Lecture2//

Nuclear Models

Liquid drop model and semiempirical mass formula.

It was noted that there is a similarity between the **nucleus** of an atom and a **droplet** of liquid, which can be summarized as follows:

1. The **density** of the nucleus is **constant** as that of a liquid **droplet**, it is independent **volume** and it is **incompressible**.
2. The **evaporation** process in a liquid is similar to the **radioactivity** in the nucleus.

The basic assumptions of this model are:

1. The **nucleus** is composed of a non-**contractile** material.
2. The **nuclear force** is **identical** for every nucleon and, saturated.

While **semiempirical mass formula** is equal to the **difference** between the binding energy and the sum of the masses of the nucleus components. So, the **mass** of the nucleus can be written:

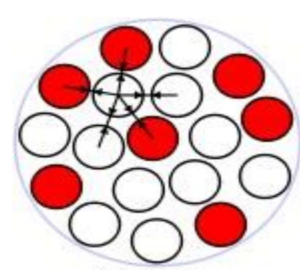
$$M(A, Z) = Zm_p + Nm_n - B(A, Z)$$

The value of binding energy $\boldsymbol{B(A, Z)}$ is determined by several influencing factors, are:

1. **Volume Energy**: It is proportional to the **mass** number and hence the **size** of the nucleus.

$$B_v \, \alpha \, A$$

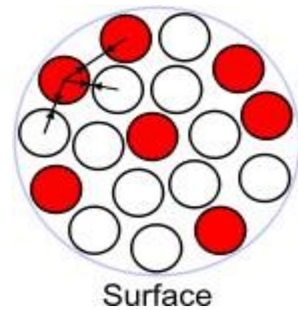
$$B_v = a_v A$$



Where a_v is constant (14.1 Mev)

Volume Energy represents the largest contribution to the value of the binding energy, and thus it increases the total binding energy of the nucleus, i.e., it increases the stability of the nucleus, so it has a positive value.

2. **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 that into account and is therefore **negative** and is proportional to the **surface area**.

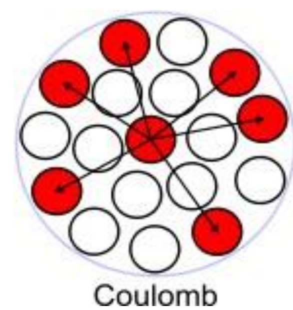


$$B_s \, \alpha \, R^2 \, \alpha \, R_0^2 \, A^{2/3}$$
$$B_s = - a_s \, A^{2/3}$$

Where a_s is constant (13 Mev)

3. **Coulomb Energy:** The electric **repulsion** between each pair of protons in a nucleus contributes toward **decreasing** its binding energy.

The electrostatic energy of the coulomb B_c for a nucleus of atomic number (Z) equals the work required to bring the protons from infinity to a size equal to that of the nucleus. *Therefore*, B_c is directly proportional to $\frac{Z(Z-1)}{2}$, which represents "the **number of corresponding pairs of protons in the nucleus**" and also, B_c is **inversely** proportional to the **radius** of the nucleus $R = R_0 A^{1/3}$, so the **Coulomb energy** is equal to:



$$B_C = ac \, Z(Z-1) / A^{1/3}$$

Where a_C is constant (0.595 Mev)

The **binding energy** in the nucleus **decreases** as a result of the repulsion between the protons, thus its value is **negative**.

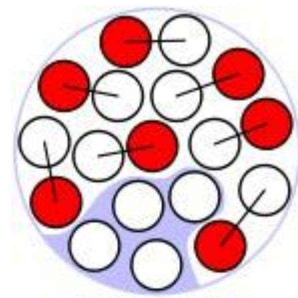
4. **Asymmetry Energy:**

When looking at the nuclear stability **curve**, that is, the relationship between the atomic number and the number of neutrons, we find that the light nuclei have $Z=N$. While in heavier nucleus, it is relatively less stable when $Z \neq N$. This increase in the number of neutrons indicates the nucleus attempts to prove its stability and overcome the **Coulomb force** in it.

The ***difference*** between **neutrons** and **protons** in the nucleus is equal to (***A-2Z***), and this difference is proportional to the number of neutrons and the mass number:

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

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

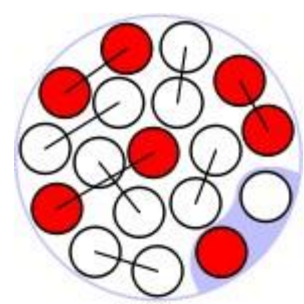


Where a_a is constant (19 Mev)

The symmetry coefficient a_a is **negative** value because it causes a **decrease** in the binding energy of the nucleus.

5. **Coupling Energy:**

The most stable and abundant nuclei in nature contain even numbers of ***Z*** and ***N***. This is due to the pairing symmetry of nuclei at the **ground levels** and also, the t**otal angular momentum** of the nucleus is equal to ***zero***, and accordingly, the paired **even-even** nuclei are the most **abundant** and **stable** nuclei, and this is due to the nature of the nuclear force that leads to stronger bonding between similar pairs of nuclei.



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