Problem 1.

Use the NIST ASTAR to find the range of a 10 MeV alpha particle, and then use the range values at lower energies to determine at what depth a 10 MeV/nucleon alpha particle has traveled 99% of its range. Do the same for a 20 MeV/nucleon alpha and 50 MeV/nucleon alpha. Use this information for your semester stopping power assignment to help guide you in determining a lower energy limit/cutoff when calculating ranges.

Solution

T	CSDA	1% CSDA	T′
10 MeV	1.13×10^{-2} cm	1.13×10^{-4} cm	7.00×10^{-2} MeV
40 MeV	1.240×10^{-1} cm	1.240×10^{-3} cm	2.25 MeV
80 MeV	4.287×10^{-1} cm	4.287×10^{-3} cm	5.5 MeV
200 MeV	2.240 cm	2.240×10^{-2} cm	15 MeV

Table 1: Estimated ranges after 99% energy loss

From ASTAR, a 10 MeV α particle travels 1.13×10^{-2} cm in water. At the time that it has travelled 99% of this range, it has an energy of 7×10^{-2} MeV. Similar results are summarized in table 1

Problem 2. Anderson 4.2

Use Eqution 4.13 to calculate the range of a 5 MeV alpha particle in N_2 gas at 760 mmHg pressure. Assume that the exponential integral at T_1 (low-energy limit) and $R_1(T_1)$ can be neglected.

$$\begin{aligned} R &= \frac{Mc^2 I^2}{32 z^2 \pi r_0^2 \left(m_e c^2\right)^3 N_A \left(Z/M_m\right) \rho} \int_{u_1}^{u_0} \frac{du}{\ln u} + R_1\left(T_1\right) \\ &= \frac{Mc^2 I^2}{32 z^2 \pi r_0^2 \left(m_e c^2\right)^3 N_A \left(Z/M_m\right) \rho} \left[\mathrm{Ei}\left(\ln u_0\right) - \mathrm{Ei}\left(\ln u_1\right)\right] + R_1\left(T_1\right) \end{aligned} \tag{4.13}$$

with

$$u = \left(\frac{4 m_e c^2 \tau}{I}\right)^2 = \left(\frac{4 m_e \cancel{c^2} T}{I M \cancel{c^2}}\right)^2 \tag{1}$$

Solution

See attached addendum for calculations.

$$\text{R} = 3.04$$

Problem 3. Anderson 4.5

Calculate the ratio of the range of a 14 MeV $^{14}N^{+++}$ ion to the range of a 1 MeV proton. Use equation 4.18.

$$(R\rho)_b \approx \frac{(M/z^2)_b}{(M/z^2)_a} (R\rho)_a \tag{4.18}$$

Solution

We know that for particles with similar values of $\tau = T/mc^2$, equation 4.18 can be used to compare Range-density values. Therefore:

$$\begin{aligned}(R\rho)_b &\approx \frac{(M/z^2)_b}{(M/z^2)_a} (R\rho)_a \\ &\approx \frac{(14/3^2)_b}{(1/1^2)_a} (R\rho)_a \\ &\approx 1.56\,(R\rho)_a\end{aligned}$$

The 14 MeV $^{14}N^{+++}$ ion will travel approximately 1.56 times further than the 1 MeV proton.

Problem 4.

Use the NIST PSTAR utility to do the following: produce a Bragg Curve for 250 MeV protons passing through a variable water column, as measured by two air ionization chambers, each 1 cm thick. Neglect energy loss in the ion chamber windows and in any air gaps between the ion chambers and water column. NIST states a 250 MeV proton ranges out in about 38 cm of water, so calculate the ratio of the ion chamber currents at 0 cm, 10 cm, 20 cm, 30 cm, 35 cm, 36 cm, 37 cm and 38 cm of water between the ion chambers.

Assume dry air in the ion chambers at a density of 0.0012 g/cm^3. More details about this problem will be covered in class.

Solution