Nuclear Decay

Nuclear Reactions

The standard nuclear reactions are

$$\alpha\text{-Decay: } (Z,N) \rightarrow (Z-2,N-2) + \alpha$$

$$\beta^-\text{-Decay: } (Z,N) \rightarrow (Z+1,N-1) + e^- + \overline{\nu}$$

$$\beta^+\text{-Decay: } (Z,N) \rightarrow (Z-1,N+1) + e^+ + \nu$$

$$e^- \text{ Capture: } (Z,N) + e^- \rightarrow (Z-1,N+1) + \nu$$

For them to happen spontaneously, they must release energy. That is, the rest masses of the daughter nucleus and any products must be less than that of the parent nucleus.

$$K = \Delta Mc^2 = \left\{ m_{nucleus}(Z,N) - \left[m_{daughter} + m_{product} \right] \right\} c^2$$

where the daughter nucleus and product depend on the decay process. Appendix D in TZDII gives atomic masses, not nuclear masses. We can convert the masses of nuclei to those of atoms by adding and subtracting Zm_e and assciating them with the appropriate nuclei (see TZDII §16.7). thus, the energy equations of the reactions are:

$$K_\alpha = \Delta Mc^2 = \left\{ m_{atom}(Z,N) - \left[m_{atom}(Z-2,N-2) + m_{He} \right] \right\} c^2$$

$$K_{\beta+} = \Delta Mc^2 = \left\{ m_{atom}(Z,N) - \left[m_{atom}(Z-1,N+1) + 2m_e \right] \right\} c^2$$

The original atom has an extra electron when $p^+ \rightarrow n^0$ and the emitted mass of the e+ (= m_e), gives 2me as products in β^- decay.

$$K_{\beta-} = \Delta Mc^2 = \left\{ m_{atom}(Z,N) - \left[m_{atom}(Z+1,N-1) \right] \right\} c^2$$

If a different reaction occurs, say the emission of a neutron, a proton, or a ^{12}C atom, the energy will have to take into account the atomic mass of the product (i.e. TZDII Pr. 17.27).

$$K_{n0} = \Delta Mc^2 = \left\{ m_{atom}(Z,N) - \left[m_{atom}(Z,N-1) + m_n \right] \right\} c^2$$

$$K_{p+} = \Delta Mc^2 = \left\{ m_{atom}(Z,N) - \left[m_{atom}(Z-1,N) + m_H \right] \right\} c^2$$

$$K_{12C} = \Delta Mc^2 = \left\{ m_{atom}(Z,N) - \left[m_{atom}(Z-6,N-6) + m_{12C} \right] \right\} c^2$$

All of these ultimately require the conversion from uc^2 to MeV using the conversion factor:

$$1\ u = 931.5 \frac{MeV}{c^2}.$$