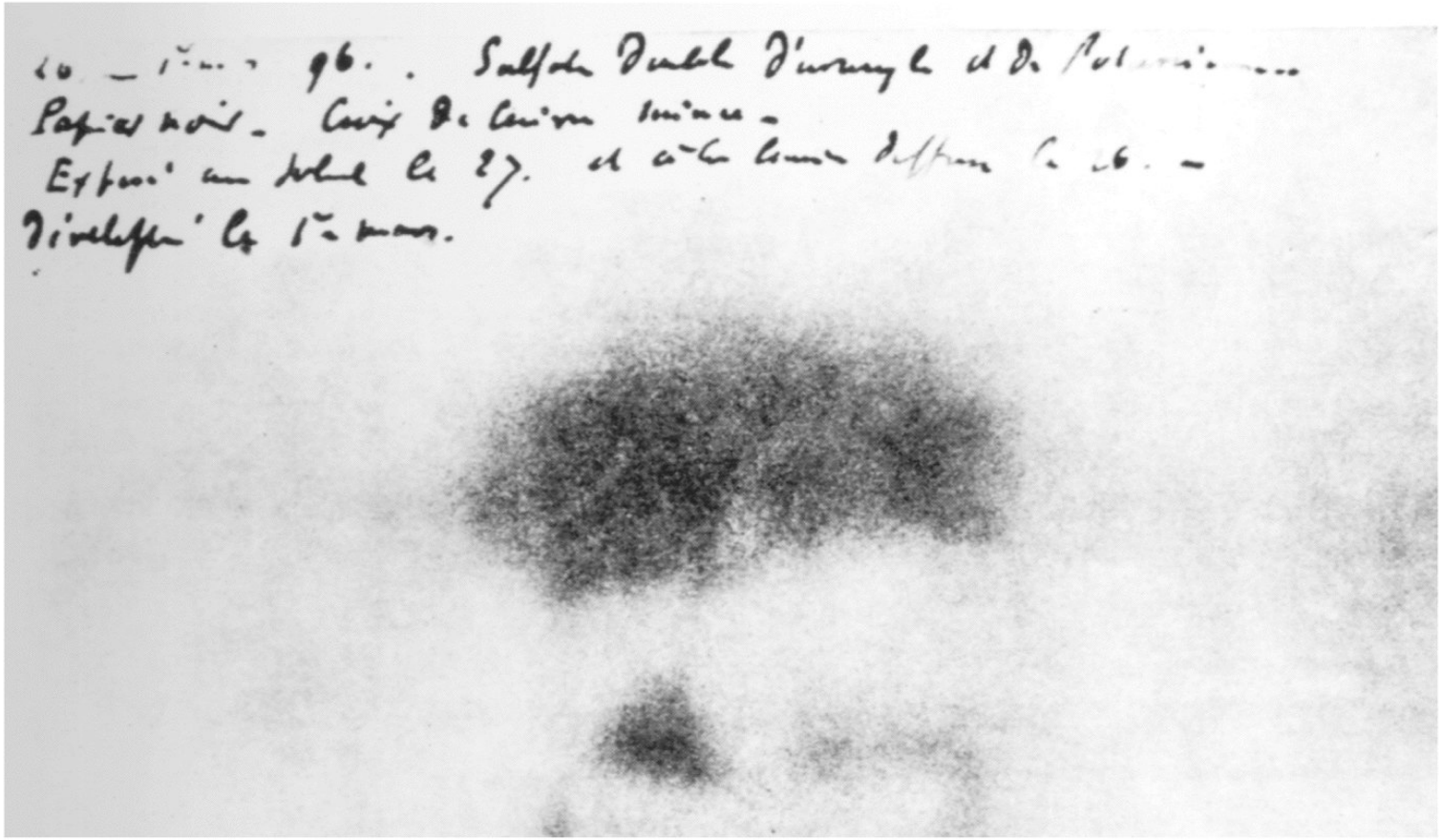
Chapter 17 – Nuclear Chemistry

- Nuclear Decay
- Nuclear Radiation
- Nuclear Energy

Nuclear Decay

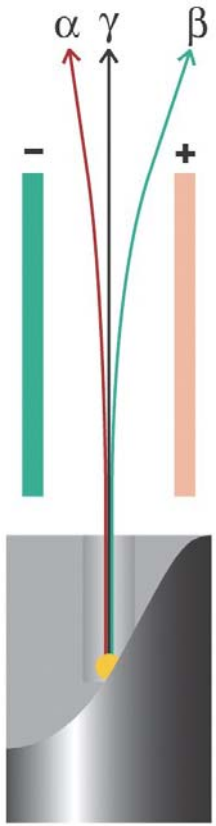
History



Henri Becquerel stored uranium oxide in a drawer with photographic plates. The uranium oxide darkened the plates therefore the uranium oxide must have given off some type of radiation

Nuclear Decay

History



Ernest Rutherford passed the radiation through two electrically charged plates and found that the radiation was made up of three primary particles (α, β, and γ) each having a different charge.

Nuclear Decay

Types of Particles

TABLE 17.1 Nuclear Radiation

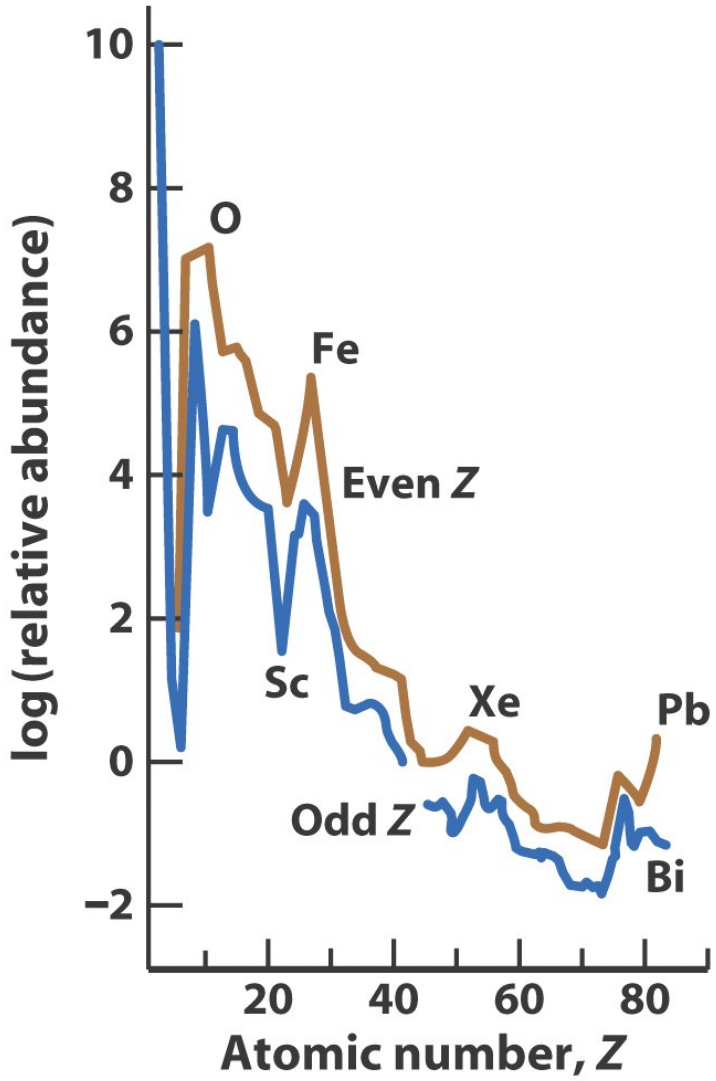
Type	Degree of penetration	Speed*	Particle†	Mass number	Charge	Example
α	not penetrating but damaging	10% of *c*	helium-4 nucleus $^{4}_{2}He^{2+}$, $^{4}_{2}\alpha$, α	4	+2	$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + \alpha$ (Fig. 17.7)
β	moderately penetrating	less than 90% of *c*	electron $^{0}_{-1}e$, β^-, β	0	−1	$^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{0}_{-1}e$ (Fig. 17.8)
electron capture‡	—	—	electron	0	−1	$^{44}_{22}Ti + {}^{0}_{-1}e \rightarrow {}^{44}_{21}Sc$ (Fig. 17.9)
γ	very penetrating; often accompanies other radiation	*c*	photon	0	0	$^{60}_{27}Co^{\S} \rightarrow {}^{60}_{27}Co + \gamma$ (Fig. 17.6)
β^+	moderately penetrating	less than 90% of *c*	positron $^{0}_{+1}e$, β^+	0	+1	$^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{+1}e$ (Fig. 17.10)
p	moderate or low penetration	10% of *c*	proton $^{1}_{1}H^{+}$, $^{1}_{1}p$, p	1	+1	$^{53}_{27}Co \rightarrow {}^{52}_{26}Fe + {}^{1}_{1}p$
n	very penetrating	less than 10% of *c*	neutron $^{1}_{0}n$, n	1	0	$^{137}_{53}I \rightarrow {}^{136}_{53}I + {}^{1}_{0}n$

*c is the speed of light.
†Alternative symbols are given for the particles; often it is sufficient to use the simplest (the one on the right).
‡Electron capture is not nuclear radiation but is included for completeness.
§An energetically excited state of a nucleus is usually denoted by an asterisk (*).

Scientists have discovered other types of particles but these types of radiation are far less common than α, β, and γ radiation.

Nuclear Decay

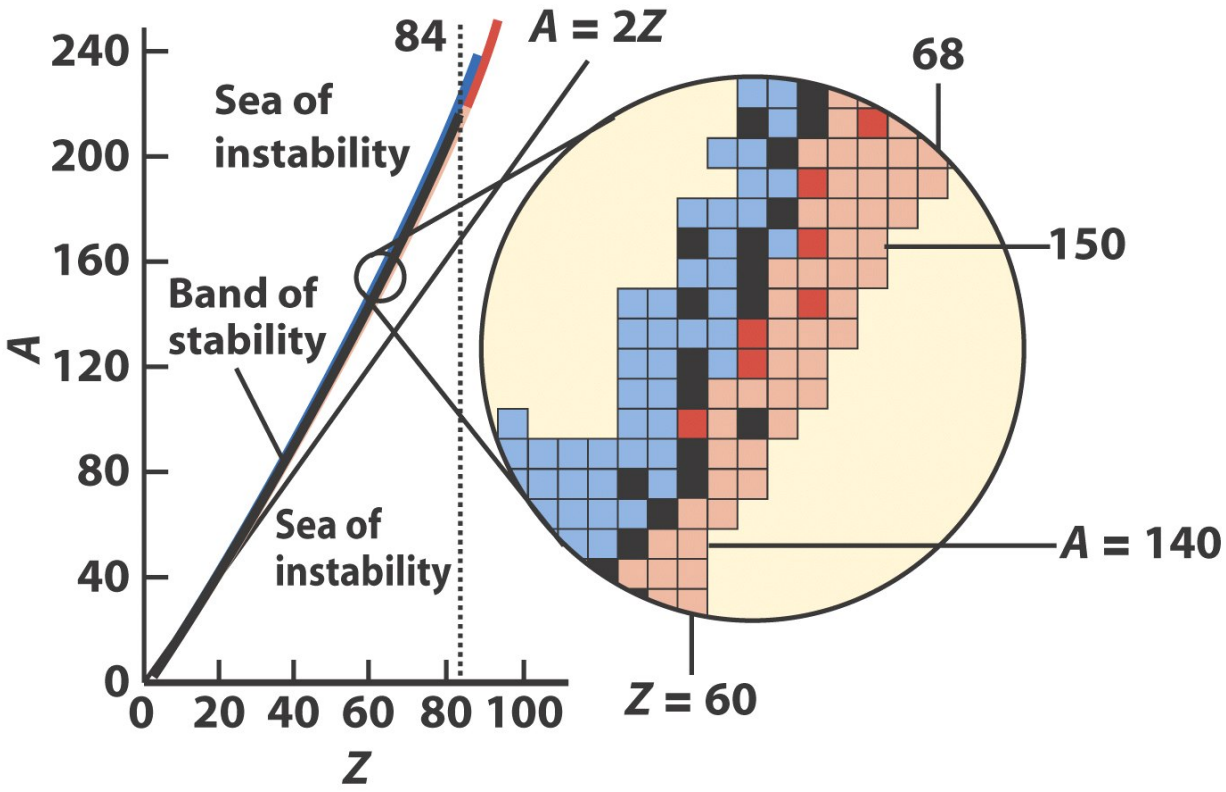
Elemental Amounts



The number of elements with even atomic numbers are more abundant than the elements with odd atomic numbers.

Nuclear Decay

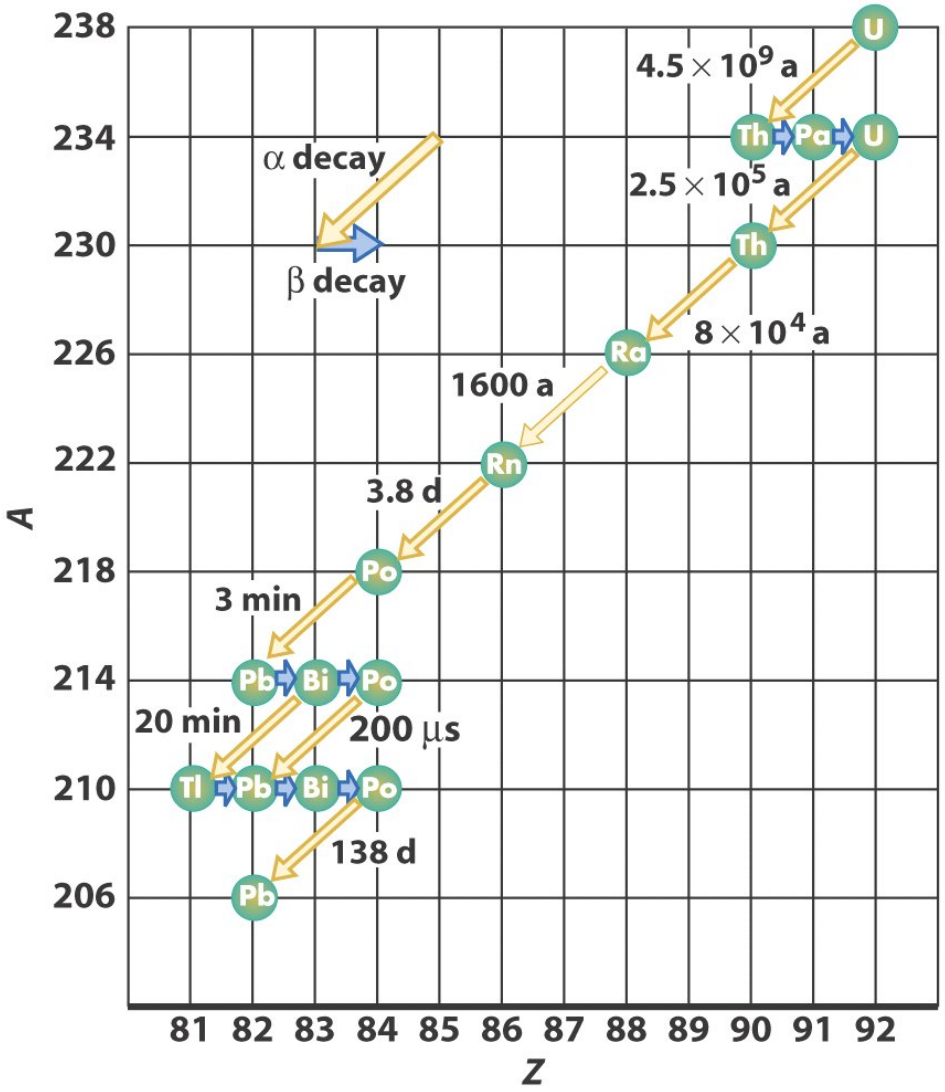
Elemental Amounts



A band of stability is found with a sea of instability at either side. For low atomic number the band of stability lies on the A = 2Z line. As the atomic number increases the protons repel each other more making it necessary for more neutrons to be present in the nucleus.

Nuclear Decay

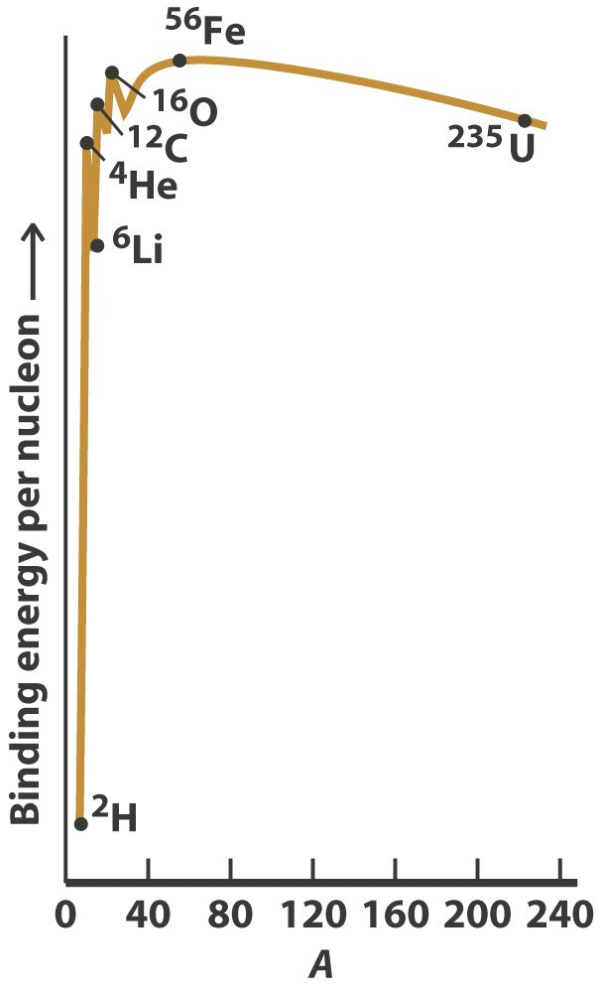
Radioactive Series for U-238



Radioactive series is a series of radioactive decays that a nuclei undergoes until a stable nucleus is formed.

Nuclear Energy

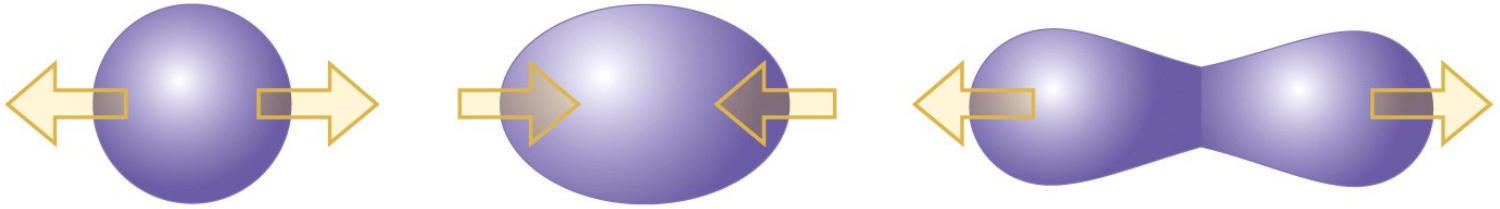
Binding Energy



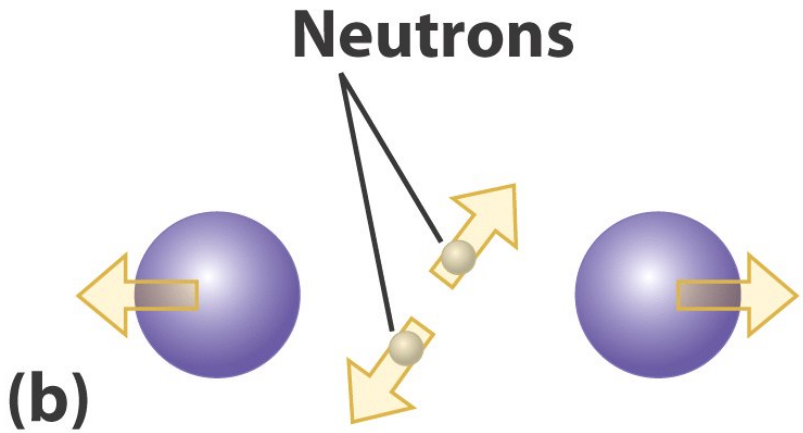
A plot of the binding energy per nucleon vs. atomic number shows that the nucleons that are most strongly bonded together are near iron and nickel. This is one of the reasons that iron and nickel are abundant in meteorites and on rocky planets such as earth. Suggesting that nuclei of lighter atoms become more stable when they "fuse" together and that the heaver nuclei become more stable when they undergo "fission" and split into lighter nuclei.

Nuclear Energy

Spontaneous Nuclear Fission



(a)



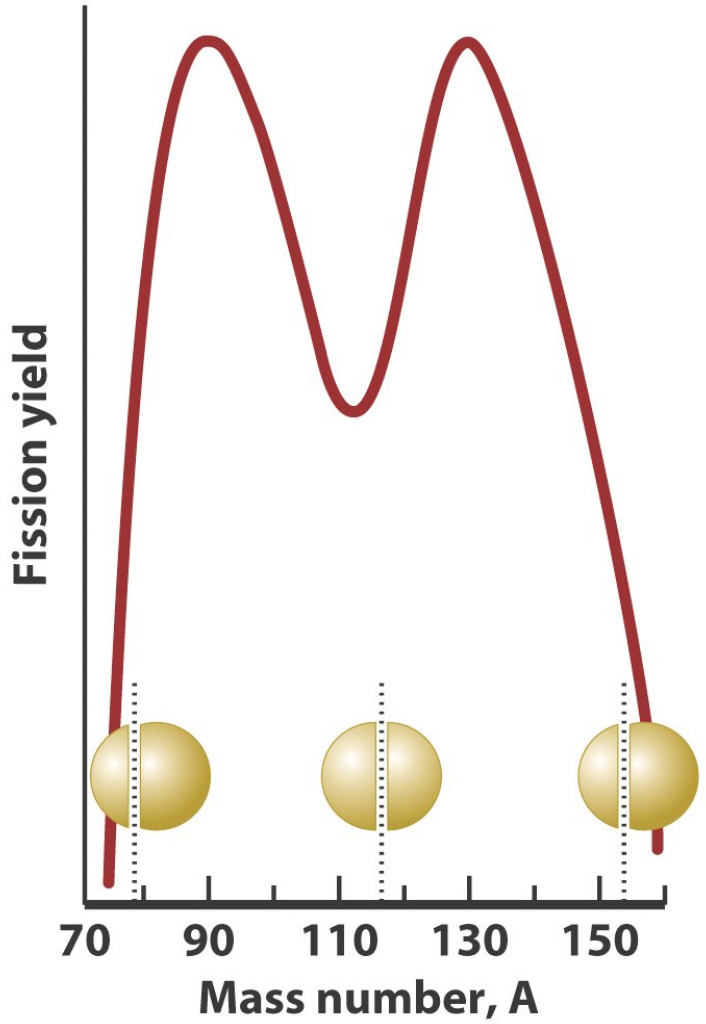
(b)

Spontaneous nuclear fission takes place when the natural oscillation of a heavy nucleus causes it to break into two nuclei of similar mass. An example is the disintegration of americium-244 into iodine and molybdenum.

$^{244}_{95}Am \rightarrow {}^{134}_{53}I + {}^{107}_{42}Mo + 3\,{}^{1}_{0}n$

Nuclear Energy

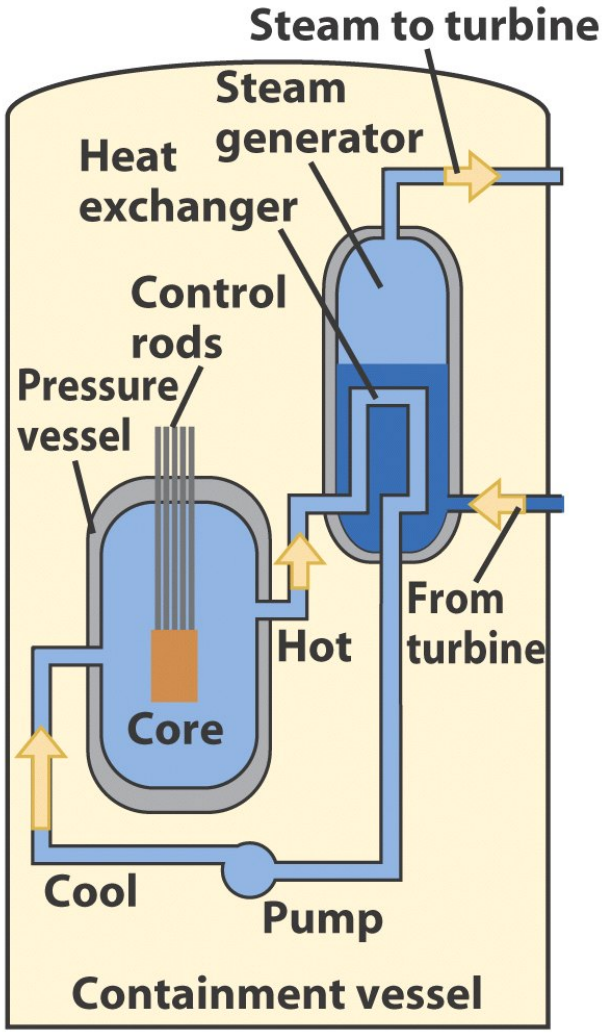
Fission Yield for Uranium-235



Fission does not happen the same way every time. The fission yield of uranium-235 mainly yields products close to A=90 and A=130 and relatively few nuclide corresponding to symmetric fission (close to 117) are formed.

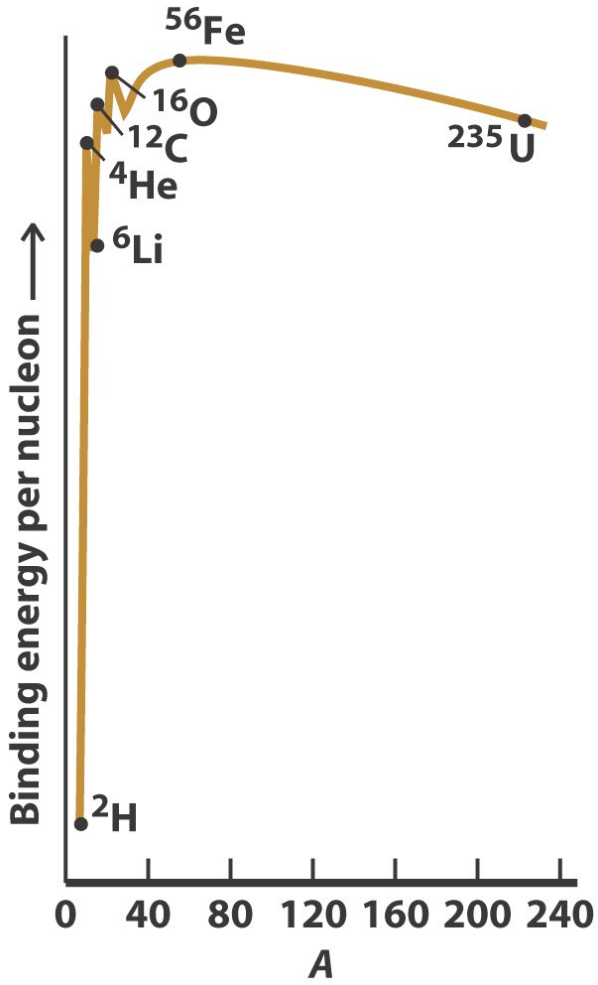
Nuclear Energy

Nuclear Power Plant



Nuclear Energy

Binding Energy



It can be seen that there is a large increase in nuclear binding energy per nucleon going from one lighter element to another. Consequently a large amount of energy is released when hydrogen nuclei fuse together to form nuclei of bigger elements.