CBSE Test Paper-03

Class - 12 Physics (Nuclei)

1. Atomic mass unit (u) is defined as ________ of the mass of the carbon ($^{12}\mathrm{C}$) atom.
   a. $\left(\frac{1}{10}\right)^{th}$
   b. $\left(\frac{1}{16}\right)^{th}$
   c. $\left(\frac{1}{12}\right)^{th}$
   d. $\left(\frac{1}{14}\right)^{th}$
2. In a nuclear fission, 0.1% mass is converted into energy. The energy released by the fission of 1 kg mass will be:
   a. $9 \times 10^{13} J$
   b. $9 \times 10^{16} J$
   c. $9 \times 10^{17} J$
   d. $9 \times 10^{19} J$
3. What is the percentage of the mass of an atom concentrated in the nucleus?
   a. 66.9 $\%$
   b. 50.9$\%$
   c. 99.9$\%$
   d. 79.9$\%$
4. A uranium nucleus (atomic number 92, mass number 238) emits an alpha particle and the resultant nucleus emits a β particle. The atomic and mass numbers respectively of the final nucleus are
   a. 90,236
   b. 90,240
   c. 91,234
   d. 92,232
5. The percentage of the original quantity of a radioactive material left after five half lives is approximately
   a. 20%
   b. 5.67%
   c. 1%

d. 3.12%

6. Name the reaction which takes place when a slow neutron beam strikes. $^{235}_{92}U$ nuclei. Write the nuclear reaction involved.
7. A radioactive isotope has a half life of T years. How long will it take the activity to reduce to (a) 3.125% (b) 1% of its original value?
8. The radioactive decay rate of a radioactive element is found to be 10^3 disintegrations / sec, at a certain time. If half life of the element is one second, what would be the decay rate after 1 sec., and after 3 sec.?
9. In a given sample, two radio isotopes A and B are initially present in the ratio of 1: 4. The half-lives of A and B are 100yr and 50yr, respectively. Find the time after which the amounts of A and B become equal.
10. 'Heavy water is often used as a modulator in thermal nuclear reactors? Give reason.
11. Why is the ionizing power of α- particle greater than that of gamma rays?
12. i. Complete the following nuclear reactions:
    a. $^{208}_{84}Po \rightarrow ^{204}_{82}Pb + \ldots\ldots$
    b. $^{32}_{15}P \rightarrow ^{32}_{16}S + \ldots\ldots$

    ii. Write the basic process involved in nuclei responsible for (a) β^- and

    iii. Why is it found experimentally difficult to detect neutrinos?
13. i. Why is the binding energy per nucleon found to be constant for nuclei in the range of mass number (A) lying between 30 and 170?

    ii. When a heavy nucleus with mass number A = 240 breaks into two nuclei, A = 120, energy is released in the process.
14. Would the energy be released or needed for the following D-T reaction $^2_1H + ^3_1H \rightarrow ^4_2He + ^1_0n$ to occur?Given: $m\left(^2_1H\right) = 2.014102u$, $m\left(^3_1H\right) = 3.016049u$ $m\left(^4_2He\right)$ = 4.002603 u, $m\left(^1_0n\right)$ = 1.008665 u. Calculate this energy in MeV.
15. A radioactive substance has a half life period of 30 days.

    Calculate:

    i. time taken for $\frac{3}{4}$ of original number of atoms to disintegrate and

    ii. time taken for $\frac{1}{8}$ of the original number of atoms to remain unchanged.

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Answers

1. c. $\left(\frac{1}{12}\right)^{th}$

   Explanation: For standardization, a specific atomic nucleus (carbon-12) had to be chosen because the average mass of a nucleon depends on the count of the nucleons in the atomic nucleus due to mass defect. This is also why the mass of a proton or neutron by itself is more than (and not equal to) 1 u.

2. a. $9 \times 10^{13} J$

   Explanation: Energy released
   $E = mc^2 = \frac{0.1}{100} \times 1 \times (3 \times 10^8)^2 J = 9 \times 10^{13} J$

3. c. 99.9%

   Explanation: A proton and a neutron have roughly 2000 times the mass of an electron. The numbers of an electron in a stable atom (not isotope) is equal to the electrons. So for most atoms, the nucleus will hold roughly 4000 times the mass of its electron cloud. Thus, $\frac{m_{nucleus}}{m_{atom}} = \frac{4000}{4001} \times 100\% \approx 99.9\%$

4. c. 91,234

   Explanation: ${}_{92}U^{238} \to {}_{90}U^{234}$ + ${}_{2}He^{4}$ + Q(Energy) α decay

   ${}_{90}U^{234} \to {}_{91}U^{234}$ + ${}_{-1}e^{0}$ β decay

   So atomic and mass no of final nuclei are 91 and 234.

5. d. 3.12%

   Explanation: $\left(\frac{1}{2}\right)^5 = \frac{1}{32}$
   $\frac{N}{N_o} = \frac{1}{32} \times 100 = 3.12\%$

6. Nuclear fission of nuclei takes place when a slow neutron strikes ${}^{235}_{92}U$.
   ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n + energy$

7. a. The fraction of the original sample left $= \frac{3.125}{100}$
   $= \frac{1}{32} = \left(\frac{1}{2}\right)^5$
   Hence, there are 5 half lives of T years spent. Thus, the time taken is 5T years.

   b. The fraction of the original sample left $= \frac{1}{100} = \left(\frac{1}{2}\right)^n$

or $2^n = 100 \Leftrightarrow n\log 2 = \log 100$
Hence $n = \frac{\log 100}{\log 2} = \frac{2}{0.301} = 6.64$ = 6.64
Hence, there are 6.64 half lives of T years spent. Thus, the time taken is 6.64 T years.

8. It is known that radioactive decay rate is directly proportional to the number of nuclei left. N_0 corresponds to 10^3 (disintegrations / sec.)

   As, half life T = 1 sec. therefore,

   i. Number of half lives in 1 sec., n = 1
   As, $N = N_0\left(\frac{1}{2}\right)^n \therefore N = 1000\left(\frac{1}{2}\right)^1$ = 500
   $\therefore$ Number of disintegrations / sec. after one sec. = 500
   ii. Number of half lives in 3 sec. $n = \frac{3}{1} = 3$
   As, $N = N_0\left(\frac{1}{2}\right)^n$
   $\therefore N = 1000\left(\frac{1}{2}\right)^3 = \frac{1000}{8}$ = 125
   $\therefore$ Number of disintegrations/sec. after three sec. = 125

9. A radioactive substance is often described in terms of its **half-life**, which is the time required for half the material to decompose. Let N_A be the concentration of A after time t_A and N_B be the concentration of B after time t_B. From radioactive disintegration equation,
   $N_A = N_0 e^{-\lambda_A t_A}$ (Here we have assumed that sample initially contains N_0 nuclides)
   $N_B = 4N_0 e^{-\lambda_B t_B}\ [As, N_{0B} = 4N_{0A}]$
   Now, the half-life of A is 100 yr and B is 50 yr.
   So, $\lambda_A = \frac{\ln 2}{100}$ .... (i)
   and $\lambda_B = \frac{\ln 2}{50}$ .... (ii)
   On dividing Eq. (i) by Eq. (ii), we get
   $\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$
   or $\lambda_B = 2\lambda_A$
   Let after t years, $N_A = N_B$
   So, $\frac{N_A}{N_B} = \frac{e^{-\lambda_A t}}{4e^{-\lambda_B t}}\ [\because N_A = N_B]$
   $\Rightarrow \quad 4e^{-\lambda_B t} = e^{-\lambda_A t}$
   $\Rightarrow \quad 4 = e^{-(\lambda_A - \lambda_B)t}$

$\ln 4 = -(+\lambda_A - 2\lambda_A)\,t\ [\because \lambda_B = 2\lambda_A]$
$\ln 4 = \lambda_A t$
$t = \frac{\ln 4}{\ln 2} \times 100 = 200\text{yr}\left[\because \lambda_A = \frac{\ln 2}{100}\right]$

So from above calculation we can say that approximate time required for both the samples to have same number of nuclides will be 200 years.

10. Heavy water is used as a moderator because its mass is nearest to that of a neutron and it has negligible chances for neutron absorption.

11. The ionizing power of $\alpha-$ particle greater than of gamma rays, because α- particle is positively charged and can interact more strongly with matter than gamma rays.

12. i. Radioactive emission include emissions of alpha,beta and gamma rays along with other subatomic particles.
    a. ${}^{208}_{84}Po \rightarrow {}^{204}_{82}\ Pb + {}^{4}_{2}\,He$
    $208 = 204 + A \Rightarrow A = 208 - 204 = 4$
    84 = 82 + Z; Z = 84 - 82 = 2
    b. ${}^{32}_{15}P \rightarrow {}^{32}_{16}\ S + -1e^0 + \overline{v}$
    32 = 32 + A, 32 - 32 = 0:
    15 = 16 + Z, z = 15 - 16 = -1
    A = 0, z = -1
    $\Rightarrow {}_{-1}e^0$

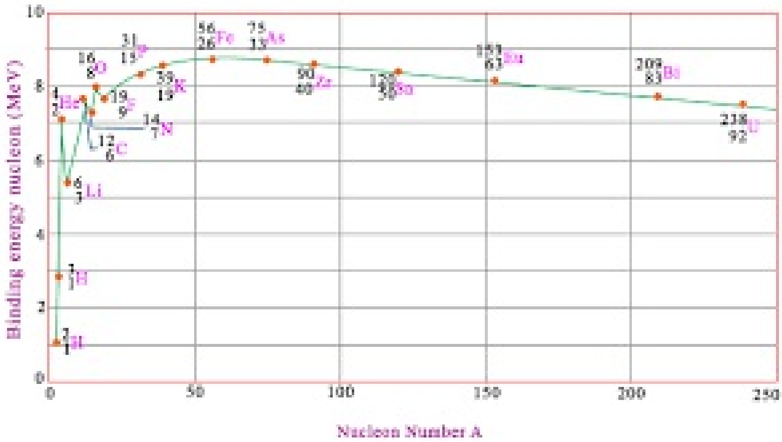
    ii. In both processes, the conversion of a neutron to proton and proton to neutron inside the nucleus takes places as follows
    ${}^{A}_{Z}X \rightarrow \beta^- + {}^{A}_{Z+1}\,Y + \overline{v}(\beta^- - decay)$
    ${}^{A}_{Z}X \rightarrow \beta^+ + {}^{A}_{Z-1}\,Y +\ v(\beta^+ - decay)$

    iii. A neutrino is a subatomic particle that is very similar to an electron, but has no electrical charge and a very small mass, which might even be zero. Neutrinos are one of the most abundant particles in the universe. Because they have very little interaction with matter, however, they are incredibly difficult to detect.Neutrino and anti neutrino are subatomic particles that are antimatter to each other.

13. i. The binding energy per nucleon of a nucleus is the binding energy divided by the total number of nucleons.

Measure of stability of the nucleus: Larger the binding energy per nucleon, the greater the work that must be done to remove the nucleon from the nucleus, the more stable the nucleus.

ii. The binding energy per nucleon for the nucleus of range, 30<A <170 is close to its maximum value. So, the nucleus belongs to this region is highly stable and does not show radioactivity.
Binding energy per nucleon is smaller for heavier nuclei than the middle ones, i.e. heavier nuclei are less stable. When a heavier nucleus such as a nucleus of mass number 240 splits into lighter nuclei (mass number 120), the BE/nucleon changes from about 7.6 MeV to 8.4 MeV. Greater BE of the product nuclei results in the liberation of energy.



14. Mass $\left({}^2_1H\right) + mass\left({}^2_1H\right)$ = 2.014102 + 3.016049
= 5.030151 u
$m\left({}^4_2He\right) + m\left({}^1_0n\right)$= 4.002603 + 1.008665
= 5.011268 u
Energy is released in this reaction. ($\because$as mass of reactant is larger than products)
Mass defect (Δm) = 5.030151 - 5.011268
= 0.018863 u
Now, energy required $= (\Delta m) \times 931 MeV$
$= 0.018863 \times 931 MeV$
= 17.561453 MeV
= 17.56 MeV

15. **Numerical:**

Number of atoms disintegrated $= \left(\frac{3}{4}\right) N_0$

Number of atoms left after time t,

$N = N_0 - \frac{3}{4} N_0 = \frac{1}{4} N_0$

Number of half-lives in time t days,

T = Half-lives time

n = No. of half lives

t = time for disintegrates

$n = \frac{t}{T} = \frac{t}{30}$

1. Number of nuclei left after n half-lives is given by
   $N = N_0 \left(\frac{1}{2}\right)^n$
   $\therefore \frac{N_0}{4} = N_0 \left(\frac{1}{2}\right)^{t/30}$ or $(2)^{t/30} = 4 = (2)^2$
   or $\frac{t}{30} = 2$ or t = 60 days
2. Since, $N = N_0 \left(\frac{1}{2}\right)^n$
   $\therefore \frac{N_0}{8} = N_0 \left(\frac{1}{2}\right)^{t/30}$
   or $(2)^{t/30} = 8 = (2)^3$
   or, $\frac{t}{30} = 3$
   or, t = 90 days