Introduction to Reactor System

K.S. Rajan
Professor, School of Chemical & Biotechnology
SASTRA University
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1 Quiz

1.1 Questions

1. Determine the number of nucleons in $^{238}_{92}U$.

2. What is the equivalent of 1 J in MeV?

3. Write Einstein’s mass-energy relationship.

4. From Einstein’s mass-energy relationship, prove that binding energy corresponding to mass defect of 1 amu is approximately 931 MeV.

5. Determine the binding energy of the nucleus in $^{233}_{90}Th$. The mass of Th-233 is 233.041581 amu.

6. Determine the average binding energy of the nucleus in $^4_2He$. The mass of $^4He$ is 4.002603 amu.

7. Calculate the velocity of a neutron whose kinetic energy is 2 MeV.

1.2 Answers

1. Number of nucleons = number of particles heavier than electron = number of protons + number of neutrons

   Number of protons = 92
   Number of neutrons = 238 - 92 = 146
   Number of nucleons = 146 + 92 = 238

2. $1 \text{ MeV} = 1.6 \times 10^{-13} \text{ J}$

   Therefore, $1 \text{ J} = 6.25 \times 10^{12} \text{ MeV}$

3. $E = mc^2$ (E is the energy, m is the mass and c is the velocity of light)
4. \( E = m_d c^2 \)

\[
c = 2.998 \times 10^8 \text{ m/s}; \ m_d = 1 \text{ amu} = 1.66 \times 10^{-24} \text{ g} = 1.66 \times 10^{-27} \text{ kg}
\]

\[
E = 1.66 \times 10^{-27} \times (2.998 \times 10^8)^2 = 932.5 \text{ MeV}
\]

The difference between the calculated and target values is very small. This could be due to errors in rounding off.

5. Recalling Eq. (2), \( m_d = Z(1.007825) + N(1.008665) - M \)

\[Z = 90; \ A = 233; \ N = A - Z = 143, \ M = 233.041581 \text{ amu} \]

Substituting above in Eq. (2) yields a mass defect (\( m_d \)) of 1.90176 amu.

Recalling that 1 amu corresponds to 931 MeV, the binding energy of U-235 is 1770.5 MeV

6. Recalling Eq. (2), \( m_d = Z(1.007825) + N(1.008665) - M \)

\[Z = 2; \ A = 4; \ N = A - Z = 2, \ M = 4.002603 \text{ amu} \]

Substituting above in Eq. (2) yields a mass defect (\( m_d \)) of 0.030377 amu.

Recalling that 1 amu corresponds to 931 MeV, the binding energy of U-235 is 28.281 MeV

Average binding energy = Binding energy/A = 28.281/4 = 7.07025 MeV

7. From Eq. (6), we have \( 0.5m_n u_n^2 = E_n \)

\[m_n = 1.008665 \text{ amu} = 1.6744 \times 10^{-27} \text{ kg} \]

\[E_n = 2 \text{ MeV} = 3.2 \times 10^{-13} \text{ J} \]

Substituting for \( m_n \) and \( E_n \) in Eq. (6), we get the velocity of neutron as 19550 km/s