RADIOACTIVITY

Radioactivity may be defined as a process in which nuclei of certain elements spontaneously disintegrate (transformation into another element by the ejection of α -or β - particle)at a rate characteristic for each particular active isotope (Becquerel, 1896). All the heavy elements from bismuth (atomic number 83) through uranium and also a few of the lighter elements possess radioactive properties. However, the radioactive property of the different radioactive elements differs widely, e.g. radium atoms have about three million times the activity of uranium atoms. Uranium in the form of potassium uranyl sulphate, $KUO_2(SO_4)_2$ was the first compound found to be radioactive. Radioactive changes are spontaneous. These are not controlled by temperature, pressure or nature of chemical combination.

Radioactive disintegration

The atomic nuclei of radioactive elements can disintegrate any moment. During disintegration, atoms of new elements having different physical and chemical properties are formed, called daughter elements.

Disintegration occurs by the following processes :

(i) **α-particle emission :** When an α-particle (^4_2He) is emitted from the nucleus of parent element, the new element formed called daughter element, possess atomic mass less by 4 unit & atomic number less by 2 units.

	Parent element $\xrightarrow{-\alpha}$	Daughter element
Atomic mass	A	A – 4
Atomic number	Z	Z – 2

For e.g., $^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^4_2He$

(ii) **β-particle emission :** When β-particle is emitted from parent element thus formed daughter elements possesses same atomic mass but atomic no. is increased by 1 unit.

	Parent element $\xrightarrow{-\beta}$	Daughter element
Atomic mass	A	A
Atomic number	Z	Z + 1

1. Iso series :

* Elements having same mass number called isobars. (A - same, Z- different)

$\therefore$ daughter element formed by the β-particle emission is an isobar of parent element.

e.g., $^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$

If in a radioactive transformation α & β both are emitted then atomic mass & atomic number changes accordingly & produces an isotope of the parent element.

$$^A_ZA \xrightarrow{-\alpha} {}^{A-4}_{Z-2}B \xrightarrow{-\beta} {}^{A-4}_{Z-1}C \xrightarrow{-\beta} {}^{A-4}_{Z}D$$

(A & D are isotopes)

* Elements having same no. of protons called isotopes. e.g., $^{12}_6C$, $^{14}_6C$ and $^{16}_8O$, $^{17}_8O$ etc.

(A - different, Z- same)

* Elements having same no. of neutrons are called <u>isotones</u>. e.g., ${}^{14}_{6}C$, ${}^{16}_{8}O$ & ${}^{19}_{9}F$, ${}^{18}_{8}O$ etc. (A - different, Z- different)

* Elements having same value of $(A-2Z)$ are called <u>isodiaphers</u>. e.g., ${}^{19}_{9}F$, ${}^{39}_{19}K$

  (A - different, Z- different, $A-2Z$ -same)

* Elements having same number of electrons are called <u>isoelectronic</u>. e.g., SO_4^{-2}, PO_4^{-3}

* Compounds having same number of atoms as well as same number of electrons are called <u>isosters</u>.

Isotopes, Isobars and Isotones :

S.No	Isotopes	Isobars	Isotones
1.	The atoms of the same elements whose charge number (Z) is same but mass number is different are known as isotopes.	The atoms with mass number same and charge number different are known as isobars.	The atoms with same neutron number but A and Z are different are known as isotones
2.	Chemical properties are same	Chemical properties are different	Chemical properties are different
3.	Number of electrons is same	Number of electrons is different	Number of electrons is different
4.	Occupy same place in periodic table	Occupy different places in periodic table	Occupy different places in periodic table.
5.	Example ${}_8O^{16}, {}_8O^{17}, {}_8O^{18}$ ${}_1H^1, {}_1H^2, {}_1H^3$ ${}_{10}Ne^{20}, {}_{10}Ne^{21}, {}_{10}Ne^{22}$	${}_1H^3$ and ${}_2He^3$ ${}_6C^{14}$ and ${}_7N^{14}$ ${}_8O^{17}$ and ${}_9F^{17}$	${}_3Li^7$ and ${}_4Be^8$ ${}_1H^2$ and ${}_2He^3$ ${}_1H^3$ and ${}_2He^4$

Radioactive Isotpes :

The isotopes of elements which spontaneously decay by emitting radioactive radiations are defined as radioactive isotopes.

They are two types .

(a) Natural radioactive isotopes **(b)** Artificial radioactive isotopes

(a) **Natural radioactive isotopes :** Those radioactive isotopes which exist naturally are known as natural radioactive isotopes. e.g. Th^{232}, Pu^{240} etc.

(b) **Artificial radioactive isotopes :** Those isotopes, which are prepared artificially by bombarding fundamental particles like α, β, γ, p,n etc, no matter, are known as artificial isotopes.

2. Analysis of Radioactive Radiations :

In 1904, **Rutherformd and his co-workers** observed that when radioactive radiations were subjected to a magnetic field or a strong electric field, these were split into three types, as shown in fig.. The rays which are attracted towards the negative plate are positively charged and are called **alpha (α) rays**. The rays which are deflected towards the positive plate are negatively charged and are called **beta (β) rays**. The third type of rays which are not deflected on any side but move straight are known as **gamma (γ) rays**.

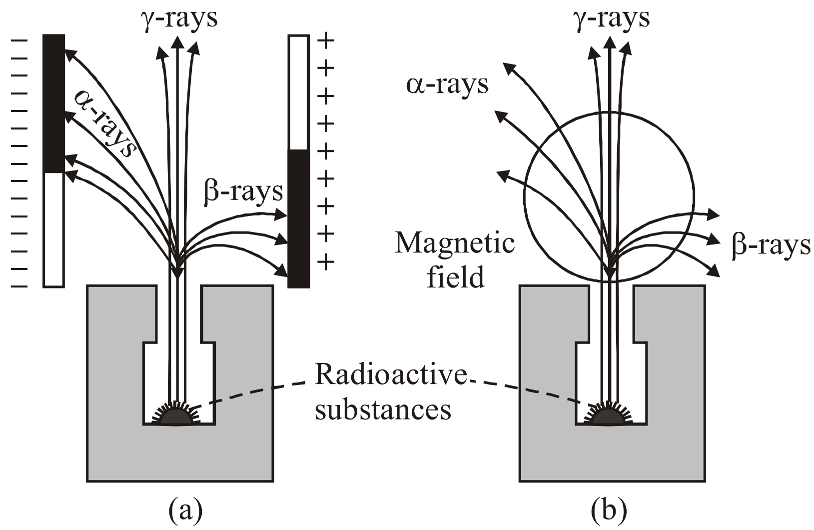


Fig. : (a) Deflection of radioactive rays in electric field and
(b) emission of radioactive rays and their deflection in a magnetic field

3. Characteristics of α,β, γ :

a-emission :

(a) Characterstictics of α –decay :

(i) The spectrum of α -particles is a discrete line spectrum.

(ii) Spectrum of α -particles has fine structure i.e. every spectral line consists of a number of fine lines.

(iii) The α -emitting nuclei have discrete energy levels i.e energy levels in nuclei are analogous to discrete energy levels in atoms..

(iv) α -decay is explained on the basis of tunnel effect.

(v) Geiger-Muller law - $\log_e^{\lambda} = A + B\log_e R$ For radioactive series B is same whereas A is different

(b) Range of α -particles :

(i) The maximum distance traversed by α -particles in air before being finally stopped is defined as the range of α -particles.

(ii) The maximum distance transversed by α -particles before being finally absorbed after ionizing gas molecules, is defined as the range of α -particles.

(iii) The range of α -particles in air is from 2.6cm to 8.6cm.

(iv) Relations between the range of α -particles and their energy

(I) $R = 0.318E^{3/2}$ **(II)** $\log R = \log 0.318 + \frac{3}{2}\log E$

(c) Size of the nucleus decreases by α emission

Characteristic of β-decay :

(i) The energy spectrum of β -particles is continuous i.e. β -particles of all energies upto a certain maximum are emitted

(ii) The number of such β -particles is maximum whose energy is equal to the maximum probable energy i.e. at $E = E_{mp}$, N_B =maximum.

(iii) There is a characteristic maximum value of energy in the spectrum of β -particles which is known as the end point energy $\left(E_0\right)$

(iv) In β-decay process, a neutron is converted into proton or proton is converted into neutron.

$${}_0n^1 = {}_1p^1 + {}_{-1}e^0 \quad (\beta^- \ Particle) \qquad {}_1p^1 = {}_0n^1 + {}_1e^0 \quad (\beta^+ \ Particle)$$

(v) The energy of β-particles emitted by the same radioactive material may be same or different.

(vi) The number of β-particles with energy $E = E_0$ (end point energy) is zero.

Neutrino Hypothesis :

(a) According to Pauli, whenever neutron is converted into proton or proton into neutron then this process is accompanied with the emission of a new particle to which he named as neutrino.

$${}_1p^1 = {}_0n^1 + {}_1e^0 + v; \quad {}_0n^1 = {}_1p^1 + {}_{-1}e^0 + \overline{v}$$

(b) **Properties of neutrino :**

(i) The charge on neutrino is zero

(ii) The rest mass of neutrino is zero

(iii) Its spin angular momentum is $\pm\frac{h}{2}$

(iv) Its speed is equal to that of light.

(v) It has infinite magnetic moment but the magnitude is very small

(vi) Its antiparticle is anti-neutrino.

(vii) The linear momentum vector $\vec{p}$ and spin vector $\vec{S}$ are mutually in opposite directions.

(viii) Its energy is equal to $(E_{end} - E_\beta)$.

(ix) It does not interact with matter.

(x) Neutrino was discovered by Pauli and its experimental verification is done by Reines and Cowan.

(a) Characterstics of γ-decay

(i) The spectrum of γ-rays is a discrete line spectrum.

(ii) Whenever α *or* β - particles is emitted by a nucleus then the daughter nucleus is left in the excited state. It suddenly makes transition in the ground state thereby emitting γ-rays.

(iii) Knowledge about nuclear energy levels is obtained by γ-spectrum.

(iv) γ-rays interact with matter as a consequence of which the phenomena of photoelectric effect, Compton effect and pair production happen. (At low energy photoelectric effect and at high energy pair-production are effective).

(b) Intensity of γ-rays in materials

(i) When γ-rays penetrate matter, then their intensity (a) decreases exponentially with depth (x) inside the matter. The intensity of γ-rays at depth x inside the matter is given by $I = I_0 e^{-\mu x}$.

(ii) The thickness of matter, at which the intensity of γ-rays (I) reduces to half its initial maximum value (I_0), is known as its half-value thickness. $\left(X_{1/2} = \frac{0.693}{\mu}\right)$

(iii) The reciprocal of the distance inside matter, at which the intensity (I) reduces to $\frac{1}{e}$ or 37 % of its maximum value (I_0), is defined as the coefficient of absorption (μ) of that material.

(iv) Coefficient of absorption

(I) $\mu = -\frac{dI/I}{dx}$

(II) μ depends on the wavelength of γ-rays $(\mu \ \alpha \ \lambda^3)$ and the nature of absorbing material

S.No	Property	α-Particles	β-Particles	γ-rays
1.	Nature and value of charge	Positive and double of the charge of the proton	Negative and equal to the charge of electron 1.6×10^{-19} C	Uncharged (Neutral)
2.	Nature of particle	Doubly ionized helium atom (2 protons and 2 neutrons)	Electron (or) positron	Electromagnetic waves
3.	Mass	Four times the mass of the proton $(4\times1.67\times10^{-27} kg)$	Equal to the mass of electron $9.1\times10^{-31} kg$	Mass less
4.	Specific charge $\frac{q}{m}$	$\frac{3.2\times10^{-19}}{4\times1.67\times10^{-27}}$ = 4.79 × 10^7	$1.7\times10^{11} Ckg^{-1}$	Uncharged and mass less
5.	Explained by	Tunnel effect	Neutrino hypothesis	Transitions of nuclei into the ground energy level after α and β decay
6.	Effect of electric and magnetic fields	Deflected by electric and magnetic fields	Deflected by electric and magnetic fields	Unaffected
7.	Penetrating power	1	100	10000
8.	Ionizing power	100000	100	1
9.	Velocity	Less than the velocity of light $(1.4\times10^7 m/s \ to \ 2.2\times10^7 ms^{-1})$	Approximately equal to the velocity of light	$3\times10^8 m/s$
10.	Mutual interaction with matter	Produce heat	Produce heat	Produce the phenomenon of Photoelectric effect, Compton effect, Pair production

4. Radioactivity :

(a) The phenomenon of spontaneous disintegration of nuclei of unstable atoms is defined as radioactivity.

(b) Generally it is exhibited by atoms with A > 192 and Z > 82

(c) It was discovered by Henry Becqurel

(d) Lead isotope is the stable end product of any natural radioactive series

(e) Radio activity is a nuclear process and not an atomic process

(f) Radioactivity is not associated with the electron configuration of the atom.

Cause of radioactivity :

Except in the case of ordinary hydrogen, all other nuclei contains both neutrons and protons. A look at the stable nuclei shows that the ratio n/p (neutrons/protons) in them is either equal to 1 or more than 1. The ratio is ≈ 1 in all the light-stable nuclei up to calcium $({}^{40}_{20}Ca)$ and thereafter the ratio is greater than 1 and increases up to 1.6 for heavy stable nuclei as shown in the following table:

Neutron-proton ratio in some stable nuclei

Isotope:	${}^{12}_{6}C$	${}^{14}_{7}N$	${}^{16}_{8}O$	${}^{20}_{10}Ne$	${}^{40}_{20}Ca$	${}^{64}_{30}Zn$	${}^{90}_{40}Zr$	${}^{120}_{50}Sn$	${}^{150}_{60}Nd$	${}^{202}_{80}Hg$
	6	7	8	10	20	34	50	70	90	122
	6	7	8	10	20	30	40	50	60	80
	1	1	1	1	1	1.13	1.25	1.40	1.50	1.53

The variation of n versus p for some nuclei is shown in fig. 3.3

The stable nuclei lie within the shaded area which is called the **region** or **zone of stability**. All the nuclei falling outside this zone are invariably radioactive and unstable in nature. **Nuclei that fall aobve the stability zone have an excess of neutrons while those lying below have more protons.** Both of these cause instability. These nuclei attain stability by making adjustment in the n/p ratio.

Two cases thus arise:

(i) n/p ratio is higher than required for stability. Such nuclei have the tendency to emit β-rays, i.e., transforming a neutron into proton.

$$ {}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e\,(\beta - \text{particle}) $$

Thus, in b-emission n/p ratio decreases. For example, the change of ${}^{14}_{6}C$ to ${}^{14}_{7}N$, n/p ratio decreases from 1.33 to 1.

$$ {}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e $$

similarly, in the following examples, the n/p ratio decreases during b-emission:

$$ {}^{32}_{15}P \rightarrow {}^{32}_{16}S + {}^{0}_{-1}e $$

n/p ratio 17/15 16/16

$$ {}^{87}_{36}Kr \rightarrow {}^{87}_{37}Rb + {}^{0}_{-1}e $$

n/p ratio 51/30 50/37

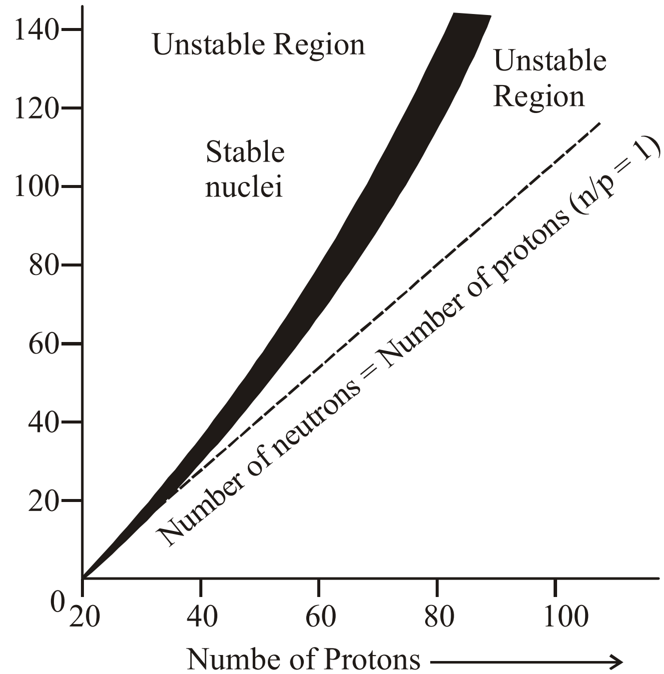


Fig. : Variation of numbe of number of neutrons with number of protons in stable non-radioactive nuclei

(ii) **n/p ratio is lower than required for stability.** Such nuclei can increase n/p ratio any adopting any one of the following three ways:

(a) **by emission of an alpha particle (Natural radioactivity):**

$$^{238}_{92}U \longrightarrow \, ^{234}_{90}Th + \, ^{4}_{2}e \quad (\alpha\text{-particle})$$

n/p ratio 146/92 = 1.58 144/90 = 1.60

(b) **By emission of a positron (Artificial emission) :**

$$^{13}_{7}N \longrightarrow \, ^{13}_{6}C + \, ^{4}_{2}He$$

n/p ratio 6/7

(c) **By K-electron capture:**

$$^{194}_{79}Au + \, ^{0}_{-1}e \longrightarrow \, ^{194}_{78}Pt$$

n/p ratio 115/79 116/78

Alpha emission is usually observed in natural radioactive isotopes while emission of positron or K-electron capture is observed in artificial radioactive isotopes. The unstable nuclei continue to emit alpha or beta particles until a stable nucleus comes into existence.

Conclusion : (i) For the elements (mass number A $\leq$ 40), natyure prefers the number of protons and neutrons in the nucleus to be same.

(ii) For the elements (mass number A $\geq$ 40), there is preference for the number of neutrons to be greater than the number of protons (n > Z), e.g., $^{11}_{5}B$ is stable but $^{11}_{6}C$ is not. There are two stable elements $^{1}_{1}H$ and $^{3}_{2}He$, in which number of neutrons is less than that of protons.

SIGNIFICANT FACTS ABOUT STABLE NUCLEI

A study of stable nuclei have revealed the following interesting facts.

- Even-Even nuclides. About 60% of the stable nuclei have both even number of protons and even number of neutrons. Some example being $^{12}_{6}C$, $^{16}_{8}O$, $^{40}_{20}Ca$, etc. Almost all the remaining stable nuclei have either odd number of protons or odd number of neutrons.

- Odd-odd nuclei. The nuclei with odd number of protons and odd number of neutrons are least stable. The only exception, being ${}_{1}^{2}H$, ${}_{3}^{6}Li$, ${}_{5}^{10}B$, ${}_{7}^{14}N$, ${}_{73}^{180}Ta$.
- Nuclei with Z > 83 and A > 209 are unstable and spontaneously transform themselves into lighter one through radioactive emissions.
- Magic numbers. Nuclei with number of neutrons or number of protons equal to 2, 8, 20, 50 82 or 126 are stable. These numbers are called magic numbers. The nuclei with magic number of protons as well as magic number of neutrons are most stable. Some examples being, ${}_{2}^{4}He$, ${}_{8}^{16}O$, ${}_{20}^{40}Ca$, ${}_{82}^{208}Pb$.

5. Theory of Radioactive disintegration :

Soddy-Fajaan's Law :

(a) During an α-decay, mass number decreases by 4 units and atomic number by 2 units.

$$X_Z^A \xrightarrow{\alpha-ray} Y_{Z-2}^{A-4} + E$$

Daughter nucleus will occupy two positions before that of parent nucleus, in periodic table.

(b) During β-decay mass number of the atom will not change and atomic number increases by 1 unit

$$X_Z^A \xrightarrow{\beta-ray} Y_{Z+1}^{A}$$

Daughter nucleus will occupy one position on the right of that of parent nucleus in periodic table

(c) During γ-decay, the mass number and atomic number of the nucleus remain unchanged

$$X_Z^A \xrightarrow{\gamma-ray} Y_Z^A + E$$

4.

(a) Emission of α-particle means loss of two protons and two neutrons

(b) Emission of β-particle means loss of an electron.

(c) Emission of a γ-ray means no change in charge and mass, but only energy changes

To Calculate no. of α-particles and β-Particles emitted :

$$X_Z^A \longrightarrow Y_{Z^1}^{A^1} + x\alpha + y\beta$$

x: no of α-particles emitted   y: no of β-particles emitted

$$X_Z^A \longrightarrow Y_{Z^1}^{A^1} + xHe_2^4 + ye_{-1}^0$$

$A = A^1 + 4x$ $x = \dfrac{A - A^1}{4}$

$Z = Z^1 + 2x - y$ $y = Z^1 - Z + 2x$ $y = \left(\dfrac{A - A^1}{2}\right) - (Z - Z^1)$

eg : $U_{92}^{238} \longrightarrow Pb_{82}^{206} + xHe_2^4 + ye_{-1}^0$

$$x = \frac{A - A^1}{4} = \frac{238 - 206}{4} = 8\alpha - \text{particles}$$

$$y = \left(\frac{A - A^1}{2}\right) - (Z - Z^1) = \left(\frac{238 - 206}{2}\right) - (92 - 82) = 16 - 10 = 6\beta - \text{particles}$$

6. Group displacement law :

The result of α- and β- particle changes can be summed up in the form of group displacement law. *"In an α-particle change the resulting element has an atomic weight less by four units and atomic number less by two units and it falls in a group of the periodic table two columns to the left of the original element, and in a β-particle change the resulting element has same atomic weight but its atomic number is increased by one than its parent and hence it lies one column to right".*

e.g.,(i) ${}^{214}_{84}Po \longrightarrow {}^{210}_{82}Pb + {}^{4}_{2}He$ (ii) ${}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

(VI A) (IV A) (IV A) (V A)

Daily Practice Problems - 13

1. Calculate the number of neutrons in the remaining atom after emission of an alpha particle from ${}^{238}_{92}U$ atom.

2. Radioactive disintegration of ${}^{226}_{88}Ra$ takes place in the following manner into RaC.

$$Ra \xrightarrow{-\alpha} Rn \xrightarrow{-\alpha} RaA \xrightarrow{-\alpha} RaB \xrightarrow{-\beta} RaC$$

Determine mass number and atomic number of RaC.

3. A radioactive element A disintegrates in the following manner

$$A \xrightarrow{-\alpha} B \xrightarrow{-\beta} C \xrightarrow{-\beta} D$$

(i) Which one of the elements A, B, C, D are isotopes ?
(ii) Which one of the elements A, B, C, D are isobars ?

4. Write the particles emitted from each nucleides in the following reactions :

(a) ${}^{231}_{90}Th \xrightarrow[(i)]{} {}^{231}_{91}Pa \xrightarrow[(ii)]{} {}^{227}_{89}Ac$ (b) ${}^{217}_{85}At \xrightarrow[(i)]{} {}^{213}_{83}Bi \xrightarrow[(ii)]{} {}^{209}_{81}Tl$

5. An atom has atomic mass 232 and atomic number 90. During the course of disintegration, it emits 2β-particles and few α-particles. The resultant atom has atomic mass 212 and atomic number 82. How many α-particles are emitted during this process.

6. In the sequence of the following nuclear reaction

$${}^{238}_{98}X \xrightarrow{-\alpha} Y \xrightarrow{-\beta} Z \xrightarrow{-\beta} L \xrightarrow{n\alpha} {}^{218}_{90}M$$

what is the value of n

(A) 3 (B) 4 (C) 5 (D) 6

7. The isotope ${}^{235}_{92}U$ decays in a number of steps to an isotope of ${}^{207}_{82}Pb$. The groups of particles emitted in this process will be

(A) 4α, 7β (B) 6α, 4β (C) 7α, 4β (D) 10α, 8β

8. The ${}^{238}_{92}U$ disintegrates to give 4 α-and 6-β particles. The atomic number of the end product is

(A) 92 (B) 96 (C) 84 (D) 90

9. Following are the atoms having the number of neutrons and protons as given below :

Atoms	Protons	Neutron
A	8	8
B	8	9
C	8	10
D	7	8
E	7	9

Select incorrect conclusion(s) :

(A) A, B and C, D are isotopes (B) A and D are isotones
(C) A and E are isobars (D) A and B are isodiaphers

10. An alkaline earth element is radioactive. It and its daughter elements decay by emitting there α-particles in sucession. The daughter element formed wil belong to group -
(A) 8 (B) 16 (C) 14 (D) 12

11. $^{210}_{84}Po \longrightarrow ^{206}_{82}Pb + ^{4}_{2}He$
In above reaction, predict the position of Po in the periodic table when lead belongs to IVB group :
(A) IIA (B) VI B (C) IV B (D) V B

Daily Practice Problems - 14

1. Calculate α and β particles emitted during the process.

(i) $^{230}_{90}X \longrightarrow ^{210}_{85}Y$ (ii) $^{208}_{82}X \longrightarrow ^{196}_{82}Y$

(iii) $^{252}_{90}Th \longrightarrow ^{208}_{82}Pb$ (iv) $^{238}_{92}U \longrightarrow ^{234}_{92}U$

(v) $^{238}_{92}U \longrightarrow ^{226}_{88}Ra$ (vi) $^{226}_{88}Ra \longrightarrow ^{214}_{83}Bi$

(vii) $^{234}_{90}Th \longrightarrow ^{218}_{84}Po$ (viii) $^{237}_{93}NP \longrightarrow ^{209}_{83}Bi$

(ix) $^{235}_{92}U \longrightarrow ^{207}_{92}Pb$ (x) $^{220}_{86}X \longrightarrow ^{200}_{80}Y$

2. The triad of nuclei that represents isotopes is:
(A) $_6C^{14}, _7N^{14}, _9F^{19}$ (B) $_6C^{12}, _7N^{14}, _9F^{19}$
(C) $_6C^{14}, _6C^{13}, _6C^{12}$ (D) $_6C^{14}, _7N^{14}, _9F^{17}$

3. The triad of nuclei that represents isotones is:
(A) $_6C^{12}, _7N^{14}, _9F^{19}$ (B) $_6C^{14}, _7N^{15}, _9F^{17}$
(C) $_6C^{14}, _7N^{14}, _9F^{17}$ (D) $_6C^{14}, _7N^{14}, _9F^{19}$

4. The atomic mass of thorium is 232 and its atomic number number is 90. During the course of its radioactive disintegration 6α and 4 β-particles are emitted. What is the atomic mass and atomic number of the final atom?

5. How many moles of helium are produced when one mole of $^{238}_{92}U$ disintegrates into $^{206}_{82}Pb$?

6. $^{238}_{92}U$ is a natural and α-amiter. after α-mission, the residual nucleus U_{x_2} inturns emits a β-particle to produce another nucleus U_{x_2} . Find out the atomic number and mass number of U_{x_1} and U_{x_2} . Also if uranium belongs to IIIrd group to which group U_{x_1} and U_{x_2} belong.

7. During the transformation of $^{a}_{c}X$ to $^{b}_{d}Y$, the number of b-particles emitted are:

(A) $\frac{a-b}{4}$ (B) $d+\frac{a-b}{2}+c$ (C) $d+\left(\frac{a-b}{2}\right)-c$ (D) 2c – d + a – b

8. In which of the following tranformations, the b-particles are emitted?
(A) Proton to neutron (B) Neutron to proton
(C) Proton to proton (D) Neutron to neutron

9. In the radioactive decay:

$${}_{Z}^{A}X \longrightarrow {}_{Z+1}^{A}Y \longrightarrow {}_{Z-1}^{A-4}Z \longrightarrow {}_{Z-1}^{A-4}Z^{*}$$

The sequence of emission is:

(A) α, β, γ (B) β, α, γ (C) γ, α, β (D) β, γ, α

10. Which of the following elements is an isodiaphere of ${}_{92}^{235}U$?

(A) ${}_{83}^{209}Bi$ (B) ${}_{82}^{212}Pb$ (C) ${}_{90}^{231}Th$ (D) ${}_{91}^{231}Pa$

7. Radioactive Disintegration series :

If parent element is unstable then it will dissociate into daughter element & if this daughter element is still unstable, then it will again dissociate into a new daughter element & process continuous till the formation of a stable element. Series of element obtained from parent element to the finally stable non-radioactive element is known as radioactive disintegration series.

(4n + 1) is artificial series & 4n, (4n + 2), (4n + 3) are natural series.

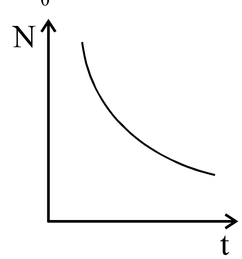
S.No	Series	Name of the series	Initial element	Final element	Nature of series	No of α & β Particles emittted
1.	4n+2	Uranium series	${}_{92}U^{238}$	${}_{82}Pb^{206}$	Natural	$8\alpha, 6\beta$
2.	4n+3	Actinium series	${}_{92}U^{235}$	${}_{82}Pb^{207}$	Natural	$7\alpha, 4\beta$
3.	4n	Thorium series	${}_{90}Th^{232}$	${}_{82}Pb^{208}$	Natural	$6\alpha, 4\beta$
4.	4n+1	Neptunium series	${}_{93}Np^{237}$	${}_{83}Bi^{209}$	Artificial	$7\alpha, 4\beta$

8. Law of Radioactive decay :

(a) If N is the number of radioactive nuclei present in a sample at a given instant of time, then the rate of decay at that instant is proportional to N i.e.,

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

(b) If N_0 is the number of radioactive nuclei at time t = 0, then the number of radioactive nuclei at a later time t is given by , $N = N_0 e^{-\lambda t}$



(c) The nuclei of unstable atoms decay spontaneously emitting α, β particles and γ rays

(d) Radioactivity remains unaffected due to the physical and chemical changes of the material.

(e) Radioactivity obeys the law of probability i.e it is uncertain that when a particular atom will decay.

9. Activity (A) :

(a) The number of atoms of any material decaying per second is defined as the activity of that material.

(b) Its value depends on the quantity and nature of that material.

(c) Units of activity –
fundamental unit – disintegrations per second i.e., Bq

$1\,Bq = 1\,\text{disintegration/s}$

(d) Practical units: curie and rutherford.
1 curie $= 3.7 \times 10^{10}$ disintegration/second:
1 Rutherford $= 10^{6}$ disintegrations/second.

(e) Formulae of activity

(i) $A = -\frac{dN}{dt}$ (ii) $A = \lambda N$ (iii) $A_0 = \lambda N_0$ (iv) $A = A_0 e^{-\lambda t}$ (v) $A = \frac{0.693 N_A m}{WT}$

where A_0 = maximum initial activity; A= activity after time t, λ =decay constant,
N_A = Avogadro number , m = mass of material ,
W = atomic weight of material , T = half life of material

Specific activity : It is the measure of radioactivity of a radioactive substance. It is defined as 'the number of radioactive nuclei which decay per second per gram of radioactive isotope'. Mathematically, if 'm' is the mass of radioactive isotope, then

$$\text{Specific activity} = \frac{\text{Rate of decay}}{\text{m}} = \frac{\lambda N}{m} = \lambda \times \frac{\text{Avogadro number}}{\text{Atomic mass in g}}$$

Where N is the number of radioactive nuclei, which undergoes disintegration.

10. Decay Constant (λ) :

The ratio between the number of atoms disintegrating in unit time to the total number of atoms present at that time is called the decay constant of that nuclide.

(a) Decay constant is equal to the reciprocal of that time in which the activity of the material reduces to $\frac{1}{e}$ or 37 % of its initial activity.

(b) $$\lambda = \frac{-\frac{dN}{dt}}{N} = \frac{No.\ of\ atoms\ decaying\ per\ second\ (Rate\ of\ disintegration)}{No.\ of\ atoms\ remaining\ after\ decay}$$

i.e. The rate of disintegration per atom is defined as decay constant

(c) Decay constant does not depend on temperature, pressure and volume. It depends on the nature of material and it is a characteristic of a nuclide not of an element.

(d) Its unit per second.

(e) Decay constant $\left(\lambda = \frac{-\frac{dN}{dt}}{N}\right)$ represents the probability of decay per second.

(f) $$\lambda = \frac{2.303}{t}\log_{10}\frac{N_0}{N} = \frac{2.303}{t}\log_{10}\frac{A_0}{A} = \frac{2.303}{t}\log_{10}\frac{M_0}{M}$$

(g) Its value is equal to the negative of the slope of N-t curve.
(h) The decay constant of stable element is zero.
(i) Its value is always less than one.

11. Half-life ($T_{1/2}$) :

(a) The time, in which the number of atoms (N) reduces to half of its initial value (N_0), is defined as the half-life of the element (i.e. half of the atoms decay). $t = T_{\frac{1}{2}}, \quad N = \frac{N_0}{2}$

(b) The time in which the activity reduces to half of its initial value is defined as half life.

At $t = T_{\frac{1}{2}}, \quad A = \frac{A_0}{2}$

(c) Its unit is second
(d) Formulae of half life

(i) $T_{\frac{1}{2}} = \frac{0.693}{\lambda} = \frac{\log_e 2}{\lambda}$

(ii) $T_{\frac{1}{2}} = \frac{\log_e 2}{\log_{10}\left(\frac{N_0}{N}\right)} = \frac{\log_e 2}{\log_{10}\left(\frac{A_0}{A}\right)} = \frac{\log_e 2}{\log_{10}\left(\frac{M_0}{M}\right)}$

(iii) $T_{\frac{1}{2}} = \frac{t}{n}$ where n=No. of half lives

(iv) Time of disintegration $t = \frac{T\log_{10}\left(\frac{N_0}{N}\right)}{\log_{10} 2} = \frac{T\log_{10}\left(\frac{N_0}{N}\right)}{0.3010}$

12. Mean life (τ) :

(a) The time, for which a radioactive material remains active, is defined as mean life of that material :

(b) $\tau = \frac{Sum\ of\ lives\ of\ all\ atoms}{total\ number\ of\ atoms\ present} = \frac{\int t|dN|}{N_0}$

(c) The average time taken in decaying by the atoms of an element is defined as its mean life τ.
(d) $\tau = 1/\lambda$
(e) Its units are second, minute, hour day, month, year etc.
(f) Mean life does not depend on the mass of material. It depends on the nature of the material.
(g) The magnitude of slope of decay curve is equal to the mean life.
(h) Relation between the mean life and half-life.

(i) $\tau = \frac{T_{\frac{1}{2}}}{0.693}$ **(ii)** $\tau = 1.44T_{\frac{1}{2}}$ **(iii)** $\tau > T_{\frac{1}{2}}$

(iv) The time, in which the number of radioactive atoms decays to 1/e or 37% of its initial value, is defined as the mean life of that material.

13. Important Formulae Related to Law of Disintegration (τ) :

(a) $N = N_0 e^{-\lambda t}$ **(b)** $A = A_0 e^{-\lambda t}$ **(c)** $M = M_0 e^{-\lambda t}$

(d) $\lambda = \dfrac{2.3027 \log_{10}\left(\dfrac{N_0}{N}\right)}{t}$ **(e)** $\lambda = \dfrac{2.3027 \log_{10}\left(\dfrac{A_0}{A}\right)}{t}$

(f) $\lambda = \dfrac{2.3027 \log_{10}\left(\dfrac{M_0}{M}\right)}{t}$ **(g)** $\lambda = \lambda_\alpha + \lambda_\beta$

(h) $\tau = \dfrac{\tau_\alpha \tau_\beta}{\tau_\alpha + \tau_\beta}$ (When two particles decay simultaneously)

(i) $N = \dfrac{N_0}{2^n} = \dfrac{N_0}{2^{\left(\frac{T}{T_{1/2}}\right)}}$ **(j)** $A = \dfrac{A_0}{2^{\left(\frac{T}{T_{1/2}}\right)}}$ **(k)** $M = \dfrac{M_0}{2^{\left(\frac{T}{T_{1/2}}\right)}}$

14. Useful Hints :

(i) Percentage decreases in activity $= \left[1 - \dfrac{A}{A_0}\right] \times 100$

(ii) Number of atoms remaining after n half lives $N = \dfrac{N_0}{2^n}$

(iii) Number of atoms decayed after time $t = N_0 - N = N_0\left[1 - \dfrac{1}{2^n}\right]$

(iv) The fraction of radioactive material at time T .$= \left[1 - \dfrac{N}{N_0}\right] = \left[1 - \dfrac{1}{2^{\frac{T}{T_{1/2}}}}\right]$

(v) Percentage of radioactive material decayed at time T $= \left[1 - \dfrac{N}{N_0}\right] \times 100 = \left[1 - \dfrac{1}{2^{\frac{T}{T_{1/2}}}}\right] \times 100$

(vi) Percentage of radioactive material decayed in n halflives $= \dfrac{N}{N_0} \times 100 = \dfrac{1}{2^{\frac{T}{T_{1/2}}}} \times 100$

(vii) Fraction of radioactive material decayed in n half lives $= 1 - \dfrac{N}{N_0} = \left[1 - \dfrac{1}{2^n}\right]$

(viii) Percentage of radioactive material decayed in n half lives $\left[1 - \dfrac{N}{N_0}\right] \times 100 = \left[1 - \dfrac{1}{2^n}\right] \times 100$

(ix) Percentage of radioactive material remaining after n half-lives. $\dfrac{N}{N_0} \times 100 = \dfrac{1}{2^n} \times 100$

(x) When decay process is too slow then $N = N_0 - N_0 \lambda t$ *or* $N = -(N_0 \lambda)t + N_0$

(xi) N-t graph is a straight line with –ve slope, for slow decay process.

15. Units of radioactivity :

The unit of radioactivity is curie (Ci). It is the quantity of any radioactivity substance which has decay rate of 3.7×10^{10} disintegrations per second.

1 millicurie (mCi) = 3.7×10^{7} disintegrations per sec.

1 microcurie (μCi) = 3.7×10^{4} disintegrations per sec.

There is another unit called rutherford (Rd) which is defined as the amount of a radioactive substance which undergoes 10^{6} disintegrations per second.

1 milli rutherford = 10^{3} disintegration per sec.

1 micro rutherford = 1 disintegration per sec.

The SI unit radioactivity is proposed as Becquerel which refers to one dps.

1 curie = 3.7×10^{4} Rutherford

1 curie = 3.7 GBq

Here, G stands for 10^{9}, i.e., giga.

16. Points to Remember :

1. Rate of decay (activity, A) is the number of atoms undergoing decay to unit time; it is represented by $-\frac{dN_t}{dt}$.

2. Rate of decay of a nuclide is directly proportional to the number of atoms of that nuclide present at that moment , hence.

$$\frac{dN_t}{dt} \propto N \quad \text{or} \quad \frac{dN_t}{dt} = \lambda N_b$$

(the negative sign shows that the number of radioactive atoms, N_t decreases as time t increases)

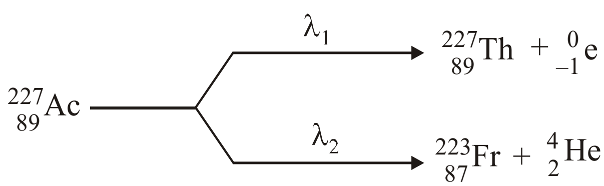
3. Rate of decay of nuclide is independent of temperature, so its energy of activation is zero.

4. Since the rate of decay is directly proportional to the amount of the radioactive nuclide present and as the number of undecomposed atoms decreases with increase in time, the rate of decay also decreases with the increase in time.

17. Special Cases of Radioactivity :

Parallel Radioactive distintegration

Very often the radioactive substance disintegrates to form different sets of products. For example, 227Ac decays through two parallel paths one leadikng to 227Th and the other to 223Fr. If λ_1 and λ_2 are the decay constants of two processes respectively. Then the overall decay constant is equal to the sum of the decay constants of two parallel paths.



Overall decay decay constant $(\lambda_{Ac}) = 11 + 12$

The fractional yield of the either process is given by the ratio of the decay constant of that process to the overall decay constant .

Fractional yield of Th = $\frac{\lambda_1}{\lambda_{Ac}}$

Fractional yield of Fr = $\frac{\lambda_2}{\lambda_{Ac}}$

Successive radioactive disintegration

Successive radioactive disintegration refer to the further disintegration of the daughter nuclide formed by decay of the parent nuclide.

$$\underset{\text{Parent nuclides}}{A} \xrightarrow[(t_{1/2})_1]{\lambda_1} \underset{\text{Daughternuclide}}{B} \xrightarrow[(t_{1/2})_2]{\lambda_2} C$$

If N is initial number of nuclide A, then

Number of nuclide A left after time t(N2) = $\frac{\lambda_1 N}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$

Time required for daughter element to reach its maximum activity (i.e., maximum concentration) is given by

$$tm = \frac{2.303(\log\lambda_1 - \log\lambda_2)}{\lambda_1 - \lambda_2}.$$

Radioactive Equilibrium

During successive radioactive disintegration, a state may reach when the amounts of intermediate nuclides become constant. It is because of the fact that their rates of disintegration become equal. This refers to radioactive equilibrium.

$$\text{..........}A \xrightarrow[(t_{1/2})_A]{\lambda_A} B \xrightarrow[(t_{1/2})_B]{\lambda_B} C\text{........}$$

Now, if NA, NB ...... are the number of nuclides of A and B at the equilibrium, then

$$-\frac{dN_A}{dt} = -\frac{dN_B}{dt} = \frac{dN_C}{dt}$$

or $\lambda_A N_A = \lambda_B N_B = \lambda_C N_C$ or $\frac{N_A}{N_B} = \frac{\lambda_B}{\lambda_A}$

Since l is inversely proportional to t1/2. Hence the relationship can be put as

$$\frac{N_A}{N_B} = \frac{\lambda_B}{\lambda_A} = \frac{(t_{1/2})_A}{(t_{1/2})_B}$$

18. Uses of Radioactive Isotopes :

(a) In Medicine :

(i) For testing blood chromium-51

(ii) For testing blood circulation-Sodium-24

(iii) For detecting brain tumor-Radio mercury-203

(iv) For detecting fault in thyroid gland-Ratio iodine-131

(v) For cancer-Cobalt-60

(vi) For blood-Gold-189

(vii) For skin diseases-Phosphorous-31

(b) In Archaeology :

(i) For determining age of archaeological sample (Carbon dating) - C^{14}

(ii) For determining age of meteorites - K^{40}

(iii) For determining age of earth-Land isotopes

(c) In Agriculture :

(i) For protecting potato crop from earthworm – Cobalt-60

(ii) For artificial rains AgI

(iii) As fertilizers-Phosphorous-32

(d) As tracers :

Very small quantity of radio isotopes present in a mixture is known as tracer . Tracer technique is used for studying biochemical reactions in trees and animals.

(e) In industries :

(i) For detecting leakage in oil or water pipe lines.

(ii) For testing machine parts

(f) In research :

(i) In the study of carbon-nitrogen cycle.

(ii) For determining the age of planets.

Daily Practice Problems - 15

1. Radioactive substance of 1 curie is the amount that can produce .... disintegrations per second.

2. The last member of 4n + 1 series is an isotope of ....

3. The 4n series starts from Th-232 and ends at

(A) Pb-208 (B) Bi-209 (C) Pb-206 (D) Pb-207

4. Select the wrong statement

(A) Nuclear isomers contain the same number of protons and neutrons

(B) The decay constant is independent of the amount of the substance taken

(C) One curie = 3.7×10^{10} dis/minute

(D) Actinium series starts with U^{238}

5. The correct starting material and product of different disintegration series are :

(A) $^{232}Th, ^{208}Pb$ (B) $^{235}U, ^{206}Pb$ (C) $^{238}U, ^{207}Pb$ (D) $^{237}Np, ^{209}Bi$

6. Which of the following is/are correct

(A) 1 curie = 3.7×10^{10} d/s (B) 1 rutherford = 10^6 d/s

(C) 1 becquerel = 1 d/s (D) 1 fermi = 10^3 d/s

7. To which radioactive families do the following nucleides belong ?

$^{222}Rn, ^{228}Ra, ^{207}Pb, ^{209}Bi, ^{233}Pa$.

8. Balance the following nuclear reactions.

(i) $^{9}_{4}Be + ^{4}_{2}He \longrightarrow .... + ^{1}_{0}n$ (ii) $^{6}_{3}Li + ... \longrightarrow ^{7}_{3}Li + ^{1}_{1}H$

(iii) $^{9}_{4}Be + ... \longrightarrow ^{8}_{4}Be + ^{1}_{0}n$

(iv) $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ... + 3\ ^{1}_{0}n$

(v) $^{31}_{15}P + ^{1}_{1}H \longrightarrow ^{31}_{16}S + ...$ (vi) $^{75}_{33}As + ^{2}_{1}H \longrightarrow .... + ^{1}_{1}H$

(vii) $^{63}_{29}Cu + ^{4}_{2}He \longrightarrow ^{37}_{17}Cl + 14\ ^{1}_{1}H + ...$

(viii) $^{2}_{1}H + ^{3}_{1}H \longrightarrow .... + ^{1}_{0}n$

9. When a radioactive element emits an electron the daughter element formed will have:
(A) Mass number one unit less (B) Atomic number one unit less
(C) Mass number one unit more (D) Atomic number one unit more

10. Decrease in atomic no. is observed during:
(A) Alpha emission (B) Electron capture (C) Positron emission (D) all

Daily Practice Problems - 16

1. If N_0 is the initial number of nuclei, number of nuclei remaining undecayed at the end of nth half life is:
(A) $2^{-n} N_0$ (B) $2^{n} N_0$ (C) $n^{-2} N_0$ (D) $n^{2} N_0$

2. Which one of the following nuclear reaction is correct:
(A) $_6C^{13} + {_1H^1} \longrightarrow {_7N^{13}} + \beta^- + \gamma$ (B) $_{11}Na^{23} + {_1H^1} \longrightarrow {_{10}Ne^{20}} + {_2He^4}$
(C) $_{13}Al^{23} + {_0n^1} \longrightarrow {_{11}Na^{23}} + {_{-1}e^0}$ (D) $_{12}Mg^{24} + {_2He^4} \longrightarrow {_{13}Al^{27}} + {_0n^1}$

3. The activity of a radionuclide (X^{100}) is 6.023 curie. If the disintegration constant is 3.7×10^4 sec^{-1}, the mass of radionuclide is:
(A) 10^{-14} g (B) 10^{-6} g (C) 10^{-15} g (D) 10^{-3} g

4. The half life of I^{131} is 8 day. Given a sample of I^{131} at t = 0, we can assert that:
(A) No nucleus will decay at t = 4 day
(B) No nucleus will decay before t = 8 day
(C) All nucleus will decay before t = 16 day
(D) A given nucleus may decay at any time after t = 0

5. If 5g of a radioactive substance has $t_{1/2}$ = 14 hr., 2 g of the same substance will have a $t_{1/2}$ equal to:
(A) 56 hr (B) 3.5 hr (C) 14 hr (D) 28 hr

6. A certain radioactive isotope has a half life of 50 day. Fraction of the material left behind after 100 day will be:
(A) 50% (B) 75% (C) 12.5% (D) 25%

7. The half life period of a radioactive elements is 140 day. After 560 day, 1 g of the element will reduce to:
(A) 0.5 g (B) 0.25 g (C) 1/8 g (D) 1/16 g

8. 75% of a first order reaction was completed in 32 minute. When will be 50% of the reaction complete.
(A) 24 minute (B) 16 minute (C) 8 minute (D) 4 minute

9. The half life of a radioactive isotope is 1.5 hour. The mass of it that decayed after 6 hour is (the initial mass of the isotope is 32 g):
(A) 32 g (B) 16 g (C) 30 g (D) 2 g

10. Half life period of a substance is 1600 minute. What fraction of the substance will remain after 6400 minute:
(A) 1/16 (B) 1/4 (C) 1/8 (D) 1/2

Daily Practice Problems - 17

1. The counting rate observed from a radioactive source at t = 0 seconds was 1600 counts/sec and at t = 8 sec it was 100 counts/sec. The counting rate observed as count per sec at t = 6 sec will be:
(A) 400 (B) 300 (C) 200 (D) 150

2. A freshly prepared radioactive source of half life 2 hr. emits radiations of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is:
(A) 6 hr (B) 12 hr (C) 24 hr (D) 128 hr

3. One mole of A present in a closed vessel undergoes decay as ${}_{z}A^{m} \longrightarrow {}_{z-4}B^{m-8} + 2\ {}_{2}He^{4}$. The volume of He collected at NTP after 20 days is ($t_{1/2}$ = 10 day):
(A) 11.2 litre (B) 22.4 litre (C) 33.6 litre (D) 67.2 litre

4. The rate of radioactive disintegration........... with time:
(A) Increases (B) Decreases (C) Is constant (D) May increase

5. Successive emission of an α-particle and two β-particles by an atom of an element results in the formation of its:
(A) Isodiapher (B) Isomorph (C) Isotope (D) Isotherm

6. The half life of a radioactive isotope is 2.5 hour. The mass of it that remains undecayed after 10 hour is (If the initial mass of the isotope was 16 g):
(A) 32 g (B) 16 g (C) 4 g (D) 1 g

7. The number of α-and β-particles emitted during the transformation of ${}^{232}_{90}Th$ to ${}^{208}_{82}Pb$ is respectively:
(A) 2, 2 (B) 4, 2 (C) 6, 4 (D) 8, 6

8. If 75% quantity of a radioactive isotope disintegrates in 2 hour, its half life would be:
(A) 1 hour (B) 45 minute (C) 30 minute (D)15 minute

9. The half life period of a radioactive nuclide is 3 hour. In 9 hour its activity will be reduced by
(A) 1/9 (B) 7/8 (C) 1/27 (D) 1/6

10. A radioactive isotope having a half life of 3 day was received after 12 day. It was found that there were 3 g of the isotope in the container. The initial weight of the isotope when packed was:
(A) 12 g (B) 24 g (C) 36 g (D) 48 g

Daily Practice Problems - 18

1. A sample of rock from moon contains equal number of atoms of uranium and lead ($t_{1/2}$ for U = 4.5×10^{9} year). The age of the rock would be:
(A) 4.5×10^{9} year (B) 9×10^{9} year (C) 13.5×10^{9} year (D) 2.25×10^{9} year

2. Two radioactive elements X and Y have half lives of 50 and 100 minute respectively. Initial sample of both the elements have same no. of atoms. The ratio of the remaining number of atoms of X and Y after 200 minute is:
(A) 2 (B) 1/2 (C) 4 (D) 1/4

3. The time in which activity of an element is reduced to 90% of its original value is, (given $t_{1/2}$ = 1.4×10^{10} yr):
(A) 1.128×10^{9} yr (B) 2.128×10^{9} yr (C) 3.128×10^{9} yr (D) None

4. The number of α- and β- particles emitted in the nuclear reaction ${}^{228}_{90}Th \longrightarrow {}^{212}_{83}Bi$ are:
(A) 4α and 1β (B) 3α and 7β (C) 8α and 1β (D) 4α and 7β

5. Two radioisotopes P and Q of atomic weight 10 and 20 respectively are mixed in equal amount by weight. After 20 day, their weight ratio is found to be 1 : 4. Isotope P has a half life of 10 day. The half life of isotope Q is:
(A) Zero (B) 5 day (C) 20 day (D) infinite

6. The radioactivity due to the C^{14} isotope ($t_{1/2}$ = 6000 year) of a sample of wood from an ancient tomb was found to be nearly half that of fresh wood; the tomb is, therefore, about:
(A) 3000 year old (B) 6000 year old (C) 9000 year old (D) 12000 year old

7. The activity of a radioactive sample drops to 1/64th of its original value in 2hr. The decay constant for the sample is:
(A) 5.775×10^{-4} sec.$^{-1}$ (B) 5.775×10^{4} sec.$^{-1}$ (C) 5.775×10^{2} sec.$^{-1}$ (D) None

8. A radioactive element has a half life of 4.5×10^9 year. If 80 g of this was taken, the time taken for it to decay to 40 g will be:
(A) 2.25×10^9 year (B) 4.50×10^9 year (C) 6.75×10^9 year (D) 8.75×10^9 year

9. A certain nuclide has a half life period of 30 minute. If a sample containing 6000 atoms is allowed to decay for 90 minute, how many atoms will remain:
(A) 200 atoms (B) 450 atoms (C) 750 atoms (D) 150 atoms

10. A substance is kept for 2 hour and three fourth disintegrates during this period. The half life of the substance is:
(A) 2 hour (B) 1 hour (C) 30 minute (D) 4 hour

Daily Practice Problems - 19

1. The binding energy of an element is 64 MeV. If BE/nucleon is 6.4, the number of nucleons are:
(A) 10 (B) 64 (C) 16 (D) 6

2. The half life of ${}_{92}U^{238}$ against α-decay is 4.5×10^9 year. The time taken in year for the decay of 15/16 part of this isotope is:
(A) 9.0×10^9 (B) 1.8×10^{10} (C) 4.5×10^9 (D) 2.7×10^{10}

3. A radioactive isotope has a half life of 10 day. If today there are 125g of it left, what was its original weight 40 day earlier:
(A) 600 g (B) 1000 g (C) 1250 g (D) 2000 g

4. Radium has atomic weight 226 and half life of 1600 year. The number of disintegration produced per sec. from 1 g are:
(A) 4.8×10^{10} (B) 3.7×10^{10} (C) 9.2×10^6 (D) 3.7×10^8

5. If the amount of radioactive substance is increased three times, the number of atoms disintegrated per unit time would:
(A) Be double (B) Be triple (C) Remain one third (D) Not change

6. The half life of a radioactive element is 35 year. If there are 4×10^6 nuclei at the start, then after how many year they will be left 0.5×10^6.
(A) 35 (B) 70 (C) 105 (D) 140

7. Wooden article and freshly cut tree show activity 7.6 and 15.2 min^{-1} g^{-1} of carbon ($t_{1/2}$ = 5760 year) respectively. The age of the article is:

(A) 5760 year (B) $5760 \times \frac{15.2}{7.6}$ year (C) $5760 \times \frac{7.6}{15.2}$ year (D) $5760 \times (15.2 - 7.6)$ year

8. For a radioactive substance with half life period 500 year, the time for complete decay of 100 milligram of it would be:

(A) 1000 year (B) 100 × 500 year (C) 500 year (D) Infinite time

9. The decay constant of a radioactive element is defined as the reciprocal of the time interval after which the number of atoms of the radioactive element falls to nearly:

(A) 50% of its original number (B) 36.8% of its original number
(C) 63.2% of its original number (D) 75% of its original number

10. The radioactive decay rate of a radioactive element is found to be 10^3 dps at a certain time. If the half life of element is 1sec, the decay rate after 1 sec. is..... and after 3 sec. is......

(A) 500, 125 (B) 125, 500 (C) 10^3, 10^3 (D) 100, 10

ANSWER SHEET

Daily Practice Problems - 13

1. 144 **2.** 214, 83 **3.** (i) AD (ii) BCD
4. (a) i-β ii-α, (b) i-α, ii-α **5.** 5
6. B **7.** C **8.** D **9.** A,D
10. C **11.** B

Daily Practice Problems - 14

1. (i) $5\alpha,5\beta$ (ii) $3\alpha,6\beta$ (iii) $11\alpha,14\beta$ (iv) $\alpha,2\beta$ (v) 2α
(vi) $3\alpha,\beta$ (vii) $4\alpha,2\beta$ (viii) $7\alpha,4\beta$ (ix) $7\alpha,14\beta$ (x) $5\alpha,4\beta$
2. C **3.** B **4.** 82 **5.** 8
6. $^{234}_{90}U_{X_1}$, $^{234}_{91}U_{X_2}$ Both U_{x_1} **7.** C **8.** B
9. B **10.** C

Daily Practice Problems - 15

1. 3.7×10^{10} **2.** Bi **3.** A **4.** C, D **5.** A, D
6. A, B, C **7.** 4n+2, 4n, 4n+3, 4n+1, 4n+1
8. (i) $^{12}_{6}C$ (ii) $^{1}_{1}H$ (iii) γ (iv) $^{92}_{36}Kr$ (v) $^{1}_{0}n$
(vi) $^{76}_{33}As$ (vii) $16\,^{1}_{0}n$ (viii) $^{4}_{2}He$ **9.** D **10.** D

Daily Practice Problems - 16

1. A **2.** B **3.** C **4.** D **5.** C **6.** D
7. D **8.** B **9.** C **10.** A

Daily Practice Problems - 17

1. C **2.** B **3.** C **4.** B **5.** C **6.** D
7. C **8.** A **9.** B **10.** D

Daily Practice Problems - 18

1. A **2.** D **3.** D **4.** A **5.** D **6.** B
7. A **8.** B **9.** C **10.** B

Daily Practice Problems - 19

1. A **2.** B **3.** D **4.** B **5.** B **6.** C
7. A **8.** D **9.** B **10.** A