Nuclei

CHAPTER 13

NCERT FOCUS

ANSWERS

Topic 1

1. The $^{14}_{7}N$ nucleus contains 7 protons and 7 neutrons.

Mass of 7 protons = 7 × 1.00783 = 7.05481 amu
Mass of 7 neutrons = 7 × 1.00867 = 7.06069 amu
Total mass = 14.11550 amu
Mass of $^{14}_{7}N$ nucleus = 14.00307 amu
Mass defect, = Δm = 0.11243 amu
B.E. of nitrogen nucleus = 0.11243 × 931 = 104.67 MeV.

2. Let us first find the binding energy of $^{56}_{26}Fe$.
No. of protons in Fe = Z = 26
Mass of protons = 26 × 1.007825 u = 26.203450 u
No. of neutrons in Fe, $n = A - Z = 56 - 26 = 30$
Mass of neutrons = 30 × 1.008665 u = 30.259950 u
Total theoretical mass of nucleus
= 26.203450 u + 30.259950 u = 56.463400 u
Actual mass of Fe nucleus 55.934939 u
Mass defect Δm = Total mass – Actual mass = 0.528461 u
B.E. of $^{56}_{26}Fe$ nucleus $E = \Delta mc^2 = \Delta m$ 931.5 MeV
= 0.528461 (931.5) MeV = 492.26 MeV

$$\frac{\text{B.E}}{\text{nucleon}} \text{ of } ^{56}_{26}Fe = \frac{492.26}{56}\text{ MeV} = 8.79\text{ MeV}$$

Now binding energy of $^{209}_{83}Bi$
No. of protons in Bi = Z = 83
No. of neutrons in Bi $n = A - Z = 209 - 83 = 126$
Mass of protons = 83 × 1.007825 u = 83.649475 u
Mass of neutrons = 126 × 1.008665 u = 127.091790 u
Total theoretical mass of nucleus = 210.741265 u
Actual mass of Bi nucleus = 208.980388 u
Mass defect, Δm = 210.741260 – 208.980388 = 1.760877 u
$\Rightarrow$ B.E. of $^{209}_{83}Bi$ nucleus $\Rightarrow$ Δmc^2
$\Rightarrow$ Δm (931.5 MeV)
$\Rightarrow$ 1.760877 × 931.5 MeV $\Rightarrow$ 1640.3 MeV

$$\frac{\text{B.E}}{\text{nucleon}} \text{ of } ^{209}_{83}Bi = \frac{1640.3}{209}\text{ MeV} = 7.85\text{ MeV}$$

So, $^{56}_{26}Fe$ is much more stable than $^{209}_{83}Bi$, due to more binding energy per nucleon.

3. Let us first find the B.E. of each copper nucleus and then we can find binding energy of 300 g of $^{63}_{29}Cu$.
Mass of 29 protons = 29 × 1.00783 = 29.22707 u
Mass of 34 neutrons = 34 × 1.00867 = 34.29478 u
Total theoretical mass = 63.52185 u
Actual mass of Cu nucleus = 62.92960 u
Mass of defect = Theoretical mass – Actual mass = 0.59225 u
B.E. of each Cu nucleus = Δm [931.5 MeV]
= 0.59225 [931.5 MeV] = 551.385 MeV
Number of atoms in 3 g of copper

$$n = \frac{\text{Avogadro number}}{\text{Mass number}} \times 3$$

or $$n = \frac{6.023\times10^{23}\times3}{63} = 2.86\times10^{22}$$

Total binding energy in 3 g of copper
= 2.86 × 10^{22} × 551.385 MeV = 1.6 × 10^{25} MeV
So, the energy required to separate all the neutrons and protons from each other in 3 g copper coin will be 1.6 × 10^{25} MeV.

4. We know the radius of nucleus depend upon mass number 'A'
As, $R = R_0A^{1/3}$, where $R_0 = 1.1 \times 10^{-15}$ m

$$\therefore \quad \frac{R(^{197}Au)}{R(^{107}Ag)} = \left(\frac{197}{107}\right)^{1/3} \simeq 1.23$$

Since the nuclear mass density is independent of the size of the nucleus, so $\frac{\rho_{nu}(Au)}{\rho_{nu}(Ag)} \simeq 1$.

Topic 2

1. The fission of Fe-56 into two fragments of $^{28}_{13}Al$ with energy released Q can be written as

$$^{56}_{26}Fe \rightarrow {}^{28}_{13}Al + {}^{28}_{13}Al + Q$$

$$Q = \left[m(^{56}_{26}Fe) - 2m(^{28}_{13}Al)\right]c^2$$

= [55.93494 – 2 × 27.98191] × 931.5 MeV
= –0.02888 × 931.5 = – 26.90 MeV

As the Q-value is negative, the fission is not possible energetically.

2. (i) Let us find the Q value in given first equation,

$$^{1}_{1}H + {}^{3}_{1}H \rightarrow {}^{2}_{1}H + {}^{2}_{1}H$$

$$Q = \left[m(^{1}_{1}H) + m(^{3}_{1}H) - 2m(^{2}_{1}H)\right]c^2$$

= [1.007825 + 3.016049 – 2 × 2.014102] × (931 MeV)
Q = [4.023874 – 4.028204] 931.5 MeV = – 4.033 MeV
Negative Q value shows that reaction is endothermic.
(ii) Q value in the given second equation

$$^{12}_{6}C + {}^{12}_{6}C \rightarrow {}^{20}_{10}Ne + {}^{4}_{2}He$$

$$Q = \left[2m(^{12}_{6}C) - m(^{20}_{10}Ne) - m(^{4}_{2}He)\right]c^2$$

Q = [2 × 12.0000 – 19.992439 – 4.002603] × 931.5 MeV
Q = 0.004958 × 931.5 MeV = 4.618 MeV
Positive Q shows that the reaction is exothermic.

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