

# Physics

## NCERT Exemplar Problems

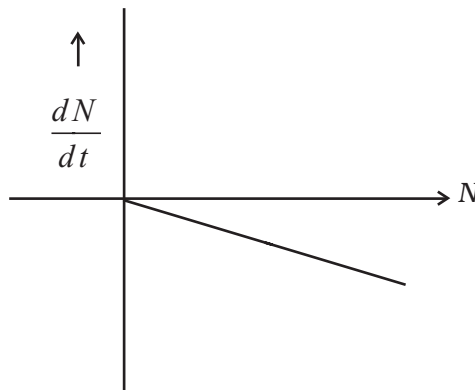
### Chapter 13

#### Nuclei

#### Answers

- 13.1 (c)  
13.2 (b)  
13.3 (b)  
13.4 (a)  
13.5 (a)  
13.6 (b)  
13.7 (b)  
13.8 (a), (b)  
13.9 (b), (d)  
13.10 (c), (d)  
13.11 No, the binding energy of  $H_1^3$  is greater.

13.12

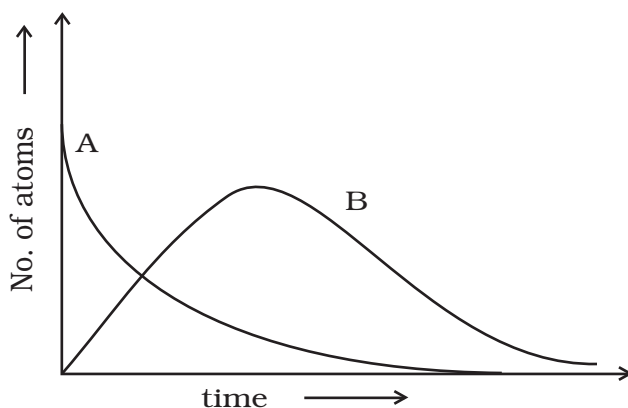


- 13.13 B has shorter mean life as  $\lambda$  is greater for B.  
13.14 Excited electron because energy of electronic energy levels is in the range of eV, only not in MeV. as  $\gamma$ -radiation has energy in MeV.

**13.15**  $2\gamma$  photons are produced which move in opposite directions to conserve momentum.

**13.16** Protons are positively charged and repel one another electrically. This repulsion becomes so great in nuclei with more than 10 protons or so, that an excess of neutrons which produce only attractive forces, is required for stability.

**13.17**



At  $t = 0$ ,  $N_A = N_0$  while  $N_B = 0$ . As time increases,  $N_A$  falls off exponentially, the number of atoms of B increases, becomes maximum and finally decays to zero at  $\infty$  (following exponential decay law).

**13.18**

$$t = \frac{1}{\lambda} \ln \frac{R_0}{R}$$

$$= \frac{5760}{0.693} \ln \frac{16}{12} = \frac{5760}{0.693} \ln \frac{4}{3}$$

$$= \frac{5760}{0.693} \times 2.303 \log \frac{4}{3} = 2391.12 \text{ years.}$$

**13.19** To resolve two objects separated by distance  $d$ , the wavelength  $\lambda$  of the probing signal must be less than  $d$ . Therefore, to detect separate parts inside a nucleon, the electron must have a wavelength less than  $10^{-15}$  m.

$$\lambda = \frac{h}{p} \text{ and } K \approx pc \Rightarrow K \approx pc = \frac{hc}{\lambda}$$

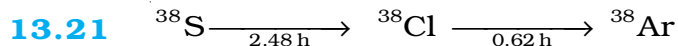
$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 10^{-15}} \text{ eV}$$

$$= 10^9 \text{ eV.} = 1 \text{ GeV.}$$

**13.20** (a)  ${}_{11}^{23}\text{Na}$  :  $Z_1 = 11$ ,  $N_1 = 12$

$\therefore$  Mirror isobar of  ${}_{11}^{23}\text{Na} = {}_{12}^{23}\text{Mg}$ .

(b) Since  $Z_2 > Z_1$ , Mg has greater binding energy than Na.



At time  $t$ , Let  ${}^{38}\text{S}$  have  $N_1(t)$  active nuclei and  ${}^{38}\text{Cl}$  have  $N_2(t)$  active nuclei.

$$\frac{dN_1}{dt} = -\lambda_1 N_1 = \text{rate of formation of Cl}^{38}. \text{ Also}$$

$$\frac{dN_2}{dt} = -\lambda_2 N_2 + \lambda_1 N_1$$

But  $N_1 = N_0 e^{-\lambda_1 t}$

$$\frac{dN_2}{dt} = -\lambda_2 N_0 e^{-\lambda_1 t} - \lambda_2 N_2$$

Multiplying by  $e^{\lambda_2 t} dt$  and rearranging

$$e^{\lambda_2 t} dN_2 + \lambda_2 N_2 e^{\lambda_2 t} dt = \lambda_1 N_0 e^{(\lambda_2 - \lambda_1)t} dt$$

Integrating both sides.

$$N_2 e^{\lambda_2 t} = \frac{N_0 \lambda_1}{\lambda_2 - \lambda_1} e^{(\lambda_2 - \lambda_1)t} + C$$

Since at  $t = 0$ ,  $N_2 = 0$ ,  $C = -\frac{N_0 \lambda_1}{\lambda_2 - \lambda_1}$

$$\therefore N_2 e^{\lambda_2 t} = \frac{N_0 \lambda_1}{\lambda_2 - \lambda_1} (e^{(\lambda_2 - \lambda_1)t} - 1)$$

$$N_2 = \frac{N_0 \lambda_1}{\lambda_2 - \lambda_1} (e^{-\lambda_1 t} - e^{-\lambda_2 t})$$

For maximum count,  $\frac{dN_2}{dt} = 0$

On solving,  $t = \left( \ln \frac{\lambda_1}{\lambda_2} \right) / (\lambda_1 - \lambda_2)$

$$= \ln \frac{2.48}{0.62} / (2.48 - 0.62)$$

$$= \frac{\ln 4}{1.86} = \frac{2.303 \log 4}{1.86}$$

$$= 0.745 \text{ s.}$$

**13.22** From conservation of energy

$$E - B = K_n + K_p = \frac{p_n^2}{2m} + \frac{p_p^2}{2m} \quad (1)$$

From conservation of momentum

$$p_n + p_p = \frac{E}{c} \quad (2)$$

If  $E = B$ , the first equation gives  $p_n = p_p = 0$  and hence the second equation cannot be satisfied, and the process cannot take place.

For the process to take place, Let  $E = B + \lambda$ , where  $\lambda$  would be  $\ll B$ .

Then : substituting for  $p_n$  from Equation (2) into Equation (1),

$$\lambda = \frac{1}{2m}(p_p^2 + p_n^2) = \frac{1}{2m}(p_p^2 + (p_p - E/c)^2)$$

$$\therefore 2p_p^2 - \frac{2E}{c}p_p + \left(\frac{E^2}{c^2} - 2m\lambda\right) = 0$$

$$\therefore p_p = \frac{2E/c \pm \sqrt{4E^2/c^2 - 8\left(\frac{E^2}{c^2} - 2m\lambda\right)}}{4}$$

Since the determinant must be positive for  $p_p$  to be real :

$$\frac{4E^2}{c^2} - 8\left(\frac{E^2}{c^2} - 2m\lambda\right) = 0$$

$$\text{Or, } 16m\lambda = \frac{4E^2}{c^2}, \therefore \lambda = \frac{E^2}{4mc^2} \approx \frac{B^2}{4mc^2}.$$

**13.23** The binding energy in H atom  $E = \frac{me^4}{8\epsilon_0^2 h^2} = 13.6 \text{ eV}.$  (1)

If proton and neutron had charge  $e'$  each and were governed by the same electrostatic force, then in the above equation we would need to replace electronic mass  $m$  by the reduced mass  $m'$  of proton-neutron and the electronic charge  $e$  by  $e'$ .

$$m' = \frac{M}{2} = \frac{1836m}{2} = 918m.$$

$$\therefore \text{Binding energy} = \frac{918me'^2}{8\epsilon_0^2 h^2} = 2.2 \text{ MeV} \quad (\text{given}) \quad (2)$$

Dividing (2) by (1)

$$918 \left( \frac{e'}{e} \right)^4 = \frac{2.2 \text{ MeV}}{13.6 \text{ eV}}$$

$$\Rightarrow \frac{e'}{e} \approx 11.$$

**13.24** Before  $\beta$  decay, neutron is at rest. Hence  $E_n = m_n c^2, p_n = 0$

After  $\beta$  decay, from conservation of momentum:

$$\mathbf{p}_n = \mathbf{p}_p + \mathbf{p}_e$$

$$\text{Or } \mathbf{p}_p + \mathbf{p}_e = 0 \Rightarrow |\mathbf{p}_p| = |\mathbf{p}_e| = p$$

$$\text{Also, } E_p = (m_p^2 c^4 + p^2 c^2)^{\frac{1}{2}},$$

$$E_e = (m_e^2 c^4 + p^2 c^2)^{\frac{1}{2}} = (m_e^2 c^4 + p^2 c^2)^{\frac{1}{2}}$$

From conservation of energy:

$$(m_p^2 c^4 + p^2 c^2)^{\frac{1}{2}} + (m_e^2 c^4 + p^2 c^2)^{\frac{1}{2}} = m_n c^2$$

$$m_p c^2 \approx 936 \text{ MeV}, m_n c^2 \approx 938 \text{ MeV}, m_e c^2 = 0.51 \text{ MeV}$$

Since the energy difference between  $n$  and  $p$  is small,  $pc$  will be small,  $pc \ll m_p c^2$ , while  $pc$  may be greater than  $m_e c^2$ .

$$\Rightarrow m_p c^2 + \frac{p^2 c^2}{2m_p c^2}; m_n c^2 - pc$$

$$\text{To first order } pc; m_n c^2 - m_p c^2 = 938 \text{ MeV} - 936 \text{ MeV} = 2 \text{ MeV}$$

This gives the momentum.

Then,

$$E_p = (m_p^2 c^4 + p^2 c^2)^{\frac{1}{2}} = \sqrt{936^2 + 2^2}; 936 \text{ MeV}$$

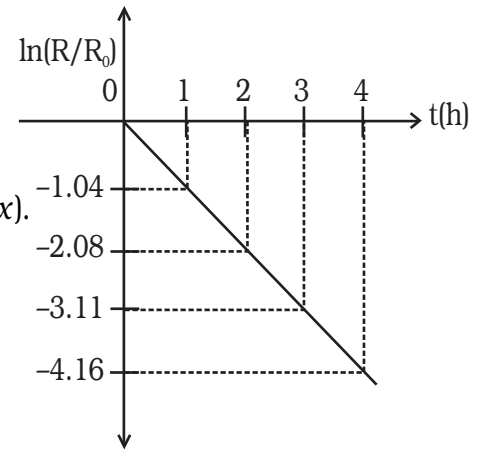
$$E_e = (m_e^2 c^4 + p^2 c^2)^{\frac{1}{2}} = \sqrt{(0.51)^2 + 2^2}; 2.06 \text{ MeV}$$

**13.25** (i)  $t_{1/2} = 40 \text{ min}$  (approx).

(ii) Slope of graph =  $-\lambda$

$$\text{So } \lambda = -\left(\frac{-4.16+3.11}{1}\right) = 1.05\text{h}$$

$$\text{So } t_{1/2} = \frac{0.693}{1.05} = 0.66\text{h} = 39.6 \text{ min or } 40 \text{ min (approx).}$$



**13.26** (i)  $S_{p\text{Sn}} = (M_{119,70} + M_H - M_{120,70})c^2$

$$= (118.9058 + 1.0078252 - 119.902199)c^2$$

$$= 0.0114362 c^2$$

$$S_{p\text{Sb}} = (M_{120,70} + M_H - M_{121,70})c^2$$

$$= (119.902199 + 1.0078252 - 120.903822)c^2$$

$$= 0.0059912 c^2$$

Since  $S_{p\text{Sn}} > S_{p\text{Sb}}$ , Sn nucleus is more stable than Sb nucleus.

- (ii) It indicates shell structure of nucleus similar to the shell structure of an atom. This also explains the peaks in BE/nucleon curve.