

## Howework day 2: DWBA and CC calculations with collective models

### Useful resources:

- Fresco and Xfresco: [fresco.org.uk](http://fresco.org.uk)
- TUNL Nuclear Data Project: <http://www.tunl.duke.edu/NuclData/>
- Evaluated Nuclear Structure Data File ( ENSDF): <http://www.nndc.bnl.gov/ensdf/>
- Experimental Nuclear Reaction Data (EXFOR): <http://www.nndc.bnl.gov/exfor/exfor.htm>

### Exercise:

1. *Coupled-channels analysis of  ${}^7\text{Li}+{}^{208}\text{Pb}$  with a collective rotational model.* We plan to study the elastic and inelastic scattering of  ${}^7\text{Li}$  on  ${}^{208}\text{Pb}$  at  $E_{lab}=33$  MeV within a coupled-channels method, including the ground state ( $3/2^-$ ) and first excited state ( $1/2^-$ ) of  ${}^7\text{Li}$ , assuming that these two states are members of a  $K = 1/2$  rotational band. Consider Coulomb quadrupole couplings using the (intrinsic) reduced matrix element  $M_n(E2) = 5.06 e \text{ fm}^2$ . For the nuclear excitation, use the (intrinsic) *deformation lengths*  $\delta_2^{(r)} = 1.63 \text{ fm}$  and  $\delta_2^{(i)} = 1.91 \text{ fm}$ , for the real and imaginary parts, respectively.

For the real and imaginary parts of the central interaction between  ${}^7\text{Li}$  and  ${}^{208}\text{Pb}$ , consider a standard Woods-Saxon potential with the parameters of the table below ( $R_x = r_x(7^{1/3} + 208^{1/3})$ ).

System	$V_0$ (MeV)	$r_0$ (fm)	$a_0$ (fm)	$W_v$ (MeV)	$r_i$ (fm)	$a_i$ (fm)	$r_c$ (fm)
${}^7\text{Li}+{}^{208}\text{Pb}$	15.4	1.3	0.65	13.2	1.3	0.65	0.983

### Questions:

- (a) Calculate the elastic and inelastic angular distributions. Compare your results with the data from NPA614, 112 (1997).
- (b) Calculate the inelastic angular distribution, switching off the nuclear deformation ( $\beta_2 = 0$ ). Repeat the calculation including the nuclear deformation, but removing the Coulomb quadrupole couplings  $M_n = 0$ . Compare the results with the full calculation (i.e. including both kinds of couplings simultaneously) and interpret the results.
- (c) Using the value of  $M_n(E2)$ , derive the values of  $B(E2; 3/2^- \rightarrow 1/2^-)$  and  $Q$  (quadrupole moment). Compare with the experimental values:  $B(E2; 3/2^- \rightarrow 1/2^-) = 8.3 \pm 0.5 e^2\text{fm}^4$  and  $Q = -4.0 e \text{ fm}^2$ . In view of these results, what can we conclude regarding the validity of the rotational model?

2. *Collective model with general matrix elements.* Consider the reaction  $^{16}\text{O}+^{64}\text{Zn}$  at  $E_{c.m.}=35.2$  MeV, reported by Tenreiro *et al* [Phys Rev C53 (1996) 2870]. We want to study the inelastic channel corresponding to the excitation of the first excited state in  $^{64}\text{Zn}$  ( $E_x=0.992$  MeV,  $2^+$ ), using the coupled-channels formalism and the *collective model*. For the central part of the  $^{16}\text{O}+^{64}\text{Zn}$  potential, use the depths listed in Table IV (depths) and I (radii, diffuseness) of the referred paper. For the Coulomb excitation, we will consider the experimental value of the electric transition probability  $B(E2; 0^+ \rightarrow 2^+)=1680 e^2\text{fm}^4$ . The nuclear transition potential is obtained from the *derivative* of the central potential, multiplied by the reduced matrix elements of the deformation length operator (do *not* assume the rotational model). For the latter, use the values listed in Table IV of the referred paper ( $\beta R \equiv \langle 2^+ || \hat{\delta}_2 || 0^+ \rangle$ ) according to our notation).

**Questions:**

- (a) Estimate the height of the Coulomb barrier for this system.
- (b) Calculate the elastic and inelastic scattering angular distribution, and compare with the data from Tenreiro *et al* (these data can be obtained from the EXFOR database: <http://www.nndc.bnl.gov/exfor>) and included also at the course website.
- (c) Consider separately the effect of the nuclear and Coulomb excitation and compare the results with the full calculation (i.e. including both kinds of couplings simultaneously). Interpret the results.
- (d) Repeat the calculation using the DWBA approximation (ITER=1, IBLOCK=0) and see how the elastic and inelastic angular distribution changes, in comparison with the full CC calculation. In view of these results, what can we conclude about the importance of multi-step couplings?