Nuclear & Particle Physics

JEST-2013

Q1. ^{238}U decays with a half life of 4.51×10^{9} years, the decay series eventually ending at ^{206}Pb, which is stable. A rock sample analysis shows that the ratio of the numbers of atoms of ^{206}Pb to ^{238}U is 0.0058. Assuming that all the ^{206}Pb has been produced by the decay of ^{238}U and that all other half-lives in the chain are negligible, the age of the rock sample is

(a) 38×10^{6} years (b) 48×10^{6} years (c) 38×10^{7} years (d) 48×10^{7} years

Ans.: (a)

Solution: $t=\frac{1}{\lambda_u}\ln\left(\frac{N_{pb}+N_u}{N_u}\right)$

Since, $\frac{1}{\lambda_\mu}=\frac{t_{1/2}}{0.693}=\frac{4.51\times10^{9}}{0.693}=6.507\times10^{9}$

Hence, $t=6.507\times10^{9}\ln(0.0058+1)=0.005783\times6.507\times10^{9}=37\times10^{6}$ year

Q2. The binding energy of the k-shell electron in a Uranium atom $(Z=92,\ A=238)$ will be modified due to (i) screening caused by other electrons and (ii) the finite extent of the nucleus as follows:

(a) increases due to (i), remains unchanged due to (ii)

(b) decreases due to (i), decreases due to (ii)

(c) increases due to (i), increases due to (ii)

(d) decreases due to (i), remains unchanged due to (ii)

Ans.: (b)

JEST-2014

Q3. In the mixture of isotopes normally found on the earth at the present time, $^{238}_{92}U$ has an abundance of 99.3% and $^{235}_{92}U$ has an abundance of 0.7%. The measured lifetimes of these isotopes are 6.52×10^{9} years and 1.02×10^{9} years, respectively. Assuming that they were equally abundant when the earth was formed, the estimated age of the earth, in years is

(a) 6.0×10^{9} (b) 1.0×10^{9} (c) 6.0×10^{8} (d) 1.0×10^{8}

Ans.: (a)

Solution: If the number of ${}^{92}U^{238}$ nuclei originally formed is N, the number present now is

$$N_{238} = Ne^{-t/T} = Ne^{-t/6.52}$$

where t is elapsed time in units of 10^9 year and T is life time of U. Since the number of ${}^{92}U^{235}$ nuclei originally formed is. The number now present is

$$N_{235} = Ne^{-t/1.02}$$

The present abundance of ${}^{92}U^{235}$ is

$$7\times10^{-3} = \frac{N_{235}}{N_{238}+N_{235}} \approx \frac{N_{235}}{N_{238}} = \frac{Ne^{-t/1.02}}{Ne^{-t/6.52}} = e^{0.827t} \approx \frac{1}{7\times10^{-3}} = 143 = t = \frac{4.96}{0.827} = 6.0$$

That is, the elapsed time is $t = 6.0\times10^9$ yr.

JEST-2015

Q4. The stable nucleus that has $\frac{1}{3}$ the radius of ${}^{189}Os$ nucleus is,

(a) ${}^{7}Li$ (b) ${}^{16}O$ (c) ${}^{4}He$ (d) ${}^{14}N$

Ans.: (a)

Solution: $R = \frac{1}{3}R_{Os} \Rightarrow R_0(A)^{1/3} = \frac{1}{3}R_0(189)^{1/3} \Rightarrow A = 7$

Q5. The reaction $e^+ + e^- \rightarrow \gamma$ is forbidden because,

(a) lepton number is not conserved (b) linear momentum is not conserved

(c) angular momentum is not conserved (d) charge is not conserved

Ans.: (b)

Solution: In order to conserve linear momentum two photons are required that move in opposite direction.

JEST-2016

Q6. The half-life of a radioactive nuclear source is 9 days. The fraction of nuclei which are left under caved after 3 days is:

(a) $\frac{7}{8}$ (b) $\frac{1}{3}$ (c) $\frac{5}{6}$ (d) $\frac{1}{2^{1/3}}$

Ans. : (d)

Solution: $N = N_0\left(\frac{1}{2}\right)^n = N_0\left(\frac{1}{2}\right)^{3/9} \Rightarrow \frac{N}{N_0} = \frac{1}{2^{1/3}}$

JEST-2019

Q7. A cyclotron can accelerate deuteron to $16\,MeV$. If the cyclotron is used to accelerate α - particles, what will be their energy? Take the mass of deuteron to be twice the mass of proton and mass of alpha particles to be four times the mass of protons.

(a) $8\,MeV$ (b) $16\,MeV$ (c) $32\,MeV$ (d) $64\,MeV$

Ans. : (c)

Solution: Energy gain in cyclotron is

$$E = \frac{q^2 B^2 R^2}{2m}$$

Let E_d, m_d, E_α and m_α are the energy of mass of deuteron and α - particle

$$\therefore \frac{E_d}{E_\alpha} = \frac{m_\alpha}{m_d}$$

$$\Rightarrow E_\alpha = \frac{m_d}{m_\alpha} E_d = \frac{2m_\alpha}{m_\alpha} \times 16\,MeV$$

$$E_\alpha = 32\,MeV$$