PHYSICS

BOOKS - U-LIKE PHYSICS (HINGLISH)

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Ncert Textbook Question

1. (a) Two stable isotopes of lithium $_3^6Li$and $_3^7Li$ have respective abundances of 7.5% and 92.5%. These isotopes have masses 6.01512u and 7.01600u, respectively. Find the atomic mass of lithium.

(b) Boron has two stable isotopes, $_5^{10}B$ and $_5^{11}B$. Their respective massis are 10.01294u and 11.00931u, and the atomic mass of boron is 10.811 u. Find the abundances of $_5^{10}B$ and $_5^{11}B$.

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2. The three stable isotopes of neon: $^{20}_{10}Ne$, $^{21}_{10}Ne$ and $^{22}_{10}Ne$ have respective abundances of 90.51%, 0.27% and 9.22%. The atomic masses of three isotopes are 19.99 u, 20.99 u and 21.99 u, respectively. Obtain the average atomic mass of neon.

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3. Obtain the binding energy (in MeV) of a nitrogen nucleus ($^{14}_{7}N$). Given m($^{14}_{7}N$) = 14.00307 u.

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4. Obtain the binding energy of the nuclei $^{56}_{26}Fe$ and $^{209}_{83}Bi$ in units of MeV from the following data :

m($^{56}_{26}Fe$) = 55.934939 u and m($^{209}_{83}Bi$) = 208.980388 u.

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5. A given coin has a mass of 3.0 g. Calculate the nuclear energy that would be required to separate all the neutrons and protons from each other. For simplicity assume that the coin is entirely made of $^{29}_{63}Bi$ atoms (of mass 62.92960 u).

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6. Write nuclear reaction equations for :

(i) α-decay of $^{226}_{88}Ra$ (ii) α-decay of $^{242}_{94}Pu$ (iii) β^--decay of $^{32}_{15}P$

(iv) β^--decay of $^{210}_{83}Bi$ (v) β^+-decay of $^{11}_{6}C$ (vi) β^+-decay of $^{97}_{43}Tc$

(vii) Electron capture of $^{210}_{83}Xe$

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7. A radioactive isotope has a half-life of T years. How long will it take the activity to reduce to (a) 3.125%, (b) 1% of its original value ?

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8. The normal activity of living carbon-containing matter is found to be about 15 decays per minute for every gram of carbon. This activity arises from the small proportion of radioactive $^{14}_{6}C$ present with the stable carbon isotope $^{12}_{6}C$. When the organism is dead, its interaction with the atmosphere (which maintains the above equilibrium activity) ceases and its activity begins to drop. From the known half-life (5730 years) of $^{14}_{6}C$, and the measured activity, the age of the specimen can be approximately estimated. This is the principle of $^{14}_{6}C$ dating used in archaeology. Suppose a specimen from Mohenjodaro gives an activity of 9 decays per minute per gram of carbon. Estimate the approximate age of the Indus-Valley civilisation.

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9. Obtain the amount of $^{60}_{27}Co$ necessary to provide a radioactive source of 8.0 mCi strength. The half-life of $^{60}_{27}Co$ is 5.3 years.

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10. The half-life of $^{90}_{38}Sr$ is 28 years. What is the disintegration rate of 15 mg of this isotope ?

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11. Obtain approximately the ratio of the nuclear radii of the gold isotope $79^{197}Au$ and the silver isotope $^{107}_{47}Ag$.

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12. Find the Q-value and the kinetic energy of the emitted o-particle in the a-decay of

(a) $^{226}_{88}Ra$ and (b) $^{220}_{86}Rn$.

Given : m($^{226Ra}_{88}$)=226.02540 u, m($^{222}_{86}Rn$)=222.01750 u, m($^{220}_{86}Rn$)=220.01137u, m($^{216}_{84}Po$)=216.00189 u.

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13. The radionuclide ^{11}C decays according to

$^{11}_{6}C(\rightarrow)\ ^{11}_{5}B+e^{+}+\nu : T_{\frac{1}{2}}=20.3\text{min}$

The maximum energy of the emitted positron is 0.960 MeV.

Given the mass values: m($^{11}_{6}C)=11.011434u$ and m($^{11}_{6}B)=11.009305u$, Calculate Q and compare it with the maximum energy of the positron emitted.

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14. The nucleus $^{23}_{10}Ne$ decays by β^{-} emission. Write down the β-decay equation and determine the maximum kinetic energy of the electrons emitted. Given that : $m(\ ^{23}_{10}Ne)=22.994466u$, and m($^{23}_{11}Na)=22.089770u$

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15. The Q-value of a nuclear reaction A + b $\rightarrow$ C + d is defined by Q= $[m_A+m_b-m_C-m_d]c^2$

where the masses refer to the respective nuclei. Determine from the given data the Q-value of following reactions and state whether the reactions are exothermic or endothermic.

(i) $^{1}_{1}H + \ ^{3}_{1}H(\rightarrow) \ ^{2}_{1}H + \ ^{2}_{1}H$ (ii) $^{12}_{6}C + \ ^{12}_{6}C(\rightarrow) \ ^{20}_{10}Ne + \ ^{4}_{2}He$

Atomic masses are given to be m($^{2}_{1}H) = 2.014102u$, m($^{3}_{1}H) = 3.016049u$, $m(\ ^{12}_{6}C) = 12.000000u$, m($^{20}_{10}Ne) = 19.992439u$.

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16. Suppose, we think of fission of a $^{56}_{26}Fe$ nucleus into two equal fragments, $^{28}_{13}Al$. Is the fission energetically possible ? Argue by working out Q of the process. Given m($^{56}_{26}Fe) = 55.93494u$ and m($^{28}_{13}Al) = 27.98191u$.

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17. The fission properties of $_{94}^{239}Pu$ are very similar to those of $_{92}^{235}U$. The average energy released per fission is 180 MeV. How much energy, in MeV, is released if all the atoms in 1 kg of pure $_{94}^{239}Pu$ undergo fission ?

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18. A 1000 MW fission reactor consumes half of its fuel in 5.00 y. How much $_{92}^{235}U$ did it contain initially ? Assume that the reactor operaters 80% of the time, that all the energy generated arises from the fission of $_{92}^{235}U$ and that this nuclide is consumed only by the fission process.

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19. How long can an electric lamp of 100 W be kept glowing by fusion of 2.0 kg of deuterium ? Take the fusion reaction as

$$_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + n + 3.27 MeV.$$

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20. Calculate the height of the potential barrier for a head on collision of two deuterons.

(Hint : The height of the potential barrier is given by the Coulomb repulsion between the two deuterons when they just touch each other. Assume that they can be taken as hard spheres of radius 2.0 fm.)

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21. From the relation $R = R_0 A^{\frac{1}{3}}$, where R_0 is a constant and A is the mass number of a nucleus, show that the nuclear matter density is nearly constant (i.e., independent of A).

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Additional Question

1. In a periodic table, the average atomic mass of magnesium is given as 24,312 u. The average value is based on their relative natural abundance on earth. The three isotopes and their masses are $^{24}_{12}Mg$(23.98504 u), $^{25}_{12}Mg$ (24.98584 u) and $^{26}_{12}Mg$(25.98259 u). The natural abundance of $^{24}_{12}Mg$ is 78.99% by mass. Calculate the abundances of the other two isotopes.

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2. The neutron separation energy is defined as the energy required to remove a neutron from the nucleus. Obtain the neutron separation energies of the nuclei $^{41}_{20}Ca$ and $^{27}_{13}Al$ from the following data:

m(

$$^{40}_{20}Ca) = 39.962591u, m(\; ^{41}_{20}Ca) = 40.962278u, m(\; ^{26}_{13}Al) = 25.98689$$

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3. A source contains two phosphorus radio nuclides $^{32}_{15}P\left(T_{\frac{1}{2}} = 14.3d\right)$ and $^{33}_{15}P\left(T_{\frac{1}{2}} = 25.3d\right)$. Initially, 10% of the decays come from $^{33}_{15}P$. How long one must wait until 90% do so ?

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4. Under certain circumstances, a nucleus can decay by emitting a particle more massive than α-particle. Consider the following decay processes:

$^{223}_{88}Ra \rightarrow \ ^{209}_{82}Pb + \ ^{14}_{6}C$

$^{223}_{88}Ra \rightarrow \ ^{219}_{86}Rn + \ ^{4}_{2}He$. Calculate the Q-values for these decays and determine that both are energetically allowed.

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5. Consider the fission of $^{238}_{92}U$ by fast neutrons. In one fission event, no neutrons are emitted and the final end products, after the beta decay of the primary fragments, are $^{140}_{58}Ce$ and $^{99}_{44}Ru$. Calculate Q for this fission process. The relevant atomic and particle masses are $m(\ ^{238}_{92}U) = 238.05079u, m(\ ^{140}_{58}Ce) = 139.90543u, m(\ ^{99}_{44}Ru) = 98.9$

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6. Consider the D-T reaction (deuterium-tritium fusion)

$$^{2}_{1}H + \ ^{3}_{1}H \rightarrow \ ^{4}_{2}He + n$$

(a) Calculate the energy released in MeV in this reaction from the data:

$m(\ ^{2}_{1}H) = 2.014102u, m(\ ^{3}_{1}H) = 3.016049u$

(b) Consider the radius of both deuterium and tritium to be approximately 2.0 fm. What is the kinetic energy needed to overcome the coulomb repulsion between the two nuclei ? To what temperature must the gas be heated to initiate the reaction ? (Hint: Kinetic energy required for one fusion event = average thermal kinetic energy available with the interacting particles = 2(3kT/2), k = Boltzman's constant, T = absolute temperature.)

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7. Obtain the maximum kinetic energy of B-particles, and the radiation frequencies of y decays in the decay scheme shown in Fig.13.01. You are given that

$m\left({}^{198}Au\right) = 197.968233u$ and $m\left({}^{198}Hg\right) = 197.966760u$

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8. Calculate and compare the energy released by (a) fusion of 1.0 kg of hydrogen deep within Sun and (b) the fission of 1.0 kg of ${}^{235}U$ in a fission reactor.

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9. Suppose India had a target of producing by 2020 AD, 200,000 MW of electric power, ten per cent of which was to be obtained from nuclear power plants. Suppose we are given that, on an average, the efficiency of utilisation (i.e, conversion to electric energy) of thermal energy produced in a reactor was 25%. How much amount of fissionable uranium would our country need per year by 2020 ? Take the heat energy per fission of ${}^{235}U$ to be about 200 MeV.

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Cbse Based Source Based Integrated Questions

1. Read the following passage and then answer questions (a) - (e) on the basis of your understanding of the passage and the related studied concepts.

Rutherford was the pioneer who established the existence of the atomic nucleus. Result of Geiger and Marsden experiment on the scattering of a-particles from thin gold foils, performed at Rutherford's suggestion, revealed that the distance of closest approach to a gold nucleus of an a-particle of kinetic energy 5.5 MeV is about $4.0 \times 10^{-14} m$. The said scattering effect was explained by Rutherford by assuming that the Coulombian repulsive force was solely responsible for scattering. Since the positive charge is confined to the nucleus, the actual size of the nucleus has to be less than 4.0×10^{-14}m.

If we use a-particles of higher energies, the distance of closest approach to the gold nucleus will be still smaller. At some point the scattering will begin to be affected by the short range nuclear forces and differ from

Rutherford's calculations. From the distance at which deviations set it, nuclear size can be inferred.

(a) Define MeV and express its value in terms of SI unit of energy.

(b) What is distance of closest approach ?

(c) Write an expression for distance of closest approach of a-particle to a gold nucleus.

(d) What was Rutherford's hypothesis regarding the existence of the atomic nucleus ?

(e) How can you show that volume of the nucleus of an element is proportional to its mass number ?

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2. Read the following passage and then answer questions (a) — (e) on the basis of your understanding of the passage and the related studied concepts.

Before the advent of Einstein's special theory of relativity it was presumed that mass and energy were conserved separately in a reaction. But Einstein showed, from this theory of special relativity, equivalence of mass and energy and gave the famous mass-energy equivalence relation E = mc^2, where c is the speed of light in vacuum. So now we speak about a unified law of conservation of energy considering mass-energy also as a form of energy.

The most convincing evidence that of mass energy equivalence principle operates in nature comes from the results of nuclear physics. It is central to our understanding of nuclear energy and harnessing it as a source of electrical power. Using this principle, we can easily explain the concept of binding energy of nuclei as well as the Q-value of a nuclear process (either nuclear decay or nuclear reaction).

(a) What is an atomic mass unit ?

(b) Calculate the energy equivalent of one atomic unit and express your answer in MeV.

(c) Define mass defect of a nucleus.

(d) How is mass defect of a nucleus related to its binding energy ?

(e) Name any two phenomenon where large amount of energy is produced in accordance with mass-energy equivalence.

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3. Read the following passage and then answer questions (a) — (e) on the basis of your understanding of the passage and the related studied concepts.

Henry Becquerel, in 1896, discovered the radioactivity purely by accident when he observed that pieces of uraniumpotassiumsulphate emit something which are able to penetrate black paper as well as a silver foil. Subsequent experiments showed that radioactivity was a nuclear phenomenon in which a unstable nucleus undergoes a decay. Three types of radioactive decay occur in nature, namely (i) α-decay in which a helium nucleus, $\left({}_2^4He \right)$ is emitted, (ii) β-decay in which electrons (or positrons) are emitted, and (iii) γ-decay in which high energy photons are emitted. The decay rate of a radioactive sample is a measurable quantity and is known as 'activity'. A common way to characteristic decay rate of a substance is 'half-life period' $\left(T_{\frac{1}{2}}\right)$ which is the time during which half of the radioactive material decays and one half remains intact. Another related measure is the average or mean life τ. It is related to $T_{\frac{1}{2}}$ as per relation $T_{\frac{1}{2}} = 0.693\tau$.

(a) What is radioactivity?

(b) Give two examples of radioactive elements?

(c) Out of three types of radioactive radiations which are deflected by an electric and a magnetic field and why?

(d) A radioactive sample has a half-life period of 5 hours. What fraction of original sample remains undecayed after 20 hours.

(e) Complete the following nuclear reaction :

$$ {}^{180}_{72}A \xrightarrow{\alpha} A_1 \xrightarrow{\beta^-} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4 $$

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Multiple Choice Questions

1. Order of magnitude of density of uranium nucleus is

A. $10^{20} kgm^{-3}$

B. $10^{17} kgm^{-3}$

C. $10^{14} kgm^{-3}$

D. $10^{11} kgm^{-3}$

Answer: B

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2. When a nucleus in an atom undergoes a radioactive decay, the electronic energy levels of the atom

A. do not change for any type of radioactivity.

B. change for α and β radioactivity but not γ-radioactivity.

C. change for α-radioactivity but not for others

D. change for β-radioactivity but not for others

Answer: B

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3. M_n and M_p represent mass of neutron and proton respectively. If an element having nuclear mass M has N neutron and Z protons, then the correct relation will be

A. $M < [NM_n + ZM_p]$

B. $M > [NM_n + ZM_p]$

C. $M = [NM_n + ZM_p]$

D. $M = N[M_n + M_p]$

Answer: A

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4. The energy released in a typical nuclear fusion reaction is approximately

A. 25MeV

B. 200MeV

C. 800MeV

D. 1050MeV

Answer: A

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5. The binding energy per nucleon of deuterium and helium atom is 1.1 MeV and 7.0 MeV. If two Deuterium nuclei fuse to form helium, the energy released is

A. 19.2MeV

B. 23.6MeV

C. 26.9MeV

D. 13.9MeV

Answer: B

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6. Heavy stable nuclei have more neutrons than protons. This is because of the fact that

A. neutrons are heavier than protons.

B. electrostatic force between protons are repulsive.

C. neutrons decay into protons through beta decay.

D. nuclear forces between neutrons are weaker than that between protons.

Answer: B

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7. The nuclei of which one of the following pairs of nuclei are isotones

A. $^{74}_{34}Se, \quad ^{71}_{31}Ga$

B. $^{92}_{42}Mo, \quad ^{92}_{40}Zr$

C. $^{81}_{38}Sr, \quad ^{86}_{38}Sr$

D. $^{40}_{20}Ca, \quad ^{32}_{16}S$

Answer: A

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8. If radius of $^{27}_{13}Al$ nucleus is estimated to be 3.6fm, then the radius of $^{125}_{32}Te$ nucleus be nearly

A. 4fm

B. 5fm

C. 6fm

D. 8fm

Answer: C

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9. The half-life of radium is about 1600 years. Of 100g of radium existing now, 25g will remain unchanged after

A. 2400 years

B. 4800 years

C. 3200 years

D. 6400 years

Answer: C

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10. Two nuclei have their mass numbers in the ratio of 1:3. The ratio of their nuclear densities whould be

A. $1:1$

B. $1:3$

C. $3:1$

D. $[3]^{\frac{1}{3}}:1$

Answer: A

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11. The half-life period of a radioactive element X is same as the mean lifetime of another radioactive element Y. Initially they have the same number of atoms. Then

A. X and Y decay at same rate aways.

B. X will decay faster than Y.

C. Y will decay faster than X.

D. X and Y have same decay rate initially.

Answer: C

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12. A radioactive nucleus of mass M emits a photon of frequency ν and the nucleus recoils. The recoil energy will be

A. $h\nu$

B. $Mc^2 - h\nu$

C. $\frac{h^2\nu^2}{2Mc^2}$

D. zero

Answer: C

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13. In the nuclear decay given below $^{A}_{Z}X \rightarrow \ ^{A}_{Z+1}Y \rightarrow \ ^{A-4}_{Z-1}B^{\cdot} \rightarrow \ ^{A-4}_{Z-1}B$, the particles emitted in the sequence are :

A. β, α, γ

B. γ, β, α

C. β, γ, α

D. α, β, γ

Answer: A

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14. The size of the nucleus of an atom of mass number A is proportional to

A. $A^{\frac{3}{4}}$

B. $A^{\frac{2}{3}}$

C. $A^{\frac{1}{3}}$

D. $A^{\frac{5}{3}}$

Answer: C

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15. 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

A. $\frac{A - Z - 8}{Z - 4}$

B. $\frac{A - Z - 4}{Z - 8}$

C. $\frac{A - Z - 12}{Z - 4}$

D. $\frac{A - Z - 4}{Z - 2}$

Answer: B

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16. Energy equivalent of one atomic mass unit is

A. 931eV

B. 931keV

C. 931 MeV

D. 931 J

Answer: C

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17. Atomic mass of boron is 10.81 and it has two isotopes $^{10}_{5}B$ and $^{11}_{5}B$. The ratio of $^{10}_{5}B$ to $^{11}_{5}B$ in nature would be

A. $19:81$

B. $10:11$

C. $15:16$

D. $81:19$

Answer: A

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18. If binding energy per nucleon in $^{7}_{3}Li$ and $^{2}_{4}He$ nuclei be 5.60 MeV and 7.06 MeV respectively, then energy released in nuclear reaction $^{7}_{3}Li + \ ^{1}_{1}H \rightarrow 2\ ^{4}_{2}He$ is

A. 19.6 MeV

B. 2.4 MeV

C. 8.4 MeV

D. 17.3 MeV

Answer: D

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19. Energy generation in stars is mainly due to

A. Chemical reactions

B. nuclear fission to heavy nuclei

C. fusion of light nuclei

D. fusion of heavy nuclei

Answer: C

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20. In the nuclear reaction $^{11}_{6}C \rightarrow {}^{11}_{5}B + {}^{0}_{+1}e + X$, what does X stand for

A. an electron

B. a proton

C. a neutron

D. a neutrino

Answer: D

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21. A free neutron decays into a proton, an electron and

A. a neutrino

B. a γ-ray photon

C. an antineutrino

D. a neutron

Answer: C

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22. A nucleus of $^{238}_{92}U$, originally at rest, emits an α-particle with a speed ν. Recoil speed of the daughter nucleus will be

A. $\frac{4\nu}{234}$

B. $\frac{4\nu}{238}$

C. $\frac{234}{4\nu}$

D. $\frac{238}{4\nu}$

Answer: A

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23. Half-life period of radium is 1600 years. Its average life period is

A. 3200 years

B. 2319 years

C. 1131 years

D. 4800 years

Answer: B

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24. The average life period (τ) of a radioactive material and its disintegration constant (λ) are correlated as

A. $\tau\lambda$=1

B. $\frac{\tau}{\lambda}$

C. $\tau = \frac{0.693}{\lambda}$

D. $\tau = 0.693\lambda$

Answer: A

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25. Half-life of a radioactive sample is 5 days. What time is taken for $\frac{7}{8}$th part of the sample of decay ?

A. 3.4 days

B. 10 days

C. 15 days

D. 20 days

Answer: B

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26. A nuclide of $^{232}_{90}Th$ decays successively in a number of steps and finally we get $^{208}_{82}Pb$. The number of alpha and beta particles emitted in the process are

A. $\alpha = 3, \beta = 3$

B. $\alpha = 6, \beta = 4$

C. $\alpha = 6, \beta = 0$

D. $\alpha = 4, \beta = 6$

Answer: B

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27. The decay constant of a radioactive sample is $0.01s^{-1}$. Its half-life period is

A. 693 s

B. 6.93 s

C. 0.693 s

D. 69.3 s

Answer: D

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28. The activity of a radioactive source initially is 1600 Bq and after 8 s the activity falls to 100 Bq. What is its activity at time t=6s ?

A. 400 Bq

B. 300 Bq

C. 200 Bq

D. 150 Bq

Answer: C

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29. The half-life of $^{131}_{53}I$ is 8 days. Give a sample of $^{131}_{53}I$ 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

Answer: D

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30. The electron emitted in beta radiation originates from

A. inner orbits of atom

B. free electrons existing in nuclei

C. decay of a neutron in a nucleus

D. photon escaping from the nucleus

Answer: C

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Fill In The Blanks

1. Nuclei having the same .... but different .... are called isotopes.

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2. The order of magnitude of the density of nuclear matter is ....

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3. The average binding energy per nucleon for the nuclei lying in the middle of periodic table, mass number 'A' ranging from 40 to 120, is nearly ....

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4. A radioactive material has a half-life of 5 hours. In 20 hours 1g of material is reduced to ....

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5. Half-life period $(T_{\frac{1}{2}})$ and mean life period (τ) of a radioactive sample are corelated as ....

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6. Complete the reaction : $^{180}_{72}A \xrightarrow{-\alpha} A_1 \xrightarrow{-\beta^-} A_2$

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7. The process responsible for energy production in the Sun is ....

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8. Two nuclides have mass number 64 and 125 respectively. Ratio of their radii is ....

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9. Nuclides of $^{235}_{92}U$ can undergoes nuclear fission when bombarded by ....

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10. A nuclear fission reactor, designed to produce electric power at a uniform rate, makes use of the phenomenon of ....

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11. Isotones are the nuclides which contain ....

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Assertion Reason Type Questions

1. Assertion (A) : Nuclear density has same value for all nuclei irrespective of their atomic numbers and mass numbers.

Reason (R) : Radius of a nucleus is directly proportional to the cube root of its mass number.

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2. Assertion (A) : Radioactive nuclei emit β- particles whose charge and rest mass are exactly same as that of electrons .

Reason (R) : Electrons exists inside the nucleus .

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3. Assertion (A) : Neutrons penetrate matter more readily than protons .

Reason (R) : Neutrons are slightly more massive than protons .

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4. Assertion (A) : Isobars are the nuclei having same mass number but different atomic number.

Reason (R) : Neutrons and protons are present inside a nucleus .

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5. Assertion (A) : When U-235 isotope is bombarded by slow neutrons , nuclear fission takes place with a release of about 200 Me V of energy .

Reason (R) : The disintegration energy is fission event first appears as the kinetic energy of fragments and neutrons but eventually it is transferred to the surrounding matter appearing as heat .

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Very Short Answer Question

1. How is the radius of a nucleus related to its mass number?

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

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3. Two nuclei have mass numbers in the ratio 27:125. What is the ratio of their nuclear radii?

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4. Assuming the nuclei to be spherical in shape, how does the surface area of a nucleus of mass number A_1 compare with that of a nucleus of mass number A_2.

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

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6. Why is the ionising power of α-particles greater than of γ-rays?

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7. Define the term 'activity' of a radionuclide. Write its SI unit.

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8. Name and define the SI unit for the activity of a given sample of radioactive nuclei.

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9. Define the binding energy of a nucleus.

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10. A nucleus of mass number A has a mass defect Δm. Give the formula, for the binding energy per nucleon of this nucleus.

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11. Write the relation between half-life and decay constant of a radioactive sample.

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12. Define decay constant of a radioactive sample.

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13. What is the relationship between the half-life and mean life of a radioactive substance ?

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14. Plutonium decays with a half-life of 24000 years. If plutonium is stored for 72000 years, what fraction of it remains ?

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15. A nucleus undergoes β-decay. How does its (i) mass number, (ii) atomic number change ?

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16. A nucleus $^{238}_{92}U$ undergoes alpha decay and transforms to thorium. What is (i) the mass number, and (ii) atomic number of the nucleus formed ?

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17. Write the nuclear decay process for β^--decay of $^{32}_{15}P$.

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18. Out of the two characteristics, the mass number (A) and the atomic number (Z) of a nucleus, which one does not change during nuclear β-decay?

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19. Give an equation representing the decay of a free neutron?

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20. Why is it difficult to detect the presence of an antineutrino during β-decay ?

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21. ${}_{2}^{3}He$ and ${}_{1}^{3}H$ nuclei have the same mass number. Do they have the same binding energy ?

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22. The radioactive isotope D decays according to the sequence $D \xrightarrow{\beta^-} D_1 \xrightarrow{\alpha - \text{particle}} D_2$ If the mass number and atomic number of D, are 176 and 71 respectively, what is (i) the mass number (ii) atomic number of D ?

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23. Name the reaction responsible for energy production in the Sun.

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24. Why is it found experimentally difficult to detect neutrinos in nuclear β-decay process ?

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25. Draw a graph showing the variation of decay rate $\left(-\frac{dN}{dt}\right)$ with number (N) of radioactive nuclei.

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26. Which sample A or B, shown in Fig. 13.03, has shorter mean life ?

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27. Four nuclei of an element undergo fusion to form a heavier nucleus, with release of energy. Which of the two — the parent or the daughter nucleus — would have higher binding energy per nucleon ?

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28. What is a thermo-nuclear reaction ?

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29. State with reason why light nuclei usually undergo nuclear fusion.

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30. State two characteristic properties of nuclear forces.

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Short Answer Questions

1. How is size of a nucleus experimentally determined? Write the relation between the radius and mass number of the nucleus. Show that the density of nucleus is independent of its mass number.

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2. Distinguish between isotopes and isobars, giving one example for each.

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3. Draw a graph showing the variation of binding energy per nucleon with mass number of different nuclei. State two inferences from this graph.

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4. Classify the following six nuclides into (i) isotones, (ii) isotopes, and (iii) isobars :

$${}^{12}_{6}C, \quad {}^{3}_{2}He, \quad {}^{198}_{80}Hg, \quad {}^{3}_{1}H, \quad {}^{197}_{79}Au, \quad {}^{14}_{6}C$$

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5. Draw a plot of the binding energy per nucleon as a function of mass number for a large number of nuclei, $2 \leq A \leq 240$. How do you explain the constancy of binding energy per nucleon in the range $30 < A < 170$ using the property that nuclear force is short-ranged ?

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6. Draw the graph showing the variation of binding energy per nucleon with mass number. Give the reason for the decrease of binding energy per nucleon for nuclei with high mass numbers.

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7. Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release in energy in the processes of nuclear fission and nuclear fusion can be explained.

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8. Write important features of nuclear forces.

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9. State two characteristics of nuclear force. Why does the binding energy per nucleon decrease with increase in mass number for heavy nuclei like ^{235}U ?

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10. If both the number of protons and neutrons in a nuclear reaction is conserved, in what way is mass converted into energy (or vice versa) ? Explain giving one example.

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11. Plot a graph showing the variation of undecayed nuclei N versus time t. From the graph, find out how one can determine the half-life and average life of the radioactive nuclei.

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12. Calculate the energy released in MeV in the following nuclear reaction :

$$ {}_{92}^{238}U \rightarrow {}_{90}^{234}Th + {}_{2}^{4}He + Q $$

mass of ${}_{92}^{238}U = 238.05079u$, mass of ${}_{90}^{234}Th = 234.043630u$, mass of ${}_{2}^{4}He = 4.00260u, 1u = 931.5Me\frac{V}{c^2}$.

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13. Define 'disintegration constant' and 'mean life' of a radioactive substance. Give the unit of each.

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14. Define half-life period of a radioactive substance. Establish its relationship with the decay constant.

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15. A radio nuclide sample has N_0 nuclei at t=0. Its number of undecayed nuclei get reduced to $\frac{N_0}{e}$ at t=τ. What does the term 'τ' stand for ? Write in terms of 'τ', the time interval T in which half of the original number of nuclei of this radio nuclide would have got decayed.

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16. A radioactive substance has half-life $T_{\frac{1}{2}}$ and number of radioactive nuclides present initially was N_0. What is the number of radioactive nuclides at time t ?

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17. A radioactive nucleus 'A' undergoes a series of decays according to the following scheme :

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

The mass number and atomic number of A are 180 and 72 respectively. What are these numbers for A_4?

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18. Complete the following nuclear reactions :

(a) $${}_{5}^{10}B + {}_{0}^{1}n \rightarrow {}_{2}^{4}He + \ldots\ldots .$$ (b)

$${}_{42}^{94}Mo + {}_{1}^{2}H \rightarrow {}_{43}^{95}Te + \ldots\ldots\ldots$$

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19. Draw a plot of potential energy of a pair of nucleons as a function of their separation. What is the significance of negative potential energy in the graph drawn ?

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20. Draw a graph showing the variation of potential energy between a pair of nucleons as a function of their separation. Indicate the regions in which the nuclear force is (i) attractive, (ii) repulsive.

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21. Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions which you can draw regarding the nature of nuclear forces.

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22. Distinguish between the phenomena of nuclear fission and fusion.

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23. The half-life of $^{238}_{92}U$ undergoing α-decay is 4.5×10^9 years. Find the activity of 1 g sample of $^{238}_{92}U$.

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24. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV.

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25. A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks into two fragments each of A= 120 with BE/A = 8.5 MeV. Calculate the released energy.

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26. Calculate the energy released in fusion reaction : ${}_1^2H + {}_1^2H \rightarrow {}_2^3He + n$, where BE of ${}_1^2H = 2.23 MeV$ and of ${}_2^3He = 7.73 MeV$.

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27. A radioactive sample has activity of 10,000 disintegrations per second after 20 hours. After next 10 hours its activity reduces to 5,000 disintegrations per second. Find out its half-life and initial activity.

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28. (a) Write two distinguishing features of nuclear forces.

(b) Complete the following nuclear reactions for a and B decay:

(i) $^{238}_{92}U \rightarrow ? + \ ^{4}_{2}He + Q$ (ii) $^{22}_{11}Na \rightarrow \ ^{22}_{10}Ne + ? + \nu$

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Long Answer Question I

1. (i) What characteristic property of nuclear force explains the constancy of binding energy per nucleon (BE/A) in the range of mass number 'A' lying $30 < A < 170$?

(ii) Show that the density of nucleus over a wide range of nuclei is constant-independent of mass number A.

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2. (a) Write the relation for binding energy (in MeV) of a nucleus $^{A}_{Z}X$ of atomic number 'Z' and mass number 'A' in terms of the masses of its constituents — neutrons and protons.

(b) Draw a plot of binding energy per nucleon versus mass number 'A' for $2 \leq A \leq 240$. Use this graph to explain the release of energy in the process of nuclear fusion of two light nuclei.

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3. Draw the graph to show variation of binding energy per nucleon with mass number of different atomic nuclei. Calculate binding energy per nucleon of $^{40}_{20}Ca$ nucleus. Given : mass of $^{40}_{20}Ca = 39.962589u$, mass of proton=1.007825 u, mass of neutron=1.008665 u and 1 u=931 MeV/c^2.

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4. (a) In a typical nuclear reaction, e.g.,

$$^2_1H + \ ^2_1H \rightarrow \ ^3_2He + n + 3.27MeV,$$

although number of nucleons is conserved, yet energy is released. How ? Explain.

(b) Show that nuclear density in a given nucleus is independent of mass number A.

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5. What is the basic mechanism for the emission of β^- or β^+ particles in a nuclide? Give an example by writing explicitly a decay process for B' emission.

Is (a) the energy of the emitted β^- particles continuous or discrete,

(b) the daughter nucleus obtained through β-decay an isotope or an isobar of the parent nucleus ?

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6. (i) A radioactive nucleus 'A' undergoes a series of decays as given below :

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

The mass number and atomic number of A_2 are 176 and 71 respectively.

Determine the mass and atomic numbers of A_4 and A.

(ii) Write the basic nuclear processes underlying β^+ and β^- decays.

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7. (a) Write the basic nuclear process involved in the emission of β^+ in asymbolic form, by a radioactive nucleus.

(b) In the reactions given below:

(i)

$${}^{11}_{6}C \to {}^{z}_{y}B + x + \nu \qquad (ii) \quad {}^{12}_{6}C + {}^{12}_{6}C \to {}^{20}_{a}Ne + {}^{c}_{b}He$$

Find the values of x, y and z and a, b and c.

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8. (i) Define 'activity' of a radioactive material and write its SI unit.

(ii) Plot a graph showing variation of activity of a given radioactive sample with time.

(iii) The sequence of stepwise decay of a radioactive nucleus is

$D \xrightarrow{\alpha} D_1 \overset{\beta^-}{D}_2$

If the atomic number and mass number of D_2 are 71 and 176 respectively, what are their corresponding values for D?

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9. Derive the relation $N_t = N_0 e^{-\lambda t}$ for radioactive decay. Obtain the relation between disintegration constant and half-life.

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10. (a) Deduce the expression, $N = N_0 e^{-\lambda t}$ for the law of radioactive decay.

(b) (i) Write symbolically the process expressing the β^+ decay of $^{22}_{11}Na$. Also write the basic nuclear process underlying this decay.

(ii) Is the nucleus formed in the decay of the nucleus $^{22}_{11}Na$, an isotope or isobar ?

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11. (a) Write symbolically the β^{-} decay process of $_{15}^{32}P$.

(b) Derive an expression for the average life of a radionuclide. Give its relationship with the half-life.

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12. State the law of radioactive decay.

Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half-life $T_{\frac{1}{2}}$.

Depict in the plot the number of undecayed nuclei at (i) $t = T_{\frac{1}{2}}$ and (ii) $t = 5T_{\frac{1}{2}}$.

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13. (a) The number of nuclei of a given radioactive sample at time t = 0 and t= T are N_0 and $\frac{N_0}{n}$ respectively. Obtain an expression for the half-life $T_{\frac{1}{2}}$. of the nuclide in terms of n and T.

(b) Write the basic nuclear process underlying β^--decay of a given radioactive nucleus.

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14. An observer, in a laboratory, starts with N_0 nuclei of a radioactive sample and keeps on observing the number (N) of left over nuclei at regular intervals of 10 minutes each. She prepares the following table on the basis of her observations :

Use this data to plot a graph of $\log_e\left(\frac{N_0}{N}\right)$ vs time (t) and calculate the

(i) decay constant and

(ii) half-life of the given sample.

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15. Define the term 'decay constant' of a radioactive sample. The rate of disintegration of a given radioactive nucleus is 10000 disintegrations/s and 5000 disintegrations/s after 20 h and 30 h respectively from start. Calculate the half-life and initial number of nuclei at t = 0.

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16. (a) Define the term activity of a sample of radioactive nucleus. Write its SI unit.

(b) The half-life of $_{92}^{238}U$ undergoing α-decay is 4.5×10^9 years. Determine the activity of 10 g sample of $_{92}^{238}U$. Given that 1 g of $_{92}^{238}U$ contains 25.3×10^{20} atoms.

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17. (a) Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A.

(b) A radioactive isotope has a half-life of 10 years. How long will it take for the activity to reduce to 3.125%?

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18. Explain giving necessary reactions, how energy is released during (i) fission, and (ii) fusion.

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19. (a) Distinguish between nuclear fission and fusion. Show how in both these processes energy is released.

(b) Calculate the energy release in MeV in the deuterium-tritium fusion reaction :

$$ {}_1^2H + {}_1^3H \to {}_2^4He + n $$

Using the data:

$m({}_1^2H) = 2.014102u$, $m({}_1^3H) = 3.016049u$, $m({}_2^4He) = 4.002603u$,

and $1u = 931.5Me\frac{V}{c^2}$.

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20. (a) Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions where the nuclear force is (i) attractive, and (ii) repulsive.

(b) In the nuclear reaction

$n + \ {}^{235}_{92}U \rightarrow \ {}^{a}_{54}Xe + \ {}^{97}_{b}Sr + 2n$ determine the values of 'a' and 'b'.

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21. A radioactive sample contains 2.2 mg of pure ${}^{11}_{6}C$ which has half-life period of 1224 seconds. Calculate :

(i) the number of atoms present initially.

(ii) the activity when $5\mu g$ of the sample will be left.

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22. (a) Draw the energy level diagram showing the emission of β-particles followed by γ-rays by a ${}^{60}_{27}Co$ nucleus.

(b) Plot the distribution of kinetic energy of β-particles and state why the energy spectrum is continuous.

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Long Answer Question Ii

1. (a) Draw the plot of binding energy per nucleon (BE/A) as a function of mass number A. Write two important conclusions that can be drawn regarding the nature of nuclear force.

(b) Use this graph to explain the release of energy in both the processes of nuclear fusion and fission.

(c) Write the basic nuclear process of neutron undergoing β-decay. Why is the detection of neutrinos found very difficult ?

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2. (a) Define the term 'activity' of a given sample of radio nuclide. Write the expression for the law of radioactive decay in terms of the activity of a given sample.

(b) A radioactive isotope has a half-life of T years. How long will it take the activity to reduce to 3.125% of its original value ?

(c) When a nucleus (X) undergoes β-decay, it transforms to the nucleus (Y). Does the pair (X, Y) form isotopes, isobars or isotones ? Justify your answer.

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Self Assessment Test

1. The binding energy of $_{1}^{2}H$ is 1.112 MeV per nucleon and an alpha-particle $_{2}^{4}He$ has a binding energy of 7.047 MeV per nucleon. In the fusion reaction $_{1}^{2}H + \ _{1}^{2}H \rightarrow \ _{2}^{4}He + Q$, the energy released is

A. 1MeV

B. 11.9MeV

C. 23.8 MeV

D. 931 MeV

Answer: C

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2. In a nuclear reaction, which of the following is conserved ?

A. Atomic number

B. Mass number

C. Atomic number, mass number and energy

D. None of these

Answer: C

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3. Which of the following is in the increasing order of penetrating power ?

A. α, β, γ

B. β, α, γ

C. γ, α, β

D. γ, β, α

Answer: A

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4. A radioactive sample decays to form a stable nuclide. A graph showing variation of rate of disintegration $\left(\frac{dN}{dt}\right)$ of radioactive sample with time (t) is

A.

B.

C.

D.

Answer: C

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5. 1 curie is equal to

A. $3 \times 10^{10} Bq$

B. $3.7 \times 10^{7} Bq$

C. $5 \times 10^{7} Bq$

D. $3.7 \times 10^{10} Bq$

Answer: D

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6. A radioactive nuclide with Z protons and N neutrons emit an α-particle, two β-particles and two γ-rays. The number of protons and neutrons in the nuclide formed after the decay are

A. Z-3,N-1

B. Z-2,N-2

C. Z-1,N-3

D. Z,N-4

Answer: D

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7. During average life (τ) of a radioactive material, the number of nuclei left intact is .... where $N_0 =$ number of nuclides at time t =0.

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8. Calculate the energy released, in MeV, in the reaction

$$ {}_{3}^{6}Li + \ {}_{0}^{1}n \rightarrow \ {}_{2}^{4}He + \ {}_{1}^{3}H $$

Given that mass (${}_{3}^{6}Li) = 6.015126u,$ mass$(n) = 1.008665u,$ $m(\ {}_{2}^{4}He) = 4.002604$and $m(\ {}_{1}^{3}H) = 3.010000$. Take $1u = 931Me\frac{V}{c^2}$

.

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9. The half-life of ${}_{92}^{238}U$ undergoing α-decay is $4.5 \times 10^9 years$. Find the activity of 1 g sample of ${}_{92}^{238}U$.

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10. (a) State the law of radioactive decay. Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half-life $T_{\frac{1}{2}}$.

Depict in the plot the number of undecayed nucei at (i) $t = 3T_{\frac{1}{2}}$ and (ii) $t = 5T_{\frac{1}{2}}$.

(b) The half-life, of a given radioactive nuclide, is 138.6 days. What is the mean life of this nuclide? After how much time will a given sample of this radioactive nuclide get reduced to only 12.5% of its initial value?

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