(12.11) In an experiment one hopes to produce the long-lived (2.6 y) ^{22}Na through a d,2n-reaction on neon. What is (a) the Q-value, (b) the threshold energy, (c) the Coulomb barrier height, and (d) the minimum deuteron energy for the reaction? The mass excesses (in keV) are -5185 for ^{22}Na and -8027 for ^{22}Ne.

First data and units

$$MeV := 1.60217733 \cdot 10^{-13} \cdot joule \qquad\qquad amu := 1.6605402 \cdot 10^{-27} \cdot kg$$

$$M_n := 1.00866490 \cdot amu \qquad\qquad M_d := 2.014102 \cdot amu$$

Then masses from the given mass excesses:

$$M_{Ne} := 22 \cdot amu - \frac{8.027 \cdot MeV}{931.5 \cdot \dfrac{MeV}{amu}} \qquad\qquad M_{Na} := 22 \cdot amu - \frac{5.185 \cdot MeV}{931.5 \cdot \dfrac{MeV}{amu}}$$

(a)

$$Q := -931.5 \cdot \frac{MeV}{amu} \cdot \left(M_{Na} + 2 \cdot M_n - M_{Ne} - M_d \right) \qquad Q = -9.371 \cdot 10^{-13} \cdot joule \qquad Q = -5.85 \cdot MeV$$

(b)

$$E_{tr} := -Q \cdot \left(\frac{M_{Na} + M_d}{M_{Na}} \right) \qquad \text{The ( ) contains the recoil correction} \qquad E_{tr} = 6.38 \cdot MeV$$

(c) $\quad A_1 := 2 \qquad Z_1 := 1 \qquad A_2 := 22 \qquad Z_2 := 10$

$$E_{cbmin} := 1.109 \cdot \left(A_1 + A_2 \right) \cdot \frac{Z_1 \cdot Z_2}{A_2 \cdot \left(A_1^{\frac{1}{3}} + A_2^{\frac{1}{3}} \right)} \cdot MeV \qquad\qquad E_{cbmin} = 2.98 \cdot MeV$$

(d) Because E_{cbmin} is less than E_{tr} and the change in coulomb energy is included in Q we have:

$$E_{proj} := E_{tr} \qquad\qquad E_{proj} = 6.38 \cdot MeV$$