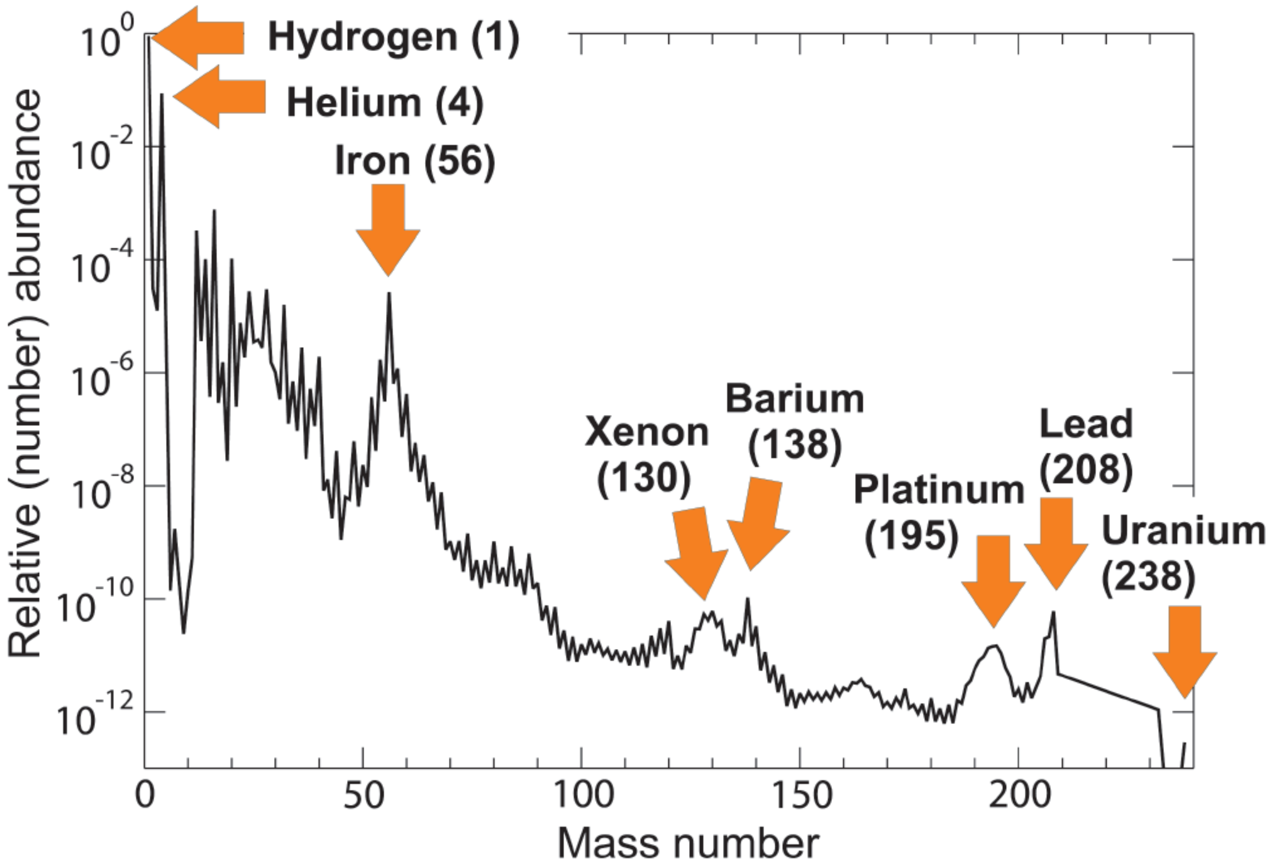
Isotopic Abundance

Example: relative abundance of different masses in the solar system. Labeled peaks are where one isotope dominates.



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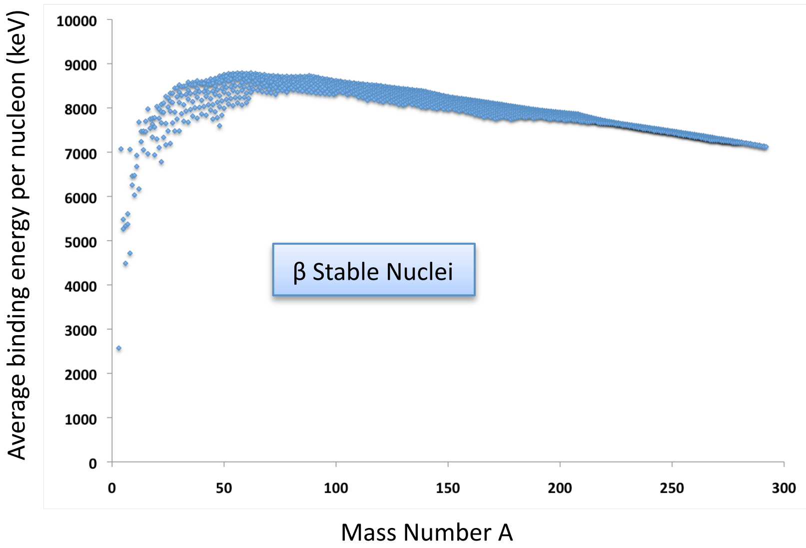
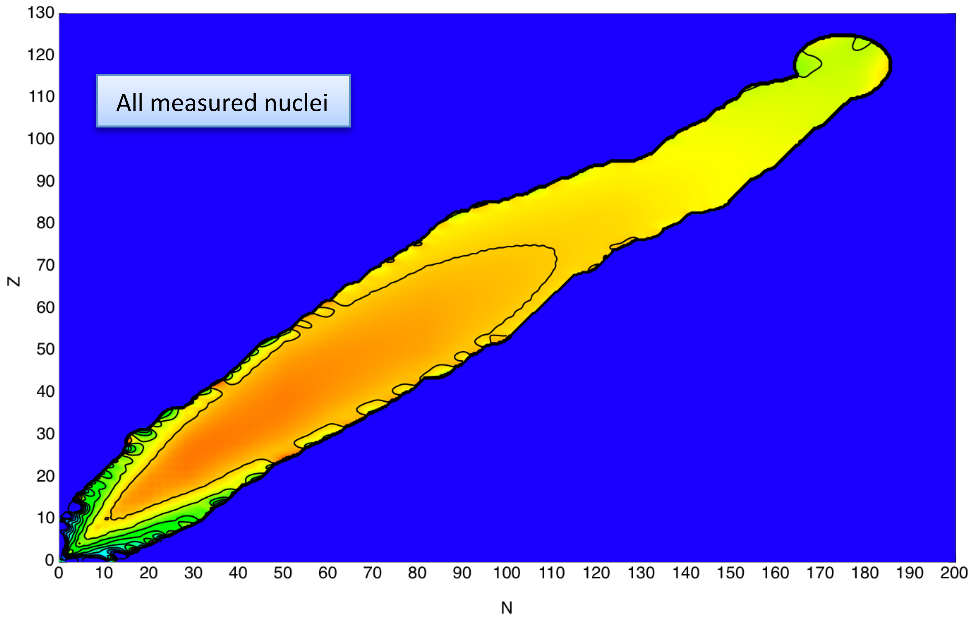
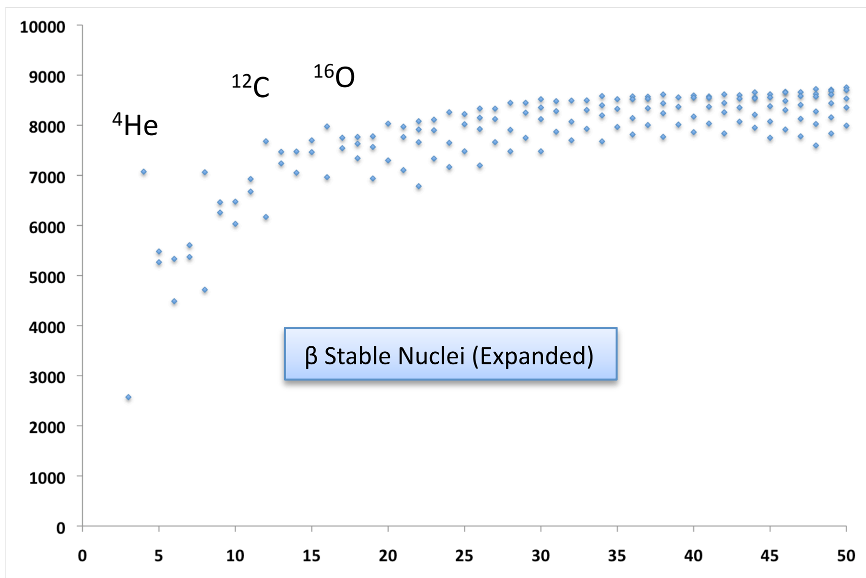
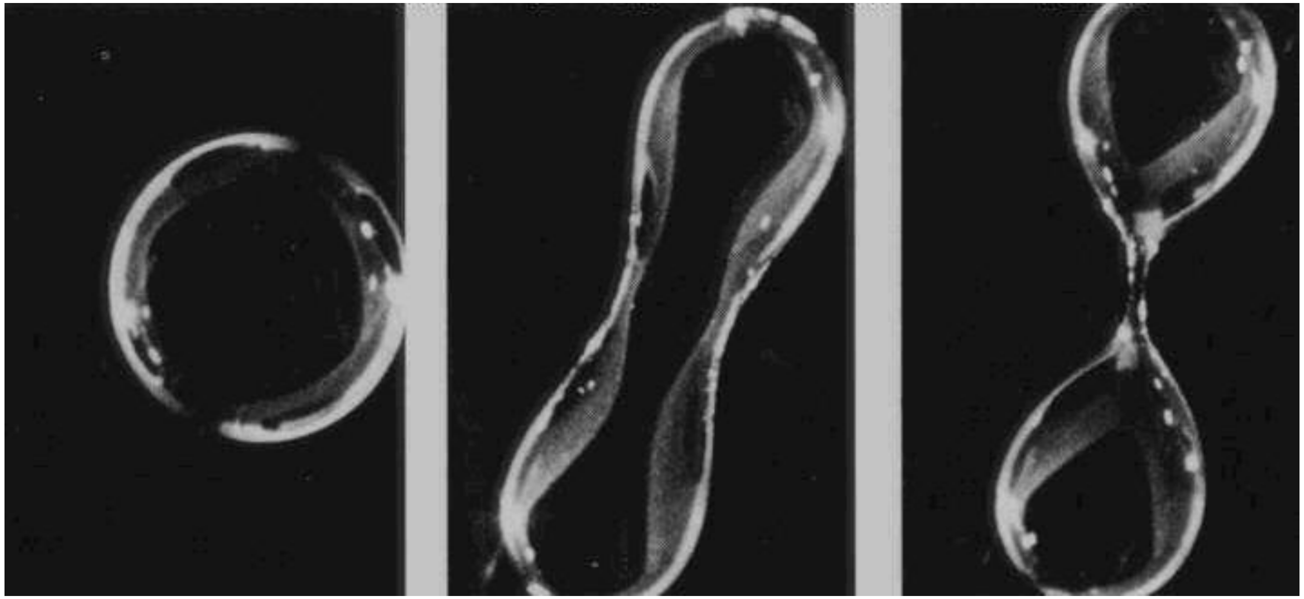
Average Binding Energy per Nucleon



- Most nuclei BE/A is pretty constant around 7 to 8.5 MeV/A.
- Very steep rise in light nuclei until around A=10-12.
- Some nuclei have unusually high BE/A compared to their neighbours e.g. ^{4}He has highest BE/A for A<12.
- Highest BE/A is 8794.549 keV/A for ^{62}Ni.
- Lowest BE/A for a stable, bound nucleus is ^{2}H with 1112.283 keV/A







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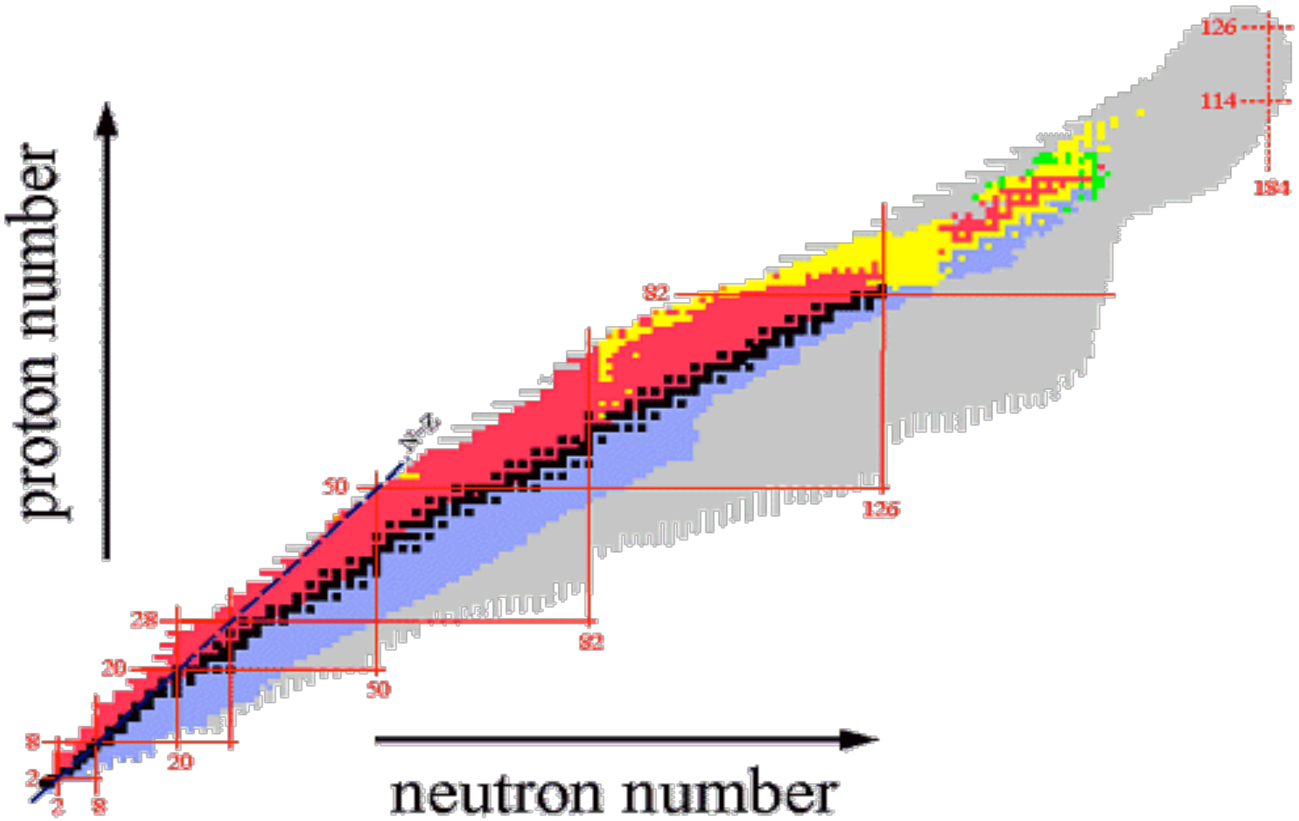
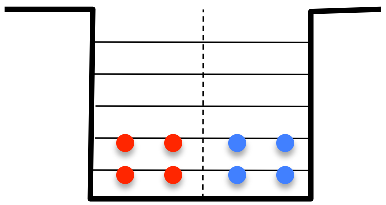
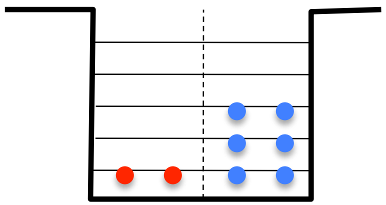


Light nucleus with different N/Z ratios:

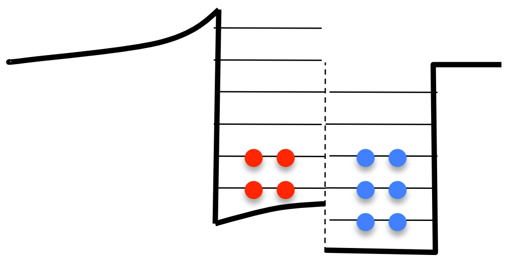


Lower total energy;
higher BE.

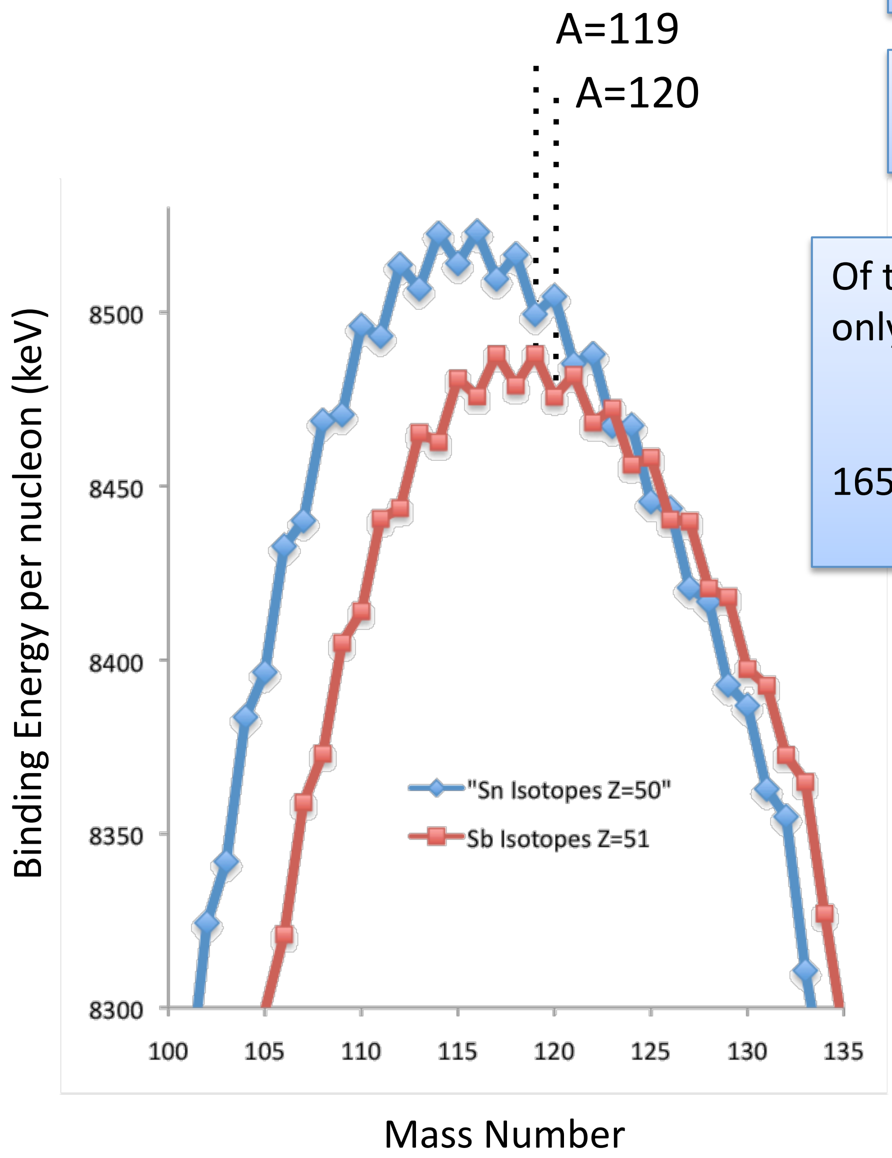


Higher total energy;
lower BE.
β decays!

Heavy nucleus with significant Coulomb:



Neutron excess.



Sn Z=50: even-even isotopes higher BE than odd-even isotopes

Sb Z=51: even-odd isotopes higher BE than odd-odd isotopes

Of the 284 terrestrially-occurring isotopes, only 9 odd-odd:

^{2}H, ^{6}Li, ^{10}B and ^{14}N are stable

^{40}K, ^{50}V, ^{138}La, ^{176}Lu and ^{180m}Ta are long lived.

165 even-even and 110 odd-even/even-odd

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Semi-Empirical Mass Formula

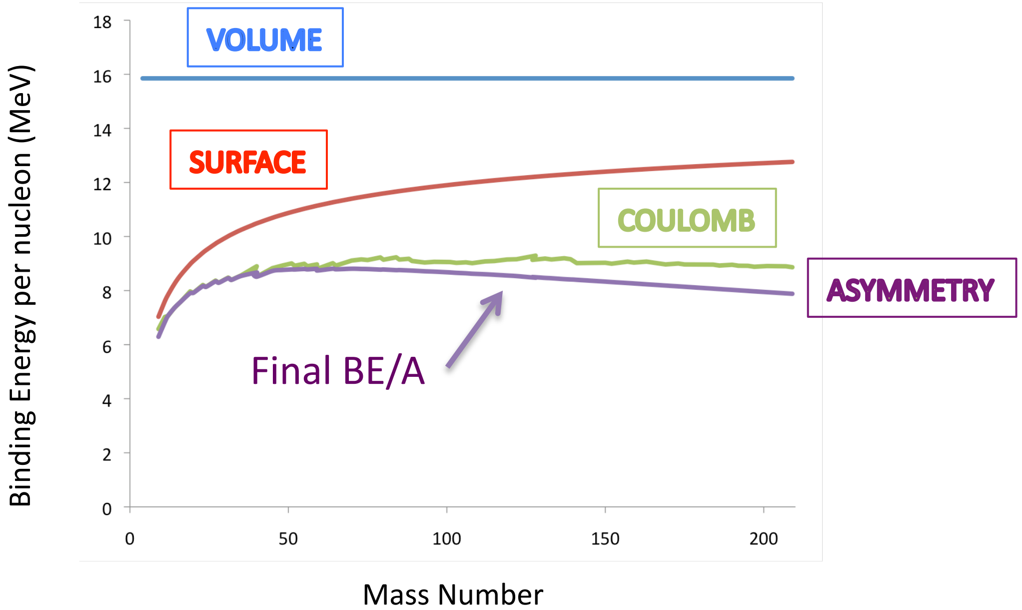
First version by Carl Friedrich von Weizsäcker in 1935.
Modern versions available with various improvements, including removing the restriction to spherical nuclei.
Example: P. Möller et al., At. Data Nucl. Data Tables 59 (1995) 185

$$\mathrm{BE} = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_a \frac{(N-Z)^2}{A} \pm a_p A^{-1/2}$$

Can perform a least-squares fit to experimental data and find the values of the coefficients....various sets available due to small differences in how this is done and over what nuclei.

$$a_v = 15.85 \text{ MeV}$$
$$a_s = 18.34 \text{ MeV}$$
$$a_c = 0.71 \text{ MeV}$$
$$a_a = 23.21 \text{ MeV}$$
$$a_p = 12 \text{ MeV}$$

Wapstra et al.
Nucl. Data Tables 9 (1971) 267



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Some comments on using the Semi-Empirical Mass Formula

(a) If you want the mass of a particular nucleus, use a specific value from a table or from the end of an exam question.
(b) If you are interested in GLOBAL trends, then the SEMF is useful. It should be clear in an exam question when to use it.

Typical examples:

What's the most stable Z in an isobar? $$\left[\frac{\partial \mathrm{BE}}{\partial Z}\right]_A = 0 \text{ i.e. max}$$

When is a decay process energetically possible? $$Q = \sum m_{\text{before}} - \sum m_{\text{after}}$$

$$Q > 0$$

Something to think about:

Do neutron stars count as BIG nuclei? Would the SEMF work for them?
What is missing from it?