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COMPARISON OF NEUTRON ELASTIC DIFFERENTIAL CROSS-SECTIONS FOR ^{60}Ni WITH INCIDENT ENERGIES 4.34 MeV, 4.92 MeV, 6.44 MeV AND 7.54 MeV

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Abstract

The neutron elastic differential cross-sections for ^{60}Ni with incident energies 4.34 MeV, 4.92 MeV, 6.44 MeV and 7.54 MeV are calculated by using SCAT2 computer code. Five optical model potential parameter sets for neutron reactions, Wilmore Hodgson, Bechetti Grenless, Ferer Rapaport, Bersillon Cindro and Madland are used to calculate the require elastic differential cross-sections. Experimental elastic differential cross-section data are obtained from EXFOR experimental nuclear reaction data Library. Comparisons of calculated and experimental elastic differential cross-sections for different optical model potential parameter sets are made in each incident neutron energy. The best fit optical model potential parameter sets for the reactions in accordance with experimental results are also discussed.

Keywords: Optical Model, Potential Parameter Set, Elastic Differential Cross-sections, Computer Code, Potential Depth Parameters, Form Factors

Introduction

There are many different models, which explain nuclear reactions. But the most well known models used in research works are optical, statistical and pre-equilibrium models. The present work concerns with optical model. In optical model, the nuclear potential is taken to be complex to describe absorption of particles by the nucleus. This is similar to physical optics where the refractive index is taken to be complex to describe absorption of light by translucent materials. Some part of wave can be reflected from the surface, some part can be absorbed inside the nucleus, and some part can be transmitted through the nucleus. Due to the similarity between nucleus and translucent material, the term "Optical Model" has been applied. There are two types of optical potential namely deformed and spherical potential. Deformed potential should be used for the nuclei in the region $40 \leq N \leq 112$ and $Z \leq 88$ due to their large spin values. For medium nuclei, $N \leq 34$ and $Z \leq 30$, it requires only to consider spherical optical potential. A spherical optical potential may consist of many adjustable parameters and one suitable set of these parameters can be called a set of parameterization [Enge H A, (1975)].

Spherical Optical Model

The spherical optical potential is generally written as

$$U(r) = V_c(r) - V_r f(r) - i[-4W_D g(r) + W_V f(r) + W_D' g'(r)] + \vec{\ell}.\vec{s} C_{so} V_{so} h(r)$$

where the six terms represent a Coulomb potential, a real volume potential, an imaginary surface potential, an imaginary volume potential, a second form of imaginary surface potential and a spin-orbit potential respectively. f(r), g(r), g'(r) and h(r) are the form factors. Five potential terms except Coulomb potential are adjustable in accordance with experiments.

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Optical Model Parameterizations

The adjustable values of optical model potential are called optical model parameters. V_r, W_D, W_V, W'_D and V_{so} are called depth parameters and their values may depend on charge and mass of target nucleus and incident energy.

The reduced radius, r_i and diffuseness or surface thickness, a_i, ($i = 1 \rightarrow 4$) are called geometric parameters which specify from factors of each potential. They may also have charge, mass and energy dependent values. a_i cause an effect on the slope of form factor. It is evident that a_i is less than r_i for the respective pair.

One of the long-standing tasks in the field of nuclear data evaluation is the search for a unique set of optical potential parameters, which can accurately describe as much experimental data as possible in wide regions of neutron energies and nuclear masses [Blatt J M, and V F Weiskoff, (1952)].

Angular Distributions for Neutrons

The shape elastic angular distribution is

$$\frac{d\sigma_{\mathrm{E}}}{\mathrm{d}\omega} = |A(\theta)|^2 + |B(\theta)|^2$$

$$A(\theta) = \frac{i}{2k}\sum_{\ell=0}^{\infty}[(\ell+1)(1-\eta_\ell^+) + \ell(1-\eta_\ell^-)]P_\ell(\cos\theta)$$

$$B(\theta) = \frac{-i}{2k}\sum_{\ell=0}^{\infty}(\eta_\ell^+ - \eta_\ell^-)]P_\ell^1(\cos\theta)$$

where the incident energy is expressed in MeV, the total cross section in barns and the differential cross section in barns/steradian [Kaplan I, (1962)].

The SCAT2 Computer Code

The first version of spherical optical model code SCAT 2 is created in 1977 in order to produce evaluated nuclear data files. New 1991 version of SCAT 2 program includes 19 subroutines.

Input part of the program includes physical system: charge and mass of incident particle and target nucleus and optical model potential parameters [Bersillon O, (1992)].

Application of the Code

The SCAT2 computer code uses two input files and four output files. The first input file is a collection of the five file names of second input file and the four output files that we have named particularly. The name of this first file is SCAT2.DAT in PC version. We need to describe the names of five following files in SCAT2.DAT.

1. The input data file
2. The output (listing) file
3. The transmission coefficient file
4. The temporary file
5. The summary file

The usual extension names of these files are *.dat, *.lst, *.gna, *.scr and *.sum.

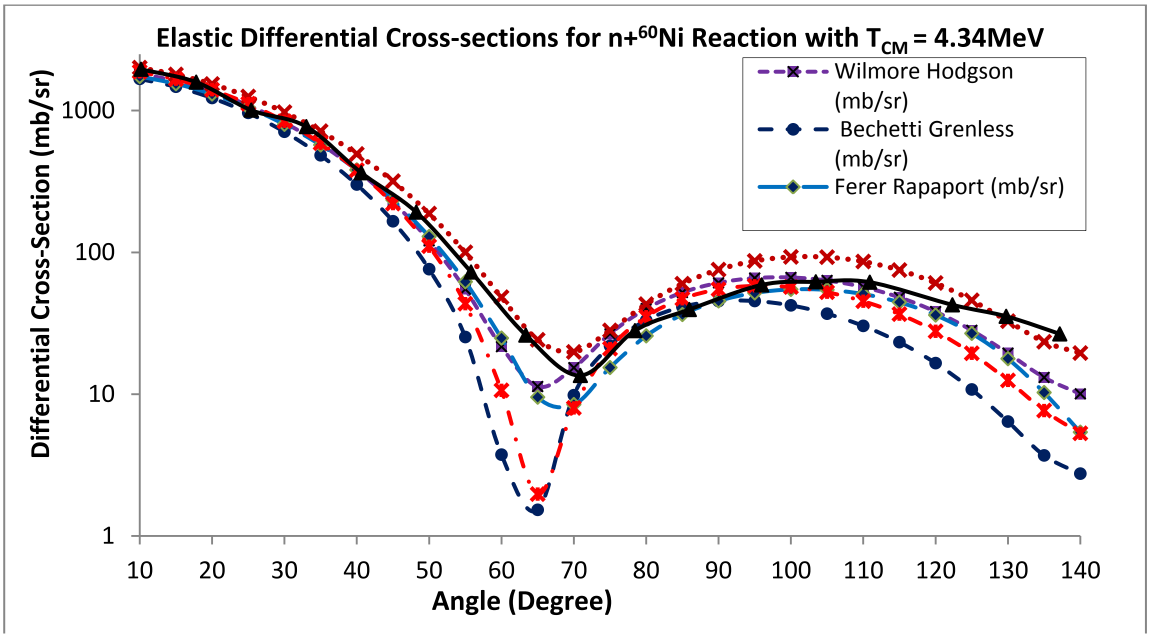

Figure 1 Elastic Differential Cross-sections for n+^{60}Ni Reaction with T(CM) = 4.34MeV

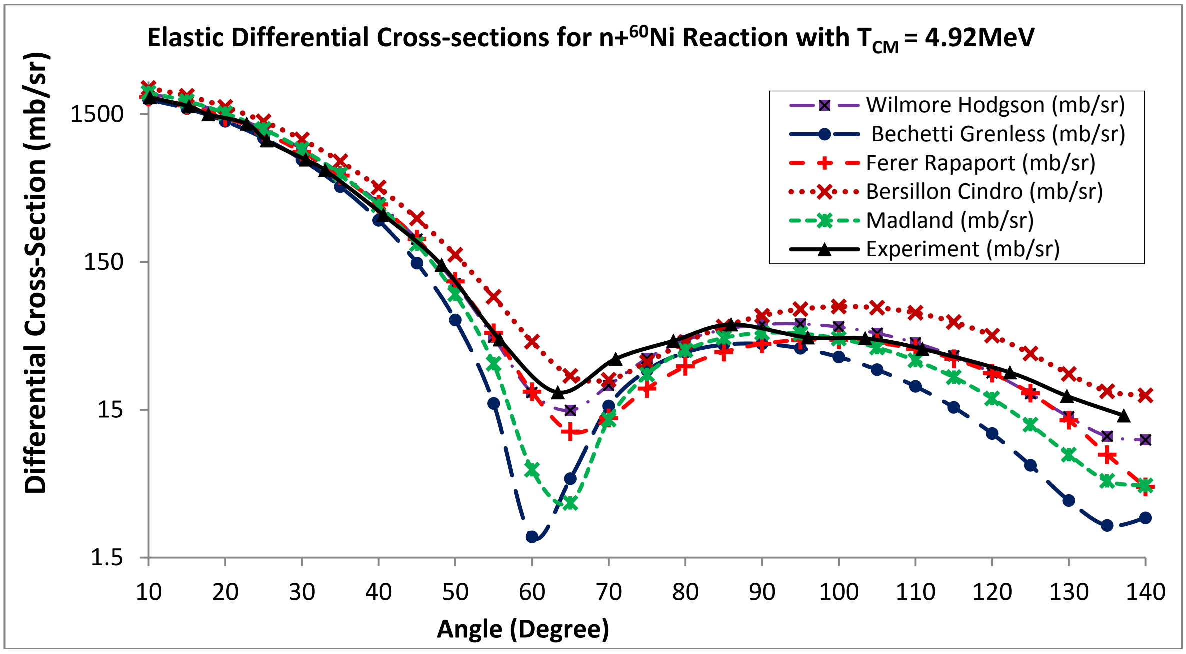

Figure 2 Elastic Differential Cross-sections for n+^{60}Ni Reaction with T(CM) = 4.92MeV

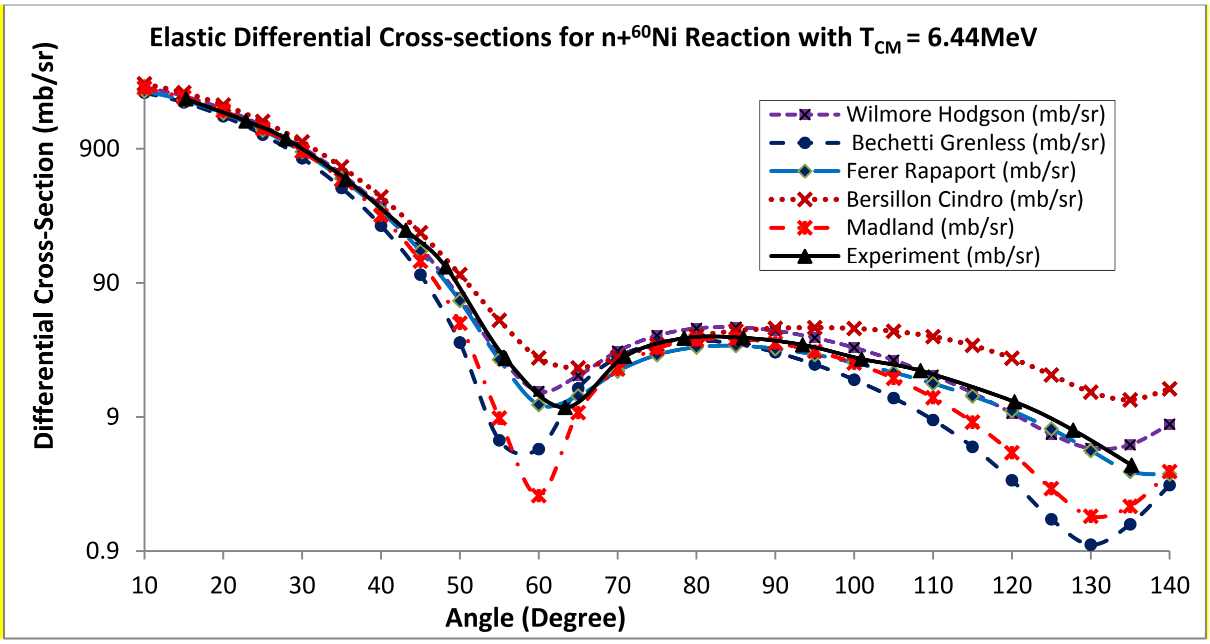

Figure 3 Elastic Differential Cross-sections for n+^{60}Ni Reaction with T(CM) = 6.44 MeV

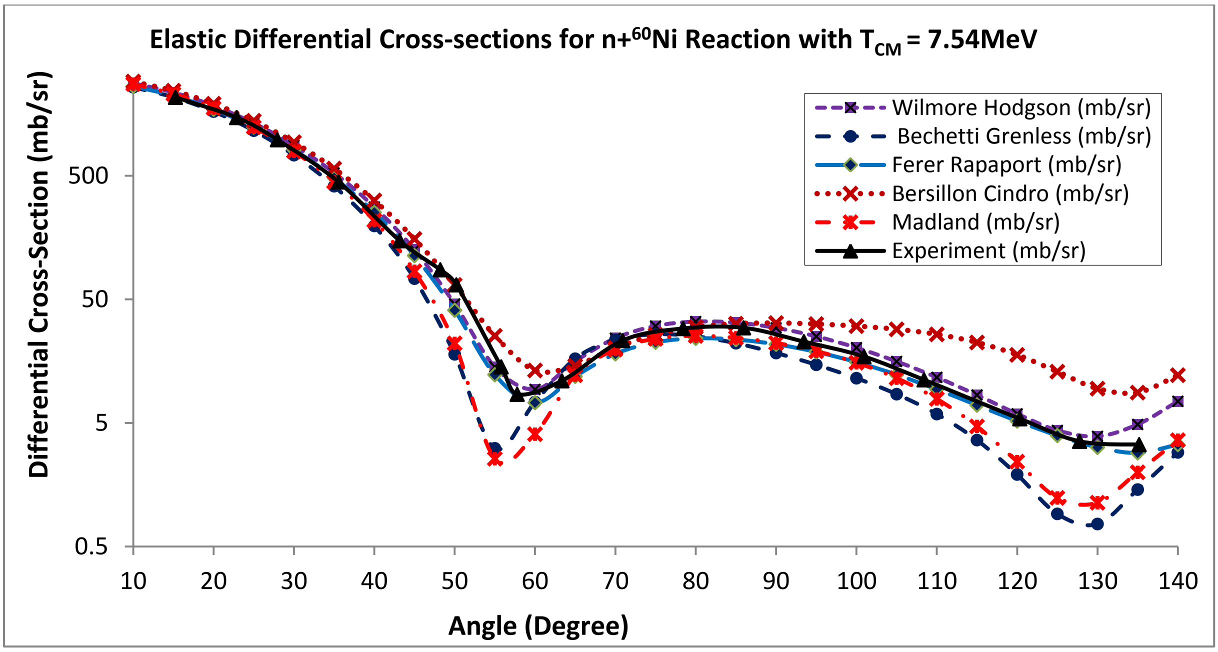

Figure 4 Elastic Differential Cross-sections for n+^{60}Ni Reaction with T(CM) = 7.54 MeV

Results and Discussion

For the reaction with incident neutron energy 4.34 MeV calculated elastic differential cross-sections obtained from Ferer Rapaport optical model potential parameters set are the most consistent with experimental elastic differential cross-sections. Calculated elastic differential cross-sections that are the second most consistent with experimental elastic differential cross-sections are those obtained from Wilmore Hodgson optical model potential parameters set. Third most consistent with experimental results are the results obtained from Bersillon Cindro optical model potential parameters set.

For the reaction with incident neutron energy 4.92 MeV calculated elastic differential cross-sections obtained from Wilmore Hodgson optical model potential parameters set are the most consistent with experimental elastic differential cross-sections. Calculated elastic differential cross-sections that are the second most consistent with experimental elastic differential cross-sections are those obtained from Ferer Rapaport optical model potential parameters set. The results obtained from Bersillon Cindro optical model potential parameters set are the third most consistent with experimental results.

Similar to the first case, calculated elastic differential cross-sections obtained from Ferer Rapaport optical model potential parameters set are the most consistent with experimental elastic differential cross-sections for the reaction with incident neutron energy 6.44 MeV. Calculated elastic differential cross-sections that are the second most consistent with experimental elastic differential cross-sections are those obtained from Wilmore Hodgson optical model potential parameters set. The results obtained from Bersillon Cindro optical model potential parameters set are the third most consistent with experimental results.

Similar to incident neutron energy 4.92 MeV, it was also found that the calculated elastic differential cross-sections obtained from Wilmore Hodgson optical model potential parameters set are the most consistent with experimental elastic differential cross-sections for the reaction with incident neutron energy 7.54 MeV. Calculated elastic differential cross-sections that are the second most consistent with experimental elastic differential cross-sections are those obtained from Ferer Rapaport optical model potential parameters set. The results obtained from Bersillon Cindro optical model potential parameters set are the third most consistent with experimental results.

Conclusion

For all four cases of incident neutron energies, it was found that the results obtained from Ferer Rapaport optical model potential parameters set are the most consistent with experimental results and the results obtained from Wilmore Hodgson optical model potential parameters set are the second most consistent with experimental results. Most of the calculated and experimental elastic differential cross-sections are nearly equal for scattering angles below 45 degree. Differences in calculated and experimental elastic differential cross-sections can be seen in scattering angles above 45 degree. For further research, calculations of reaction cross-sections, scattering cross-sections and total cross-sections for this reaction in different range of incident neutron energies should be made by using Ferer Rapaport optical model potential parameters set.

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