NUCLEAR PHYSICS

SYNOPSIS

NUCLEUS:

- In alpha-ray scattering experiment nucleus was discovered by Rutherford.
- The nucleus of an atom is at the centre. Most of the mass of an atom is at the centre. The entire positive charge of an atom lies in the nucleus.
- Nucleus consists of protons and neutrons. They are called nucleons.
- Generally, atomic number is denoted by Z and mass number is denoted by A. (A-Z) gives number of neutrons in the nucleus.
- Nucleus is positively charged and its shape is considered as spherical.
- Nucleus of an element is represented by $_zX^A$.

TYPES OF NUCLEI:

- ISOTOPES: Atomic nuclei having same atomic number but different mass numbers are known as isotopes. They occupy same position in the periodic table and posses identical chemical properties. They have same proton number.

  Ex: 1) $_3Li^6, _3Li^7$ 2) $_1H^1, _1H^2, _1H^3$
- ISOTONES : Atomic nuclei having same number of neutrons are called isotones.

  Ex.: 1) $_{17}Cl^{37}, _{19}K^{39}$, 2) $_7N^{17}, _8O^{18}, _9F^{19}$
- ISOBARS: Atomic nuclei having same mass number but different atomic numbers are called Isobars.

  They have same number of nucleons.

  Ex.:–1) $_{18}Ar^{40}, _{20}Ca^{40}$, 2) $_{32}Ge^{76}, _{34}Se^{76}$
- ISOMERS: Atomic nuclei having same mass number and same atomic number but different nulear properties are called isomers.

  Ex:- $_{35}Br^{80}$ has two isomers with different half lifes

SIZE OF THE NUCLEUS:

- The size of the nucleus is measured by various scattering experiments.
- Nuclear sizes are measured in fermi. 1 fermi=10^{-15}m
- Radius of the nucleus depends on number of nucleons.

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

  Value of $R_o = 1.1 \times 10^{-15}$m
- Radius of the nucleus is in the order of 10^{-15} m.
- Size of an atom is in the order of 10^{-10}m.

DENSITY OF THE NUCLEUS:

- Density of nucleus is independent of mass number of the atom.
- Density of the nucleus is 2.97×10^{17} Kgm$^{-3.}$
- The density is maximum at the centre and gradually falls to zero as we move radially out words.
- Nucleus has no sharp boundaries.
- Radius of the nucleus is taken as the distance between the centre and the point where the density falls to half of its value at the centre.
- Nuclear charge = no of protons x charge of proton = Z x 1.6 x 10^{-19}C.

ATOMIC MASS UNIT:

- Atomic mass unit is $\frac{1}{12}th$ of the mass of $_6C^{12}$ atom
- l amu = 1.66 x 10^{-27} Kg .

EINSTEIN'S MASS ENERGY EQUIVALENCE:

- By virtue of mass, a body possesses energy.
- When matter is completely annihilated, energy released is $E = mc^2$
- The energy equivalent to 1 amu is 931.5 M eV = $1.4925 \times 10^{-10} J$.

NUCLEAR FORCES:

The Nuclear Forces are of Four Typess

1) Attractive Forces 2) Repulsive Forces
3) Coloumb Forces 4) Tensor Forces

- ATTRACTIVE FORCES: The forces that exist between proton-proton, proton-neutron, nuetron-neuton are termed as attractive forces.

  Their characteristics are
  - Short range: They will act upto nearly one fermi. Beyond that they become negligible.
  - Charge independent : $F_{pp} = F_{pn} = F_{nn}$
  - Spin dependent : For parallel spins the force is maximum. For anti parallel spins the force is minimum.
  - Saturation : Each nucleon can attract only a certain number of nucleons around it, but not all the nucleons around it.
  - Non-central : They do not act along the line joining the centres of the nucleons.

Note: Yukawa's theory says that nuclear particles inside the nucleus exchange pions between them and bound to nucleus.

1. The only difference neutrons and protons is the composition of their respective meson clouds.
2. The nuclear forece between a neutron and pro-

ton is the result of the exchange of charged mesons $\left(\pi^+ \text{ and } \pi^-\right)$ between them. When a π^+ meson jumps from a proton to a neutron, the proton is converted to a neutron, and vice versa.

P € $n+\pi^+$

3. When a π^- meson jumps from a neutron to proton, the neutron is converted to a proton and vice versa. P € $p+\pi^-$

4. The forces between tow protons and two neutrons arise by the exchange of neutral mesons $\left(\pi^0\right)$ between them. $p \rightarrow n+\pi^0 \quad n \rightarrow n+\pi^0$

5. Nucleus is an ever changing structure.

- **REPULSIVE FORCES:** These forces are stronger than attractive forces. These are also known as hard core forces. They come into to effect when nucleons are at a distance less than 0.5 fermi. Due to these hard core forces, definite size is assigned to the nucleus.
- **COLOUMB FORCES:** These electrostatic coloumb forces exist between protons only. As atomic number increases size of nucleus increases as a results repulsive forces increase and cause instability.
- **TENSOR FORCES:** Nucleons behave as magnetic dipoles due to their spin. Due to the spin of nucleons, tensor forces exist between nucleons.
- The ratio of gravitational, electrostatic and nuclear forces between the two protons is $F_g:F_e:F_n = 1:10^{36} : 10^{38}$
- MASS DEFECT: Atomic mass is always less than the sum of the masses of constituent particles. The difference between the total mass of the nucleons and mass of the nucleus of an atom gives mass defect.

$$\Delta m = \left[\left[ZM_p + (A-Z)M_n\right] - M_{nucleus}\right]$$

Z	=	Atomic number
M_p	=	Mass of proton
M_n	=	Mass of neutron
A	=	Mass number
$M_{nucleus}$	=	Mass of nucleus.

- **BINDING ENERGY:** The energy required to bring the nucleons from infinity to form the nucleus is called binding energy. It is energy equivalent of mass defect

BE= $[\Delta m]C^2$

NOTE: BE = mass defect x 931.5 MeV if mass is expressed in a.m.u.

Binding Energy per nucleon : The ratio of the binding energy of a nucleus to its mass number is called binding energy per nucleon. It is also called binding fraction.

B.E. per nucleon = Binding Energy/Mass number

PACKING FRACTION OF A NUCLEUS :

Packing fraction : It is defined as the mass defect per each nucleon.

Packing fraction = $\dfrac{\Delta m}{A}$.

If the packing fraction is negative then the nucleus is more stable.

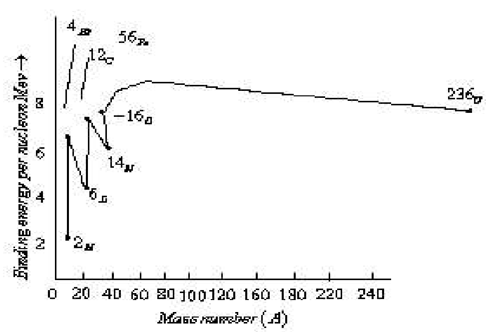
If the packing fraction is positive then the nucleus is unstable.

Pacing fraction is zero for ${}_6C^{12}$

- Packing fraction is a fundamental property of a nucleus and is directly related to the availability of nuclear energy and stability.

VARIATION OF B.E. PER NUCLEON WITH MASS NUMBER:

- Binding energy per nucleon increases and then decreases slowly as mass number increases.
- The minimum binding energy per nucleon is 1.1 MeV for ${}_1H^2$.
- The Maximum value of Binding energy per nucleon is 8.8 Mev for Fe^{56}.
- For most of the nuclei, it ranges from 7.5 Mev to 8.8 MeV



- Over the wide range the average BE per nucleon is 8 Mev.

If A>> 56, the nuclear fission is possible with release of energy.

If A< 20, the nuclear fusion is possible with release of energy.

STABILITY OF NUCLEUS:

- Stability of nucleus is an important parameter in explaining several nuclear properties.
- Binding energy per nucleon is an indirect measure of stability.
- Most of the stable nucleii have more binding energy per nucleon.

Nuclear Radiation Hazards :

- Radiation causes genetic mutation.
- Radioactive Radon (gas) inhaled is injurious to lungs.
- Radio iodine is dangerous as it is concentrated in the thyroid gland.
- They damage intestinal mucosa; system of producing antibodies, lens of the eye.
- Radiation damages human being due to
  1. Intake of radio active materials
  2. Exposure to radiation

Radio Isotopes :

- Produced by artificial means (in a nuclear reactor)
- Used in the field of medicine ; agriculture ; engineering and industry.
- Eg: Radio iodine, Radio sodium, Radio phosphorus etc.

Uses in Medicine :

● Radio Iodine :

- Half-life - 8 days.
- decays through - β emission (fast electron particles)
- used in determining size, activity and functioning of thyroid gland.
- Radiologist gets information about the size and location of brain tumour.

● Radio Sodium :

- Used to located the spot where the circulation of blood is restricted.

● Radio phosphorus and Radiogold :

- Used in treatment of Leukamea.
- half life period 3.25 mts

$${}_{15}P^{30} \rightarrow {}_{14}Si^{30} + {}_{+1}e^{0}$$

●Radio Cobalt CO^{60}

- Used in the treatment of canceroustissues.

In Agriculture :

- Radio phosphorus is used in fertilizers to detect the extent upto which a plant absorbs phosphorus and to improve plant growth.
- Radio isotopes are used to make seeds resistant to diseases.
- Radio isotopes are used in crop mutations (New type of hybrid plants are made)

In Industry :

Isotopes test wear and tear of engine parts like ball bearings and in deciding efficiency of lubricants. Eg: Radio cobalt is used as catalyst in the manufacture of hydrogen bromide and ethylene.

Radio Active Dating :

- It is the process of determining the time interval elapsed by making use of the radio active decay of a given sample of radio active substance.
- Computing the age of old things by means of carbon dating has become a standard technique.

Non Destructive testing :

Radio isotopes are used to test the metal castings and welds without causing any damage to material.

NEUTRON:

- Rutherford predicted the existence of neutron.
- Bothe – Becker equation:

$${}_{4}Be^{9} + {}_{2}He^{4} \rightarrow \left[{}_{6}C^{13}\right] \rightarrow {}_{6}C^{12} + {}_{0}n^{1}$$

- Chadwick discovered neutron.
- It has no charge.
- Neutron is unstable outside the nucleus.

$${}_{0}n^{1} \rightarrow {}_{1}H^{1} + {}_{-1}e^{0} + \bar{\nu} \text{ (anti neutrino)}$$

- Its mass is near to that of proton.
- It has high penetrating power and low ionizing power.
- Thermal neutrons are a part of slow moving neutrons. Thermal neutrons possess the same kinetic energy as that of the surrounding gas molecules.
- Thermal neutrons have an average energy of nearly 0.025 eV. Fast moving neutrons have an average energy of 2 MeV.

NUCLEAR FISSION:

- Nuclear Fission is a nuclear reaction in which a heavy atomic nucleus like U^{235} splits into two approximately equal parts, emitting neutrons and liberating large amount of energy.
- Otto Hahn and Strassman discovered the nuclear fission.

- Nucleus of U^{235} undergoes fission when it is struck by slow neutrons. This fission is not due to the impact of neutron.
- Energy of about 200 MeV is released during one fission reaction of $_{92}U^{235}$. The most probable nuclear fission reaction is

$$_{92}U^{235} + {_0}n^1 \rightarrow {_{56}}Ba^{141} + {_{36}}Kr^{92} + 3\,{_0}n^1 + \text{energy}$$

There is no guarantee that U^{235} always breaks into Barium and Krypton.
- The total mass of the products is less than that of the reactants. This mass difference appears as energy. Most of the energy appears as kinetic energy of fission fragments.
- On an average,in the fission of U^{235} 2.5 neutrons are emitted per fission when fission occurs due to slow neutrons. U^{235} undergoes fission with fast neutrons also. But the probability is minimum.
- Fission process can be explained by liquid drop model of nucleus. It was proposed by Bohr and Wheeler.
- Fission fragments are unstable and emit neutrons for some time after fission reaction which are called "delayed neutrons"
- 99% of neutrons emitted during fission process are prompt.
- Delayed neutrons play an important role in chain reaction

CHAIN REACTION:

- If the mass of fissionable material exceeds a critical value, chain reaction or self propagating fission reaction takes place.
- The rate of reaction increases in geometric proportion during uncontrolled chain reaction.
- Chain-reaction : The process of nuclear fission which when once started continues spontaneously is defined as chain reaction.

  Reproduction factor (K) : " It is the ratio of number of neutrons in any particular generation to the number of neutrons in the preceeding generation.

  Case (i) : $K<1$; Chain reaction is not maintained.(sub-critical state)

  Case (ii) ; $K=1$: Chain reaction is just initiated.(critical state)

  Case (iii); $K>1$: Chain reaction becomes self sustained.(super critical state)
- Uncontrolled chain reaction takes place in atom bomb.

NUCLEAR REACTOR OR ATOMIC PILE:

- Nuclear reactor is a device in which nuclear fission is produced by controlled self sustaining chain reaction.
- The first nuclear reactor was constructed by FERMI and is used for the production of nuclear power (energy).
- The essential parts of a nuclear reactor are (i) the fuel, (ii) moderator, (iii) control rods, (iv) coolant, (v) radiation shields.

  ● THE FUEL: The common fuels used are uranium $\left(U^{238}\right)$, enriched uranium (U^{235}) and plutonium i$\left(Pu^{236}\right)$ and TH^{232}.

● **MODERATOR:**

● The function of a moderator is to slow down the fast moving neutrons or to thermalize the neutrons to increase the rate of fission.

● The commonly used moderators in the order of efficiency are (i) Heavy water , (ii) graphite, (iii) Berillium and Berillium Oxide

● A good moderator should have (1) low atomic mass (2) poor absorption of neutrons (3) good scattering property. (4) The size of moderator atom should be nearly of same size as that of the size of a prompt neutron.

● **CONTROL RODS:**

- The function of a control rod is to absorb (capture) the neutrons.
- Cadmium, Boron and steel rods are used as control rods in a nuclear reactor.
- They regulate the net rate of neutron production and hence they control the intensity of fission process.

● **COOLANT:**

- The function of a coolant is to keep the reactor temperature at a low value so that there may not be any danger of heat damage to the reactor.
- In a power reactor the coolant transfers the fission energy in the form of heat to convert water into steam, which runs the turbines to generate electricity.
- Air and CO_2 are used as gaseous coolants. Water, Organic liquids, Helium, Liquid Sodium are used as liquid coolants.

● ● Protective shield :The proces of preventing radioactive effect around neclear reactor is called Protective Shield.

● During the working of a nuclear reactor dangerous radiations such as high energy neutrons, gamma rays and thermal radiation are produced.

To protect the persons working there, the reactor is thoroughly shielded with concrete several feet thick and lined with metals like lead.

● Rules to prevent radiation hazards were worked out by ICRP (Internal Commission of Radiation Protection)

BREEDER REACTOR:

A breeder reactor is that which not only generates power but also produces more fuel of its own than it consumes. In this reactor U^{238} is converted into Pu^{239} by absorbing fast neutrons. This process is called breeding. Thermal breeder reactor uses thermal neutrons for fission process.

Note: The decreasing order of easiness for fission.

1) Pu^{239} 2) U^{235} 3) U^{233} 4) U^{238}

POWER OF A NUCLEAR REACTOR

- The output power of a nuclear reactor is given by
  P = nE
  n = No. of fissions taking place in 1 sec.
  E = Energy released per fission
- If "x" grams of a nuclear fuel of mass number 'A' undergo fission in a time of 't' sec. 'E' is energy released per fission, then the power output of the nuclear reactor is given by

$$P=\frac{NEx}{At}$$ where N - Avagadro number

NUCLEAR FUSION:

- The phenomenon in which two lighter nuclei combine to form a heavier nucleus of mass less than the total mass of the combining nucleus is called nuclear fusion. The mass defect appears as energy.
- At temperatures of about 10^7K, light nuclei combine to give heavier nuclei. Hence, fusion reactions are called thermo nuclear reactions.
- Nuclear fusion takes place in the sun and other stars.
- Energy produced in a single fission of ${}_{92}U^{235}$ is larger than that in a single fusion of Hydrogen into Helium.
- But fusion produces more energy than fission per nucleon.
- In fission, 0.09% of mass is converted into energy. In fusion 0.66% of mass is converted into energy.
- Hydrogen bomb is a fission – fusion bomb.

STELLAR AND SOLAR ENERGY:

- Stellar and solar energy is due to fusion.
  The cycles that occur are.
  - Proton - Proton Cycle
  - Carbon - Nitrogen Cycle
  - PROTON - PROTON CYCLE:

The Thermonuclear reactions involved are:

$$2({}_1H^1)+2({}_1H^1) \rightarrow 2({}_1H^2) + 2({}_{+1}e^0) + Q_1$$

$$2({}_1H^2)+2({}_1H^1) \rightarrow 2({}_2He^3)+Q_2$$

$$2({}_2He^3) \rightarrow ({}_2He^4) + 2({}_1H^2) + Q_3$$

On adding up these reactions, we obtain.

$$4({}_1H^1) \rightarrow {}_2He^4 + 2\,{}_{+1}e^0 + Q$$

Where $Q=Q_1+Q_2+Q_3$ is the total energy evolved in the fusion of 4 hydrogen nuclei to form Helium nucleus. The value of Q as calculated from mass defect comes out to be 26.7MeV

- **CARBON - NITROGEN CYCLE:**
  - It consists of following reactions.

$${}_6C^{12} +{}_1H^1 \rightarrow {}_7N^{13} + Q_1$$

$${}_7N^{13} \rightarrow {}_6C^{13}+({}_1e^0)+Q_2$$

$${}_6C^{13} +{}_1H^1 \rightarrow {}_7N^{14} + Q_2$$

$${}_7N^{14} +{}_1H^1 \rightarrow {}_8O^{15} + Q_4$$

$${}_8O^{15} \rightarrow {}_7N^{15}+({}_{+1}e^0)+Q_5$$

$${}_7N^{15} +{}_1H^1 \rightarrow {}_6C^{12} + {}_2He^4 + Q_6$$

On adding all these equations, we get

$$4\,{}_1H^1 \rightarrow {}_2He^4 + 2({}_{+1}e^0)+ Q$$

Where $Q=Q_1+Q_2+Q_3+Q_4+Q_5+Q_6$ The value of Q as calculated from mass defect is 26.7 Mev.

- In the sun both proton - proton cycle and carbon- nitrogen cycles occur with equal probabilities. In stars, whose interior temperatures are less than that of the sun, proton -proton cycle dominates the energy generation. Again in stars, whose interior temperatures are more than that of the sun, the energy generation is mainly due to carbon- nitrogen cycle.
- The core temperature of heavier stars may be larger than that of the sun and much larger nuclei may be formed.

NOTE: Due to enormous energy released in Sun and Stars the atmosphere of them will be ionised state which is called Plasma (Which contains fast moving neutrons and electrons)

Nuclear Fission	Nuclear Fusion
1) Neutrons are required for it.	1) Protons are required for it.
2) It is possible at normal pressure and temperature	2) It is possible at high pressure and temperature
3) Energy released per nucleon $\cong$ 0.9MeV	3) Energy released per nucleon $\cong$ 6MeV
4) % of mass getting converted into energy =0.1%	4) % of mass getting converted into energy = 0.7%
5) Fissionable materials are expensive.	5) Fusion materials are cheap
6) Harmful reactions are produced.	6) Harmful reactions are not produced.

ELEMENTARY PARTICLES:

- Particles without any internal structure are called elementary particles.
- Protons, neutrons, electrons and photons are considered as fundamental particles.
- Mass, charge, spin and magnetic moment are the basic quantities used to identify elementary particles.
- The elementary particles are divided into four types:
  - (i) Photons - representing electromagnetic interactions.
  - (ii) Leptons - representing weak interactions.
  - (iii) Hadrons - representing strong interactions.
  - (iv) Gravitons - representing gravitational interactions.
- **PHOTONS:** Particles that carry electro magnetic energy are called photons. They posses no mass, no charge, spin = 1, and are stable. Photons can stay at rest without any reference system.
- **LEPTONS:** These are light particles with spin =1/2 and do not participate in strong interactions. POSITRON: Positron is the first antiparticle predicted by Dirac and discovered by Anderson. Positron combines with electron in 10^{-7} s and both annihilate into gamma radiation. The rest mass energy of a positron is equal to that of an electron and is equal to 0.51 MeV.
- μ **MESONS OR MUONS:** These may be positive or negative. Mass of meson is about 207 times the rest mass of an electron. These are unstable having half life equal to 10^{-6} s. They decay into electrons or positrons and neutrinos. These particles are discovered by Anderson and Neddermeyer in cosmic radiation.
- **HADRONS:** They are subjected to strong interactions. They are:
- **MESONS:**
  - π **MESONS OR PIONS:**
  - These are discovered by Powell.
  - These are also called primary mesons.
  - These may be positive, negative or neutral represented as π^+, π^- and π^0
  - These particles possess mass about 273 times the rest mass of an electron.
  - These are unstable having a half life of 10^{-8} second and spin is equal to zero.
  - K-MESONS OR KAONS:
  - These particles may be positive or negative or neutral.
  - The mass of these particles is 966 times the mass of an electron, half life equalto 10^{-8} s and spin is zero.
- π^- and K^- are antiparticles
- **BARYONS:** These are heavier than mesons.
  - Nucleons:
  - Protons, antiprotons, neutrons, antineutrons are known as nucleons.
  - Proton is a stable particle having a half life of 10^{30} year.
  - Hyperons:
  - These are unstable Baryons and are man made particles.
  - These particles are heavier than nucleons having half life of about 10^{-10} s.
- **GRAVITONS:** Hypothetical particles that carry gravitational energy are called Gravitons. They possess no mass, no charge and spin = 2 as proposed by Dirac.
- **FERMIONS:** Particles which obey Pauli exclusion principle and possess half spin are called fermions.
  Eg : Electrons, Protons and Neutrons.
- Antiparticle : An antiparticle has the same mass and same numerical value of spin as its associated particle,but the electromagnetic properties such as charge and magnetic moment etc., are opposite in particle and antiparticle.

LIST OF PARTICLES AND THEIR ANTI PARTICLES:

PARTICLE	ANTI PARTICLE
Electron	Positron
Proton	Anti Proton
Neutron	Anti neutron
Positive π meson	Negative π Meson
Negative μ meson	Positive μ meson

ANNIHILATION: It is a reaction between a particle and its anti particle, for example, between an electron and a positron. The energy released is equal to the sum of the rest energies of the particles and their kinetic energies. In order that momentum be conserved two photons are formed moving away in opposite directions. The annihilation radiation is in the gamma - ray region of the electromagnetic spectrum. When electron and positron combine 1.02 MeV energy is released.

PAIR PRODUCTION: Gamma rays of sufficient energy when passing near a nucleus disappear and materialize into pair of an electron and a positron. To have pair production, minimum energy of γ ray radiation is 1.02 MeV.

ELEMENTARY PARTICLES:

Name of Particle	Rest mass (MeV)	Charge (quanta)	Spin in $h/2\pi$	Mean life
Photon	0	0	1	stable
neutrino(μ)	0		1/2	stable
electron	0.511	-1	1/2	stable
proton	938.2	+1	1/2	stable
neutron	939.6	0	1/2	918 s
μ meson	105.7	-1	1/2	2.2×10^{-6} s
π^{+} meson	139.6	+1	0	2.6×10^{-8} s
π^{0} meson	135.0	0	0	8.3×10^{-17} s

CONCEPTUAL QUESTIONS

1. The particle A is converted to C via following reactions then
   $A \rightarrow B + {}_{2}He^{4}$
   $B \rightarrow C + 2\,{}_{-1}e^{0}$
   1) A and C are isobars
   2) A and C are isotopes
   3) A and B are isobars
   4) A and B are isotopes
2. The particles which can be added to the nucleus of an atom without changing its chemical properties are
   1) electrons 2) protons
   3) neutrons 4) none of these
3. The radius of the nuclues is proportional to, (if A is the atomic mass number)
   1) A 2) A^{3} 3) $A^{1/3}$ 4) $A^{2/3}$
4. The radius of a nucleus mainly depends on
   1) Proton number 2) Electron Number
   3) Mass number 4) Neutron number
5. The nuclei ${}_{6}C^{13}$ and ${}_{7}N^{14}$ can be described as
   1) isotones 2) isobars 3) isomers 4) isotopes
6. Assertion (A) : Isotopes of an element can be separated by using a mass spectrometer.
   Reason (R) : Separation of isotopes is possible of difference in electron number of isotopes.
   1. Both A and R are true and R is correct explanation of A
   2. Both A and R are true and R is not correct explanation of A
   3. A is true but R is false
   4. A is false but R is true
7. The graph of $\ln(R/R_0)$ versus $\ln A$
   (R =radius) of nucleus. A is atomic number is
   1) Straight line 2) Parabola
   3) Ellipse 4) Circle
8. The short range attractive nuclear forces that are responsible for the binding of nucleons in a nucleus are supposed to be caused by the role played by the particles called
   1) Positron 2) μ - Meson
   3) K-Meson 4) π - Meson
9. The strong interaction exists in
   1) Gravitational forces
   2) Electrostatic force of attraction
   3) Nuclear forces
   4) Magnetic force on a moving charge
10. Among the following, short range, charge independent and spin dependent forces are
    1) Gravitational forces 2) Nuclear forces
    3) Electromagnetic forces 4) Weak forces
11. Identify the correct statement/statements
    a) At greater distances nuclear forces are negligible
    b) Nuclear forces are non central forces
    c) Nuclear forces are weakest in nature
    d) Nuclear forces are charge dependent forces
    1. a, b 2. b, c 3. c, d 4. a, d
12. 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) $F_{pp}<F_{pn}=F_{nn}$

13. Two protons are kept at a seperation of 10nm.Let F_n be the nuclear force and F_e be electro magnetic force between them. Then

1) $F_e=F_n$ 2) $F_e>>F_n$ 3) $F_e<<F_n$ 4) $F_n= 3F_e$

14. Two protons attract each other when

1) the distance between them is 10^{-10} m

2) the distance between them is 10^{-1} m

3) the distance between them is 10^{-15} m

4) the distance between them is 10^{-6} m

15. Among gravitational,electrostatic and nuclear forces,the two attractive forces between two neutrons are

1) Electrostatic and nuclear

2) Electrostatic and gravitational

3) Gravitational and nuclear

4) All the above

16. Which of the following interactions is of least significance in nuclear physics?

1) nuclear interaction

2) gravitational interaction

3) electrostatic interaction

4) electromagnetic interaction

17. M,M_n and M_p denotes the masses of a nucleus of ${}_ZX^{A,}$ a neutron, and a proton respectively. If the nucleus is separated in to its individual protons and neutrons then

1) $M=(A-Z)M_n+ZM_p$ 2) $M=ZM_n+(A-Z)M_p$

3) $M>(A-Z)M_n+ZM_p$ 4) $M<(A-Z)M_n+ZM_p$

18. Consider the following statements (A) and (B) and identify the correct answer given below:

Statement A : Positive values of packing fraction implies a large value of binding energy Statement B : The difference between the mass of the nucleus and the mass number of the nucleus is called packing fraction.

1. A and B are correct2. A and B are false

3. A is true B is false 4. A is false, B is true

19. The difference between the mass of a nucleus and the combined mass of its nucleons is

1) zero 2) positive

3) negative

4) zero, positive or negative

20. The parameter used to measure the stability of the nucleus is

1) Average binding energy 2) No of protons

3) No of neutrons 4) No of electrons

21. When the number of nucleons in a nuclues increases the binding energy per nucleon

1) Increase continuously with mass number

2) Decreases continuously with mass number

3) Remains constant with mass number

4) First increases and then decreases with in -crease in mass number

22. Maximum value of binding energy per nucleon is

1) 8MeV 2) 8.8MeV

3) 7.6MeV 4) 1.1MeV

23. Average binding energy per nucleon over a wide range is

1) 8MeV 2) 8.8MeV

3) 7.6MeV 4) 1.1MeV

24. The wrong statement about binding energy is

1) It is the sum of the rest mass energies of nucleons minus the rest mass energy of the nucleus.

2) It is the energy released when the nucleons combine to form a nucleus.

3) It is the energy required to break a given nucleus into its constituent nucleons.

4) It is the sum of the kinetic energies of all the nucleons in the nucleus.

25. The binding energies of a deutron and an α-particle are 1.125, 7.2 MeV/nucleon respectively. The more stable of the two, is

1) deutron 2) α-particle 3) both

4) sometimes deutron and sometimes α-particle

26. Mass defect of an atom refers to

1) inaccurate measurement of mass of neutrons

2) mass annihilated to produce energy to bind the nucleons

3) packing fraction

4) difference in the number of neutrons and protons in the nucleus

27. A nucleus with an excess of neutrons may decay with the emission of

1) a neutron 2) a proton

3) an electron 4) a positron

28. The age of pottery is determined by archeologists using a radioisotope of

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

29. During an artificial transmutation the resulting nucleus

1) emits β-particles 2) emits α-particles

3) gives off γ-particles

4) any of the above may be emitted or given off or in combination with a γ-ray

30. When two deuterium nuclei fuse together to form a tritium nucleus, we get a
1) neutron 2) deuteron
3) alpha particle 4) proton

31. The most penetrating atom smashing particle is
1) neutron 2) proton
3) alpha particle 4) deuteron

32. Identify the correct statement/statements
a) Radiation causes genetic mutation
b) Restriction in blood circulation can be detected using radio-iodine
c) Hydrocarbon plastics are used as moderators in a nuclear reactor
d) The damage caused due to α-radiation is small due to its small penetrating power
1. a,b,c 2. a,c,d 3. b,c,d 4. a,b,d

33. Assertion (A) : All the radioactive elements are ultimately converted into lead
Reason (R): All the elements above lead are unstable.
1. Both A and R are true and R is correct explanation of A
2. Both A and R are true and R is not correct explanation of A
3. A is true but R is false 4. A is false but R is true

34. Match the following

Radio isotope	**Cures disease**
i) Radio sodium	a) Thyroid gland
ii) Radio phosphorus	b) Cancer
iii) Radio cobalt	c) Blocks in blood circulation
iv) Radio iodine	d) Leukamia

1. i - c, ii - b, iii - a, iv - d
2. i - a, ii -c, iii - b, iv - d
3. i - c, ii - d, iii - b, iv - a
4. i - d, ii - b, iii - c, iv - a

35. Bombardment of Beryllium by alpha particles resulted in the discovery of
1) Proton 2) Nucleus 3) Neutron 4) Positron

36. In neutron discovery experiment Beryllium target is bombarded by
1) Protons 2) Alpha particles
3) Neutrons 4) Deutrons

37. Slow neutrons are sometimes refer to as thermal neutrons because
1) they are sort of heat radiations
2) they are in thermal equilibrium
3) they are capable of generating heat
4) their energies are of same order as that of molecular energies at ambient temperatures.

38. Thermal neutrons are
1) Prompt neutrons 2) Slow neutrons
3) Neutrons which are in the nucleus
4) Neutrons from the sun

39. Regarding Prompt neutrons
1) They are highly energetic
2) They constitute 99.36%
3) Cannot initiate chain reaction
4) 1,2,3 are correct

40. At least how many thermal neutrons should be available to start a fission reaction
1) 2 2) 3 3) 1 4) 4

41. During the fission process of Uranium,the amount of energy liberated per fission is nearly
1) 100MeV 2) 200MeV
3) 150MeV 4) 300MeV

42. The number of neutrons that are released on the average during the fission of U^{235} nucleus is
1) 3 2) 1 3) 2.5 4) 5

43. It is possible to understand nuclear fission on the basis of
1) Independent particle model of the nucleus
2) Liquid drop model of the nucleus
3) Meson theory of nucleus
4) Proton -Proton type

44. Percentage of mass lost during the fission of $_{92}U^{235}$ approximately is
1) 0.01% 2) 0.1% 2) 0.7% 4) 0.9%

45. The critical mass of a fissionable material is
1) 0.1kg equivalent
2) The minimum mass needed for chain reaction
3) The rest mass equivalent to 1020 joule
4) 0.5kg

46. For fast chain reaction, the size of U^{235} block, as compared to its critical size, must be
1) greater 2) smaller 3) same 4) anything.

47. The critical mass of fissionable uranium-235 can be reduced by
1) adding impurities 2)heating material
3) surrounding it by a neutron-reflecting material
4) surrounding it by a neutron-absorbing material

48. Nuclear energy is released in fission since binding energy per nucleon is
1) smaller for fission fragments than for parent nucleus
2) the same for fission fragments and parent nucleus

3) larger for fission fragments than for parent nucleus
4) sometimes larger and sometimes smaller

49. In a critical chain reaction
1) energy is released at increasing rate
2) energy is released at steady rate
3) energy is released at decreasing rate
4) energy is not released

50. Which of the following is wrong
1. The energy of thermal neutrons is about 25 meV
2. In a nuclear reactor, when neutrons multiplication factor, K = 1 then the reaction is said to be critical
3. ${}_{92}U^{235}$ undergoes fission by bombardment of high energy neutron
4. On average 2.5 neutrons are emitted per fis -sion of ${}_{92}U^{235}$

51. In the process of fission, the binding energy per nucleon
1. Increases
2. Decreases
3. Remains uncharged
4. Increases for mass number A < 56 nuclei but decreases for mass number A> 56

52. Assertion (A) : Fragments produced in the fission of U^{235} are radioactive.
Reason (R) : The fragments have abnormally high proton to neutron ratio
1. Both A and R are true and R is correct explanation of A
2. Both A and R are true and R is not correct explanation of A
3. A is true but R is false
4. A is false but R is true

53. Assertion (A) : In the process of nuclear fission, the fragments emit two or three neutrons as soon as they are formed and subsequently emit particles.
Reason (R) : As the fragments contain an excess of neutrons over proton, emission of neutrons and particles bring their neutron/proton ratio to stable values.
1. Both A and R are true and R is correct explanation of A
2. Both A and R are true and R is not correct explanation of A
3. A is true but R is false
4. A is false but R is true

54. Consider the following statements A and B. Identify the correct in the given answer.
A) p-n; p-p; 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 and B are wrong
3) A is wrong B is correct
4) A is correct B is wrong

55. The process of fission is responsible for the release of energy in
1) The hydrogen bomb
2) The atom bomb
3) The sun
4) All the above

56. Control rods are
1) Boron rods
2) Codmium rods
3) Copper rods
4) 1 and 2

57. Nuclear reactor is surrounded by concrete walls to
1) Strengthen the construction
2) Control the chain reaction
3) form a protective shield
4) as moderator

58. The coolant in the nuclear reactor is
1) Liquid sodium
2) cadmium
3) Deuterium
4) Liquid hydrogen

59. Substance used to slow down the fast neutrons released during nuclear fission is called.
1) Fuel
2) Moderator
3) Controlling rods
4) Reflecting rods

60. If the neutron reproduction factor K is
1) greater than 1 the fission reaction is accelerated
2) less than 1 the fission reaction retards
3) equal to 1 the fission reaction is at steady state
4) All the above phenomenon happens

61. The man-made element which was made in the nuclear reactor is
1) polonium
2) plutonium
3) thorium
4) uranium

62. In a fast breeder reactor, the main charm is that the nuclear ash is that it is
1) more fissile than parent fuel
2) not dangerous as a potential pollutant
3) easily disposed off
4) stable in terms of further decay

63. If "X" gm of a nuclear fuel of mass number "A" undergoes fission inside a reactor then the number of fissions will be (N-Avagadro number)

1) $\frac{NA}{x}$ 2) NAx 3) $\frac{Nx}{A}$ 4) $\frac{Ax}{N}$

64. The reactor which produces power due to fission by fast neutron and at the same time regenerates more fissionable material than it consumes is

1. Thermal reactor 2. Breeder reactor 3 . Both the above 4. None

65. A good moderator should

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

66. The source of energy in sun and stars is

1) Nuclear fission 2) Nuclear fusion
3) Burning of coal 4) Vibration of electrons

67. The percentage of mass lost during nuclear fusion is

1) 0.1% 2) 0.4% 3) 0.5% 4) 0.65%

68. Nuclear fusion requires high temperature because

1) All nuclear reactions absorb heat
2) The particles can not come together unless they are moving rapidly.
3) The binding energy must be supplied from an external source.
4) The mass defect must be supplied.

69. Which of the following is true?

1) Energy released per nucleon is same in both fission and fusion reactions
2) Energy released per nucleon is more in fission than in fusion reaction
3) Energy released per nucleon is less in fission then in fusion reaction
4) No energy is released in fusion reaction

70. Fusion reaction take place at high temperature because

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

71. In the carbon cycle from which stars hotter than the sun obtain their energy the ${}_{6}C^{12}$ isotope

1) splits up into three alpha particles
2) fuses with another ${}_{6}C^{12}$ nucleus to form ${}_{12}Mg^{24}$
3) is completely converted into energy
4) is regenerated at the end of the cycle

72. 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

73. Source of solar energy can be said to be due to natural fusion in which hydrogen gets converted into helium with carbon serving as a natural catalyst. This carbon cycle was proposed by

1) Bothe 2) Yukawa 3) Fermi 4) Soddy

74. Assertion (A) : If a heavy nucleus is split into two medium sized parts ; each of the new nuclei will have more binding energy per nucleon than the original nucleus.

Reason (R): Joining two light nuclei together to give a single nucleus of medium size means more binding energy per nucleon in the new nucleus.

1. Both A and R are true and R is correct explanation of A
2. Both A and R are true and R is not correct explanation of A
3. A is true but R is false
4. A is false but R is true

75. (A) Fission is a thermonuclear process (B) Fusion is a thermonuclear process (C) Fusion is exothermic and (D) Fission is exothermic

Choose the correct answer

1) A and B are correct 2) B and C are correct
3) A and C are correct 4) B and D are correct

76. Assertion (A): Nuclear fusion reactions are considered as thermo-nuclear reactions

Reason (R): The source of stellar energy is nuclear fusion

1) Both A & R are true and R is the correct explanation of A
2) Both A & R are true and R is not correct explanation of A
3) A is true but R is false 4) A is false but R is true

77. The nucleus finally formed in fusion of proton in proton cycle is that of

1) Helium 2) Deuterium
3) Carbon 4) Hydrogen

78. In carbon cycle of fusion, 4 protons combine to yield one alpha particle and
1) One positron 2) Two positrons
3) Ten positrons 4) Three positrons

79. Inside the sun
1) Four nuclei of hydrogen combine to form two nuclei of helium
2) Four nuclei of hydrogen combine to form four nuclei of helium
3) Four nuclei of hydrogen combine to form one nucleus of helium
4) Four nuclei of hydrogen is transformed into one nucleus of helium

80. In the carbon cycle of nuclear fusion carbon acts like a
1) Moderator 2) Activator
3) Catalyst 4) Controller

81. In a fusion process a proton and neutron combine to give a deuterium nucleus. If m_o and m_p be the mass of neutron and proton respectively the mass of deuterium nucleus is
1) equal to m_o+m_p 2) more than m_o+m_p
3) less than m_o+m_p
4) can be less than or more than (m_o+m_p)

82. The binding energies of the atoms of elements P and Q are E_P and E_Q respectively. Three atoms of elements Q fuse to form one atom of element P. In this process the energy released is e. The correct relation between E_P, E_Q and e will be
1) $E_Q=3E_P+e$ 2) $E_Q=3E_P-e$
3) $E_P=3E_Q+e$ 4) $E_P=3E_Q-e$

83. The $\frac{B.E.}{A}$ for deutron and an α- particle are X_1 and X_2 respectively. The energy released in the fusion of deuterium into α particle is.
1) $4(X_2-X_1)$ 2) $2(X_2-X_1)$
3) $4(X_2+X_1)$ 4) $\frac{X_2-X_1}{4}$

84. If Q_1 and Q_2 are the energies released in the fusion of hydrogen in Carbon - nitrogen cycle and proton - proton cycle respectively then
1) $Q_1 > Q_2$ 2) $Q_1 = Q_2$
3) $Q_1 < Q_2$ 4) $Q_1 \geq Q_2$

85. In an exo-ergic reaction the binding energies of reactants and products are respectively then
1) $E_1<E_2$ 2) $E_1=E_2$ 3) $E_1>E_2$ 4) $E_1 \geq E_2$

86. In an endo-ergic reaction the binding energies of reactants and products are respectively
1) $E_1<E_2$ 2) $E_1=E_2$ 3) $E_1>E_2$ 4) $E_1 \geq E_2$

87. Which one of the following reactions is impossible?
1) ${}_2He^4+{}_4Be^9= {}_0n^1+{}_6C^{12}$
2) ${}_2He^4+{}_7N^{14}= {}_1H^1+{}_8O^{17}$
3) $4({}_1H^1) ={}_2He^4 +2 ({}_{-1}e^0)$
4) ${}_3Li^7+{}_1H^1 = {}_4Be^8$

88. If the nuclei of masses X and Y are fused together to form a nucleus of mass m and some energy is released, then
1) X+Y = m 2) X + Y< m
3) X + Y > m 4) X - Y= m

89. Fusion reactions take place at about
1) 3×10^2 K 2) 3×10^3 K
3) 3×10^4 K 4) 3×10^6 K

90. The energy emitted per second by sun is approximately
1. 3.8×10^{26} *Joule* 2. 3.8×10^{14} *Joule*
3. 3.8×10^{12} *Joule* 4. 3.8×10^{-26} *Joule*

91. The particle which has no antiparticle
1) Proton 2) Electron 3) Neutron 4) Photon

92. The elementary particles having zero spin
1) Leptons 2) Mesons 3) Photons 4) Bosons.

93. The phenomenon of pair production is
1) The production of an electron and a positron from γ radiations
2) Ejection of an electron from a metal surface when exposed to ultraviolet light
3) Ejection of an electron from a nucleus
4) Ionization of a neutral atom

94. Which one of the following particles belongs to baryons.
1) Neutron 2) Mu-meson
3) Positron 4) π-meson

95. The particle which has no charge and negligible rest mass is
1) $\sum-meson$ 2) K-meson
3) Positron 4) Neutrino

96. Of the following particles, the one which is unstable in free space is
1) electron 2) proton 3) neutron 4) alpha particle

97. Which one of the following statements regarding neutrino is wrong?
1) neutrino has spin ½
2) neutrino has zero rest mass

3) neutrino does not interact with matter

4) neutrino has charge equal to 1.6×10^{-19} C

98. Which one of the following is its own antiparticle?
1) photon 2) electron 3) proton 4) π-meson

99. A π mason at rest decays into two gamma rays, i.e. $\pi^0 \rightarrow \gamma+\gamma$ .Then the following can happen
1) the two γ-rays have unequal energies
2) both are γ-rays move in the same direction
3) the two γ-rays in the directions opposite to each other
4) the γ-rays periodically approaching and receding from each other

100. The half life of k-meson is
1) 8×10^{-9} s 2) 9×10^{-12} s
3) 8×10^{-15} s 4) 8×10^{-18} s

101. Which of the following is a baryon?
1) neutron 2) μ-meson
3) electron 4) π-meson

102. A negative pi meson at rest can decay as $\pi^- \rightarrow \mu^- + \bar{\nu}$. Then the energy of μ^-
1) can be anything 2) is a fixed quantity
3) is zero 4) is equal to mc^2

103. When an electron and a positron are annihilated, then the number of photons produced is
1) two 2) one 3) three 4) four

104. The charge of a π^+ meson is
1) equal to electron charge 2) zero
3) equal to proton charge 4) none of these

105. The elementary particles heavier than protons are called
1) mesons 2) neutrons
3) hyperons 4) leptons

106. Anti-particle of proton is
1) electron 2) antiproton
3) positron 4) neutron

107. Among the following the lightest particle is
1) electron 2) proton
3) π^0 meson 4) neutron

108. When the particle and its antiparticle unite, the result is
1) a heavier particle
2) two or more smaller particles
3) photons 4) partly matter and partly photons.

109. Regarding Photons pick out correct statement of following
1) They have zero rest mass and zero spin
2) They have zero rest mass and half integral spin
3) They have zero rest mass and spin of unity
4) All the above

110. Pickout the hyperon of following
1) λ (Lambda) 2) Σ (Sigma)
3) Ω (Omega) 4) All the above

111. $_{+1}e^0 + {}_{-1}e^0 \rightarrow 2\gamma$
The above equation satisfies law of conservation of
1) Charge 2) energy
3) momentum 4) All the above

112. To produce pair production, the minimum energy of γ-ray should be
1) 0.15 MeV 2) 1 MeV
3) 1.02 MeV 4) 1.5 MeV

113. The rest energy of electron or positron is
1) 0.51 MeV 2) 1 MeV
3) 1.02 MeV 4) 1.5 MeV

114. A positron and an electron came close together to give a neutral one called
1) Electronium 2) Positronium
3) γ-photon 4)None

115. Positronium is converted into
1) 2 Photons each of energy 0.51MeV
2) 1 Photon of energy 1.02 MeV
3) 2 Photons each of energy 1.02MeV
4) One Photon of energy 0.51MeV

116. A particle having no charge and almost no mass is
1) positron 2) neutron 3) electron 4) neutrino

117. Assertion (A): Due to annihilation of electron positron pair two γ-ray photons are produced.
Reason (R): This is in accordance with law of conservation of linear momentum.
1) Both A & R are true and R is the correct explanation of A
2) Both A & R are true and R is not correct explanation of A
3) A is true but R is false
4) A is false but R is true

118. Out of the following : (a) The rest mass of photon is zero. (b) π-meson in nuclear field is analogous to photon in electromagnetic field. (c) Neutral π-meson decays into two γ-ray photons and (d) Graviton of gravitational field has an integral spin
1) a,c and d 2) a and b
3) a,b,c and d 4) a,b and d