Evaluation exercise: analysis of X(d,d)X* at 171 or 183 MeV

Guidelines:

- To facilitate the correction, include screenshots of the relevant Theo4Exp windows with the inserted parameters and calculated observables
- Experimental data and potential parametrizations can be found in Ref. 1: Korff *et al*, PRC 70 (2004) 067601; (https://doi.org/10.1103/PhysRevC.70.067601). Experimental data can be extracted from the EXFOR database.
- In the reference there are five nuclei for which elastic and inelastic cross sections are presented: ^{32}S, ^{70,72}Ge, ^{90}Sr and ^{116}Sn. Select one of these nuclei to study.

Part I: Elastic scattering

a) *Potential barrier.* For the potential of this work use set BC from Table II. For the Coulomb reduced radius use $r_c = 1.3$ fm. Note that the reduced radii correspond to formula $R = r_0^{ref} A_t^{1/3}$ and that both volume W_S and surface W_D imaginary terms have the same reduced radius and diffuseness. Also note that for the spin-orbit term the depth that must be input in R4E is **half** the value on the table, due a a different definition.

   Make a plot of the real (nuclear + Coulomb) and imaginary parts of the d+X potential. Obtain from the plot the height of the potential barrier V_b and the associated distance (R_b) and compare with the approximated formulas given in class.

b) *Differential cross section.* Compute, using its definition, the Sommerfeld parameter (η). From this parameter and the incident energy, do you expect that the elastic scattering correspond to any of the patterns studied in the course? Plot the ratio to the Rutherford cross section for the elastic scattering data as well as for the theoretical calculation and comment on the agreement. Keep in mind that the Rutherford formula must be expressed in mb (1 fm^2=10 mb).

c) *Grazing angular momentum.* Estimate the grazing angular momentum (ℓ_g) of the reaction from theoretical σ/σ_R angular distribution. Obtain also the grazing distance (R_g). Compare the extracted value of R_g with that obtained with the simple estimate studied in the course ($R_g = 1.44(A_p^{1/3} + A_t^{1/3})$ fm) and with $R_g = 1.44 A_t^{1/3}$ fm and comment on their consistency.

d) *Elastic S-matrix.* Plot the modulus of the S-matrix as a function of the orbital angular momentum ℓ. Explain its behaviour. Using the computed S-matrix, obtain an alternative estimate of the grazing angular momentum ℓ_g. Is this value consistent with the previous estimation?

e) *Classical calculation.* Perform the classical calculation and obtain the deflection function. Are there any rainbows or orbiting? At which angles?. Is the classical description accurate for this reaction? Justify the answer.

Part II: Inelastic scattering

Consider inelastic scattering to the first 2^+ excited state of the considered nucleus using the optical potential from the previous section. The values of angular momenta and energies of ground state and first excited state can be obtained from NuDat. The value of β_2 can be found at the beginning of the last page in the reference.

a) Compute the deformation length δ_2 for the real and imaginary parts of the potential and the value of $M_n(E2)$ using

$$M_n(E2) = \frac{3Z\beta_2 R_c^2}{4\pi} \tag{1}$$

$$\delta_2 = \beta_2 R_n \tag{2}$$

$$R_i = r_{0i} A_t^{1/3} \tag{3}$$

You don't need to consider the deformation of the spin-orbit potential.

b) Calculate the differential cross section for inelastic scattering. Does the shape of the calculated cross section agree with that of the experimental data? Does the magnitude?

c) Study the effects of the deformation of the Coulomb potential and the real and imaginary parts of the nuclear potential. Which ones give the largest contribution: Coulomb potential, real nuclear potential and/or imaginary nuclear potential? Would this answer have changed if the experimental data had been measured in other angular ranges?