

Stuff for Thursday, May 3, 2012

- No problem set due today!
 - Next two problem sets (Q12/13 and Q14/15) available.
- No quiz this week!

Stuff about nuclei and radioactivity:

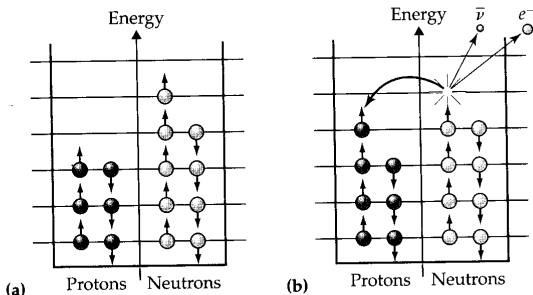
- Nuclei: ${}^A_Z X$ where A nucleons = Z protons + N neutrons
- Radius: $r \approx r_0 A^{1/3}$ with $r_0 = 1.2$ fm closest α : $r_{\min} = k(2e)(Ze)/K_0$
- 1 u = atomic mass unit $\equiv \frac{1}{12}$ (mass of ${}^{12}_6\text{C}$) = 931.48 MeV/ c^2
 - $m_p = 1.007277$ u $m_n = 1.008665$ u $m_e = 0.0005486$ u
- Binding energy $E_b \equiv E_{\text{parts}} - E_{\text{system}}$, $\Delta m \equiv m_{\text{parts}} - m_{\text{sys}} = E_b/c^2$
 - nucleus: $\Delta m = Zm_H + Nm_n - m_{\text{atom}}$ where $m_H = 1.007825$ u
- Stability: Can the nucleus lower its energy by radioactive decay?
- Decays: alpha, beta (neutron β^- , proton β^+ , EC) $\implies \nu$ or $\bar{\nu}$, gamma

Unstable nuclei

Figure Q13.2

(a) The ground-state configuration for a hypothetical $^{15}_6\text{C}$ 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 $^{15}_7\text{N}$ nucleus).



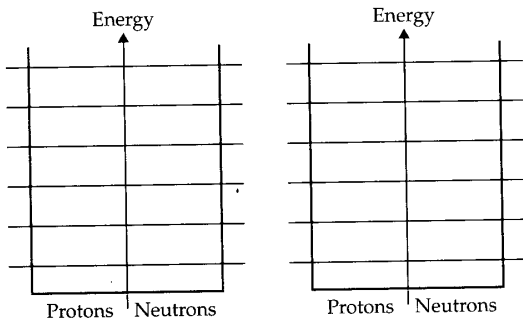
Check **Table of Nuclides** (google, e.g., <http://atom.kaeri.re.kr/>)

Binding energy calculation:

$$(6 \cdot 1.007825\text{u} + 9 \cdot 1.008665\text{u} - 15.0105993\text{u}) \cdot 931.48 \text{ MeV/u} = 106.501 \text{ MeV}$$

Exercise Q13X.1

Now let's consider a nucleus with an overabundance of protons. $^{13}_8\text{O}$ is observed to decay with a half-life of 8.9 ms to $^{13}_7\text{N}$, a positron, and a neutrino. Use the blank energy-level diagrams below to explain why.



Exercise Q13X.2

Explain why a neutron in a $^{12}_6\text{C}$ 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

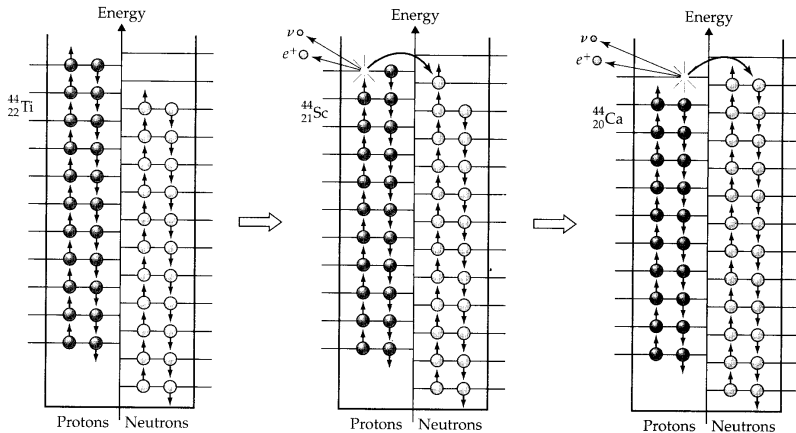


Figure Q13.3

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

Symmetry Energy

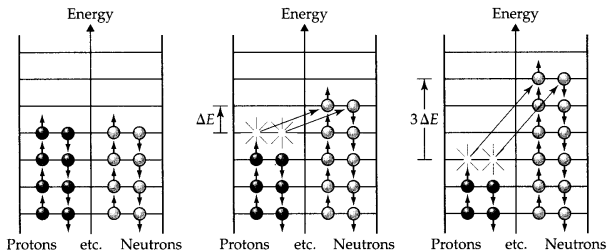


Figure Q13.5

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