MASS-ENERGY AND N UCLEAR BINDING ENERGY

Einstein showed that mass is another form of energy and one can convert mass-energy into other forms of energy, say kinetic energy and vice-versa.

Einstein gave the famous mass-energy equivalence relation

$$E = mc^2$$

Thus, if one gram of matter is converted to energy, there is a release of enormous amount of energy

Nuclear binding energy

Experimental verification of the Einstein's mass-energy relation has been achieved in the study of nuclear reactions amongst nucleons, nuclei, electrons and other more recently discovered particles.

We have

Mass of 8 neutrons = 8×1.00866 u

Mass of 8 protons = 8×1.00727 u

Mass of 8 electrons = 8×0.00055 u

mass defect ΔM

The difference in mass of a nucleus and its constituents, Δ**M**, is called the **mass defect**, and is given by

$$\Delta M = [Zm_p + (A - Z)m_n] - M$$

If one wants to break the oxygen nucleus into constituent nucleons , the extra energy $\Delta M c^2$, has to supplied.

This energy required E_b is related to the mass defect by $\mathbf{E_b = \Delta M c^2}$

If a certain number of neutrons and protons are brought together to form a nucleus of a certain charge and mass, an energy E_b will be released in the process. The energy Eb is called the binding energy of the nucleus.

If we separate a nucleus into its nucleons, we would have to supply a total energy equal to Eb, to those particles binding energy per nucleon

A more useful measure of the binding between the constituents of the nucleus is the binding energy per nucleon, E_{bn},

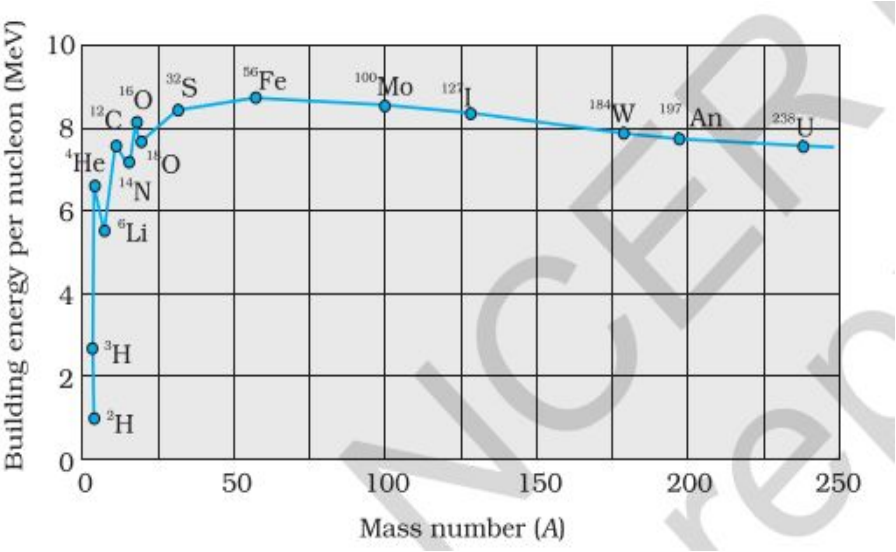
which is the ratio of the

binding energy E_b of a

nucleus to the number of the

nucleons, A, in that nucleus:

$$\mathbf{E_{bn} = E_b / A}$$



features of the plot

(i) the binding energy per nucleon, E_{bn} , is practically constant, i.e. practically independent of the atomic number for nuclei of

middle mass number (30 < A < 170). The curve has a maximum of about 8.75 MeV for A = 56 and has a value of 7.6 MeV

(ii) E_{bn} is lower for both light nuclei (A<30) and heavy nuclei (A>170).

conclusions

(i) The force is attractive and sufficiently strong to produce a binding energy of a **few MeV per nucleon**.

(ii) The constancy of the binding energy in the range $30 < A < 170$ is a consequence of the fact that the nuclear force is **short-ranged**

fission for stability

(iii) A very heavy nucleus, say A = 240, has lower binding energy per nucleon compared to that of a nucleus with A = 120. Thus if a nucleus A = 240 breaks into two A = 120 nuclei, nucleons get **more** tightly bound.

This implies energy would be released in the process.

It has very important implications for **energy production** through **fission**, fusion for stability

(iv) Consider two very light nuclei (A ≤ 10) joining to form a heavier nucleus. The **binding energy per nucleon** of the fused **heavier** nuclei is **more** than the **binding energy per nucleon** of the lighter nuclei. This means that the final system is more tightly bound than the initial system. Again energy would be released in such a process of fusion.