AP 4010 Introduction to Nuclear Science
Fall 2004

Homework Assignment 2: Due September 28, 2004

1. Do any four of the first six problems at the end of Chapter 5 in Lilley's *Nuclear Physics*, either Problem 5.1, 5.2, 5.3, 5.4, 5.5, or 5.6. [Again notice: the answers are in Appendix G, so show the essential steps of your solution.]

2. Classical Rutherford scattering theory gives a relationship between the scattering angle and the impact parameter as

$$\tan(\theta/2) = \frac{1}{2}\left(\frac{b^*}{b}\right)$$

where b is the impact parameter and b^* is the closest distance of approach (for head-on collisions) = $z_1\, z_2$ 1.44 fm/E(MeV) = $z_1\, z_2\, e^2 / 4\pi\varepsilon_o$.)

Assuming that energetic particle is far from the scattering center (so that b is large and θ is small), derive the approximate relationship that $\theta \sim b^* / b$. [Hint: $\theta \sim$ (final perpendicular momentum)/(incident momentum) and see Prob. 5.2.]

3. When the mass of the charged particle is comparable to the mass of the fixed scatterer, then the Rutherford formula must be modified. With M = the mass of the fixed scattering particle, the differential cross section becomes

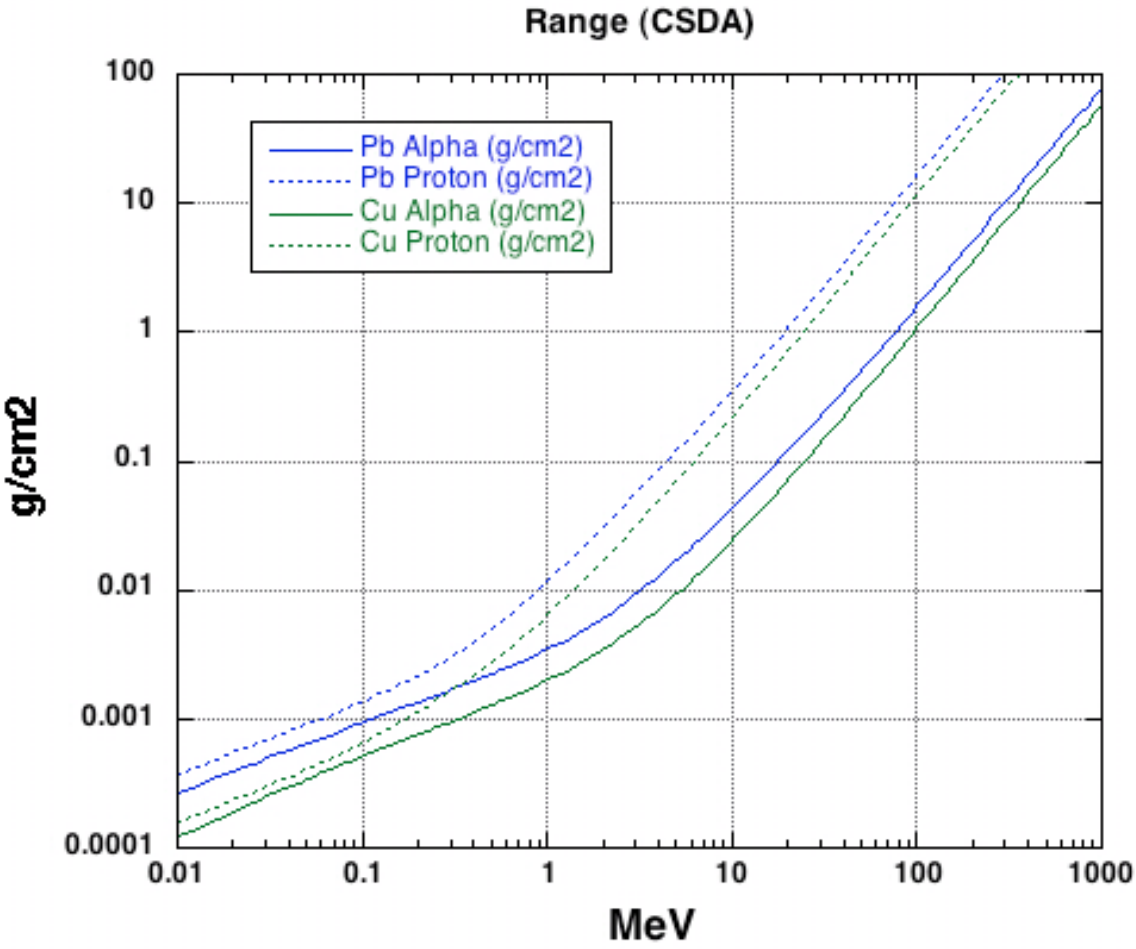
$$\frac{d\sigma}{d\Omega} = \left.\frac{d\sigma}{d\Omega}\right|_{M\to\infty} \times 4\,\frac{\left\{\cos\theta \pm [1-(m/M)^2\sin^2\theta]^{1/2}\right\}^2}{[1-(m/M)^2\sin^2\theta]^{1/2}}$$

Use this expression to find the maximum scattering angle for alpha particles impinging onto protons.

4. From the NIST range and stopping power website,
http://physics.nist.gov/PhysRefData/Star/Text/contents.html
are plotted (on the next page) the range of protons and alpha particles in copper and lead.

Examine the figure, and use your understanding of the ratio of the range of energetic charged particles to explain the variation in the four range curves in terms of the scaling factor, M / z^2, and the particle speed (proportional to energy/M).

Finally, estimate the range of a 30 MeV deuteron in both Cu and Pb.



Range data from the NIST website:
http://physics.nist.gov/PhysRefData/Star/Text/contents.html

The CSDA range uses the "continuous slowing-down approximation" to determine the range of the particle's track. This is longer than the "projected range" that indicates the depth to which a particle will penetrate.