NUCLEAR PHYSICS

It exists at the centre of an atom, containing entire positive charge and almost whole of mass. The electron resolve around the neuleus to form an atom. The nucleus consists of protons (+ve charge) and neutrons. A proton has positive charge equal in magnitude to that of an electron ($+\ 1.6 \times 10^{-19}$ C) and a mass equal to 1840 C) and a mass equal to 1840 times that of an electron. A neutron has no charge and mass is approximately equal to that of proton.

PROPERTIES OF A NUCLEUS

(1) Nuclear Mass :

As we know that every nucleus contains protons and neutrons and so every nucleus has a define mass. However, since the mass of electron is negligible so atomic mass is roughly equal to nuclear mass.

Atomic masses are measured in atomic mass unit (a.m.u.) defiined as

⇒ $1\text{u} = 931.478\ \text{MeV/c}^2$

and its energy equivalent is 931.48 MeV

Thye number of protons is a nucleus of an atom is called as the atomic number (Z) of that atom. The number of protons plus neutrons (called as Nucleus) in a nucleus of an atom is called as mass number (A) of that atom.

A partiicular set of nucleons forming an atom is called as nuclide. It is represented as $_Z X^A$. The nuclides having same number of protons (Z), but different number of nucleons (A) are called as isotopes. The nuclide having same number of nucleons (A), but different number of protons (Z) are called as isobars. The nuclide having same number of neutrons (A-Z) are called as isotones.

(2) Nuclear Charge :

Since nucleus contain +vely charged protons (charge = 1.67×10^{-19} C) and neutrons (neutral) so every nucleus has a net +ve charge.

(3) Nuclear Radius :

A rough estiimate of nuclear size suggests us that the radius of the nucleus of an atom having mass number 'A' is given by

$$R = R_0 A^{1/3}$$

Where R_0 is a constant found to be equal to

$$R_0 = 1.4 \times 10^{-15}\ \text{m} = 1.4\ \text{fm}.$$

(4) Nuclear Density :

In spite of the fact that nuclear radius depends on mass number of the atom but nuclear density is independent of mass number because if neutrons are supposed to be of almost the same mass as that of protons then the total mass of a nucleus is proportional to A. If each nucleon are supposed to have a mass m then nuclear density is given by

$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} = \frac{3m}{4\pi R_0^3} \qquad \text{(Which is independent of A)}$$

(5) Nuclear spin and magnetic moment

Like orbial electrons in an atom, nucleons inside nucleus have well defined quantum states. Correspondingly they have angular momentum and hence a magnetic moment. Like electrons nucleons also have intrinsic angular momentum and 'magnetic' moment corresponding to their spin.

RADIOACTIVITY

INTRODUCTION

Among about 2500 known nuclides, fewer than 300 are stable. The others are unstable structures that decay to form other nuclides by spontaneously emitting particles and electromagnetic radiation, a process called radioactivity. The time scale of these decay processes ranges from a small fraction of a microsecond to billions of years. The substances which emit these radiations are called as radioactive substances. It was discovered by Henry Becquerel for atoms of Uranium. Later iit was discovered that many naturally occurring compounds of heavy elements like radium, thorium etc. also emit radiations.

At present, it is known that all the naturally occurring elements having atomic number greater than 82 are radioactive. For example some of them are; radium, polonium, thorium, actinium, uranium, radon etc. Later on Rutherford found that emission of radiation always accompained by transformation of one element (transmutation) into another. In actual radioactivity is the result of disintegration of an unable nucleus. Rutherford studied the nature of thesed radiations and found that these mainly consist of α,β,γ particles (rays).

α-Particles : $({}_2He^4)$

These carry a charge of +2e and mass equal to $4m_p$. These are nuclei of helium atoms. The energies of α-particles very form 5 Me V to 9 Me V ; theiir velocities vary from 0.01 – 0..1 times of c (velocity of light). They can be deflected by electric and magnetic field and have lower penetrating power but high ionising power.

β-Particles : $({}_1e^0)$

These are fast moving electrons having charge equal to e and mass $m_e = 9.1 \times 10^{-31}$ kg. Their velocities very from 1% to 99% of the velocity of light (c). They can also be deflected by electric and magnetic fields. They have low ionising power but high penetrating power.

γ-particles : $({}_0\gamma^0)$

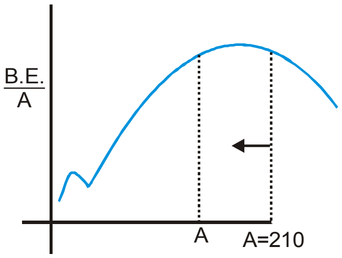
These are electro-magnetic waves of nuclear origin and of very short wavelength. They have no masss. They have maximum penetrating power and minimum ionising power. The energy released in a nuclear reaction is mainly emitted in from these γ-radiations.

RADIOACTIVE DECAYS

Generally, there are three types of radioactive decays **(i)** α decay **(ii)** β^- and β^+ decay **(iii)** γ decay

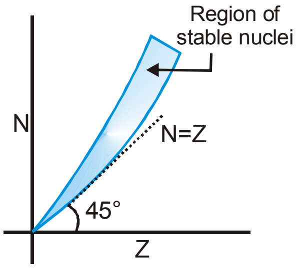
(i) α decay

In α decay, the unstable nucleus emits an α particle. By emitting α particle, the nucleus decreases it's mass energy number and move towards stability. Nucleus having A>210 shows α decay.By releasing α particle, it can attain higher stability and Q value is positive.



(ii) β decay

In beta decay (N/Z) ratio of nucleus is changed. This decay is shown by unstable nuclei. In beta decay, either a neutron is converted into proton or proton is converted into neutron. For better understanding we discuss N/Z graph. There are two type of unstable nuclides



❖ A type

For A type nuclides $(N/Z)_A > (N/Z)$ stable

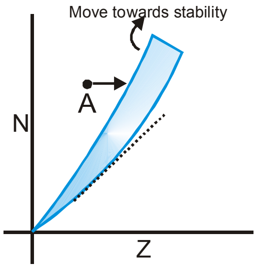
To achieve stability, it increases Z by conversion of neutron into proton

$$_0n^1 \rightarrow \, _1p^1 + e^{-1} + \overline{\nu}, \; _ZX^A \rightarrow \, _{Z+1}Y^A + \underset{(\beta \text{ particle})}{e^{-1}} + \overline{\nu}$$

This decay is called β^{-1} decay.

Kinetic energy available for e^{-1} and $\overline{\nu}$ is, $Q = K_\beta + K_{\overline{\nu}}$

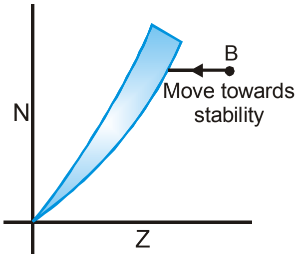
K.E. of β satisfies the condition $0 < K_\beta < Q$



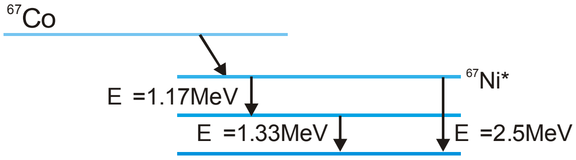
❖ B type

For B type nuclides $(N/Z)_B < (N/Z)$ stable

To achieve stability it decreases Z by the conversion of a proton into neutron. That is, $p \rightarrow n + \underset{(\text{positron})}{e^+} + \underset{(\text{neutrino})}{\nu}, \; _ZX^A \rightarrow _{Z-1}Y^A + \underset{(\beta^+ \text{particle})}{e^+} + \nu$



(iii) γ decay : when an α or β decay takes place, the daughter nucleus is usually in higher energy state, such a nucleus comes to ground state by emitting a photon or photons.



Order of energy of γ photon is 100 KeV e.g. $^{67}_{27}Co \rightarrow \underset{(\text{higher energy state})}{^{67}_{28}Ni^*} + \beta^- + \overline{\nu}, \; ^{67}_{28}Ni^* \rightarrow ^{67}_{28}Ni + \gamma$ photon

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1. NUCLEAR COLLISIONS

We can represent a nuclear collision or reaction by the following notation, which means X (a, b) Y

$$\underset{\text{(bombarding particle)}}{a} \quad + \quad \underset{\text{(at rest)}}{X} \quad \rightarrow \quad Y + b$$

We can apply :

(a) Conservation of momentum **(b)** Conservation of charge **(c)** Conservation of mass- energy

For any nuclear reaction $\underset{K_1}{a} + \underset{K_2}{X} \rightarrow \underset{K_3\ K_4}{Y + b}$

By mass energy conservation

(a) $K_1 + K_2 + (m_\alpha + m_x)c^2 = K_3 + K_4 + (m_Y + m_b)c^2$

(b) Energy released in any nuclear reaction or collision is called Q value of the reaction

(c) $Q = (K_3 + K_4) - (K_1 + K_2) = \sum K_p - \sum K_R = \left(\sum m_R - \sum m_p\right)c^2$

(d) If Q is positive, energy is released and products are more stable in comparison to reactants.

(e) If Q is negative, energy is absorbed and products are less stable in comparison to reactants.

$$Q = \sum (\text{B.E})_{\text{products}} - \sum (\text{B.E})_{\text{reactants}}$$

2. Nuclear Fission

In 1938 by Hahn and Strassmann. By attack of a particle splitting of a heavy nucleus ($A > 230$) into two or more lighter nuclei. In this process certain mass disappears which is obtained in the form of energy (enormous amount)

$$A + p \rightarrow \text{excited nucleus} \rightarrow B + C + Q$$

3. Nuclear Fusion

It is the phenomenon of fusing two or more lighter nuclei to form a single heavy nucleus.

$$A + B \rightarrow C + Q\ (\text{Energy})$$

The product (C) is more stable then reactants (A and B) and $m_c < (m_a + m_b)$ and mass defect

$$\Delta m = \left[(m_a + m_b) - m_c\right] \text{ amu}$$

Energy released is $E = \Delta m\ 931$ MeV

The total binding energy and binding energy per nucleon C both are more than of A and B.

$$\Delta E = E_c - (E_a + E_b)$$

4. Radioactivity

Radioactive Decays : Generally, there are three types of radioactive decays

(a) α decay **(b)** β^- and β^+ dacay **(c)** γ decay

(a) **α decay :** By emitting α particle, the nucleus decreases it's mass number and move towards stability. Nucleus having $A > 210$ shows a decay.

(b) **β decay :** In beta decay, either a neutron is converted into proton or proton is converted into neutron.

(c) **γ decay :** When an α or β decay takes place, the daughter nucleus is usually in higher energy state, such a nucleus comes to ground state by emitting a photon or photons.

Order of energy of γ photon is 100 keV

SOLVED EXAMPLES

Ex.1 Calculate the electric potential energy due to the electric repulsion between two nuclei of ^{12}C when they 'touch' each other at the surface.

Sol. The radius of a ^{12}C nucleus is

$$R = R_0A^{1/3}$$

$$= (1.1\ \text{fm})\,(12)^{1/3} = 2.52\ \text{fm}.$$

The separation between the centres of the nuclei is 2R = 5.04 fm. The potential energy of the pair is

$$U = \frac{q_1q_2}{4\pi\varepsilon_0 r}$$

$$= (9 \times 10^9\ \text{N m}^2\,\text{C}^{-2})\ \frac{(6\times1.6\times10^{-19}\,\text{C})^2}{5.04\times10^{-15}\ \text{m}}$$

$$= 1.64 \times 10^{-12}\ \text{J} = 10.2\ \text{MeV}.$$

Ex.2 Find the binding energy of $^{56}_{26}Fe$. Atomic mass of ^{56}Fe is 55.9349 u and that of ^{1}H is 1.00783 u. Mass of neutron = 1.00867 u.

Sol. The number of protons in $^{56}_{26}Fe$ = 26 and the number of neutrons = 56 – 26 = 30. The binding energy of $^{56}_{26}Fe$ is

$$= [26 \times 1.00783\ \text{u} + 30 \times 1.00867\ \text{u} - 55.9349\ \text{u}]c^2$$

$$= (0.52878\ \text{u})\, c^2$$

$$= (0.52878\ \text{u})\,(931\ \text{MeV u}^{-1}) = 492\ \text{MeV}.$$

Ex.3 Find the kinetic energy of the α-particle emitted in the decay $^{238}Pu \rightarrow {}^{234}U + \alpha$. The atomic masses needed are as follows :

^{238}Pu	^{234}U	^{4}He
238.04955 u	234.04095 u	4.002603 u

Neglect any recoil of the residual nucleus.

Sol. Using energy conservation,

$$m(^{238}Pu)\,c^2 = m(^{234}U)c^2 + m(^{4}He)c^2 + K$$

or,

$$K = [m(^{238}Pu) - m(^{234}U) - m(^{4}He)]c^2$$

$$= [238.04955\ \text{u} - 234.04095\ \text{u} - 4.002603\ \text{u}]\,(931\ \text{MeV u}^{-1})$$

$$= 5.58\ \text{MeV}.$$

Ex.4 Calculate the Q-value in the following decays :

(a) $^{19}O \rightarrow {}^{19}F + e + \overline{v}$

(b) $^{25}Al \rightarrow {}^{25}Mg + e^{+} + v.$

The atomic masses needed are as follows :

^{19}O	^{19}F	^{25}Al	^{25}Mg
19.003576 u	18.998403 u	24.990432 u	24.985839 u

Exercise # 1

[Single Correct Choice Type Questions]

1. The stable nucleus that has a radius 1/3 that of Os^{189} is -

(A) $_3Li^7$ **(B)** $_2He^4$ **(C)** $_5B^{10}$ **(D)** $_6C^{12}$

2. The mass number of a nucleus is

(A) always less than its atomic number

(B) always more than its atomic number

(C) equal to its atomic number

(D) sometimes more than and sometimes equal to its atomic number

3. As the mass number A increases, the binding energy per nucleon in a nucleus

(A) increases **(B)** decreases

(C) remains the same **(D)** varies in a way that depends on the actual value of A.

4. The energy of the reaction $Li^7 + p \longrightarrow 2\ He^4$ is (the binding energy per nucleon in Li^7 and He^4 nuclei are 5.60 and 7.06 MeV respectively.)

(A) 17.3 MeV **(B)** 1.73 MeV

(C) 1.46 MeV **(D)** depends on binding energy of proton

5. Which of the following is a wrong description of binding energy of a nucleus ?

(A) It is the energy required to break a nucleus into its constituent nucleons.

(B) It is the energy released when free nucleons combine to from a nucleus

(C) It is the sum of the rest mass energies of its nucleons minus the rest mass energy of the nucleus

(D) It is the sum of the kinetic energy of all the nucleons in the nucleus

6. A free neutron decays into a proton, an electron and :

(A) A neutrino **(B)** An antineutrino

(C) An α-particle **(D)** A β-particle

7. An α-particle is bombarded on ^{14}N. As a result, a ^{17}O nucleus is formed and a particle is emitted. This particle is a

(A) neutron **(B)** proton **(C)** electron **(D)** positron

8. The atomic weight of boron is 10.81 g/mole and it has two isotopes $^{10}_{5}B$ and $^{11}_{5}B$. The ratio (by number) of $^{10}_{5}B : ^{11}_{5}B$ in nature would be :

(A) 19 : 81 **(B)** 10 : 11 **(C)** 15 : 16 **(D)** 81 : 19

9. Nuclei X decay into nuclei Y by emitting α particles. Energies of α particle are found to be only 1 MeV & 1.4 MeV. Disregarding the recoil of nuclei Y. The energy of γ photon emitted will be

(A) 0.8 MeV **(B)** 1.4 MeV **(C)** 1 MeV **(D)** 0.4 MeV

10. Two isotopes P and Q of atomic weight 10 and 20, respectively are mixed in equal amount by weight. After 20 days their weight ratio is found to be 1 : 4. Isotope P has a half-life of 10 days. The half-life of isotope Q is

(A) zero **(B)** 5 days **(C)** 20 days **(D)** inifinite

11. In one average-life

(A) half the active nuclei decay **(B)** less than half the active nuclei decay

(C) more than half the active nuclei decay **(D)** all the nuclei decay

Exercise # 2 Part # I [Multiple Correct Choice Type Questions]

1. The heavier stable nuclei tend to have larger N/Z ratio because -

(A) a neutron is heavier than a proton

(B) a neutron is an unstable particle

(C) a neutron does not exert electric repulsion

(D) Coulomb forces have longer range compared to nuclear forces

2. If a nucleus $^{A}_{Z}x$ emits one α particle and one β (negative β) particle in succession, then the daughter nucleus will have which of the following configurations?

(A) $A-4$ nucleons **(B)** 4 nucleons

(C) $A-Z-3$ neutrons **(D)** $Z-2$ protons

3. A U^{238} sample of mass 1.0 g emits alpha particles at the rate 1.24×10^4 particles per second. $(N_A = 6.023 \times 10^{23})$

(A) The half life of this nuclide is 4.5×10^9 years

(B) The half life of this nuclide is 9×10^9 years

(C) The activity of the prepared sample is 2.48×10^4 particles/sec

(D) The activity of the prepared sample is 1.24×10^4 particles/sec.

4. The decay constant of a radio active substance is 0.173 $(\text{years})^{-1}$. Therefore:

(A) Nearly 63% of the radioactive substance will decay in (1/0.173) year.

(B) half life of the radio active substance is (1/0.173) year.

(C) one -forth of the radioactive substance will be left after nearly 8 years.

(D) half of the substance will decay in one average life time.

Use approximation $\ell n2 = 0.692$

5. A nitrogen nucleus $_7N^{14}$ absorbs a neutron and can transform into lithium nucleus $_3Li^7$ under suitable conditions, after emitting

(A) 4 protons and 4 neutrons

(B) 5 protons and 1 negative beta particle

(C) 2 alpha particles and 2 gamma particles

(D) 1 alpha particle, 4 protons and 2 negative beta particles.

6. Let m_p be the mass of a proton, m_n the mass of a neutron, M_1 the mass of a $^{20}_{10}Ne$ nucleus & M_2 the mass of a $^{40}_{20}Ca$ nucleus. Then :

(A) $M_2 = 2\,M_1$ **(B)** $M_2 > 2\,M_1$ **(C)** $M_2 < 2\,M_1$ **(D)** $M_1 < 10\,(m_n + m_p)$

Exercise # 3

Part # I [Matrix Match Type Questions]

1. In column-I, consider each process just before and just after it occurs. Initial system is isolated from all other bodies. Consider all product particles (even those having rest mass zero) in the system. Match the system in column-I with the result they produce in column-II.

Column-I	**Column-II**
(A) Spontaneous radioactive decay of an uranium nucleus initially at rest as given by reaction ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He} + \ldots$	**(P)** Number of protons is increased
(B) Fusion reaction of two hydrogen nuclei as given by reaction ${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{1}\text{H} + \ldots..$	**(Q)** Momentum is conserved
(C) Fission of U^{235} nucleus initiated by a thermal neutron as given by reaction ${}^{1}_{0}\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{144}_{56}\text{Ba} + {}^{89}_{36}\text{Kr} + 3{}^{1}_{0}\text{n} + \ldots$	**(R)** Mass is converted to energy or vice versa
(D) β^- decay (negative beta decay)	**(S)** Charge is conserved

2. Match the column-I of properties with column-II of reactions

Column-I	**Column-II**
(A) Mass of product formed is less than the original mass of the system in	**(P)** α-decay
(B) Binding energy per nucleon increase in	**(Q)** β-decay
(C) Mass number is conserved in	**(R)** Nuclear fission
(D) Charge number is conserved in	**(S)** Nuclear fusion

3. Four physical quantities are listed in column I. Their values are listed in Column II in a random order.

	Column I		**Column II**
(A)	Thermal energy of air molecules at room temperature	**(E)**	0.04 eV
(B)	Binding energy of heavy nuclei per nucleon	**(F)**	2 eV
(C)	X–ray photon energy	**(G)**	1 KeV
(D)	Photon energy of visible light	**(H)**	7 MeV

The correct matching of columns I & II is given by :

(A) A – E, B – H, C – G, D – F

(B) A – E, B – G, C – F, D – H

(C) A – F, B – E, C – G, D – H

(D) A – F, B – H, C – E, D – G

Part # II [Comprehension Type Questions]

Comprehension # 1

Consider the following nuclear decay : (initially ${}^{236}U_{92}$ is at rest)

$$ {}^{236}_{92}\text{U} \longrightarrow {}^{232}_{90}\text{Th} + X $$

1. Regarding this nuclear decay select the correct statement :

(A) The nucleus X may be at rest.

(B) The ${}^{232}_{90}\text{Th}$ nucleus may be in excited state.

(C) The X may have kinetic energy but ${}^{232}_{90}\text{Th}$ will be at rest

(D) The Q value is Δmc^2 where Δm is mass difference of (${}^{236}_{92}\text{U}$ and ${}^{232}_{90}\text{Th}$) and c is speed of light.

Exercise # 4

[Subjective Type Questions]

If required, you can use the following data:

Mass of proton m_p = 1.007276 u, Mass of $_1H^1$ atom = 1.007825 u, Mass of neutron m_n = 1.008665 u, Mass of electron = 0.0005486 u = 511 KeV/c^2, 1 u = 931 MeV/c^2. $N_A = 6.023 \times 10^{23}$

Atomic mass of : H^2 = 2.01410 u, Be^8 = 8.00531u, B^{11} = 11.00930u, Li^7 = 7.01601u, He^4 = 4.002603u.

1. Find the binding energy of the nucleus of lithium isotope $_3Li^7$ and hence find the binding energy per nucleon in it.

2. A neutron star has a density equal to that of the nuclear matter($\approx 3 \times 10^{17}$ kg/m^3). Assuming the star to be spherical, find the radius of a neutron star whose mass is **(i)** 4.0×10^{30} kg (twice the mass of the sun) **(ii)** 6×10^{24} Kg (around mass of the earth).

3. Find the energy required for separation of a $_{10}Ne^{20}$ nucleus into two α – particles and a $_6C^{12}$ nucleus if it is known that the binding energies per nucleon in $_{10}Ne^{20}$, $_2He^4$ and $_6C^{12}$ nuclei are equal to 8.03, 7.07 and 7.68 MeV respectively.

4. In the decay $^{64}Cu \rightarrow {}^{64}Ni + e^+ + \nu$, the maximum kinetic energy carried by the positron is found to be 0.680 MeV **(a)** Find the energy of the neutrino which was emitted together with a positron of energy 0.180 MeV **(b)** What is the momentum of this neutrino in kg–m /s ? Use the formula applicable to photon.

5. The kinetic energy of an α – particle which flies out of the nucleus of a Ra^{226} atom in radioactive disintegration is 4.78 MeV. Find the total energy evolved during the escape of the α – particle.

6. Calculate the specific activities of Na^{24} & U^{235} nuclides whose half lives are 15 hours and 7.1×10^8 years respectively.

7. How many β – particles are emitted during one hour by 1.0 μg of Na^{24} radionuclide whose half–life is 15 hours? [Take $e^{(-0.693/15)} = 0.955$, and avagadro number $= 6 \times 10^{23}$]

8. Beta decay of a free neutron takes place with a half life of 14 minutes. Then find **(a)** decay constant **(b)** energy liberated in the process.

9. Consider the case of bombardment of U^{235} nucleus with a thermal neutron. The fission products are Mo^{95} & La^{139} and two neutrons. Calculate the energy released by one U^{235} nucleus. (Rest masses of the nuclides are U^{235} = 235.0439 u, ^1_0n = 1.0087 u, Mo^{95} = 94.9058 u, La^{139} = 138.9061 u).

10. Consider a point source emitting α-particles and receptor of area 1 cm^2 placed 1 m away from source. Receptor records any α-particle falling on it. If the source contains $N_0 = 3.0 \times 10^{16}$ active nuclei and the receptor records a rate of A = 50000 counts/second, find the decay constant. Assume that the source emits alpha particles uniformly in all directions and the alpha particles fall nearly normally on the window.

11. Energy evolved from the fusion reaction $2\,^2_1H = {}^4_2He + Q$ is to be used for the production of power. Assuming the efficiency of the process to be 30 %. Find the mass of deuterium that will be consumed in a second for an output of 50 MW.

Exercise # 5

Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

1. If N_0 is the original mass of the substance of half-life period $t_{1/2} = 5$ years, then the amount of substance left after 15 years is : **(AIEEE 2002)**

(1) $N_0/8$ **(2)** $N_0/16$ **(3)** $N_0/2$ **(4)** $N_0/4$

2. Which of the following radiations has the least wavelength? **(AIEEE 2003)**

(1) γ-rays **(2)** β-rays **(3)** α-rays **(4)** X-rays

3. When U^{238} nucleus originally at rest, decays by emitting an alpha particle having a speed u, the recoil speed of the residual nucleus is : **(AIEEE 2003)**

(1) $\frac{4u}{238}$ **(2)** $-\frac{4u}{234}$ **(3)** $\frac{4u}{234}$ **(4)** $-\frac{4u}{238}$

4. A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute. After 5 minutes, the rate is 1250 disintegrations per minute. Then, the decay constant (per minute) is : **(AIEEE 2003)**

(1) 0.4 ln 2 **(2)** 0.2 ln 2 **(3)** 0.1 ln 2 **(4)** 0.8 ln 2

5. A nucleus with Z = 92 emits the following in a sequence : $\alpha, \alpha, \beta^-, \beta^-, \alpha, \alpha, \alpha, \alpha; \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$. The Z of the resulting nucleus is : **AIEEE 2003)**

(1) 76 **(2)** 78 **(3)** 82 **(4)** 74

6. Which of the following cannot be emitted by radioactive substances during their decay? **(AIEEE 2003)**

(1) Protons **(2)** Neutrinos **(3)** Helium nuclei **(4)** Electrons

7. In the nuclear fusion reaction, **(AIEEE 2003)**

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + n$$

given that the repulsive potential energy between the two nuclei is $\sim 7.7 \times 10^{-14}$ J, the temperature at which the gases must be heated to initiate the reaction is nearly (Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K): **(AIEEE 2003)**

(1) 10^7 K **(2)** 10^5 K **(3)** 10^3 K **(4)** 10^9 K

8. A nucleus disintegrates into two nuclear parts which have their velocities in the ratio 2 : 1. The ratio of their nuclear sizes will be : **(AIEEE 2004)**

(1) $2^{1/3} : 1$ **(2)** $1 : 3^{1/2}$ **(3)** $3^{1/2} : 1$ **(4)** $1 : 2^{1/3}$

9. The binding energy per nucleon of deuteron $\left(^{2}_{1}H\right)$ and helium nucleus $\left(^{4}_{2}He\right)$ is 1.1 MeV and 7 MeV respectively. If two deuteron nuclei react to form a single helium nucleus, then the energy released is : **(AIEEE 2004)**

(1) 13.9 MeV **(2)** 26.9 MeV **(3)** 23.6 MeV **(4)** 19.2 MeV

10. An α-particle of energy 5 MeV is scattered through 180º by a fixed uranium nucleus. The distance of the closest approach is of the order of : **(AIEEE 2004)**

(1) 1 Å **(2)** 10^{-10} cm **(3)** 10^{-12} cm **(4)** 10^{-15} cm