High Level Problems (HLP)

SUBJECTIVE QUESTIONS

1. A radioactive material decays by β-particle emission. During the first 2 seconds of a measurement, n β-particles are emitted and the next 2 seconds 0.75 n β-particles are emitted. Calculate the mean-life of this material in seconds to the nearest whole number. (ℓn 3 = 1.0986 and ℓn 2 = 0.6931). **[JEE 2003 Main) 2/60]**

2. What kinetic energy must an α-particle possess to split a deuteron H^2 whose binding energy is E_b = 2.2 MeV ?

3. A nucleus at rest undergoes α – decay according to the equation, ${}^{225}_{92}X \longrightarrow Y + \alpha$. At time t = 0, the emitted α-particle enters in a region of space where a uniform magnetic field $\vec{B} = B_0\hat{i}$ and electric field $\vec{E} = E_0\hat{i}$ exist. The α-particle enters in the region with velocity $\vec{V} = v_0\hat{j}$ from origin. At time $t = \sqrt{3} \times 10^7 \frac{m_\alpha}{q_\alpha E_0}$ sec., where m_α is the mass and q_α is the charge of α – particle. The particle was observed to have speed twice the initial speed v_0. Then find :

(a) the initial speed v_0 of the α – particle

(b) the velocity of α – particle at time t

(c) the binding energy per nucleon of X .

Given that : m (Y) = 221.03 u, m (He) = 4.003 u, m(n) = 1.009 u,

m (p) = 1.0084 u and 1 u = 1.67 × 10^{-27} kg = 931 MeV/c^2

4. A neutron collides elastically with an initially stationary deuteron. Find the fraction of the kinetic energy lost by the neutron (a) in a head-on collision; (b) in scattering at right angles.

5. Find the binding energy of a nucleus consisting of equal numbers of protons and neutrons and having the radius one and a half time smaller than that of Al^{27} nucleus. [Atomic mass of ${}_4Be^8$ = 8.0053 u, ${}_1H^1$ = 1.007826u, ${}_0n^1$= 1.008665 u]

6. A radio nuclide with half life T = 69.31 second emits β-particles of average kinetic energy E = 11.25 eV. At an instant concentration of β-particles at distance, r = 2 m from nuclide is n = 3 × 10^{13} per m^3.

(i) Calculate number of nuclei in the nuclide at that instant.

(ii) If a small circular plate is placed at distance r from nuclide such that β-particles strike the plate normally and come to rest, calculate pressure experienced by the plate due to collision of β-particle. (Mass of β-particle = 9 × 10^{-31} kg) ($\log_e 2$ = 0.693)

7. (a) Find the energy needed to remove a neutron from the nucleus of the calcium isotope ${}^{42}_{20}Ca$

(b) Find the energy needed to remove a proton from this nucleus

(c) Why are these energies different ?

Atomic masses of ${}^{41}_{20}Ca$ and ${}^{42}_{20}Ca$ are 40.962278 u and 41.958622 u respectively.

Atomic mass of ${}^{41}_{19}K$ is 40.961825 u, Mass of Proton is 1.007826 u

8. A nucleus X, initially at rest, undergoes alpha-decay according to the equation. **[JEE 1991; 2+4+2M]**

${}^{A}_{92}X \rightarrow + {}^{228}_{Z}Y + \alpha$

(a) Find the values of A and Z in the above process.

(b) The alpha particle produced in the above process is found to move in a circular track of radius 0.11 m in a uniform magnetic field of 3 tesla. Find the energy (in MeV) released during the process and the binding energy of the parent nucleus X.

Given that m (Y) = 228.03 u; m(${}^{1}_{0}n$) = 1.009 u.

m ${}^{4}_{2}He$ = 4.003 u ; m(${}^{1}_{1}H$) = 1.008 u.

9. 100 millicuries of radon which emits 5.5 MeV α - particles are contained in a glass capillary tube 5 cm long with internal and external diameters 2 and 6mm respectively Neglecting and effects and assuming that the inside of the tube is uniformly irradiated by the particles which are stopped at the surface calculate the temperature difference between the walls of a tube when steady thermal conditions have been reached.
Thermal conductivity of glass = 0.025 Cal cm^{-2} s^{-1} C^{-1}
Curie = 3.7 × 10^{10} disintergration per second
J = 4.18 joule Cal^{-1}

10. Radium being a member of the uranium series occurs in uranium ores. If the half lives of uranium and radium are respectively 4.5 × 10^9 and 1620 years calculate the $\frac{N_{radiun}}{N_{Uranium}}$ in Uranium ore at equlibrium.

11. ^{90}Sr decays to ^{90}Y by β decay with a half-life of 28 years. ^{90}Y decays by β decay to ^{90}Zr with a half-life of 64h. A pure sample of ^{90}Sr is allowed to decay. What is the value of $\frac{N_{Sr}}{N_y}$ after (a) 1h (b) 10 years?

12. The element Curium $^{248}{}_{96}$Cm has a mean life of 10^{13} seconds. Its primary decay modes are spontaneous fission and α-decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200 MeV of energy. The masses involved in α-decay are as follows : atomic masses of atoms are $^{248}{}_{96}$Cm = 248.072220 u, He^4 = 4.002603 u & Pu^{244} = 244.064100 u. (1 u = 931 MeV/c^2). Calculate the power output from a sample of 10^{20} Cm atoms. **[IIT - 1997]**

13. Nucleus $_3A^7$ has binding energy per nucleon of 10 MeV. It absorbs a proton and its mass increases by $\frac{99}{100}$ times the mass of proton. Find the new binding energy of the nucleus so formed. [Take energy equivalent of proton = 930 MeV]

14. The nucleus of $^{230}_{90}$Th is unstable against α-decay with a half-life of 7.6 × 10^3 years. Write down the equation of the decay and estimate the kinetic energy of the emitted α-particle from the following data : $m\left({}^{230}_{90}Th\right)$=230.0381 amu, $m\left({}^{226}_{88}Ra\right)$ = 226.0254 amu and $m\left({}^{4}_{2}He\right)$ = 4.0026 amu.

15. When ^{30}Si is bombarded with a deuteron. ^{31}Si is formed in its ground state with the emission of a proton. The energy released in this reaction from the following information is E then find [E]:
$^{31}Si \rightarrow {}^{31}P + \beta^- + 1.51$ MeV
$^{30}Si + d \rightarrow {}^{31}P + n + 5.10$ MeV
$n \rightarrow P + \beta^- + \bar{\nu} + 0.78$ MeV

HLP Answers

1. 6.954 sec **2.** 6.6 MeV

3. (a) $v_0 = 10^7$ m/s Ans. (b) $\vec{v}\,(t) = \frac{qE_0}{m} t\hat{i} + 10^7 \cos \omega t\hat{j} - 10^7 \sin \omega t\hat{k}$ where $\omega = qB/m$
(c) 8.11 MeV/nucleon

4. (a) $\eta = 4mM/(m+M)^2 = 0.89$; (b) $\eta = 2m/(m + M) = 2/3$. Here m and M are the masses of a neutron and deuteron.

5. Be^8, E_b = 56.5 MeV. **6.** (i) 9.6 π × 10^{22}, (ii) 1.08 × 10^{-4} Nm^{-2}

7. (a) 11.48 MeV (b) 10.27 MeV (c) The neutron was acted upon only by attractive nuclear forces whereas the proton was also acted upon by repulsive electric forces that decrease its binding energy.

8. (a) 232, 90 (b) 5.3 MeV, 1823.2 MeV **9.** $(T_1 - T_2)$ = 1.09 °C

10. 1/2.78 × 10^6

11. (a) For t = 1 h and using the values for the decay constans N_{sr}/N_y = 3.56 × 10^5
(b) For t = 10 years, N_{sr}/N_y = 3823

12. 3.32 × 10^{-5} Js^{-1} **13.** 79.3 MeV **14.** ${}^{230}_{90}Th \rightarrow {}^{226}_{88}Ra + {}^{4}_{2}He + Q$; 9.25 MeV.

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