## Exercise - III (Subjective Problems)

### Nuclear Physics

**1.** Calculate the mass of an $\alpha$-particle. Its binding energy is 28.2 MeV.

**2.** Find the binding of $^{56}_{20}Fe$. Atomic mass of $^{56}Fe$ is 55.9349 u and that of $^{1}H$ is 1.00783 u. Mass of neutron = 1.00867 u.

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

| $^{238}Pu$ | $^{234}U$ | $^{4}H$ |
|---|---|---|
| 238.04955 u | 234.04095 u | 4.002603 u |

Neglect any recoil of the residual nucleus.

**4.** How much energy is released in the following reaction ?

$$^{7}Li + p \rightarrow \alpha + \alpha$$

Atomic mass of $^{7}Li$ = 7.0160 u and that of $^{4}He$ = 4.0026 u.

**5.** $^{32}P$ beta-decays to $^{32}S$. Find the sum of the energy of the antineutrino and the kinetic energy of the $\beta$-particle. Neglect the recoil of the daughter nucleus. Atomic mass of $^{32}P$ = 31.974 u and that of $^{32}S$ = 31.972 u.

**6.** Potassium- 40 can decay in three modes. It can decay by $\beta^-$-emission, $\beta^+$-emission or electron capture. (a) Write the equations showing the end products. (b) Find the Q-values in each of the three cases. Atomic masses of $^{40}_{18}Ar, ^{40}_{19}K$ and $^{40}_{20}C$ are 39.9624 u, 39.9640 u and 39.9626 u respectively.

**7.** $^{228}Th$ emits an alpha particle to reduce to $^{224}Ra$. Calculate the kinetic energy of the alpha particle emitted in the following decay.

$$^{228}Th \rightarrow {}^{224}Ra^* + \alpha$$
$$^{224}Ra^* \rightarrow {}^{224}Ra + \gamma(217\ keV).$$

Atomic mass of $^{228}Th$ is 228.028726 u, that of $^{224}Ra$ is 224.020196 u and that of $^{4}_{2}He$ is 4.00260 u.

**8.** Calculate the maximum kinetic energy of the beta particle emitted in the following decay scheme :

$$^{12}N \rightarrow {}^{12}C^* + e^+ + v$$
$$^{12}C^* \rightarrow {}^{12}C + \gamma(4.43\ MeV)$$

The atomic mass of $^{12}N$ is 12.018613 u.

**9.** Calculate the Q-value in the following decays :

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

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

The atomic masses needed are as follows :

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

**10.** Find the maximum energy that a beta particle can have in the following decay

$$^{176}Lu \rightarrow {}^{176}Hf + e + \bar{v}$$

Atomic mass of $^{176}Lu$ is 175.942694 u and that of $^{176}Hf$ is 175.941420 u.

**11.** Consider the beta decay

$$^{198}Au \rightarrow {}^{196}Hg^* + \beta^- + \bar{v}$$

where $^{198}Hg^*$ represents a mercury nucleus in an excited state at energy 1.088 MeV above the ground state. What can be the maximum kinetic energy of the electron emitted ? The atomic mass of $^{198}Au$ is 197.968233 u and that of $^{198}Hg$ is 197.966760 u.

**12.** A uranium reactor develops thermal energy at a rate of 300 MW. Calculate the amount of $^{235}U$ being consumed every second. Average energy released per fission is 200 MeV.

**13.** Calculate the Q-value of the fusion reaction

$$^{4}He + {}^{4}He = {}^{8}Be.$$

Is such a fusion energetically favourable ? Atomic mass of $^{8}Be$ is 8.0053 u and that of $^{4}He$ is 4.0026 u.

**14.** The binding energies per nucleon for deuteron ($_1H^2$) and helium ($_2He^4$) are 1.1 MeV and 7.0 MeV respectively. The energy released when two deuterons fuse to form a helium nucleus ($_2He^4$) is ____________.

**15.** Suppose that the Sun consists entirely of hydrogen atom and releases the energy by the nuclear reaction, $4{}^{1}_{1}H \rightarrow {}^{4}_{2}He$ with 26 MeV of energy released. If the total output power of the Sun is assumed to remain constant at $3.9 \times 10^{26}$ W, find the time it will take to burn all the hydrogen. Take the mass of the Sun as $1.7 \times 10^{30}$ kg.

**16.** To positron is a fundamental particle with the same mass as that of the electron and with a charge equal to that of an electron but of opposite sign. When a positron and an electron collide, they may annihilate each other. The energy corresponding to their mass appears in two photons of equal energy. Find the wavelength of the radiation emitted.

[Take: mass of electron = $(0.5/C^2)$MeV and hC = $1.2 \times 10^{-12}$ MeV.m where h is the Plank's constant and C is the velocity of light in air]

**17.** When two deutrons ($_1H^2$) fuse to from a helium nucleus $_2He^4$, 23.6 MeV energy is released. Find the binding energy of helium if it is 1.1 MeV for each nucleon of deutrim.

**18.** A $\pi^+$ meson of negligible initial velocity decays to a $\mu^+$ (muon) and a neutrino. With what kinetic energy (in eV) does the muon move? (The rest mass of neutrino can be considered zero. The rest mass of the $\pi^+$ meson is 150 MeV and the rest mass of the muon is 100 MeV.) Take neutrino to behave like a photon.

Take = $\sqrt{2}$ = 1.41.

**19.** Consider the following reaction;

$$^2H_1 + {}^2H_1 = {}^4He_2 + Q.$$

Mass of the deuterium atom = 2.0141u; Mass of the helium atom = 4.0024 u
This is a nuclear _____ reaction in which the energy Q is released is ______ MeV.

**20.** The activity of a radioactive sample falls from 600 $s^{-1}$ to 500 $s^{-1}$ in 40 minutes. Calculate its half-life.

**21.** The number of $^{238}$U atoms in an ancient rock equals the number of $^{206}$Pb atoms. The half-life of decay of $^{238}$U is $4.5 \times 10^9$ y. Estimate the age of the rock assuming that all the $^{206}$Pb atoms are formed from the decay of $^{238}$U.

**22.** A radioactive decay counter is switched on at t = 0. A b - active sample is present near the counter. The counter registers the number of b - particles emitted by the sample. The counter registers $1 \times 10^5$ b - particles at t = 36 s and $1.11 \times 10^5$ b - particles at t = 108s. Find $T_{1/2}$ of this sample

**23.** An isotopes of Potassium $^{40}_{19}K$ has a half life of $1.4 \times 10^9$ year and decays to Argon $^{40}_{18}Ar$ which is stable.
(i) Write down the nuclear reaction representing this decay.
(ii) A sample of rock taken from the moon contains both potassium and argon in the ratio 1/7. Find age of rock

**24.** At t = 0, a sample is placed in a reactor. An unstable nuclide is produced at a constant rate R in the sample by neutron absorption. This nuclide $\beta$ - decays with half life $\tau$. Find the time required to produce 80% of the equilibrium quantity of this unstable nuclide.

**25.** Radioactive $^{131}$I has a half-life of 8.0 days. A sample containing $^{131}$I has activity 20 μCi at t = 0. (a) What is its activity at t = 4.0 days ? (b) What is its decay constant at t = 4.0 days ?

**26.** The decay constant of $^{238}$U is $4.9 \times 10^{-18}$ $s^{-1}$. (a) What is the average-life of $^{238}$U ? (b) What is the half-life of $^{238}$U ? (c) By what factor does the activity of a $^{238}$U sample decrease in $9 \times 10^9$ years ?

**27.** Carbon (Z = 6) with mass number 11 decyas to boron (Z = 5). (a) Is it a $\beta^+$-decay or a $\beta^-$ decay ? (b) The half-life of the decay scheme is 20.3 minutes. How much time will elapse before a mixture of 90% carbon-11 and 10% born 11 converts itself into a mixture of 10 % Carbon-11 and 90% Boron-11.

**28.** $^{238}$U decays to $^{206}$Pb with a half-life of $4.47 \times 10^9$ y. This happens in a number of steps. Can you justify a single half-life for this chain of processes ? A sample of rock is found to contain 2.00 mg of $^{238}$U and 0.600 mg of $^{206}$Pb. Assuming that all the lead has come from uranium. find the life of the rock.

**29.** Nuclei of radioactive element A are being produced at a constant rate $\alpha$. The element has a decay constant $\lambda$. At time t = 0, there are $N_0$ nuclei of the element.
(a) Calculate the number N of nuclie of A at time t.
(b) If $\alpha = 2N_0\lambda$, calculate the number of nuclei of A after one halflife of A & also the limiting value of N as $t \longrightarrow \infty$.