LT P C
4- - 4

Objective: Nuclear reactions are responsible for the production of energy in the universe. This paper explains the physics of nuclei and their reactions and nuclear energy.

UNIT I

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about size, mass, charge density (matter energy), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states.

UNIT II

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of various terms, condition of nuclear stability. Two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

UNIT III

Nuclear Reactions: Nuclear fission - Energy released in fission - Bohr and Wheeler's theory of nuclear fission - Chain reaction - Multiplication factor - Natural uranium and chain reaction - Design of nuclear reactor - Breeder reactor - Nuclear fusion - Source of stellar energy - Thermonuclear reactions - Transuranic elements.

Ionization chamber – Geiger-Muller counter – Proportional counter – Wilson's cloud chamber – Bubble chamber – Their principles and working.

UNIT IV

Nuclear Reactions: Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

UNIT V

Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model.

Reference Books:

1. Introductory nuclear Physics by Kenneth S.Krane (Wiley India Pvt. Ltd., 2008). Concepts of nuclear physics by Bernard L.Cohen.(Tata Mcgraw Hill, 1998).
2. Introduction to the physics of nuclei & particles, R.A.Dunlap. (Thomson Asia, 2004)
3. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
4. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000)

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University Established Under Section 3 of UGC Act 1956)

Coimbatore – 641 021.

LECTURE PLAN

DEPARTMENT OF PHYSICS

STAFF NAME: Mrs.S.SHARMILA
SUBJECT NAME: NUCLEAR AND PARTICLE PHYSICS SUB.CODE:16PHU402
SEMESTER: IV CLASS: II B.Sc (PHY)

S.No	Lecture Duration Period	Topics to be Covered	Support Material/Page Nos
1	1	Constituents of nucleus and their Intrinsic properties,	T1– 392
2	1	mass, charge density (matter energy),	T1-393
3	1	quantitative facts about size	T1-392
4	1	Binding energy , average binding energy and its variation with mass number	T1-394-395
5	1	main features of binding energy versus mass number curve, N/A plot	T1-396
6	1	angular momentum	T1-393
7	1	Parity	T1-407
8	1	magnetic moment	T3-25, T2-140
9	1	electric moments	T3-23
10	1	nuclear excites states	T3-33-36
11	1	Revision	
	Total no. of hours for unit-I = 11		
	Unit-II		
1	1	condition of nuclear stability. Two nucleon separation energies,	T3-414-416

2	1	Liquid drop model approach	T1-401
3	1	Continuation	
4	1	Semi empirical mass formula and significance of various terms	T1-402
5	1	Continuation	
6	1	basic assumption of shell model	T1-403-404
7	1	Continuation	
8	1	Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas),	T1410-411
9	1	evidence for nuclear shell structure, nuclear, , concept of mean field, residual interaction, concept of nuclear force	
10	1	Continuation	
11	1	magic numbers	T3-420-422
12	1	Revision	
	Total no. of hours for unit-II = 12		
	UNIT-III		
1	1	Nuclear fission, Energy released in fission	T1-503-504
2	1	Bohr and Wheeler's theory of nuclear fission	T1-505
3	1	Design of nuclear reactor - Breeder reactor	T1-509-510
4	1	Wilson's cloud chamber	T1-420-421
5	1	Multiplication factor Chain reaction-	T1-506-507

6	1	Natural uranium and chain reaction	T1-507-508
7	1	Nuclear fusion - Source of stellar energy	T1-511-512,
8	1	Thermonuclear reactions	T1-512-513,
9	1	Transuranic elements.	T1-515,
10	1	Ionization chamber	T1-414-415
11	1	Proportional counter	T1-417-418
12	1	Geiger-Muller counter	T1-418-419
13	1	Bubble chamber – Their principles and working.	T1-422-423
14	1	Revision	
	Total no. of hours for unit-III = 14		
	UNIT-IV		
1	1	Conservation Laws,	T2-407
2	1	kinematics of reactions, Q-value, reaction rate,	T1-483-485
3	1	Continuation	
4	1	reaction cross section,	T1-489-491
5	1	Concept of compound and direct reaction.	T2-433-441
6	1	Continuation	
7	1	resonance reaction	W1
8	1	Continuation	
9	1	Coulomb scattering (Rutherford scattering)	W2
10	1	Continuation	

11	1	Revision	
	Total no. of hours for unit-IV = 11		
	UNIT-V		
1	1	Particle interactions; basic features,	T2-528
2	1	Continuation	
3	1	types of particles and its families.	T2-525
4	1	Continuation	
5	1	Symmetries and Conservation Laws: energy and momentum, angular momentum,	T2-545
6	1	parity, baryon number, Lepton number, Isospin, Strangeness and charm,	T2-526
7	1	Continuation	
8	1	concept of quark model	T2-580-581
9	1	Revision	
10	1	Old question paper discussion	
11	1	Old question paper discussion	
12	1	Old question paper discussion	
	Total no. of hours for unit-V = 12		
Total hours planned	**60**		

TEXTBOOK

T1- Modern Physics by R.Murugeshan and Kiruthiga Sivaprasath, S.Chand & company ltd, Ram Nagar, New Delhi

T2- Elements of Nuclear Physics –M.L. Pandya , R.P.S. Yadhav, KedarNath RamNath & co.

T3- Nuclear Physics –D.C Tayal, Himalaya Publishing house, Mumbai.

REFERENCE BOOKS

R1-Introductory to Nuclear Physics –Kenneth.S Crane, Wiley India Ltd.

WEBSITES:

W1-www.nuclear-power.net

W2-http://mysite.du.edu/Njcalvert/phys/ruther.html

UNIT -1

UNIT-I

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about size, mass, charge density (matter energy), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states.

CLASSIFICATION OF NUCLEI:-

ISOTOPES

Same elements having the same atomic number but differs in mass number E.g.: - $_1H^1\,_1H^2\,_1H^3$

ISOBARS

Different elements having same mass number, but differs in atomic number E.g.: -$_8O^{16}$, $_7N^{17}$

ISOTONES

Different element having the same number of neutrons E.g.: -$_6C^{15}$ $_7N^{16}$

ISOMERS

Different elements with some atomic and mass number differs from one another from its nuclear energy states internal structure may be also different life time.

MIRROR NUCLEI:-

Difference element with same mass number with the proton and the neutron number interchanged number of protons in one is equal to the number of neutrons in other depends up to a number of counts

1.odd-odd

2.even-even

3.odd-even

4.even-odd

GENERAL PROPERTIES OF NUCLEI

NUCLEAR SIZE

Nuclear size is calculated from the formula R=$r_0A^{1/3}$, where A is the mass number of the nucleus. For example $_6C^{12}$, R=$1.3*10^{-15}*(12)^{1/3}$, R=$2.976*10^{-15}$

Practical verification for nuclear size was done by electric and nuclear method. Electrical method such as Mesonic X-ray, Electronic scattering and Coulomb-energy of mirror nuclei. Nuclear method like neutron scattering, α-decay and α-scattering isotopic shift in line spectra.

NUCLEAR MASS

Nuclear consists of protons and neutrons the mass of the nuclei can be assumed nuclear mass=Zm_p+Nm_n, where m_p and m_n is the mass of the proton and neutrons respectively, the nuclear mass can be obtained experimentally using a mass spectrometer. It shows that real nuclear mass < Zm_p+Nm_n the difference in mass is

$$Zm_p+Nm_n\text{-real nuclear mass-}\Delta m$$

$$\Delta m - mass\ defect$$

NUCLEAR DENSITY

$$\text{Nuclear density}=\frac{nuclear\ \ mass}{nuclear\ \ volume}$$

$$=\frac{Am_N}{\frac{4}{3}\pi(A^{1/3}r_0)^3}$$

$$=\frac{m_N}{\frac{4}{3}\pi r_{0^3}}$$

nuclear density=$1.816*10^{17}$ kg/m^3

This shows that nuclear matter is in extremely compressed state certain starts like white dwarf composed of atoms whose electron shell have collapsed owing enormous pressure and density such states apporaches pure nucleus matter.

NUCLEAR CHARGE

The charge of the nucleus is due to protons in it.Each proton has a positive charge of $1.6*10^{-19}$ C. The nuclear charge is Ze, where Z- atomic number of nucleus, the value of Z is known from X-ray scattering experiment from nuclear scattering α-particles and X-ray spectrum.

SPIN ANGULAR MOMENTUM

Both the proton and neutron like an electron having an intrinsic spin the spin angular momentum is computed by spin angular momentum =s=$\sqrt{l(l+1)}\frac{h}{2\pi}$

where l is the quantum number called spin is equal to ½ . $l_{s=\frac{\sqrt{3}}{2}\frac{h}{2\pi}}$

RESULTANT ANGULAR MOMENTUM

The proton and the neutrons in the nucleus have a orbital angular momentum. The resultant angular momentum of a nucleus is obtained by the spin and orbital angular momentum of all the nucleons with the nucleus. The total angular momentum of the nucleus is given by $l_n = \sqrt{l_n(l_n+1)}.\frac{h}{2\pi}$

NUCLEAR MAGNETIC DIPOLE MOMENT

The spinning electron has a magnetic dipole moment of 1 Bhor magnetron $\mu_e = \frac{eh/_{2\pi}}{2m_e}$

Proton has positive elementary charge and due to its spin, it has magnetic dipole moment According to Dirac

$$\mu_N = \frac{eh/_{2\pi}}{2m_p}$$

where μ_N *is nuclear magnetron*

$$\mu_N = 5.050 * 10^{27} J, \ m_p=1836*m_e$$

The nuclear magnetron is 1/1836 times of bhor magnetron for nucleon,

$$\mu_p = 2.7925 * \mu_N \ and \ \mu = -1.9128 * \mu_N$$

BINDING ENERGY

The theoretical explanation of mass defect is based on Einstein equation E=mc^2.When Z protons and N neutrons combine to make the nucleus. Some of the mass Δm disappear because it is converted into an amount of energy $\Delta E = \Delta mc^2$. This energy is called binding energy. To disrupt a stable nucleus into its constituent neutrons and protons.The energy required is binding energy. The magnitude of the binding energy of a nucleus determines its stability against disintegration. If the binding energy is large the nucleus is stable. The nucleus having least possible energy as binding energy it is said to be in the ground state. If the nucleus has an energy $E < E_{minimum}$ is said to existed state. The case E=0 corresponds to disassociation of the nucleus into constitutional nucleons.

If m is experimentally determined mass of nuclei having Z proton and N neutron then binding energy={(Zm_p+Nm_n)-M} c^2

If binding energy>0 the nucleus is stable and the energy is must be supplied from outside to disrupt. The binding energy <0 the nucleus is unstable and it will disintegrate by itself.

Example

Let us illustrate the calculation of binding energy by taking example as deuterons is formed by a proton and neutron.

mass of proton =1.007276a.m.u

mass of neutron=1.008665a.m.u

therefore,

mass of proton + mass of neutron in free state =2.015941a.m.u

mass of deuteron nucleus= 2.013553a.m.u

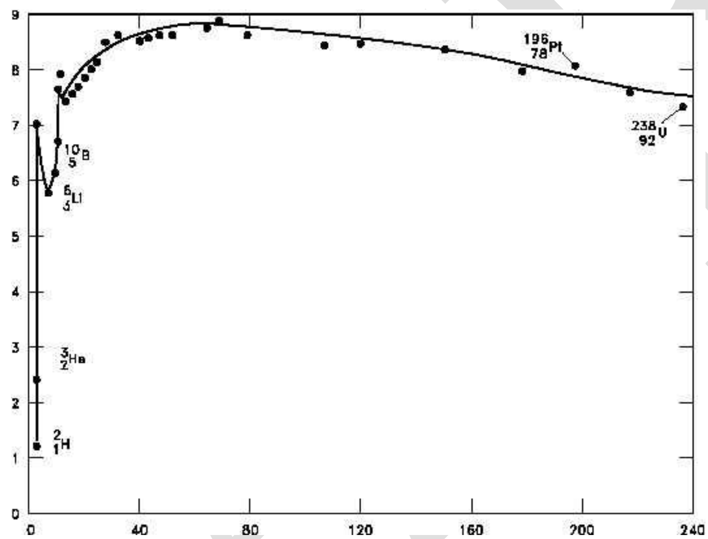
mass defect $\Delta m = 2.015941 - 2.013553 = 0.002388 \text{a.m.u}$

binding energy=$\Delta m * 931 = 0.002388 * 931 = 2.23 Mev$

1a.m.u=931Mev

STABILITY OF NUCLEUS AND BINDING ENERGY

Binding energy per nucleon=$\frac{total\ binding\ energy\ of\ nucleus}{the\ number\ of\ nucleon\ it\ contains}$



The binding energy per nucleon is plotted as the function of mass number (A) the curve rises steeply at first, then more gradually until it reaches a maximum of 8.75Mev at A=56 corresponding to the iron nucleus Fe_{26}^{56} . The curve then drops slowly to 7.6Mev at the highest mass number. Evidently, nuclei of intermediate masses or the most stable since the greatest amount of energy must be supplied to liberate each of their nucleons. This fact suggests that a larger amount of energy will be liberated if heavier nuclei can be split into lighter one or if lighter nuclei be joined to form heavier one.

PACKING FRACTION

The ratio between mass defect Δm to the mass number A is called as packing fraction.

$$packing\ fraction = \frac{Isotopic\ mass - mass\ number}{mass\ number} \times 10^4$$

or

$$packing\ fraction = \frac{\Delta m}{A} \times 10^4$$

packing fraction means the mass defect per nucleon. Since atomic masses are measured relative to C-12, The packing fraction for this isotope is zero. Packing fraction is a measure of the comparative stability of an atom.

Packing fraction may have a negative or positive sign. If the packing fraction is negative, the isotopic mass is less than mass number. In such cases, some mass gets transformed into energy in the formation of a nucleus. In accordance with Einstein's equation $E = mc^2$ Such nuclei are more stable. A positive packing fraction would imply a tendency towards instability. But it is not correct to the low atomic mass element.

Plot of packing fraction against the mass number of the element shows that helium, carbon and oxygen atom of the mass 4, 12, 16 respectively not fall on this curve.

ANGULAR MOMENTUM OF THE NUCLEUS

The angular momentum of the nucleus is often referred as spin, but this not the correct usage of the term the word should refer only to the angular momentum of the elementary particles. The total angular momentum of the nucleus is made up of the spin of the nucleons and of their angular momentum.

Each nucleon in the nucleus has an angular momentum which presumably due to the spinning motion of the particles about an axis through its centre of mass. The magnitude of this spin angular momentum is 1/2 $\frac{h}{2\pi}$. According to the wave mechanics this type of angular momentum is described by two states.

1.The spin is parallel to a given direction.

2.Spin axis is anti-parallel to a given direction.

The components of the spin along the direction i.e. that is Z axis is either $\frac{1}{2}.\frac{h}{2\pi}$ or $-\frac{1}{2}.\frac{h}{2\pi}$

Besides the spinning motion of each nucleon has an angular momentum associated with the orbital motion within the nucleus. According to quantum theory the orbital angular momentum is a general possible component in any given direction is an integral multiple of $\frac{h}{2\pi}$.

Each nucleon therefore has a total angular momentum about a given direction is $i = l \pm s$ where,

l - orbital angular momentum

s - spin angular momentum

In the nuclei containing more than one particle, the resultant angular momentum of the nucleus is

$$I = L \pm S$$

where,

L - Total angular momentum

S - Total spin angular momentum

The total angular momentum is a vector I and the scalar quantity, magnitude in any given direction. the orbital angular momentum L is an integral multiple of $\frac{h}{2\pi}$, g is an even half integral of $\frac{h}{2\pi}$.

If the nucleus of nucleon particle is even and an odd half integral multiple if the number of particles is odd. Hence I is an integral of $\frac{h}{2\pi}$ when A is even and an odd half integral multiple when A is odd.

NUCLEAR MAGNETIC MOMENT

When a charge particles moves in a closed path it produces both angular momentum and a magnetic field. The magnetic field at large distance may be describe as due to magnetic dipole located at the centre of current loop. Thus the orbital and spin angular momentum of protons produce extra nuclear magnetic field which can be assumed as due to magnetic dipole located at the centre of nucleus.

Consider a charge particles of mass M and charge e when charge revolves in a circular orbit it is equivalent to a current of the strength $i = \frac{e.\omega}{2\pi}$

ω-angular frequency of revolution

The magnetic field of this current is equivalent to that of a magnetic dipole moment of the value

$$\mu = \pi r^2 i$$

r-radius of the circular path

orbital angular momentum of the particles -$\hbar\sqrt{l(l+1)}$. Thus the angular momentum is $Mr^2\omega = m_l\,\hbar$ .m_l-projection of l in field direction, the maximum value of magnetic moments along the field direction due to orbital motion is given by m_l=l

$$\mu_{max}\,(orbital\,) = \frac{e\hbar l}{2M}$$

and due to intrinsic spin,

$$\mu_{max}\,(spin) = \frac{e\hbar s}{M}$$

the spin angular moment is twice as large as the expected value because spin frequency is double that of orbital frequency.Total frequency momentum of the nucleus is the contribution due to orbit and spin motion. The magnetic dipole moment is written as,

$$\mu = \mu_N g_N I$$

g-nuclear g factor

$$\mu = \frac{\hbar e}{2m_p}$$

m_p- the proton rest mass

μ-vector in a direction of I.The maximum observable component of μ is known as moment of the nucleus.

$$\mu = \mu_N g_N I$$

PARITY

Parity is the fundamental nuclear property which is considered more important than spin. According to quantum mechanics, associated with each particle is a wave function ψ which depends upon the space co-ordinates (x, y, z). The probability of finding a particle is given by $|\psi|^2=\psi\psi^*$ where ψ^* is the complex conjugate of ψ. The question as to how ψ behaves when the signs of (x, y, z) are changed is decided by parity. The transformation of co-ordinates (from positive to negative) is equivalent to reflecting the particle at the origin in the (x, y, z) system, on operation which must either leave the wave function unchanged, or only change its sign, so the quantity $\psi\psi^*$ is not changed. If the change of sign x, y, z does not change the wave function ψ, the particle is said to have positive or even parity. If on the other hand the wave function also changes with change in sign, the particle is said to have negative or odd parity. Thus ψ(x, y, z) = ψ (-x,-y,-z) represents even or positive parity and ψ(x, y, z) =− ψ (-x, -y, -z) represents odd or negative parity.

In has been shown that the spatial part of ψ, on reflection of the particle not change sign if the angular momentum quantum number l is even but if l is odd it does change sign. As a general rule, the parity, is given by $(-1)^l$. For the system of particles, the parity will be even, if the sum of the individual numerical value l for all its particles i.e. $\sum l$ is even and odd parity when $\sum l$ is odd. A system containing a even number of even number of odd parity particles and any number of even parity particles will have even parity. A system with an odd number of odd parity particles and any number of even parity particles will have odd parity.

Nuclear states are characterized by a definite parity which may be different to different states of the same nucleus. Parity is conserved in interactions between nucleons and the law of conservation states that the parity of an isolated system cannot change, no matter which transformations or recombination take place within it. Suppose, for example, that a nucleus in an existed state is described by a wave function with even parity. If it emits γ-ray and makes a transition to lower energy state then the system "recoiling nucleus+ γ-ray" must continue to have even parity. Thus the conservation of parity has put some restriction on γ-ray transitions and this has led to formulation of selection rules. The selection rules for all nuclear transitions involve a statement of whether or not the nucleus changes the parity as a result of the transition. Thus the rotation yes denotes that the nuclear parity changes (from even to odd or from odd to even) hence the emitted or absorbed particles or quanta have odd total parity. Thus an emitted α-ray which has l=0 with respect to emitting nucleus will have odd parity and can be emitted on if the nuclear parity changes. Similarly, the selection rule no means that the initial and final nuclei have the same parity (both even or both odd). An emitted α-ray which has l=2 with respect to the emitting nucleus will have even parity and can be emitted only if the nuclear parity does not change. Similar restrictions are placed on nuclear reactions also.

NUCLEAR ELECTRIC DIPOLE MOMENT

The atomic number Z of the nucleus is credited for giving information about the number of protons in the nucleus, the magnitude of Coulomb potential and chemical properties of the concerned element. However, Z does not picture the charge distribution within the nucleus and that is why it cannot be used to investigate those nuclear properties which depend on charge distribution. The electrical dipole is defined as a set of two equal and different charges at a distance r. The dipole moment of the system is D=er. In the case of the nucleus which consists of protons and neutrons the dipole moment is Zer. Where Ze is the total charge of protons and r is the distance between center of gravity of two fluids (protons and neutrons). It is clear that dipole moment will exits when the center of the two fluids does not coincide. To be more precise, the total charge and the Z component of dipole moment is written as,

$$Ze = \int \rho\,(x, y, z) d\tau,$$

$$D_Z = \int Z\rho(x, y, z) d\tau$$

Where ρ (x, y, z) is the charge distribution relative to the center of mass, dτ is the volume element around the point r (x, y, z) and z is measured from the center of mass.

Now we wish to show that atomic nuclei in their ground state do not possess electric dipole moments. If their exist a plane of symmetry passing through the centre of mass of the nucleus, the above result transforms to the quantum mechanical theorem which states that the "electric dipole moment is necessarily zero for any quantum-mechanical system in i^{th} stationary state". The quantum mechanical analogue of charge distribution

$$\rho(r) = \sum_{i=1}^{z} e\, P_i(r)$$

Possible questions

2 marks

What is called binding energy?
What is called parity?
Define isotopes and isobars.
Define nuclear density and nuclear mass.
What is called spin angular momentum?

6 marks

What is called binding energy? Explain M/A plot.
Explain the nuclear mass, size and density.
What are the intrinsic properties of nucleus? Explain it.
Discuss about angular momentum and parity.
Give a note on nuclear properties.
Discuss in detail about nuclear magnetic and electric moments.

KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE – 21

DEPARTMENT OF PHYSICS

CLASS: II B. Sc., PHYSICS BATCH: 2016-2019

NUCLEAR & PARTICLE PHYSICS (16PHU402)

MULTIPLE CHOICE QUESTIONS

Question	Choice 1	Choice 2	Choice 3	Choice 4	Answer
UNIT I					
The atomic mass is almost equal to _____	the mass of the electron	the mass of the nucleus	the mass of the protons	the mass of the neutrons	the mass of the nucleus
The nuclear radius is proportional to	A^2/3	A	A^1/3	A^2	A^1/3
The nucleon density at the centre of any nucleus is	proportional to A	proportional A^2	proportional Z	almost the same	almost the same
The force which holds the nucleons together in a nucleus is	elelctromagnetic force	gravitational force	strong nuclear force	weak interaction	strong nuclear force
The non-central part of the nuclear force is called	elelctromagnetic force	tensor force	magnetic force	static force	tensor force
Nuclear exchange forces arise due to	exchange of mesons	exchange of charge	exchange moments	exxchange of strangeness	exchange of mesons
Nucleus is	positively charged	negatively charged	neutral	charge keeps on changing	positively charged
Proton has the charge	1637 times of an electron	1737 times of an electron	1837 times of an electron	1937 times of an electron	1837 times of an electron
Neutrons has the charge	1639 times of an electron	1739 times of an electron	1839 times of an electron	1939 times of an electron	1839 times of an electron
As per modern theory, the atom has a diameter of about	10^-4mm	10^-5mm	10^-6mm	10^-7mm	10^-7mm
The mass of pi meson is	270 times that of electron	270 times that of proton	140 times that of electron	140 times that of proton	270 times that of electron
The potential energy of interaction between two nucleons obtained from meson theory is known as	electromagnetic potential	electrostatic potential	Yukawa potential	magnetic potential	Yukawa potential
The range of nuclear force is	2.2 Fermi	1.4 Fermi	infinity	2.8 Fermi	2.2 Fermi
Nucler force is of	infinite range	short range	medium range	long range	short range
The difference between the total mass of the individual nucleons and the mass of the nucleus is known as	mass defect	binding energy	packing fraction	mass excess	mass defect
The mass of the nucleus is normally -------- the total mass of the nucleons	greater than	equal to	less than	can be anything	less than
The energy equivalent of mass defect is	packing energy	binding energy	mass excess	packing fraction	binding energy
The difference between atomic weight and mass number is known as	mass defect	binding energy	mass excess	packing fraction	mass excess
The fractional difference between atomic weight and mass number is known as	mass defect	binding energy	mass excess	packing fraction	packing fraction
The mass number is	a whole number	a fraction	a whole number or fraction	half integer	a whole number
The mass of the neutron is	equal to that of proton	equal to that of electron	half of that of proton	1836 times that of proton	equal to that of proton
For a nucleus of orbital number L even, the parity is	even	odd	even or odd	no parity	even
According to proton-neutron theory	electron pre-exists in the nucleus which is emitted as beta particle	electron is created at the time of beta emission	neotron gets converted into a proton, electron and a neutrino	electron is emitted from the outer shell	neotron gets converted into a proton, electron and a neutrino
Pairing up of neucleons inside the nucleus is confirmed by the emission of	alpha particles	beta particles	gamma rays	any particles	alpha particles
Which of the following statements if not true?	There are discrete energy levels in the nucleus	The energy of the nucleus has a continuous range	There are discrete but varying energies for the nucleus	All the above statements are correct	There are discrete energy levels in the nucleus
Electromagnetic force is normally of	short range	long range	medium range	infinite range	infinite range
The hypothesis that nuclear forces possess an exchange character was put forward by	Pauli	Rutherford	Heisenberg	Max Plank	Heisenberg
Instrument used to measure nuclear masses and their other properties is called	Mass spectrograph	nuclear spectrometer	NMR spectrometer	magnetic spectrometer	Mass spectrograph
The existence of mesons were first observed in	particle accelerators	cosmic rays	mass spectrometers	none of the above	cosmic rays
The density of nucleus is approximately	10^17 g/m^3	10^44 kg/m^3	10^20 kg/m^3	10^17 kg/m^3	10^17 kg/m^3
The number of nucleons per unit unit volume is approximately	10^17 /m^3	10^44 /m^3	10^20 /m^3	10^17 /m^3	10^44 /m^3

The binding energy per nucleon is maximum when	f(packing fraction) is maximum	fa has medium value	f is minimum	binding energy does not depend on f	f is minimum
The strong nuclear force, which holds the nucleons together in the nucleus is	attractive everywhere	attractive to some extent and repulsive for very close distances of approach	repulsive everywhere	repulsive in the beginning and attractive at very close distances of approach	attractive to some extent and repulsive for very close distances of approach
The binding energy per nucleon	increases linearly through out with mass number	decreases linearly through out with mass number	increases linearly in the beginning and becomes almost constant	remains constant throught	increases linearly in the beginning and becomes almost constant
The binding energy per nucleuon is	positive for all the nuclei	negative for all the nuclei	positive for nuclei of low mass number and negative for nuclei of higher mass number	negative for nuclei of low mass number and positive for nuclei of higher mass number	positive for all the nuclei
Neutron was discovered by	Chadwik	Rutherford	Bothe	Jobliot	Chadwik
The value of fine structure constant is approximately	1/200	137	1/137	200	1/137
When a particle indident on a target nucleus is completely absorbed, without the emission of another particle, is called	elastic scttering	inelastic scattering	radiative capture	decay	radiative capture
"The wave function must be antisymmetric with respect to the intercange of any two identical spin-1/2 particles." This is the most fundamental statement of	Pauli's exclusion principle	Heisenberg's principle	Einstein's theory	Curie theory	Pauli's exclusion principle
In a nucleus, the wave function changes its sign at a point which is mirror reflection of the original point. This means	parity is negative	parity is positive	parity is zero	parity is infinite	parity is negative
The nucleus consists of	neutrons	protons	neutrons and protons	electrons and neutrons	neutrons and protons
In neutral atom, the electrons are bound to the nucleus by	Magnetic force	Electrostatic force	Friction force	Centripetal force	Electrostatic force
One atomic mass unit (AMU) is equal to	1.66 x 10^-20 g	1.66 x 10^-22 g	1.66 x 10^-24 g	1.66 x 10^-26 g	1.66 x 10^-24 g
In isotope	Number of electrons = Number of protons	They have different chemical properties	They have different atomic number	They have different mass number	They have different mass number
The difference in the mass of the resultant nucleus and the sum of the masses of two parent nuclear particle is known as	mass defect	solid defect	weight defect	nucleus defect	mass defect
At higher energy, bodies have	small mass	large mass	zero mass	smaller weight	large mass
Minimum energy required to pull nucleus apart is called	ionization energy	electron affinity	chemical energy	binding energy	binding energy
If nucleus is formed from separate nucleons, then energy is	gained	released	converted	absorbed	released
The maximum value of the binding energy per nucleon of the atom and the corresponding mass number are	8.5 MeV around A = 20	8.8 MeV around A = 50	8.5 MeV around A = 50	8.8 MeV around A = 20	8.8 MeV around A = 50
The binding energy of 8O16 is 127.63 MeV. The average binding energy per nucleon is	7.977 MeV	15.95 MeV	79.77 MeV	7.977 eV	7.977 eV
BE/A curve shows that iron nucleus is	most stable	unstable	radio active	heavy	most stable
For nuclei having mass numbers between 40 and 120, the average binding energy is	8.8 MeV	8.5 MeV	8.2 MeV	8 MeV	8.5 MeV
Binding energy of helium is	less than that hydrogen	less than that of lithium	more than that of lithium	equal to that of hydrogen	more than that of lithium
A device used for the determination of atomic masses is called	Spectrometer	Bragg spectrometer	Mass spectrometer	Geiger – Muller counter	Mass spectrometer
If the B.E per nucleon of an element having atomic number 83 is 7.6 MeV, then the element is	stable	non-radioactive	radioactive and unstable	most stable one	radioactive and unstable
Mean distance between atoms in the range of	25nm	2.5 nm	0.25 nm	0.025 nm	0.25 nm
Particles that most effects material properties	neutrons	protons	electrons	valence electrons	valence electrons
Atomic packing factor is	Distance between two adjacent atoms	Projected area fraction of atoms on a plane	Volume fraction of atoms in cell	none	Volume fraction of atoms in cell
What force is responsible for the radioactive decay of the nucleus?	Gravitational force	Weak Nuclear force	Strong Nuclear force	Electromagnetic force	Weak Nuclear force
Which of the following is correct for the number of neutrons in the nucleus?	N=A-Z	N=A+Z	N=Z	N=A	N=A-Z

Prepared by: Mrs.S.Sharmila, Assistant Professor, Department of Physics, KAHE, Coimbatore.

UNIT-II

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of various terms, condition of nuclear stability. Two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

LIQUID-DROP MODEL

In the liquid-drop model the forces acting in the nucleus are assumed to the molecular forces in a droplet of some liquid. This model was proposed by Neils Bohr, who observed that there are certain marked similarities between an atomic nucleus and a liquid drop.

1. The nucleus is supposed to be spherical in shape in the stable state just as a liquid drop is spherical due to the symmetrical surface tension forces.
2. The forces of surface tension acts on the surface of the liquid drop, similarly there is a potential barrier at the surface of the nucleus.
3. The density of a liquid drop is independent of its volume similarly the density of the nucleus is independent of its volume.
4. The intermolecular forces in a liquid are short ranges the molecules in a liquid drop interact only with their immediate neighbors, similarly the nucleus also interacts only with their immediate neighbors. This leads to the saturation in the nuclear forces and a constant B.E per nucleons
5. The molecules evaporates from a liquid drop on raising the temperature of the liquid due to the their increased energy of thermal agitation. Similarly when energy is given to a nucleus by bombarding it with nuclear projectiles, a compound nucleus is formed which emits nuclear radiation almost immediately.
6. When a small drop of liquid is allowed to oscillate it breaks up into two smaller nuclei.

Merits

The liquid drop model accounts for many of the silent features of nucleus matters such as the observed binding energy of nuclei and the stability against the α, β disintegration as well as nuclear fusion.Calculation of atomic nucleus and binding energy can be done good with accuracy in liquid drop model however this model fails to explain the other properties in particular magic numbers and spin and magnetic moment of the nuclei.

Semi-empirical mass formula

It helps to obtain an expression for binding energy of the nuclear Weizacker proposed semi-empirical nuclear of mass number A containing Z protons and N neutrons

$$B.E = aA - bA^{2/3} - c\frac{z(z-1)}{A^{1/3}} - \frac{d(n-z)}{A} \pm \frac{\delta}{A^{3/4}}$$

where a, b ,c ,d are constant

The first term is the equation is called as volume energy of the nucleus the larger the total number of nucleon A the more difficult to remove it will be to remove the individual protons and neutrons the binding energy is directly proportional to total number of nucleons A.

The nucleon at the surface of the nucleus are not completely surrounded by other nucleons depends upon the surface area of the nucleus. A nucleus of radius R has an area of $4\pi R^2=4\mu r_0^2 A^{2/3}$. Hence the surface effect reduces the binding energy by $e_x=bA^{2/3}$. The negative energy it is most significant for the lighter nuclei since a greater fraction of nucleons on the surface.

The electrostatic repulsion between each pair of protons in a nucleus also constitutes towards decrease its BE. The coulomb energy E_e of a nucleus the work that must be done to bring together Z protons from infinity into a volume equal to that a nucleus. Hence E_c is proportional to Z (Z-1)/2 and E_c is inversely proportional to the nuclear radius $R=r_0A^{1/3}$. E_c is negative because it arises from a force that opposes nuclear stability.

The final correction term δ allows for the fact that even-even nuclei are more stable than odd nuclei. Z is positive fir even-even pair and negative for odd-odd pair, zero for odd A.

FERMI-GAS MODEL

The degenerate gas model was suggested by Fermi and the nucleus as a gas of neutrons and protons in this model the force between pairs of nucleons and also the surface effect like capillarity are omitted. Protons and neutrons exist in a box in nuclear dimensions and fill the lowest available quantum state to the extinct permitted by the exclusion principle. Since both protons and neutrons have spins of half they are fermions and obey Fermi-Dirac statics. It is assumed that the nucleons are confined to a small volume equal to $\frac{4}{3}\pi R_0 A$. Under these circumstances the nucleus is completely degenerate even in the first few existed states. That is unlike a classical gas confined to such a small volume as that of the nuclear dimension of the order of several Mev. as the excitation energy of the first few exited states as greater this ground states are completely degenerate the de Brogli's wavelength for a nucleus of radius R and particles of waves is a$\lambda = \frac{R}{A^{1/3}}$.

SHELL MODEL

The shell model of the nucleus assumes that the energy structure of the nucleus is similar to that of an electron shell in an atom. According to this model the protons and the neutrons are grouped in shells in the nucleus extra -nuclear electrons in various shells outside the nucleus. The shells are regarded as filled. When they contain a specific number of protons and neutrons are both the no. of nucleons in each shell is limited by Pauli exclusion principle. The shell model Referred to independent particle model because it assumes that each nucleons moves independently of all the other nucleons and acted by an average nuclear field produced by the action of all other nucleus.

Evidence for shell model

Nucleus is stable if it has a certain definite number of a the protons and neutrons, these number are known as magic numbers the magic numbers are 2 8 20 50 82 126.Thus nuclei containing 2 8 20 50 82 126 nucleons of same kind from sort of closed nuclear shell structure. the main points are:

1.The inert Gases with the closest electron shells exhibit a high degree of chemical stability. Similarly nucleus whose nuclei containing a magic number of nucleons of same kind exhibit more than average stability.

2. Isotopes of elements having an isotope abundance greater than 60 % belongs to the magic number category

3.Tin has 10 stable isotopes while calcium has 6 stable isotopes so elements with Z=50, 20 are more than usually stable

4.The three Radioactive series uranium actinium Thorium decay to Pb_{82}^{208} with Z=82 N=126 thus lead is the most stable isotope this again shows that 82 and 126 indicates stability

5.Nuclei having no.of neutrons equal to magic number cannot capture a neutrons because the shells are closed and they cannot contain an extra neutron.

6. It is found that some isotopes are spontaneous neutron emitters when excited about the nuclear binding energy by a preceding beta decay. These are $_{8}O^{17}$ $_{36}Kr^{87}$ and $_{54}Xe^{137}$ for which N= 9,51 and 83 which can be written as 8+1, 50+1 and 82+1 if We interpret this loosely bound neutron as a valance neutron, the neutron numbers 8, 50, 82 to the represent greatest stability than other neutron number.

Nuclear behavior is often determined by the are excess or deficiency of nucleons with respect to closed shells of nucleons corresponding to magic numbers. The nucleons revolve inside the nucleus just as electrons revolve outside in specific permitted orbits.

The neutrons and protons move in two separate systems of orbits around the centre of mass of all nucleons. It moves in Orbit around a common centre of constituents of all nucleus. each nucleon shelll has a specific maximum capacity. They give rise to particular number of characteristics of unusual stability.

The shell model is able to account for several nuclear phenomena in addition to magic numbers.

1. It is observed that even - even nuclei are more stable then odd-odd nuclei. This is obvious from the shell model. According to Pauli principle, a single energy sub level can have a maximum of two nucleons. Therefore in an even-even nucleus only completed sub level are present, which means greater stability on the other hand odd-odd nucleus contain incomplete sub levels which means lesser stability .

2. The shell model Able to predict the total angular momentum of nuclei. In even-even nuclei the protons and neutrons should pair off so as to cancel out one another spin and orbital angular momentum. Thus even-even nuclei have zero nuclear angular momenta. In even odd & odd-even nuclei, the half integral spin off the single extra nucleon should be combined with the integral angular momentum of the rest of nucleons for a half integral total angular momentum. Odd odd nuclei each have an extra neutron and an extra proton whose half integral spin should yield integral total angular momenta. These are experimentally confirmed.

Possible Questions

2 marks

Define semi-empirical formula.
Give a note on liquid drop model.
What is called magic numbers?
Give any four similarities between liquid drop and nucleus.
Give a note on Fermi gas model.

6 marks

Compare liquid drop model and shell model.
Explain Fermi gas model.
What are the significance of terms in liquid drop model?
Give a note on magic numbers.
What are the basic assumptions of shell model?
Briefly discuss about liquid drop model.
Discuss in detail about shell model of the nucleus.

KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE – 21
DEPARTMENT OF PHYSICS
CLASS: II B. Sc., PHYSICS BATCH: 2016-2019

NUCLEAR & PARTICLE PHYSICS (16PHU402)

MULTIPLE CHOICE QUESTIONS

Question	Choice 1	Choice 2	Choice 3	Choice 4	Answer
UNIT II					
The constant nucleon density inside the nucleus supports	liquid drop model of the nucleus	shell model	collective model	unified model	liquid drop model of the nucleus
The nuclear wave functions and particle motions support	Fermi gas model	unified model	collective model	liquid drop model	Fermi gas model
The constant binding energy per nucleon supports	shell model	collective model	liquid drop model	unified model	liquid drop model
In which of the following model of nucleus, the protons and neutrons are considered as gas particles?	shell model	Fermi gas model	unified model	liquid drop model	Fermi gas model
In the Fermi gas model of the nucleus, the gas is characterised by the kinetic energy of the highest filled state called	ionisation energy	binding energy	Fermi energy	packing fraction	Fermi energy
In the Fermi gas model, the neutron gas is contained in a potential energy well of depth	38 MeV	83 MeV	3.8 MeV	38 keV	38 MeV
The depth of the potential well for proton gas in a Fermi model is	equal to the depth of potential well of neutron gas	less than the depth of the potential well of the neutron gas	more than the depth of the potential well of the neutron gas	can be less or more than that of neutron gas	less than the depth of the potential well of the neutron gas
The degenerate gas model was suggested by	Rutherford	Niel Bohr	Fermi	Prout	Fermi
The liquid drop model was suggested by	Bohr and Kalcker	Fermi	Rutherford	Fermi	Bohr and Kalcker
The average kinetic energy of nucleons inside nucleus is of the order of	1 MeV	10 MeV	100 MeV	0.1 MeV	10 MeV
The de Broglie wavelength corresponding to the average energy of nucleons inside nucleus is of the order of	10^-15 m	10^-15 cm	10^-5 m	10^-5 cm	10^-15 m
In the liquid drop model, the restoring force after deformation is supplied by	internal force	gravitational attraction	surface tension	repulsion	surface tension
The surface energy is proportional to ---- where A is the mass number	A	A^1/3	A^2/3	A^2	A^2/3
The binding energy per nucleon for majority of the nuclei is approximately	7 MeV	8 MeV	16 MeV	17 MeV	8 MeV
The average energy of majority of the alpha particles is	7 Mev	8 Mev	16 Mev	17 MeV	7 Mev
The liquid drop model could not explain satisfactorily ----	surface vibration of the nuclei	surface energy of the nuclei	all the above	low lying discrete energy levels of nuclei	low lying discrete energy levels of nuclei
According to alpha particle model, a nucleus can be considered as	a sphere of individual nucleons	poly-atomic molecule of alpha particles	alpha and beta particles	poly-atomic molecule of beta particles	poly-atomic molecule of alpha particles
Alpha particle model could not describe the ground and excited states of	nuclei other than even-even nuclides	even-even nuclides	even-odd nuclides	odd-even nuclides	nuclei other than even-even nuclides
It is seen that nuclei with ----- nucleons are most stable, where n=1,2,3,….	2n-1	4n-2	4n	2n	4n
The nuclei with Z = ----- and ------ are found to be more than usually stable	50, 20	50,40	20, 40	30, 40	50, 20
In ------ model, the nucleus is assumed to be containing a gas of protons and neutrons	liquid drop model	alpha particle model	collective model	Fermi gas model	Fermi gas model
The resemblance of the nucleus with a drop of liquid led to the suggestion of ----- model.	Fermi gas model	collective model	liquid drop model	Shell model	liquid drop model
In Fermi Gas model, the neutron is in a potential well of depth	8 MeV	16 MeV	38 MeV	38 keV	38 MeV
Fermi gas model is not useful for explaining	higher level energy levels	low lying energy states	medium level energy states	all the three	low lying energy states
In the liquid drop model, the nuclear force is	identical for every nucleon	different for every nucleon	higher for inner nucleons and lower for surface nucleuons	lower for inner nucleons and higher for surface nucleons	identical for every nucleon
In the liquid drop model, the nuclei consist of	compressible matter	incompressible matter	liquid matter	solid matter	incompressible matter

Which of the following statements is correct?	Liquid drop model could nto give atomic masses and binding energy accurately	Liquid drop model could not predict anpha and beta emission properties	Liquid drop model could give atomic masses and binding energy accurately, but could not predict alpha and beta emission properties	Liquid drop model not could give atomic masses and binding energy accurately, but also could predict alpha and beta emission properties	Liquid drop model not could give atomic masses and binding energy accurately, but also could predict alpha and beta emission properties
For certain numbers of neutrons and protons, called ------, nuclei exhibit specral characteristics of stability	nuclear quantum numbers	isospin	magic numbers	isomers	magic numbers
The nuclear fission can be best explained using	shell model	liquid drop model	Fermi gas model	collective model	liquid drop model
Bohr-Wheeler theory of nuclear fission is based on	shell model	Fermi gas model	collective model	Liquid drop model	Liquid drop model
As per liquid drop model, if the energy of the incident neutron is less than the critical energy, ----- takes place.	radiative capture	fusion	gamma ray emission	fission	radiative capture
Shell model fails to explain	The large electric quadrupole moments which many nuclei possess	The ground states of odd nuclei in the range 150≤A≤190	The excited states of even-even nuclei	All the above	All the above
Standing waves will occur whenever the radius of the body is an odd multiple of the wavelength divided by	4	3	2	1	4
Which model is the combination of liquid drop and shell model	Collective model	Unified model	optical model	Super-conductivity model	Collective model
The unified model was developed by	Bohr	Mottelson	Bohr and Mottelson	Rainwater	Bohr and Mottelson
Which is the hybrid of liquid drop model and distorted shell model	Collective model	optical model	Unified model	Fermi gas model	Unified model
In which model the shell model potential is assumed non-spherical and the nucleons move independently	Collective model	Liquid drop model	Optical model	unified model	unified model
The mathematical theory of unified model was developed by	Nilsson	Rainwater	Davydov and Chaban	Bohr and Kalcker	Nilsson
The optical model of the nucleus is developed from an analogy of nuclear scattering with that of-	Scattering of light	Reflection	Diffraction	refraction	Scattering of light
The collective motion of the nucleons in a deformed nucleus may be ……………………..in character	rotational	vibrational	rotational or vibrational	electronic	rotational or vibrational
Which nucleon needs large energy for excitation	Paired nucleon	unpaired nucleon	odd neutron	odd proton	Paired nucleon
Odd nuclei consists of one or two	unpaired nucleons	paired nucleons	unpaired neutron and proton	paired neutron and proton	unpaired nucleons
The series of rotational levels, beginning with the ground state of an even-even nucleus has	J=2,4,6	J=1,2,3	J=1,3,5	J=0,1,2,3,4	J=2,4,6
Negative parity have only ………………….of angular momentum	even values	odd values	even or odd values	zero	odd values
The study of nuclear shell model introduces many new ideas familiar in	molecular physics	quantum physics	Atomic physics	Thermal physics	Atomic physics
Which model introduces many new ideas familiar in molecular physics, into nuclear physics	Unified model	Liquid drop model	Collective model	Nilsson model	Collective model
In which model, it is assumed that the nucleons in the nucleus move independently in a common potential	Extreme single particle model	Collective model	unified model	Nilsson model	Extreme single particle model
The closure of a shell for the harmonic oscillator potential occurs corresponding to neutron or proton numbers	8,18,20,34,40 and 50	2,8,20,40,70,112 and 168	18,30,50, 82 and 126	2,8,20,28,50,82,126	2,8,20,40,70,112 and 168
The shell closes at particle numbers 2,8,18,20,34,40,58… for	Square-well of infinite	harmonic oscillator	spin-orbit potential	finite square-well	Square-well of infinite
Tin has ……………	Ten stable isotopes	six stable isotopes	unstable isotopes	six unstable isotopes	Ten stable isotopes
Which model is the forerunner of the collective model of nuclear	Shell model	Liquid drop model	Fermi gas model	unified model	Liquid drop model
Nilsson found that, upon deformation of the nuclear surface, each level splits into	2(2j+1)	(2j+1)/2	j+1	2j+1	(2j+1)/2
The nuclear isomerism has been successfully explained by	Liquid drop model	unified model	single particle model	Fermi gas model	single particle model
Nuclei with N or Z near the end of a shell are found in …………. Distinct groups, known as islands of isomerism	three	two	seven	four	four
The mechanism of nuclear fission was first explained by Bohr and Wheeler on the basis of	liquid drop model of the nucleus	Shell model	Optical model	Unified model	liquid drop model of the nucleus
Angular momenta and parity for N^{16} is	$½^-$	$5/2^+$	2^-	3^-	2^-
The expected shell model spin and parity assignment for the ground state of ^{11}B is	$3/2^+$	$3/2^-$	$5/2^+$	$½^-$	$3/2^-$

Prepared by: Mrs.S.Sharmila, Assistant Professor, Department of Physics, KAHE, Coimbatore.

UNIT-III

Nuclear Reactions: Nuclear fission - Energy released in fission - Bohr and Wheeler's theory of nuclear fission - Chain reaction - Multiplication factor - Natural uranium and chain reaction - Design of nuclear reactor - Breeder reactor - Nuclear fusion - Source of stellar energy - Thermonuclear reactions - Transuranic elements.
Ionization chamber – Geiger-Muller counter – Proportional counter – Wilson's cloud chamber – Bubble chamber – Their principles and working.

Nuclear Fission

The process of breaking up of nucleus of a heavy nucleus into two, more or less equal fragements with the release of a large amount of energy is known as nuclear fission.

When uranium is bombarded with neutrons, a uranium nucleus captures a slow neutron, forming an unstable compound nucleus. The compound nucleus split into two nearly equal parts. Some neutrons are also releases in this process.

The schematic equation for the fission process is

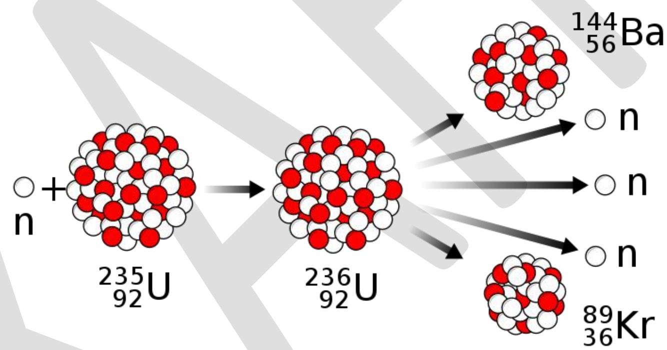
$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{92}U^{236} \longrightarrow X + Y + \text{neutrons} \qquad .... (1)$$

${}_{92}U^{236}$ is a highly unstable isotope, and X and Y are the fission fragment. The fragment net uniquely determined, because there are various combinations of fragments possible and a number of neutrons are given off. Typical fission reaction are

$${}_{92}U^{235} + o^{n\,1} \longrightarrow {}_{92}U^{236} \longrightarrow {}_{56}Ba^{141} + 36^{Kr\,92} + 3o^{n\,1} + Q \qquad .... (2)$$

$${}_{92}U^{235} + o^{n\,1} \longrightarrow {}_{92}U^{236} \longrightarrow {}_{54}Xe^{140} + 38^{Sr\,94} + 2o^{n\,1} + Q \qquad .... (3)$$

Where Q is the energy released in the reaction.



According to Eqn (2), when $92^{U\,235}$ is bombarded by a slow moving neutron the nucleus becomes unstable ($92^{U\,236}$) and splits into $56^{Ba\,141}$ and $36^{Kr\,92}$ releasing 3 neutrons and energy Q.

ENERGY RELEASED IN FISSION

The energy liberated per fission can be calculated as follows:

Let us consider the fission of ${}_{92}U^{235}$

The total mass before and after fission is 97.906 + 135.9072 + 2.0174 = 235.8306 u.

The mass difference is 0.2220 u.

The energy release = 0.2220 * 931.3 = 206.7 MeV

Energy released by 1 kg of uranium.

Number of atoms in 1kg of uranium = $(6.023 * 10^{26})/235$

Energy released in one fission = 200 Mev

Energy produced by 1kg of uranium during fission= E = $\frac{6.023 * 10^{26}}{235} * 200 = 5.128 * 10^{26}$ MeV

E = $(5.128 * 10^{26}) * (1.6 * 10^{-13})\ J$ (1 MeV = $1.6 * 10^{-13}$ J)

$$= \frac{(5.128 * 10^{26}) * (1.6 * 10^{-13})}{3.6 * 10^{6}} \text{k Wh} \quad (1\text{K Wh} = 3.6 * 10^{6}\ J)$$

$$= 2.26 * 10^{7} \text{K Wh}$$

Thus the energy released by fission of 1 kg of U^{235} is $2.26 * 10^{7}$ kWh. Due to this reason nuclear energy is being used for the generation of electricity. The most striking aspect of nuclear fission is the magnitude of the energy involved. Ordinary chemical reaction such as those that participate in the combustion of coal and oil, liberate only a few electron volts per indidual reaction. Most of the energy that is released during fission goes into the K.E of the fission fragment. The emitted neutrons, β and γ-rays and neutrinos carry off perhaps 20% of the total energy.

BOHR AND WHEELER'S THEORY OF NUCLEAR FISSION

Bohr and wheeler successfully explained the phenomenon of nuclear fission on liquid drop model. A liquid drop has a spherical form due to internal molecular force responsible for surface tension. According to their theory, an excited liquid drop may oscillate in a number of ways. On applying a large external force, the sphere may change into an ellipsoid. If the external force is sufficiently large, the ellipsoid may change into a dumb-bell shape and may even break at the narrow end into two portions.

The analogy may be extended to a nucleus which behaves like a liquid drop. When a nucleus absorbs a neutron, it forms a compound nucleus which is highly energetic. The extra energy possessed by it comes mostly from the binding energy of the neutron absorbed by it. The extra energy may set a series of rapid oscillations in the spherical compound nucleus. As a result of these oscillations, the shape of the nucleus may change at time from spherical to ellipsoidal shown as B. If the extra energy is large, oscillations may be so violent that stage C and ultimately stage D may be approached. The nucleus is now dumbbell shaped (Stage D). Each bell of the dumb-bell has now a positive charge and one repels the other. This result in a fission (Stage E).

The nuclei that results from fission are called fission fragments. Usually fission fragments are of unequal size. A heavy nucleus undergoes fission when it acquires enough excitation energy to oscillate violently. Certain nuclei, notably ${}_{92}U^{235}$ are sufficiently excited by the mere absorption of an individual neutron. Other nuclei, notably ${}_{92}U^{235}$ requires more excitation energy for fission than the binding energy released when another neutron is absorbed. ${}_{92}U^{235}$ undergoes fission only by reaction with fast neutron whose kinetic energies exceed about 1MeV.

CHAIN REACTION

A chain reaction is a self-propagating process in which number of neutrons goes on multiplying rapidly almost in geometrical progression during fission till whole of fissile material is grated.

Example: Suppose a single neutron causing fission in a uranium nucleus produces 3 prompt neutrons. The three neutrons in turn may cause fission in three uranium nuclei producing 9 neutrons. These nine neutrons in turn may cause fission in nine uranium nuclei producing 27 neutron and so on. The number of neutrons produced in n such generation is 3^n. The ratio of secondary neutrons produced to the original neutrons is called the multiplication factor (k).

Consider 1 kg of ${}_{92}u^{235}$ which contains $6.023*10^{26}/235$ or $25*10^{23}$ atoms. Suppose a stray neutron causes fission in a uranium nucleus. Each fission will release on the average 2.5 neutrons. The velocity of a neutron among the uranium atoms is such that a fission capture of a thermal neutron by the ${}_{92}U^{235}$ nuclei takes place in about 10^{-8}s. Each of these fission, in turn, will release 2.5 neutron. Let us assume that all these neutrons are available for inducing further fission reaction. Et be the number of stages of fission captures required to disrupt the entire mass of 1 kg of ${}_{92}U^{235}$.Then

$$(2.5)^n = 25*10^{23} \text{ or } n=60$$

The time required for 60 fission to take place = $60*10^{-8}$ =0.6μs.

Since each fission releases about 200 Mev of energy. That a total of 200*25* ....=$5*10^{26}$ MeV of energy is released in 0.6μs. The released of this tremendous amount of energy such a short time interval leads to a violent explosion. This result in power air bests and temperature of the order of 10^7 K or more, beside intense radioactivity. The self-propagating process described here is called a chain reaction.

Two types of chain reaction are possible. In one. The reaction is fist accelarted the neutron are built up to certain level and there after the number of fission producing neutron kept constant. This is controlled chain reaction. Such a controlled chain reaction is used is called reactor. In the other type of chain reaction, the number of neutrons is allowed to multiply and the entire energy id released all at once. This type of reaction takes place in atom bombs.

Multiplication factor (k): The ratio of secondary neutrons produced to the original neutrons is called the multiplication factor. It is defined as

$$k=\frac{Number\ \ of\ neutrons\ \ in\ any\ on\ generation}{Number\ \ of\ neutrons\ \ in\ the\ preceding\ \ generation}$$

The fission chain reaction will be "Critical" or steady when k=1, it will be building "supercritical" whn k > 1 and it will be dying down or "subcritical" when k<1.

Critical Size For Maintenance Of Chain Reaction

Consider a system consisting of uranium (as fissile material) and a moderator. Even each neutron that produces fission ejects 2.5 neutrons on un average, all of them are not available for further fission. The maintenance of the chain reaction depends upon a favourable balance of neutrons among the three processes given below:

(1) The fission of uranium nuclei which produces more neutrons than the number of neutrons used for inducing fission.

(2) Non-fission processes, including the radiative capture of neutrons by the uanium and the parasitic capture by the different substance in the system and by impurities.

(3) Escape or leakage of neutrons through the surface of the system.

If the loss of neutrons due to the last two causes is less than the surplus of neurons produced in the first, a chain reaction takes places. Otherwise it cannot take place.

The escape of neutron take place from the surface of the reacting body and fission occurs

Throughout its volume.

Escape rate varies as r^2 and production rate varies as r^3

$$\frac{Escape\ \ rate}{production\ \ rate}\alpha\frac{1}{r}$$

The larger the size of the body the smaller is the escape rate. This it is clear that by increasing the volume of the system, the loss of neutrons by escape from the system is reduced. The greater the size of the system, the lesser is the probability of the escape of neutrons. In this case, the production of neutrons will be more than the loss due in other causes and a chain reaction can be maintained. Thus there is a critical size for the system. Critical size of a system containing fissile material is defused as the minimum size for which the number of neutrons produced in the fission process just balance those lost by leakage and non-fission capture. The mass of te fissionable material at this size is called the critical mass. If the size is less than critical size, a chain reaction is not possible.

Natural uranium and chain reaction. Nature uranium consists of 99.28% of U^{238} and 0.72% of U^{235}.As most of the mass of natural uranium consists of U^{238} mostly and very few will bombard U^{235}, U^{235} undergoes fission even by neutrons of small energy like thermal neutrons. U^{238} is fissionable only with fast neutrons of energy 1 MeV or more. It has been found that very few neutrons can cause fission of U^{238} but neutrons of all possible energies can cause fission of U^{235}. Thus chain reaction is not possible in natural uranium.

A chain reaction can, however be made to develop in natural uranium, if the fast neutrons from it are quickly reduced to thermal ones before they are lost through non-fission capture in the uranium.

NUCEAR REACTORS

During the fusion of U^{235} a large amount of energy is released. The atom bomb is due to an uncontrolled chain reaction. A very large amount of energy is liberated within an extremely small interval of time. Hence it is not possible to direct this energy for any useful purpose. But in a nuclear reactor, the chain reaction is brought about under controlled conditions. If the chain reaction is put under control, after some time a steady state is established. Under a steady state, the rate of energy production also attains a constant level. Such a device in which energy is released at a given rate is known as a nuclear reactor.

Nuclear reactor consist of five main elements:

(1) The fissionable material called fuel,

(2) Moderator,

(3) Neutron reflector,

(4) Cooling system and

(5) The safety and control systems.

(1) The fissionable substance: The commonly used fissionable materials are the uranium isotopes U^{235}, U^{238} , the thorium isotope Th^{232}, and the plutonium isotopes Pu^{239} , Pu^{240} and $Pu^{2441.}$

(2) Moderator: The function of the moderator is to slow down the highly energetic neutrons produced in the process of fission of U^{235} to thermal energies, Heavy water (D_20), graphite, beryllium, etc., are used as moderators. Ideally, moderators have low atomic weight and low absorption cross-section for neutrons.

(3) Neutron reflector: By the use of reflectors on the surface of reactors, leakage of neutrons can be very much reduced and the neutrons flux- in the interior can be increased. Materials of high scattering cross-section and low absorption cross-section are good reflectors.

(4) Cooling system: The cooling system removes the heat evolved in the reactor core. This heat is evolved from the K.E., of the fission fragments when they are slowed down in the fissionable substance and moderato. The coolant or heat-transfer agent (Water, Steam, He, CO_2, air and curtains molten metals and alloys) is pumped through the reactor core. Then, through a heat exchanger, the coolant transfers heat to the secondary thermal system of the reactor.

(5) Control and safety system: The control system enable the chain reaction to be controlled and prevent it from spontaneously running away. This is accomplished by pushing control rods into the reactor core. These rods are of a material (boron or cadmium) having a large neutron absorption cross- section. These rods absorb the neutrons and hence cut down the reactivity. By pushing in the rods, the operation of the reactor can be made to die down, by pulling them out to build up, the safety systems protect the space surrounding the reactor against intensive neutron flux and gamma rays existing in the reactor core. This is achieved by surrounding the reactor with massive walls of concrete and lead which would absorb neutrons and gamma rays.

Power reactor. The heat generated in a nuclear is used for producing power is a nuclear power plant. A quantity of enriched uranium in the form of pure metal or solution of a soluble salt in water constitutes the centre of the heat energy source. A large quantity of heat is produced in the fission process. The cadmium regulate the temperature to a pre-determined value. If it is desired to bring down the temperature the calcium rods are pushed downs further as to absorb more neutrons. If the temperature has to be raised the cadmium rods are pulled up a little. A fluid is circulated through the shielded reactor and heat exchanger. The bot fluid while flowing through the heat exchanger, converts water into steam. The steam produced conventional turbines to produce electricity.

Breeder Reactor. If a thermal reactor core with U^{235} fuel is surrounded by blanket of fertile material like U^{238}, U^{238} can be converted into fissile fuel. Reactors of this type are called the producing reactor. The reaction are as follows :

$$_{92}U^{238} + {}_{o}n^{1} \longrightarrow {}_{92}U^{239} + \gamma$$

This is followed by $_{92}U^{239} \longrightarrow {}_{93}NP^{239} + \beta$

$_{93}NP^{239}$ is also radioactive It emits a β-particle to form plutonium.

$$_{93}NP^{239} \longrightarrow {}_{94}Pu^{239} + \beta + \gamma$$

This process of producing on type of fissionable material (Pu^{23}) from a non-fissionable material (U^{238}) is called breeding and the reactor a breeder reactor.

$$\frac{232}{90}Th + n \longrightarrow \frac{232}{90}Th^{*} \xrightarrow[22min]{\beta^{-}} \frac{233}{91}Pa \xrightarrow[27d]{\beta^{-}} \frac{233}{92}U(T_{u2} = 1.6{*}10^{5\ yrs})$$

Uses of Nuclear Reactors.

(1) Nuclear power. Nuclear reactor are used in the production of electric energy.

(2) Production of radioisotopes. Nuclear reactors are useful in producing a large number of radio-isotopes. To produce, a suitable compound is drawn into the centre of the reactor core where the flux of neutrons may well be more than 10^{16} /m^2/sec. Sodium-24 is manufactured it this way.

$$_{11}Na^{23} + {}_{0}n^{1} \longrightarrow {}_{11}Na^{24}$$

(3) Scientific research. Reactors produce a number of radioactive materials needed for research purpose. The reactors provide a huge source of neutrons. Using these neutrons, several radioisotopes have been artificially produced and the several nuclear reaction has been studied. We may also study the effect of neutrons on biological tissues. Reactors may also be used to study solution damage.

NUCLEAR FUSION

Nuclear Fusion. In this process two or more light nuclei combine together to form a single heavier nucleus. For example, when four hydrogen nuclei are fused together, a helium nucleus is formed. The mass of the single nucleus formed is always less than the sum of the masses of the individual light nuclei. The difference in mass is converted into energy according to Einstein's equation $E = mc^2$

Example. Consider a single helium nucleus formed by the fusion of two deuterium nuclei mass of ${}_1H^2$=2.014102$_u$; mass of ${}_2He^4$ = 4.002604$_u$

The initial mass of 2 deuterium atoms = 2 * 2.014102 = 4.028204$_u$.

Mass of helium atom = 4.002604$_u$.

Energy released = 0.025600*931.3 MeV = 23.84 MeV.

Thus the energy released in fusion is 23.84 MeV.

SOURCE OF STELLAR ENERGY

The temperature of the stars is very high and they radiate tremendous amount of energy. The sun is one of the innumerable stars. The sun radiates $3.8 * 10^{26}$ joules of energy each second. The origin of such a tremendous amount of energy is neither chemical nor gravitational. The fusion of protons is supposed to release the energy in the sun and other stars. Bethe suggested the following carbon-nitrogen cycle as one of the most important nuclear reaction for release of energy by fusion.

Carbon-Nitrogen Cycle. The cycle is as follows

$${}_6C^{12}+{}_1H^1 \longrightarrow {}_7N^{13*}+\gamma \quad .... (1)$$

$${}_7N^{13*} \longrightarrow {}_6C^{13}+{}_1e^0+v \quad .... (2)$$

$${}_6C^{13}+{}_1H^1 \longrightarrow {}_7N^{14}+\gamma .... (3)$$

$${}_7N^{14}+{}_1H^1 \longrightarrow {}_8O^{15*}+\gamma \quad .... (4)$$

$${}_8O^{15} \longrightarrow {}_7N^{15}+{}_1e^0+v \quad .... (5)$$

$${}_7N^{15}+{}_1H^1 \longrightarrow {}_6C^{12}+{}_2He^4 .... (6)$$

THERMONUCLEAR REACTIONS

The source of stellar energy is fusion. This suggests that a large amount of energy can be obtained by nuclear fusion. But it is not easy to fuse the light nuclei into a single nucleus. The main difficulty in the fusion of nuclei is the electric force of repulsion between the positively changed nuclei. Fusion is possible when the K.E of each of the nuclei is large enough to overcome the repulsion. Fusion reaction can take place only at very high temperatures (of the order of 10^7 to 10^9 K).Only at these very high temperatures, the nuclei are able to overcome their mutual coulomb repulsion and enter the zone of nuclear attractive forces. Hence these reaction are called thermonuclear reactions.

A star is able to control thermonuclear fusion in its core because of its strong self-gravity. Hydrogen bomb: hydrogen bomb is a device which makes us of the principle of nuclear fusion. The very high temperature required for an uncontrolled thermonuclear reaction is obtained by the detonation of an atom bomb. In this weapon, hydrogen is the core. The fission bomb produces a very high temperature, at which thermonuclear reaction start resulting in the fusion of hydrogen nuclei to form helium. Greater energy per unit mass is obtained from a hydrogen bomb than from a nuclear fission bomb.

Controlled thermonuclear reactions: A large amount of energy is released in a fraction of a second in a hydrogen bomb. If the thermonuclear reaction could be controlled to take place more slowly, the energy released can be used for constructive purposes. We know that very high temperature are needed to bring about a nuclear fusion process. The main problem is to produce such a high temperature and to find a container for the gas which can stand this temperature. At this temperature the gas is highly ionised and is called plasma. One of the severe engineering problems is the design of a "container" in which a very hot plasma can be contained under high pressure to initiate a fusion reaction. Since almost any container would melt in the presence of a plasma, attempts are being made to contain and control plasmas trapped in a specially shaped magnetic field. By increasing the field and changing the field and changing the shape of the field, it is hoped that the plasma in this "magnetic bottle" can be raised to the required temperature and pressure for fusion reactions.

Nuclear fusion as an energy source will be a boon to humanity because of the following reaction:

(1) Hydrogen is available everywhere on t planet in various forms.

(2) The lightness of the reactant nuclei makes the energy yield per unit mass of the reacting material much greater than that in nuclear fission process.

(3) A fusion reactor does not leave behind as in fission reactor radioactive waste, the disposal of which poses a tremendous problem.

TRANSURANIC ELEMENTS

Elements with their atomic numbers greater than of uranium (Z=92) are called transuranic elements. All these are man-made and radioactive. Some of these elements are fissionable and hence useful. The following is the list of transuranic elements.

Z=93	94	95	96	97	98
Np	Pu	Am	Cm	Bk	Cf
Neptunium	Plutonium	Americium	Curium	Berkelium	Californium
Z=99	100	101	102	103	104
Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium	kurchatovium

Such transuranic elements may be produced in the laboratory by the bombardment of certain heavy nuclides with neutrons. We give below typical methods of production, the reactions involved and the radioactive dacays of two of these nuclides.

(1) Neptunium (Z=93) : when 92^{U239} is bombarded with slow energy neutrons, neptunium is formed according to the reaction

$$92^{U\,238} + o^{n1} \longrightarrow 92^{U\,239}$$

$$92^{U\,238} \longrightarrow 93Np^{239} + -1e^{0}$$

(2) Plutonium (Z=4): Neptunium ($93Np^{239}$) is itself radioactive. It emits a β-particles and produces plutonium according to the reaction

$$93Np^{239} \longrightarrow 94Pu^{239} + -1e^{0}$$

Plutonium emits α-particles and decays into $92^{U\,235}$ with a half-life of 24000 years.

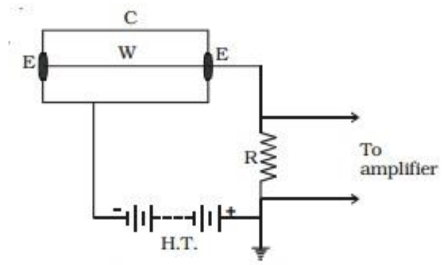
$$94PU^{23} \longrightarrow 92^{U\,235} + 2He^{4}$$

GEIGER - MULLER COUNTER

Geiger - Muller counter is used to measure the intensity of the radioactive radiation. When nuclear radiations pass through gas, ionization is produced. This is the principle of this device.

Construction

The G.M tube consists of $_{E}$ a metal tube with glass envelope (C) acting as the cathode and a fine tungsten wire (W) along the axis of the tube, which acts as anode. The tube is well insulated from the anode wire.



The tube is filled with an inert gas like argon at a low pressure. One end is fitted with a thin mica sheet and this end acts as a window through which radiations enter the tube. A high potential difference of about 1000 V is applied between the electrodes through a high resistance R of about 100 mega ohm.

Operation

When an ionising radiation enters the counter, primary ionisation takes place and a few ions are produced. These ions are accelerated with greater energy due to the high potential difference and they cause further ionisation and these ions are multiplied by further collisions. Thus an avalanche of electrons is produced in a short interval of time. This avalanche of electrons on reaching the anode generates a current pulse, which when passing through R develops a potential difference. This is amplified by electronic circuits and is used to operate an electronic counter. The counts in the counter are directly proportional to the intensity of the ionizing radiation.

The ionization of the gas is independent of the type of the incident radiation. Hence, G.M. counter does not distinguish the type of radiation that enters the chamber.

Wilson's cloud chamber is another type of particle detector. This was the first instrument to record the visual observation of the tracks of the charged particles, when they pass through matter.

Ionization chamber

The essential components of the ionization chamber are its two collecting electrodes: the anode and cathode (the anode is positively charged with respect to the cathode). In most cases, but not all, the outer chamber wall serves as the cathode. The potential difference between the anode and cathode is often in the 100 to 500 volt range. The most appropriate voltage depends on a number of things such as the chamber size (the larger the chamber, the higher the required voltage).

The shape of the electrodes in an ionization chamber are more variable than those of a Geiger-Mueller detector or proportional counter. In general, the outer chamber wall (the cathode) is a cylinder or sphere while the anode is usually rod-shaped. Nevertheless, the anode might take other shapes, e.g., a cylinder or cone. In some cases, the two electrodes might even be flat parallel plates.

Another common type of ionization chamber is the well detector in which the outer chamber wall projects down inside a hollow tubular anode. This greatly increases the system's sensitivity because the sample can be positioned in the center of the chamber.

The presence of radiation causes charged particles to traverse the gas inside the ionization chamber. These charged particles might be alpha or beta particles from a radioactive sample

The charged particles might be electrons to which gamma rays or x-rays have transferred energy via the photoelectric effect, Compton scattering or pair production. Most of these gamma ray or x-ray interactions occur in the wall of the detector, but some also occur in the chamber fill gas. If the chamber wall is thin enough, these electrons might even originate in gamma ray or x-ray interactions outside the chamber.

The movement of the charged particles through the chamber ionizes the atoms or molecules of the gas, i.e., creates ion pairs. For example, this ionization process might involve an electron being stripped away from a nitrogen molecule - the freed electron would be the negative member of the ion pair and the positively charged nitrogen molecule would be the positive member of the ion pair.

The electric field created by the potential difference between the anode and cathode causes the negative member (electron) of each ion pair to move to the anode while the positively charged gas atom or molecule is drawn to the cathode. The movement of the ions to the collecting electrodes results in an electronic pulse. Since these pulses are usually too small to be detected, the most common approach is to measure the ion chamber's current which is produced by many radiation interactions in the detector and is more easily measured than the individual pulses.

Wilson Cloud chamber

Principle: If there is a sudden expansion of saturated vapour in a chamber, supercooling of the vapour occurs. Tiny droplets will be formed by condensation over the dust particles present in the chamber. If therefore, we have completely dust-free and saturated air, and if it is suddenly allowed to expand and threby cool, condensation will not take place. But if ions are available in the chamber during the expansion, they serve as nuclei for condensation. Hence, if an ionising particle passes through the chamber during an expansion, ions are produced along its path and droplets condense as these ions. Hence the "track" of the particle become visible.

Description: the apparatus consists of a large cylindrical chamber A, with walls and ceiling made of glass. It contains dust-free air saturated with water vapor, P is a piston working inside the chamber. When the piston moves down rapidly, adiabatic expansion of the air inside the chamber takes place. The piston is connected to a large evacuated vessel F through a valve V, when the valve is opened, the air under the piston rushes into the evacuated vessel F, thereby causing the piston to drop suddenly. The wooden blocks WW reduce the air space inside the piston. Water at the bottom of the apparatus ensures saturation in the chamber. The expansion ratio can be adjusted by altering the height of the piston. Water at the bottom of the apparatus ensures saturation in the chamber. The expansion ratio can be adjusted by altering the height of the piston.

As soon as the gas in the expansion chamber is subjected to sudden expansion, the ionizing particles are shot into the chamber through a side window. A large number of extremely fine droplets are formed on all the ions produced by the ionizing particles. These droplets from a track of the moving ionizing particles. At this stage the expansion chamber is profusely illuminated by a powerful beam of light L. Two cameras of expansion shooting of the ionising particles into the expansion chamber, illuminating the chamber and clicking the camera must all be carried out in rapid succession in order to get satisfactory results.

The ionising agent can be easily identified from its path in the cloud chamber.α-particles, being comparatively massive, go straight and their paths are thick, straight and sharply defined. B-particles being lighter, are easily deflected by collision and affair paths are thin and crooked. The cloud chamber has led to the discovery of many elementary particles like position meson etc

Advantages (1) cloud chamber can be used to study the variation of specific ionisation along the track of a charge particle and the range of such particles.

(2) The sign of the electric charge and the momentum p of the particle can be determined if the chamber is placed in a strong magnetic field. Let a particle of mass m and charge q move with a velocity v perpendicular to the direction of the magnetic field of flux density B. The particle will be forced by the field to follow a circular path of radius R. The magnetic force Bqv is exactly balanced by the centrifugal mv^2/R

Thus $Bqv = Mv^2/R$ or $mv=p=BRq$

The K.E of the particle can be calculated if the rest mass energy m_oc^2 of the particle is known by the relation

$$k.E. = E_k=\sqrt{[p^2 c^2+ (m_oc^2)^2]}-m_oc^2$$

Limitation: (i) one is not always sure of the sense of track photographed

(ii) The range of the particle may exceed the dimensions of the chamber so that the whole track is not photographed.

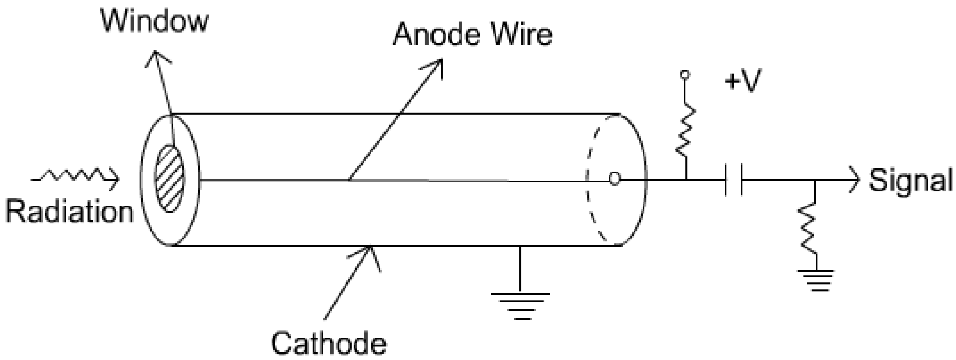
(iii) There remain a certain amount of uncertainty about the nuclei constituting the arms of the forked tracks.

Proportional counter

The proportional counter consists of a cylindrical gas filled tube with a very thin central wire which serves as the anode. The outer cylinder serves as a cathode. In the case of the simple ionization chamber, the pulse height generated by an event is proportional to the intensity of the beam. But because of the comparatively low applied voltages, the current produced is always very small.

If the voltage applied to an ionization chamber is increased past a certain value, the electrons acquire enough energy while moving toward the anode to create further ion pairs along the way. The resulting avalanche of secondary electrons that reaches the anode may represent sent a multiplication factor of as much as 1000 with a correspondingly larger output pulse. In a certain range of applied voltage. The pulse size is proportional to the original number of ion pairs, and device is called a proportional counter.

Since the central wire is very thin and the p.d fairly large the electric field E=dv/dr at a distance r from the centre is very high. If b is the radius of the cylinder and a the radius of the wire, the radial field E at a distance r from the centre is given by $E= V/r \log_e (b/a)$



Where V is the positive voltage of the central wire relative to the outer cylinder. Thus in a proportion counter, the field strength near the wire is very great. Hence electrons travelling toward the wire are rapidly accelerated when near it, and produce additional electrons in that region due to the phenomena of ionization by collision. This process is called the gas multiplication.

The main region used for measurements are: (1) The ionization chamber region AB (2) the proportional counter region CD (3) the Geiger-Muller region EF. After the point F, the tube becomes a simple discharge tube in which the current is produced even after the ionization event has ceased. Like the ionization chamber, the proportional counter gives single pulses of height proportional to the ionizing power of the radiation.

KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE – 21
DEPARTMENT OF PHYSICS
CLASS: II B. Sc., PHYSICS BATCH: 2016-2019

NUCLEAR & PARTICLE PHYSICS (16PHU402)

MULTIPLE CHOICE QUESTIONS

Question	Choice 1	Choice 2	Choice 3	Choice 4	Answer
UNIT III					
As per liquid drop model of nucleus, if the energy of the incident neutron is greater than a threshold energy, ----- takes place	a radiative capture	fusion	gamma ray emission	nuclear fission	nuclear fission
Nuclear species which have the same atomic and mass numbers, but have different radio active properties, are caled	isobars	nuclear isomers	isotopes	isotones	nuclear isomers
The phenomenon of nuclear isomerism was discovered by	Bohr	Rutherford	Pauli	O.Halan	O.Halan
The property of nuclear isomerism is attributed to	different nuclear energy	different nuclear size	different number of nucleons	different nuclear density	different nuclear energy
Nuclei with mass number equal to one of the magic numbers is called	magic nuclei	stable nuclei	Pauli nuclei	unstable nuclei	magic nuclei
The mass numbers of magic nuclei are	divisible by 12	divisible by 8	divisible by 4	there is no such common propety	divisible by 4
Interaction in which parity is not conserved	strong interactin	weak interaction	electromagnetic interaction	gravitational interaction	weak interaction
In ------ model, the nucleus is considered as a poly atomic molecule of alpha particles	collective model	liquid drop model	shell model	alpha particle model	alpha particle model
The alpha particle model 1 fails in nuclei with A =	4n	2n	4n+2	4n-1	4n+2
What happens in a nuclear fusion?	light nucleus are formed	antimatter orgins	nucleuses fuses	neutrinos orgin	
New nucleus after alpha particle decays, is called	parent nucleus	daughter nucleus	decayed nucleus	undecayed nucleus	daughter nucleus
The unit of half life is	pound	kilogram	second	meter	second
Nuclear fission occurs when	a nucleus divides spontaneously, with no apparent reason	electrical forces inside a nucleus overpower nuclear forces	one nucleus bumps into another cuasing a chain reaction	cut nuclei in two with a very small cutting device	one nucleus bumps into another cuasing a chain reaction
When a neutron leaves a nucleus, its mass	stays the same	decreases	increases	triples	decreases
The element with the least mass per nucleon is	uranium	helium	iron	hydrogen	iron
The energy we get in nuclear reaction comes from	water	mass of the fuel	sun	energy we put into the reactor	mass of the fuel
Nuclear fusion releases energy when	very light nuclei fuse together	uranium splits into two fragments	uranium emits a neutron	heavy ions fuse together	very light nuclei fuse together
The primary fuel for a nuclear fusion reactor is	uranium	hydrogen	helium	plutonium	hydrogen
The splitting of a nucleus into smaller nuclei is	fusion	fission	half-life	gamma radiation	fission
The product of nuclear fission includes	neutrons and electrons	several nuclei and neutrons	several nuclei and electrons	several nuclei and protons	several nuclei and neutrons
What is a beneficial aspect of nuclear fission?	The ability to absorb energy	The ability to release tremendous amounts of energy	The ability to produce more energy than nuclear fusion	There are no beneficial aspects of nuclear fission	The ability to release tremendous amounts of energy
Two nuclei with low masses are combined to form one nucleus of larger mass is called what?	nuclear fission	nuclear fusion	nuclear half-life	Half-life	nuclear fusion
Which of the following is true about nuclear fusion?	It is easy to implement	It produces less energy than nuclear fission	It produces more energy than nuclear fission	It has the ability to occur easily in everyday life	It produces more energy than nuclear fission
How do nuclear power-plants work?	fusion	fission	half-life	fusion or fission	fission
In nuclear fusion, as compared to masses of original nuclei, final nucleus is always	equal	more	less	zero	less
Release of energy from sun is due to	nuclear fission	nuclear fusion	burning of gases	chemical reaction	nuclear fusion
Radiations burn mainly due to	alpha radiations	beta radiations	gamma radiations	beta and gamma radiations	beta and gamma radiations
Nuclear fission was discovered in experiment in	1948	1938	1928	1918	1938
Nuclear fission was discovered in experiment by	Fritz Stresemann	Lisa Meitner	Otto Hahn	Fran	Otto Hahn
Fast breeder reactors do not	use Th-232 as fissile fuel	use fast neutrons for fission	use molten sodium as coolant	convert fertile material to fissile material	use Th-232 as fissile fuel
The decrease in the atomic number is not observed in case of	α-emission	β-emission	electron capture	positron emission	β-emission

Which of the following may not need a control rod ?	Candu reactor	Fast breeder reactor	Liquid metal cooled reactor	None	None
Which of the following is not a naturally occurring nuclear fuel ?	Uranium-238	Thorium-233	Plutonium-239	uranium- 235	Plutonium-239
Nuclides having the same atomic number are termed as?	isobars	isotones	isomers	isotopes	isomers
Main source of __________ is monazite sand	Uranium	polonium	halfnium	thorium	thorium
A fertile material is the one, which can be	material on absorption of neutron	fissioned by either slow or fast neutrons	fissioned by fast neutrons	fissioned by slow (thermal) neutrons	material on absorption of neutron
Which is radioactive in nature?	Helium	Deuterium	Tritium	Heavy Hydrogen	Tritium
he most commonly used nuclear fuel in boiling water reactor is	enriched uranium	plutonium	natural uranium	monazite sand	enriched uranium
Enrichment of uranium is done to increase the concentration of __________ in the natural uranium	U-235	U-233	U-238	PU-239	U-235
The first underground nuclear test was conducted by India at	Pokhran	Kalpakkam	Jaisalmer	Narora	Pokhran
The function of a moderator is to	absorb the part of the Kinetic energy of the neutrons	extract the heat	reflect back some of the neutrons	start the reactor	absorb the part of the Kinetic energy of the neutrons
Which of the following is not used as moderator?	water	heavy water	graphite	boron	water
The function of coolant is to	extract heat from reactor	slow down neutrons	control the reaction	reflect the neutrons	extract heat from reactor
Which of the following has highest moderating ratio?	D2O	H2O	Carbon	Helium	D2O
The reactor performs the following function as that of _____ in a steam power plant.	furnace	turbine	electric generator	boiler	furnace
In pressurized water reactor	light water is used as coolant	light water is used as coolant and moderator	heavy water is used as coolant	heavy water is used as coolant and moderator	light water is used as coolant and moderator
In which of the following reactors, heat exchanger is not used?	Pressurized water reactor	Boiling water reactor	CANDU reactor	Gas cooled reactor	Boiling water reactor
In which of the following, an intermediate heat exchanger is used	Pressurized water reactor	Boiling water reactor	Gas cooled reactor	Liquid metal cooled reactor	Liquid metal cooled reactor
Moderator is not required in	Pressurized water reactor	Gas cooled reactor	Boiling water reactor	Breeder reactor	Breeder reactor
In Sodium-Graphite reactor, sodium is used as	Coolant	Moderator	Reflector	transmitor	Coolant
Gas cooled reactors are _____ moderated.	Light water	Heavy water	Graphite	Beryllium	Graphite
Which of the following may be used to measure the rate of nuclear disintegration?	Cyclotron	Cold chamber	Mass spectrograph	Geiger-Muller Counter	Geiger-Muller Counter
The function of moderators in nuclear reactor is to	control the chain reaction.	absorb the secondary neutrons.	slow down the secondary neutrons.	cool the chamber	slow down the secondary neutrons.
Thorium can be converted into U-233 in a __________ reactor.	thermal	swimming pool	fast breeder	liquid metal cooled	fast breeder
Bohr and Wheeler theory is explained based on	Shell model	Unified model	nilsson model	Liquid drop model	Liquid drop model
A condition for nuclear isomerism	The presence of an energy level near the ground state	The presence of an energy level near the ground state differing strongly in angular momentum	The presence of states differing in angular momentum	The existence of mirror nuclei	The presence of an energy level near the ground state differing strongly in angular momentum
Nilsson found that, upon deformation of the nuclear surface, each level splits into	2(2j+1)	(2j+1)/2	j+1	2j+1	(2j+1)/2
Which of the following reactions involves no change in target nucleus	disintegration	radiative capture	direct reactions	elastic scattering	elastic scattering

Prepared by: Mrs.S.Sharmila, Assistant Professor, Department of Physics, KAHE, Coimbatore.

UNIT-IV

Nuclear Reactions: Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

Conservation laws:

1.Conservation of charge:

In nuclear reaction the total charge before and after the reaction is conserved. In other words,the sum of charge on the reactants side is equal to the sum of the charge the product sides .

2. Conservation of mass number:

In nuclear reaction the total mass number or total number of nucleons before reaction and after the reaction remains same.This is because the nucleons neither be created or destroyed.

3. Conservation of mass-energy:

In any nuclear reaction neither K.E. nor rest mass energy conserved separately, but their total energy is always conserved .

4.Conservation of linear momentum:

In nuclear reaction the total linear momentum of the particle taking part in a nuclear reaction must be the same before and after the reaction, If v_a , v_b and V_y are the velocities of the incident particles, the emitted particles and the product of nucleus respectively, then their linear momentum is $m_a v_a$, $m_b v_b$ My V_y must be capable of representation by the sides of the triangle taken in order because their vector sum must be zero .

5 .Conservation of angular momentum:

The angular momentum I→I→ is composed of intrinsic spin angular momentum s→s→ and relative orbital angular momentum I→I→ In any nuclear reaction, the vector sum of the total angular momenta of the atoms must be conserved before and after of the reaction .

6. Conservation of spin and statistics:

In nuclear reaction, the spin and statistical character must remain the same before and after the nuclear reaction. Thus the statistics followed by the product must be the same as that followed by the reactants ; either Fermi-Dirac (for even A) or Bose-Einstein (for odd A)

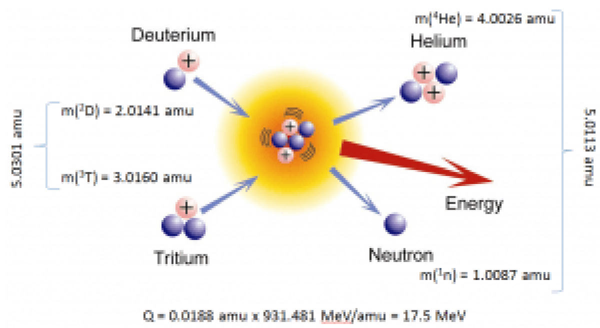
7.Conservation of parity:

The total parity of the system is the product of the intrinsic parities of the target nucleus and the bombarding (nucleus) particle.The net parity before and after the reaction must be equal.

NoViolation of parity has been observed in a nuclear reaction for strong nuclear force. However, parity does not appear to be conserved in weak interactions .

8.Conservation of nucleons:The total number of nucleons before and after a reaction are the same.

Q-VALUE



Q-value of DT fusion reaction

In nuclear and particle physics the **energetics of nuclear reactions** is determined by the **Q-value** of that reaction. The **Q-value** of the reaction is defined as the **difference** between the sum of the **masses** of the **initial reactants** and the sum of the **masses** of the **final products**, in energy units (usually in MeV).

Consider a typical reaction, in which the projectile a and the target A gives place to two products, B and b. This can also be expressed in the notation that we used so far, **a + A → B + b**, or even in a more compact notation, **A(a,b)B**.

$$E=mc^2$$

The **Q-value** of this reaction is given by:

$$\mathbf{Q = [m_a + m_A - (m_b + m_B)]c^2}$$

which is the same as the **excess kinetic energy** of the final products:

$$\mathbf{Q = T_{final} - T_{initial}}$$

$$\mathbf{= T_b + T_B - (T_a + T_A)}$$

For reactions in which there is an increase in the kinetic energy of the products **Q is positive**. The positive Q reactions are said to be **exothermic** (or **exergic**). There is a net release of energy, since the kinetic energy of the final state is greater than the kinetic energy of the initial state.

For reactions in which there is a decrease in the kinetic energy of the products **Q is negative**. The negative Q reactions are said to be **endothermic** (or **endoergic**) and they require a net energy input.

Reaction Cross section

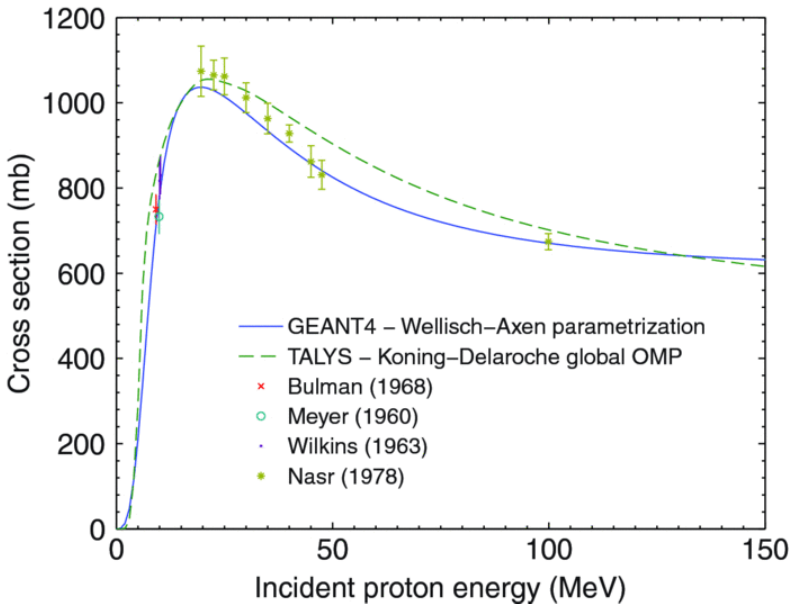
As nuclear reaction is a statistical phenomenon, it is required to define some physical quantity to determine the probability of a nuclear reaction. The quantity which gives the idea of the probability of any physical process (e.g. nuclear reaction) to occur is known as cross-section. Nuclear reaction cross section can be defined in the following manner:

σ = Number of given types of events per unit time per nucleus/number of projectile particles per unit area, unit time. Considering two broad physical process i.e. scattering and absorption, the total cross section σ_{tot} is written as: $\sigma_{tot} = \sigma_{sc} + \sigma_a$

where σ_{sc} =scattering cross-section, σ_a =absorptioncross-section.

The unit of cross-section is 'barn' having the dimension of area (1 barn = 10^{-24} cm^2 = 10^{-28}m^2).

A nuclear reaction is symbolized by a parenthesis containing the projectile and product particle symbolically. At the beginning of the parenthesis, the symbol of target nucleus, and after the parenthesis, the symbol of the product nucleus is written. To represent a particular reaction, say, a deuteron irradiating $^{14}_{7}N$ to produce $^{15}_{7}N$ and a proton, the symbol is $^{14}_{7}N(d,p)^{15}_{7}N$. Depending on the projectile and the product particle, a large number of nuclear reactions are possible.



Continuum theory of nuclear reaction:

At higher bombarding energies the individual levels of the compound nucleus become broader and also more closely spaced. The total width Γ becomes much greater than D, the spacing of the levels. The width and number of levels may be found in it. Sharp resonances are no longer observable when Γ>D. the spacing between levels is completely occupied, so the space is described as continuum. The cross-section for the formation of a compound nucleus is larger for neutrons than for charged particles because coulomb repulsion between the incident charged particles because coulomb repulsion between the incident charged particle and the target nucleus is important in the latter case. In the medium and heavy nuclei, the individual level becomes broader at levels become more closer when the energy of the incident particle is large. The continuum theory nuclear reaction cross-sections treats the individual level not separately but as an average over many resonances.

The nucleus is described by an absorption coefficient σ which gives the probability per unit time that an incident particle becomes amalgamated with the nucleus . This absorption coefficient appears as an imaginary potential in the Schrödinger equation. It is shown that a gradual decrease of σ at the nuclear boundary is essential for achieving agreement with experiments. This model gives automatically unit sticking probability for fast neutrons, a cross section proportional to 1v for slow neutrons, and no one-particle resonances for particles which have to penetrate a potential barrier. Quantitative calculations are made with σ varying as $e^{-(r-R)b}$ outside the nucleus. For neutrons of zero orbital momentum, the formation probability of the compound nucleus is found to be $\zeta=1-e^{-2\pi kb}$ where k is the wave number. It is significant that ζ depends on the diffuseness b of the nuclear boundary rather than on the nuclear radius R. On the other hand, the factor 2π ensures that ζ is close to unity already for energies of about 1 Mev . The total cross section in the region of overlapping levels, and the average level width in the region of separated levels are expressed in terms of the formation probability ζ. The relation with the elastic scattering is discussed . The case of slow neutrons is treated in detail. With an average spacing D of 10 volts between levels of the same J, the average neutron width is about 2×10^{-3E12} for a neutron energy E, in rough agreement with the meager experimental data. With these assumptions, the neutron width will become larger than the radiation width already for E≈103 ev; experiments on the capture of "medium fast" neutrons (≈2×105 ev) can be interpreted roughly on this basis.

The elastic potential scattering of slow neutrons is shown to be equivalent to the scattering from a hard sphere whose radius R′ is defined by the condition that $\sigma(R')=(\hbar^2 mb^2)e^{-2C}$ where C is Euler's constant 0.577. The case of particles which move in a non-nuclear potential V (electrostatic or centrifugal) is treated in for various relations between the energy E of the incident particle and the height V(R′) of the potential barrier. If E−V(R′) is more than about 1 Mev, the formation probability is close to one, as for a fast neutron . If E is about equal to V(R′), ζ is still of the order of unity . For E<V(R′), ζ contains the well-known penetrability of the potential barrier, $e^{-2G,}$ aside from other factors which increase slowly with |E−V(R′)| . The magnitude of σ inside the nucleus is derived for the case of extremely high energies from the Born approximation and the variation of σ with energy is shown to be slight in this case. Although quantitative conclusions on the case of moderate energies cannot be drawn, it seems likely that σ is at least 20-40 Mev in that case. Finally, it is shown that no appreciable change of results is caused by an attractive or repulsive nuclear potential added to the nuclear absorption potential . In the main part of the paper, it has been assumed that the average interaction between nucleus and particle is zero.

Direct reactions:(stripping and pickup reaction):

Nuclear reactions, that occur in a **time comparable to the time of transit** of an incident particle across the nucleus ($\sim 10^{-22}$s), are called **direct nuclear reactions.** Interaction time is critical for defining the reaction mechanism. The very short interaction time allows for an **interaction of a single nucleon** only (in extreme cases). In fact, there is always some non-direct (a multiple internuclear interaction) component in all reactions, but the direct reactions have this component limited. To limit the time available for multiple internuclear interactions, the reaction have to occur **at high energy.**

Direct reactions have another property which is very important. **Products** of a direct reaction **are not distributed isotropically in angle**, but they are forward focused. This reflects the fact that the projectiles makes only one, or very few, collisions with nucleons in the target nucleus and its forward momentum is not transferred to an entire compound state.

The cross-sections for direct reactions vary smoothly and slowly with energy in contrast to the compound nucleus reactions and these cross-sections are comparable to the geometrical cross-sections of target nuclei. Types of direct reactions:

- **Elastic scattering** in which a passing particle and a targes stay in their ground states.
- **Inelastic scattering** in which a passing particle changes its energy state. For example the (p, p’) reaction.
- **Transfer reactions** in which one or more nucleons are transferred to the othes nucleus. These reactions are further classified to as:
    - **Stripping reaction** in which one or more nucleons are transferred to a target nucleus from passing particle. For example the neutron stripping in the (d, p) reaction.
    - **Pick-up reaction** in which one or more nucleons are transferred from a target nucleus to a passing particle. For example the neutron pick-up in the (p, d) reaction
- **Break-up reaction** in which a breakup of a projectile into two or more fragments occurs.
- **Knock-out reaction** in which a single nucleon or a light cluster is removed from the projectile by a collision with the target.

$$ {}^{1}_{0}n + {}^{10}_{5}B \xrightarrow{(E_k > 1.2MeV)} {}^{3}_{1}H + {}^{4}_{2}He + {}^{4}_{2}He $$

Example: This threshold reaction of fast neutron with an isotope ^{10}B is one of the ways, how radioactive tritium in primary circuit of all PWRs is generated.

Possible Questions

2 marks

What is called compound nucleus?
Define threshold energy.
What is called beam particle?

6 marks

Explain conservation laws.
Discuss in detail Rutherford scattering.
Discuss in detail Q value.
Explain about resonance reaction.
What is called reaction rate? Explain it.

KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE – 21

DEPARTMENT OF PHYSICS

CLASS: II B. Sc., PHYSICS BATCH: 2016-2019

NUCLEAR & PARTICLE PHYSICS (16PHU402)

MULTIPLE CHOICE QUESTIONS

Question	**Choice 1**	**Choice 2**	**Choice 3**	**Choice 4**	**Answer**
UNIT IV					
When a particle is incident on a nucleus, it can cause	either scattering or reaction	scattering only	reaction only	both scattering and	either scattering or reaction
When a particle is incident on a nucleus, scattering can be of ----- types	2 types	only 1 types	3 types	4 types	2 types
If the incident particle causes scattering, the structure of the target nucleus -----	changes	does not change	splits	absorbs the incident particle	does not change
The scattering process in which the kinetic energy is conserved is called	inelastic scattering	photo disintegration	elastic scattering	degradation	elastic scattering
In inelastic scattering -----	the kinetic energy is conserved	kinetic energy is not conserved	structure of the nucleus changes	structure of the nucleus not changes	kinetic energy is not conserved
The interaction process in which the internal structure of the nucleus is changed is called	elastic scattering	inelastic scattering	nuclear reaction	nuclear disintegration	nuclear reaction
A particle striking on the target nucleus, is absorbed by it and a new particle is ejected. This is an example of	photo disintegration	radiative capture	elastic scattering	disintegration	disintegration
A gamma ray incident on a nucleus is absorbed and a particle is ejected. This is an example of	photo disintegration	radiative capture	elastic scattering	disintegration	photo disintegration
A particle bombarded on a nucleus is absorbed by the nucleus and a new nucleus is formed, with the emission of gamma ray. This process is	photo disintegration	radiative capture	elastic scattering	disintegration	radiative capture
Emission of alpha and beta rays is an example of	photo disintegration	radiative capture	spontaneous decay	spallation reaction	spontaneous decay
The following reaction is an example of -----. 92U235 + 0n1 ==> 40Zr96 + 52Te136 + 2 0n1	radiative capture	spontaneous decay	disintegration	spallation reaction	spallation reaction
The quantum number used to describe the quantum states of nucleons is	magnetic quantum number	parity	nuclear quantum number	isospin	isospin
The Q value of a nuclear reaction is	the difference between the kinetic energy of the initial particles and that of the products	the sum of the kinetic energies of the reactants and products	the kinetic energy of the products	the kinetic energy of the product nucleus alone	the difference between the kinetic energy of the initial particles and that of the products
A nuclear reaction in which the Q value is negative is called	endoergic reaction	exoergic reaction	nucler reaction	spallation reaction	endoergic reaction
A nuclear reaction in which the Q value is positive is called	endoergic reaction	exoergic reaction	nucler reaction	spallation reaction	exoergic reaction
The general equation a + X ==> Y + b, is an example of -----	elastic scttering	inelastic scattering	nuclear reaction	spallation reaction	nuclear reaction
The probability that an event may occur when a single nucleus is exposed to a beam of particles of total flux of one particle per unit area, is called	probability of reaction	nuclear reaction cross section	scattering cross section	proton cross section	nucler reaction cross section
Total interaction cross section is	the sum of scattering cross section and reaction cross sectoin	the nuclear reaction cross section itself	scattering cross section itself	any of the above	the sum of scattering cross section and reaction cross sectoin
At a higher bombarding energies, the energy levels are very close to each other and they are called	discrete energy levels	continuum	space	charge	continuum
The cross section for formation of a compound nucleus is ---- for neutrons than for charged particles	less than	same as	larger than	can be anything	larger than
The theory of nuclear reactions is formed using the	liquid drop model	Fermi gas model	liquid drop model and shell model	Shell model	liquid drop model and shell model
The first state of nuclear reaction is called	independent stage	compound nucleus	final stage	intial stage	independent stage
The second stage of the nuclear reaction is called	independent stage	compound nucleus	final stage	intial stage	compound nucleus
According to Weisskopf, during the first stage of nuclear reaction, called independent stage, the interaction between the incident wave and nuclear potential may lead to partial reflection of the incident wve, called	elastic scattering	shape elastic scattering	inelastic scattering	photo disintegration	shape elastic scattering
A reaction in which a compound nucleus is not formed is called	independent stage	inelastic scattering	elastic scattering	direct reaction	direct reaction

A type of direct reaction in which the incoming compound particle splits into two fragments, one of which is absorbed by the target nucleus and the other continues, is called	stripping reaction	pickup reaction	inelastic stattering	elastic scattering	stripping reaction
Stripping reaction was first observed by	Bohr	Rutherford	Oppenheimer and Phillips	Bruno Rossi	Oppenheimer and Phillips
The direct reaction in which the incident particle removes one or two nucleons from the target nucleus is known as	Stripping reaction	pickup reaction	inelastic stattering	elastic scattering	pickup reaction
The inverse reaction of stripping reaction is known as	Stripping reaction	pickup reaction	inelastic stattering	elastic scattering	pickup reaction
In light nuclei, the energy levels of the compound nuclei are	closely spaced	continuous	well separated	discrete	well separated
In heavier nuclei, the levels are	closely sapced	continuous	well separated	discrete	closely sapced
In theoretical treatment of nuclear reactions ----- is commonly used	Fermi statistics	Bose-Einstein statistics	Any of the above	Maxwell-Boltzmann	Fermi statistics
In the theoretical treatment of nuclear reactions, the compound nucleus is pictured as	a gas	a hot liquid or solid from which particles evaporate	solid	liquid	a hot liquid or solid from which particles evaporate
From the hot liquid or solid of heavy nuclei, ----- evaporate most easily	neutrons	protons	alpha particles	beta particles	neutrons
The quantum theory of low energy stripping reactions was first developed by	Born	Bohr	Oppenheimer	Butler	Butler
The reactions: 13A27 + 1H1 ==> 13Al26 +1H2 is an example of	stripping reaction	pickup reaction	direct reaction	indirect reaction	pickup reaction
When a nucleus is excited, the excitation energy is considered as increase in temperature, and this is known as ----	nuclear temperature	excitation temperature	temperature coefficient	neutron temperature	nuclear temperature
Rutherford's alpha particle scattering experiment established that	protons are not evenly distributed throughout an atom	electrons have a negative charge	electrons have a positive charge	atoms are made of protons, neutrons, and electrons	protons are not evenly distributed throughout an atom
When a target nucleus is bombarded with a particle, the occurrence of resonance is characterised by	sharp decrease in the cross section	sharp increase in the cross section	increase in the number of output partices	decrease in the number of output partices	sharp increase in the cross section
Compound nucleus is formed in	elastic scttering	inelastic scattering	optical model	direct reaction	optical model
The most penetratin type of radiation is the	alpha particles	beta particles	gamma rays	uranium- 235	gamma rays
A helium nucleus with two protons and two neutrons is called a(n)	alpha particles	beta particles	gamma particle	quark	alpha particles
Negatively charged particles emiitted from a nucleus at a high speed are	alpha particles	beta particles	gamma rays	quark	beta particles
The process by which nuclei having low masses are united to form nuclei with large masses is	chain reaction	gamma reaction	nuclear fission	nuclear fusion	nuclear fusion
Which of the following scientists developed the "plum-pudding" model of the atom?	John Dalton	Robert Millikan	J. J. Thomson	Henry Moseley	J. J. Thomson
The isotope of uranium capable of sustaining chain reaction is	U-235	U-238	U-239	U-239	U-235
Direct reactions include	pickup reactions	stripping reaction	stripping and pickup reactions	spontaneous decay	stripping and pickup reactions
A device in which nuclear fission can be carried out through a sustained and a controlled chain reaction is called	Nuclear power house	Nuclear reactor	Nuclear transmission	none	Nuclear reactor
Nuclear fuel, moderator control rods, coolant and protective shield are the parts of	Nuclear reactor	Nuclear power house	Nuclear energy	none	Nuclear reactor
The following reaction: $^2H_1+^3H_1 \rightarrow ^4He_2+^1n_0$ is called	Fusion	Fission	Alpha decay	Beta decay	Fusion
What is fission?	The joining together of atoms	The process of creating heat	The splitting of atoms into smaller pieces.	The scientific creation of bubbles rising to the surface	The splitting of atoms into smaller pieces.
The initial fragments formed by fission have	More protons than neutrons	More neutrons than protons	About the same number of each	Number of proton and neutron does not matter	More neutrons than protons
A generic fission event is $^{235}U + n \rightarrow X+Y+2n$. Which of the following pairs cannot represent X and Y?	$^{141}Xe + ^{93}Sr$	$^{139}Cs + ^{95}Rb$	$^{156}Nd + ^{79}Ge$	none	$^{156}Nd + ^{79}Ge$
The following reaction: He_2^4+O_8^16→H_1^1+F_9^18 is called	An elastic reaction	An inelastic scattering reaction	A pick up reaction	A stripping reaction	A stripping reaction
Which of the following argument is not concerned with the statement " electrons do not exist in the nucleus"?	Statistics	Binding energy	Electron magnetic moment	β-decay	Electron magnetic moment
A thermal neutron having speed ν impinges on a ^{235}U nucleus. The reaction cross-section is proportional to	ν^{-1}	ν	$\nu^{1/2}$	ν-$^{1/2}$	ν^{-1}

The disintegration series of the heavy elements will give ^{209}Bi as a stable nucleus	Actinium series	Neptunium series	Thorium series	Uranium series	Neptunium series
In a nuclear reaction, the mass of the reaction products is	Always equal to the sum of the masses of the colliding nuclei	Always less than the sum of the masses of the colliding nuclei	Always greater than the sum of the masses of the colliding nuclei	different from the sum of colliding nuclear masses of the colliding nuclei	Always less than the sum of the masses of the colliding nuclei
On the basis of Q values, determine if the ^{98}Tc nucleus can decay by β^- decay	1.796MeV	0.662MeV	1.684MeV	1.684eV	1.796MeV
On the basis of Q values, determine if the ^{98}Tc nucleus can decay by β^+ decay	1.796MeV	0.662MeV	1.684MeV	1.684mV	0.662MeV
On the basis of Q values, determine if the ^{98}Tc nucleus can decay by electron capture	1.796MeV	0.662MeV	1.684MeV	1.684meV	1.684MeV

Prepared by: Mrs.S.Sharmila, Assistant Professor, Department of Physics, KAHE, Coimbatore.

PARTICLE INTRACTION, BASIC FEATURE

In order to study the decay modes of the elementary particles and their other properties, it is essential to have a knowledge of the various fundamental interaction to which they are subjected.

All the phenomena in high energy physics experiments can be explained in terms of the behavior of a few classes of elementary particles and those particles are governed by only four types of fundamental interactions i.e. there are only four different types of physical forces that are known although we speak of many more such as chemical, electrical, muscular, molecular etc. but they all can be classified as examples of these four fundamental interactions.

In order to explore the nature of physical force, we proceed on the following lines:-

1. what kind of objects (particles) participate in the interaction? or what is the charge that acts as a source?
2. how does the interaction depend upon the distance between the 'charges'?
3. what is the direction of the forces?
4. does the interaction depend upon the relative velocity and orientation of the participants?
5. what is the strength of the force relative to the other three?
6. how is the interaction propagated though space? is there any mess-senger? does the effect take time or propagated instantaneously?

Introduction to Elementary Particles

The branch of physics that deals with the property,interaction and structure of elementary particles is known as particle physics. Elementary particles are the fundamental constituent of all the matter in this universe. These microscopic scale particles plays an important role in this universe. So, elementary particles are the building blocks of the universe.

Elementary Particles:

Simply elementary particles are the indivisible particles which are not made up of other particles. There are more than 100 elementary particles discovered so far. Till the time of John Dalton, atoms were considered to be the fundamental particles. With the growth and development of scientific research, James Chadwick discovered neutron, JJ Thompson discovered the electron and later Rutherford discoverd the atomic nucleus and proved that atom is divisible to further sub atomic particles. The discovery of quantum nature of particle by Max Planck revolutionize the understanding of elementary particles in microscopic scale. The research in elementary particles grew up higher with the advancement of science and technology. So, we have more than 200 short lived elementary particles today. Still researchers are devoting their whole career for the discovery of more subatomic particles. Some of the important particles are as follows:

Electron: It is the first fundamental particle discovered by JJ Thompson. It has charge equals to -1.6 × 10^16C and mass of 9.1 × 10^-31Kg.

Proton: It was discovered by Rutherford. It hs charge 1.6×10^{-19} column and mass of 1.6×10^{-27}Kg. Itis 1836 times heavier than electron.

Neutron: It was discovered by Chadwick. It has mass of 1.67×10^{-27}Kg and has no charge.

Positron: It was discovered by Anderson. It's mass and charge is equal to that of proton but it is positively charged. So, it is also called as anti electron.

Antiproton: The mass and charge of antiproton is same as that of proton but it is negatively charged. So, it is also called anti-proton.

Antineutron: It has mass equal to that of neutron. When neutron and antineutron spins in same direction, their magnetic moment will be in opposite direction.

Neutrino and Anti neutrino: Neutrino was discoverd by Pauli. They have rest mass and charge equal to zero but carry momentum and energy. Both of them are stable particles. The only difference between them is their spins is in opposite directions.

Photons: Photons are the packet of electromagnetic energy that travels with the speed of light. Rest mass of photon is zero.

Classification of Elementary Particles: Elementary particles are categorized on the basis of their nature and properties. They are classified on the basis of mass, charge, average lifetime, spin, interaction etc.

On the basis of mass, particles are divided into four types:

- Massless particles
- Light particles
- Intermediate particles
- Heavy particles

On the basis of charge, particles are divided into three types:

- Positive particles
- Negative particles
- Neutral particles

On the basis of spin, particles are divided into two types:

- Boson
- Fermions

On the basis of Interaction, particles are divided into four types

GRAVITATION INTERACTION

The gravitational interaction is always is attractive and does not depend upon the color size or any parameter expect inertia. here 'charges' is the 'mass'.

The force is $\frac{1}{r^2}$ type and acts along the line joining the mass and does not depend upon the velocity and orientation of the mass or their spins. its magnitude is relatively small and is conjectured to be propagated by means of a particle called 'graviton' which has eluded observation so for. The force is characterized by a dimensionless coupling constant

$$\frac{GM_N}{\hbar c} = \frac{(6.67 * 10^{-11}) * (1.67 * 10^{-27})^2}{(1.67 * 10 - 34) * (3 * 10^8)} \cong 5 * 10^{-39}$$

where M_N =nucleon mass, G=the gravitational constant, its characterized time is 10^{16} seconds.

ELECTROMAGNETIC INTERACTION

The electromagnetic interaction charge dependent or attractive as well as repulsive. The force is comparatively long range character in us much as it is $\frac{1}{r^2}$ type. Electromagnetic interaction depends upon the velocity and magnitude of the charge and is not directed towards the charge but perpendicular to the direction of motion. The quantum of the electromagnetic field is

$$\frac{e^2}{\varepsilon_0 \hbar c} = \frac{(1.6 * 10^{-19})^2}{(8.85424 * 10^{-12}) * (1.06 * 10^{-34}) * (3 * 10^8)} \cong \frac{1}{137}$$

constant and has a characteristic time of 10^{-20} seconds. Its magnitude is much greater than that of the gravitation interaction.

STRONG INTERACTION

In order to explain the existence of stable nuclei, of force of a nuclear origin, strong enough to overcome the large repulsive forces between the densely packed protons in the nucleus is needed the force cannot be of gravitation origin as it is too weak to supply the necessary binding energy. The strong nuclear force is charge-independent i.e. the p-p, n-n, and n-p, forces are the same. The force cannot be easily described in terms of strength-distance relationship. It certainly not $\frac{1}{r^2}$ type but is a very short range force it does not depend up to on the relative orientation of the nucleons the quantum of the field is the $\pi - meson$ are kaon. It is characterized by a coupling constant $\frac{g^2}{\hbar c} \cong 1$ and has a characteristic time of 10^{23}seconds.

WEAK INTERACTIONS

Most of the elementary particles have short lives. Hyperons decay down into nucleons and nucleons, in terms of the order 10^{-10}seconds the pions decays into muons in about 10^{-8} seconds and muons collapse into electron into 10^{-8}seconds these times are small and humans scale but they are very large on nuclear time scale, suitable unit of which is the time taken by a photon to cross the diameter, which comes out to be a order of 10^{-23}seconds.

All the strong interactions takes place in times of the order of 10^{-23}. In the case of $\beta - decay$ of radioactive nuclei it is found that the process is very slow and does not take effect until a time10^{13} time greater than that involved in strong interaction. The strong nuclear and electromagnetic cannot account of such a long stability. So either particles are not subject who these forces or else some new prohibition for bides the decay. Since eventually the decay takes place there must be a fourth type of interaction. The existence of such an interaction is proposed by fermi in1930's to explain $\beta - decay$. The force is comparatively, very weak and it is dimensionless coupling constant $g_f^2/(hc)^2 \approx 5 * 10^{-14}$.

where g_f=1.41*10^{-23} joule-m^3 characteristics times is of 10^{-10} seconds. The essential characteristics of the four fundamental interactions are tabulated below

interaction	Relative magnitude	Carrier particle	Characteristic time	range
Gravitational	10^{-39}	graviton	10^{16}seconds	Infinity
Electromagnetic	10^{-2}	Photon	10^{-21} seconds	Infinity
Strong interaction	1	Pion,kaon	10^{-23} seconds	10^{-15} m
Weak interaction	10^{-14}	Intermediate bosons	10^{-10} seconds	Almost zero

CLASSIFICATION OF ELEMENTARY PARTICLE

After the discovery of the fundamental particles, a great deal of a effort had gone into exploring the properties like masses, spins, parity, life times and decay modes of these particles.

The elementary particles can be grouped into two broad categories differentiated from each other by a property called spin which is intimately connected to the kind of statics the particles are governed by. Almost all the elementary particles spin about their axes and if they are charged, spin makes them tiny magnets. In units of h, the electron, proton and neutron all have 1/2 spin while a proton has a spin 1. An important property of elementary particles related to spin, it's a kind of statics the particles follow. It has been found that half odd integral spin particles (in units of 'h') are governed by Pauli's exclusion principle and obey Fermi-Dirac statistics and so are called as fermions. Proton, electron and neutron, all fall in this category of fermions the integral spin particles such as photons and pions, obey Bose Einstein statistics and such as called bosons. One of the important differences between these classes, viz. Fermions and bosons, is that although there is no conservation law governing the total number of bosons in the universe but the total number of fermions in the universe is strictly conserved in all transformations.

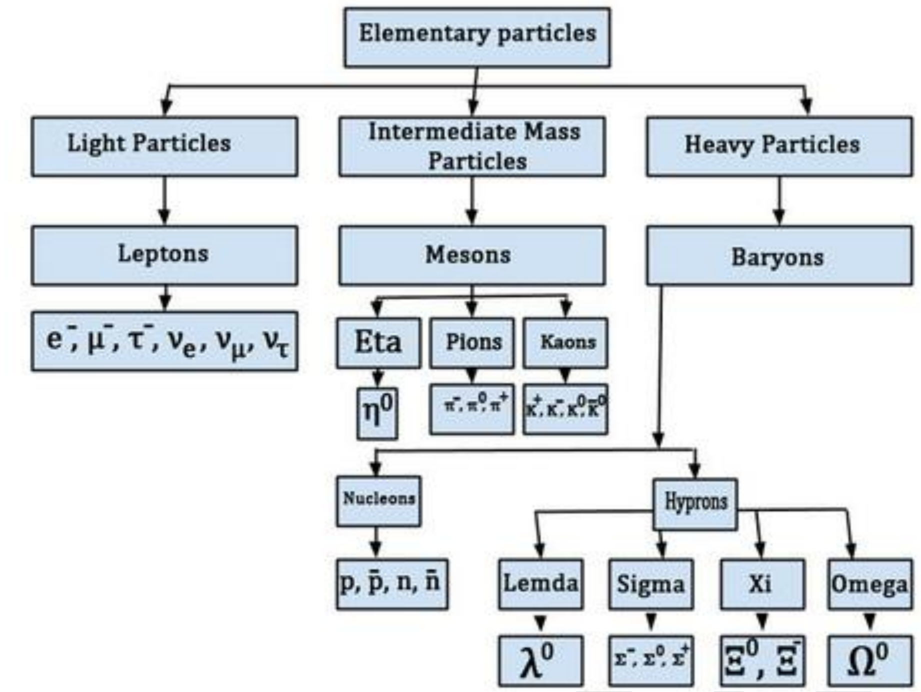
Next, these two general groups of elementary particles, viz. The fermions and the bosons can be further classified in accordance with the rest masses of the particles.

The fermions and the bosons can be further classified in accordance with the rest masses of the particles.

Leptons(weakly interacting fermions): This category consists of fermions of spin 1/2 which have a mass lesser than that of the nucleons. these particles are subject to electromagnet and weak (fermi) interaction only. members of these groups are:-

Muons(μ^+, μ^-), electron (e^-), positron(e^+), neutrino muon(υ_μ), antineutrino muon ($\overline{\upsilon_\mu}$), neutrino electron(υ_e) and antineutrino electron $\overline{(\upsilon_e})$.

Lepton carry on additively conserve internal quantum number called the lepton number L, which has a L=+1 for leptons (μ^-, e^-, υ_e, υ_μ) and L=-1for anti-leptons (e^+, μ^-, $\overline{\upsilon_e}$, $\bar{(}\upsilon_\mu$)



CONSERVATIVE LAWS AND THIER VALIDITY

The photons must be scattered or reflected to our eyes from the object. When an interactions take place, the participants of the interactions, change their motion and sometimes their motion and sometimes their very nature as in case of nuclear reactions. However here we do not want to concentrate on the study of such changes.

In an interaction although the motions etc of the participants change but a characteristic of still more importance than these is that there are certain quantities which do not change during the interaction but rather always conserved. It is these quantities the scientists have been search of, because they enable the interaction to be analyzed mathematically and many a times lead to the discovery of many a new fundamental particles. The discovery of neutrino in β-decay process is an example. In fact assuming the validity of these conservative laws, many of the fundamental particles are first predicted theoretically and later discovered experimentally. Some of the conservation laws familiar from classical mechanics are:

(i) conservation of mass-energy

(ii) conservation of linear momentum

(iii) conservation of angular momentum

(iv) conservation of electric charge .

In addition to above conservation laws which are essential features of all interactions, there are certain other conservation laws which have only a limited jurisdiction i.e. they are conserved in some interactions and not in others and also for some kind of particles and not for other.

SYMMETRIES AND CONSERVATIVE LAWS:

The various quantum numbers such as angular momentum quantum number, isospin, strangeness, hypercharge etc. represent conserved quantities in appropriate physical interactions. can be derived from invariance principles and are directly associated with symmetries inherent in the formulation of the physical process. From group theory considerations, classical conservation properties are derived from continuous symmetry groups and yield additive quantum numbers, whereas quantum mechanical conservation properties result from discrete symmetry group giving rise to multiplicative quantum numbers. Thus:

Invariance with respect to time translations points at **energy** conservation
Invariance with respect to time **spatial translations** points at **momentum** conservation
Invariance with respect to time **spatial rotation** points at **angular momentum** conservation
Invariance with respect to time **spatial inversion** points at **angular momentum** conservation.

Thus we find that the conservation of energy momentum and angular momentum are related to the invariance properties of space time continuum. Conservation of charge is related to the also called gauge invariance of the electromagnetic field. For certain other conservative properties although, we have no theoretical justification but the experimental data argue very strongly in favor of their validity. For example the conservation of baryons and leptons.

The quantities conserved and the quantum numbers behave in two radically different ways when one considered a system composed of two or more sub-systems. For instance angular momentum and linear momentum are additive i.e. equal to the sum of the component moment and therefore the corresponding quantum numbers are called additive quantum numbers. But this is not the case with parity of a composite system. The parity of the composite number is equal to the product of the parities of the component parts and hence corresponding quantum number is called multiplicative quantum number.

Lepton

Three generations of matter.

A **lepton** is an elementary, half-integer spin (spin 1⁄2) particle that **does not undergo strong interactions**. Particles that do participate in strong interactions are called **hadrons**.

There are **six leptons** in the present structure, the **electron, muon,** and**tau particles** and **their associated neutrinos**. Leptons are said to be elementary particles; that is, they do not appear to be made up of smaller units of matter. They behave as point-like particles. All leptons are fermions, i.e. leptons are spin-1⁄2 particles and thus that they are subject to the **Pauli exclusion principle**. This fact has key implications for the building up of the periodic table of elements.

Any of the six elementary particles that (with their antiparticles) are not quarks are leptons. **Two main classes** of leptons exist:

- **Charged leptons.** Charged leptons can combine with other particles to form various composite particles such as **atoms** and **positronium**.
    - **Electron**. The electron is a negatively charged particle with a mass that is approximately 1/1836 that of the proton. Electrons are located in an electron cloud, which is the area surrounding the nucleus of the atom. The electron is only one member of a class of elementary particles, which forms an atom.
    - **Muon**. The muon is an elementary particle similar to the electron, with an electric charge of **−1 e** and a spin of **½**. Muons are heavier, having more than 200 times as much mass as electrons. The muon is an unstable subatomic particle with a mean lifetime of 2.2 μs.
    - **Tau**. The tau (τ), also called the tau lepton, tau particle, or tauon, is an elementary particle similar to the electron, with an electric charge of −1 e and a spin of ½. Taus are approximately 3,700 times more massive than electrons. Tau leptons have a lifetime of 2.9×10^{-13} s.
- **Neutral leptons** (better known as neutrinos) are electrically neutral particles that rarely interact with anything, and are consequently rarely observed. **A neutrino** is an elementary subatomic particle with **infinitesimal mass** (less than 0.3 eV..?) and with **no**

electric charge. Neutrinos are **weakly interacting** subatomic particles with ½ unit of spin.

- **Electron neutrino**. The electron neutrino is a subatomic lepton elementary particle which has the symbol ν_e. It has no net electric charge and a spin of ½. Together with the electron it forms the first generation of leptons, hence the name electron neutrino.
- **Muon neutrino**. The muon neutrino is a subatomic lepton elementary particle which has the symbol ν_μ. It has no net electric charge and a spin of ½. Together with the muon it forms the second generation of leptons, hence the name muon neutrino.
- **Tau neutrino**. The tau neutrino is a subatomic lepton elementary particle which has the symbol ν_τ. It has no net electric charge and a spin of ½. Together with the tauon it forms the third generation of leptons, hence the name tau neutrino.

Law of Conservation of Lepton Number

In particle physics, the **lepton number** is used to denote which particles are leptons and which particles are not. Each **lepton** has a lepton number of **1** and each **antilepton** has a lepton number of **-1**. Other non-leptonic particles have a lepton number of 0. The lepton number is a **conserved quantum number**in all particle reactions. A slight asymmetry in the laws of physics allowed leptons to be created in the Big Bang.

The conservation of lepton number means that whenever a lepton of a certain generation is created or destroyed in a reaction, a corresponding antilepton from the **same generation** must be created or destroyed. It must be added, there is a separate requirement for each of the three generations of leptons, the electron, muon and tau and their associated neutrinos.

Conservation of Lepton Number – Electron Capture

Consider the **electron capture** mode. The reaction involves only first generation leptons: electrons and neutrinos:

$$p + e^- \rightarrow n + v$$

$$Lepton\ Number: \ 0 + 1 \ \rightarrow 0 \ + 1$$

The **antineutrino cannot be** emitted, because in this case the **conservation law** would not be fulfilled. The particle emitted with the neutron must be a neutrino.

Conservation of Lepton Number – Neutron Decay

Consider the decay of the neutron. The reaction involves only **first generation leptons**: electrons and neutrinos:

$$n \rightarrow p + e^- + \overline{\upsilon_e}$$

$$Lepton\ Number:\ 0 \rightarrow 0\ +1\ \ -1$$

Since the lepton number must be equal to zero on both sides and it was found that the reaction is a three-particle decay (**the electrons emitted in beta decay have a continuous rather than a discrete spectrum**), the third particle must be an electron antineutrino.

Conservation of Lepton Number – Muon Decay

The observation of the following decay reaction leads to the conclusion that there is a separate **lepton number** for muons which must also be conserved.

$$\mu^- \rightarrow e^- + \overline{\upsilon_e} + \upsilon_\mu$$

$$Electron\ Lepton\ Number:\ 0 \rightarrow\ +1\ -1$$

$$Muon\ Lepton\ Number:\ 1 \rightarrow\ 0\ \ +0+1$$

Baryon Number

In particle physics, the **baryon number** is used to denote which particles are baryons and which particles are not. Each baryon has a baryon number of 1 and each antibaryon has a baryon number of -1. Other non-baryonic particles have a baryon number of 0. Since there are exotic hadrons like pentaquarks and tetraquarks, there is a general definition of baryon number as:

$$B = {}^1/_3\left(n_q - n_{\overline{q}}\right)$$

where n_q is the number of quarks, and n_q is the number of antiquarks.

The **baryon number is a conserved quantum number** in all particle reactions. The term conserved means that the sum of the baryon number of all incoming particles is the same as the sum of the baryon numbers of all particles resulting from the reaction. A slight asymmetry in the laws of physics allowed baryons to be created in the Big Bang.

Law of Conservation of Baryon Number

In analyzing nuclear reactions, apply **many conservation laws**. **Nuclear reactions** are subject to classical **conservation laws for, momentum, angular momentum, and energy** (including rest energies). Additional conservation laws, not anticipated by classical physics, are **electric charge**, **lepton number and baryon number**. Certain of these laws are obeyed under all circumstances, others are not.

Baryon number is a generalization of **nucleon number**, which is conserved in nonrelativistic nuclear reactions and decays. The **law of conservation of baryon number** states that:

The sum of the baryon number of all incoming particles is the same as the sum of the baryon numbers of all particles resulting from the reaction.

For example, the following reaction has never been observed:

$$p + n \rightarrow p + p + \overline{p}$$

$$Baryon\,Number: \;\; 1 + 1 \rightarrow 1 + 1 - 1$$

even if the incoming proton has sufficient energy and charge, energy, and so on, are conserved. This reaction does not conserve baryon number since the left side has B =+2, and the right has B =+1.

On the other hand, the following reaction (proton-antiproton pair production) does conserve B and does occur if the incoming proton has sufficient energy (the threshold energy = 5.6 GeV):

$$p + p \rightarrow p + p + \overline{p} + p$$

$$Baryon\,Number: \;\; 1 + 1 \rightarrow 1 + 1 - 1 + 1$$

As indicated, B = +2 on both sides of this equation.

From these and other reactions, the conservation of baryon number has been established as a basic principle of physics.

This principle provides basis for the **stability of the proton**. Since the proton is the lightest particle among all baryons, the hypothetical products of its decay would have to be non-baryons. Thus, the decay would violate the conservation of baryon number. It must be added some theories have suggested that protons are in fact unstable with very long half-life (~10^{30} years) and that they decay into leptons. There is currently no experimental evidence that proton decay occurs.

Posssible Questions

2 marks

Give a note on lepton and baryon.
Define heavy particles.
How the parity is conserved?
Give a note on hyperons.

6 marks

What are the classification of particles?
How the baryon and lepton numbers are conserved?
Explain the interaction of particles.
Explain the composition of hadrons.
Discuss about the symmetries and conservation laws.
Explain the concept of quark model.
Give a note on strangeness and charm.
How the baryon and lepton numbers are conserved?

KARPAGAM ACADEMY OF HIGHER EDUCATION, COIMBATORE – 21
DEPARTMENT OF PHYSICS
CLASS: II B. Sc., PHYSICS BATCH: 2016-2019

NUCLEAR & PARTICLE PHYSICS (16PHU402)

MULTIPLE CHOICE QUESTIONS

Question	Choice 1	Choice 2	Choice 3	Choice 4	Answer
UNIT-V					
The class of elementary particles wth half odd integral spin and obey Fermi Dirac statistics is known as	Fermions	Baryons	Mesons	photons	Fermions
Proton, neutron and electron are examples of	baryons	mesons	Fermions	phonons	Fermions
Bosons are particles of ----- spin	zero	half integral	1	integral	integral
Bosons obey ----- statistics	Fermi	Fermi Dirac	Bose-Einstein	Bose	Bose-Einstein
Which of the following statements is not correct?	There is no conservation law of bosons	Number of Fermions are strictly conserved	Fermions are not consvered	Bosons are of integral spin	Fermions are not consvered
The category of Fermions of spin 1/2, having mass less than that of nucleons is called	bosons	Leptons	massless bosons	baryons	Leptons
The lepton number of negative muon is	1	-1	+ or - 1	0	1
=------ are weakly interacting Fermions	protons	leptons	Mesons	kryptons	leptons
----- are strongly interaction Fermions	protons	Leptons	Baryons	mesons	Baryons
Baryons have spin	integral	zero	half integral	1/2	half integral
Mass of bayrons is	equal to or greater than the mass of nucleuons	less than the mass of neucleons	equal to the mass of electrons	greater than the mass of nucleuons	equal to or greater than the mass of nucleuons
Protons are examples of	leptons	hyperons	bosons	baryons	baryons
Baryons having mass greater than that of nucleons are called	bosons	Leptons	hyperons	mesons	hyperons
Lambda particle is an example of	boson	leptons	Mesons	hyperons	hyperons
Baryons number is ----- for baryons and ----- for antibaryons	1 and -1	-1 and 1	0 and 1	1 and 0	1 and -1
The only massless boson is	proton	electron	photon	hyperons	photon
The photon is subject to ----- interaction only	gravitational	weak	strong	electromagnetic	electromagnetic
The strongly interacting bosons are having spin	0	1/2	half integer	1	0
The strongly interacting bosons are known as	photons	mesons	Baryons	electons	mesons
Mesons are particles with mass	less than that of electrons	greater than that of protons	equal to that of protons	intermediate between electron and proton	intermediate between electron and proton
Which of the following statements is correct?	baryons are subject to strong interaction only	baryons are subject to weak interaction only	baryons are subject to strong, weak and electromagnetic interactions	baryons are subject to strong and weak interaction only	baryons are subject to strong, weak and electromagnetic interactions
Mesons are subject to	strong interaction only	weak interaction only	electromagnetic interaction only	strong, weak and electromagnetic interactions	strong, weak and electromagnetic interactions
Neutron belongs to	baryons	mesons	bosons	massless bosons	baryons
Baryons and mesons together are termed as	bosons	fermions	leptons	hadrons	hadrons
Gravitational interaction is	always attractive	always repulsive	can be attractive or repulsive, depending on its charge	can be attractive or repulsive, depending on its mass	always attractive
Electromagnetic interaction is proportional to	1/r	1/r^2	r^2	r	1/r^2
The strong nuclear force is	charge dependent	both charge and size dependent	charge indendent	size dependent	charge indendent
The force involved in the beta decay is	electromagnetic interaction	gravitational interaction	strong interaction	weak interaction	weak interaction
Presence of a force called weak interaction was suggested by	Fermi	Born	Bohr	Rutherford	Fermi
The characteristic time of weak interaction is of the order of	10^10 s	10^-23 s	2.5 x 10^-8 s	10^-10 s	10^-10 s
The positive and negative pions decay into muons with a mean life time of	10^10 s	10^-23 s	2.5 x 10^-8 s	10^-10 s	2.5 x 10^-8 s
The neutral pions decay into ---- with a mean life time of -----	gamma rays with a mean life time 2.3 x 10^-16 s	muons, with a mean life time of 2.5 10^-8 s	Electron and positron, with a mean life time of 2.3 x 10^-16 s	hadrons, with a mean life time of 2.5 10^-8 s	gamma rays with a mean life time 2.3 x 10^-16 s

The fundamental particles with mean life times of the order of 10^-23 s are called	elementary particles	mesons	resonance particles	hadrons	resonance particles
The charged pions decay into	2 gamma rays	electron and neutrino	muon and neutrino	kryptons	muon and neutrino
The particle predicted, and later confirmed, to avoid violation of energy and momentum conservation laws, during beta decay is	pi meson	neutrino	mu meson	Bosons	neutrino
Nucleons belong to the class	hyperons	baryons	bosons	leptons	baryons
Characteristic time scale of gravitational interaction is of the order of	10^16 s	10^-16 s	10^10 s	10^-10 s	10^16 s
Characteristic time of electromagnetic interaction is of the order of	10^16 s	10^-16 s	10^10 s	10^-10 s	10^-16 s
The characteristic time scale of strong interaction is of the order of	10^16 s	10^-16 s	10^-23 s	10^-10 s	10^-23 s
The characteristic time scale of weak interaction is	10^16 s	10^-16 s	10^10 s	10^-10 s	10^-10 s
Particles like kaons and muons etc, were found out by	looking at cosmic rays	looking at particles in accelerators	looking closely at atom	looking at cosmic rays and at particles in accelerators	looking at cosmic rays and at particles in accelerators
Each hadron consists of a proper combination of a few elementary components called	photons	vector bosons	quark	meson-baryon pair	quark
Which of the following is *not* conserved in a nuclear reaction?	nucleon number	baryon number	charge	All are conserved	All are conserved
In our universe, positrons have a very short-term existence because	they rapidly decay to other particles	of the large number of electrons in our universe	their speeds are very near the speed of light	they "die" due to extremely low energy levels	of the large number of electrons in our universe
The first antiparticle found was the	positron	hyperons	quark	baryon	positron
The proton, neutron, electron, and the photon are called	secondary particles	fundamental particles	basic particles	initial particles	fundamental particles
The exchange particle of the electromagnetic force is the	gluon	muon	proton	photon	photon
Particles that interact by the strong force are called	leptons	hadrons	muons	electrons	hadrons
At the present time, the elementary particles are considered to be the	photons and baryons	leptons and quarks	baryons and quarks	baryons and leptons	leptons and quarks
The electron and muon are both	hadrons	leptons	baryons	mesons	leptons
Particles that make up the family of hadrons are	baryons and mesons	leptons and baryons	protons and electrons	muons and leptons	baryons and mesons
What are the fundamental particles of an atom?	Quarks, gluons and electrons	Protons, neutrons and electrons	The nucleus and electron orbits	An atom cannot be broken down into anything smaller than itself	Quarks, gluons and electrons
What are fermions?	Elements with ferrous metallic properties	Fundamental particles of matter	Hard subatomic solids	Groups of particles with the same charge or mass	Fundamental particles of matter
What are bosons?	Elementary crew members on merchant vessels	A term in particle physics used to describe matter	Subatomic particles that carry forces	An electron switch used in nano-circuits	Subatomic particles that carry forces
What are mesons?	A type of composite particle produced by high energy	A contagious disease caught by subatomic particles	An antimatter version of the electron	A type of Japanese soup	A type of composite particle produced by high energy
Which was the first particle discovered which is still today believed to be elementary, i.e. not made up of further constituents?	electron	gluon	proton	photon	electron
The particles carrying the strong force are the	photons	gluon	Z- or W-bosons	phonons	gluon
A conservation law that is not universal but applies only to certain kinds of interactions is conservation of	baryon number	spin	charge	strangeness	strangeness
A moderator is used to slow	protons	neutrons	beta particles	photons	neutrons
Particles that participate in the strong nuclear interaction are called	neutrinos	hadrons	leptons	electrons	hadrons

Prepared by: Mrs.S.Sharmila, Assistant Professor, Department of Physics, KAHE, Coimbatore.

Reg. No. : ---------------

[16PHU402]

KARPAGAM ACADEMY OF HIGHER EDUCATION,
COIMBATORE – 641 021
DEPARTMENT OF PHYSICS
II B.Sc PHYSICS
Fourth Semester
I INTERNAL EXAMINATION, JAN., 2018
NUCLEAR AND PARTICLE PHYSICS

Duration: 2 hours Maximum: 50 marks

PART – A (20 x 1=20 Marks)

Answer all the questions:

1.The atomic mass is almost equal to ______
a)the mass of the electron b)the mass of the nucleus
c)the mass of the protons d)the mass of the neutrons

2.The nuclear radius is proportional to
a)$A^{2/3}$ b)A c)$A^{1/3}$ d)A^2

3.The nucleon density at the centre of any nucleus is
a)proportional to A b)proportional A^2
c)proportional Z d)almost the same

4.Neutrons has the charge
a)1739 times of an electron b)1839 times of an electron
c)1939 times of an electron d)1639 times of an electron

5.As per modern theory, the atom has a diameter of about
a)10^{-4}mm b)10^{-5}mm c)10^{-6}mm d)10^{-7}mm

6.Electromagnetic force is normally of
a)short range b)long range c)medium range
d)infinite range

7.The hypothesis that nuclear forces possess an exchange character was put forward by
a)Pauli b)Rutherford c)Heisenberg d)Max Plank

8.The density of nucleus is approximately
a)10^{17} g/m^3 b)10^{44} kg/m^3 c)10^{20} kg/m^3
d)10^{17} kg/m^3

9. The number of nucleons per unit unit volume is approximately
a)10^{17} /m^3 b)10^{44} /m^3 c)10^{20} /m^3 d)10^{17} /m^3

10. What force is responsible for the radioactive decay of the nucleus?
a)Gravitational force b)Weak Nuclear force
c)Strong Nuclear force d)Electromagnetic force

11. Which of the following is correct for the number of neutrons in the nucleus?
a)N=A-Z b)N=A+Z c)N=Z d)N=A

12. At higher energy, bodies have
a)small mass b) large mass c)zero mass d)smaller weight

13. Minimum energy required to pull nucleus apart is called
a)ionization energy b)electron affinity
c)chemical energy d)binding energy

14. The constant nucleon density inside the nucleus supports
a)liquid drop model of the nucleus b)shell model
c)collective model d)unified model

15. The nuclear wave functions and particle motions support
a)Fermi gas model b)unified model c)collective model d)liquid drop model

16. The constant binding energy per nucleon supports
a)shell model b)collective model c)liquid drop model
d)unified model

17. The liquid drop model was suggested by
a)Bohr and Kalcker b)Fermi c)Rutherford d)Ferm

18. The average kinetic energy of nucleons inside nucleus is the order of
a)1 MeV b)10 MeV c)100 MeV d)0.1 MeV

19. The de Broglie wavelength corresponding to the aver energy of nucleons inside nucleus is of the order of

a)10^{-15} m b)10^{-15} cm c)10^{-5} m d)10^{-5} cm

20. In Fermi Gas model, the neutron is in a potential well of depth

a)8 MeV b)16 MeV c)38 MeV d)38 keV

PART – B (3 x 2=6 Marks)

21. Define packing fraction.
22. Give a note nuclear mass.
23. What are the similarities between the nucleus and a liquid?

PART – C (3 x 8=24 Marks)

24. a) Explain different properties of nuclei.

(OR)

b) Discuss about the binding energy of the nucleus.

25. a) Give a note on magnetic moment and electric moment of the nucleus.

(OR)

b) Briefly discuss about liquid drop model.

26. a) Write a note on Fermi gas model of the nucleus.

(OR)

b) What are all the evidence for nuclear shell structure? Explain it.