CBSE Test Paper-05
Class - 12 Physics (Nuclei)

1. Cadmium rods are used in a nuclear reactor for
   a. absorbing neutrons in any generation
   b. speeding up slow neutrons
   c. slowing down fast neutrons
   d. regulating the power level of the reactor.
2. The nuclei of isotopes of a given element contain the same number of
   a. Neutrinos
   b. Positrons
   c. Protons
   d. Neutrons
3. Two radioactive sources A and B initially contain equal number of radioactive atoms. Source A has a half-life of 1 hour and source B has a half-life of 2 hours. At the end of 2 hours, the ratio of the rate of disintegration of A to that of B is
   a. 1 : 2
   b. 1
   c. 2 : 1
   d. 1 : 4
4. B^{210} has a half life of 5 days. The time taken for seven-eighth of a sample to decay is
   a. 3.4 days
   b. 15 days
   c. 10 days
   d. 20 days
5. A nucleus of mass number A has a radius R such that
   1. $R = R_0 A^{\frac{1}{3}}$
   2. $R = R_0 A^{\frac{2}{3}}$
   3. $R = R_0 A^{\frac{4}{3}}$
   4. $R = R_0 A^{\frac{5}{3}}$
6. Calculate the energy in fusion reaction ${}_1^2\mathrm{H} +{}_1^2 \mathrm{H} \longrightarrow{}_2^3 \mathrm{He} + n$, where BE of

${}_1^2\mathrm{H} = 2.23\mathrm{MeV}$ and ${}_2^3\mathrm{He} = 7.73\mathrm{MeV}$.

7. Write any two characteristic properties of nuclear force.
8. How is the radius of a nucleus related to its mass number?
9. When four hydrogen nuclei combine to form a helium nucleus estimate the amount of energy in MeV released in this process of fusion (Neglect the masses of electrons and neutrons).

   Given:

   i. Mass of ${}_1^1H = 1.007825u$
   ii. Mass of helium nucleus = 4.002603u,

      1u = 931MeV/c^2
10. It is found from an experiment that the radioactive substance emits one beta particle for each decay process. Also an average of 8.4 beta particles are emitted each second by 2.5 miligram of substance. The atomic weight of substance is 230. What is the half life?
11. A radioactive nucleus A undergoes a series of decays according to the following scheme

    $$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

    The mass number and atomic number of A_4 are 172 and 69, respectively. What are these numbers for A?
12. Two radioactive nuclei X and Y initially contain equal number of atoms. The half life is 1 hour and 2 hours respectively. Calculate the ratio of their rates of disintegration after two hours.
13. From the relation R = $R_0A^{1/3}$ where R_0 is a constant and A is the mass number of a nucleus, show that the nuclear matter density is nearly constant (i.e. independent of A).
14. If a nucleus ${}_{26}^{56}Fe$ splits into two nuclei of ${}_{13}^{28}Al$, would the energy be released or needed for this process to occur? Given, Mass $m\left({}_{26}^{56}Fe\right)$ = 55.93494 u, $m\left({}_{13}^{28}Al\right)$ = 27.98191 u and 1u = 931meV/C^2 Calculate this energy in MeV.
15. A nucleus with A = 235 splits into two new nuclei whose mass number are in the ratio of 2 : 1. Find the radii of the new nuclei.

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Answers

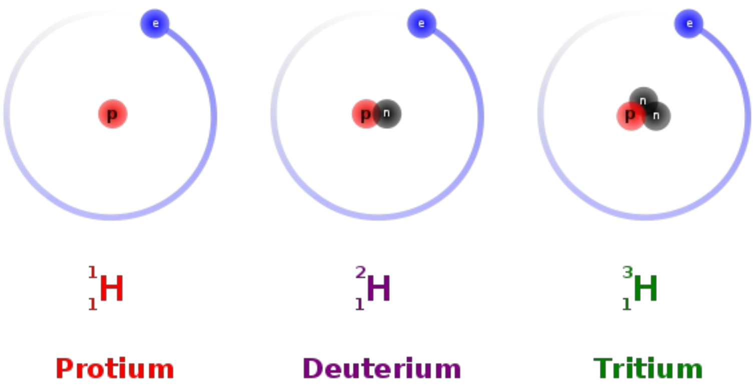
1. a. absorbing neutrons in any generation

   Explanation: Cd rods are used as a controlled rods to perform controlled chain reactions. Cd rods are capable of absorbing many neutrons without themselves fissioning.

   Controlled rods are used in nuclear reactors to control fission rate of uranium and plutonium.

2. c. Protons

   Explanation: Isotopes are variants of a particular chemical element which differ in neutron number. All isotopes of a given element have the same number of protons in each atom.



3. b. 1

   Explanation: Half life of x, T_1 = 1 hrs

   Half life of y, T_2 = 2hr

   Ratio of x left after 2 hrs

   $N_1 = \left(\frac{1}{2}\right)^{\frac{2}{1}} N_0 = \frac{1}{4} N_0$

   Ratio of y left after 2 hrs

   $N_2 = \left(\frac{1}{2}\right)^{\frac{2}{2}} N_0 = \frac{1}{2} N_0$

   Now decay rate is given by

   $R = \alpha N = \frac{0.693N}{T_{\frac{1}{2}}}$

$R\,\alpha \frac{N}{T_{\frac{1}{2}}}$

i.e. $\frac{R_1}{R_2} = \frac{\left(T_{\frac{1}{2}}\right)_2}{\left(T_{\frac{1}{2}}\right)_1} \times \frac{N_1}{N_2} = \frac{2}{1} \times \frac{\frac{N_0}{4}}{\frac{N_0}{2}}$

$\frac{R_1}{R_2} = 1$

4. b. 15 days

Explanation: $\frac{N}{N_0} = \frac{1}{8} = \left(\frac{1}{2}\right)^3$

$N = 3 = \frac{t}{t_{\frac{1}{2}}}$

$t = 3t_{\frac{1}{2}} = 3 \times 5 = 15\ days$

5. a. $R = R_0 A^{\frac{1}{3}}$

Explanation: A stable nucleus has approximately constant density. Packing protons and neutrons in the nucleus gives *approximately* the same total size result as packing hard spheres of a constant size (like marbles) into a tight spherical or almost spherical bag.

6. When any two or more nuclides fused together to form daughter nucleus, Total binding energy of the final product is less than the former one which is called Q value of the reaction.

According to question,

$_1^2\mathrm{H} +_1^2 \mathrm{H} \longrightarrow_2^3 \mathrm{He} +_0 n^1$

Energy of fusion = Binding energy of

$_2^3He\ -2 \times$ Binding energy of $_1^2\mathrm{H}$

$= 7.73 - 2 \times 2.23 = 3.27\mathrm{MeV}$

7. Nuclear force is the responsible force behind the stability of the nucleus, Its characteristics can be stated as -

    i. These are short range forces.
    ii. These are the strongest forces of attractive nature upto a certain distance i.e upto 10^{-12} m.

8. Radius of any nucleus is proportional to its Mass number and can be related as-

Radius of nucleus, $R = R_0 A^{1/3}$

where, R = radius of nucleus,

A = mass number

and R_0 = 1.2 fm = 1.2 $\times$ 10^{-15} m is the radius of hydrogen nuclide or base radius.

9. Energy released $= \Delta m \times 931\mathrm{MeV}$
   $\Delta m = 4m\left({}_1^1H\right) - m\left({}_2^4He\right)$
   Energy released
   $Q = \left[4.m\left({}_1^1H\right) - m\left({}_2^4He\right) \times 931\right] MeV$
   $= [4 \times 1.007825 - 4.002603] \times 931\mathrm{MeV}$
   = 26.72 MeV

10. The activity = 8.4 $\sec^{-1}$
    Number of atoms in kilomole (i.e. 230 kg) = 6.02×10^{26}
    $\therefore N = \frac{6.02\times10^{26}}{230} \times 2.5 \times 10^{-6} = 6.54 \times 10^{18}$
    $8.4 = \lambda N = \lambda \times 6.54 \times 10^{18}$
    $\lambda = \frac{8.4\times10^{-18}}{6.54} = 1.28 \times 10^{-18}/\sec$
    Half life $T = \frac{0.693}{\lambda} = \frac{0.693}{1.28\times10^{-18}}$
    $= 5.41 \times 10^{17}\sec$
    $= \frac{5.41\times10^{17}}{3.16\times10^{7}} = 1.7 \times 10^{10} years$

11. In a-decay, the atomic number decreases by 2 units and mass number decreases by 4 units. In $\beta -$ decay, the atomic number increases by 1 unit but mass number does not change. In γ -decay, there is no change in atomic number and mass number. Let the mass number and atomic number of A be X and Y, respectively.
    So, ${}_Y A^x \xrightarrow{\alpha} {}_{Y-2}\ A_1^{x-4} \longrightarrow {}_{Y-2+1}\ A_2^{X-4}$
    or ${}_{Y-1}A_2^{X-8} \xrightarrow{\alpha} {}_{Y-1-2}A_3^{X-4-4}$
    or ${}_{Y-3}A_3^{x-8} \longrightarrow {}_{Y-3}\ A_4^{X-8}$
    According to the question, the mass number and atomic number of A_4 are 172 and 69.
    $\therefore \quad X - 8 = 172 \Rightarrow X = 172 + 8 = 180$
    $Y - 3 = 69 \Rightarrow Y = 72$

12. After two hours, the ratio of radioactive sample of X left,

$N_1 = \left(\frac{1}{2}\right)^{2/1} N_0 = \frac{1}{4} N_0$

After two hours, the ratio of radioactive sample of Y left,

$N_2 = \left(\frac{1}{2}\right)^{2/2} N_0 = \frac{1}{2} N_0$

$R = \lambda N = \frac{0.693N}{T_{1/2}}$ (R is rate of decay $\frac{dN}{dt}$)

or $R \propto \frac{N}{T_{1/2}}$

So $\frac{R_1}{R_2} = \frac{\left(T_{1/2}\right)_2}{\left(T_{1/2}\right)_1} \times \frac{N_1}{N_2} = \frac{2}{1} \times \frac{\frac{N_0}{4}}{\frac{N_0}{2}} = 1$

Hence, the activity of the two samples will be equal after 2 hours.

13. It is found that a nucleus of mass number A has a radius

$R = R_0 A^{1/3}$

Where, $R_0 = 1.2 \times 10^{-15} m$

This implies that the volume of the nucleus, which is proportional to R^3 is proportional to A.

Volume of nucleus $= \frac{4}{3}\pi R^3$

$= \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 = \frac{4}{3}\pi R_0^3 A$

Density of nucleus $= \frac{mass\ of\ nucleus}{volume\ of\ nucleus}$

$= \frac{mA}{\frac{4}{3}\pi R_0^3 A}$

$= \frac{3m}{4\pi R_0^3}$

Above derived equation shows that density of nucleus is constant, independent of A, for all nuclei and density of nuclear matter is approximately $2.3 \times 10^7 kg\ m^{-3}$ which is very large as compared to ordinary matter, say water which is 10^3 kg m^{-3} .

14. Yes, the energy be released as the nuclear reaction is fission which is given as

$^{56}_{26}Fe \rightarrow 2^{28}_{13}Al + energy$

Mass defect $(\Delta m) = 2 \times m\left(^{28}_{13}Al\right) - m\left(^{56}_{26}Fe\right)$

= 2 $\times$ 27.98191 - 55.93494

= 55.96382 - 55.93494

= 0.02888 u

Energy required = 0.02888 $\times$ 931 ($\because$as mass of reactants is smaller than product)

= 26.88728 MeV

15. We know that the radius R of a nucleus of mass number A is given by the relation.

$R = R_0 A^{1/3}$

where experiments show that the value of R_0 is 1.4 fm. Let A_1 and A_2 represent the mass numbers of the new nuclei which are formed when the nucleus with mass number A splits into two halves. Let R_1 and R_2 be the radii of the new nuclei so formed. Then we have

$A_1 = \frac{1}{3}(235)$

and $A_2 = \frac{2}{3}(235)$

Using, $R = R_0(A)^{1/3}$ we have

$R_1 = R_0(A_1)^{1/3}$

$= (1.4fm)\left(\frac{235}{3}\right)^{1/3}$ = 5.99 fm

and $R_2 = R_0(A_2)^{1/3}$

$= (1.4fm)\left(\frac{235\times2}{3}\right)^{1/3}$ = 7.55 fm