# SOLVED EXAMPLES

**Ex.1** Calculate the electric potential energy due to the electric repulsion between two nuclei of $^{12}C$ when they 'touch' each other at the surface.

**Sol.** The radius of a $^{12}C$ nucleus is

$$R = R_0A^{1/3}$$
$$= (1.1\ \text{fm})(12)^{1/3} = 2.52\ \text{fm}.$$

The separation between the centres of the nuclei is 2R = 5.04 fm. The potential energy of the pair is

$$U = \frac{q_1q_2}{4\pi\varepsilon_0 r}$$

$$= (9 \times 10^9\ \text{N m}^2\ \text{C}^{-2})\ \frac{(6\times1.6\times10^{-19}\ \text{C})^2}{5.04\times10^{-15}\ \text{m}}$$

$$= 1.64 \times 10^{-12}\ \text{J} = 10.2\ \text{MeV}.$$

**Ex.2** Find the binding energy of $^{56}_{26}Fe$. Atomic mass of $^{56}Fe$ is 55.9349 u and that of $^1H$ is 1.00783 u. Mass of neutron = 1.00867 u.

**Sol.** The number of protons in $^{56}_{26}Fe$ = 26 and the number of neutrons = 56 – 26 = 30. The binding energy of $^{56}_{26}Fe$ is

$$= [26 \times 1.00783\ \text{u} + 30 \times 1.00867\ \text{u} - 55.9349\ \text{u}]c^2$$
$$= (0.52878\ \text{u})\ c^2$$
$$= (0.52878\ \text{u})\ (931\ \text{MeV u}^{-1}) = 492\ \text{MeV}.$$

**Ex.3** Find the kinetic energy of the α-particle emitted in the decay $^{238}Pu \rightarrow {}^{234}U + \alpha$. The atomic masses needed are as follows :

| $^{238}Pu$ | $^{234}U$ | $^{4}He$ |
|---|---|---|
| 238.04955 u | 234.04095 u | 4.002603 u |

Neglect any recoil of the residual nucleus.

**Sol.** Using energy conservation,

$$m(^{238}Pu)\ c^2 = m(^{234}U)c^2 + m(^4He)c^2 + K$$

or, $$K = [m(^{238}Pu) - m(^{234}U) - m(^4He)]c^2$$
$$= [238.04955\ \text{u} - 234.04095\ \text{u} - 4.002603\ \text{u}]\ (931\ \text{MeV u}^{-1})$$
$$= 5.58\ \text{MeV}.$$

**Ex.4** Calculate the Q-value in the following decays :

**(a)** $^{19}O \rightarrow {}^{19}F + e + \overline{v}$

**(b)** $^{25}Al \rightarrow {}^{25}Mg + e^+ + v$.

The atomic masses needed are as follows :

| $^{19}O$ | $^{19}F$ | $^{25}Al$ | $^{25}Mg$ |
|---|---|---|---|
| 19.003576 u | 18.998403 u | 24.990432 u | 24.985839 u |

**Sol.**

**(a)** The Q-value of $\beta^-$-decay is

$Q = [m(^{19}O) - m(^{19}F)]c^2$

$= [19.003576\ u - 18.998403\ u]\ (931\ MeV\ u^{-1})$

$= 4.816\ MeV.$

**(b)** The Q-value of $\beta^+$-decay is

$Q = [m(^{25}Al) - m(^{25}Mg) - 2m_e]c^2$

$= [24.990432\ u - 24.985839\ u - 2 \times 0.511\ MeV\ c^{-2}]\ c^2$

$= (0.004593\ u)\ (931\ MeV\ u^{-1}) - 1.022\ MeV$

$= 4.276\ MeV - 1.022\ MeV = 3.254\ MeV.$

**Ex.5** Find the maximum energy that a beta particle can have in the following decay

$$^{176}Lu \rightarrow\ ^{176}Hf + e + \bar{\nu}.$$

Atomic mass of $^{176}Lu$ is 175.942694 u and that of $^{176}Hf$ is 175.941420 u.

**Sol.** The kinetic energy available for the beta particle and the antineutrino is

$Q = [m(^{176}Lu) - m(^{176}Hf)]c^2$

$= (175.942694\ u - 175.941420\ u)\ (931\ MeVu^{-1})$

$= 1.182\ MeV.$

This energy is shared by the beta particle and the antineutrino. The maximum kinetic energy of a beta particle in this decay is, therefore, 1.182 MeV when the antineutrino practically does not get any share.

**Ex.6** Consider the beta decay

$$^{198}Au \rightarrow\ ^{198}Hg^* + \beta^- + \bar{\nu}$$

where $^{198}Hg^*$ represents a mercury nucleus in an excited state at energy 1.088 MeV above the ground state. What can be the maximum kinetic energy of the electron emitted ? The atomic mass of $^{198}Au$ is 197.968233 u and that of $^{198}Hg$ is 197.966760 u.

**Sol.** If the product nucleus $^{198}Hg$ is formed in its ground state, the kinetic energy available to the electron and the antineutrino is

$Q = [m(^{198}Au) - m(^{198}Hg)]\ c^2.$

As $^{198}Hg^*$ has energy 1.088 MeV more than $^{198}Hg$ in ground state, the kinetic energy actually available is

$Q = [m(^{198}Au) - m(^{198}Hg)]c^2 - 1.088\ MeV$

$= (197.968233\ u - 197.966760\ u)\ (931\ MeV\ u^{-1}) - 1.088\ MeV$

$= 1.3686\ MeV - 1.088\ MeV = 0.2806\ MeV$

This is also the maximum possible kinetic energy of the electron emitted.

**Ex.7** The half-life of $^{198}Au$ is 2.7 days. Calculate (a) the decay constant, (b) the average-life and (c) the activity of 1.00 mg of $^{198}Au$. Take atomic weight of $^{198}Au$ to be 198 g mol$^{-1}$.

**Sol.** **(a)** The half-life and the decay constant are related as

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

or, $$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{2.7 days}$$

$$= \frac{0.693}{2.7 \times 24 \times 3600 s} = 2.9 \times 10^{-6}\ s^{-1}.$$

**(b)** The average-life is $t_{av} = \frac{1}{\lambda} = 3.9$ days.

**(c)** The activity is $A = \lambda N$. Now, 198 g of $^{198}Au$ has $6 \times 10^{23}$ atoms. The number of atoms in 1.00 mg of $^{198}Au$ is

$$N = 6 \times 10^{23} \times \frac{1.0\,mg}{198\,g} = 3.03 \times 10^{18}.$$

Thus, $A = \lambda N$

$= (2.9 \times 10^{-6}\ s^{-1})\ (3.03 \times 10^{18})$

$= 8.8 \times 10^{12}$ disintegrations $s^{-1}$

$$= \frac{8.8 \times 10^{12}}{3.7 \times 10^{10}}\,Ci = 240\ Ci.$$

**Ex.8** A radioactive sample has $6.0 \times 10^{18}$ active nuclei at a certain instant. How may of these nuclei will still be in the same active state after two half-lives?

**Sol.** In one half-life the number of active nuclei reduces to half the original number. Thus, in two half-lives the number is reduced to $\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)$ of the original number. The numbher of remaining active nuclei is,

therefore,

$$6.0 \times 10^{18} \times \left(\frac{1}{2}\right) \times \left(\frac{1}{2}\right)$$

$$= 1.5 \times 10^{18}.$$

**Ex.9** The activity of a radioactive sample falls from 600 $s^{-1}$ to 500 $s^{-1}$ in 40 minutes. Calculate its half-life.

**Sol.** : We have,

$$A = A_0 e^{-\lambda t}$$

or, $500\ s^{-1} = (600\ s^{-1})e^{-\lambda t}$

or, $e^{-\lambda t} = \frac{5}{6}$

or, $\lambda t = \ln(6/5)$

or, $\lambda = \frac{\ln(6/5)}{t} = \frac{\ln(6/5)}{40\,min}$

The half-life is $t_{1/2} = \frac{\ln 2}{\lambda}$

$$= \frac{\ln 2}{\ln(6/5)} \times 40$$

$$= 152\ min.$$

**Ex.10** The number of $^{238}U$ atoms in an ancient rock equals the number of $^{206}Pb$ atoms. The half-life of decay of $^{238}U$ is $4.5 \times 10^{9}$ y. Estimate the age of the rock assuming that all the $^{206}Pb$ atoms are formed from the decay of $^{238}U$.

**Sol.** Since the number of $^{206}Pb$ atoms equals the number of $^{238}U$ atoms, half of the original $^{238}U$ atoms have decayed. It takes one half-life to decay half of the active nuclei. Thus, the sample is $4.5 \times 10^{9}$ y old.

**Ex.11** Equal masses of two samples of charcoal A and B are burnt separately and the resulting carbon dioxide are collected in two vessels. The radioactivity of $^{14}C$ is measured for both the gas samples. The gas from the charcoal A gives 2100 counts per week and the gas from the charcoal B gives 1400 counts per week. Find the age difference between the two samples. Half-life of $^{14}C$ = 5730 y.

**Sol.** The activity of sample A is 2100 counts per week. After a certain time t, its activity will be reduced to 1400 counts per week. This is because a fraction of the active $^{14}C$ nuclei will decay in time t. The sample B must be a time t older than the sample A.

We have,

$$A = A_0 e^{-\lambda t}$$

or, $$1400\ s^{-1} = 2100\ s^{-1}\ e^{-\lambda t}$$

or, $$e^{-\lambda t} = \frac{2}{3}$$

$$t = \frac{\ln(3/2)}{\lambda}$$

$$= \frac{0.4055}{0.693} \times 5730\ y = 3352\ y.$$

**Ex.12** Suppose, the daughter nucleus in a nucleus in a nuclear decay is itself radioactive. Let $\lambda_p$ and $\lambda_d$ be the decay constants of the parent and the daughter nuclei. Also, let $N_p$ and $N_d$ be the number of parent and daughter nuclei at time t. Find the condition for which the number of daughter nuclei becomes constant.

**Sol.** The number of parent nuclei decaying in a short time interval t to t + dt is $\lambda_p N_p dt$. This is also the number of daughter nuclei produced in this interval. The number of daughter nuclei decaying during the same time interval is $\lambda_d N_d dt$. The number of the daughter nuclei will be constant if

$$\lambda_p N_p dt = \lambda_d N_d dt$$

or, $$\lambda_p N_p = \lambda_d N_d$$

**Ex.13** A radioactive sample decays with an average-life of 20 ms. A capacitor of capacitance 100 μF is charged to some potential and then the plates are connected through a resistance R. What should be the value of R so that the ratio of the charge on the capacitor to the activity of the radioactive sample remains constant in time?

**Sol.** The activity of the sample at time t is given by

$$A = A_0 e^{-\lambda t}$$

where $\lambda$ is the decay constant and $A_0$ is the activity at time t = 0 when the capacitor plates are connected. The charge on the capacitor at time t is given by

$$Q = Q_0 e^{-t/CR}$$

where $Q_0$ is the charge at t = 0 and C = 100 μF is the capacitance. Thus,

$$\frac{Q}{A} = \frac{Q_0}{A_0}\frac{e^{-t/CR}}{e^{-\lambda t}}$$

It is independent of t if $\lambda = \frac{1}{CR}$

or, $$R = \frac{1}{\lambda C} = \frac{t_{av}}{C} = \frac{20 \times 10^{-3}\ s}{100 \times 10^{-6}\ F} = 200\,\Omega$$

**Ex.14** A radioactive nucleus can decay by two different process. the half-life for the first process is $t_1$ and that for the second process $t_2$. Show that the effective half-life t of the nucleus is given by

$$\frac{1}{t}=\frac{1}{t_1}+\frac{1}{t_2}$$

**Sol.** The decay constant for the first process is $\lambda_1=\frac{\ln 2}{t_1}$ and for the second process it is $\lambda_2=\frac{\ln 2}{t_1}$. The probability that an active nucleus decays by the first process in a time interval dt is $\lambda_1 dt$. Similarly, the probability that it decays by the second process is $\lambda_2 dt$. The probability that it either decays by the first process or by the second process is $\lambda_1 dt + \lambda_2 dt$. If the effective decay constant is $\lambda$, this probability is also equal to $\lambda dt$. Thus,

$$\lambda dt=\lambda_1 dt+\lambda_2 dt$$

or, $$\lambda=\lambda_1+\lambda_2$$

or, $$\frac{1}{t}=\frac{1}{t_1}+\frac{1}{t_2}.$$

**Ex.15** Calculate the energy released when three alpha particles combine to form a $_{12}C$ nucleus. The atomic mass of $^4_2He$ is 4.002603 u.

**Sol.** The mass of a $^{12}C$ atom is exactly 12 u. The energy released in the reaction $3\left(^4_2He\right)\rightarrow {}^{12}_6C$ is

$$[3m(^4_2He)-m(^{12}_6C]c^2$$

$$=[3\times 4.002603\text{ u}-12\text{ u}]\,(931\text{ MeV u}^{-1})=7.27\text{ MeV}.$$

# Exercise # 1

**[Single Correct Choice Type Questions]**

**1.** The stable nucleus that has a radius 1/3 that of $Os^{189}$ is -

**(A)** ${}_3Li^7$ **(B)** ${}_2He^4$ **(C)** ${}_5B^{10}$ **(D)** ${}_6C^{12}$

**2.** The mass number of a nucleus is

**(A)** always less than its atomic number

**(B)** always more than its atomic number

**(C)** equal to its atomic number

**(D)** sometimes more than and sometimes equal to its atomic number

**3.** As the mass number A increases, the binding energy per nucleon in a nucleus

**(A)** increases **(B)** decreases

**(C)** remains the same **(D)** varies in a way that depends on the actual value of A.

**4.** The energy of the reaction $Li^7 + p \longrightarrow 2\ He^4$ is (the binding energy per nucleon in $Li^7$ and $He^4$ nuclei are 5.60 and 7.06 MeV respectively.)

**(A)** 17.3 MeV **(B)** 1.73 MeV

**(C)** 1.46 MeV **(D)** depends on binding energy of proton

**5.** Which of the following is a wrong description of binding energy of a nucleus ?

**(A)** It is the energy required to break a nucleus into its constituent nucleons.

**(B)** It is the energy released when free nucleons combine to from a nucleus

**(C)** It is the sum of the rest mass energies of its nucleons minus the rest mass energy of the nucleus

**(D)** It is the sum of the kinetic energy of all the nucleons in the nucleus

**6.** A free neutron decays into a proton, an electron and :

**(A)** A neutrino **(B)** An antineutrino

**(C)** An $\alpha$-particle **(D)** A $\beta$-particle

**7.** An $\alpha$-particle is bombarded on ${}^{14}N$. As a result, a ${}^{17}O$ nucleus is formed and a particle is emitted. This particle is a

**(A)** neutron **(B)** proton **(C)** electron **(D)** positron

**8.** The atomic weight of boron is 10.81 g/mole and it has two isotopes ${}^{10}_{5}B$ and ${}^{11}_{5}B$. The ratio (by number) of ${}^{10}_{5}B : {}^{11}_{5}B$ in nature would be :

**(A)** 19 : 81 **(B)** 10 : 11 **(C)** 15 : 16 **(D)** 81 : 19

**9.** Nuclei X decay into nuclei Y by emitting $\alpha$ particles. Energies of $\alpha$ particle are found to be only 1 MeV & 1.4 MeV. Disregarding the recoil of nuclei Y. The energy of $\gamma$ photon emitted will be

**(A)** 0.8 MeV **(B)** 1.4 MeV **(C)** 1 MeV **(D)** 0.4 MeV

**10.** Two isotopes P and Q of atomic weight 10 and 20, respectively are mixed in equal amount by weight. After 20 days their weight ratio is found to be 1 : 4. Isotope P has a half-life of 10 days. The half-life of isotope Q is

**(A)** zero **(B)** 5 days **(C)** 20 days **(D)** inifinite

**11.** In one average-life

**(A)** half the active nuclei decay **(B)** less than half the active nuclei decay

**(C)** more than half the active nuclei decay **(D)** all the nuclei decay

**12.** A freshly prepared radioactive source of half-life 2 h emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is -

**(A)** 6 h **(B)** 12 h **(C)** 24 h **(D)** 128 h

**13.** $A \xrightarrow{\lambda} B \xrightarrow{2\lambda} C$

| | | | |
|---|---|---|---|
| t = 0 | $N_0$ | 0 | 0 |
| t | $N_1$ | $N_2$ | $N_3$ |

The ratio of $N_1$ to $N_2$ when $N_2$ is maximum is :

**(A)** at no time this is possible **(B)** 2

**(C)** 1/2 **(D)** $\frac{\ell n\ 2}{2}$

**14.** 10 grams of $^{57}Co$ kept in an open container beta-decays with a half-life of 270 days. The weight of the material inside the container after 540 days will be very nearly -

**(A)** 10 g **(B)** 7.5 g **(C)** 5 g **(D)** 2.5 g

**15.** $_{92}U^{235}$ nucleus absorbs a slow neutron and undergoes fission into $_{54}X^{139}$ and $_{38}Sr^{94}$ nuclei. The other particles produced in this fission process are

**(A)** 1 β and 1 α **(B)** 2 β and 1 neutron **(C)** 2 neturons **(D)** 3 neutrons

**16.** The half-life of $^{131}I$ is 8 days. Given a sample of $^{131}I$ at time t = 0, we can assert that

**(A)** No nucleus will decay before t = 4 days

**(B)** No nucleus will decay before t = 8 days

**(C)** All nuclei will decay before t = 16 days

**(D)** A given nucleus may decay at any time after t = 0.

**17.** Two lithium $^{6}Li$ nuclei in a lithium vapour at room temperature do not combine to form a carbon $^{12}C$ nucleus because

**(A)** a lithium nucleus is more tightly bound than a carbon nucleus

**(B)** carbon nucleus is an unstable particle

**(C)** it is not energetically favourable

**(D)** Coulomb repulsion does not allow the nuclei to come very close

**18.** Choose the statement which is true.

**(A)** The energy released per unit mass is more in fission than in fusion

**(B)** The energy released per atom is more in fusion than in fission.

**(C)** The energy released per unit mass is more in fusion and that per atom is more in fission.

**(D)** Both fission and fusion produce same amount of energy per atom as well as per unit mass.

**19.** In a uranium reactor whose thermal power is P = 100 MW, if the average number of neutrons liberated in each nuclear splitting is 2.5. Each splitting is assumed to release an energy E = 200 MeV. The number of neutrons generated per unit time is -

**(A)** $4 \times 10^{18}\ s^{-1}$ **(B)** $8 \times 10^{23}\ s^{-1}$ **(C)** $8 \times 10^{19}\ s^{-1}$ **(D)** $\frac{125}{16} \times 10^{18}\ s^{-1}$

**20.** In a fission reaction

$$^{236}_{92}U \longrightarrow {}^{117}X + {}^{117}Y + n + n$$

the average binding energy per nucleon of X and Y is 8.5 MeV whereas that of $^{236}U$ is 7.6 MeV. The total energy liberated will be about :

$$^{236}_{92}U \longrightarrow {}^{117}X + {}^{117}Y + n + n$$

**(A)** 200 keV **(B)** 2 MeV **(C)** 200 MeV **(D)** 2000 MeV

**21.** Fusion reaction is possible at high temperature because -

**(A)** atoms are ionised at high temperature

**(B)** molecules break-up at high temperature

**(C)** nuclei break-up at high temperature

**(D)** kinetic energy is high enough to overcome repulsion between nuclei.

**22.** Assuming that about 20 MeV of energy is released per fusion reaction, $_1H^2 + {}_1H^3 \rightarrow {}_0n^1 + {}_2He^4$, the mass of $_1H^2$ consumed per day in a future fusion reactor of power 1 MW would be approximately

**(A)** 0.1 gm **(B)** 0.01 gm **(C)** 1 gm **(D)** 10 gm

**23.** A heavy nucleus having mass number 200 gets disintegrated into two small fragments of mass number 80 and 120. If binding energy per nucleon for parent atom is 6.5 M eV and for daughter nuclei is 7 M eV and 8 M eV respectively, then the energy released in each decay will be :

**(A)** 200 M eV **(B)** – 220 M eV **(C)** 220 M eV **(D)** 180 M eV

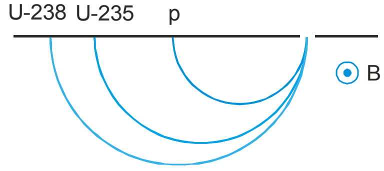
**24.** Let $F_{pp}$, $F_{pn}$ and $F_{nn}$ denote the magnitudes of the nuclear force by a proton on a proton, by a proton on a neutron and by a neutron on a neutron respectively. When the separation is 1 fm,

**(A)** $F_{pp} > F_{pn} = F_{nn}$ **(B)** $F_{pp} = F_{pn} = F_{nn}$ **(C)** $F_{pp} > F_{pn} > F_{nn}$ **(D)** $F_{pp} < F_{pn} = F_{nn}$

**25.** The graph of $\ell n(R/R_0)$ versus $\ell n A$ (R = radius of a nucleus and A = its mass number) is

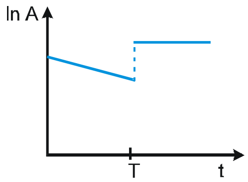
**(A)** a straight line **(B)** a parabola **(C)** an ellipse **(D)** none of them

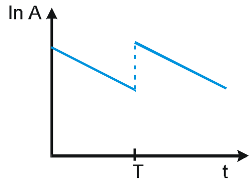
**26.** Protons and singly ionized atoms of $U^{235}$ & $U^{238}$ are passed in turn (which means one after the other and not at the same time) through a velocity selector and then enter a uniform magnetic field. The protons describe semicircles of radius 10 mm. The separation between the ions of $U^{235}$ and $U^{238}$ after describing semicircle is given by

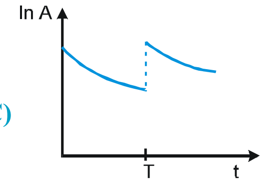


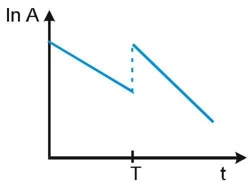

**(A)** 60 mm **(B)** 30 mm **(C)** 2350 mm **(D)** 2380 mm

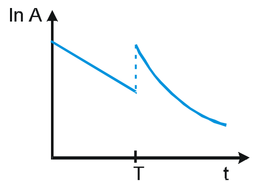
**27.** At time t = 0, some radioactive gas is injected into a sealed vessel. At time T, some more of the same gas is injected into the same vessel. Which one of the following graphs best represents the variation of the logarithm of the activity A of the gas with time t?

**(A)** 


**(B)** 


**(C)** 


**(D)** 


**(E)** 


**28.** When a $\beta^-$-particle is emitted from a nucleus, the neutron-proton ratio :

**(A)** is decreased  **(B)** is increased  **(C)** remains the same  **(D)** first (A) then (B)

**29.** A sample of radioactive material has mass *m*, decay constant $\lambda$, and molecular weight *M*. Avogadro constant = $N_A$. The initial acitvity of the sample is :

**(A)** $\lambda m$  **(B)** $\frac{\lambda m}{M}$  **(C)** $\frac{\lambda m N_A}{M}$  **(D)** $mN_Ae^{\lambda}$

**30.** **Match the following :**

| Column I | Column II |
|---|---|
| **(A)** Photoelectric effect | I. Photon |
| **(B)** Wave | II. Frequency |
| **(C)** X rays | III. K capture |
| **(D)** Nucleus | IV. $\gamma$ rays |

**(A)** a – I, b – II, c – III, d – IV  **(B)** a – II, b – I, c – IV, d – III
**(C)** a – II, b – I, c – III, d – IV  **(D)** None of these

**31.** Consider a sample of a pure beta-active material
**(A)** All the beta particles emitted have the same energy
**(B)** The beta particles originally exist inside the nucleus and are ejected at the time of beta decay
**(C)** The antineutrino emitted in a beta decay has zero rest mass and hence zero momentum.
**(D)** The active nucleus changes to one of its isobars after the beta decay

**32.** 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)** 2 : 1  **(C)** 1 : 1  **(D)** 1 : 4

**33.** A free neutron decays to a proton but a free proton does not decay to a neutron. This is because
**(A)** neutron is a composite particle made of a proton and an electron whereas proton is fundamental particle
**(B)** neutron is an uncharged particle whereas proton is a charged particle
**(C)** neutron has larger rest mass than the proton
**(D)** weak forces can operate in a neutron but not in a proton.

**34.** $A \xrightarrow{\lambda_1} B \xrightarrow{\lambda_2} C$

| | | | |
|---|---|---|---|
| $t = 0$ | $N_0$ | 0 | 0 |
| $t$ | $N_1$ | $N_2$ | $N_3$ |

In the above radioactive decay C is stable nucleus. Then:

**(A)** rate of decay of A will first increase and then decrease

**(B)** number of nuclei of B will first increase and then decrease

**(C)** if $\lambda_2 > \lambda_1$, then activity of B will always be higher than activity of A

**(D)** if $\lambda_1 >> \lambda_2$, then number of nucleus of C will always be less than number of nucleus of B.

**35.** Two identical samples (same material and same amount initially) P and Q of a radioactive substance having mean life T are observed to have activities $A_P$ & $A_Q$ respectively at the time of observation. If P is older than Q, then the difference in their ages is:

**(A)** $T\,\ell n\left(\frac{A_P}{A_Q}\right)$ **(B)** $T\,\ell n\left(\frac{A_Q}{A_P}\right)$ **(C)** $\frac{1}{T}\,\ell n\left(\frac{A_P}{A_Q}\right)$ **(D)** $T\left(\frac{A_P}{A_Q}\right)$

**36.** Radio isotope $^{234}Ra_{88}$ decays by a series emission of three β-particles and two α-particles. The end product X is

**(A)** $^{220}X_{88}$ **(B)** $^{226}X_{87}$ **(C)** $^{234}X_{90}$ **(D)** $^{216}X_{88}$

**37.** N atoms of a radioactive element emit n alpha particles per second at an instant. Then the half - life of the element is:

**(A)** $\frac{n}{N}$ sec. **(B)** $1.44\ \frac{n}{N}$ sec. **(C)** $0.69\ \frac{n}{N}$ sec. **(D)** $0.69\ \frac{N}{n}$ sec.

**38.** Masses of two isobars $^{64}_{29}Cu$ and $^{64}_{30}Zn$ are 63.9298 u and 63.9292 u respectively. It can be concluded from these data that :

**(A)** Both the isobars are stable

**(B)** $^{64}Zn$ is radioactive, decaying to $^{64}Cu$ through β-decay

**(C)** $^{64}Cu$ is radioactive, decaying to $^{64}Zn$ through γ-decay

**(D)** $^{64}Cu$ is radioactive, decaying to $^{64}Zn$ through β-decay

# Exercise # 2

## Part # I [Multiple Correct Choice Type Questions]

**1.** The heavier stable nuclei tend to have larger N/Z ratio because -

**(A)** a neutron is heavier than a proton

**(B)** a neutron is an unstable particle

**(C)** a neutron does not exert electric repulsion

**(D)** Coulomb forces have longer range compared to nuclear forces

**2.** If a nucleus $^{A}_{Z}x$ emits one $\alpha$ particle and one $\beta$ (negative $\beta$) particle in succession, then the daughter nucleus will have which of the following configurations?

**(A)** $A-4$ nucleons **(B)** 4 nucleons

**(C)** $A-Z-3$ neutrons **(D)** $Z-2$ protons

**3.** A $U^{238}$ sample of mass 1.0 g emits alpha particles at the rate $1.24 \times 10^4$ particles per second.
($N_A = 6.023 \times 10^{23}$)

**(A)** The half life of this nuclide is $4.5 \times 10^9$ years

**(B)** The half life of this nuclide is $9 \times 10^9$ years

**(C)** The activity of the prepared sample is $2.48 \times 10^4$ particles/sec

**(D)** The activity of the prepared sample is $1.24 \times 10^4$ particles/sec.

**4.** The decay constant of a radio active substance is 0.173 $(\text{years})^{-1}$. Therefore:

**(A)** Nearly 63% of the radioactive substance will decay in (1/0.173) year.

**(B)** half life of the radio active substance is (1/0.173) year.

**(C)** one -forth of the radioactive substance will be left after nearly 8 years.

**(D)** half of the substance will decay in one average life time.

Use approximation $\ell n2 = 0.692$

**5.** A nitrogen nucleus $_7N^{14}$ absorbs a neutron and can transform into lithium nucleus $_3Li^7$ under suitable conditions, after emitting

**(A)** 4 protons and 4 neutrons

**(B)** 5 protons and 1 negative beta particle

**(C)** 2 alpha particles and 2 gamma particles

**(D)** 1 alpha particle, 4 protons and 2 negative beta particles.

**6.** Let $m_p$ be the mass of a proton, $m_n$ the mass of a neutron, $M_1$ the mass of a $^{20}_{10}Ne$ nucleus & $M_2$ the mass of a $^{40}_{20}Ca$ nucleus. Then :

**(A)** $M_2 = 2 M_1$ **(B)** $M_2 > 2 M_1$ **(C)** $M_2 < 2 M_1$ **(D)** $M_1 < 10 (m_n + m_p)$

## Part # II [Assertion & Reason Type Questions]

In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it . Of the statements mark the correct answer as

**(A)** Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

**(B)** Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

**(C)** Statement-1 is True, Statement-2 is False

**(D)** Statement-1 is False, Statement-2 is True.

**1.** **Statement-1 :** Q- value of a reaction : $A + B \rightarrow C + Q$ is – 30 MeV. B is at rest. The minimum kinetic energy of bombarding nucleus A to initiate the nuclear reaction is 30 MeV.

**Statement-2 :** Momentum will conserve in the endoergic reaction also.

**2.** **Statement-1 :** ${}_{Z}X^{A}$ undergoes 2 $\alpha$ decays, $2\beta$ decays (negative $\beta$) and 2 $\gamma$ decays. As a result the daughter product is ${}_{Z-2}Y^{A-8}$.

**Statement-2 :** In $\alpha$ decay the mass number decreases by 4 unit and atomic number decreases by 2 unit. In $\beta$ decay (negative $\beta$) the mass number remains unchanged and atomic number increases by 1 unit. In $\gamma$ decay, mass number and atomic number remains unchanged.

**3.** **Statement-1 :** In spontaneous fission, the energy is always released.

**Statement-2 :** Spontaneous fission occurs to lower the binding energy of reactant nuclei.

# Exercise # 3

## Part # I [Matrix Match Type Questions]

**1.** In column-I, consider each process just before and just after it occurs. Initial system is isolated from all other bodies. Consider all product particles (even those having rest mass zero) in the system. Match the system in column-I with the result they produce in column-II.

| Column-I | Column-II |
|---|---|
| **(A)** Spontaneous radioactive decay of an uranium nucleus initially at rest as given by reaction ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + ...$ | **(P)** Number of protons is increased |
| **(B)** Fusion reaction of two hydrogen nuclei as given by reaction ${}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + .....$ | **(Q)** Momentum is conserved |
| **(C)** Fission of $U^{235}$ nucleus initiated by a thermal neutron as given by reaction ${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3{}^{1}_{0}n + ...$ | **(R)** Mass is converted to energy or vice versa |
| **(D)** $\beta^-$ decay (negative beta decay) | **(S)** Charge is conserved |

**2.** Match the column-I of properties with column-II of reactions

| Column-I | Column-II |
|---|---|
| **(A)** Mass of product formed is less than the original mass of the system in | **(P)** α-decay |
| **(B)** Binding energy per nucleon increase in | **(Q)** β-decay |
| **(C)** Mass number is conserved in | **(R)** Nuclear fission |
| **(D)** Charge number is conserved in | **(S)** Nuclear fusion |

**3.** Four physical quantities are listed in column I. Their values are listed in Column II in a random order.

| | Column I | | Column II |
|---|---|---|---|
| **(A)** | Thermal energy of air molecules at room temperature | **(E)** | 0.04 eV |
| **(B)** | Binding energy of heavy nuclei per nucleon | **(F)** | 2 eV |
| **(C)** | X–ray photon energy | **(G)** | 1 KeV |
| **(D)** | Photon energy of visible light | **(H)** | 7 MeV |

**The correct matching of columns I & II is given by :**

**(A)** A – E, B – H, C – G, D – F
**(B)** A – E, B – G, C – F, D – H
**(C)** A – F, B – E, C – G, D – H
**(D)** A – F, B – H, C – E, D – G

## Part # II [Comprehension Type Questions]

### Comprehension # 1

Consider the following nuclear decay : (initially ${}^{236}U_{92}$ is at rest)

$${}^{236}_{92}U \longrightarrow {}^{232}_{90}Th + X$$

**1.** Regarding this nuclear decay select the correct statement :
**(A)** The nucleus X may be at rest.
**(B)** The ${}^{232}_{90}Th$ nucleus may be in excited state.
**(C)** The X may have kinetic energy but ${}^{232}_{90}Th$ will be at rest
**(D)** The Q value is $\Delta mc^2$ where $\Delta m$ is mass difference of ( ${}^{236}_{92}U$ and ${}^{232}_{90}Th$ ) and c is speed of light.

**2.** If the uranium nucleus is at rest before its decay, which one of the following statement is true concerning the final nuclei ?

**(A)** They have equal kinetic energies, but the thorium nucleus has much more momentum.

**(B)** They have equal kinetic energies and momenta of equal magnitudes.

**(C)** The have momenta of equal magnitudes, but the thorium nucleus has much more kinetic energy.

**(D)** They have momentum of equal magnitudes, but X has much more kinetic energy.

**3.** Following atomic masses and conversion factor are provided

$^{236}_{92}U = 236.045\,562$ u ;

$^{232}_{90}Th = 232.038054$ u ;

$^{1}_{0}n = 1.008665$ u ; $^{1}_{1}p = 1.007277$ u ;

$^{4}_{2}He = 4.002603$ u and

$1\text{ u} = 1.5 \times 10^{-10}$ J

The amount of energy released in this decay is equal to :

**(A)** $3.5 \times 10^{-8}$ J **(B)** $4.6 \times 10^{-12}$ J **(C)** $6.0 \times 10^{-10}$ J **(D)** $7.4 \times 10^{-13}$ J

## Comprehension # 2

The radionuclide $^{56}$Mn is being produced in a cyclotron at a constant rate P by bombarding a maganese target with deutrons. $^{56}$Mn has a half life of 2.5 hours and the target contains large number of only the stable maganese isotope $^{55}$Mn. The reaction that produces $^{56}$Mn is :

$$^{55}Mn + d \rightarrow {}^{56}Mn + p$$

After being bombarded for a long time, the activity of $^{56}$Mn becomes constant equal to $13.86 \times 10^{10}\ s^{-1}$ .

(Use $\ell n2 = 0.693$; Avogadro No $= 6 \times 10^{23}$; atomic weight $^{56}$Mn = 56 gm/mole)

**1.** At what constant rate P, $^{56}$Mn nuclei are being produced in the cyclotron during the bombardment ?

**(A)** $2 \times 10^{11}$ nuclei/s **(B)** $13.86 \times 10^{10}$ nuclei/s **(C)** $9.6 \times 10^{10}$ nuclei/s **(D)** $6.93 \times 10^{10}$ nuclei/s

**2.** After the activity of $^{56}$Mn becomes constant, number of $^{56}$Mn nuclei present in the target, is equal to

**(A)** $5 \times 10^{11}$ **(B)** $20 \times 10^{11}$ **(C)** $1.2 \times 10^{14}$ **(D)** $1.8 \times 10^{15}$

**3.** After a long time bombardment, number of $^{56}$Mn nuclei present in the target depends upon

(A) the number of $^{56}$Mn nuclei present at the start of the process.

(B) half life of the $^{56}$Mn

(C) the constant rate of production P.

**(A)** All (A), (B) and (C) are correct **(B)** only (A) and (B) are correct

**(C)** only (B) and (C) are correct **(D)** only (A) and (C) are correct

# Exercise # 4 [Subjective Type Questions]

**If required, you can use the following data:**

**Mass of proton $m_p$ = 1.007276 u, Mass of $_1H^1$ atom = 1.007825 u, Mass of neutron $m_n$ = 1.008665 u, Mass of electron = 0.0005486 u = 511 KeV/$c^2$, 1 u = 931 MeV/$c^2$. $N_A = 6.023 \times 10^{23}$**

**Atomic mass of : $H^2$ = 2.01410 u, $Be^8$ = 8.00531u, $B^{11}$ = 11.00930u, $Li^7$ = 7.01601u, $He^4$ = 4.002603u.**

1. Find the binding energy of the nucleus of lithium isotope $_3Li^7$ and hence find the binding energy per nucleon in it.

2. A neutron star has a density equal to that of the nuclear matter($\approx 3 \times 10^{17}$ kg/m$^3$). Assuming the star to be spherical, find the radius of a neutron star whose mass is **(i)** $4.0 \times 10^{30}$ kg (twice the mass of the sun) **(ii)** $6 \times 10^{24}$ Kg (around mass of the earth).

3. Find the energy required for separation of a $_{10}Ne^{20}$ nucleus into two $\alpha$ – particles and a $_6C^{12}$ nucleus if it is known that the binding energies per nucleon in $_{10}Ne^{20}$, $_2He^4$ and $_6C^{12}$ nuclei are equal to 8.03, 7.07 and 7.68 MeV respectively.

4. In the decay $^{64}Cu \rightarrow {}^{64}Ni + e^+ + \nu$, the maximum kinetic energy carried by the positron is found to be 0.680 MeV **(a)** Find the energy of the neutrino which was emitted together with a positron of energy 0.180 MeV **(b)** What is the momentum of this neutrino in kg–m /s ? Use the formula applicable to photon.

5. The kinetic energy of an $\alpha$ – particle which flies out of the nucleus of a $Ra^{226}$ atom in radioactive disintegration is 4.78 MeV. Find the total energy evolved during the escape of the $\alpha$ – particle.

6. Calculate the specific activities of $Na^{24}$ & $U^{235}$ nuclides whose half lives are 15 hours and $7.1 \times 10^8$ years respectively.

7. How many $\beta$ – particles are emitted during one hour by 1.0 μg of $Na^{24}$ radionuclide whose half–life is 15 hours? [Take $e^{(-0.693/15)} = 0.955$, and avagadro number $= 6 \times 10^{23}$ ]

8. Beta decay of a free neutron takes place with a half life of 14 minutes. Then find **(a)** decay constant **(b)** energy liberated in the process.

9. Consider the case of bombardment of $U^{235}$ nucleus with a thermal neutron. The fission products are $Mo^{95}$ & $La^{139}$ and two neutrons. Calculate the energy released by one $U^{235}$ nucleus. (Rest masses of the nuclides are $U^{235}$ = 235.0439 u, ${}^1_0n$ = 1.0087 u, $Mo^{95}$ = 94.9058 u, $La^{139}$ = 138.9061 u).

10. Consider a point source emitting $\alpha$-particles and receptor of area 1 cm$^2$ placed 1 m away from source. Receptor records any $\alpha$-particle falling on it. If the source contains $N_0 = 3.0 \times 10^{16}$ active nuclei and the receptor records a rate of A = 50000 counts/second, find the decay constant. Assume that the source emits alpha particles uniformly in all directions and the alpha particles fall nearly normally on the window.

11. Energy evolved from the fusion reaction $2\,{}^2_1H = {}^4_2He + Q$ is to be used for the production of power. Assuming the efficiency of the process to be 30 %. Find the mass of deuterium that will be consumed in a second for an output of 50 MW.

**12.** For the D–T fusion reaction, find the rate at which deuterium & tritium are consumed to produce 1 MW. The Q–value of D–T reaction is 17.6 MeV & assume all the energy from the fusion reaction is available.

**13.** A radioactive isotope is being produced at a constant rate dN/dt = R in an experiment .The isotope has a half-life $t_{1/2}$. Show that after a time $t >> t_{1/2}$, the number of active nuclei will become constant. Find the value of this constant. Suppose the production of the radioactive isotope starts at t = 0. Find the number of active nuclei at time t.

**14.** The half-life of $^{40}K$ is $T = 1.30 \times 10^{9}$ y. A sample of m = 1.00 g of pure KCI gives c = 480 counts/s. Calculate the relative percentage abundance of $^{40}K$ (fraction of $^{40}K$ present in term of number of atoms) in natural potassium. Molecular weight of KCl is M = 74.5, Avogadro number $N_A = 6.02 \times 10^{23}$, $1y = 3.15 \times 10^7$ s

**15.** A charged capacitor of capacitance C is discharged through a resistance R. A radioactive sample decays with an average life τ. Find the value of R for which the ratio of the electrostatic field energy stored in the capacitor to the activity of the radioactive sample is independent of time.

**16.** A $Bi^{210}$ radionuclide decays via the chain $Bi^{210} \xrightarrow[\lambda_1]{\beta^- - \text{decay}} Po^{210} \xrightarrow[\lambda_2]{\alpha - \text{decay}} Pb^{206}$ (stable), where the decay constants are $\lambda_1 = 1.6 \times 10^{-6}\ s^{-1}$, $T_{1/2} \approx 5$ days , $\lambda_2 = 5.8 \times 10^{-8}\ s^{-1}$, $T_{1/2} \approx 4.6$ months. Calculate α & β activities of the $Bi^{210}$ sample of mass 1.00 mg a month after its manufacture. $2^{-\frac{1}{4.6}} = 0.86$

**17.** Knowing the decay constant λ of a substance, find the probability of decay of a nucleus during the time from 0 to t.

**18.** About 185 MeV of usable energy is released in the neutron induced fissioning of a $^{235}_{92}U$ nucleus. If the reactor using $^{235}_{92}U$ as fuel continuously generates 100 MW of power how long will it take for 1 Kg of the uranium $^{235}_{92}U$ to be used up?

**19.** Consider a fusion reaction

$$^4He + {}^4He = {}^8Be.$$

For the reaction find.

**(1)** mass defect

**(2)** Q-value

**(3)** Is such a fusion energetically favourable? Atomic mass of $^8Be$ is 8.0053 u and that of $^4He$ is 4.0026 u.

**20.** A sample has two isotopes $A^{150}$ and B having masses 50 g and 30 g respectively. A is radioactive and B is stable. A decays to A′ by emitting α particles. The half life of A is 2 hrs. Find the mass of total sample after 4 hours and number of α particles emitted.

**21.** The $_{92}U^{235}$ absorbs a slow neutron (thermal neutron) & undergoes a fission represented by

$$_{92}U^{235} + {}_0n^1 \longrightarrow {}_{92}U^{236} \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_0n^1 + E.$$ Calculate:

**(i)** The energy released E per fission.

**(ii)** The energy released when 1 g of $_{92}U^{235}$ undergoes complete fission.

Given $_{92}U^{235} = 235.1175$ amu (atom) ;
$_{56}Ba^{141} = 140.9577$ amu (atom);
$_{36}Kr^{92} = 91.9264$ amu (atom) ; $_0n^1 = 1.00898$ amu, 1 amu = 931 MeV/$C^2$

**22.** To activate the reaction (n, α) with stationary $B^{11}$ nuclei, neutrons must have the activation kinetic energy $T_{th}$ = 4.0 MeV. (n, α) means that n is bombarded to obtain α. Find the energy of this reaction.

**23.** Consider a nuclear reaction A + B → C. A nucleus 'A' moving with kinetic energy of 5 MeV collides with a nucleus 'B' moving with kinetic energy of 3 MeV and form a nucleus 'C' in excited state. Find the kinetic energy of nucleus 'C' just after its formation, if it is formed in a state with excitation energy 10 MeV. Take masses of nuclei of A, B and C as 25.0, 10.0, 34.995 amu respectively. 1 amu = 930 MeV/$c^2$.

**24.** A radionuclide with half life T = 693.1 days emits β-particles of average kinetic energy $E = 8.4 \times 10^{-14}$ joule. This radionuclide is used as source in a machine which generates electrical energy with efficiency η = 12.6%. Calculate number of moles of the nuclide required to generate electrical energy at an initial rate P = 441 KW. ($\log_e 2 = 0.6931$) $N_A = 6.023 \times 10^{23}$

**25.** Find the Q value of the reaction

$$N^{14} + \alpha \longrightarrow O^{17} + p$$

The masses of $N^{14}$, $He^4$, $H^1$, $O^{17}$ are respectively
14.00307 u, 4.00260 u, 1.00783 u and 16.99913 u.
Find the total kinetic energy of the products if the striking α particle has the minimum kinetic energy required to initiate the reaction. 1 amu = 931.5 MeV/$C^2$

**26.** The element Curium $^{248}_{96}Cm$ has a mean life of $10^{13}$ seconds. Its primary decay modes are spontaneous fission and α-decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200 MeV of energy. The masses involved in α-decay are as follows : atomic masses of atoms are $^{248}_{96}Cm$ = 248.072220 u , $He^4$ = 4.002603 u & $Pu^{244}$ = 244.064100 u. (1 u = 931 MeV/$c^2$). Calculate the power output from a sample of $10^{20}$ Cm atoms.

**27.** Assuming the radius of a nucleus to be equal to $R = 1.3\ A^{1/3} \times 10^{-15}$ m, where A is its mass number, evaluate the density of nuclei and the number of nucleons per unit volume of the nucleus. Take mass of one nucleon = $1.67 \times 10^{-27}$ kg

**28.** Nucleus $_3A^7$ has binding energy per nucleon of 10 MeV. It absorbs a proton and its mass increases by $\frac{99}{100}$ times the mass of proton. Find the new binding energy of the nucleus so formed. [Take energy equivalent of proton = 930 MeV]

# Exercise # 5

## Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

**1.** If $N_0$ is the original mass of the substance of half-life period $t_{1/2}$ = 5 years, then the amount of substance left after 15 years is : **(AIEEE 2002)**

**(1)** $N_0 / 8$ **(2)** $N_0 / 16$ **(3)** $N_0 / 2$ **(4)** $N_0 / 4$

**2.** Which of the following radiations has the least wavelength? **(AIEEE 2003)**

**(1)** $\gamma$-rays **(2)** $\beta$-rays **(3)** $\alpha$-rays **(4)** X-rays

**3.** When $U^{238}$ nucleus originally at rest, decays by emitting an alpha particle having a speed u, the recoil speed of the residual nucleus is : **(AIEEE 2003)**

**(1)** $\frac{4u}{238}$ **(2)** $-\frac{4u}{234}$ **(3)** $\frac{4u}{234}$ **(4)** $-\frac{4u}{238}$

**4.** A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute. After 5 minutes, the rate is 1250 disintegrations per minute. Then, the decay constant (per minute) is : **(AIEEE 2003)**

**(1)** 0.4 ln 2 **(2)** 0.2 ln 2 **(3)** 0.1 ln 2 **(4)** 0.8 ln 2

**5.** A nucleus with Z = 92 emits the following in a sequence : $\alpha, \alpha, \beta^-, \beta^-, \alpha, \alpha, \alpha, \alpha; \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$. The Z of the resulting nucleus is : **AIEEE 2003)**

**(1)** 76 **(2)** 78 **(3)** 82 **(4)** 74

**6.** Which of the following cannot be emitted by radioactive substances during their decay? **(AIEEE 2003)**

**(1)** Protons **(2)** Neutrinos **(3)** Helium nuclei **(4)** Electrons

**7.** In the nuclear fusion reaction, **(AIEEE 2003)**

$$_1^2H + _1^3H \longrightarrow _2^4He + n$$

given that the repulsive potential energy between the two nuclei is ~ $7.7 \times 10^{-14}$ J, the temperature at which the gases must be heated to initiate the reaction is nearly (Boltzmann's constant k = $1.38 \times 10^{-23}$ J/K): **(AIEEE 2003)**

**(1)** $10^7$ K **(2)** $10^5$ K **(3)** $10^3$ K **(4)** $10^9$ K

**8.** A nucleus disintegrates into two nuclear parts which have their velocities in the ratio 2 : 1. The ratio of their nuclear sizes will be : **(AIEEE 2004)**

**(1)** $2^{1/3} : 1$ **(2)** $1 : 3^{1/2}$ **(3)** $3^{1/2} : 1$ **(4)** $1 : 2^{1/3}$

**9.** The binding energy per nucleon of deuteron $\left(_1^2H\right)$ and helium nucleus $\left(_2^4He\right)$ is 1.1 MeV and 7 MeV respectively. If two deuteron nuclei react to form a single helium nucleus, then the energy released is : **(AIEEE 2004)**

**(1)** 13.9 MeV **(2)** 26.9 MeV **(3)** 23.6 MeV **(4)** 19.2 MeV

**10.** An $\alpha$-particle of energy 5 MeV is scattered through 180º by a fixed uranium nucleus. The distance of the closest approach is of the order of : **(AIEEE 2004)**

**(1)** 1 Å **(2)** $10^{-10}$ cm **(3)** $10^{-12}$ cm **(4)** $10^{-15}$ cm

**11.** Starting with a sample of pure $^{66}Cu$, 7/8 of it decays into Zn in 15 minutes. The corresponding half-life is : **(AIEEE 2005)**

**(1)** 10 minute  **(2)** 15 minute  **(3)** 5 minute  **(4)** $7\frac{1}{2}$ minute

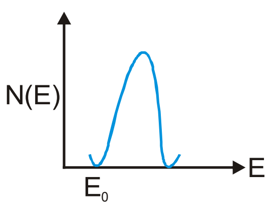
**12.** If radius of the $^{27}_{13}Al$ nucleus is estimated to be 3.6 Fermi, then the radius of $^{125}_{52}Te$ nucleus be nearly : **(AIEEE 2005)**

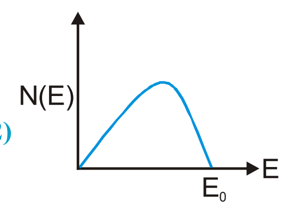
**(1)** 6 Fermi  **(2)** 8 Fermi  **(3)** 4 Fermi  **(4)** 5 Fermi

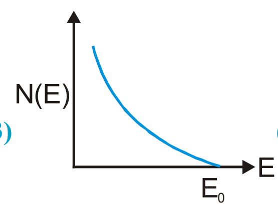
**13.** A nuclear transformation is denoted by $X(n, \alpha) \rightarrow {}^7_3Li$. Which of the following is the nucleus of element X? **(AIEEE 2005)**

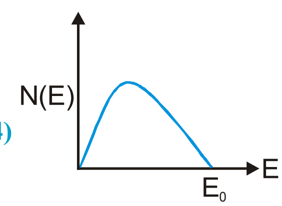
**(1)** $^{12}_{6}C$  **(2)** $^{10}_{5}B$  **(3)** $^{9}_{5}B$  **(4)** $^{11}_{4}Be$

**14.** The energy spectrum of β-particles (number N(E) as a function of β-energy E) emitted from a radioactive source is : **(AIEEE 2006)**

**(1)** 


**(2)** 


**(3)** 


**(4)** 


**15.** When $_3Li^7$ nuclei are bombarded by protons, and the resultant nuclei are $_4Be^8$, the emitted particles will be **(AIEEE 2006)**

**(1)** neutrons  **(2)** alpha particles  **(3)** beta particles  **(4)** gamma photons

**16.** The 'rad' is the correct unit used to report the measurement of **(AIEEE 2006)**

**(1)** the rate of decay of radioactive source
**(2)** the ability of a beam of gamma ray photons to produce ions in a target
**(3)** the energy delivered by radiation to a target.
**(4)** the biological effect of radiation

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

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

energy of proton must be : **(AIEEE 2006)**

**(1)** 39.2 MeV  **(2)** 28.24 MeV  **(3)** 17.28 MeV  **(4)** 1.46 MeV

**18.** If $M_o$ is the mass of an oxygen isotope $_8O^{17}$, $M_p$ and $M_N$ are the masses of a proton and a neutron respectively, the nuclear binding energy of the isotope is : **[AIEEE 2007]**

**(1)** $(M_o - 8M_P)C^2$  **(2)** $(M_o - 8M_P - 9M_N)C^2$  **(3)** $M_oC^2$  **(4)** $(M_o - 17M_N)C^2$

**19.** In gamma ray emission from a nucleus : **[AIEEE 2007]**

**(1)** both the neutron number and the proton number change
**(2)** there is no change in the proton number and the neutron number
**(3)** only the neutron number changes
**(4)** only the proton number changes

**20.** The half-life period of a radio-active element X is same as the mean life time of another radio-active element Y. Initially they have the same number of atoms. Then : **[AIEEE 2007]**

**(1)** X will decay faster than Y **(2)** Y will decay faster than X

**(3)** X and Y have same decay rate initially **(4)** X and Y decay at same rate always

**21.** This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements. **[AIEEE 2008]**

**Statement-1 :** Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion.

and

**Statement-2 :**

For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z.

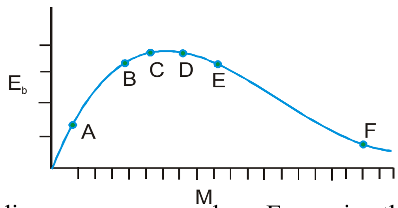
**(1)** Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1

**(2)** Statment-1 is true, Statement-2 is true; Statement-2 is not a correct explanation for Statement-1

**(3)** Statement-1 is true, Statement-2 is false

**(4)** Statement-1 is false, Statement-2 is true

**22.**




The above is a plot of binding energy per nucleon $E_b$, agains the nuclear mass M; A, B, C, D, E, correspond to different nuclei. Consider four reactions : **[AIEEE 2009]**

**(i)** $A + B \rightarrow C + \varepsilon$ **(ii)** $C \rightarrow A + B + \varepsilon$ **(iii)** $D + E \rightarrow F + \varepsilon$ and **(iv)** $F \rightarrow D + E + \varepsilon$,
where $\varepsilon$ is the energy released? In which reactions is $\varepsilon$ positive?

**(1)** (i) and (iii) **(2)** (ii) and (iv) **(3)** (ii) and (iii) **(4)** (i) and (iv)

**Directions :** Question number 23 – 25 are based on the following paragraph.

The nucleus of mass $M + \Delta m$ is at rest and decays into two daughter nuclei of equal mass $\frac{M}{2}$ each.. Speed of light is c.

**[AIEEE 2010]**

**23.** This binding energy per nucleon for the parent nucleus is $E_1$ and that for the daughter nuclei is $E_2$. Then :

**(1)** $E_1 = 2E_2$ **(2)** $E_1 > E_2$ **(3)** $E_2 > E_1$ **(4)** $E_2 = 2E_1$

**24.** The speed of daughter nuclei is

**(1)** $c\,\frac{\Delta m}{M + \Delta m}$ **(2)** $c\sqrt{\frac{2\Delta m}{M}}$ **(3)** $c\sqrt{\frac{\Delta m}{M}}$ **(4)** $c\sqrt{\frac{\Delta m}{M + \Delta m}}$

**25.** A radioactive nucleus (initial mass number A and atomic number Z) emits 3 $\alpha$-particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be

**(1)** $\frac{A - Z - 8}{Z - 4}$ **(2)** $\frac{A - Z - 4}{Z - 8}$

**(3)** $\frac{A - Z - 12}{Z - 4}$ **(4)** $\frac{A - Z - 4}{Z - 2}$

**26.** The half life of a radioactive substance is 20 minutes. The approximate time interval $(t_2 - t_1)$ between the time $t_2$ when $\frac{2}{3}$ of it has decayed and time $t_1$ when $\frac{1}{3}$ of it had decayed is : **[AIEEE - 2011]**

**(1)** 7 min **(2)** 14 min **(3)** 20 min **(4)** 28 min

**27.** **Statement - 1 :**
A nucleus having energy $E_1$ decays by $\beta^-$ emission to daughter nucleus having energy $E_2$, but the $\beta^-$ rays are emitted with a continuous energy spectrum having end point energy $E_1 - E_2$.
**Statement - 2:**
To conserve energy and momentum in β-decay at least three particles must take part in the transformation. **[AIEEE 2011]**

**(1)** Statement-1 is correct but statement-2 is not correct.
**(2)** Statement-1 and statement-2 both are correct and stateemnt-2 is the correct explanation of statement-1.
**(3)** Statement-1 is correct, statement-2 is correct and statement-2 is not the correct explanation of statement-1
**(4)** Statement-1 is incorrect, statement-2 is correct.

**28.** Assume that a neutron breaks into a proton and an electron. The energy released during this process is :
(mass of neutron = $1.6725 \times 10^{-27}$ kg, Mass of proton = $1.6725 \times 10^{-27}$ kg, mass of electron = $9 \times 10^{-31}$ kg) **[AIEEE 2012]**

**(1)** 0.73 MeV **(2)** 7.10 MeV **(3)** 6.30 MeV **(4)** 5.4 MeV

**29.** In a hydrogen like atom electron make transition from an energy level with quantum number n to another with quantum number (n–1). If n>>1, the frequency of radiation emitted is proportional to : **[JEE-Mains 2013]**

**(1)** $\frac{1}{n}$ **(2)** $\frac{1}{n^2}$ **(3)** $\frac{1}{n^{3/2}}$ **(4)** $\frac{1}{n^3}$

**30.** Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes respectively. Initially, the samples have equal number of nuclei. After 80 minutes, the ratio of decayed numbers of A and B nuclei will be : **[JEE-Main 2016]**

**(1)** 4 : 1 **(2)** 1 : 4 **(3)** 5 : 4 **(4)** 1 : 16

## Part # II [Previous Year Questions][IIT-JEE ADVANCED]

**1.** **(I)** Which of the following processes represents a gamma decay?

**(A)** ${}^{A}X_{Z} + \gamma \longrightarrow {}^{A}X_{Z-1} + a + b$
**(B)** ${}^{A}X_{Z} + {}^{1}n_{0} \longrightarrow {}^{A-3}X_{Z-2} + c$
**(C)** ${}^{A}X_{Z} \longrightarrow {}^{A}X_{Z} + f$
**(D)** ${}^{A}X_{Z} + e_{-1} \longrightarrow {}^{A}X_{Z-1} + g$

**(II)** The half life of ${}^{215}At$ is 100 µs. The time taken for the radioactivity of a sample of ${}^{215}At$ to decay to $1/16^{th}$ of its initial value is : **[JEE 2002]**

**(A)** 400 µs **(B)** 6.3 µs **(C)** 40 µs **(D)** 300 µs

**2.** A nucleus with mass number 220 initially at rest emits an α-particle. If the Q value of the reaction is 5.5 MeV, calculate the kinetic energy of the α-particle **[JEE 2003]**

**(A)** 4.4 MeV **(B)** 5.4 MeV **(C)** 5.6 MeV **(D)** 6.5 MeV

**3.** For uranium nucleus how does its mass vary with volume? **[JEE 2003]**

**(A)** $m \propto V$ **(B)** $m \propto 1/V$ **(C)** $m \propto \sqrt{V}$ **(D)** $m \propto V^2$

**4.** A radioactive material decays by β-particle emission. During the first 2 seconds of a measurement, *n* β-particles are emitted and the next 2 seconds 0.75 *n* β-particles are emitted. Calculate the mean-life of this material in seconds to the nearest whole number. ($\ell n\, 3 = 1.0986$ and $\ell n\, 2 = 0.6931$). **[JEE 2003]**

**5.** A 280 days old sample of a radioactive substance has activity of 6000 dps. In next 140 days activity falls to 3000 dps. Then initial activity of sample would have been **[JEE 2004]**

**(A)** 9000 **(B)** 24000 **(C)** 12,000 **(D)** 18,000

**6.** The age of a rock containing lead and uranium is equal to $1.5 \times 10^9$ yrs. The uranium is decaying into lead with half life equal to $4.5 \times 10^9$ yrs. Find the ratio of lead to uranium present in the rock, assuming initially no lead was present in the rock. (Given $2^{1/3} = 1.259$) **[JEE 2004]**

**7.** Helium nuclei combine to form an oxygen nucleus. The energy released in the reaction is if $m_O = 15.9994$ amu and $m_{He} = 4.0026$ amu **[JEE 2005]**

**(A)** 10.24 MeV **(B)** 0 MeV **(C)** 5.24 MeV **(D)** 4 MeV

**8.** Half life of a radio active substance 'A' is 4 days. The probability that a nucleus will decay in two half lives is: **[JEE 2006]**

**(A)** $\frac{1}{4}$ **(B)** $\frac{3}{4}$ **(C)** $\frac{1}{2}$ **(D)** 1

**9.** **Match the following** **[JEE 2006]**

| Column 1 | Column 2 |
|---|---|
| **(A)** Nuclear fission | **(P)** Converts some matter into energy |
| **(B)** Nuclear fusion | **(Q)** Possible for nuclei with low atomic number |
| **(C)** β - decay | **(R)** Possible for nuclei with high atomic number |
| **(D)** Exothermic nuclear reaction | **(S)** Essentially proceeds by weak nuclear forces. |

**10.** In the options given below, let E denote the rest mass energy of a nucleus and n a neutron. The correct options is : **[IIT-JEE 2007]**

**(A)** $E\left({}^{236}_{92}U\right) > E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$
**(B)** $E\left({}^{236}_{92}U\right) < E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$
**(C)** $E\left({}^{236}_{92}U\right) < E\left({}^{140}_{56}Ba\right) + \left({}^{94}_{36}Kr\right) + 2E(n)$
**(D)** $E\left({}^{236}_{92}U\right) = E\left({}^{140}_{56}Ba\right) + E\left({}^{94}_{36}Kr\right) + 2E(n)$

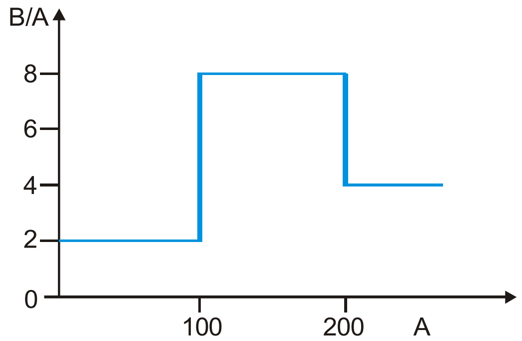
**11.** Some laws / processes are given in Column I. Match these with the physical phenomena given in Column II and indicate your answer by darkening appropriate bubbles in the 4 × 4 matrix given in the ORS.

**[IIT-JEE 2007]**

| | Column I | | Column II |
|---|---|---|---|
| (A) | Transition between two atomic energy levels | (P) | Characteristic X-rays |
| (B) | Electron emission from a material | (Q) | Photoelectric effect |
| (C) | Mosley's law | (R) | Hydrogen spectrum |
| (D) | Change of photon energy into kinetic energy of electrons | (S) | β-decay |

**12.** Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is as shown in the figure. Use this plot to choose the correct choice(s) given below. **[JEE 2008]**

Figure :




**(A)** Fusion of two nuclei with mass numbers lying in the range of $1 < A < 50$ will release energy

**(B)** Fusion of two nuclei with mass numbers lying in the range of $51 < A < 100$ will release energy

**(C)** Fission of a nucleus lying in the mass range of $100 < A < 200$ will release energy when broken into two equal fragments

**(D)** Fission of a nucleus lying in the mass range of $200 < A < 260$ will release energy when broken into two equal fragments

**13.** A radioactive sample $S_1$ having an activity of 5μCi has twice the number of nuclei as another sample $S_2$ which has an activity of 10μCi. The half lives of $S_1$ and $S_2$ can be **[JEE 2008]**

**(A)** 20 years and 5 years, respectively
**(B)** 20 years and 10 years, respectively
**(C)** 10 years each
**(D)** 5 years each

**Paragraph for Question Nos. 14 to 16** **[JEE 2009]**

Scientists are working hard to develop nuclear fusion reactor. Nuclei of heavy hydrogen, ${}_1^2H$, known as deuteron and denoted by D, can be thought of as a candidate for fusion reactor. The D-D reaction is ${}_1^2H + {}_1^2H \rightarrow {}_2^3He + n + \text{energy}$. In the core of fusion reactor, a gas of heavy hydrogen is fully ionized into deuteron nuclei and electrons. This collection of ${}_1^2H$ nuclei and electrons is known as plasma. The nuclei move randomly in the reactor core and occasionally come close enough for nuclear fusion to take place. Usually, the temperatures in the reactor core are too high and no material wall can be used to confine the plasma. Special techniques are used which confine the plasma for a time $t_0$ before the particles fly away from the core. If n is the density (number/volume) of deuterons, the product $nt_0$ is called Lawson number. In one of the criteria, a reactor is termed successful if Lawson number is greater than $5\times10^{14}$ s/cm$^3$.

It may be helpful to use the following: Boltzman constant $k = 8.6\times10^{-5}$ eV/K ; $\frac{e^2}{4\pi\varepsilon_0} = 1.44 \times 10^{-9}$ eVm.

**14.** In the core of nuclear fusion reactor, the gas becomes plasma because of
**(A)** strong nuclear force acting between the deuterons
**(B)** Coulomb force acting between the deuterons
**(C)** Coulomb force acting between deuterons-electrons pairs
**(D)** the high temperature maintained inside the reactor core

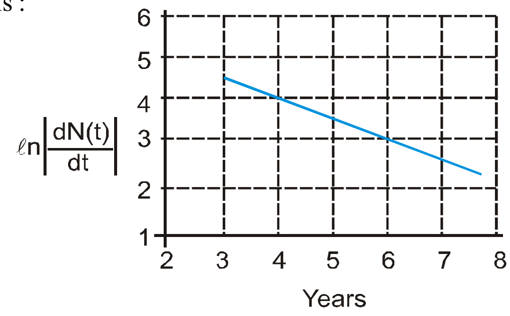
**15.** Assume that two deuteron nuclei in the core of fusion reactor at temperature T are moving towards each other, each with kinetic energy 1.5 kT, when the separation between them is large enough to neglect Coulomb potential energy. Also neglect any interaction from other particles in the core. The minimum temperature T required for them to reach a separation of $4 \times 10^{-15}$ m in the range.
**(A)** $1.0 \times 10^9 K < T < 2.0 \times 10^9 K$ **(B)** $2.0 \times 10^9 K < T < 3.0 \times 10^9 K$
**(C)** $3.0 \times 10^9 K < T < 4.0 \times 10^9 K$ **(D)** $4.0 \times 10^9 K < T < 5.0 \times 10^9 K$

**16.** Results of calculations for four different designs of a fusion reactor using D-D reaction are given below. Which of these is most promising based on Lawson criterion ?
**(A)** deuteron density = $2.0 \times 10^{12}$ cm$^{-3}$, confinement time = $5.0 \times 10^{-3}$ s
**(B)** deuteron density = $8.0 \times 10^{14}$ cm$^{-3}$, confinement time = $9.0 \times 10^{-1}$ s
**(C)** deuteron density = $4.0 \times 10^{23}$ cm$^{-3}$, confinement time = $1.0 \times 10^{-11}$ s
**(D)** deuteron density = $1.0 \times 10^{24}$ cm$^{-3}$, confinement time = $4.0 \times 10^{-12}$ s

**17.** Column II gives certain systems undergoing a process. Column I suggests changes in some of the parameters related to the system. Match the statements in Column-I to the appropriate process(es) from Column II. **[JEE 2009]**

| Column–I | Column–II |
|---|---|
| **(A)** The energy of the system is increased. | **(P)** System: A capacitor, initially uncharged<br>Process: It is connected to a battery. |
| **(B)** Mechanical energy is provided to the system, which is converted into energy of random motion of its parts | **(Q)** System: A gas in an adiabatic container fitted with an adiabatic piston<br>Process: The gas is compressed by pushing the piston |
| **(C)** Internal energy of the system is converted into its mechanical energy | **(R)** System: A gas in a rigid container<br>Process: The gas gets cooled due to colder atmosphere surrounding it |
| **(D)** Mass of the system is decreased | **(S)** System: A heavy nucleus, initially at rest<br>Process: The nucleus fissions into two fragments of nearly equal masses and some neutrons are emitted |
| | **(T)** System: A resistive wire loop<br>Process: The loop is placed in a time varying magnetic field perpendicular to its plane |

**18.** To determine the half life of a radioactive element, a student plots a graph of $\ell n\left|\frac{dN(t)}{dt}\right|$ versus t. Here $\frac{dN(t)}{dt}$ is the rate of radioactive decay at time t. If the number of radioactive nuclei of this element decreases by a factor of p after 4.16 years, the value of p is : **[JEE 2010]**



**19.** The activity of a freshly prepared radioactive sample is $10^{10}$ disintegrations per second, whose mean life is $10^9$ s. The mass of an atom of this radioisotope is $10^{-25}$ kg. The mass (in mg) of the radioactive sample is **[IIT-JEE 2011]**

**20.** A proton is fired from very far away towards a nucleus with charge Q = 120 e, where e is the electronic charge. It makes a closest approach of 10 fm to the nucleus. The de Brogle wavelength (in units of fm) of the proton at its start is :

(take the proton mass, $m_p = (5/3) \times 10^{-27}$ kg, $h/e = 4.2 \times 10^{-15}$ J.s/C ; $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ m/F ; 1 fm = $10^{-15}$ m)

**[IIT-JEE-2012]**

**Paragraph for Questions 21 and 22**

The β- decay process, discovered around 1900, is basically the decay of a neutron (n), In the laboratory, a proton (p) and an electron ($e^-$) are observed as the decay products of the neutron. therefore, considering the decay of a neutron as a tro-body dcay process, it was predicted theoretically that thekinetic energy of the electron should be a constant. But experimentally, it was observed that the electron kinetic energy has a continuous spectrum. Considering a three-body decay process, i.e. $n \to p + e^- + \bar{\nu}_e$, around 1930, Pauli explained the observed electron energy spectrum. Assuming the anti-neutrino ($\bar{\nu}_e$) to be massless and possessing negligible energy, and neutron to be at rest, momentum and energy conservation principles are applied. From this calculation, the maximum kinetic energy of the lectron is $0.8 \times 10^6$ eV. The kinetic energy carried by the proton is only the recoil energy.

**21.** What is the maximum energy of the anti-neutrino ? **[IIT-JEE-2012]**

**(A)** Zero
**(B)** Much less than $0.8 \times 10^6$ eV
**(C)** Nearly $0.8 \times 10^6$ eV
**(D)** Much larger than $0.8 \times 10^6$ eV

**22.** If the anti-neutrino had a mass of $3eV/c^2$ (where c is the speed of light) instead of zero mass, what should be the range of the kinetic energy, K, of the electron ? **[IIT-JEE-2012]**

**(A)** $0 \le K \le 0.8 \times 10^6$ eV
**(B)** $3.0\text{ eV} \le K \le 0.8 \times 10^6$ eV
**(C)** $3.0\text{ eV} \le K < 0.8 \times 10^6$ eV
**(D)** $0 \le K < 0.8 \times 10^6$ eV

**23.** A nuclear power plant supplying electrical power to a village uses a radioactive material of half life T years as the fuel. The amount of fuel at the beginning is such that the total power requirement of the village is 12.5% of the electrical power available from the plant at that time. If the plant is able to meet the total power needs of the village for a maximum period of nT years, then the value of n is **[JEE-Advanced-2014]**

**24.** Match the nuclear processes given in column I withthe appropriate option(s) in column II. **[JEE-Advanced-2015]**

| | **Column I** | | **Column II** |
|---|---|---|---|
| **(A)** | Nuclear fusion | **(P)** | Absorption of thermal neutrons by $^{235}_{92}U$ **(B)** |
| **(B)** | Fission in a nuclear reactor | **(Q)** | $^{60}_{27}Co$ nucleus |
| **(C)** | β–decay | **(R)** | Energy production in stars via hydrogen conversion to helium |
| **(D)** | y-ray emission | **(S)** | Heavy water |
| | | **(T)** | Neutrino emission |

**25.** For a radioactive material, its activity A and rate of change of its activity R are defined as $A = -\frac{dN}{dt}$ and $R = -\frac{dA}{dt}$, where N(t) is the number of nuclei at time t. Two radioactive sources P (mean life τ) and Q (mean life 2τ) have the same activity at t = 0. Their rates of change of activities at t = 2τ are RP and RQ, respectively. If $\frac{R_P}{R_Q} = \frac{n}{e}$, then the value of n is -

**[JEE-Advanced-2015]**

**26.** A fission reaction is given by $^{236}_{92}U \rightarrow {}^{140}_{38}Xe + {}^{94}_{38}Sr + x + y$, where x and y are two particles. Considering $^{236}_{92}U$ to be at rest, the kinetic energies of the products are denoted by KXe, KSr, KX (2MeV) and Ky (2 MeV), respectively. Let the binding energies per nucleon of $^{236}_{92}U$, $^{140}_{54}Xe$ and $^{94}_{38}Sr$ be 7.5 MeV, 8.5 MeV and 8.5 MeV, respectively. Considering different conservation laws, the correct option (s) is (are) **[JEE-Advanced-2015]**

**(A)** x=n, y = n, KSr = 129 MeV, KXe = 86 MeV

**(B)** x=p, y = e–, KSr = 129 MeV, KXe = 86 MeV

**(C)** x=p, y = n, KSr = 129 MeV, KXe = 86 MeV

**(D)** x=n, y = n, KSr = 86 MeV, KXe = 129 MeV

**27.** The electrostatic energy of Z protons uniformly distributed throughout a spherical nucleus of radius R is given by

$$E = \frac{3}{5}\frac{Z(Z-1)e^2}{4\pi\varepsilon_0 R}$$

The measured masses of the neutron, $^1_1H$, $^{15}_7N$ and $^{15}_8O$ are 1.008665 u, 1.007825 u, 15.000109 u and 15.003065 u, respectively. Given that the radii of both the $^{15}_7N$ and $^{15}_8O$ nuclei are same, 1 u = 931.5 MeV/$e^2$ (c is the speed of light) and $e^2/(4\pi\varepsilon_0)$ = 1.44 MeV fm. Assuming that the difference between the binding energies of $^{15}_7N$ and $^{15}_8O$ is purely due to the electrostatic energy, the radius of either of the nuclie is **[JEE-Advanced-2016]**

(1 fm = 10–15 m)

**(A)** 2.85 fm **(B)** 3.03 fm **(C)** 3.42 fm **(D)** 3.80 fm

**28.** An accident in a nuclear laboratory resulted in deposition of a certain amount of radioactive material of half-life 18 days inside the laboratroy. Thests revealed that the radiatoin was 64 times more than the permissible level required for safe operation of the laboratory. What is the minimum number of days after which the laboratory can be considered safe for use? **[JEE-Advanced-2016]**

**(A)** 64 **(B)** 90 **(C)** 108 **(D)** 120

**29.** The isotope $^{12}_5B$ having a mass 12.014 u undergoes β-decay to $^{12}_6C$. $^{12}_6C$ has an excited state of the nucleus $\left(^{12}_6C^*\right)$ at 4.041 MeV above its ground state. If $^{12}_5B$ decays to $^{12}_6C^*$, the maximum kinetic energy of the β- particle in units of MeV is (1 u = 931.5 MeV/$c^2$, where $c$ is the speed of light in vacuum). **[JEE-Advanced-2016]**

# ANSWER KEY

## EXERCISE - 1

**1.** A **2.** D **3.** D **4.** A **5.** D **6.** B **7.** B **8.** A **9.** D **10.** D **11.** C **12.** B **13.** B
**14.** A **15.** D **16.** D **17.** D **18.** C **19.** D **20.** C **21.** D **22.** A **23.** C **24.** B **25.** A **26.** A
**27.** B **28.** A **29.** C **30.** A **31.** D **32.** C **33.** C **34.** B **35.** B **36.** B **37.** D **38.** D

## EXERCISE - 2 : PART # I

**1.** C,D **2.** A,C **3.** A,D **4.** A,C **5.** A,C,D **6.** C,D

### PART # II

**1.** D **2.** A **3.** C

## EXERCISE - 3 : PART # I

**1.** A → Q,R,S; B → Q,R,S; C → Q,R,S ; D → P,Q,R,S **2.** A → P,Q,R,S; B → P,Q,R,S; C→ P,Q,R,S; D→P,Q,R,S
**3.** A

### PART # II

**Comp, # 1** **1.** B **2.** D **3.** D **Comp, # 2** **1.** B **2.** D **3.** C

## EXERCISE - 4

**1.** $B.E.=\left[3M_{{}_1H^1}+4m_{{}_0n^1}-M_{{}_3Li^7}\right]931\text{ MeV}=39.22\text{ MeV}, \frac{B.E.}{A}=\frac{39.22}{7}=5.6\text{ MeV}$

**2 (i)** $r_1=\left[\frac{4\times10^{30}}{3\times10^{17}}\times\frac{3}{4\pi}\right]^{1/3}=14.71\text{ km}$ **(ii)** $r_2=\left[\frac{6\times10^{24}}{3\times10^{17}}\times\frac{3}{4\pi}\right]^{1/3}=168.4\text{ m}$

**3.** $E=20\times(8.03)-2\times4\,(7.07)-12(7.68) = 11.9\text{ MeV}$

**4. (a)** $(0.680-0.180)\text{ MeV}=500\text{ keV}$ **(b)** $\frac{500\times10^3 e}{C}=2.67\times10^{-22}\text{ kg–m/s}$ **5.** $\frac{226}{222}\times4.78=4.87\text{ MeV.}$

**6.** $\frac{N_A}{24}\times\frac{0.693}{15\times60\times60}=3.2\times10^{17}\text{ dps}$ & $\frac{N_A}{235}\times\frac{0.693}{7.1\times10^8\times365\times86400}=0.8\times10^5\text{ dps}$

**7.** $\frac{6\times10^{23}\times10^{-6}}{24}\left[1-e^{-0.693/15}\right]=1.125\times10^{15}$ **8. (a)** $\frac{0.693}{14\times60}=8.25\times10^{-4}\text{ s}^{-1}$ **(b)** $(m_n-m_p-m_e)\,931=782\text{ keV}$

**9.** $[M_U+m_n-M_{Mo}-M_{La}-2m_n]\,931 = 207.9\text{ MeV}$ **10.** $\frac{5\times10^4\times4\pi}{10^{-4}\times3\times10^{16}}=\frac{2\pi}{3}\times10^{-7}\text{s}^{-1}=1.05\times10^{-7}\text{ s}^{-1}\Rightarrow$

**Ans.** $\frac{4\pi R^2 A}{a\,N_0}$ **11.** $\frac{2}{Q}\times\frac{100}{30}\times\frac{50}{1.6\times10^{-19}}\times\frac{2}{N_A}\times10^{-3}\text{Kg}=2.9\times10^{-7}\text{ kg}$ ; where $Q=(2M_{{}_1H^2}-M_{{}_2He^4})\times931$

$=23.834531\text{ MeV}$ **12.** $\frac{2}{N_A}\times\frac{1}{17.6\,e}\times10^{-3}\text{ Kg/s}=1.179\times10^{-9}\text{ kg/s}$, $\frac{3}{N_A}\times\frac{1}{17.6\,e}\times10^{-3}\text{ Kg/s}=1.769\times10^{-9}\text{ kg/s}$

**13.** $\frac{Rt_{1/2}}{\ell n2}$ ; $\frac{R}{\lambda}(1-e^{-\lambda t})$ **14.** $\frac{CTM\times100}{m\ N_A\ \ell n2} = \frac{480\times75.5\times1.3\times10^9\times365\times86400\times100}{0.693\times N_A} = 0.36\%$ **15.** $2\tau/C$

**16.** $A_\beta = N_0\lambda_1 \exp.(-\lambda_1 t) = 0.72 \times 10^{11}$ part/s, $A_\alpha = \frac{N_0\lambda_1\lambda_2}{\lambda_2-\lambda_1}\left[e^{-\lambda_1 t} - e^{-\lambda_2 t}\right] \approx \lambda_2 N_0\ 2^{-\frac{1}{4.6}} = 1.4\times10^{11}\ s^{-1}$

**17.** $P = 1 - e^{-\lambda t}$ **18.** $\frac{1850}{235}eN_A$ sec. = 8.781 days **19.** **(1)** – 0.0001 amu **(2)** – 93.1 Kev **(3)** no **20.** 79 gm, $\frac{N_A}{4}$

**21.** **(i)** $E = [M_U + m_n - M_{Ba} - M_{Kr} - 3m_n]\,931 = 200.57$ MeV **(ii)** $\frac{N_A}{235}\times E = 22.84$ MWh **22.** $Q = -\frac{11}{12}T_{th} = -3.7$ MeV

**23.** 2.65 MeV **24.** 6000 **25.** $Q_{value} = -1.20$ MeV and $K_{product} = 0.34$ MeV **26.** $3.32\times10^{-5}\ Js^{-1}$

**27.** $2\times10^{11}$ kg/cm³, $1\times10^{38}$ nucl./cm³ **28.** 79.3 MeV

## EXERCISE - 5 : PART # I

**1.** 1 **2.** 1 **3.** 3 **4.** 1 **5.** 2 **6.** 1 **7.** 4 **8.** 4 **9.** 3 **10.** 3 **11.** 3 **12.** 1 **13.** 2
**14.** 4 **15.** 4 **16.** 4 **17.** 3 **18.** 2 **19.** 2 **20.** 2 **21.** 3 **22.** 4 **23.** 3 **24.** 2 **25.** 2 **26.** 3
**27.** 2 **28.** 1 **29.** 4 **30.** 3

## PART # II

**1.** (I) C (II) A **2.** B **3.** A **4.** 6.954 sec **5.** B **6.** 0.259 **7.** A **8.** B **9.** A → P,R ; B → P, Q
C → P, Q, R, S; D → P,Q ,R **10.** A **11.** A → P, R; B → Q, S; C → P; D → Q **12.** A, B **13.** A **14.** D **15.** A **16.** B **17.** A → P, Q, T; B → Q, T; C → S; D → S **18.** 8 **19.** 1 **20.** 7 **21.** C **22.** D **23.** 3
**24.** A→ R,T ; B→ P,Q,S ; C→ Q,(R),(T) ; D→P,Q,R/P,Q,R,T **25.** 2 **26.** A **27.** C **28.** C **29.** 9



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