Homework Set 25: Nuclear Masses and Energies

Due Monday, April 21, 2025

Problems from or after TZDII[1]

16.31) Enlarge Fig. 16.11 to include the nuclei ^{12}Be and ^{12}O. By how much (in terms of $\triangle$E shown in Fig. 16.11) does the energy of each isobar with $Z \neq N$ exceed the energy of ^{12}C?

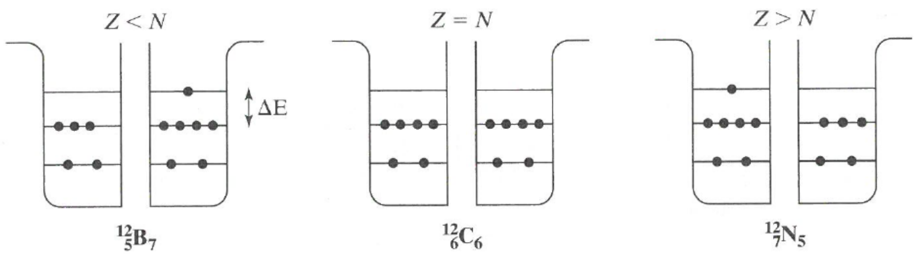


FIGURE 16.11
The ground states of the three isobars ^{12}B, ^{12}C, and ^{12}N. Because of the Pauli principle, the two nuclei with $Z \neq N$ have higher energy by the amount shown as ΔE.

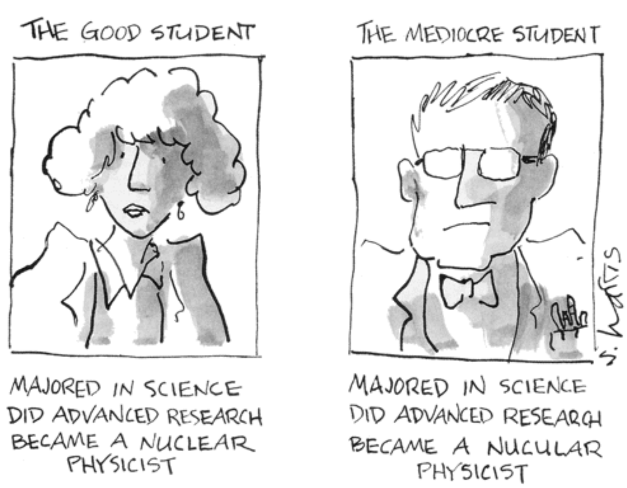
16.33) a) Find the mass (in u) of the ^{4}He atom in Appendix D.

b) Find the mass of the ^{4}He nucleus to 7 figures (but ignore corrections due to the atomic electrons' binding energy … TAKE $m_{nuc} = m_{atom} - m_{e-}$).

c) Do any of the seven figures change if you take into account the electrons' binding energy (about 80 eV total)?

16.37) a) The proton separatin energy S_p (energy to remove one proton) for ^{198}Hg is 7.1 MeV. Given that the total binding energy of ^{197}Au is 1559.4 MeV, find thet total binding energy of ^{198}Hg.

b) Compare your answer with the answer obtained directly from the mass of ^{198}Hg given in Appendix D.



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

Atomic and nuclear masses and binding energy

Atomic masses include masses of the nucleus and electrons, plus the electron binding energy

$$m_{\text{TZDII Appendix D}} = m_{atom} = m_{nuc} + Zm_e = Nm_n + Zm_p + Zm_e$$

$$m_{atom} = Nm_n + Z\left(m_p + m_e\right) = Nm_n + Zm_H$$

The mass of the nucleus is reduced by the binding energy of the nucleons

$$m_{nucleus} = Zm_p + Nm_n - \frac{B}{c^2} \qquad \text{TZDII (16.17)}$$

The binding energy, B, is thus

$$B = \left(Zm_p + Nm_n - m_{nucleus}\right)c^2 \qquad \text{TZDII (16.18)}$$

To account for the binding energy of the electrons to the nucleus in the atom's mass, change the mass of Z protons to the mass of Z hydrogen atoms (with that binding energy included) by adding & subtracting m_e,

$$B = \left(Zm_p + Nm_n - m_{nucleus}\right)c^2 + Z\left(m_e - m_e\right)c^2$$

Rearranging,

$$B = \left(Zm_p + Zm_e + Nm_n\right)c^2 - \left(m_{nucleus} + Zm_e\right)c^2$$

Substituting Zm_H for $Z(m_p + m_e)$ includes the binding energy of the electrons so that we can write $m_{nucleus} + Zm_e$ as the mass of the atom, giving

$$B = \underbrace{\left(Zm_H + Nm_n\right)}_{\text{the parts}}c^2 - \underbrace{\left(m_{atom}\right)}_{\text{the whole}}c^2 \qquad \text{TZDII (16.19)}$$