(13.1) In a small linear accelerator containing 30 stages, $He^{2+}$ ions are accelerated by a 150 kV, 100 MHz RF source. The ions are used to bombard a metal target to induce a specific reaction. (a) What is the proper length of the last drift tube? (b) What is the maximum projectile energy achieved? (c) What is the heaviest target in which a nuclear transformation can be induced (no tunneling)?

Basic definitions of units and constants:

$q_e := 1.6021773 \cdot 10^{-19} \cdot coul$ $\quad c_{light} := 299792458 \cdot m \cdot sec^{-1}$ $\quad MeV := 1.60217733 \cdot 10^{-13} \cdot joule$

$amu := 1.6605402 \cdot 10^{-27} \cdot kg$ $\quad N_A := 6.0221367 \cdot 10^{23} \cdot mole^{-1}$ $\quad kV := 1000 \cdot volt$

$M_e := 5.485799 \cdot 10^{-4} \cdot \frac{gm}{mole}$ $\quad M_{He} := 4.002603 \cdot \frac{gm}{mole}$

Data for the accelerator:

$E_{acc} := 150 \cdot kV$ $\quad n_{stages} := 30$ $\quad z := 2$ $\quad f_{RF} := 100 \cdot MHz$

$\lambda := \frac{c_{light}}{f_{RF}}$ $\quad m_0 := \frac{M_{He} - z \cdot M_e}{N_A}$ $\quad m_0 = 6.645 \cdot 10^{-27} \cdot \text{kg}$

Calculations:

**(a)** $k_x := \frac{q_e \cdot z \cdot E_{acc}}{m_0 \cdot c_{light}^2}$ $\quad L_{30} := \frac{\lambda}{2} \cdot \sqrt{1 - \left(n_{stages} \cdot k_x + 1\right)^{-2}}$ $\quad L_{30} = 10.4 \cdot cm$

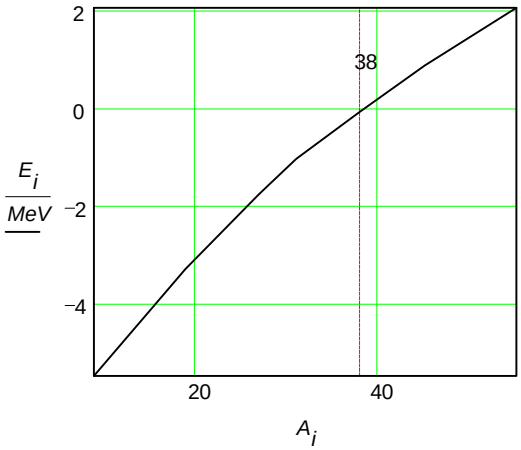
**(b)** $E_{proj} := n_{stages} \cdot E_{acc} \cdot z \cdot q_e$ $\quad E_{proj} = 9 \cdot MeV$

**(c)** $A_1 := 4$ $\quad Z_1 := 2$ $\quad i := 1 .. 8$ Make a Table of possible targets and test each value:

$A_i :=$ $\quad Z_i :=$

| $A_i$ | $Z_i$ |
|---|---|
| 9 | 4 |
| 19 | 9 |
| 23 | 11 |
| 27 | 13 |
| 31 | 15 |
| 38 | 18 |
| 45 | 21 |
| 55 | 25 |

eqn.(12.14) $E_i := \left[1.109 \cdot \left(A_1 + A_i\right) \cdot \frac{Z_1 \cdot Z_i}{A_i \cdot \left[A_1^{\frac{1}{3}} + \left(A_i\right)^{\frac{1}{3}}\right]} - 9\right] \cdot MeV$




Heaviest target about $^{38}Ar$ ($Z$ for $A$ from Table above)