Exercise-1

☞ **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 × 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.

✍ **Marked Questions can be used as Revision Questions.**

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Properties of Nucleus

A-1 A neutron star has a density equal to that of the nuclear matter(≈ 3 × 10^{17} kg/m^3). Assuming the star to be spherical, find the radius of a neutron star whose mass is (i) 4.0 × 10^{30} kg (twice the mass of the sun) (ii) 6 × 10^{24} Kg (around mass of the earth).

A-2. Assuming the radius of a nucleus to be equal to R = 1.3 $A^{1/3}$ × 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 × 10^{-27} kg

Section (B) : Mass defect and binding energy

B-1. Find the binding energy of the nucleus of lithium isotope $_3Li^7$ and hence find the binding energy per nucleon in it. ($M_{_3Li^7}$ = 7.014353 amu, $M_{_1H^1}$ = 1.007826, mass of neutron= 1.00867 u)

B-2.✍ Find the energy required for separation of a $_{10}Ne^{20}$ nucleus into two α – 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.

Section (C) : Radioactive decay & Displacement law

C-1. The kinetic energy of an α – 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 α – particle.

C-2. 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.

Section (D) : Statistical law of Radioactive decay

D-1.✍ 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.

D-2.✍ How many β – 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 × 10^{23}]

D-3. Calculate the specific activities of Na^{24} & U^{235} nuclides whose half lives are 15 hours and 7.1 × 10^8 years respectively.

Section (E) : Nuclear Fission and Fusion

E-1. 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).

E-2. 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. $_2He^4$ = 4.002603 amu and $_1H^2$ = 2.014102 amu.

E-3. 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.

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Properties of Nucleus

A-1. 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

A-2. The stable nucleus that has a radius 1/3 that of Os^{189} is -
(A) $_3Li^7$ (B) $_2He^4$ (C) $_5B^{10}$ (D) $_6C^{12}$

A-3. 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

A-4. For uranium nucleus how does its mass vary with volume? **[JEE 2003 (Screening) 3,–1/84]**
(A) $m \propto V$ (B) $m \propto 1/V$ (C) $m \propto \sqrt{V}$ (D) $m \propto V^2$

A-5. 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) $F_{pp} < F_{pn} = F_{nn}$

Section (B) : Mass Defect and Binding Energy

B-1. 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.

B-2. 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

B-3. 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

B-4. The atomic weight of boron is 10.81 g/mole and it has two isotopes ${}^{10}{}_5B$ and ${}^{11}{}_5B$. The ratio (by number) of ${}^{10}{}_5B$: ${}^{11}{}_5B$ in nature would be :
(A) 19 : 81 (B) 10 : 11 (C) 15 : 16 (D) 81 : 19

Section (C) : Radioactive Decay & Displacement law

C-1 Which of the following processes represents a gamma decay?
(A) ${}^AX_Z + \gamma \longrightarrow {}^AX_{Z-1} + a + b$ (B) ${}^AX_Z + {}^1n_0 \longrightarrow {}^{A-3}X_{Z-2} + c$
(C) ${}^AX_Z \longrightarrow {}^AX_Z + f$ (D) ${}^AX_Z + e_{-1} \longrightarrow {}^AX_{Z-1} + g$

C-2. An α-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

C-3. A free neutron decays into a proton, an electron and :
(A) A neutrino (B) An antineutrino (C) An α-particle (D) A β-particle

C-4. Nuclei X decay into nuclei Y by emitting α particles. Energies of α particle are found to be only 1 MeV & 1.4 MeV. Disregarding the recoil of nuclei Y. The energy of γ photon emitted will be
(A) 0.8 MeV (B) 1.4 MeV (C) 1 MeV (D) 0.4 MeV

Section (D) : Statistical Law of Radioactive decay

D-1. 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

D-2. 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

D-3. 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

D-4. 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

D-5. $A \xrightarrow{\lambda} B \xrightarrow{2\lambda} C$

	A	B	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) $\frac{\ell n2}{2}$

D-6. The half-life of ^{131}I is 8 days. Given a sample of ^{131}I at time t = 0, we can assert that **[JEE-1999]**
(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.

Section (E) : Nuclear Fission and Fusion

E-1. $_{92}U^{235}$ 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

E-2. 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

E-3. 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) 4×10^{18} s^{-1} (B) 8×10^{23} s^{-1} (C) 8×10^{19} s^{-1} (D) $\frac{125}{16} \times 10^{18}$ s^{-1}

E-4. 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.

E-5. 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.

E-6. 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 :
(A) 200 keV (B) 2 MeV (C) 200 MeV (D) 2000 MeV

E-7. 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

E-8. 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

PART - III : MATCH THE COLUMN

1. 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

2. 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) β^- decay (negative beta decay)	(S) Charge is conserved

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

Exercise-2

✍ Marked Questions can be used as Revision Questions.

PART - I : ONLY ONE OPTION CORRECT TYPE

1. Choose the wrong statement.
(A) The nuclear force becomes weak if the nucleus contains too many protons compared to the number of neutrons
(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 very strong if the nucleus contains a large number of nucleons.

2. Binding Energy per nucleon of a fixed nucleus X^A is 6 MeV. It absorbs a neutron moving with KE = 2 MeV, and converts into Y at ground state, emitting a photon of energy 1 MeV. The Binding Energy per nucleon of Y (in MeV) is -
(A) $\frac{(6A+1)}{(A+1)}$ (B) $\frac{(6A-1)}{(A+1)}$ (C) 7 (D) $\frac{7}{6}$

3. The half life of ^{215}At is 100 μs. The time taken for the radioactivity of a sample of ^{215}At to decay to 1/16th of its initial value is : **[JEE 2002 (Screening) 2 × 3, –1 = 6/90]**
(A) 400 μs (B) 6.3 μs (C) 40 μs (D) 300 μs

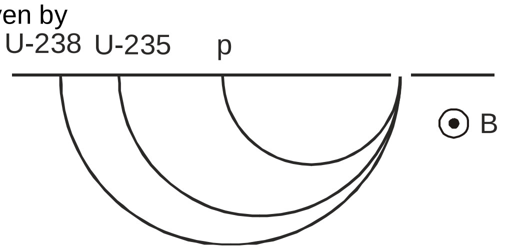
4. A free neutron decays to a proton but a free proton does not decay to a neutron. This is because
(A) neutron is a composite particle made of a proton and an electron whereas proton is fundamental particle
(B) neutron is an uncharged particle whereas proton is a charged particle
(C) neutron has larger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

5. **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. γ 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

6.✍ 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

7. When a β^--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)

8. 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

9. 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 : **[IIT - 1997]**
(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

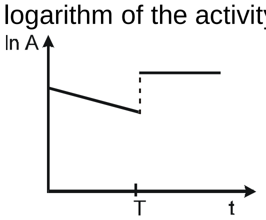
10. In an α-decay the Kinetic energy of α particle is 48 MeV and Q-value of the reaction is 50 MeV. The mass number of the mother nucleus is:- (Assume that daughter nucleus is in ground state)
(A) 96 (B) 100 (C) 104 (D) none of these

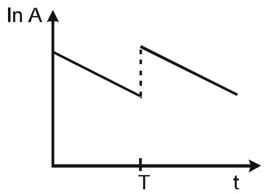
11. Free ^{238}U nuclei kept in a train emit alpha particles. When the train is stationary and a uranium nucleus decays, a passenger measures that the separation between the alpha particle and the recoiling nucleus becomes x in time t after the decay. If a decay takes place when the train is moving at a uniform speed υ, the distance between the alpha particle and the recoiling nucleus at a time t after the decay, as measured by the passenger will be –
(A) $x + \upsilon t$ (B) $x - \upsilon t$ (C) x
(D) depends on the direction of the train

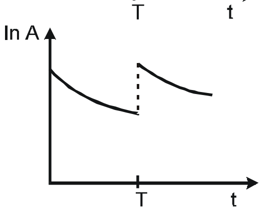
12. A nucleus with mass number 220 initially at rest emits an α-particle. If the Q value of the reaction is 5.5 MeV, calculate the kinetic energy of the α-particle **[JEE 2003 (Screening) 3,–1/84]**
(A) 4.4 MeV (B) 5.4 MeV (C) 5.6 MeV (D) 6.5 MeV

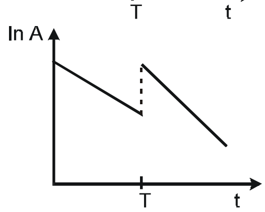
13. A charged capacitor of capacitance C is discharged through a resistance R. A radioactive sample decays with an average life τ. Find the value of R for which the ratio of the electrostatic field energy stored in the capacitor to the activity of the radioactive sample is independent of time.
(A) $\frac{\tau}{C}$ (B) $\frac{2\tau}{C}$ (C) $\frac{\tau}{2C}$ (D) $\frac{3\tau}{2C}$

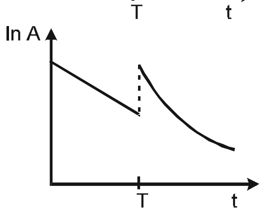
14. At time t = 0, some radioactive gas is injected into a sealed vessel. At time T, some more of the same gas is injected into the same vessel. Which one of the following graphs best represents the variation of the logarithm of the activity A of the gas with time t ?

(A)


(B)


(C)


(D)


(E)


15. A sample of radioactive material has mass m, decay constant λ, and molecular weight M. Avogadro constant = N_A. The initial acitvity of the sample is :

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

16. 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

17. 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) $T\left(\frac{A_P}{A_Q}\right)$

18. 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.

19. The radioactivity of an old sample of a liquid due to tritium (half life 12.5 years) was found to be only about 3% of that measured in a recently purchased bottle marked '7 year old'. The sample must have been prepared about :

(A) 70 year (B) 220 year (C) 420 year (D) 300 year

20.

$$A \xrightarrow{\lambda_1} B \xrightarrow{\lambda_2} C$$

	A	B	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.

21. Ninety percent of a radioactive sample is left over after a time interval t. The percentage of initial sample that will disintegrate in an interval 2t is **[OLYMPIAD 2011]**

(A) 38% (B) 19% (C) 9% (D) 62%

22. The intensity of gamma radiation from a given source is I. On passing through 36 mm of lead, it is reduced to 1/8. The thickness of lead, which will reduce the intensity to 1/2 will be : **[AIEEE 2005 4/300]**

(A) 6 mm (B) 9 mm (C) 18 mm (D) 12 mm

23._ The fraction of the original number of nuclei of a radioactive atom having a mean life of 10 days, that decays during the 5^{th} day is : **[Olympiad (State-1) 2017]**

(A) 0.15 (B) 0.30 (C) 0.045 (D) 0.064

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

1. Consider a point source emitting α-particles and receptor of area 1 cm^2 placed 1 m away from source. Receptor records any α-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. Assume that the source emits alpha particles uniformly in all directions and the alpha particles fall nearly normally on the window. If decay constant is $3n \times 10^{-(n+1)}$, then find the value of n

2. In an ore containing uranium, the ratio (by number) of U-238 to Pb-206 is 3. Assuming that all the lead present in the ore is the final stable product of U-238. If age of the ore is 1.868×10^n years, then value of the n (Take the half life of U-238 to be 4.5×10^9 years. (ℓn 4/3 = 0.2876)) **[IIT - 1997]**

3. A Bi^{210} radionuclide decays via the chain (stable), $Bi^{210} \xrightarrow[\lambda_1]{\beta^- - decay} Po^{210} \xrightarrow[\lambda_2]{\alpha - decay} Pb^{206}$ 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. α activity of the Bi^{210} sample of mass 1.00 mg a month after its manufacture is $\frac{x}{5} \times 10^{11}$ Find x. $2^{-\frac{1}{4.6}} = 0.86$

4. 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. The mass of total sample after 4 hours is nearly $4n \times 10^{-n}$ kg. Find n

5. 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 $\eta = 12.6\%$. Number of moles of the nuclide required to generate electrical energy at an initial rate of 441 KW is $n \times 10^m$ then find out value of $\frac{n}{m}$ ($\log_e 2 = 0.6931$, $N_A = 6.023 \times 10^{23}$)

6. There is a stream of neutrons with a kinetic energy of 0.0327 eV. If the half-life of neutrons is 700 seconds, if the fraction of neutrons will decay before they travel a distance of 10 m is 3.90×10^{-n}. Find n **[1986; 6M]**

7. A sealed box was found which stated to have contained alloy composed of equal parts by weight of two metals A and B. These metals are radioactive, with half lives of 12 years and 18 years, respectively and when the container was opened it was found to contain 0.53 kg of A and 2.20 kg of B. The age of the alloy is M ×10 + n then find M – n.

8. The half-life of ^{40}K is $T = 1.30 \times 10^9$ y. A sample of m = 1.00 g of pure KCl gives c = 480 counts/s. If the relative percentage abundance of ^{40}K (fraction of ^{40}K present in term of number of atoms) in natural potassium is $n \times 10^{-2}$ % then value of n. Molecular weight of KCl is M = 74.5 , Avogadro number $N_A = 6.02 \times 10^{23}$, $1y = 3.15 \times 10^7$ s

9. Consider a fusion reaction $^4He + {}^4He = {}^8Be$. For the reaction Q-value is –(90 + n) KeV. Find n. Take 1 amu = $\frac{930}{c^2}$ MeV. Atomic mass of ^8Be is 8.0053 u and that of ^4He is 4.0026 u.

10. 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 power. The time it will take for 1 Kg of the uranium $^{235}_{92}U$ to be used up is n days. Find [n]? [n] is grestest integer value of n.

11. Consider a nuclear reaction A + B $\rightarrow$ 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. If the kinetic energy of nucleus ‘C’ just after its formation is E MeV then find [E] . 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 [E] is greatest integer of E

12. The binding energy per nucleon of $^{16}_{8}O$ is 7.97 MeV and that of $^{17}_{8}O$ of 7.75 MeV. The energy required to remove a neutron from $^{17}_{8}O$ is 0.423×10^n MeV then find n

13. A π^o meson at rest decays into two photons of equal energy. If the wavelength (in m) of the photons is 1.8×10^{-n} then find n/2 (The mass of the π^o is 135 MeV/c^2)

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. If a nucleus ${}^{A}_{Z}x$ emits one α particle and one β (negative β) 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

2. 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

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

(A) The half life of this nuclide is 4.5×10^9 years
(B) The half life of this nuclide is 9×10^9 years
(C) The activity of the prepared sample is 2.48×10^4 particles/sec
(D) The activity of the prepared sample is 1.24×10^4 particles/sec.

4. 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.

5. The decay constant of a radioactive 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 radioactive 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 $\ell n2 = 0.692$

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 : **[JEE 1998, 2]**

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

7. Nuclei of radioactive element A are being produced at a constant rate α. The element has a decay constant λ. At time t = 0, there are N_0 nuclei of the element. **[IIT - 1998]**

(A) Number of nuclei of A at time t is $\frac{1}{\lambda}\,[\alpha - (\alpha - \lambda N_0)\,e^{-\lambda t}]$

(B) Number of nuclei of A at time t is $\frac{1}{\lambda}\,[(\alpha - \lambda N_0)\,e^{-\lambda t}]$

(C) If $\alpha = 2N_0\lambda$, then the limiting value of number of nuclei of A ($t \to \infty$) will be $2N_0$.

(D) If $\alpha = 2N_0\lambda$, then the number of nuclei of A after one half-life of A will be $N_0/2$.

PART - IV : COMPREHENSION

Comprehension-1

The radionuclide ^{56}Mn is being produced in a cyclotron at a constant rate P by bombarding a manganese target with deutrons. ^{56}Mn has a half life of 2.5 hours and the target contains large number of only the stable manganese 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 13.86×10^{10} s^{-1}.

(Use $\ell n2 = 0.693$; Avogadro No = 6×10^{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) 2×10^{11} nuclei/s
(B) 13.86×10^{10} nuclei/s
(C) 9.6×10^{10} nuclei/s
(D) 6.93×10^{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) 5×10^{11}
(B) 20×10^{11}
(C) 1.2×10^{14}
(D) 1.8×10^{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

Comprehension-2

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

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

4. 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 Δmc^2 where Δm is mass difference of (${}^{236}_{92}U$ and ${}^{232}_{90}Th$) and c is speed of light.

5. 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.

6. 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 u = 1.5×10^{-10} J

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

(A) 3.5×10^{-8} J
(B) 4.6×10^{-12} J
(C) 6.0×10^{-10} J
(D) 7.4×10^{-13} J

Exercise-3

✍ **Marked Questions can be used as Revision Questions.**
*** Marked Questions may have more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1. Half life of a radioactive substance 'A' is 4 days. The probability that a nucleus will decay in two half **[JEE 2006 3/184]**

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

2. **Match the following** **[JEE 2006 5/184]**

Column 1
(A) Nuclear fission
(B) Nuclear fusion
(C) β - decay
(D) Exothermic nuclear reaction

Column 2
(p) Converts some matter into energy
(q) Possible for nuclei with low atomic number
(r) Possible for nuclei with high atomic number
(s) Essentially proceeds by weak nuclear forces.

3. In the options given below, let E denote the rest mass energy of a nucleus and n a neutron. The correct option is : **[IIT-JEE 2007' 3/81]**

(A) $E\left({}^{236}_{92}U\right) > E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$ (B) $E\left({}^{236}_{92}U\right) < E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$

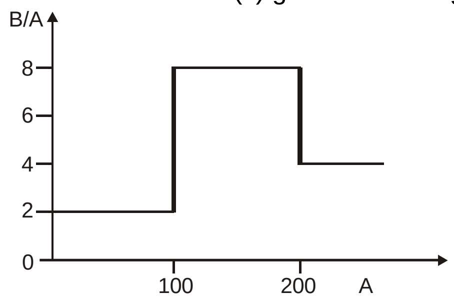
(C) $E\left({}^{236}_{92}U\right) < E\left({}^{140}_{56}Ba\right) + \left({}^{94}_{36}Kr\right) + 2E(n)$ (D) $E\left({}^{236}_{92}U\right) = E\left({}^{140}_{56}Ba\right) + E\left({}^{94}_{36}Kr\right) + 2E(n)$

4. 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' 6/81]**

Column I
(A) Transition between two atomic energy levels
(B) Electron emission from a material
(C) Mosley's law
(D) Change of photon energy into kinetic energy of electrons

Column II
(p) Characteristic X-rays
(q) Photoelectric effect
(r) Hydrogen spectrum
(s) β-decay

5*. 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. Figure : **[JEE 2008, 4/163]**



(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

6. 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, 3/163]**

(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. 7 to 9

Scientists are working hard to develop nuclear fusion reactor. Nuclei of heavy hydrogen, ${}^{2}_{1}H$, known as deuteron and denoted by D, can be thought of as a candidate for fusion reactor. The D-D reaction is ${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + n + \text{energy}$. In the core of fusion reactor, a gas of heavy hydrogen is fully ionized into deuteron nuclei and electrons. This collection of ${}^{2}_{1}H$ 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 5×10^{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. **[JEE 2009, 4/160, –1]**

7. 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

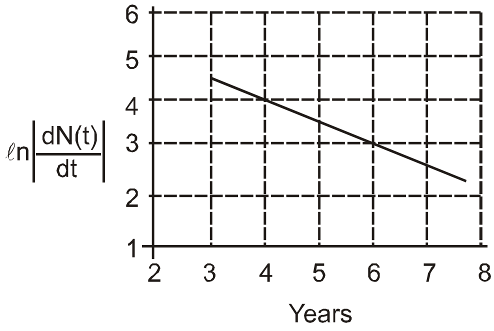
8. Assume that two deuteron nuclei in the core of fusion reactor at temperature T are moving towards each other, each with kinetic energy 1.5 kT, when the separation between them is large enough to neglect Coulomb potential energy. Also neglect any interaction from other particles in the core. The minimum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

9. 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 = 2.0×10^{12} cm^{-3}, confinement time = 5.0×10^{-3} s
(B) deuteron density = 8.0×10^{14} cm^{-3}, confinement time = 9.0×10^{-1} s
(C) deuteron density = 4.0×10^{23} cm^{-3}, confinement time = 1.0×10^{-11} s
(D) deuteron density = 1.0×10^{24} cm^{-3}, confinement time = 4.0×10^{-12} s

10. **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 2009,8/160]**

	Column-I		Column-II
(A)	The energy of the system is increased.	(p)	System: A capacitor, initially uncharged 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. 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 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 Process: The nucleus fissions into two fragments of nearly equal masses and some neutrons are emitted
		(t)	System: A resistive wire loop Process: The loop is placed in a time varying magnetic field perpendicular to its plane

11. 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, 3/163]**



12. 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; 4/160]**

13. 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, Paper-1; 4/70]**

Paragraph for Questions 14 and 15

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 tri-body decay process, it was predicted theoretically that the kinetic 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. $n \rightarrow p + e^- + \bar{\nu}_e$, 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 electron is 0.8×10^6 eV. The kinetic energy carried by the proton is only the recoil energy.

14. What is the maximum energy of the anti-neutrino ? **[IIT-JEE-2012, Paper-2; 4/66]**

(A) Zero
(B) Much less than 0.8×10^6 eV
(C) Nearly 0.8×10^6 eV
(D) Much larger than 0.8×10^6 eV

15. 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, Paper-2; 4/66]**

(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

16. A freshly prepared sample of a radioisotope of half-life 1386 s has activity 10^3 disintegrations per second. Given that ln 2 = 0.693, the fraction of the initial number of nuclei (expressed in nearest integer percentage) that will decay in the first 80s after preparation of the sample is : **[JEE (Advanced) 2013; 3/60]**

17. Match List I of the nuclear processes with List II containing parent nucleus and one of the end products of each process and then select the correct answer using the codes given below the lists :

[JEE (Advanced) 2013 ; 3/60, –1]

List I	**List II**
P. Alpha decay	1. ${}^{15}_{8}O \rightarrow {}^{15}_{7}N + ...$
Q. β^+ decay	2. ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + ...$
R. Fission	3. ${}^{185}_{83}Bi \rightarrow {}^{184}_{82}Pb + ...$
S. Proton emission	4. ${}^{239}_{94}Pu \rightarrow {}^{140}_{57}La + ...$

Codes :

	P	Q	R	S
(A)	4	2	1	3
(B)	1	3	2	4
(C)	2	1	4	3
(D)	4	3	2	1

Paragraph for Questions 18 and 19

The mass of a ${}^{A}_{Z}X$ nucleus is less than the sum of the masses of (A – Z) number of neutrons and Z number of protons in the nucleus. The energy equivalent to the corresponding mass difference is known as the binding energy of the nucleus. A heavy nucleus of mass M can break into two light nuclei of masses m_1 and m_2 only if $(m_1 + m_2) < M$. Also two light nuclei of masses m_3 and m_4 can undergo complete fusion and form a heavy nucleus of mass M' only if $(m_3 + m_4) > M'$. The masses of some neutral atoms are given in the table below : **[JEE (Advanced) 2013 ; 3/60, –1]**

${}^{1}_{1}H$	1.007825u	${}^{2}_{1}H$	2.014102u	${}^{3}_{1}H$	3.016050u	${}^{4}_{2}He$	4.002603u
${}^{6}_{3}Li$	6.015123u	${}^{7}_{3}Li$	7.016004u	${}^{70}_{30}Zn$	69.925325u	${}^{82}_{34}Se$	81.916709u
${}^{152}_{64}Gd$	151.919803u	${}^{206}_{82}Pb$	205.974455u	${}^{209}_{83}Bi$	208.980388u	${}^{210}_{84}Po$	209.982876u

18. The correct statement is :

(A) The nucleus ${}^{6}_{3}Li$ can emit an alpha particle

(B) The nucleus ${}^{210}_{84}Po$ can emit a proton

(C) Deuteron and alpha particle can undergo complete fusion.

(D) The nuclei ${}^{70}_{30}Zn$ and ${}^{82}_{34}Se$ can undergo complete fusion.

19. The kinetic energy (in keV) of the alpha particle, when the nucleus ${}^{210}_{84}Po$ at rest undergoes alpha decay, is:

(A) 5319 (B) 5422 (C) 5707 (D) 5818

20. 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) 2015 ; P-1, 4/88]

21. Match the nuclear processes given in **Column I** with the appropriate option(s) in **Column II**.

[JEE(Advanced) 2015 ; P-1, 8/88, –1]

Column-I	**Column-II**
(A) Nuclear fusion	(P) Absorption of thermal neutrons by ${}^{235}_{92}U$
(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) γ–ray emission	(S) Heavy water
	(T) Neutrino emission

22. 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 $t = 2\tau$ are R_P and R_Q, respectively. If $\frac{R_P}{R_Q} = \frac{n}{e}$, then the value of n is : **[JEE(Advanced) 2015 ; P-2,4/88]**

23. A fission reaction is given by ${}^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + x + y$, where x and y are two particles. Considering ${}^{236}_{92}U$ to be at rest, the kinetic energies of the products are denoted by K_{Xe}, K_{Sr}, K_x (2MeV) and K_y (2MeV), 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 ; P-2,4/88, –2]**

(A) x = n, y = n, K_{Sr} = 129 MeV, K_{Xe} = 86 MeV (B) x = p, y = e^-, K_{Sr} = 129 MeV, K_{Xe} = 86 MeV

(C) x = p, y = n, K_{Sr} = 129 MeV, K_{Xe} = 86 MeV (D) x = n, y = n, K_{Sr} = 86 MeV, K_{Xe} = 129 MeV

24. The isotope ${}^{12}_{5}B$ having a mass 12.014 u undergoes β-decay to ${}^{12}_{6}C$. ${}^{12}_{6}C$ has an excited state of the nucleus (${}^{12}_{6}C^*$) at 4.041 MeV above its ground state. If ${}^{12}_{5}B$ decays to ${}^{12}_{6}C^*$, the maximum kinetic energy of the β-particle in units of MeV is : (1u = 931.5 MeV/c^2, where c is the speed of light in vacuum) **[JEE (Advanced) 2016, 3/62]**

25. An accident in a nuclear laboratory resulted in deposition of a certain amount of radioactive material of half-life 18 days inside the laboratory. Tests revealed that the radiation 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 ; P-2, 3/62, –1]**

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

26. 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, ${}^{1}_{1}H$, ${}^{15}_{7}N$, and ${}^{15}_{8}O$ are 1.008665 u, 1.007825 u, 15.000109 u and 15.003065 u, respectively. Given that the radii of both the ${}^{15}_{7}N$ and ${}^{15}_{8}O$ nuclei are same, 1 u = 931.5 MeV/c^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 ${}^{15}_{7}N$ and ${}^{15}_{8}O$ is purely due to the electrostatic energy, the radius of either of the nuclei is (1 fm = 10^{-15} m) **[JEE (Advanced) 2016 ; P-2, 3/62, –1]**

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

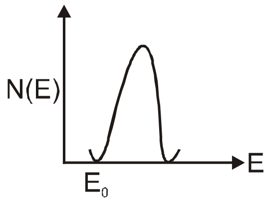
27. ^{131}I is an isotope of Iodine that β decays to an isotope of Xenon with a half-life of 8days. A small amount of a serum labelled with ^{131}I is injected into the blood of a person. The activity of the amount of ^{131}I injected was 2.4×10^5 Becquerel (Bq). It is known that the injected serum will get distributed uniformly in the blood stream in less than half an hour. After 11.5 hours, 2.5 ml of blood is drawn from the person's body, and gives an activity of 115 Bq. The total volume of blood in the person's body, in liters is approximately (you may use $e^x \approx 1 + x$ for $|x| << 1$ and ln 2 ≈ 0.7).**[JEE (Advanced) 2017 ; P-1, 3/61]**

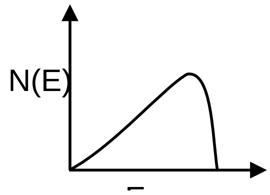
28*. In a radioactive decay chain, ${}^{232}_{90}Th$ nucleus decays to ${}^{212}_{90}Pb$ nucleus. Let N_α and N_β be the number of α and β^- particles, respectively, emitted in this decay process. Which of the following statements is (are) true? **[JEE (Advanced) 2018 ; P-2, 4/60, –2]**

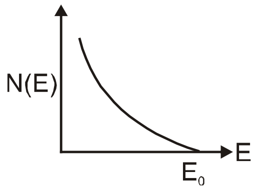
(A) N_α = 5 (B) N_α = 6 (C) N_β = 2 (D) N_β = 4

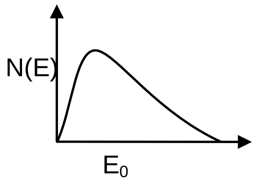
PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. The energy spectrum of β-particles (number N(E) as a function of β-energy E) emitted from a radioactive source is : **[AIEEE 2006 ; 3/180, –1]**

(1) 

(2) 

(3) 

(4) 

2. When $_3Li^7$ nuclei are bombarded by protons, and the resultant nuclei are $_4Be^8$, the emitted particles will be **[AIEEE 2006 ; 4.5/180]**
(1) neutrons (2) alpha particles (3) beta particles (4) gamma photons

3. The 'rad' is the correct unit used to report the measurement of **[AIEEE 2006 ; 4.5/180]**
(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

4. 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 ; 4.5/180]**
(1) 39.2 MeV (2) 28.24 MeV (3) 17.28 MeV (4) 1.46 MeV

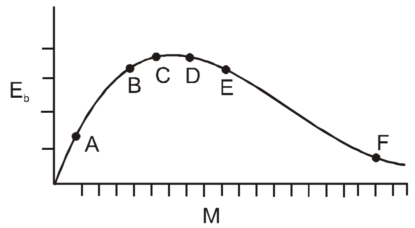
5. If M_o is the mass of an oxygen isotope $_8O^{17}$, M_p and M_N are the masses of a proton and a neutron respectively, the nuclear binding energy of the isotope is : **[AIEEE 2007 ; 3/120, –1]**
(1) $(M_o - 8M_P)C^2$ (2) $(M_o - 8M_P - 9M_N)C^2$ (3) M_oC^2 (4) $(M_o - 17M_N)C^2$

6. In gamma ray emission from a nucleus : **[AIEEE 2007 ; 3/120, –1]**
(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

7. 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 ; 3/120, –1]**
(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

8. 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 ; 3/105, –1]**
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

9.



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 ; 4/144]**

(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 ε is the energy released? In which reactions is ε positive?

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

Directions : Question number 10 – 12 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 3/144, –1]**

10. 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) $E_2 = 2E_1$

11. 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) $c\sqrt{\frac{\Delta m}{M+\Delta m}}$

12. A radioactive nucleus (initial mass number A and atomic number Z) emits 3 α-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) $\frac{A-Z-4}{Z-2}$

13. 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, 4/120, –1]**

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

14. **Statement - 1 :** A nucleus having energy E_1 decays by β^- emission to daughter nucleus having energy E_2, but the β^- 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, 11 May; 4/120, –1]**

(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.

15. Assume that a neutron breaks into a proton and an electron. The energy released during this process is (mass of neutron = 1.6725×10^{-27} kg, Mass of proton = 1.6725×10^{-27} kg, mass of electron = 9×10^{-31} kg) **[AIEEE 2012 ; 4/120, –1]**

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

16. 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 ; 4/120, –1]**

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

17. A radioactive nucleus A with a half life T, decays into a nucleus B. At t = 0, there is no nucleus B. At sometime t, the ratio of the number of B to that of A is 0.3. Then, t is given by : **[JEE (Main) 2017 ; 4/120, –1]**

(1) $t = \frac{T}{\log(1.3)}$ (2) $t = \frac{T}{2}\frac{\log 2}{\log 1.3}$ (3) $t = T\,\frac{\log 1.3}{\log 2}$ (4) $t = T \log(1.3)$

Answers

EXERCISE-1

PART – I

Section (A) :

A-1 (i) $r_1 = \left[\frac{4\times10^{30}}{3\times10^{17}}\times\frac{3}{4\pi}\right]^{1/3}$ = 14.71 km

(ii) $r_2 = \left[\frac{6\times10^{24}}{3\times10^{17}}\times\frac{3}{4\pi}\right]^{1/3}$ = 168.4 m

A-2. 2×10^{11} kg/cm^3, 1×10^{38} nucl. /cm^3

Section (B) :

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

= 39.22 MeV, $\frac{B.E.}{A}=\frac{39.22}{7}$ = 5.6 MeV

B-2 E = 20 × (8.03) – 2×4 (7.07) – 12(7.68)

= 11.9 MeV

Section (C) :

C-1 $\frac{226}{222}\times4.78=4.87$ MeV.

C-2 (a) (0.680 – 0.180) Me V = 500 ke V

(b) $\frac{500\times10^3 e}{C}$ = 2.67 × 10^{-22} kg–m/s

Section (D) :

D-1. (a) $\frac{0.693}{14\times60}$ = 8.25 × 10^{-4} s^{-1}

(b) $(m_n - m_p - m_e)$ 931 = 782 keV

D-2. $\frac{6\times10^{23}\times10^{-6}}{24}\left[1-e^{-0.693/15}\right]$ = 1.128 × 10^{15}

D-3. $\frac{N_A}{24}\times\frac{0.693}{15\times60\times60}$ = 3.2 × 10^{17} dps

& $\frac{N_A}{235}\times\frac{0.693}{7.1\times10^8\times365\times86400}$

= 0.8 × 10^5 dps

Section (E) :

E-1. $[M_U + m_n - M_{Mo} - M_{La} - 2m_n]$ 931

= 207.9 MeV

E-2. $\frac{2}{Q}\times\frac{100}{30}\times\frac{50}{1.6\times10^{-19}}\times\frac{2}{N_A}\times10^{-3}\text{Kg}$

= 2.9 × 10^{-7} kg ;

where Q= $(2M_{1H^2} - M_{2He^4})$ × 931 = 23.834531 MeV

E-3. $\frac{2}{N_A}\times\frac{1}{17.6\ e}\times10^{-3}$ Kg/s = 1.179 × 10^{-9} kg/s,

$\frac{3}{N_A}\times\frac{1}{17.6\ e}\times10^{-3}$ Kg/s = 1.769 × 10^{-9} kg/s

PART – II

Section (A) :

A-1. (D) **A-2.** (A) **A-3.** (A)
A-4. (A) **A-5.** (B)

Section (B) :

B-1. (D) **B-2.** (D) **B-3.** (A)
B-4. (A)

Section (C) :

C-1 (C) **C-2.** (B) **C-3.** (B)
C-4. (D)

Section (D) :

D-1. (C) **D-2.** (B) **D-3.** (D)
D-4. (A) **D-5.** (B) **D-6.** (D)

Section (E) :

E-1. (D) **E-2.** (D) **E-3.** (D)
E-4. (C) **E-5.** (D) **E-6.** (C)
E-7. (C) **E-8.** (A)

PART – III

1. (A) → P,Q,R,S ; (B) → P,Q,R,S ;
(C) → P,Q,R,S ; (D) → P,Q,R,S

2. (A) → Q,R,S ; (B) → Q,R,S ;
(C) → Q,R,S ; (D) → P,Q,R,S

3. (A)

EXERCISE-2

PART - I

1.	(D)	**2.**	(B)	**3.**	(A)
4.	(C)	**5.**	(A)	**6.**	(A)
7.	(A)	**8.**	(D)	**9.**	(D)
10.	(B)	**11.**	(C)	**12.**	(B)
13.	(B)	**14.**	(B)	**15.**	(C)
16.	(C)	**17.**	(B)	**18.**	(D)
19.	(A)	**20.**	(B)	**21.**	(B)
22.	(D)	**23.**	(D)		

PART - II

1.	7	**2.**	9	**3.**	7
4.	2	**5.**	2	**6.**	6
7.	3	**8.**	36	**9.**	3
10.	8	**11.**	2	**12.**	1
13.	7				

PART - III

1.	(AC)	**2.**	(CD)	**3.**	(AD)
4.	(ACD)	**5.**	(AC)	**6.**	(CD)
7.	(AC)				

PART - IV

1.	(B)	**2.**	(D)	**3.**	(C)
4.	(B)	**5.**	(D)	**6.**	(D)

EXERCISE-3

PART - I

1. (B)

2. (A) → (p) and (r), (B) → (p) and (q),
(C) → (p), (q), (r) and (s), (D) → (p), (q) and (r)

3. (A)

4. (A)→ (p), (r); (B)→(q), (s); (C)→(p); (D)→(q)

5.	(BD)	**6.**	(A)	**7.**	(D)
8.	(A)	**9.**	(B)		

10. (A) → p,q,t ; (B) → q, t ; (C) → s, (D) → s

11.	8	**12.**	1	**13.**	7
14.	(C)	**15.**	(D)	**16.**	4
17.	(C)	**18.**	(C)	**19.**	(A)
20.	3				

21. (A) → R (B) → P,S; (C) Q,T; (D) R,T

22.	2	**23.**	(A)	**24.**	9
25.	(C)	**26.**	(C)	**27.**	(5)
28.	(AC)				

PART – II

1.	(4)	**2.**	(4)	**3.**	(4)
4.	(3)	**5.**	(2)	**6.**	(2)
7.	(2)	**8.**	(3)	**9.**	(4)
10.	(3)	**11.**	(2)	**12.**	(2)
13.	(3)	**14.**	(2)	**15.**	(1)
16.	(3)	**17.**	(3)		