be represented by

$_{0}n^{1} \rightarrow {}_{1}p^{1} + + + \bar{\vartheta}$

c) EMISSION OF y -RAYS:

When a radioactive element emits y-rays (photon) then the atomic number & mass number of daughter nucleus remain unchanged. Here, actually a newly born daughter nucleus remains in an excited state which finally comes to its ground state emitting γ-rays(photon).

The γ-ray can be represented by emission of

$$_{Z}X^{A*} \rightarrow _{Z}Y^{A} + \gamma$$

e.g. $_{27}Co^{60*} \rightarrow _{27}Co^{60} + \gamma$

Here,∗ indicates that it is in excited state.

LAWS OF RADIOACTIVE DISINTEGRATION or LAWS OF RADIOACTIVE DECAY or DECAY LAW:

The spontaneous breaking up of a nucleus is known as radioactive disintegration or decay.

RUTHERFORD & SODDY (in 1903A.D.) gave the simple laws of radioactive disintegration.

1. The radioactivity is a random & spontaneous phenomenon & is not affected by external conditions like temperature, pressure, electric field, magnetic field, etc.

2. During disintegration, each atom emits only one particle (α or β) at a time. This is called **Displacement law.**

a) When an atom disintegrates by emitting α-particles then its mass number A are reduced by 4 units & atomic number Z by 2 units.

$$_{Z}X^{A} \rightarrow {_2}\alpha^{4} + {_{Z-2}}Y^{A-4} + Q$$

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b)When an atom disintegrates by emitting β-particles, then its mass number A remains same & atomic number Z is increased by 1 unit.

$$_{Z}X^{A} \rightarrow {}_{-1}\beta^{0} + {}_{Z+1}Y^{A} + \overline{\vartheta}$$

c) When an atom or nucleus emits y-rays (photon) then the atomic number & mass of daughter nucleus remains unchanged.

$$_{Z}X^{A^{*}} \rightarrow {}_{Z}Y^{A} + \gamma$$

Here,∗ indicates that it is in excited state.

3)y-rays are emitted only after emission of α or β-particles while the first emission of α − particle or β-particle is the matter of chance .i.e. y-rays are not emitted first of all.

4)The Two α -particles or two β-particles together also cannot emit further: α -particle cannot be ejected after ejection of β-particles & vice-versa.

5)The rate of disintegration ($\frac{dN}{dt}$) is directly proportional to the number of radioactive atoms (N) present at that time.

i.e. Rate of decay a Number of atoms

Or, $\frac{\mathbf{dN}}{\mathbf{dt}}$ a N

Or, $\frac{dN}{dt} = -\lambda N.$

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This is known as **Decay law.**

Where, λ is a constant called Decay constant or Disintegration constant or Transformation constant.

& -ve sign indicates the number of atoms decreases with time.

MATHEMATICAL TREATMENT:

Let N_0 be the number of radioactive atoms present t a time t=0 second & N be the number of atoms left at time t second. If dN atom disintegrate in small time dt, then according to Decay law, we can write, $\frac{dN}{dt}$ a N

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

where λ is a constant called Decay constant or Disintegration constant or Transformation constant

& -ve sign indicates the number of atoms decreases with time.

$$\frac{dN}{N} = -\lambda\, dt \quad \text{.................(1)}$$

Integrating eqn(1) , then we get

$$\int \frac{dN}{N} = \int (-\lambda\, dt)$$

$$\ln(N) = -\lambda t + C \quad \text{...................(2)}$$

where C is integral constant

When t=0 and $N=N_0$, then from eqn(2) , we can write

$$\ln(N_0) = C \text{ ,..............(3)}$$

From eqn(2) & (3): $\ln(N) = -\lambda t + \ln(N_0)$

Or, $\ln(N) - \ln(N_0) = -\lambda t$

Or, $\ln\left(\frac{N}{N_0}\right) = -\lambda t$

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

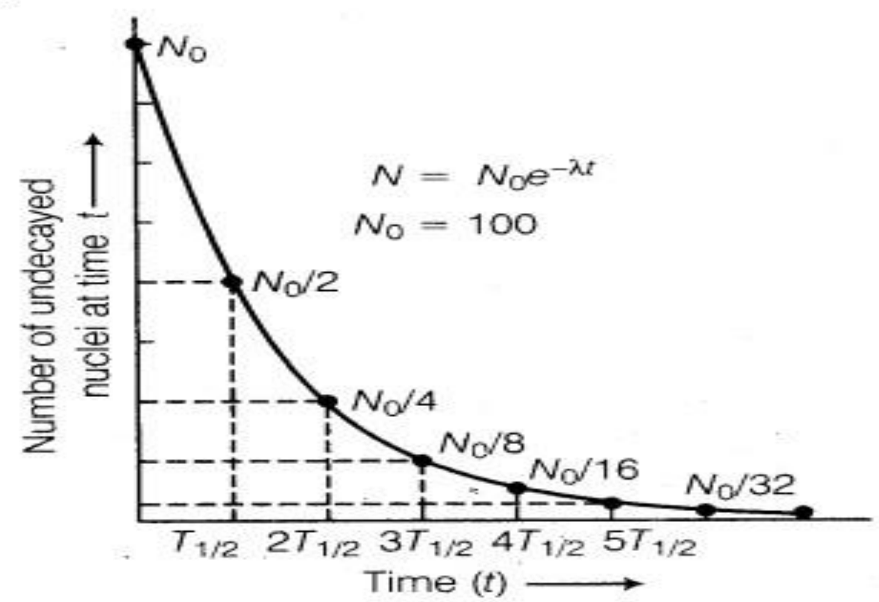
$$\therefore \; \mathbf{N = N_0\, e^{-\lambda t}}$$

This is known as Decay Equation.

This relation tells us that the number of atoms of a given radioactive substance decreases exponentially with time i.e. in beginning the decay occurs rapidly & then becomes more and more slower.

Since N becomes zero only when t=∞ seconds, so a radioactive substance will never disintegrate completely.

The curve representing the law of radioactive decay is shown as below:



Decay curve for a radioactive element **(1)**

DECAY CONSTANT or DISINTEGRATION CONSTANT or TRANSFRMATION CONSTANT:

Every radioactive substance has a particular value of decay constant (λ). Greater the value of decay constant, greater is the rate of disintegration.

The ratio of number of atoms disintegrating per second (rate of disintegration) to the number of undecayed atoms present in radioactive substance is called Decay constant.

.i.e. $\lambda = \frac{\frac{dN}{dt}}{N}$

i.e. the rate of decay per unit atom present.

Half life ($T_{1/2}$) Of radioactive substance:

The Half-life of a radioactive substance is defined as the time required to disintegrate Half of the initial number of radioactive atoms in a given sample of it.

It doesn't depend on mass of material.

It depends on nature of material.

When $N = \frac{N_0}{2}$ & $t = T_{1/2}$ then from decay equation ($N = N_0 e^{-\lambda t}$) ,we have

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

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

Taking log on both sides: $\lambda T_{1/2} = \ln(2) = 0.693$

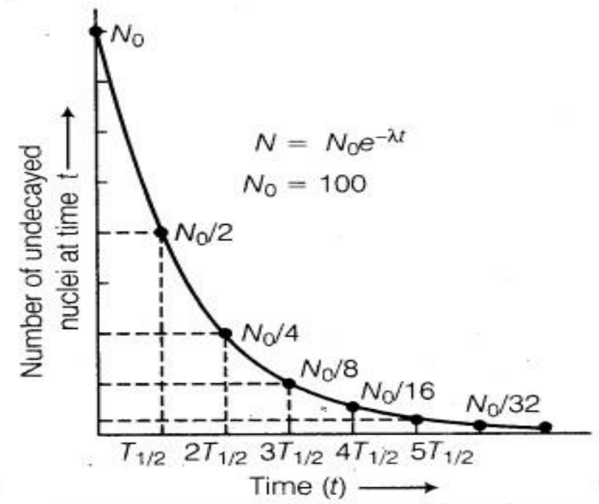
$$T_{1/2} = \frac{0.693}{\lambda}$$

Hence the half life of a radioactive substance is inversely proportional to its Decay constant.

After, second Half-life, the number of radioactive atoms will be $\frac{N_0}{4}$ & after Third half life, the number of radioactive atoms will be $\frac{N_0}{8}$ and so on.

For n^{th} Half-life, the number of radioactive atoms will be $(\frac{1}{2})^n N_0$

The curve representing the law of radioactive decay is shown as below:



Decay curve for a radioactive element **(1)**

MEANLIFE OR AVERAGE LIFE OF RADIOACTIVE SUBSTANCE (τ or $\overline{T}$):

The ratio of the sum of the lives of all the atoms to the total number of atoms in the radioactive element is called mean life or average life of radioactive substance.

i.e. Mean-life (τ or $\overline{T}$) = $\frac{\text{Sum of the lifes of all the atoms}}{\text{total number of atoms}}$

$= \frac{\text{total life time}}{\text{total number of atoms}}$ ....(1)

Suppose N_0 is the number of radioactive atoms in a given radioactive sample in the beginning (at t=o sec) & N after a time t.

If dN atoms disintegrate between t & t+dt then each of these dN atoms has a life of time t.

Now, time of existence for dN nuclei= t

∴Total time of existence for dN nuclei=t dN……………..(2)

Thus total life of N_0 atoms = $\int_0^\infty t\,dN$ ....(3)

Now from eqn(1),(2) & (3): Mean-life (τ) = $\frac{\int_0^\infty t\,dN}{N_0}$ ....(4)

Since, from **Decay equation**: $N = N_0 e^{-\lambda t}$ &

Decay law: , $\frac{dN}{dt} = \lambda N$,we have

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

$$dN = \lambda N_0 e^{-\lambda t}\, dt \quad ....(5)$$

[when t=0 then $N=N_0$ & when t=∞ then N=0]

From eqn (4)&(5):

Mean-life (τ) = $\frac{\int_0^\infty t\lambda N_0 e^{-\lambda t}\, dt}{N_0}$

$$= \int_0^\infty t\lambda\, e^{-\lambda t}\, dt$$

$$= \lambda \int_0^\infty t\, e^{-\lambda t}\, dt$$

Integrating by parts, [$\int uv\,dx = u\int v\,dx - \int du(\int v\,dx)\,dx$]

$$\tau = \lambda\left[t\frac{e^{-\lambda t}}{-\lambda} - \int 1 . \frac{e^{-\lambda t}}{-\lambda}\, dt \right]$$: integral limit 0 to ∞.

$$\therefore \tau = \frac{1}{\lambda} \quad ....(6)$$

Thus, the mean-life of a radioactive substance is equal to the reciprocal of its Decay constant.
Note: Mean -life of Radium (Ra) is 2400 years.

RELATION BETWEEN HALF-LIFE ($T_{1/2}$) & MEAN-LIFE (τ):

Half-life $T_{1/2} = \frac{0.693}{\lambda}$ ....(1)

Mean-life $\tau = \frac{1}{\lambda}$ ....(2)

From equation (1)&(2): $T_{1/2} = 0.693\,\tau$ ....(3)

Hence, Half-life of a radioactive is about 0.693 times the mean-life.

Also, $\tau = \frac{T_{1/2}}{0.693}$ ....(4)

Hence, Mean-life of a radioactive substance is 1.443 times its Half-life.

ACTIVITY OF RADIOACTIVE SUBSTANCE or RATE OF DISINTEGRATION:

The number of atoms disintegration per second is called Activity of radioactive substance. It is also known as DECAY RATE or Rate of Disintegration of radioactive substance. It is denoted by $\frac{dN}{dt}$ or A or R.

From Decay law, $\frac{dN}{dt} = -\lambda N$

We can write, $A = \lambda N$ .... (1)

where, λ is Decay constant & N be number of atoms remained undecayed after time t.

Let A_0 be initial Activity of a substance, then $A_0 = \lambda N_0$ ....(2)

Where N_0 is number of atoms present in a radioactive substance at t=0 second.

From equation (1)&(2): $\frac{A}{A_0} = \frac{N}{N_0} = \frac{\mathbf{N_0\, e^{-\lambda t}}}{\mathbf{N_0}} = \mathbf{e^{-\lambda t}}$

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

$$\therefore \mathbf{A = A_0\, e^{-\lambda t}} \text{ ....(3)}$$

This equation gives Activity of radioactive element at any time in-terms of initial Activity

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UNITS OF RADIOACTIVITY:

The activity of radioactive substance is measured by following:

1) BECQUEREL (Bq):

It is the S.I unit of radioactivity.

i.e. 1 Bq=1 disintegration/second

It is defined as the one disintegration per second.

2) RUTHERFORD (Rd):

1 Rd= 10^6 disintegration/second

It is defined as 10^6 atoms disintegration per second.

3) CURIE (Ci):

It is defined as $3.70X10^{10}$ atoms disintegration per second.

1 Ci =$3.70X10^{10}$ disintegration/second.

1 Ci =$3.70X10^{10}$Bq

1 Ci =$3.70X10^{7}$ Rd

It is approx. equal to 1 gram of Radium.

USES OF RADIOACTIVITY: RADIOCARBON DATING

A technique of estimating the age of archeological specimens of wood or rock or charcoal or a meteorite through radioactive process is called Carbon dating or radiocarbon dating.

Carbon is an essential element in all plants & animals products, living & dead. C^{12} is stable while its radioisotope C^{14} is radioactive which decays to C^{12}.

The C^{14} radioisotope is formed in atmosphere by bombarding nitrogen (${}_7N^{14}$) with neutron (${}_0n^1$) coming in cosmic rays from outer space.

i.e. ${}_7N^{14} + {}_0n^1 \rightarrow C^{14} + {}_1H^1$

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The living plants intake this radioactive isotope ${}_6C^{14}$ in the form of carbon dioxide during its photosynthesis process. The amount of ${}_6C^{14}$ in a living plant becomes gradually the same as it is found in the atmosphere. When a living organism (plants or animals) met its death, the intake of ${}_6C^{14}$ stops & it starts decaying with the Half-life of 5568 years.

Let N_{12} & N_{14} be the number of ${}_6C^{12}$ & ${}_6C^{14}$ atoms present in the sample at any time t.

∴ Total number of atoms initially present $(N_0)=N_{12} + N_{14}$ ......(1)

From Decays law,

Number of ${}_6C^{14}$ atoms remained after time t is $N_{14} = N_0 e^{-\lambda t}$

where λ=decay constant

Or, $e^{\lambda t} = \frac{N_0}{N_{14}}$

Taking log on both sides

Or, $\lambda t = \ln\left(\frac{N_0}{N_{14}}\right)$

Or, $t = \frac{1}{\lambda}\ln\left(\frac{N_0}{N_{14}}\right)$ where $T_{1/2} = \frac{0.693}{\lambda}$

Or, $t = \frac{T_{1/2}}{0.693}\ln\left(\frac{N_0}{N_{14}}\right)$ ....(2)

Using equation (1) in (2): $t = \frac{T_{1/2}}{0.693}\ln\left(1+\frac{N_{12}}{N_{14}}\right)$ ....(3)

This equation represents the age of the sample.

If A_0 be initial activity at t=0 & A be activity of the sample after time t, then $t = \frac{T_{1/2}}{0.693}\ln\left(\frac{A_0}{A}\right)$ ....(4)

This equation also gives age of sample interms of Activity.

MEDICAL USE OF NUCLEAR Radiation:

The radioisotopes are used for Diagnosis & Therapy.

1. DIAGNOSIS :(Identification of nature of illness)

- Radio-iodine I^{131} is used to determine condition of human thyroid gland, study the pumping action of heart, functioning of liver, kidney, spleen, etc
- Radios-odium Na^{24} is used to check blood circulation in a patient
- Radio-mercury Hg^{203} is used to study disorder of Kidney & liver
- Radio-iodine & some other isotopes are used in diagnosis of brain tumors.
- Radio-gallium Ga^{67} is used to locate the tumor.
- Radio-Iron Fe^{59} is used to diagnosis many diseases caused by deficiency of RBC in human body.

2. THERAPY:(treatment intended)

- Radio-isotopes of gold Au^{198} is used in the treatment of cancer.
- Radio-Cobalt Co^{60} is used to destroy cancer tumors in a body.
- Radio-Bismuth Bi-209 is used in the treatment of Syphilis.
- Radio-Iodine I^{131} is used in the treatment of over active Thyroid gland.

RADIATION HAZARD & SAFETY PRECAUTION:

The Transmission of energy in the form of waves or moving particles is called radiation. The adverse effect of radiation on living organism (animals & plants) is called **Radiation Hazard.**

Causes of radiation hazard:

- UV-radiation causes skin cancer, damage retina of our eyes etc.
- X-rays & γ-rays affect genetic mutation.
- β-particles lead to death of living organism
- α-particles can cause Lung Cancer
- Neutrons Can cause Blindness.

Safety precaution of radiation hazard:

- One should not spend more time in radiation
- Researchers & workers should wear Lead Aprons.
- Radio-isotopes should handle with remote control devices.
- Radioactive sources should be kept in the container having thick walls of lead.
- Normal access of radioactive substance should be avoided. Nuclear explosions should be carried out far away from the public area.

NUCLEAR RADIATION DECTCTOR:

An instrument which is used to detect α-particles, β-particles, γ-rays, protons, neutrons etc is called nuclear radiation detector. Thus, ionizing radiation detecting device is called nuclear radiation detector. e.g. Ionization chamber, cloud chamber, Geiger-Muller(GM) counter, Scintillation Counter etc.

GEIGER-MULLER TUBE or GM TUBE:

A radiation detecting & measuring device is called GM Tube. It is only capable to detect α-particles. In 1928A.D. Hans Geiger & his Ph.D student Walther Muller improved the counter so it could detect all kinds of ionizing radiation so it is also called GM counter.

A GM Tube is the sensing element called sensor of a GM counter instrument that it can detect a single particles of ionizing radiation.

ADVANTAGE OR MERITS OF GM TUBE:

- It can detect all kinds of ionizing radiations
- It is cheaper & easy to handle
- It produces large output signal.
- It is useful for measuring intensities of Cosmic rays & recording the events involving high energy particles.

DISADVANTAGE OR DEMERITS OF GM TUBE:

- It cannot measure the energy of radiation
- It has very low detection efficiency for γ-rays.
- It has very limited life due to the decomposition of organic vapour as the positive ions are neutralized at the cathode & break up into molecular fragments.

CONSTRUCTION & WORKING OF GM TUBE:

Construction: It consists of a cylindrical metal tube filled with inert gas such as He, Ne, Ar etc with Halogens added at low pressure (0.1 atm). The wall of the tube acts as a cathode while a coaxial Tungsten wire passing up the centre of tube acts as an anode. The tube has a thin window at one end through which ionizing radiation can easily penetrate. The other end normally has the electrical connectors. The potential difference of about 1000Volt is maintained between Anode & Cathode. The potential difference is just slightly less than that is required to ionize the gas atoms.

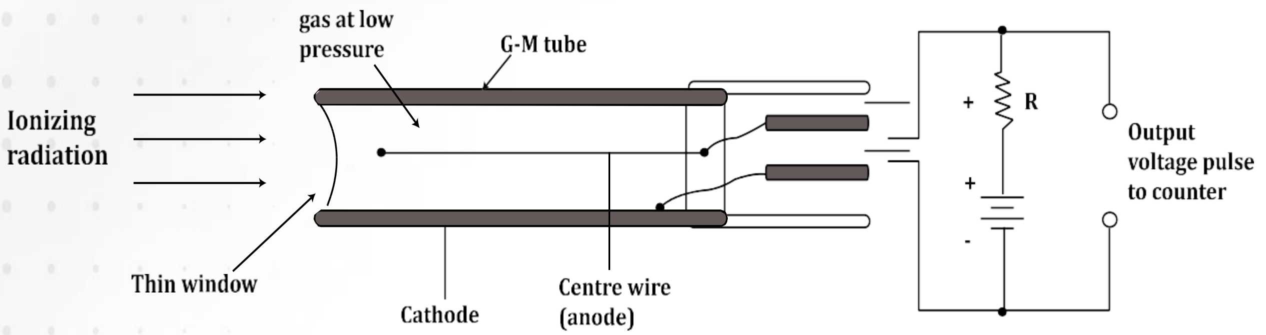

Figure 24.4: G- M tube and its connection to a counter.

Working: When the ionizing radiation enters the tube through the thin window, it ionizes a few atoms of the gas, creating positively charged ions & electrons (ion-pair). The positively charged ions are accelerated towards the Cathode while the electrons toward the anode. Acceleration of these ion-pairs collides with gas atoms & produces more ion-pair. Due to the movement of ion-pairs, the current flows inside tube which can be limited by using series of Resistance R with GM Tube. The small voltage (1V) is created across Resistance which can be amplified by amplifier, is sent to an electronic counter such as a rate meter. This rate meter counts the pulses. In this way, ionizing particle is detected by GM Counter.

Q.1) What do you mean by Radioactive Isotopes or Radio-isotopes? (V.V.I. question)

Isotopes are the atoms of same element having same atomic number (Z) but different mass number (A). If an isotope exhibits radioactivity then it is called radio-isotope or radioactive isotope. Phosphorus $_{15}P^{30}$ is a radio-isotope of natural phosphorus. It emit positron of its own due to artificially induced radioactivity. Similarly, $_{7}N^{13}$, $_{13}Al^{23}$, $_{6}C^{14}$ etc are radioisotopes Nitrogen, Aluminum & Carbon respectively.

DIFFERENCE BETWEEN ELECTRON & β- PARTICLE:

ELECTRON	β- PARTICLE
1. It revolves round the nucleus in orbit. 2. It possesses less velocity 3. It has low Kinetic energy 4. The mass of moving electron is almost equal to rest mass(m_0)	1. It comes out from nucleus during β-decay. 2. It possesses very high velocity. 3. IT has very high kinetic energy. 4. The mass of β-particles is greater than rest mass or undefined.

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Solved Problems

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WORKED OUT EXAMPLES

Example - 1. *Lanthanum has a stable isotope ^{139}La and radioactive isotope ^{138}La of half-life 1.1×10^{10} years whose atoms are 0.1% of those of the stable isotope. Estimate the rate of decay or activity of ^{138}La with 1 kg of ^{139}La. (Assume the Avogadro constant $= 6 \times 10^{23}\ mol^{-1}$.)*

Solution:

$$\text{Decay rate } \frac{dN}{dt} = -\lambda N \text{ .... (i)}$$

where λ is the decay constant and N is the number of atoms in ^{138}La. Now number of atoms in 1 kg (1000 g) of $^{139}La = \frac{6\times10^{23}\times1000}{139}$.

Since $0.1\% = 10^{-3}$, then

$$\text{Number of atoms in 138 La, } N = \frac{10^{-3}\times6\times10^{23}\times1000}{139} = \frac{6\times10^{23}}{139}$$

$$\text{Also } \lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1.1\times10^{10}\times365\times24\times3600}$$

$$\text{From (i), } \frac{dN}{dt} = \frac{0.693\times6\times10^{23}}{1.1\times10^{10}\times365\times24\times3600\times139} = 8600\ s^{-1}$$

Example - 2. *At a certain point of time 10^{12} atoms are contained in a piece of radioactive material. (i) Calculate the number of disintegration in one second. (ii) After what period of time 10^4 atoms remain? (iii) Find the count rate at this time? Half life of the material is 30 days.*

Solution:

We have, from the laws of radioactive disintegration,

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

or, $\frac{dN}{dt} = -N_o\lambda e^{-\lambda t} = -\lambda N$

Hence, when $N = 10^{12}$, $\frac{dN}{dt} = -\lambda 10^{12}$

Now $\lambda = \frac{0.693}{T} = \frac{0.693}{30\times24\times60\times60}\ s^{-1}$

∴ Number of disintegrations per second,

$$= \frac{10^{12}\times0.693}{30\times24\times60\times60} = 2.7\times10^5$$

(ii) When $N = 10^4$, we have

$$10^4 = 10^{12}e^{-\lambda t}$$

$$\therefore 10^{-8} = e^{-\lambda t}$$

Taking log to base 10,

$$-8 = -\lambda t \log e$$

$$\therefore t = \frac{8}{\lambda}\frac{1}{\log e} = \frac{8T}{0.693 \log e} = 797 \text{ days}$$

(iii) Since $\frac{dN}{dt} = -\lambda N$

∴ Number of disintegrations per hour $= \frac{0.693}{30\times24}\times10^4 = 9.6.$

Example - 3. *Calculate the time required for one tenth of a sample of radium to disintegrate. Assume the half life of radium to be 800 years.*

Solution:

Here, one tenth of a sample of radium disintegrates, so,

$$\frac{N}{N_o} = 1 - \frac{1}{10} = \frac{9}{10}$$

We know, $N = N_o e^{-\lambda t}$

or, $e^{-\lambda t} = \frac{9}{10}$

or, $\lambda t = ln\left(\frac{10}{9}\right)$

$$\therefore t = \frac{T_{1/2}}{0.693} \times \ln\frac{10}{9} = \frac{800}{0.693} \times 0.1053 = 121.63 \text{ yrs.}$$

Example - 4. *A sample of Ra–226 has half–life of 1620 years. (a) What is the mass of the sample which undergoes 20,000 disintegrations per second? (Avogadro number = 6.02×10^{23} mol^{-1})*

(b) Estimate its mass when its activity is 0.5 curie.

Solution:

We have, half life ($t_{1/2}$) = 1620 years

$$\text{Decay constant } (\lambda) = \frac{0.693}{T_{1/2}} = \frac{0.693}{1620} \text{ year}^{-1} = \frac{0.693}{1620\times365\times24\times60\times60} \text{ sec}^{-1}$$

(a) We have, $\frac{dN}{dt} = \lambda N \Rightarrow N = \frac{1}{\lambda}\frac{dN}{dt} = \frac{1620\times365\times24\times60\times60}{0.693} \times 20{,}000$

$= 1.4744 \times 10^{15}$

Mass of the sample = No. of atoms × mass of 1 atom

$= 1.4744 \times 10^{15} \times \frac{226}{6.02\times10^{23}}$

$= 5.53 \times 10^{-7}$ g = 0.553 μg

(b) Again, $N = \frac{1}{\lambda}\frac{dN}{dt} = \frac{1620\times365\times24\times60\times60}{0.693} = 0.5 \times 3.7 \times 10^{10}$

$= 1.36 \times 10^{21}$

Mass of the sample = $1.36 \times 10^{21} \times \frac{226}{6.02\times10^{23}} = 0.512$ gm

Example - 5. *The mass number of radium is 226. It is observed that 3.67×10^{10} ∝-particles are emitted per second from 1g of radium Calculate the half life of radium. (Avogadro number = 6.023×10^{23}/mole)*

Solution:

Here, mass of number of radium = 226

Avogadro number = 6.023×10^{23} mol

Number of atoms emitted per second $\frac{dN}{dt} = 3.67 \times 10^{10}$

Half life time ($T_{1/2}$) = ?

We know, 226 gm of radium contains 6.023×10^{23} atoms

1 gm of radium contains $\frac{6.023\times10^{23}}{226}$ atoms

i.e. $N = \frac{6.023\times10^{23}}{226} = 2.665 \times 10^{21}$ no. of atom

We know, $\frac{dN}{dt} = \lambda N$

or, $3.67 \times 10^{10} = \lambda \times 2.665 \times 10^{21}$

∴ $\lambda = 1.377 \times 10^{-11}$ m

Again, half life time $(T_{1/2}) = \frac{0.693}{\lambda} = \frac{0.693}{1.377\times10^{-11}} = 5.03 \times 10^{10}$ sec.

Hence, the half life time is 5.03×10^{10} sec.

Example - 6. *Find the half-life of U-238, if one gram of it emits 1.24×10^4 α-particles per second. (Avogadro's number = 6.023×10^{23})*

Solution:

Here, 238 gm of Uranium contains 6.023×10^{23} no. of atoms

∴ 1 gm of Uranium contains $\frac{6.023\times10^{23}}{238}$ no. of atoms

i.e. $N = \frac{6.023\times10^{23}}{238} = 2.53 \times 10^{21}$

We know, $\frac{dN}{dt} = \lambda N$

or, $1.24 \times 10^4 = \lambda(2.53 \times 10^{21})$

∴ $\lambda = 4.8998 \times 10^{-18}$

Half-life time $(T_{1/2}) = \frac{0.693}{\lambda} = \frac{6.023\times10^{23}}{4.8998\times10^{-18}} = 1.414 \times 10^{17}$ sec

$= 4.547 \times 10^9$ yrs.

Example - 7. *The half life of a radioactive sample is 8.3×10^4 years. Calculate the disintegration constant. How long does it take for 25% of its activity to disappear?*

Solution:

Half life of the radioactive sample ($t_{1/2}$) = 8.3×10^4 year

i) Decay constant $(\lambda) = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{8.3\times10^4} = 8.35 \times 10^{-6}$ year^{-1}

ii) As for 25% of the activity to disappear

$A = \frac{75}{100}A_o$

or, $A = \frac{3}{4}A_o \Rightarrow \frac{A}{A_o} = \frac{3}{4}$

or, $e^{-\lambda t} = \frac{3}{4}$ $\Rightarrow e^{\lambda t} = \left(\frac{4}{3}\right)$

or, $\lambda t = \ln\left(\frac{4}{3}\right)$ $\Rightarrow t = \frac{1}{\lambda}\ln\left(\frac{4}{3}\right) = \frac{1}{8.35\times10^{-6}}\ln\left(\frac{4}{3}\right)$

$= 3.44 \times 10^4$ years

Example - 8. *How long will it take for 7/8 of a given sample of radium to decay if the half life of radium is 1600 years?*

Solution:

Given, half life of radium $(t_{1/2}) = 1600$ years

The fraction of the sample decayed $= \frac{7}{8}$

The fraction of the sample remained $= 1 - \frac{7}{8} = \frac{1}{8}$

i.e $\frac{N}{N_o} = \frac{1}{8}$ $\Rightarrow e^{-\lambda t} = \frac{1}{8}$ or $e^{\lambda t} = 8$

or, $\lambda t = \ln 8$ $\Rightarrow t = \frac{1}{\lambda}\ln 8 = \frac{1}{\frac{0.693}{T_{1/2}}}\ln 8$

$= \frac{T_{1/2}}{0.693} \times 3\ln 2 = \frac{1600}{0.693} \times 3 \times 0.693$

$= 4800$ yrs.

Example - 9. *Calculate the half life of radium if its activity decreases about 1% every 25 years.*

Solution:

Let A_o be the original activity and A be the activity after 25 years, then

$\frac{A}{A_o} = \frac{99}{100}$ $\therefore A \propto N$

$\frac{N}{N_o} = \frac{99}{100}$ $\Rightarrow e^{-\lambda t} = \frac{99}{100}$ or $e^{\lambda t} = \frac{100}{99}$

$\lambda t = \ln\left(\frac{100}{99}\right)$ $\Rightarrow \lambda = \frac{1}{t}\ln\left(\frac{100}{99}\right)$

$= \frac{1}{25}\ln\left(\frac{100}{99}\right)\text{year}^{-1} = 0.000402\ \text{year}^{-1}$

$T_{1/2}$ (half–life) $= \frac{0.693}{\lambda} = \frac{0.693}{0.000402}$ years $= 1724$ years

Example - 10. *A radioactive source has decayed to one percent of its initial activity in 100 days. What its half-life?*

Solution:

Here,

The radioactive source has decayed to one percent of its initial activity in 100 days.

So, initial activity $(A_0) =$ A

Find activity (A) $= A \times \frac{1}{100} = \frac{A}{100}$

Time period (t) = 100 days

We know, $A = A_0e^{-\lambda t}$ $\Rightarrow \frac{A}{100} = A \times e^{-\lambda \times 100}$

or, $\frac{1}{100} = e^{-100\lambda}$ $\Rightarrow \ln\frac{1}{100} = -100\lambda$

$\therefore$ $\lambda = 0.046\ \text{days}^{-1}$

Now, $T_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{0.046} = 15$ days

$\therefore$ The required half life is 15 days.

Example - 11. *A radioactive substance contains 1.6 mg of Th^{234}. After 120 days only 0.05 mg remained unchanged. Calculate its half life.*

Solution:

Here, Initial mass of radioactive substance $(M_0) = 1.6$ mg

Final mass of radioactive substance (M) = 0.05 mg

Time period (T) = 120 days

So, we know $M = M_0e^{-\lambda t}$ $\Rightarrow 0.05 = 1.6 \times e^{-\lambda \times 120}$

or, $\frac{0.05}{1.6} = e^{-\lambda \times 120}$ $\Rightarrow \ln\frac{0.05}{1.6} = 120\lambda$

or, $\lambda = 2.89 \times 10^{-2}\ \text{days}^{-1}$

Now, $T_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{2.89\times10^{-2}} = 24$ days

$\therefore$ The required half life period is 24 days.

Example - 12. *How long will it take a sample of radioactive substance to decrease to 20%, if its half-life is 4 days?*

Solution:

Here, Initial mass $(M_o) =$ M

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Final mass (M) = 20% of M = $\frac{M}{5}$

Half life period ($T_{1/2}$) = 4 days

$T_{1/2} = \frac{0.693}{\lambda}$ $\Rightarrow 4 = \frac{0.693}{\lambda}$

So, $\lambda = \frac{0.693}{\lambda} = 0.17325\ \text{days}^{-1}$

∴ $N = N_0e^{-\lambda t}$ $\Rightarrow \frac{M}{5} = Me^{-0.17325 \times t}$

Now, $\frac{1}{5} = e^{-0.17325\,t}$ $\Rightarrow \ln\frac{1}{5} = -0.17325t$

or, $t = 9.3$ days

∴ The required time period is 9.3 days.

Example - 13. *A source, of which the half life is 130 days, contains initially 1.0×10^{20} radioactive atoms, and the energy released per disintegration is 8.0×10^{-13} J. Calculate (a) the activity of the source after 260 days have elapsed and (b) the total energy released during this period.*

Solution:

Here, Half life of source ($T_{1/2}$) = 130 days

Initial radioactive atoms (N_o) = 1.0×10^{20}

Energy released per disintegration (E) = 8×10^{-13} J

(a) Let N be the number of remaining radioactive atoms after 260 days then,

$$N = N_o e^{-\lambda t} = 10^{20} \times e^{\left(\frac{-0.693}{130}\times 260\right)} = 10^{20} \times e^{-1.386}$$

$$= \frac{10^{20}}{e^{1.386}} = \frac{10^{20}}{4} = 2.5 \times 10^{19}$$

∴ $$\frac{dN}{dt} = -\lambda N = \frac{0.693\,N}{T_{1/2}} = -\frac{0.693}{130\times 24\times 3600} \times 2.5 \times 10^{19}$$

$$= -1.54 \times 10^{12}\ s^{-1}$$

[The negative sign shows that the number of atoms is decreasing]

(b) Total energy released,

$= (N_o - N)\,E$

$= (10 - 2.5) \times 10^{19} \times 8 \times 10^{-13}$

$= 60 \times 10^{6}$

$= 6 \times 10^{7}$ J

Example - 14. *A monoatomic element Y has a relative atomic mass 80. A radioactive isotope X is present as 1% of Y. Calculate (i) the number of atoms of X in 10 g of Y (ii) the rate of decay $\left(\frac{dN}{dt}\right)$ of X after 10 hr if its half life is 5 hr.*

Solution:

Half life of isotope X = 5 hr

i) Relative atomic mass of Y = 80 so, molar mass = 80 gm

Since Y is monoatomic,

Number of atoms of X in 10g of Y

$$= 6.0 \times 10^{23} \times \frac{10}{80} \times \frac{1}{100} = 7.5 \times 10^{20}$$

ii) $$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{5}\text{hr}^{-1} = \frac{0.693}{5\times 60\times 60}\text{s}^{-1}$$

Let the number of atoms of X remaining in 10hr be N, then from the laws of radioactive disintegration,

$$N = N_oe^{-\lambda t} = 7.5 \times 10^{20} \times e - e^{-\left(\frac{0.693}{5}\times 10\right)}$$

$$= 7.5 \times 10^{20} \times e^{-1.386} = 7.5 \times 10^{20} \times \frac{1}{e^{1.386}}$$

$$= 7.5 \times 10^{20} \times \frac{1}{4} = 1.875 \times 10^{20}$$

Also, $\frac{dN}{dt} = \lambda N$ (in magnitude)

$$= \frac{0.693}{5\times 60\times 60} \times 1.875 \times 10^{20}$$

$$= 7.2 \times 10^{15}\ s^{-1}.$$

Example - 15. *After a certain lapse of time, the fraction of radioactive polonium undecayed is found to be 12.5% of the initial quantity. What is the duration of this time lapse if half life of polonium is 139 days?*

Solution:

We know, $N = N_0e^{-\lambda t}$

For the half life $\lambda = \frac{ln2}{T_{1/2}} = \frac{ln2}{139}$

Again, for 12.5% let t be the time then,

$N = N_0e^{-\lambda t}$

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or, $\frac{N}{N_0} = e^{-\lambda t}$ where $\frac{N}{N_0} = \frac{12.5}{100} = \frac{1}{8}$

$\therefore$ $t = \frac{\ln 8}{\lambda} = \frac{\ln 8}{\ln 2} \times 139$ days

$= 417$ days

Example - 16. *For a radioactive element, a counter measures the activity of 895 counts per minute and 10 min later 327 counts per minute. Find the decay constant, mean life and half life of the radioactive element?*

Solution:

Initial counts per min = 895 count/min

After 10 min counts per min = 327 count/min.

Then, let A_o be the original activity and A be the activity after 10 mins, then

$$\frac{C}{C_o} = \frac{A}{A_o}$$

We know, $\frac{A}{A_o} = \frac{N}{N_o} = e^{-\lambda t}$ $\therefore e^{-\lambda t} = \frac{C}{C_o} = \frac{327}{895}$

or, $e^{\lambda t} = \frac{895}{327}$

or $\lambda t = \ln\left(\frac{895}{327}\right)$

or, $\lambda = \frac{1}{t}\ln\left(\frac{895}{327}\right) = \frac{1}{10} \times 1.006864$

$= 0.1006864\ \text{min}^{-1}$

Mean life $= \frac{1}{\lambda} = 9.93$ min.

Half– life $(t_{1/2}) = \frac{0.693}{\lambda}$

$= 0.693 \times 9.93$

$= 6.88$ min.

Example - 17. *Polonium- 210 has a half life of about 140 days. If an average α-emissions per day from a 1 microgram polonium is about 12×10^{12} find the number of atoms in 1 cm^3 of polonium assuming that one emission takes place per atom. (Density of polonium is 10 gcm^{-3})*

Solution:

Total α emission per day from 1 μg of polonium = 12×10^{12}

In half–life period, the decayed number of radioactive atoms = $\frac{1}{2}$ radioactive atoms originally present

$\therefore$ Hence, in 1 mg of polonium of the number of polonium atoms

$= 2 \times 140 \times 12 \times 10^{12}$

Mass of 1 cm^3 of polonium = 10g

Since number of atoms in 1cm^3 of polonium

= Number of atoms in 10g of polonium

$= \frac{10}{10^{-6}} \times 2 \times 140 \times 12 \times 10^{12}$

$= 3.36 \times 10^{22}$

Example - 18. *A small volume of solution which contained a radioactive isotope of sodium and an activity of 12000 disintegrations per minute when it was injected into the bloodstream of a patient. After 30 hours the activity of 1.0 cm^3 of the blood was found to be 0.50 disintegrations per minute. If the half-life of the isotope is taken as 15 hours. Estimate the volume of blood in the patient.*

Solution:

Here, time taken (t) = 30 hr.

Half life time of isotope $(T_{1/2})$ = 15 hr

Volume of blood (v) = ?

Original activity of 1 cm^3 of blood $(A_o) = \frac{12000}{v}$ dis/min

Activity after 30 hrs (A) = 0.5 dis/min

We know, activity is directly proportional to the number of atom.

$\because$ $A \propto N$

$$\frac{A}{A_o} = \frac{N}{N_o} = e^{-\lambda t} = \exp\left[\frac{-0693}{T_{1/2}}t\right]$$

or, $\frac{0.5}{\frac{12000}{v}} = \exp\left[\frac{0.693 \times 30}{15}\right]$

or, $\frac{0.5v}{12000} = e^{-1.386}$ $\Rightarrow \frac{0.5v}{12000} = \frac{1}{e^{1.386}} = \frac{1}{4}$

or, $v = \frac{12000}{0.5 \times 4} = 6000$ c.c.

Example - 19. *The isotope $^{40}_{19}K$ with a half-life of 1.37×10^9 years, decays to $^{40}_{18}Ar$ which is stable Moon rocks from the Sea of Tranquility. If the ratio of these potassium atoms to argon atoms is $\frac{1}{7}$. Estimate the age of these rocks.*

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Solution:

Let the number of potassium and Argon atoms in the sample be N_k and N_{Ar} respectively.

Initial number of potassium atoms $= N_{ok} = N_k + N_{Ar}$

If the rocks be t years old then,

$$\frac{N_k}{N_{ok}} = e^{-\lambda t} \Rightarrow \frac{N_{ok}}{N_k} = e^{\lambda t}$$

or,

$$\frac{N_k + N_{Ar}}{N_k} = e^{\lambda t} \Rightarrow 1 + \frac{N_{Ar}}{N_k} = e^{\lambda t}$$

$$\because \frac{N_k}{N_{Ar}} = \frac{1}{7} \quad \therefore \frac{N_{Ar}}{N_k} = 7$$

Hence,

$$1 + 7 = e^{\lambda t} \Rightarrow \lambda t = \ln 8$$

$$t = \frac{\ln 8}{\lambda} = \frac{\ln 8}{\ln 2 / T_{\frac{1}{2}}}$$

$$= 3 \times 1.37 \times 10^9 \text{ years} = 4.11 \times 10^9 \text{ years}$$

Example - 20. *Measurements on a certain isotope show that the decay rate decreases from 8318 decays/min. to 3091 decays/min. in 4 days. What is the half life of this isotope?*

Solution:

Given, Initial activity $(A_o) =$ 8318 decays/min

Final activity $(A) =$ 3091 decays/min

Time $(t) =$ 4 days

Half life $(T_{1/2}) =$?

We know, $A = A_o e^{-\lambda t}$

or, $$3091 = 3818\, e^{(-0.693/T_{1/2})\times 4}$$

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

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

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

$$\therefore T_{1/2} = \frac{0.693 \times 4}{ln\left(\frac{8318}{3091}\right)} = 2.8 \text{ days}$$

Hence the half-life of this isotope is 2.8 days.

Numerical Problems

1. At a certain instant a piece of radioactive element contains 10^{12} atoms. The half – life of the material is 15 days. Calculate the rate of decay after 30 days have elapsed. [1.15×10^{10} dis/sec]
2. At a certain instant a piece of radioactive element contains 10^{12} atoms. The half – life of the material is 40 days. Calculate the number of disintegration in first one second. [2×10^{5}dis/sec]
3. At a certain instant a piece of radioactive element contains 10^{12} atoms. The half – life of the material is 30 days. Calculate the number of disintegration in first one second. [2.7×10^{5}dis/sec]
4. Measurement on a certain isotopes show that the decay rate decreases from 8318 decays/min. to 3091 decays/min. in 4 days. What is the half – life of this isotopes? [2.8 days]
5. The mass of radium is 226 gm. It is observed that 3.67×10^{10} $\alpha - particles$ are emitted per second from 1 gm of radium. Calculate the half life of radium. (Avogadro number = 6.023×10^{23}) [1586 years]

6. If 4 kg of radioactive material of half life period 10 years disintegrates, find out mean life of the given sample [14.43 years]

7. A radioactive source which has the half life of 130 days, contains initially 1×10^{20} radioactive atoms, and the energy released per disintegration is 8×10^{-13}J, calculate the activity of the source after 260 days have elapsed and total energy released during this period. [1.54×10^{12}dis/sec, $6 \times 10^{7} J$]

8. The initial number of atom in a radioactive element is 6×10^{20} and its half life is 10 hours. Calculate the number of atoms which have decayed in 30 hours and amount of energy liberated if the energy liberated per atom decay is 4×10^{-13}J. [5.25×10^{20}, 21×10^{7}J]

9. A sample of R-226 has a half life of 1620 years. What is the mass of the sample which undergoes 2000 dis/sec? [$5.44 \times 10^{-10} Kg$]

10. The isotope C-14 has half life 5700 years. If the sample contains 1×10^{22} C-14 nuclei. What is the activity of the sample? [$4 \times 10^{10}\ dis/sec$]

11. The unstable isotope of potassium-40 has half life of 2.4×10^{8} years how many decays occurs per second in a sample containing 2×10^{-6} gram of K-40? [2.76dis/sec]

12. Half life of Ra-226 is 1620 years. Estimate its mass when its activity is 0.5 Curie. $[0.51 \times 10^{-3} Kg]$

13. Find the half life of U-238, if 1gm of it emits $1.24 \times 10^{4}\ \alpha - particles$ per second. (Avogadro number = 6.025×10^{23}) $[4.5 \times 10^{9} years]$

14. If the half life of a radioactive substance is 2 days, after how many days will 1/ 64th part of the substance left behind? [12 days]

15. A radioactive source decayed to 1/ 28th of its initial activity after 50 days. What is the half life?

16. After a certain lapse of time, the fraction of radioactive polonium undecayed id found to be 12.5% of the initial quantity. What is the duration of his time lapse if half life of polonium is 139 days. [417.2 days]

17. If 15% of the radioactive material decays in 5 days, what would be the percentage of amount of original material left after 25 days? [44%]

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18. The isotope Ra-226 undergoes α decay with the half life of 1620 years. What is the activity of 1 gm of Ra-226? . (Avogadro number = 6.023×10^{23} $per\ mole$) [$3.6 \times 10^{10} dis/sec$]
19. Calculate the mass in grams of a radioactive sample Pb-214 having an activity of 3.7×10^4 decays/sec and half life of 26.8 minutes. [$Avogardo\ number$ 6.023×10^{23}] [$3.05 \times 10^{-14} gm$]
20. A radioactive source has decayed to one tenth of one percent of its initial activity in one hundred days. What is its half life period? [10 days]
21. A radioactive element has a half life of 2500 years. In how many years will its mass decay by 90% of its initial mass? [8297years]
22. A radioactive sample has a half life of 8.3×10^4 years. Calculate its disintegration constant and time taken for 25% of its activity to disappear. [3.43×10^4 years]
23. For a radioactive element, a counter measures the activity of 895 counts per minute and 10 min. later 327 counts per minute. Find the decay constant, mean life and half – life of the radioactive element?

24. A small volume of a solution which contain a radioactive isotope of a sodium had an activity of 12000 disintegrations per minute when it was injected into the blood stream of a patient. After 30 hours, the activity of $1cm^3$ of the blood was found to be 0.5 disintegration per minute. If the half life of the sodium isotope is 15 hours, estimate the volume of the blood in the patient. [6000 cm^3]

25. The sun obtains its radiant energy from a thermonuclear fusion process. The mass of the sun is 2 x 10^{30} kg and it radiates 4 x 10^{23} kW at a constant rate. Estimate the life time of sun in years if 0.7% of its mass is converted into radiation during the fusion process and it loses energy only by radiations (1 year = 3 x 10^7 sec., speed of light is 3 x 10^8 m/s.)

Any questions or doubts?

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Thank you!