Stuff for Monday, April 30, 2012

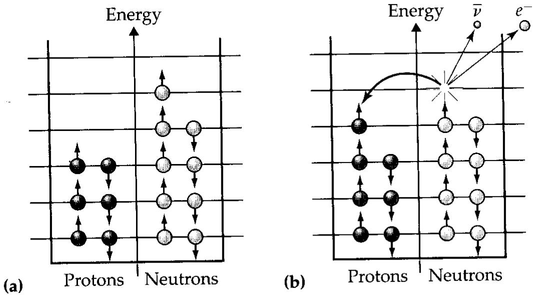
- PS #9 returned up front, PS #10 due.
- Quiz #5 returned up front. Quiz average: 8.4 (*read carefully!*)
- Midterm: 2 hours from 6:30pm to 10:00pm Wednesday in 1009.
  Does everyone have the midterm handout? Annotate as desired.
- Schedule: Q1–11 review + nuclear before midterm; no 1094/PS Thurs.

Stuff about nuclei and radioactivity:

- Nuclei: ${}^{A}_{Z}X$ where A nucleons $= Z$ protons $+ N$ neutrons
- Radius: $r \approx r_0 A^{1/3}$ with $r_0 = 1.2\,\mathrm{fm}$ closest α: $r_{\mathrm{min}} = k(2e)(Ze)/K_0$
- 1 u = atomic mass unit $\equiv \frac{1}{12}(\text{mass of } {}^{12}_{6}\mathrm{C}) = 931.48\,\mathrm{MeV}/c^2$
  - $m_p = 1.007277\,\mathrm{u}$ $m_n = 1.008665\,\mathrm{u}$ $m_e = 0.0005486\,\mathrm{u}$
- Binding energy $E_b \equiv E_{\mathrm{parts}} - E_{\mathrm{system}}$, $\Delta m \equiv m_{\mathrm{parts}} - m_{\mathrm{sys}} = E_b/c^2$
  - nucleus: $\Delta m = Z m_H + N m_n - m_{\mathrm{atom}}$ where $m_H = 1.007825\,\mathrm{u}$
- Stability: Can the nucleus lower its energy by radioactive decay?
- Decays: alpha, beta (neutron β^-, proton β^+, EC) $\Longrightarrow \nu$ or $\overline{\nu}$, gamma

Unstable nuclei

Figure Q13.2
(a) The ground-state configuration for a hypothetical $^{15}_{6}C$ nucleus. (b) This nucleus is unstable because it can lower its total energy by transforming the highest neutron into a proton, which allows it to drop to a lower energy level (this creates a $^{15}_{7}N$ nucleus).



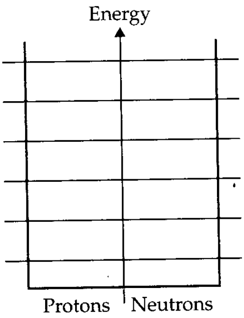
Check Table of Nuclides (google, e.g., `http://atom.kaeri.re.kr/`)

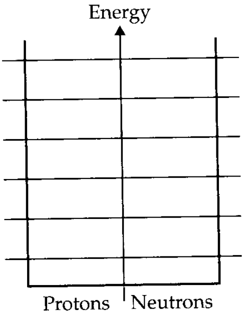
Binding energy calculation:

(6*1.007825u + 9*1.008665u – 15.0105993u)*931.48 MeV/u = 106.501 MeV

Exercise Q13X.1

Now let's consider a nucleus with an overabundance of protons. $^{13}_{8}O$ is observed to decay with a half-life of 8.9 ms to $^{13}_{7}N$, a positron, and a neutrino. Use the blank energy-level diagrams below to explain why.





Exercise Q13X.2

Explain why a neutron in a $^{12}_{6}C$ *cannot* decay to a proton or vice versa. (*Hint:* Consider conservation of energy. The difference between energy levels is on the order of magnitude of several megaelectronvolts at least.)

Coulomb Energy

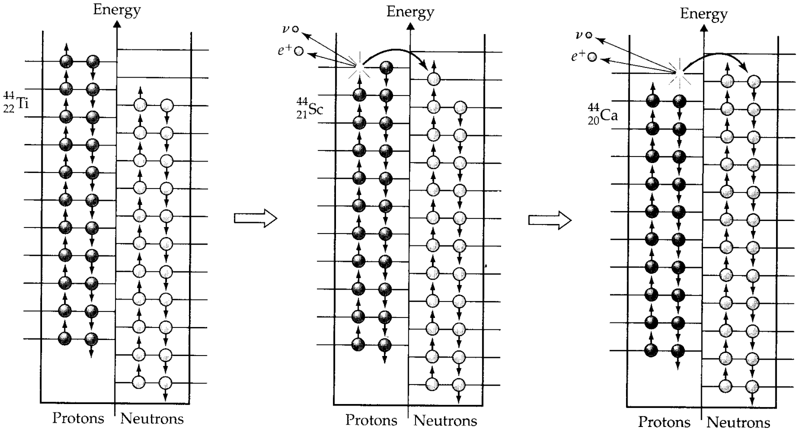


Figure Q13.3

The $^{44}_{22}$Ti nucleus, even though it has $N = Z$, decays because electrostatic repulsion lifts the proton energy levels somewhat relative to the neutron levels.

Symmetry Energy

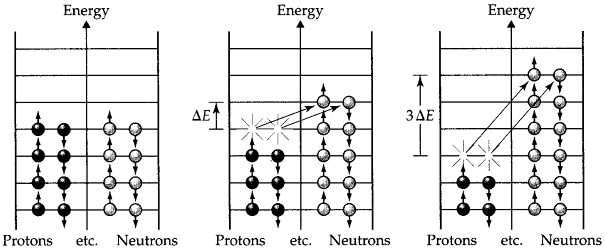


Figure Q13.5
The cost of transforming protons to neutrons is ΔE for the first pair, $3\,\Delta E$ for the second pair, and so on.