Answer on Question #51229, Physics, Other

Using the semi-empirical mass formula for the binding energy of nuclei, calculate the value of the atomic number (Z) for the most stable nucleus at a given mass number. Calculate Z_0 for A = 60. Take the values of γ = 23.7 and δ = 0.71.

Solution:

The semi-empirical mass formula:

$$M(A,Z) = ZM_H + (A-Z)M_n - \alpha A + \beta A^{\frac{2}{3}} + \delta \frac{Z(Z-1)}{A^{\frac{1}{3}}} + \gamma \frac{(A-2Z)^2}{A} - \delta_A$$

Differentiating the above equation omitting the pairing term, Z and equating it to zero, we have:

$$\left(\frac{\partial M}{\partial Z}\right)_{constA} = M_H - M_n + \delta \frac{2Z}{A^{\frac{1}{3}}} - 4\gamma \frac{A-2Z}{A} = 0$$

If $Z=Z_0$ satisfies the above relation, then

$$2\delta \frac{2Z_0}{A^{\frac{1}{3}}} - 4\gamma \frac{A-2Z_0}{A} = M_n - M_H$$

and

$$Z_0 = \left(\frac{(M_n - M_H) + 4\gamma}{2\delta A^{\frac{2}{3}} + 8\gamma}\right) A$$

Given the data, $M_n = 939.550 \text{ MeV}$, $M_H = 938.767 \text{ MeV}$, $\gamma = 23.7 \text{ MeV}$ and $\delta = 0.71 \text{ MeV}$

$$Z_0 = \left(\frac{(939.550 - 938.767) + 4 * 23.7}{2 * 0.71 * 60^{\frac{2}{3}} + 8 * 23.7}\right) * 60 = 27$$

Thus the nucleus with Z_0 = 27 is the most stable for A=60.

Answer: Z_0 = 27

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