3.3: Deeper Analysis of Nuclear Masses

To analyze the masses even better we use the atomic mass unit (amu), which is 1/12th of the mass of the neutral carbon atom,

$$1 \text{ amu} = \frac{1}{12} m_{^{12}\mathrm{C}}.$$

This can easily be converted to SI units by some chemistry. One mole of ^{12}C weighs 0.012 kg, and contains Avogadro's number particles, thus

$$1 \text{ amu} = \frac{0.001}{N_A} \text{ kg} = 1.66054 \times 10^{-27} \text{ kg} = 931.494 \mathrm{MeV}/c^2.$$

The quantity of most interest in understanding the mass is the binding energy, defined for a neutral atom as the difference between the mass of a nucleus and the mass of its constituents,

$$B(A, Z) = ZM_H c^2 + (A - Z)M_n c^2 - M(A, Z)c^2.$$

With this choice a system is bound when $B > 0$, when the mass of the nucleus is lower than the mass of its constituents. Let us first look at this quantity per nucleon as a function of A, see Figure $3.3.1$.

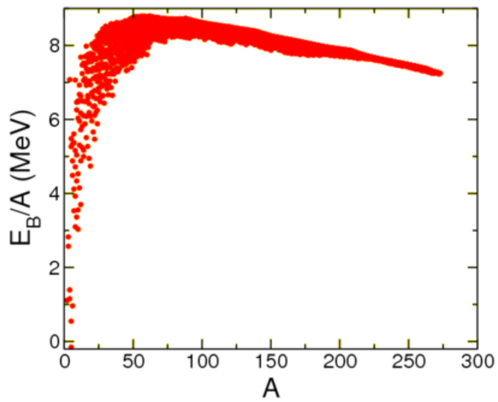

Figure $3.3.1$: B/A versus A.

This seems to show that to a reasonable degree of approximation the mass is a function of A alone, and furthermore, that it approaches a constant. This is called **nuclear saturation**. This agrees with experiment, which suggests that the radius of a nucleus scales with the 1/3rd power of A,

$$R_{\mathrm{RMS}} \approx 1.1 A^{1/3} \text{ fm}.$$

This is consistent with the saturation hypothesis made by Gamov in the 30's:

saturation hypothesis

As A increases the volume per nucleon remains constant.

For a spherical nucleus of radius R we get the condition

$$\frac{4}{3}\pi R^3 = AV_1,$$

or

$$R = \left(\frac{V_1 3}{4\pi}\right)^{1/3} A^{1/3}.$$

From which we conclude that

$$V_1 = 5.5 \text{ fm}^3$$