

in the process. The energy  $E_b$  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  $E_b$ , to those particles. Although we cannot tear apart a nucleus in this way, the nuclear binding energy is still a convenient measure of how well a nucleus is held together. 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:

$$E_{bn} = E_b / A \quad (13.9)$$

We can think of binding energy per nucleon as the average energy per nucleon needed to separate a nucleus into its individual nucleons.

Figure 13.1 is a plot of the binding energy per nucleon  $E_{bn}$  versus the mass number  $A$  for a large number of nuclei. We notice the following main features of the plot:

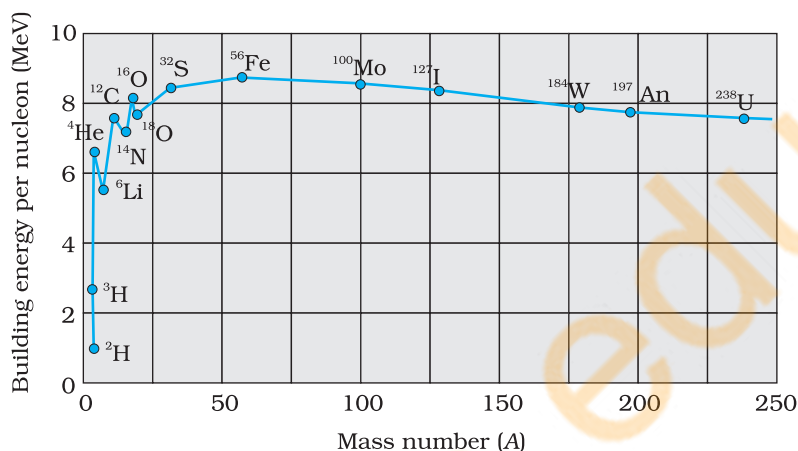


FIGURE 13.1 The binding energy per nucleon as a function of mass number.

(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 for  $A = 238$ .

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

We can draw some conclusions from these two observations:

(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. Consider a particular nucleon inside a sufficiently large nucleus. It will be under the influence of only some of its neighbours, which come within the range of the nuclear force. If any other nucleon is at a distance more than the range of the nuclear force from the particular nucleon it will have no influence on the binding energy of the nucleon under consideration. If a nucleon can have a maximum of  $p$  neighbours within the range of nuclear force, its binding energy would be proportional to  $p$ . Let the binding energy of the nucleus be  $pk$ , where  $k$  is a constant having the dimensions of energy. If we increase  $A$  by adding nucleons they will not change the binding energy of a nucleon inside. Since most of the nucleons in a large nucleus reside inside it and not on the surface, the change in binding energy per nucleon would be small. The binding energy per nucleon is a constant and is approximately equal to  $pk$ . The property that a given nucleon