CBSE Test Paper-02

Class - 12 Physics (Nuclei)

1. The half life of a radioactive substance is 10 days. This means that
    a. the substance completely disintegrates in 40 days
    b. 7/8 part of the mass of the substance disintegrates in 30 days
    c. 1/8 part of the mass of the substance will be left intact at the end of 40
    d. the substance completely disintegrates in 20 days
2. Choose the WRONG statement.
    a. The nuclear force becomes very strong if the nucleus contains a large number of nucleons
    b. The nuclear force becomes weak if the nucleus contains too many neutrons compared to the number of protons
    c. Nuclei with atomic number greater than 82 show a tendency to disintegrate.
    d. The nuclear force becomes weak if the nucleus contains too many protons compared to the number of neutrons
3. An electric field can deflect
    a. α -particle
    b. Gamma rays
    c. χ rays
    d. Neutrons
4. A radioactive element X with a half life of 2 hours decays giving a stable element Y. After a time of t hours ratio of X to Y atoms is 1:7, then the value of t is
    a. 14
    b. 6
    c. 4
    d. Between 4 and 6
5. Which rays are not deflected in electric and magnetic fields?
    a. χ -rays
    b. none of these
    c. γ –rays
    d. β –rays

6. What is the relationship between the half-life and mean life of a radioactive nucleus?

7. A radioactive material has a half life of 1 minute. If one of the nuclei decays now, when will the next one decay?

8. Two nuclei have mass numbers in the ratio 1: 2. What is the ratio of their nuclear densities?

9. If both the numbers of protons and neutrons are conserved in a nuclear reaction like
$_6C^{12} +_6 C^{12} \longrightarrow_{10} \mathrm{Ne}^{20} +_2 He^4$
In what way, is the mass converted into the energy? Explain.

10. Draw the graph showing the distribution of kinetic energy of electrons emitted during beta decay.

11. A nucleus $_nX^m$ emits one alpha particle and one beta particle. Find the mass number and atomic number of the product nucleus.

12. The half life of $^{238}_{92}U$ against $\alpha-$ decay is 4.5×10^9 years. Calculate the activity of 1g sample of $^{238}_{92}U$.

13. An observer in a laboratory starts with N_0 nuclei of a radioactive sample and keep on observing the number (N) of leftover nuclei at regular intervals of 10 min each. She prepares the following table on the basis of her observation.

Time t (in min)	$\log_e\left(\frac{N_0}{N}\right)$
0	0
10	3.465
20	6.930
30	10.395
40	13.860

Use this data to plot a graph of $\log_e(N_0/N)$ versus time (t) and calculate the

i. decay constant and
ii. half-life of the given sample.

14. Calculate the height of the potential barrier for a head on collision of two deuterons. Assume that they can be taken as hard spheres of radius 2.0 fm.
    Hint: The height of the potential barrier is given by the Coulomb repulsion between the two deuterons when they just touch each other.

15. Using the present day abundance of the two main uranium isotopes and assuming that the abundance ratio could never have been greater than unity, estimate the maximum possible age of the Earth's crust. Given that the present age ratio of main uranium isotopes is 137.8 : 1.

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Answers

1. b. 7/8 part of the mass of the substance disintegrates in 30 days

   Explanation: $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{6}{T_{1/2}}} = \left(\frac{1}{2}\right)^{\frac{30^3}{10}} = \frac{1}{8}$

   $N = \frac{1}{8} N_0$

   So $N = 1 - \frac{1}{8} = \frac{7}{8}$

2. a. The nuclear force becomes very strong if the nucleus contains a large number of nucleons

   Explanation: If the nucleus contains large no of nucleons than separation between nucleons decreases. And we know that when separation become less than 0.8 fermi then nuclear forces are repulsive. So for strong nuclear forces nucleus should contain less no of nucleons.

3. a. α –particle

   Explanation: Because alpha particles are charged species so they are deflected by electric fields.

4. b. 6

   Explanation: X:Y = 1:7

   Total Pairs = 8 = 2^3

   No of half lives (n) =3

   t = n × $T_{1/2}$

   t = 3 ×2 = 6

5. c. γ –rays

   Explanation: γ –rays are chargeless particles that's why they are not deflected by electric and magnetic fields.

6. Half life is defined as time in which any radioactive sample decays to half of its initial value which mean life is average life time of any radioactive sample.

   $T_{1/2} = \frac{\ln 2}{\lambda} = \tau \ln 2$

   where, $T_{1/2}$ is half-life and τ is mean life.

7. The next nucleus can decay any time.

8. Nuclear density of any nucleus is independent of its mass number and given as $\rho = \frac{3m}{4\pi R_0^3}$ thus, the density of nucleus is constant where, m = average mass of single nucleon which is constant i.e roughly 1.67×10^{-27} kg

9. The sum of masses of nuclei of product element is less than the sum of masses of reactants and hence, loss of mass takes place during the reaction. This difference of mass of product element and reactant converts into energy and liberated in the form of heat.

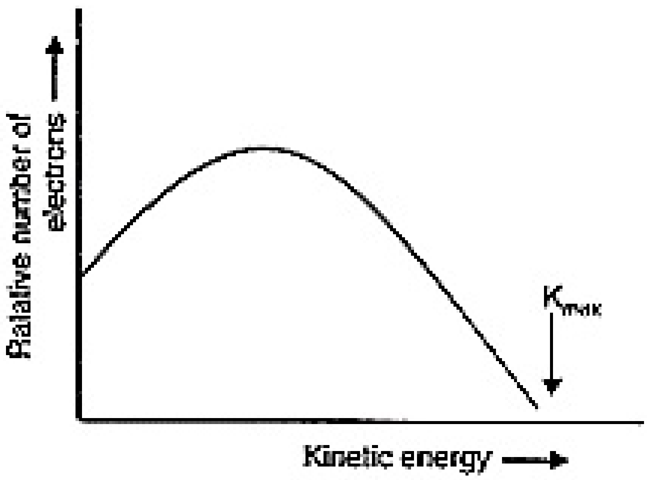
   Here, the sum of masses of ${}_{10}Ne^{20}$ and ${}_{2}He^{4}$ is less than the sum of two ${}_{6}C^{12}$ and conversion of this mass defect is used to produce energy according to Einstein's Mass Energy equivalence -

   $E = m c^2$

   where, m = mass defect

   c = speed of light

   E = 931(m) MeV

10. 

11. $${}_{n}X^{m} \xrightarrow[\alpha-decay]{{}_{2}He^{4}} {}_{n-2}X^{m-4} \xrightarrow[\beta-decay]{-1e^{0}} {}_{n-1}X^{m-4}$$

   ∴Mass number of product nucleus = m -4

   and atomic number of product nucleus = n - 1.

12. $T_{\frac{1}{2}} = 4.5 \times 10^{9}\ years = 4.5 \times 10^{9} \times 3.156 \times 10^{7} s$

Number of atoms in 1 g uranium,

$N = \frac{6.023 \times 10^{23}}{238} atoms$

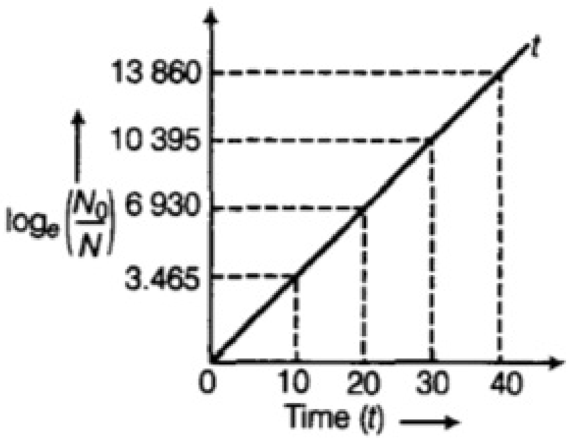
Activity of the sample $= \lambda N$

$= \frac{0.693}{T_{\frac{1}{2}}} \times N$

$= \frac{0.693 \times 6.023 \times 10^{23}}{4.5 \times 3.156 \times 10^{16} \times 238}$

$= 1.235 \times 10^4$disintegration/ second

13. When a radioactive material undergoes α, β or γ-decay, the number of nuclei undergoing the decay, per unit time, is proportional to the total number of nuclei in the sample material. If N = total number of nuclei in the sample and ΔN = number of nuclei that undergo decay in time Δt then, The graph between $\log_e\left(\frac{N_0}{N}\right)$ and time is shown as below:



i. $\log_e\left(\frac{N_0}{N}\right) = \lambda t$

$\Rightarrow$ Slope of $\log_e\left(\frac{N_0}{N}\right)$ versus time t graph gives

decay constant λ

$\therefore \quad \lambda = \frac{3.465}{10} s^{-1}$

[using observation given in table]

$= \frac{6.930}{20} = 0.3465 s^{-1}$

ii. Half-life, $T_{1/2} = \frac{0.693}{\lambda}$

$\Rightarrow \quad T_{1/2} = \frac{0.693}{0.3465} = 2\text{s}$

Half-life, $T_{1/2}$ = 2 sec So from above calculation we can conclude that decay constant of given radioactive sample is 0.3465 sec^{-1} and half life time is 2 seconds.

14. Suppose the two particles are fired at each other with the same kinetic energy K so

that they are brought to rest by their mutual Coulomb repulsion when they are just touching each other. We can take this value of K as a representative measure of the height of Coulomb barrier.

P.E. = 2 K.E

$$\frac{e^2}{4\pi\varepsilon_0(2R)} = 2K_e$$

$$2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{(2R)}$$

$$K_e = \frac{e^2}{16\pi\varepsilon_0 R}$$

$$= \frac{(1.6\times10^{-19})^2}{16\times3.14\times8.85\times10^{-12}\times2\times10^{-15}}J$$

$$= 2.8788 \times 10^{-14}J$$

$$= \frac{2.8788\times10^{-14}}{1.6\times10^{-19}\times10^3}keV$$

= 179.9 keV

15. The uranium isotopes involved are $^{238}_{92}U$ and $^{235}_{92}U$ with a present abundance ratio of 137.8 : 1

Now, for $^{235}_{92}U$ we have $N_{238} = N_{0238}e^{-\lambda,t}$ where N_{238} and N_{0238} refer to present and original number of $^{238}_{92}U$ atoms involved. t is measured from t = 0, i.e. is the age of the crust and λ_s is the radioactive decay constant of $^{238}_{92}U$ such that

$$\lambda_s = \frac{0.693}{T_S}$$

where T_S is the corresponding half life

$$\frac{N_{238}}{N_{0238}} = e^{-\lambda_S t} = e^{\frac{-0.693}{T_{238}}t}$$

Similarly, $\frac{N_{0235}}{N_{0235}} = e^{-\lambda_S t} = e^{\frac{-0.693}{T_{235}}t}$

$$\therefore \frac{N_{238}}{N_{235}}\cdot\frac{N_{0235}}{N_{0238}} = \exp\left[0.693t\left(\frac{1}{T_{235}} - \frac{1}{T_{238}}\right)\right]$$

Now, $T_{235} = 7.13 \times 10^6 years$

$$T_{238} = 4.5 \times 10^6 years$$

Also, $\frac{N_{238}}{N_{235}} = 137.8$ and we assume $\frac{N_{0235}}{N_{0238}} = 1$, the maximum value with t = t_{max}.

$$\therefore \log_{10}137.8 = 0.4343 \times 0.693 \times t_{\max} \times (8.2 \times 10^{-8})$$

where t is in year

$$2.1302 = 0.4343 \times 0.693 \times t_{\max} \times 8.2 \times 10^{-8}$$

From which $t_{\max} = 6 \times 10^9 years$