# Hands-on session on the phenomenological R-matrix method: excel program talent_rmatrix2013.xlsm

1. General remarks
    a. The program can fit elastic, inelastic or transfer cross sections.
    b. See additional help in the sheet "HELP".
    c. Data on energy levels can be found at the TUNL web page http://www.tunl.duke.edu/nucldata/index.shtml.

2. Inputs
    a. **Sheet "Main"**: the program is launched from this sheet.
    b. **Sheet "input"**: R-matrix parameters.
    Each resonance is defined by at set 2 lines (must be repeated for each resonance).
    line 1:
    J= spin of the resonance (multiplied by 2 if half-integer)
    nres: the number of resonances in the partial wave
    ell=angular lomentum
    I=channel spin (multiplied by 2 if half-integer)
    line 2:
    Energy, width (in MeV)
    For inelastic scattering or transfer, line 1 is complemented by (ell, I) in the exit channel, and line 2 by the width in the exit channel.

    c. **Sheet with the data**: contains energy, cross section, and error in the 3 first columns. Cells e1:h1 and e2 are used to specify the reaction. Other cells are not used by the program.

3. Use of the program
    a. Several data sets can be fitted simultaneously (e.g. different angles, or elastic and inelastic). The name of the data sheet(s) must be introduced in row 19 of sheet "Main").
    b. The parameters that you want to fit must be introduced in row 28. These parameters correspond to the cell of the sheet "input". **If no cell number is introduced, there is no fit. The program uses the parameters in sheet "input".**
    c. Output: chi2, and parameters on row 33
    cross sections, starting from row 36

**Questions**

**1. $^{12}$C+p elastic scattering**

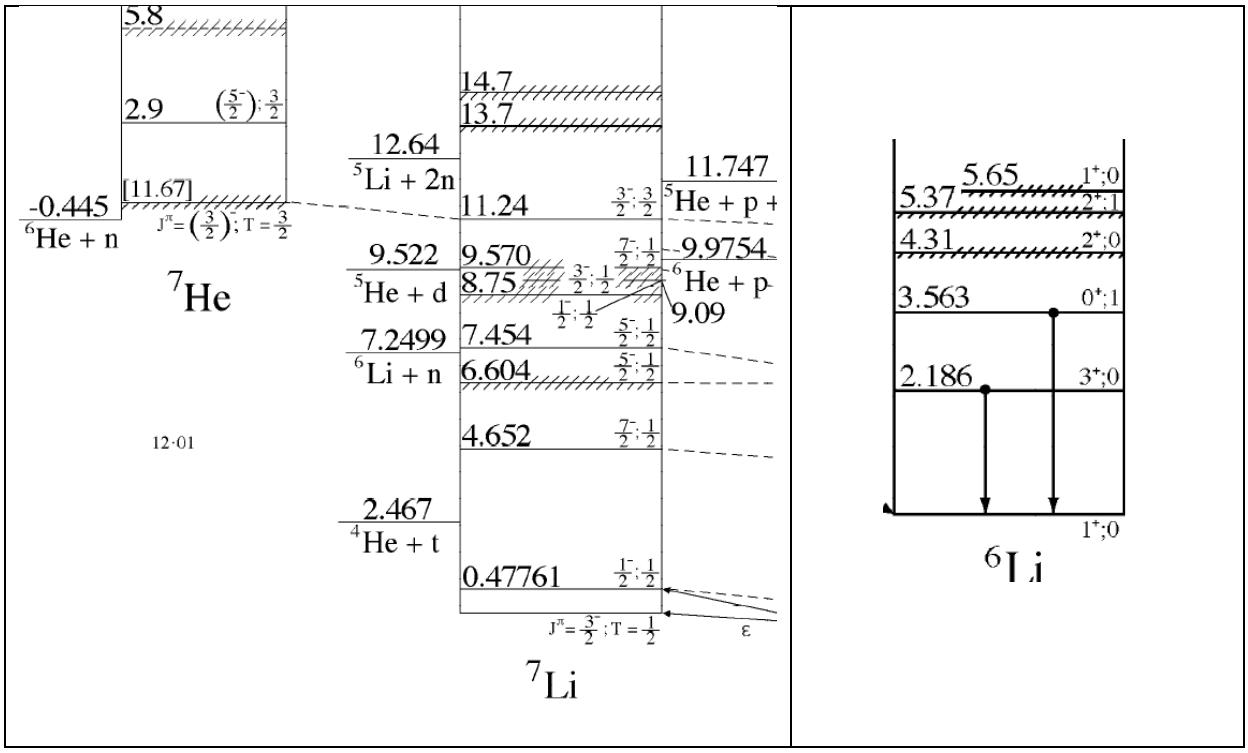
Experimental elastic cross sections for $^{12}$C+p are given in sheets "c12p_146" and "c12p_89" for $\theta_{cm} = 146.9^{o}$ and $\theta_{cm} = 89.1^{o}$ (taken from H.O. Meyer et al., Z. Phys. A279 (1976) 41). They cover the energy range from 0 to 2 MeV, where 3 resonances (1/2+, 3/2-,5/2+) are expected (see the $^{13}$N spectrum, e.g. at http://www.tunl.duke.edu/nucldata/chain/13.shtml)

- With rmax=5 fm, determine the properties (energy and proton width) of these 3 resonances by a fit of the data (use the experimental values as initial conditions).
- Check that the results (R-matrix parameters, cross sections) are nearly insensitive to the channel radius (reasonable variations).

**2. $^{6}$He(p,n) transfer**

The analog of the $^{7}$He ground state is a 3/2- resonance at Ex=11.24 MeV in $^{7}$Li (see figure below). This resonance has been investigated by Rogachev et al. (Phys. Rev. Lett. 92 (2004) 232502) by the $^{6}$He(p,n)$^{6}$Li reaction. The experimental data are given in sheet "he6pn".

- Determine the c.m. energy in the entrance channel, and the angular momentum of the resonance.
- This resonance has an isospin T=3/2. Determine the possible $^{6}$Li state(s) populated by the $^{6}$He(p,n)$^{6}$Li reaction, and the c.m. energy in the exit channel.
- The total width of the resonance is $\Gamma = 260$ keV. This width is composed of a proton and of a neutron partial widths: $\Gamma = \Gamma_{\mathrm{p}} + \Gamma_{n}$. From isospin selection rules one expects the ratio of the *reduced* widths: $\gamma_n^2/\gamma_p^2 = 2$.
  By using sheet "Coulomb" to compute the penetration factors, determine the expected values for $\Gamma_{\mathrm{p}}$ and $\Gamma_{n}$.
- Enter these values in sheet "input", and the appropriate masses and charges in sheet "Main" (check the option "Include inelastic or transfer channels"). Compare the R-matrix results with the data.
- The $^{6}$He+p elastic scattering at these energies is unknown experimentally. A sheet with "arbitrary" data is provided by he6pp. Compute the predicted elastic cross section at 180 degrees.
  Assume that the neutron width $\Gamma_n = 0$, and that the total width is given by the proton component: $\Gamma = \Gamma_{\mathrm{p}} = 260$ keV. Compare the elastic cross section.


5.8
2.9
$(\frac{5}{2}^-);\frac{3}{2}$
[11.67]
-0.445
$^6$He + n
$J^\pi=(\frac{3}{2}^-);T=\frac{3}{2}$
$^7$He
12·01
12.64
$^5$Li + 2n
9.522
$^5$He + d
7.2499
$^6$Li + n
2.467
$^4$He + t
14.7
13.7
11.24
9.570
8.75
7.454
6.604
4.652
0.47761
$\frac{3}{2}^-;\frac{3}{2}$
$\frac{7}{2}^-;\frac{1}{2}$
$\frac{3}{2}^-;\frac{1}{2}$
$\frac{1}{2}^-;\frac{1}{2}$
$\frac{5}{2}^-;\frac{1}{2}$
$\frac{5}{2}^-;\frac{1}{2}$
$\frac{7}{2}^-;\frac{1}{2}$
$\frac{1}{2}^-;\frac{1}{2}$
$J^\pi=\frac{3}{2}^-;T=\frac{1}{2}$
ε
11.747
$^5$He + p +
9.9754
$^6$He + p
9.09
$^7$Li
5.65
$1^+;0$
5.37
$2^+;1$
4.31
$2^+;0$
3.563
$0^+;1$
2.186
$3^+;0$
$1^+;0$
$^6$Li