

HOMEWORK SET 27: NUCLEAR DECAY

Due Monday, April 28, 2025

PROBLEMS FROM OR AFTER TZDII¹

17.23) If we neglect the neutrino's mass, the total kinetic energy released in β^- decay, $(Z, N) \rightarrow (Z-1, N-1) + e^- + \bar{\nu}$ is given by

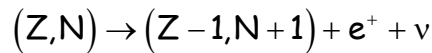
$$K = \Delta Mc^2 = \{m_{\text{atom}}(Z, N) - m_{\text{atom}}(Z+1, N-1)\} c^2 \quad (17.22)$$

In particular, the criterion that β^- decay is possible is just that K must be positive, or

$$m_{\text{atom}}(Z, N) \geq m_{\text{atom}}(Z+1, N-1) \quad (\text{for } \beta^- \text{ decay})$$

That is, one has only to compare the atomic masses involved to see if β^- decay is possible.

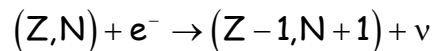
a) Find an expression for the ideal total kinetic energy released in the β^+ decay



and show that the condition for this process to be possible is

$$m_{\text{atom}}(Z, N) \geq m_{\text{atom}}(Z+1, N-1) + 2m_e \quad (\text{for } \beta^+ \text{ decay, 17.84})$$

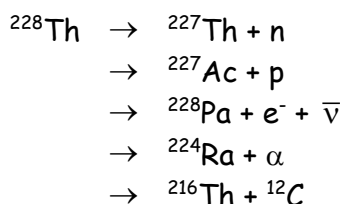
b) Do the same for the electron capture



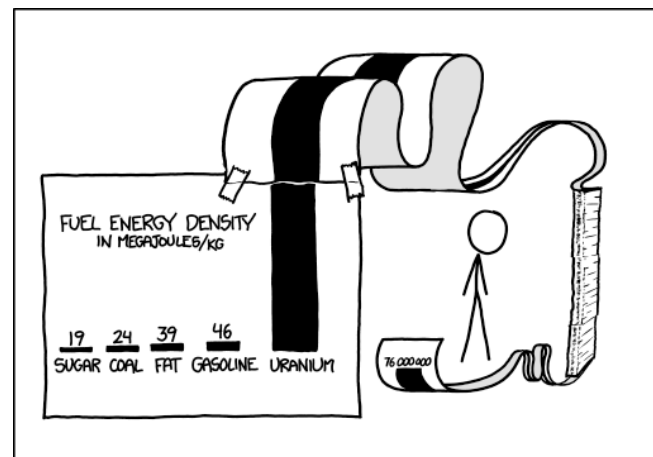
assuming that the original two particles are at rest, and show that the condition for electron capture is the same as (17.84) except that the term $2m_e$ is missing

c) The mass of ^{231}U is 231.03626 u, while that of ^{231}Pa is 231.035886 u. Show that ^{231}U can decay by electron capture, but not by β^+ emission.

17.27) Use the data in Appendix D to find the kinetic energy released in each of the following conceivable decays:



Which of these processes is possible? (Note: You will find that the last one is possible. However, its probability is so small compared to α decay, that it has not been observed.)



SCIENCE TIP: LOG SCALES ARE FOR QUITTERS WHO CAN'T FIND ENOUGH PAPER TO MAKE THEIR POINT PROPERLY.

¹ Taylor, Zafiratos, & Dubson, *Modern Physics for Scientists and Engineers*, 2nd Edition, Pearson, Prentice Hall, 2004