3. Nuclear Fission and Fusion

A. Nuclear Fission:

1. The process of splitting up of the nucleus of a heavy atom into two nuclei more or less of equal fragments when bombarded with neutron simultaneously releasing a large amount of energy is called nuclear fission.

   $^{235}_{92}U + ^{1}_{0}n \rightarrow (^{236}_{92}U) \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + Q$.

2. Where Q is energy released which is about 200 MeV.

3. This phenomenon was first observed by Strassmann and Hann. It was explained by Neils Bohr and J.A. Wheeler on the basis of liquid drop model of the nucleus. According to liquid drop model, the nucleus behaves like a liquid drop and owing to surface tension it tries to be perfectly spherical in shape. When a neutron is absorbed by the nucleus, a compound nucleus is formed and some excitation energy is imparted to the nucleus. This excitation energy tries to deform the nucleus where as the surface tension of the nucleus tries to keep the nucleus in spherical shape. Due to the struggle between the surface tension and the excitation energy, strong oscillations are set up inside the compound nucleus. These oscillations will distort the shape of the compound nucleus from spherical to ellipsoid.
4. If the excitation energy is sufficiently large, the ellipsoidal nucleus may attain the dumb bell shape. In this case the effect of nuclear attractive force is decreased because of the much increased surface area of the nucleus. Further the coulombic repulsive force drives the two portions of the dumb bell still farther and the nucleus undergoes fission, liberating two nuclei Ba and Kr and neutrons. These newly liberated neutrons are called prompt neutrons. In this process the products are not always the same, their atomic number varies from 34 to 58. Hence the number of prompt neutrons will also change with the mass number of the products. The products, emitted neutrons finally become stable. These occur within few seconds after the fission reaction. These are called delayed neutrons. They play an important role in controlling the nuclear chain reaction in a nuclear reactor.
5. **Chain Reaction :** A chain reaction is a self propagating process in which a number of neutrons multiply rapidly during fission till the whole fissionable material is disintegrated.
6. Neutron multiplication factor K and conditions required for sustained chain reaction :

   In the fission of uranium nuclei, on an average 2.5 neutrons are emitted per fission. The neutrons produced in a fission event are fast neutrons and are referred to as "neutrons of first generation". There is certain probability for some neutrons to escape without participating in further fission process. Therefore all emitted neutrons are not available for further fissions. The basic conditions for self sustained chain reaction is that at least one neutron should be available. The requirements are given below.

   a) Fast neutrons should be changed into slow neutrons by passing through moderators.
   b) At least one thermal neutron should be available to initiate the fission reaction.
   c) The state of the chain reaction depends on the neutron multiplication factor 'K' which is defined as

   $$K=\frac{\text{number of neutrons in present generation}}{\text{number of neutrons in the previous generation}}$$

   when K<1, the number of neutrons in successive generations decreases and the chain reaction cannot continue. This state is called 'sub-critical state'.

   If K=1, the chain reaction will proceed at a steady rate and this state is called 'critical state'.

   If K>1, the number of neutrons increases and the reaction is said to be 'supercritical'.
7. **Critical mass :** If the mass of uranium is too small, the neutron may escape without participating further fission. To start the fission reaction mass of material should be more than the critical mass or critical size.
8. **Principal and working of a nuclear reactor :**

   The device giving large amount of nuclear energy through fission process at a controlled rate is called a nuclear reactor or atomic pile. The first nuclear reactor was put into operation in Chicago (USA) in 1942 by Fermi. In the nuclear reactor the first fission reaction results in the production of fast neutrons. If fast moving neutrons are allowed to pass through moderator they become thermal neutrons. Subsequently these thermal neutrons are utilized for further fission reactions to produce a large amount of energy.

9. **Essential features of a nuclear reactor :**

i) **Nuclear Fuel:** The fissionable material used in the reactor is called nuclear fuel.

ii) The uranium isotopes $_{92}U^{235}$ and $_{92}U^{238}$, plutonium $_{94}Pu^{236}$ and thorium $_{90}Th^{232}$ are commonly used as fuels in the reactors. The rods of these fuels are tightly sealed in aluminium cylinders.

iii) **Moderators :** The purpose of the moderator is to slow down the fast moving neutrons produced as a result of nuclear fission. Some of the suitable materials used as moderators are heavy water, beryllium, carbon in the form of pure graphite, hydrocarbon plastics etc.

iv) **Control rods :** These are the materials used in the nuclear reactors that can absorb the neutrons and control the nuclear chain reaction. Cadmium or boron rods are generally used for this purpose. When the control rods are completely inserted into the carbon blocks, they absorb neutrons to such an extent that the chain reaction completely comes to halt.

v) **Safety rods:** These are used to reduce the neutrons rate to less than one abruptly to stop the chain reaction whenever required.

vi) **Protective Shielding :** To prevent the spreading of the radioactive effect to the space around the nuclear reactor, lead blocks, concrete walls of thickness 10 m are used.

vii) **Coolant :** The material used to absorb the heat generated in the reactor is called coolant. Commonly used coolants are light water, heavy water and sodium gas.

The coolant releases the heat energy to water and is thus converted into steam, which is used to run the turbines. These turbines in turn generate the power.

10. **Radio-isotopes (Uses):**

i) Radio-isotopes are produced in nuclear reactor.

ii) Isotopes are used to test wear and tear of engine parts like piston rings, gears, ball bearings and helps in deciding the efficiency of lubricants.

iii) Radio-iodine ($_{53}I^{131}$) has half life of 8 days is used in determining functioning of thyroid gland, information about the size and location of brain tumour.

iv) Restriction in blood circulation can be detected using radio sodium.

v) Leukemia disease is treated by radiation from radio-isotopes of phosphorus.

vi) To find the age of ancient objects found in excavations, manuscripts etc., the technique of radio-carbon dating is used.

vii) Radio-isotopes are used to test the metal castings and weldings.

11. **Radiation hazards:**

i) Damage to the intestinal mucosa, impairment of the production of the blood corpuscles, damage to the system of producing antibodies which are important in the defence against infections, damage to the lens of the eye, production of cancers including leukemia etc.

ii) The radiation damage to human beings is due to (i) intake of radioactive materials and (ii) exposure to radiation.

iii) Radio-iodine is extremely dangerous as it is concentrated in the thyroid gland, a very sensitive organ.

iv) Irradiation of the body with small dose of γ-rays or X-rays increases the body temperature.

v) Radiation causes genetic mutation.

vi) Radon inhaled is injurious to lungs.

vii) Because of small penetrating power of α-radiation into our bodies, its damage is the least. The main external hazard is posed by γ-rays and neutrons.

viii) To prevent radiation hazards, rules have been worked out by International Commission of Radiation Protection (ICRP).

ix) Tolerance doses which are permissible for individuals when exposed professionally.

B. Nuclear Fusion:

1. The process of the formation of a single stable nucleus by fusing two or more lighter nuclei is called nuclear fusion.
   $^{2}_{1}H + ^{2}_{1}H \to ^{4}_{2}He + 24\,MeV$.
2. If the energy released per nucleon in fusion is considered, then it is much higher in a fusion reaction than in the fission reaction, which is almost 7 times.
3. To carry out the fusion of two nuclei temperature nearly equal to 10^{7} K is required. Once the fusion takes place the energy released can maintain the minimum required temperature for further and the fusion continues. Nuclear fusion reaction is also termed as thermo nuclear reaction. The secret behind the production of energy of the sun and the stars is nothing but the thermo nuclear reactions (Nuclear fusion).
4. Hydrogen bomb is based on the principle of nuclear fusion.
5. **Energy of the Sun and the Stars:**

   Scientists proposed two types of cyclic processes for sources of energy in the sun and stars. The first one is known as carbon-nitrogen cycle and the second one is proton-proton cycle.

   1. Carbon-Nitrogen Cycle: Bethe (1938) proposed a set of reactions taking place in the central part of the sun and stars in which carbon and nitrogen act as catalysts.

   $^{1}_{1}H + ^{12}_{6}C \to ^{13}_{7}N + Q_1$

   $^{13}_{7}N \to ^{13}_{6}C + ^{0}_{1}e$

   $^{1}_{1}H + ^{13}_{6}C \to ^{14}_{7}N + Q_2$

   $^{1}_{1}H + ^{14}_{7}N \to ^{15}_{8}O + Q_3$

   $^{15}_{8}O \to ^{15}_{7}N + ^{0}_{1}e + Q_4$

   $^{1}_{1}H + ^{15}_{7}N \to ^{12}_{6}C + ^{4}_{2}He$

   All the above reactions are added to give the following net nuclear reaction.

   $4\,^{1}_{1}H \to ^{4}_{2}He + 2\,^{0}_{1}e + Q$

   The above set of six reactions is called carbon-nitrogen cycle. In this process the four protons are fused to form 2 positrons and helium nuclei releasing 26.72 MeV of energy.

   2. Proton-Proton Cycle : Recent experiments show that the carbon-nitrogen cycle comes at a rather late stage in the life of the stars. Scientists proposed another nuclear fusion cycle process which takes place comparatively at low temperatures than carbon-nitrogen cycle and gives the same amount of energy as shown below.

   $^{1}_{1}H + ^{1}_{1}H \to ^{2}_{1}H + ^{0}_{1}e + Q_1$

   $^{1}_{1}H + ^{2}_{1}H \to ^{3}_{2}He + Q_2$

   $^{1}_{1}H + ^{3}_{2}He \to ^{4}_{2}He + ^{0}_{1}e + Q_3$

   on adding $4\,^{1}_{1}H \to ^{4}_{2}He + 2\,^{0}_{1}e + Q$

   Energy released in this cycle is 24.6 MeV.
6. At the interior of sun, the temperature is of the order of $2x10^{6}$ K at which both of the above mentioned processes are equally probable. Stars having temperature more than that of sun obtain their energy

from carbon-nitrogen cycle and the stars at low temperature follow proton-proton cycle in energy emission.

7. Positron is the anti-particle of electron and was first discovered by Anderson, although theoretically its existence was predicted by Dirac.
8. **Pair production :**

   A γ-ray can disintigrate in to positron and an electron.

   $\gamma \rightarrow e^+ + e^-$

   The minimum energy of γ-ray to produce pair is 1.02 MeV.
9. **Pair annihilation :** An electron and positron have the same mass and spin. However, they have the opposite charge. They annihilate each other, with the emission of 2 photons, when they come into contact. This is represented by the equation.

   $e^- + e^+ = 2\gamma$

   The two photons move in opposite direction.

QUESTION BANK

1. The radioactivity of a sample is 'X' at a time 't$_1$' and 'Y' at a time 't$_2$'. If the mean life time of the specimen is τ, the number of atoms that have disintegrated in the time interval (t$_1$ - t$_2$) is :

   1) $Xt_1 - Yt_2$ 2) X-Y 3) $\frac{X-Y}{\tau}$ 4) $(X-Y)\tau$
2. 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 less than one fermi, then

   1) $F_{pp}>F_{pn}=F_{nn}$ 2) $F_{pp}=F_{pn}=F_{nn}$ 3) $F_{pp}>F_{pn}>F_{nn}$ 4) $F_{pp}<F_{pn}=F_{nn}$
3. In sun, the important source of energy is

   1) proton-proton cycle 2) carbon-nirtogen cycle

   3) carbon-caron cycle 4) nitrogen-nitrogen cycle
4. A free neutron decays spontaneously into:

   1) a proton, an electron and an anti-neutrino

   2) a proton, an electron and a neutrino

   3) a proton and electron

   4) a proton, an electron, a neutrino and an anti-neutrino
5. Particles and their anti-particles have:

   1) the same masses but opposite spins

   2) the same masses but opposite magnetic moments.

   3) the same masses and same magnetic moments

4) opposite spins and same magnetic moments

6. Consider the following two statements A and B and identify the correct answer given below:
A: Nuclear density is same for all nuclei
B: Radius of the nucleus (R) and its mass number (A) are related as $\sqrt{A} \propto R^{1/6}$
1) Both A and B are true 2) Both A and B are false
3) A is true and B is false 4) A is false B is true

7. The mass defect in a particular nuclear reaction is 0.3grams. The amount of energy liberated in kilowatt hours is : (C=3x10^8m/s)
1) $7.5\times10^5 KWH$ 2) $7.5\times10^4 KWH$ 3) $7.5\times10^3 KWH$ 4) $7.5\times10^6 KWH$

8. Consider the following statements A and B.
Identify the correct choice in the given answer.
(A) p-p, p-n, n-n forces between nucleons are not equal and charge dependent
(B) In nuclear reactor the fission reaction will be in accelerating state if the value of neutron reproduction factor k >1
1) Both A and B are correct 2) Both A an d B are wrong
3) A is wrong and B is correct 4) A is correct and B is wrong.

9. True masses of neutron, proton and deutron in a.m.u are1.00893,1.00813 and 2.01473 respectively. The packing fraction of the deutron in a.m.u is
1) 11.65 x 10^{-4} 2) 23.5 x 10^{-4} 3) 73.6 x10^{-4} 4) 47.15 x 10^{-4}

10. A heavy nucleus at rest breaks into two fragments which fly off with velocities 8:1. The ratio of radii of fragments is
1) 1:2 2) 1:4 3) 4:1 4) 2:1

11. Atomic mass of $^{13}_{6}C$ is 13.00335 amu and its mass number is 13.0. If 1amu=931 MeV, binding energy of the neutrons present in the nucleus is:
1) 0.24 MeV 2) 1.44 MeV 3) 1.68 MeV 4) 3.12 MeV

12. The following particles are Baryons:
1) Nucleons and hyperons 2) Nucleons and leptons
3) Hyperons and leptons 4) Hyperons and Bosons

13. Electron belongs to the following class of elementary particles
1) Hardon 2) Lepton 3) Boson 4) Baryon

14. Assertion(A): Nuclear forces arise from strong Coulombic interactions between protons and neutrons.
Reason (R): Nuclear forces are independent of the charge of the nucleons.
1) Both A and R are true and R is the correct explanation of A
2) Both A and R are true but R is the not correct explanation of A
3) A is true, but R is false 4) A is false, but R is true

15 The particle that possesses half integral spin is:
1) Photon 2) Pion 3) Proton 4) K-meson

16 Matching pairs in the two lists given below are

List-I	**List-II**
A) Gravitions	E) Hyperons
B) Baryons	F) Positrons
C) Pions	G) Particles with zero mass and with aspin of unity
D) Leptons	H) Decay to –mesons
	I)Massless particles with probable spin of two units.

1) A-E,B-H,C-G,D-I 2) A-I,B-E,C-H,D-F 3) A-H,B-F,C-I,D-E 4) A-F,B-G,C-E,D-H

17. A nucleus splits into two nuclear parts having radii in the ratio 1:2. Their velocities are in the ratio

1) 8:1 2) 6:1 3) 4:1 4) 2:1

18. A: Density of nucleus is independent of its mass number
B: Beryllium is used as a moderator in nuclear reactors
1) Both A and B are correct 2) Both A and B are wrong
3) A is correct, B is wrong 4) A is wrong, B is correct

19. In Carbon-Nitrogen fusion cycle , protons are fused to form a helium nucleus, positrons and release some energy. The number of protons fused and the number of positrons released in this process respectively are
1) 4,4 2) 4,2 3) 2,4 4) 4,6

20. The ratio of radii of nuclei $_{13}Al^{27}$ and $_{52}Te^{125}$ is
1) 1 : 5 2) 2: 5 3) 4 : 5 4) 3 : 5

21. In a nuclear reactor using U^{235} as a fuel , the power output is 4.8MW. The number of fissions per second is __
(Energy released per fission =200MeV, 1ev = $1.6\text{x}10^{-19}$J)
1) $1.5\text{x}10^{17}$ 2) $3\text{x}10^{19}$ 3) $1.5\text{x}10^{25}$ 4) $3\text{x}10^{25}$

22. If M(A;Z), M_p and M_n denote the masses of the nucleus ${}^{A}_{Z}X$, proton and neutron respectively in units of U(1 u = 931.5 MeV/c^2) and BE represents its bonding energy in MeV, then
1) M(A,Z) = ZM_p + (A-Z)M_n – BE 2) M(A,Z) = ZM_p + (A-Z)M_n – BE/c^2
3) M(A,Z) = ZM_p + (A-Z)M_n – BE/c^2 4) M(A,Z) = ZM_p + (A-Z)M_n + BE

23. Two nuclei have mass numbers in the ratio of 1:3. The ratio of their nuclear densities would be
1) $(3)^{1/3}$:1 2) 1:1 3) 1:3 4) 3:1

24. The ground state energy of hydrogen atom is -13.6 eV. When its electron is in the first excited state, its excitation energy is
1) 10.2 eV 2) 0 3) 3.4 eV 4) 6.8 eV

25. Two radioactive materials X_1 and X_2 have decay constants 5λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that X_2 will be 1/e after a time
1) $1/4\lambda$ 2) e/λ 3) λ 4) $\frac{1}{2}\lambda$

26. In the nuclear decay given below ${}^{A}_{Z}X \rightarrow {}^{A}_{z+1}Y \rightarrow {}^{A-4}_{Z-1}B^{*} \rightarrow {}^{A-4}_{Z-1}B$ the particles emitted in the sequence are
1) γ, β, α 2) β, γ, α 3) α, β, γ 4) β, α, γ

27. The number of beta particles emitted by a radioactive substance is twice the number of alpha particles emitted by it. The resulting daughter is an
1) isomer of parent 2) isotone of parent 3) isotope of parent 4) isobar of parent

28. In a Rutherford scattering experiment when a projectile of charge z_1 and mass M_1, approaches a target nucleus of charge z_2 and mass M_2, the distance of closes approach is r0. The energy of the projectile is
1) directly proportional to z_1z_2 2) inversely proportional to z_1
3) directly proportional to mass M_1 4) directly proportional to $M_1 \text{x} M_2$

29. Which of the following can be detected by a magnet ?
1) gamma rays 2) beta rays 3) radio waves 4) ultra-violet rays

30. The ratio of the radii of the nuclei of $_{13}Al^{27}$ and $_{52}Te^{125}$ is approximately
1) 6:10 2) 13:52 3) 40:177 4) 14:73

31. The number of neutrons in an atom X of atomic number Z and mass number A is
1) Z–A 2) Z 3) A–Z 4) A

32. The radius of a nucleus changes with the mass number A of the nucleus as

1) $r \propto A^{2/3}$ 2) $r \propto A^{1/3}$ 3) $r \propto A^0$ 4) $r \propto A$

33. The density of a nuclear matter varies with mass number A as

1) $d \propto A^3$ 2) $d \propto A^2$ 3) $d \propto A$ 4) $d \propto A^0$

34. The average binding energy of nucleus is

1) 8 eV 2) 8 keV 3) 8 MeV 4) 8 BeV

35. In a fusion process, a proton and a neutron combine to form a deuterium nucleus. If m_p and m_n denote the mass of a proton and the mass of a neutron respectively, the mass of the deuterium nucleus is

1) equal to (m_p+m_n) 2) greater than (m_p+m_n)
3) less than (m_p+m_n) 4) it has no relation with the given masses

36. The nuclei ${}_6C^{13}$ and ${}_7N^{14}$ can be described as

1) isotones 2) isobars 3) isomers 4) isotopes

37. Slow neutrons are sometimes referred to as thermal neutrons because

1) they are a sort heat radiations
2) they are in thermal equilibrium
3) they are capable of generating heat
4) their energies are of the same order as that of molecular energies at ambient temperatures

38. In a stable nuclei, the number of neutrons (N) is related to the number of protons Z in neutral atom as

1) N<Z 2) N+Z 3) N>Z 4) $N \geq Z$

39. In the reaction represented by ${}_ZX^A \to {}_{Z-2}Y^{A-4} \longrightarrow {}_{Z-2}Y^{A-4} \longrightarrow {}_{Z-1}K^{A-4}$ the decays in the sequence are

1) α, β, γ 2) β, γ, α 3) γ, α, β 4) α, γ, β

40. The number of neutrons in a chain reaction increases in

1) arthmatic progression 2) geometric progression
3) harmonic progression 4) none of these

41. Hydrogen bomb is based on the principle of

1) fission 2) fusion 3) electrolysis 4) ionization

42. A good moderator should

1) be a gas 2) have appetite for neutrons
3) be light in mass number 4) all of these

43. The main source of energy in the sun is due to

1) the burning of hydrogen in oxygen
2) fusion of uranium present in the sun
3) the energy liberated in the fusion protons during the synthesis of heavier nuclei
4) gravitational contraction

44. In the nuclear decay, ${}_7N^{13} \to {}_6C^{13}$+( )+( ) the particles represented by the two parentheses are

1) neutron and γ - ray 2) positron and neutrino
3) positron and antineutrino 4) positron and electron

45. During a nuclear fusion reaction

1) a heavy nucleus breaks into two fragments by itself
2) a light nucleus bombarded by thermal neutrons braks up
3) a heavy nucleus bombarded by thermal neutrons breaks up
4) two light nuclei combine to give a heavier nucleus and possibly other products

46. Fusion reactions take place at high temperature because

1) atoms are ionised at high temperature
2) molecules break up at high temperature
3) nuclei break up at high temperature
4) kinetic energy is high enough to overcome repulsion between nuclei

47. If the nuclear force between two protons, two neutrons and between proton and neutron is denoted by F_{pp}, F_{nn} and F_{pn} respectively, then

1) $F_{pp} = F_{nn} = F_{pn}$ 2) $F_{pp} \neq F_{nn}$ but $F_{pp} = F_{pn}$ 3) $F_6 = F_6 = F_6$ 4) $F_{pp} \neq F_{nn} \neq F_{pn}$

48. Nuclear force is a

1) short range repulsive force 2) long range repulsive force
3) short range attractive force 4) long range attractive force

49. The age of pottery is determined by archeologists using a radio isotope of

1) carbon 2) cobalt 3) iodine 4) phosphorus

50. The equation , $4{}_1H^1 \rightarrow {}_2He^4 + 2{}_{+1}e^0 + 26$ MeV represents

1) β-decay 2) γ–decay 3) fusion 4) fission

51. Of the following atoms ${}_6C^{14}$, ${}_7N^{13}$, ${}_{88}Ra^{236}$, ${}_7N^{14}$, ${}_8O^{16}$ and Rn a pair of isobars is

1) ${}_6C^{14}$, ${}_7N^{13}$ 2) ${}_7N^{13}$, ${}_7N^{14}$ 3) ${}_6C^{14}$, ${}_7N^{14}$ 4) ${}_6C^{14}$, ${}_8O^{16}$

52. In the above question a pair of isodiapheres is

1) ${}_{88}Ra^{236}$, ${}_{88}Ra^{232}$ 2) ${}_7N^{13}$, ${}_7N^{14}$ 3) ${}_6C^{14}$,${}_7N^{14}$ 4) ${}_7N^{14}$,${}_8O^{16}$

53. Mass defect of an atom refers to

1) inaccurate measurement of mass of neutrons
2) mass annihilated to produce energy to bind the nucleus
3) packing fraction
4) difference in the number of neutrons and protons in the nucleus

54. For the fission of heavy nucleus, neutron is more effective than proton or alpha particle because

1) neutron is heavier than alpha particle
2) neutron is lighter than alpha particle
3) neutron is uncharged
4) neutron moves with a small velocity

55. A deuterium nucleus ${}^2_1H$ combines with a tritium nucleus ${}^3_1H$ to form a heavier helium nucleus ${}^4_2He$ with the release of a neutron (${}^1_0n$). The fusion reaction is represented by the equation ${}^2_1H + {}^3_1H \rightarrow {}^4_2He + {}^1_0n$. In this reaction, the mass of ${}^4_2He$ + mass of ${}^1_0n$ is

1) less than the mass of ${}^2_1H$ + mass of ${}^3_1H$
2) greater than the mass of ${}^2_1H$ + mass of ${}^3_1H$
3) the same as the mass of ${}^2_1H$ + mass of ${}^3_1H$
4) twice the mass of ${}^2_1H$ + mass of ${}^3_1H$

56. Which of the following are conserved in nuclear reactions ?

1) mass number and energy 2) mass number and charge number
3) charge number and mass 4) mass number, charge number and energy

57. In carbon-nitrogen nuclear fusion cycle, protons are fused to form a helium nucleus, positrons and release some energy. The number of protons fused and the number of positrons released in this process respectively are

1) 4, 4 2) 4, 2 3) 2, 4 4) 4, 6

58. Nuclear forces are

a) charge dependent b) spin dependent c) short ranged d) neutral

1) only a and b are true 2) only a and c are true
3) only b and d are true 4) only b and c are true

59. In the fission of U^{235}

a) slow neutron is absorbed by U^{235}
b) the products in the process are not same always, their atomic number varies from 34 to 58
c) about 200 MeV energy is released per fission
d) the product are always Ba and Kr

1) only a, b & c are true 2) only b and d are true
3) only a and c are true 4) only b and c are true

60. Which of the following is true regarding nuclear fusion
a) the probable reaction in high temperature stars is carbon nitrogen cycle
b) it is generally observed on the earth
c) the probable reaction in low-temperature stars is proton-proton cycle
d) it takes place at a temperature of about 10^4 K
1) only a and b are true 2) only b and d are true
3) only a and c are true 4) only c and d are true

61. Identify the correct order of increasing order of B.E per nucleon of the following nuclei
a) Helium b) Carbon c) Oxygen e) Iron
1) a-b-c-d 2) d-c-b-a 3) c-b-d-a 4) c-b-a-b

62. Match the following

List I	List II
a) Artificial Radioactivity	e) Bethe
b) Carbon-Nitrogen cycle	f) Fermi
c) Carbon dating	g) Rutherford
d) Transmutation of atomic nuclei by α-particles	h) Libby

1) a-e, b-f, c-g, d-h 2) a-f, b-e, c-h, d-g 3) a-h, b-g, c-f, d-e 4) a-g, b-h, c-e, d-f

63. Match the following

List I	List II
a) Liquid Sodium	e) Moderation
b) Pu-239	f) Control rod
c) Graphite	g) Fuel
d) Cadmium steel	h) Coolant

1) a-f, b-g, c-e, d-h 2) a-h, b-g, c-e, d-f 3) a-e, b-g, c-f, d-h 4) a-h, b-g, c-f, d-e

Assertion & Reason : In each of the following questions, a statement is given and a corresponding statement or reason is given just below it. In the statements, marks the correct answer as
1) If both Assertion and Reason are true and Reason is correct explanation of Assertion.
2) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
3) If Assertion is true but Reason is false.
4) If both Assertion and Reason are false.

64. [A] : At least one thermal neutron should be available to initiate the fission reaction.
[R]:The state of the chain reaction depends onthe neutrons multiplication factor.

65. [A]: Neutron flux in the interior of a nuclear reactor can be increased using neutron reflector.
[R]:Fast neutrons can be changed into slow neutrons or thermal neutrons.

66 [A] : Cadmium or Boron rods are generally used as control rods.
[R] : Cadmium or Boron rods slows down fast moving neutrons.

67 [A] : In the fission of uranium nuclei on an average 2.5 neutrons are emitted per fission.
[R] : In the fission of uranium, the number of promt neutrons will change with the products.

68. [A]:The penetrating power of neutron is high.
[R]:Neutron is charge less.

69 [A]:The velocity of de-Broglie's wave associated with a moving particle is greater than the velocity of light.
[R]:de-Broglie waves are not electromagnetic waves.

70 [A]: Density of the nucleus is almost same for all nuclei.
[R] : Nuclear density is independent of atomic number

71 A] : Nuclear density is same for all nuclei.

[R] : Radius of the nucleus (R) and its mass number (A) are related as $\sqrt{A} \alpha R^{1/6}$.

72 [A] : A fusion reaction is a powerful source of energy.

[R] :Fusion reaction takes place at a very high temperature (10^6 K).

73 [A] : Electrons are not expected to be found inside the nucleus.

[R] : Electrons are much lighter than protons or neutrons.

KEY :

1)	**4**	2)	**2**	3)	**1**	4)	**1**	5)	**2**	6)	**3**	7)	**4**	8)	**3**	9)	**3**	10)	**1**
11)	**3**	12)	**1**	13)	**2**	14)	**4**	15)	**3**	16)	**2**	17)	**1**	18)	**3**	19)	**2**	20)	**2**
21)	**1**	22)	**3**	23)	**2**	24)	**1**	25)	**1**	26)	**4**	27)	**3**	28)	**3**	29)	**2**	30)	**1**
31)	**3**	32)	**3**	33)	**4**	34)	**3**	35)	**3**	36)	**1**	37)	**4**	38)	**4**	39)	**4**	40)	**2**
41)	**2**	42)	**3**	43)	**3**	44)	**2**	45)	**4**	46)	**4**	47)	**1**	48)	**3**	49)	**1**	50)	**3**
51)	**3**	52)	**4**	53)	**2**	54)	**3**	55)	**1**	56)	**4**	57)	**2**	58)	**4**	59)	**1**	60)	**3**
61)	**1**	62)	**2**	63)	**2**	64)	**3**	65)	**1**	66)	**2**	67)	**3**	68)	**2**	69)	**1**	70)	**3**
71)	**2**	72)	**3**	73)	**3**														

Solutions

1.

Ans : 4

Sol: The relation between $t_{1/2}$ *and* λ is $t_{1/2} = \frac{0.693}{\lambda}$

$\lambda t_1 = X$ …………(1)

$\lambda t_2 = Y$ ………….(2)

from (1) and (2)

$\lambda(t_1 - t_2) = X - Y \Rightarrow t_1 - t_2 = \frac{X - Y}{\lambda}$

but $\tau = \frac{1}{\lambda}$

$\therefore t_1 - t_2 = (X - Y)\tau$

2.

Ans: 2

Sol. Nuclear forces are charge independent

3. Ans: 1

Sol. Because of nuclear fusion proton – proton cycle takes place

4.

Ans: 1

Sol. ${}_0n^1 \longrightarrow {}_{-1}e^0 + {}_1H^1 + \upsilon$

5. Ans: 2

Sol.Same masses but opposite electromagnetic properties like charge, magnetic moment etc.

6.

Ans : 3

Sol: Density remains constant

$(A) : \rho$ = constant

(B) : (B) $R \propto A^{1/3}$ $\left[\sin ce \;\; R = R_0 A^{1/3}\right]$

$\Rightarrow R^3 \propto A$

$\Rightarrow R^{3/2} \propto \sqrt{A}$

7.

Ans: 4

Sol: From Einstein mass – energy equivalence

$\Delta E = \Delta MC^2$

$= 0.3\times10^{-3}\times\left(3\times10^8\right)^2$

$= 2.7\times10^{13} J = \frac{2.7\times10^3}{3600\times10^3}$

= 0.75 × 10^7 KWH

= $7.5\times10^6 KWH$

8.

Ans :3

A: The p-n, p-p and n-n nuclear forces are equal and charge independent.

B : $K = \frac{Neutrons \text{ in } one\,generation}{Neutrons \text{ in } the\;previous\;\;generation}$

Where k is called neutron multiplication factor

If K > 1, the neutron population keeps on increasing after the completion of each neutron cycle which takes time of the order of a millisecond. Which is called as super critical state

9.

Ans :3

Sol: Packing fraction = $\frac{M-A}{A}$, where M is the atomic mass and A is the mass number.

$$P = \frac{M-A}{A} = \frac{2.01473-2}{2} = 73.6\times10^{-4}$$

10.

Ans:1

Sol Momentum conservation gives

$m_1 v_1 = m_2 v_2$

$\Rightarrow \frac{v_1}{v_2} = \frac{8}{1} = \frac{m_2}{m_1}$

$\Rightarrow \frac{m_2}{m_1} = \frac{1}{8} \approx \frac{A_1}{A_2}$

$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$

11.

Ans: 3

Sol: Mass defect = 0.00335 amu

$\therefore$ binding energy of neutrons

$= \left[\frac{(0.00335)(931)}{13}\right]7$

$= 1.679 = 1.68\,MeV$

12.

Ans: 1

Sol. Nucleons and hyperons are called Baryons

13.

Ans: 2

Sol. As electrons have lighter mass. Therefore they belong to leptons

14.

Ans: 4

15

Ans: 3

Sol. Proton Possesses half integral spin.

16

Ans: 2

17.

Ans: 1

Sol: $R = R_0 A^{1/3}$

$\frac{A_1}{A_2} = \frac{M_1}{M_2} = \frac{R_1^3}{R_2^3} = \frac{1^3}{2^3} = \frac{1}{8}$ [since mass = volume x density]

$M_1 V_1 = M_2 V_2$ [from law of conservation of momentum]

$\Rightarrow \frac{V_1}{V_2} = \frac{M_2}{M_1} = 8$

18.

Ans : 3

Sol: A : $\rho = \frac{mass\ of\ nucleus}{volume} = \frac{A \times M_p}{4\pi R^3/3}$

$= \frac{3M_p}{4\pi} \frac{A}{\left(r_0 A^{1/3}\right)^3} = \frac{3M_p}{4\pi r_0^3}$ = constant [since m_p and r_0 are constant]

B: A good moderator must be light (low atomic weight) must be capable of scattering neutrons with a high probability, but should not absorb neutrons. Therefore Beryllium is not suitable for moderator

19.

Ans :2

Sol: $4\,{}_1H^1 \rightarrow {}_2He^4 + 2\,{}_1e^0 + 2\gamma$

4 protons fuses and 2 positron are released

20.

Ans:4

Sol: $R = r_0 A^{1/3}$

$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$

21.

Ans :1

Sol: Power of reactor P = $\frac{nE}{t}$

Where ‘n’ is number of fissions, ‘t’ is time and ‘E’ is energy released per fission

22. (3):

$ZM_p+(A-Z)M_n - M(A,Z)$

= mass effect = $\frac{B.E.}{c^2}$

$$\Rightarrow M(A,Z) = ZM_p + (A-Z)M_n - \frac{B.E.}{c^2}$$

23. (2) : $A_1 : A_2 = 1:3$

Their radii will be in the ratio

$$R_0 A_1^{1/3} : R_0 A_2^{1/3} = 1:3^{1/3}$$

Density = $\frac{A}{\frac{4}{3}\pi R^3}$

$$\therefore\ \rho_{A_1} : \rho_{A_2} = \frac{1}{\frac{4}{3}\pi R_0^3 . 1^3} = \frac{3}{\frac{4}{3}\pi R_0^3 . \left(3^{1/3}\right)^3}$$

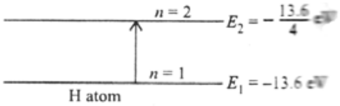
Their nuclear densities will be the same.

24. (1)

Energy of electron in nth orbit = $\frac{-13.6}{n^2} eV$

When n = 1 $E_{n_1} = -13.6\,eV$

When n = 2 $E_{n_2} = -3.4\,eV$



1st excitation energy $E_{n_2} - E_{n_1} = (-3.4+13.6)$ =10.2 eV

25 (1) $X_1 = N_0 e^{-\lambda_1 t}; X_2 = N_0 e^{-\lambda_2 t}$

$$\frac{X_1}{X_2} = e^{-1} = e^{(-\lambda_1+\lambda_2)t}; e^{-1} = e^{-(\lambda_1-\lambda_2)t}$$

$$\therefore t = \left|\frac{1}{\lambda_1 - \lambda_2}\right| = \frac{1}{(5\lambda-\lambda)} = \frac{1}{4\lambda}$$

26 (4)

Because of β emission atomic number increases by 1 unit, α- particle atomic number increases by 2 units & mass number by 4 units.

$${}_Z^A X \xrightarrow{\beta^-} {}_{Z+1}^{A} Y \xrightarrow{\alpha} {}_{Z-1}^{A-4} B^* \xrightarrow{\gamma} {}_{Z-1}^{A-4} B$$

First X decays by β^- emission emitting $\overline{\upsilon}$, antineutrino simultaneously. Y emits α resulting in the excited level of B which in turn emits a γ ray.

27 (3) ${}^{A}_{Z}X \xrightarrow{2\beta^-} {}^{A}_{Z+2}Y_1 \xrightarrow{\alpha} {}^{A-4}_{Z}Y_2$

The result daughter is an isotope of the original parent nucleus.

28. (1) : Energy of the projectile is the potential energy at closest approach, $\frac{1}{4\pi\varepsilon_0}\frac{z_1z_2}{r}$

Therefore energy $\propto z_1z_2$.

PREVIOUS EXAMINATION QUESTIONS
(AIPMT)

2012

1. Electron in hydrogen atom first jumps from third excited state to second excited state to second excited state and then from second excited to the first excited state. The ratio of the wavelengths $\lambda_1 : \lambda_2$ emitted in the two cases is

a) $\frac{7}{5}$ b) $\frac{27}{20}$ c) $\frac{27}{5}$ d) $\frac{20}{7}$

2. If the nuclear radius of ^{27}Al is 3.6 fermi, the approximate nuclear radius of ^{64}Cu in Fermi is

a) 2.4 b) 1.2 c) 4.8 d) 3.6

3. A mixture consists of two radioactive materials A_1 and A_2 with half lives of 20s and 10s respectively. Initially the mixture has 40g of A_1 and 160 g of A_2. The amount of the two in the mixture will become equal after

a) 60s b) 80 s c) 20 s d) 40 s

4. An electron of a stationary hydrogen atom passes from the fifth energy level to the ground level. The velocity that the atom acquired as a result of photon emission will be

a) $\frac{24hR}{25m}$ b) $\frac{25hR}{24m}$ c) $\frac{25m}{24hR}$ d) $\frac{24m}{25hR}$

(m is the mass of the electron, R, Rydberg constant and h Planck's constant)

2011

5. The wavelength of the first line of Lyman series for hydrogen atom is equal to that of the second line of Balmer series for a hydrogen like ion. The atomic number Z of hydrogen like ion is

a) 3 b) 4 c) 1 d) 2

6. The half life of a radioactive isotope X is 50 years. It decays to another element Y which is stable. The two elements X and Y were found to be in the ratio of 1:15 in a sample of a given rock. The age of the rock was estimated to be

a) 150 years b) 200 years c) 250 years d) 100 years

7. The power obtained in a reactor using U^{235} disintegration in 100kW. The mass decay of U^{235} per hour is

a) 10 microgram b) 20 microgram c) 40 microgram d) 1 microgram

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

a) $Mc^2 - h\upsilon$ b) $h^2\upsilon^2/2MC^2$ c) zero d) $h\upsilon$

9. A nucleus ${}^{m}_{n}X$ emits one α particle and two β-particles. The resulting nucleus is

a) ${}^{m-6}_{n-4}X$ b) ${}^{m-6}_{n}X$ c) ${}^{m-4}_{n}X$ d) ${}^{m-4}_{n-2}Y$

10. Fusion reaction takes place at high temperature because

a) nuclei break up at high temperature b) atoms get ionized at high temperature

c) kinetic energy is high enough to overcome the coulomb repulsion between nuclei

d) molecules break up at high temperature

11. An electron in the hydrogen atom jumps from excited state n to the ground state. The wavelength so emitted illuminates a photosensitive material having work function 2.75 eV. If the stopping potential of the photoelectron is 10 V, then the value of n is

a) 2　　b) 3　　c) 4　　d) 5

2010

12. The mass of a ${}_{3}^{7}Li$ nucleus is 0.042 u less than the sum of the masses of all its nucleons. The binding energy per nucleon of ${}_{3}^{7}Li$ nucleus is nearly.

a) 46 MeV　　b) 5.6 MeV　　c) 3.9 MeV　　d) 23 MeV

13. The activity of a radioactive sample is measured as N_0 counts per minute at t = 0 and N_0/e counts per minute at t = 5 minutes. The time (in minutes) at which the activity reduces to half its value is

a) $\log_e \frac{2}{5}$　　b) $\frac{5}{\log_e 2}$　　c) 5 $\log_{10}2$　　d) 5$\log_e 2$

14. The energy of a hydrogen atom in the ground state is -13.6 eV. The energy of a He^+ ion in the first excited state will be

a) -13.6 eV　　b) -27.2 eV　　c) -54.4 eV　　d) -6.8 eV

15. An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to

a) $\frac{1}{Ze}$　　b) v^2　　c) $\frac{1}{m}$　　d) $\frac{1}{v^4}$

16. The decay constant of a radio isotope is λ. If A_1 and A_2 are its activities at times t_1 and t_2 respectively, the number of nuclei which have decayed during the time (t_1-t_2)

a) $A_1t_1 = A_2t_2$　　b) $A_1 - A_2$　　c) $(A_1 - A_2)/\lambda$　　d) $\lambda(A_1 - A_2)$

17. The binding energy per nucleon in deuterium and helium nuclei are 1.1 MeV and 7.0 MeV, respectively. When two deuterium nuclei fuse to form a helium nucleus the energy released in the fusion is

a) 23.6 MeV　　b) 2.2 MeV　　c) 28.0 MeV　　d) 30.2 MeV

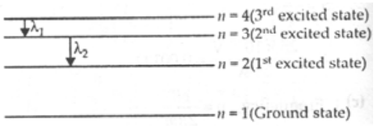
KEY

1. d	**2. c**	**3.d**	**4.a**	**5.d**	**6.b**	**7.c**
8. b	**9.c**	**10.c**	**11.c**	**12.b**	**13.d**	**14.a**
15.c	**16.c**	**17.a**				

SOLUTIONS

2012

1. (d)



According to Rydberg formula

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

In first case, $n_f = 3$, $n_i = 4$

$$\therefore \quad \frac{1}{\lambda_1} = R\left[\frac{1}{3^2} - \frac{1}{4^2}\right] = R\left[\frac{1}{9} - \frac{1}{16}\right] = \frac{7}{144}R \qquad \text{.......(i)}$$

In second case, $n_f = 2$, $n_i = 3$

$$\therefore \quad \frac{1}{\lambda_2} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5}{36}R \qquad \text{.......(ii)}$$

Divide (ii) by (i), we get

$$\frac{\lambda_1}{\lambda_2} = \frac{5}{36} \times \frac{144}{7} = \frac{20}{7}$$

2. (c)

Nuclear radius, $R = R_0 A^{1/3}$ where R_0 is a constant and A is the mass number

$$\therefore \frac{R_{Al}}{R_{Cu}} = \frac{(27)^{1/3}}{(64)^{1/3}} = \frac{3}{4}$$

Or $R_{Cu} = \frac{4}{3} \times R_{Al} = \frac{4}{3} \times 3.6$ Fermi = 4.8 fermi

3. (d)

Let after t s amount of the A_1 and A_2 will become equal in the mixture

As $N = N_0 \left(\frac{1}{2}\right)^n$

Where n is the number of half-lives

For A_1, $N_1 = N_{01}\left(\frac{1}{2}\right)^{t/20}$

For A_2, $N_2 = N_{02}\left(\frac{1}{2}\right)^{t/10}$

According to question, $N_1 = N_2$

$$\frac{40}{2^{t/20}} = \frac{160}{2^{t/10}}$$

$$2^{t/10} = 4\left(2^{t/20}\right) \text{ or } 2^{t/10} = 2^2 2^{t/20}$$

$$2^{t/10} = 2^{\left(\frac{t}{20}+2\right)}$$

$$\frac{t}{10} = \frac{t}{20} + 2 \text{ or } \frac{t}{10} - \frac{t}{20} = 2$$

Or $\frac{t}{20} = 2$ or t = 40 s

4. (a)

According to Rydberg formula

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

Here, $n_f = 1$, $n_i = 5$

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{5^2}\right] = R\left[\frac{1}{1} - \frac{1}{25}\right] = \frac{24}{25}R$$

According to conservation of linear momentum, we get

Momentum of photon = Momentum of atom

$$\frac{h}{\lambda} = m\upsilon \text{ or } \upsilon = \frac{h}{m\lambda} = \frac{h}{m}\left(\frac{24R}{25}\right) = \frac{24hR}{25m}$$

2011

5. (d) The wavelength of the first line of Lyman series for hydrogen atom is

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

The wavelength of the second line of Balmer series for hydrogen like ion is

$$\frac{1}{\lambda} = Z^2R\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$$

Or $\frac{3}{4} = \frac{3Z^2}{16}$ or $Z^2 = 4$ or $Z = 2$

6. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$

Where n is number of half lives

$\therefore \frac{1}{16} = \left(\frac{1}{2}\right)^n$ or $\left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n$ or n = 4

Let the age of rock be t years,.

$\because n = \frac{t}{T_{1/2}}$

Or $t = nT_{1/2} = 4 \times 50$ years = 200 years

7. (c) According to Einstein's mass energy relation

$E = mc^2$ or $m = \frac{E}{c^2}$

Mass decay per second

$$\frac{\Delta m}{\Delta t} = \frac{1}{c^2}\frac{\Delta E}{\Delta t} = \frac{P}{c^2} = \frac{1000\times10^3 W}{(3\times10^8 m/s)^2}$$

$= \frac{10^6}{9\times10^{16}}$ kg/s

Mass decay per hour

$$= \frac{\Delta m}{\Delta t}\times60\times60 = \left(\frac{10^6}{9\times10^{16}} kg/s\right)(3600 s)$$

$= 4\times10^{-8} kg = 40\times10^{-6} g = 40\mu g$

8. (b) Momentum of emitted photon

$= p_{photon} = \frac{h\upsilon}{c}$

From the law of conservation of linear momentum, Momentum of recoil nucleus

$= P_{nucleus} = P_{photon}$

$\therefore \qquad M\upsilon = \dfrac{h\upsilon}{c}$

Where υ is the recoil speed of the nucleus

Or $\upsilon = \dfrac{h\upsilon}{Mc}$

The recoil energy of the nucleus

$= \dfrac{1}{2}M\upsilon^2 = \dfrac{1}{2}M\left(\dfrac{h\upsilon}{Mc}\right)^2 = \dfrac{h^2\upsilon^2}{2Mc^2}$ (Using (i))

9. (c) When an alpha particle $\left({}^4_2He\right)$ is emitted, the mass number and the atomic number of the daughter nucleus decreases by four and two respectively, When a beta particles $\left(\beta^-\right)$ is emitted, the atomic number of the daughter nucleus increases by one but the mass number remains the same.

$${}^m_nX \xrightarrow{\alpha} {}^{m-4}_{n-2}Y \xrightarrow{2\beta^-} {}^{m-4}_{n}X$$

10. (c) Extremely high temperature needed for fusion make kinetic energy large enough to overcome coulomb repulsion between nuclei. Because of this they are called as thermonuclear reactions.

11 (c) Here, Stopping potential, V0= 10 V

Work function, W = 2.75 eV

According to Einstein's photoelectric equation

$eV_0 = h\upsilon - W$

Or $h\upsilon = eV_0 + W$

= 10 eV + 2.75 eV = 12.75 eV ....(i)

When an electron in the hydrogen atom makes a transition from excited state n to the gound state (n=1), then the frequency (υ) of the emitted photon is given by

$h\upsilon = E_n - E_1$

$h\upsilon = -\dfrac{13.6}{n^2} - \left(-\dfrac{13.6}{1^2}\right)$

[$\because$ For hydrogen atom, $E_n = -\dfrac{13.6}{n^2}eV$]

According to given problem

$-\dfrac{13.6}{n^2} + 13.6 = 12.75$

$\dfrac{13.6}{n^2} = 0.85 \Rightarrow n^2 = \dfrac{13.6}{0.85} = 16$

Or n = 4

2010

12 (b) For ${}^7_3Li$ nucleus,

Mass defect, $\Delta M = 0.042u$

$\because$ 1 u = 931.5 MeV/c^2

$\therefore$ ΔM = 0.042 x 931.5 MeV/c^2

= 39.1 MeV/c^2

Binding energy, E$_b$ = ΔMc^2

$$= \left(39.1\frac{MeV}{c^2}\right)c^2$$

= 39.1 MeV

Binding energy per nucleon, $= \frac{39.1MeV}{7}$ = 5.6 MeV

13 (d) According to Radio activity law $R = R_0 e^{-\lambda t}$ ....(i)

Where,

R_0 = initial activity at t = 0

R = activity at time t

λ = decay constant

According to given problem,

$R_0 = N_0$ counts per minute

$R = \frac{N_0}{e}$ counts per minute

t = 5 minutes

Substituting these values in equation (i), we get

$$\frac{N_0}{e} = N_0 e^{-5\lambda}$$

$$e^{-1} = e^{-5\lambda}$$

$5\lambda = 1$ or $\lambda = \frac{1}{5}$ per minute

At t = $T_{1/2}$, the activity R reduces to $\frac{R_0}{2}$.

Where $T_{1/2}$ = half life of a radioactive sample

From equation (i), we get

$$\frac{R_0}{2} = R_0 e^{-\lambda T_{1/2}}$$

$$e^{-\lambda T_{1/2}} = 2$$

Taking natural logarithms of both sides of above equation, we get

$$\lambda T_{1/2} = \log_e 2$$

Or $T_{1/2} = \frac{\log_e 2}{\lambda}$ = $5\log_e 2$ minutes

14. (a) Energy of an hydrogen like atom like He^+ in an n^{th} orbit is given by

$$E_n = -\frac{13.6Z^2}{n^2}eV$$

For hydrogen atom, Z= 1

$$\therefore \quad E_n = -\frac{13.6}{n^2}eV$$

For ground state, n = 1

$$\therefore \quad E_1 = -\frac{13.6}{1^2}eV = -13.6eV$$

For He+ ion, Z=2

$$E_n = -\frac{4(13.6)}{n^2}eV$$

For first excited state, n = 2

$$\therefore \quad E_2 = -\frac{4(13.6)}{(2)^2} eV = -13.6 eV$$

Hence, the energy in He^+ ion in first excited state is same that of energy of the hydrogen atom in grounds state i.e. -13.6 eV.

15. (c) At the distance of closest approach d, Kinetic energy = Potential energy

$$\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(ze)}{d}$$

Where,

Ze = charge of target nucleus

2e = charge of alpha nucleus

$\frac{1}{2}mv^2$ = kinetic energy of alpha nucleus of mass m moving with velocity υ

Or $d = \frac{2Ze^2}{4\pi\varepsilon_0\left(\frac{1}{2}m\upsilon^2\right)} \therefore d \propto \frac{1}{m}$

16 (c) : $A_1 = \lambda N_1$ at time t_1

$A_2 = \lambda N_2$ at time t_2

Therefore, number of nuclei decayed during time interval (t_1-t_2) is

$$N_1 - N_2 = \frac{[A_1 - A_2]}{\lambda}$$

17. (a) : ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + \Delta E$

The binding energy per nucleon of a deuteron = 1.1 MeV

$\therefore$ Total binding energy = 2 x 1.1 = 2.2 MeV

The binding energy per nucleon of a helium nuclei = 7 MeV

$\therefore$ Total binding energy = 4 x 7 = 28 MeV

AIIMS QUESTIONS

1. Assertion : Mass defect in nuclear reactions is less than 1%
Reason : In nuclear reaction, change in BE/N is generally less than 1%
2. Assertion : It is desirable to slow down fast moving neutrons to sustain controlled chain reactions
Reason : Slow moving neutrons efficiently collides with U^{235}.
3. Half life of a radio-active element is 8 years, how much amount will be present after 32 years?
a) $\frac{1}{4}$ b) $\frac{1}{8}$ c) $\frac{1}{16}$ d) $\frac{1}{32}$
4. The nucleus ${}_n^mX$ emits one α particle and 2β-particles. The resulting nucleus is
a) ${}_{n-2}^{m-4}Y$ b) ${}_{n-4}^{m-6}Z$ c) ${}_{n}^{m-6}Z$ d) ${}_{n}^{m-4}X$
5. Assertion : At rest, radium is decayed into Radon and an α-particle. They both moves back to back of each other.
Reason : Splitting of radioactive particle is based on conservation of linear momentum
6. Assertion : More energy is released in fusion than fission
Reason : More number of nucleons take part in fission
7.. Assertion : γ-radiation emission occurs after α and β decay

Reason : Energy levels occur in nucleus

SOLUTIONS:

1.
Sol: (a)

2.
Sol: (c)

The average energy of a neutron produced in fission of U235 is 2 MeV. These neutrons unless slowed down will escape from the reactor without interacting with uranium nuclei, unless a large amount of fissionable material is used for sustaining the chain reaction. What we needs to do is to slow down the fast neutrons by elastic scattering with light nuclei. Chadwick's experiment showed that in an elastic collision with hydrogen neutron almost come to rest.

3.
Sol: (c)

Here, $T_{1/2}$ = 8 years

T = 32 years

Using, N = $N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

$$\left(\frac{N}{N_0}\right)=\left(\frac{1}{2}\right)^{\frac{32}{8}} = \left(\frac{1}{2}\right)^4$$

$$\left(\frac{N}{N_0}\right)=\frac{1}{16}$$

4.
Sol: (d)

Emission of α-particle decreases the mass number and the atomic number and the atomic number by 4 and 2 respectively. Emission of β-particle increases the atomic number by 1 while the mass number remains unchanged.

After the emission of the one α-particle and two β-particles

Decreases in mass number = 4-0 = 4

Decreases in atomic number = 2-2=0

$\therefore$ The resulting the nucleus is ${}^{m-4}X$

5.
Sol: (a)

6.
Sol: (b)

7..
Sol: (a)