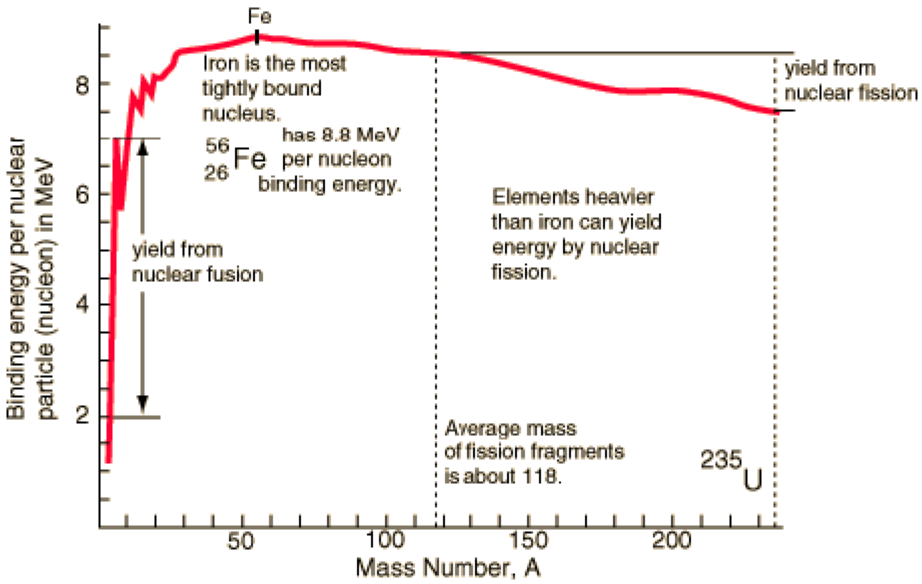
Answer on Question #51228, Physics, Other

With the help of the binding energy curve for nuclei, explain main characteristics of elements and the phenomenon of nuclear fusion and fission.

Solution:

The total energy required to break up a nucleus into its constituent protons and neutrons can be calculated from $E = \Delta mc^2$, called nuclear binding energy.

If we divide the binding energy of a nucleus by the number of protons and neutrons (number of nucleons), we get the binding energy per nucleon. This is the common term used to describe nuclear reactions because atomic numbers vary and total binding energy would be a relative term dependent upon that. The following figure, called the binding energy curve, shows a plot of nuclear binding energy as a function of mass number. The peak is at iron (Fe) with mass number equal to 56.



This curve indicates how stable atomic nuclei are; the higher the curve the more stable the nucleus. Notice the characteristic shape, with a peak near A=60. These nuclei (which are near iron in the periodic table and are called the iron peak nuclei) are the most stable in the Universe. The shape of this curve suggests two possibilities for converting significant amounts of mass into energy.

The rising of the binding energy curve at low mass numbers, tells us that energy will be released if two nuclides of small mass number combine to form a single middle-mass nuclide. This process is called **nuclear fusion**.

The eventual dropping of the binding energy curve at high mass numbers tells us on the other hand, that nucleons are more tightly bound when they are assembled into two middle-mass nuclides rather than into a single high-mass nuclide. In other words, energy can be released by the **nuclear fission**, or splitting, of a single massive nucleus into two smaller fragments.

The fission process initiated by the absorption of one neutron in uranium-235 releases about 2.5 neutrons, on the average, from the split nuclei. The neutrons released in this manner quickly cause the fission of two more atoms, thereby releasing four or more additional neutrons and initiating a self-sustaining series of nuclear fissions, or a chain reaction, which results in continuous release of nuclear energy.

Using the binding energy curve, we can estimate the energy released in this fission process. From this curve, we see that for heavy nuclides (mass about 240u), the mean biding energy per nucleon is about 7.6MeV. For middle-mass nuclides (mass about 120), it is about 8.5 MeV. This difference in total binding energy between a single large nucleus and two fragments (assumed to be equal) into which it may be split is then close to 200MeV.