What are experimental evidences in favour of nuclear shell modell? Discuss the salient features of this model and point out its success and failures.

Nuclear shell modell:-

The nuclear shell modell differs from the liquid drop model in the respect that the former postulates a more or less independent behaviour of the nucleon in the nucleus. Consequently, this model is sometimes reffered to as the independent particle model. This model is one of the most important and useful model of nuclear structure. It is based on the realization that there are specific numbers of protons and neutrons, called magic numbers or shell numbers for which the nuclei exhibit exceptional stability, just as do atoms containing certain numbers of closed shells of electrons.

In 1937 T. schmidt and H. schüler (German) showed independently that the concept of nuclear shells could be fairly well correlated in a simple manner with the known mag. moments of nuclei.

Nuclei in which either N or Z is equal to one of these magic numbers (2, 8, 20, 28, 50, 82, 126) shows certain particular which are not considerable by liquid drop model. We will see that shell model is capable of explaining not only the magic numbers but also many other nuclear properties such as spin, magnetic moment and energy levels. The magic numbers of neutrons and protons have been interpreted as forming closed shells of neutrons or protons in analogy with the filling of electrons shells in atoms, and the neutrons and proton shells appear to be independent of each other.

→ Evidence for the existance of magic number :-

① Mayer (1918) showed that nuclei with a magic number of nucleons are especially abundant in nature.

② One of the most important pieces of evidence for the magic number comes from the study of the stable nuclides. Nuclei for which

Z and N are 2 or 8, $_2He^4$ & $_8O^{16}$ are more stable than their neighbours. Thus 2 & 8 indicates stability.

(3) Above $Z = 28$, the only nuclides of even Z which have isotopic abundances exceeding 60% are

Sr^{88} $(N = 50)$, Ba^{138} $(N = 82)$

Ce^{140} $(N = 82)$, Sn^{120} $(N = 70, Z = 50)$

Pb^{208} $(N = 126, Z = 82)$.

(4) Sn $(Z = 50)$ has ten isotopes, more than any other elements, while Ca $(Z = 20)$ has six isotopes. This indicated that elements with $Z = 50$ and $Z = 20$ are more than usually stable.

(5) α-decay energies are rather smooth functions of A (mean number) for a given Z but show striking discontinuities at $N = 126$. This represents the magic characteristic of number for neutrons.

(6) Very similar relations exists among the energies are abnormally larger when the N or Z of the final nucleus assumes a magic value.

(7) It is formed that some isotopes are spontaneous neutron emitters when

excited above the nucleon binding energy, by preceding β- decay. There are:—

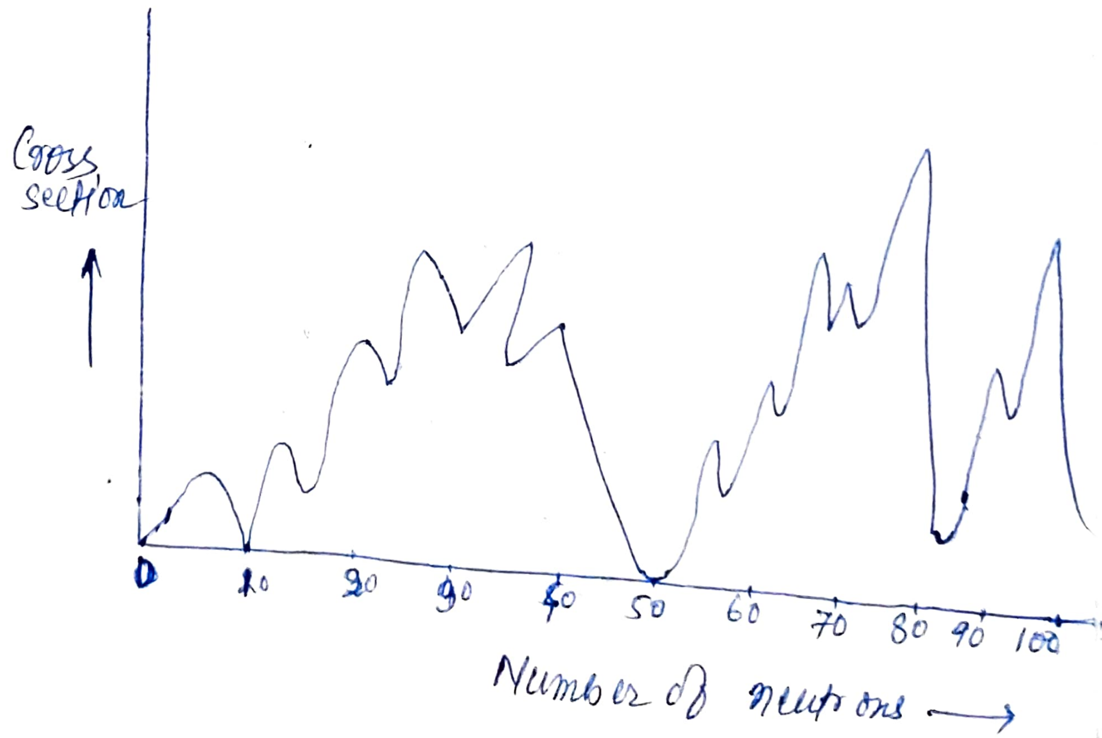
O (N=9), Kr (N=51) and Xe (N=83).

(8) Doubly magic nuclei (Z & N) both magic $_{2}He^{4}$, $_{8}O^{16}$, $_{20}Co^{40}$ and $_{82}Pb^{208}$ are particularly tightly bound.

(9) The binding energy of the next neutron or proton after a magic number is very small.

(10) The electric quadrupole moments of nuclei show sharp minima at the closed shell numbers, indicating that such nuclei are semi-spherical.

(11) Nuclei with the magic proton numbers 50 (Sn) capture (absorption) cross-section than the neighbours.



The heigh binding energy of the last neutron in the such nuclides, The departure of the total binding energy determined from the atomic mass ($\Delta E = \Delta mc^2$).

$$B.E.\ (MeV) = 14.0\,A - 0.584\,\frac{Z(Z-1)}{A^{1/2}} - 13.1\,A^{2/3} - 19.4\,\frac{(A-2Z)^2}{A} + E_i$$

Where, $E_i = \begin{cases} \frac{135}{A}, & \text{even } A \text{ \& } Z. \\ & \text{odd } A, \text{ even } Z \\ & \text{odd } A, \text{ odd } Z \\ -\frac{135}{A} & \text{even } A, \text{ odd } Z. \end{cases}$

It is seen that the behaviour of atomic nuclei is frequently determined by the excess or deficiency of nucleons w.r.to closed shells of magic numbers, just as chemical and spectral properties of atoms are dependent on an excess or deficiency of electrons. The quantum nos. n, l & m for electrons & their permissible values, can be derived from the wave mechanics. In this case it is assumed that each electrons is largely independent of the others, except that it moves in a Coulamb pot. field due to the nucleus.