Liquid drop model of nucleus of atom

Liquid Drop Model of the Nucleus: —

It has been suggested that the nucleus is similar to a small electrically charged drop of liquid.
The following analogies hold between a small drop of liquid and a nucleus.

(1) An atomic nucleus and a drop of liquid both are incompressible and homogenous. Density of atomic nucleus and a drop of particular liquid are same throughout.

(2) The drop is spherical because of symmetrical surface tension forces which act towards the centre. The nucleus is assumed to be spherical.

(3) The molecules in a liquid drop and nucleons in the nucleus both interact over short ranges. The interaction energy of nucleons is proportional to the mass number of nucleus (A).

(4) If the thermal agitation is increased by raising the temperature of liquid, evaporation of molecules takes place. If energy is given to the nucleus by bombarding particle, a compound nucleus is formed which emits nucleons almost immediately.

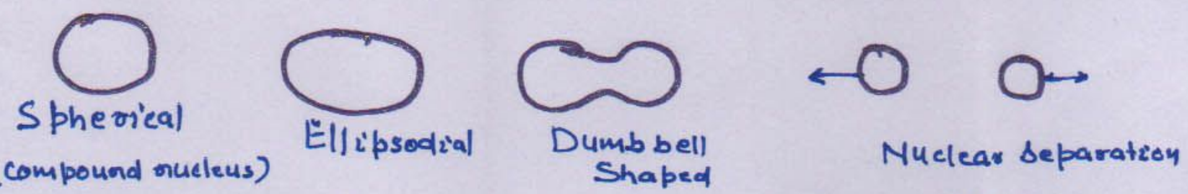
(5) If a drop of liquid grow by adding droplets, it tends to separate into two parts. Like drop if nucleus captures the neutron, the nuclear fission may occur.

(6) Deexitation of liquid drop may take place by cooling, evaporation, rupture the drop into droplets. Like this nucleus may be deexited by emission of radiation, emission of nucleons or by nuclear fission.

Merits of the liquid drop Model: —

(i) The liquid drop model explains the behaviour of nuclei in excited state.

(ii) This model is also capable of explaining the phenomenon of Nuclear fission. When a nucleus absorbs a neutron falling on it, it forms a compound, a nucleus of high energy. The extra energy may setup a series of rapid oscillations in the spherical compound nucleus.
As a result of these oscillation, the shape of the nucleus may change from spherical to ellipsoidal and then breaks into two parts of nearly equal size.



(iii) The liquid drop molel provides the basis for the Weizsaecker equation (Semi - empirical mass equation) for calculating the binding energies of nuclei and hence their atomic masses.

Semi-empirical Mass formula: —

The total binding energy of an atom is given by

$$B = 931 \, \Delta m \text{ MeV}$$

where Δm is mass loss in the synthesis of an atom.
The liquid drop model predict the binding energy of a nucleus in terms of the number of protons and neutrons it contains.
Weizsaekar proposed a simple formula for the nuclear binding energy and it also called as Semi - empirical mass formula.

Semi-empirical mass formula equation has five terms on its right hand side

$$B = B_v + B_s + B_e + B_a + B_p$$

Volume energy, Surface energy, Coulomb energy, Assymetry energy, Pairing energy

(a) Volume energy :- Volume energy is proportional to the volume of nucleus which is the main part of the nuclear binding energy. The volume of the nucleus is proportional to A. So this term is proportional to the volume.

Volume energy = $a_v A$, where a_v is a constant.

(b) Surface energy — A nucleon at the surface of a nucleus interacts with fewer other nucleons than one in the interior of the nucleus and hence its binding energy is less. This surface energy term takes this fact into account so it is negative and proportional to the surface area of the nucleus,

$$B_s = -a_s A^{2/3}$$

(c) Coulomb energy :- The electric repulsion between each pair of protons in a nucleus also contributes towards decreasing its binding energy. As each proton is repelled by (Z-1) protons, the total Coulomb energy is proportional to $Z(Z-1)\, e^2/R$

Hence,
$$B_c = -a_c \frac{Z(Z-1)}{A^{1/3}}$$

(d) Asymmetric energy :- An energy needed as a correction, when the number of neutrons is greater than the number of protons. The presence of excess neutrons results in asymmetric energy or neutron excess energy which lowers the binding energy and it is equal to,

$$B_a = -a_A \frac{(A-2Z)^2}{A}$$

(e) Pairing energy :- Complete pairing of protons with protons and neutrons with neutrons contributes positive to binding energy. The contribution is equal in magnitude but negative in sign if a proton and a neutron both remain unpaired.

The Pairing term is

$$B_p = \pm a_p A^{-1/2} \begin{cases} + \text{ for even Z, even N} \\ - \text{ for odd Z, odd N} \\ 0 \text{ for odd A} \end{cases}$$

The total binding energy of a nucleus is given by combination of the energy terms,

$$B = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_A \frac{(A-2Z)^2}{A} \pm a_p A^{-1/2}$$

The value of constants is given, the B.E,

$$B.E = 14.1\, A - 13\, A^{2/3} - 0.595 \frac{Z(Z-1)}{A^{1/3}} - \frac{19\,(A-2Z)^2}{A} \pm 135\, A^{-1/2}\ \text{MeV}$$

On using the values of A and Z, we calculate the binding energy.