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Practical exercises

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Workshop on Nuclear Data for Analytical Applications

Exercise 1. Identification of peaks in the d + ^{27}Al spectrum

Figure shows a spectrum obtained with deuterons impinging on a ^{27}Al foil. Deuterons, protons and alphas can be emitted in the exit channel. Identify peaks in the marked channels.

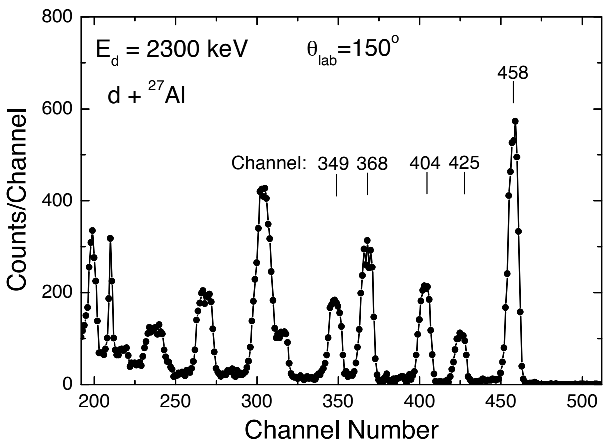
Q-values can be calculated at http://nucleardata.nuclear.lu.se/database/masses/ or http://www.nndc.bnl.gov/qcalc/.

The energies of low-lying states in the residual nuclei can be taken from http://www.nndc.bnl.gov/nudat2/ or http://www.nndc.bnl.gov/ensdf/.

Use Excel script E3.xls to calculate energies of the outgoing particles.

The energy corresponding to the channel number is defined as E=14.687·(Channel+13.7) keV.

Assume that in order to distinguish between protons and alphas the outgoing particles are registered with a "thin" silicon detector. Use SRIM tables for ions range in matter to find what minimal detector thickness is needed for registering alphas. Estimate what energy will be deposited in the detector by different proton groups.



Exercise 2. Resonances in the nuclear reactions ^{1}H(^{19}F,αγ)^{16}O and ^{19}F(p,αγ)^{16}O

A strong resonance is observed in the ^{19}F(p,αγ)^{16}O reaction at a proton energy of 872.11 keV. Its reverse reaction, ^{1}H(^{19}F,αγ)^{16}O, has commonly been used for hydrogen analysis. Find the resonance energy for this reaction in which ^{19}F is a projectile.

Use that the corresponding kinetic energy $E_{\rm rel}$ of the colliding particles in their relative motion in the CM system is

$$E_{\rm rel} = \frac{M_2}{M_1 + M_2} E_0$$

where E_0 is the projectile energy in the lab frame of reference.

Take nuclei masses from http://www.nndc.bnl.gov/masses/mass.mas03 .

Estimate an error in the resonance energy if mass numbers are used in the calculations instead of atomic masses.

Find the 872.11 keV resonance width Γ for $^{19}F(p,\alpha\gamma)^{20}Ne$ in the Table 20.29 at http://www.tunl.duke.edu/NuclData/ . Note that the width is given in the c.m. system.

Find the 872.11 keV resonance width for the $^{1}H(^{19}F,\alpha\gamma)^{16}O$ reaction.

Exercise 3. Comparison between SIMNRA calculations with different sets of cross sections

Download cross-section files for $^{12}C(\alpha,\alpha)^{12}C$ at 165°±2° from IBANDL (http://www-nds.iaea.org/ibandl) into CrSec folder of SIMNRA. Add a SigmaCalc (http://www.surreyibc.ac.uk/sigmacalc/) file and relevant data from EXFOR to the CrSec folder.

Run SIMNRA, go to Options and Update Reaction List. Close SIMNRA and then run it again.

Calculate a spectrum for $^{12}C(\alpha,\alpha)^{12}C$ elastic scattering at 165° and E_α=6000 keV from infinitely thick target with 10 keV/channel using SigmaCalc cross-sections.

Save the results as a *.nra file. Open the file using any text editor and remove all the strings preceding simulated spectrum. Rename the file into *.dat. Now this spectrum is regarded as quasi experimental. Read it in SIMNRA as ASCII file.

Calculate spectra with different cross-sections data and compare the results.

Exercise 4. Conversions between $^{3}He(d,p)^{4}He$ and $^{2}H(^{3}He,p)^{4}He$ cross-sections

The problem is to establish the correspondence between the $^{3}He(d,p)^{4}He$ and $^{2}H(^{3}He,p)^{4}He$ reactions. The cross-section maximum is reached in the $^{3}He(d,p)^{4}He$ reaction at about 420 keV. Following the procedure applied in Exercise 2 it is easy to find that the cross-section maximum in the $^{2}H(^{3}He,p)^{4}He$ reaction occurs at

$$E_{lab}^{^3He} = E_{lab}^{d}\frac{M_{^3He}}{M_d} = 420\frac{3.016029}{2.014101} = 629 \text{ keV} .$$

In the CM frame of reference, the cross sections for the direct and reverse reactions at any given energy are the same. The transformation of the $^{3}He(d,p)^{4}He$ cross section into the CM system is calculated using the Excel script CM_LAB_Q.xls with $M_1 = M_d$ and $M_2 = M_{^3He}$. To determine the result for the $^{2}H(^{3}He,p)^{4}He$ reaction, the cross section obtained in the CM system for $^{3}He(d,p)^{4}$ is reverted into the laboratory frame using the same script but assuming $M_1 = M_{^3He}$ and $M_2 = M_d$. As the end results, the calculations should show that, when protons are registered at a 130° laboratory angle and the cross section for the $^{3}He(d,p)^{4}He$ reaction is assumed to be 56.5 mb/sr at a resonance energy of E_d = 420 keV (taken from the EXFOR database, http://www-nds.iaea.org/exfor/), the $^{2}H(^{3}He,p)^{4}He$ reaction gives 55.6 mb/sr, for a resonance energy of $E_{^3He}$ = 629 keV. The difference between these two differential cross sections is small only because the reactions have a very high Q value (18.35 MeV).

Nuclear physics Internet resources relevant to IBA

The resource address	**Description**
http://www.nndc.bnl.gov/qcalc/	Q-value Calculator
http://nucleardata.nuclear.lu.se/database/masses/	Nuclear structure and decay data NuBase with the Q-value calculator
http://www.nndc.bnl.gov/ensdf/	Evaluated nuclear structure data file (ENSDF)
http://www.nndc.bnl.gov/nudat2/	Nuclear structure and decay data
http://nrv.jinr.ru/nrv/	Low energy nuclear knowledge base
http://www.nndc.bnl.gov/masses/mass.mas03	Atomic mass adjustment 2003
http://www.tunl.duke.edu/NuclData/	Energy levels of light nuclei, A=3-20
http://www-nds.iaea.org/ibandl/	IBA nuclear data library (IBANDL)
http://www-nds.iaea.org/exfor/	Experimental nuclear reaction data (EXFOR)
http://www.surreyibc.ac.uk/sigmacalc/	Evaluated differential cross sections for IBA (SigmaCalc)