The first real foundation for the concept of the nucleus was provided by Rutherford in 1911. Rutherford while conducting an experiment on the large-angle scattering of alpha particles by matter discovered that all the positive charges of the atom and whole mass of the atom were concentrated in a very tiny central hard core called the nucleus.

Every atomic nucleus contains two types of particles called the neutrons and protons. The protons and neutrons are collectively called the nucleus. The protons are positively charged and the neutrons are neutral. The number of protons in the nucleus of the atom is equal to the electrons in the atom. The number of protons or electrons in an atom is called the atomic number and it is represented as Z. The total number of protons and neutrons in a nucleus is called the mass number, which is represented using the letter A.

JEE Main Previous Year Solved Questions on Nuclear Physics

Q1: Consider the nuclear fission

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

Given that the binding energy/ nucleon of Ne^{20}, He^4 and C^{12} are 8.03 MeV, 7.07 MeV and 7.86 MeV respectively. Identify the correct statement.

(a) energy of 11.9 MeV has to be supplied

(b) energy of 12.4 MeV will be supplied

(c) 8.3 MeV energy will be released

(d) energy of 3.6 MeV will be released

Solution

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

Q – value, $E_B = (BE)_{initial} - (BE)_{final}$

$= (20 \times 8.03) - ((2 \times 7.07 \times 4) + 7.86 \times 12) = 9.72$ MeV

Answer: (a) energy of 11.9 MeV has to be supplied

Q2: An unstable heavy nucleus at rest breaks into two nuclei which move away with velocities in the ratio of 8: 27. The ratio of the radii of the nuclei (assumed to be spherical) is

(a) 3: 2

(b) 2: 3

(c) 4: 9

(d) 8: 27

Solution

As $(v_1/v_2) = 8/27$; $(r_1/r_2) = ?$

Using law of conservation of linear momentum, $0 = m_1v_1 - m_2v_2$

(As both are moving in opposite directions)

Or $m_1/m_2 = v_2/v_1 = 27/8$

$$\frac{\rho(\frac{4}{3})\pi r_1^3}{\rho(\frac{4}{3})\pi r_2^3} = \frac{27}{8}$$

Therefore, $(r_1/r_2) = 3/2$

Answer: (a) 3: 2

Q3: According to Bohr's theory, the time-averaged magnetic field at the centre (i.e. nucleus) of a hydrogen atom due to the motion of electrons in the n^{th} orbit is proportional to (n = principal quantum number)

(a) n^{-2}

(b) n^{-3}

(c) n^{-4}

(d) n^{-5}

Solution

Magnetic field at the centre, $B_n = \mu_0 I/2r_n$

For a hydrogen atom, the radius of n^{th} orbit is given by

$r_n = (n^2/m)(h/2\pi)^2(4\pi\varepsilon_0/e^2)$

$r_n \propto n^2$

$I = e/T = e/(2\pi r_n/v_n) = ev_n/2\pi r_n$

Also, $v_n \propto n^{-1}$ $\therefore$ $I \propto n^{-3}$

Hence, $B_n \propto n^{-5}$

Answer: (d) n^{-5}

Q4: Two deuterons undergo nuclear fusion to form a Helium nucleus. Energy released in this process is (given binding energy per nucleon for deuteron = 1.1 MeV and for helium = 7.0 MeV)

(a) 25.8 MeV

(b) 32.4 MeV

(c) 30.2 MeV

(d) 23.6 MeV

Solution

${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4$

Energy released = 4(Binding Energy of (${}_1{}^2H$)) – 4(Binding Energy of(${}_2{}^4He$)) = 4 × 7 – 4 × 1.1 = 23.6 MeV

Answer: (d) 23.6 MeV

Q5: As an electron makes a transition from an excited state to the ground state of a hydrogen-like atom/ion

(a) kinetic energy decreases, potential energy increases but the total energy remains the same

(b) kinetic energy and total energy decrease but potential energy increases

(c) its kinetic energy increases but potential energy and total energy decrease

(d) kinetic energy, potential energy and total energy decrease.

Solution

For an electron in n^{th} excited state of hydrogen atom,

kinetic energy = $e^2/(8\pi\epsilon_0 n^2 a_0)$

potential energy = $-e^2/(4\pi\epsilon_0 n^2 a_0)$ and total energy = $-e^2/(8\pi\epsilon_0 n^2 a_0)$

where a_0 is Bohr radius.

As an electron makes a transition from an excited state to the ground state, n decreases. Therefore kinetic energy increases but potential energy and total energy decrease.

Answer: (c) its kinetic energy increases but potential energy and total energy decrease

Q6: Energy required for the electron excitation in Li^{++} from the first to the third Bohr orbit is

(a) 12.1 eV

(b) 36.3 eV

(c) 108.8 eV

(d) 122.4 eV

Solution

Using, $E_n = (13.6Z^2/n^2)$ eV

Here, Z = 3 (For Li^{++})

Therefore, $E_1 = (13.6(3)^2/1^2) = -122.4$ eV

and $E_3 = (13.6(3)^2/3^2) = -13.6$ eV

$\Delta E = E_3 - E_1 = -13.6 + 122.4 = 108.8$ eV

Answer: (c) 108.8 eV

Q7: If the binding energy per nucleon in $_3Li^7$ and $_2He^4$ nuclei are 5.60 MeV and 7.06 MeV respectively, then in the reaction

$p + {}_3Li^7 \rightarrow 2\ {}_2He^4$

energy of proton must be

(a) 39.2 MeV

(b) 28.24 MeV

(c) 17.28 MeV

(d) 1.46 MeV

Solution

Binding energy of $_3Li^7 = 7 \times 5.60 = 39.2$ MeV

Binding energy of $_2He^4 = 4 \times 7.06 = 28.24$ MeV

Energy of proton = Energy of $[2({}_2He^4) - {}_3Li^7]$

$= 2 \times 28.24 - 39.2 = 17.28$ MeV

Answer: (c) 17.28 MeV

Q8: A nucleus disintegrates into two nuclear parts which have their velocities in the ratio 2: 1. The ratio of their nuclear sizes will be

(a) $2^{1/3}$: 1

(b) 1: $3^{1/2}$

(c) $3^{1/2}$: 1

(d) 1: $2^{1/3}$

Solution

Momentum is conserved during disintegration $m_1v_1 = m_2v_2$ ——-(1)

For an atom $R = R_0A^{1/3}$

$(R_1/R_2) = (A_1/A_2)^{1/3} = (m_1/m_2)^{1/3} = (v_2/v_1)^{1/3}$ from (1)

$(R_1/R_2) = (1/2)^{1/3} = 1/2^{1/3}$

Answer: (d) 1: $2^{1/3}$

Q9: A nuclear transformation is denoted by $X(n,\alpha){}_3Li^7$. Which of the following is the nucleus of element X?

(a) ${}_5B^9$

(b) ${}_4Be^{11}$

(c) ${}_6C^{12}$

(d) ${}_5B^{10}$

Solution

The nuclear transformation is given by

${}_ZX^A + {}_0n^1 \rightarrow {}_2He^4 + {}_3Li^7$

According to conservation of mass number

A + 1 = 4 + 7 or A = 10

According to conservation of charge number

Z + 0 → 2 + 3 or Z = 5

So the nucleus of the element be ${}_5B^{10}$.

Answer: (d) ${}_5B^{10}$

Q10: Using a nuclear counter the count rate of emitted particles from a radioactive source is measured. At t = 0 it was 1600 counts per second and at t = 8 seconds it was 100 counts per second. The count rate observed, as counts per second, at t = 6 seconds is close to

(a) 200

(b) 360

(c) 150

(d) 400

Solution

According to law of radioactivity, the count rate at t = 8 seconds is

$N_1 = N_0 e^{-\lambda t}$

$dN/dt = \lambda N = \lambda N_0 e^{-\lambda t}$

$1600 = \lambda N_0 e^0 = \lambda N_0 \Rightarrow 100 = \lambda N_0 e^{-8\lambda} = 1600 e^{-8\lambda}$

At t = 6 sec

$dN/dt = \lambda N_0 e^{-6\lambda} = 1600 \times (e^{-2\lambda})^3 = 1600 \times (18) = 200$

Answer: (a) 200