Exercise: Classical and Semiclassical Scattering

Consider the collision of the projectile nucleus at the laboratory energies considered in the list below (just do the data corresponding to your name). This nucleus collides with a target of ^{206}Pb. Projectile and target interact with the Coulomb potential, plus a nuclear potential that is given by a Volume Woods Saxon form, with $V_0 = -150$ MeV, $r_0 = 1{,}15$ fm and $a = 0{,}80$ fm. The potential radius is given by $R = r_0(A_1^{1/3} + A_2^{1/3})$. The Coulomb radius $r_c = r_0$.

1. Introduce these data on the Theo4EXP on line application to perform the classical scattering calculation of deflection functions. Download the values of the potential and obtain from them the value of the Coulomb barrier energy and its radius. Compare them with the approximate formulae described in the notes. Plot the potential, along with the energy in the centre of mass system. Download the values of the deflection function and obtain the values of the rainbow impact parameter and angle. Plot the values deflection function, along with the analytic Coulomb deflection function. Discuss the differences. Describe the qualitative behavior that you expect for the differential cross sections at scattering angles smaller, around, and larger than the rainbow angle

2. Consider only the point-Coulomb interaction and the energy in order to make analytic calculations. Obtain the values of the centre of mass energy, the Coulomb scale parameter a_0, the distance of closest approach in a head on collision and the Sommerfeld parameter η. Indicate, on the basis of these values, if you expect that the classical approximation is valid, and if the nuclear interaction will play a role. Determine the impact parameters, the distance of closest approach, and the differential cross section corresponding to the scattering angles, in the centre of mass system, 30.0, 60.0, 90.0, 120.0, 150.0 and 180.0 degrees. Discuss the minimum angle below which the nculear interaction will not play a role.

3. Consider the inelastic excitation from the ground state to the first excited state (or resonance) indicated in the table. Indicate what electric multipole matrix element will be dominant for the transition. Evaluate the Coulomb adiabaticity parameter ξ for the transition. Find in the literature the reference for the experimental value, or the theoretical estimate, for the relevant $B(E\lambda)$ value from the ground state to the excited state, indicating what experiment, or what theoretical argument, was used to obtain it. Obtain the value of the inelastic differential cross section, with the proper units, as a function of the Coulomb integral $f_\lambda(\theta, \xi)$ (See the notes on classical and semiclassical scattering).

Note: Express all the numerical values obtained with the proper units, and with 4 significant figures.

Student Letter 1st surname	Projectile	Lab energy MeV	Ground state	Excited state	Ex. energy MeV
A-B	^{6}Li	31.00	1+	3+	2.186
C-D	^{7}Li	31.00	3/2-	½-	0.4776
E-G	^{8}Li	31.00	2+	1+	0.9808
H-L	^{9}Li	31.00	3/2-	1/2-	2.691
M	^{7}Be	39.00	3/2-	½-	0.4291
N-Q	^{9}Be	39.00	3/2-	½+	1.684
R	^{10}Be	39.00	0+	2+	3.368
S-Z	^{11}Be	39.00	½+	½-	0.3200