3 Summary

Based on the available experimental data of Re and neighbored nucleus W, we obtained a set of optimum optical potential parameters for $0.001 \le E_n \le 20$ MeV. With adjusted proton and alpha particle optical potential parameters, level density and giant dipole resonance parameters as well as K, all the cross sections of neutron induced reaction on $^{185,187,Nat}Re$ were obtained. Because the calculated results for many channels are in pretty agreement with existing experimental data, the predicted cross sections in energy range where there are no any experimental data are reasonable.

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Calculation of Cross Sections for n+^{63}Cu Reaction

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Abstract

Based on the relevant experimental data, and optical model, evaporation model, $J\pi$-dependent exciton model, and the pick-up mechanism of cluster pre-formation, neutron induced reaction cross sections, the energy spectrum, angular distribution, double differential cross section and γ-production data were calculated for ^{63}Cu at incident neutron energies below 20 MeV. The calculated results were compared with experimental data.

Introduction

Copper is an important structure material in nuclear engineering, the neutron monitor cross sections for bombarding copper are also important. The calculation of cross section for n+^{63}Cu reaction is necessary and interesting.

In Sec.1 the theories and parameters used in the calculation are described. The calculated results and analyses are given in Sec.2. Finally, a summary is given in Sec.3.

1 Theories and Parameters

The calculation was made with the semi-classical theory code UNF[1]. This program consisted of the optical model, the unified Hauser-Feshbach and exiton model. The pre-equilibrium nuclear reaction processes were described with the $J\pi$-dependent exciton model, while the equilibrium processes were described by the Hauser-Feshbach theory with width fluctuation correction. The discrete levels in multi particle emissions for all of open channels were included. For composite particle emissions, the pick-up mechanism of cluster pre-formation was included. The preequilibrium and direct reaction mechanisms of γ emission were also included in this program. The direct inelastic scattering cross sections were obtained by the collective excitation distorted wave Born approximation.

Based on experimental data from EXFOR library and recent information, the code APOM[2], with which the best neutron optical potential parameters can be searched automatically by fitting relevant experimental total, nonelastic scattering cross sections and elastic scattering angular distributions, was used to obtain a set of optimum neutron optical potential parameters of $^{63,65,\mathrm{Nat}}$Cu as follows:

$$V = 51.4652-0.2687E-0.008952E^2-24(N-Z)/A$$
$$W\mathrm{s} = \max\{0.0,\ 16.4146-0.2305E-12(N-Z)/A\}$$
$$W\mathrm{v} = \max\{0.0,\ -0.9637+0.1994E-0.005988E^2\}$$
$$U\mathrm{so} = 6.2$$
$$r_\mathrm{R}=1.2428,\quad r_\mathrm{S}=1.3732,\quad r_\mathrm{V}=1.5708,\quad r_\mathrm{SO}=1.2428$$
$$a_\mathrm{R}=0.7419,\quad a_\mathrm{S}=0.3010,\quad a_\mathrm{V}=0.5596,\quad a_\mathrm{SO}=0.7419$$

Using this set of neutron optical potential parameters, adjusting charged particle optical potential parameters and level density parameters, all cross sections of n+^{63}Cu reactions were calculated by the code UNF. The direct inelastic scattering data were calculated by the code DWUCK4[3].

2 Calculated Results and Analyses

The calculated results of neutron total cross sections and nonelastic cross sections for n+^{63}Cu reaction are in good agreement with the experimental data of n+^{Nat}Cu reaction. Fig.1 and 2 show the comparison of the calculated elastic scattering cross sections and angular distributions with experimental data for n+^{63}Cu reaction. The calculated values are in good agreement with experimental data. Based on the above fitting, a set of neutron optical potential parameters in the energy region 0.01 ~ 20 MeV for n+^{63}Cu reactions were determined as shown in Eq.(1).

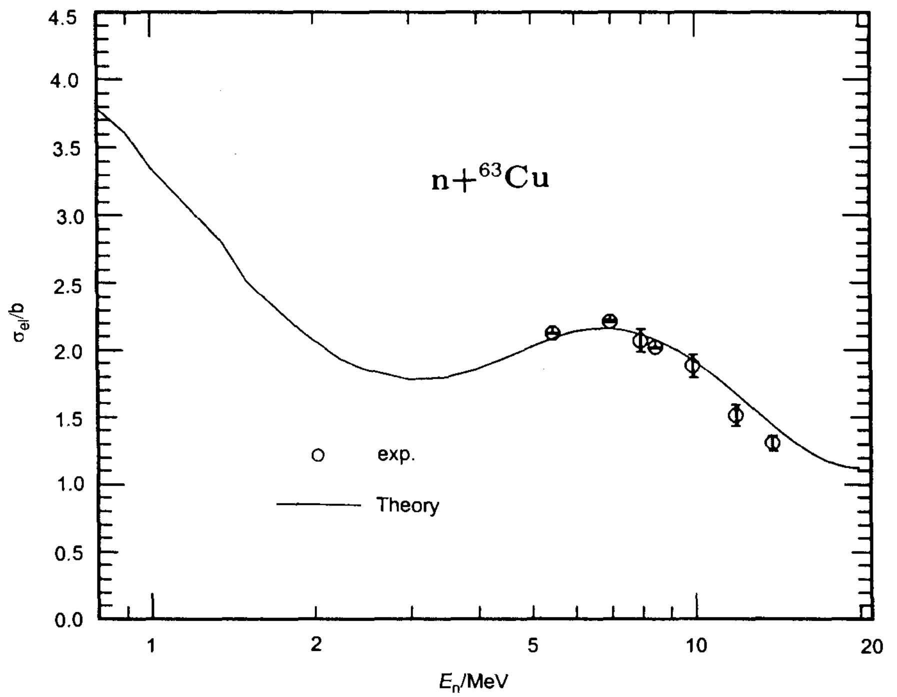

Fig. 1 The elastic scattering cross section of n+^{63}Cu reaction

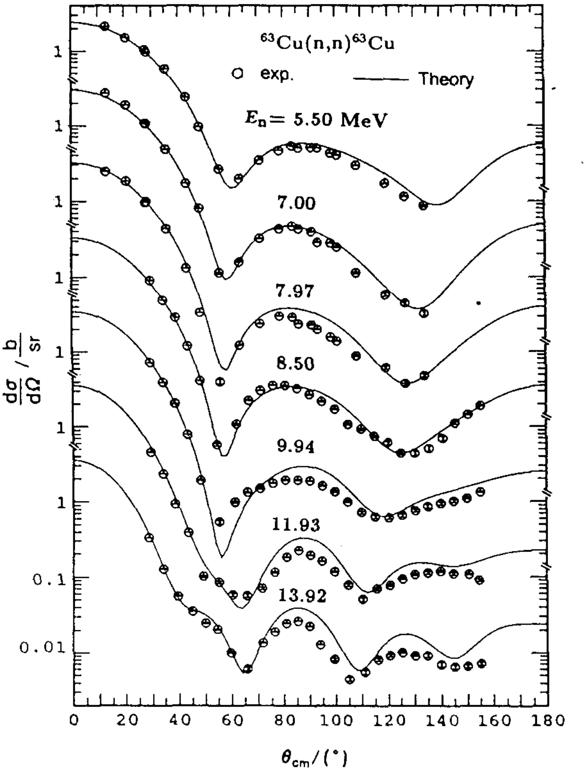

Fig. 2 The elastic scattering angular distribution of n+^{63}Cu reaction

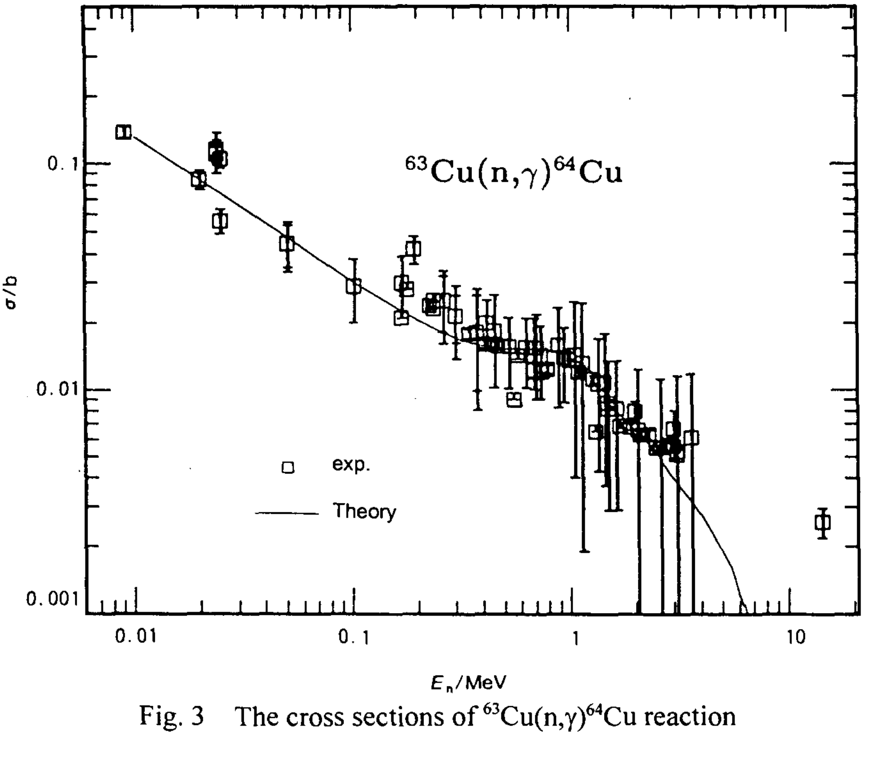

Fig. 3 The cross sections of ^{63}Cu(n,γ)^{64}Cu reaction

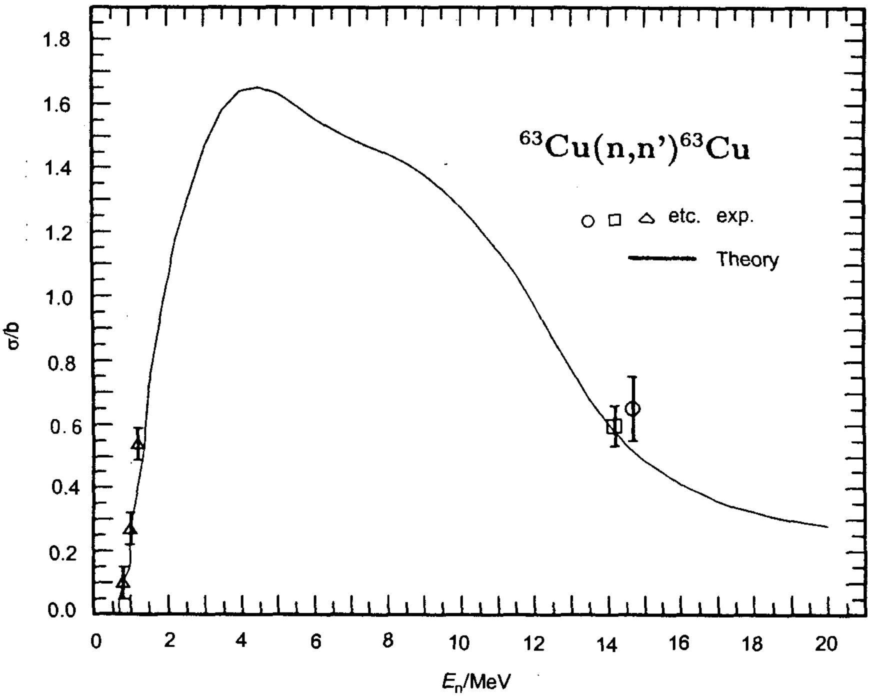

Fig. 4 The cross sections of ^{63}Cu(n,n')^{63}Cu reaction

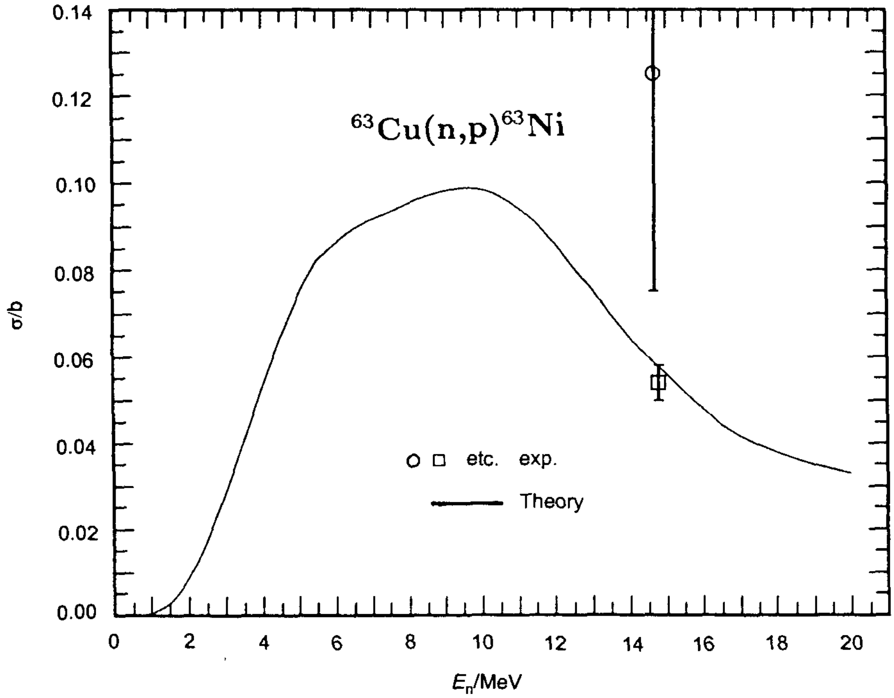

Fig. 5 The cross sections of ^{63}Cu(n,p)^{63}Ni reaction

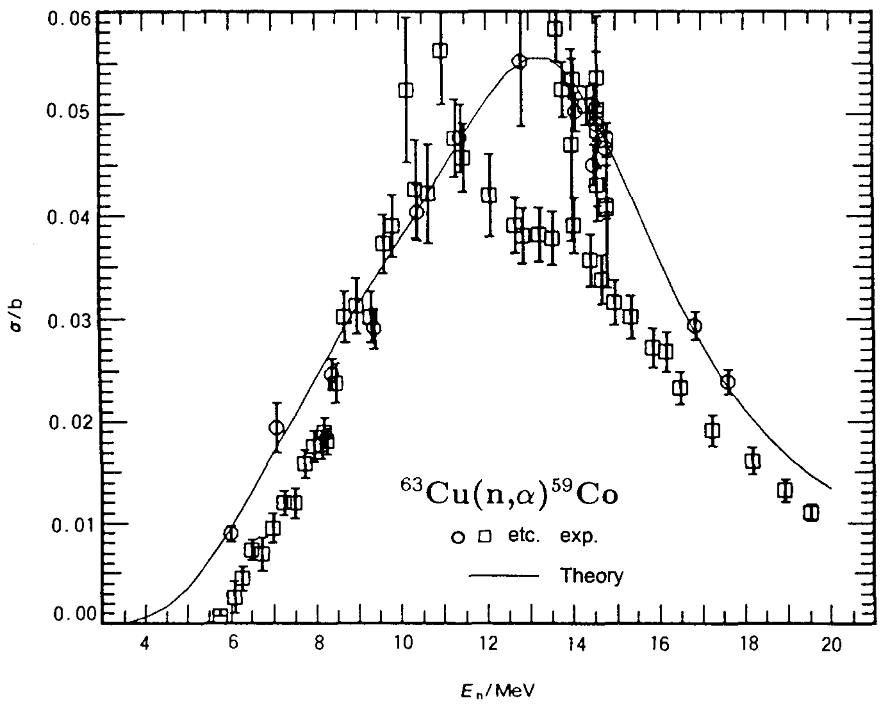

Fig. 6 The cross sections of $^{63}Cu(n,\alpha)^{59}Co$ reaction

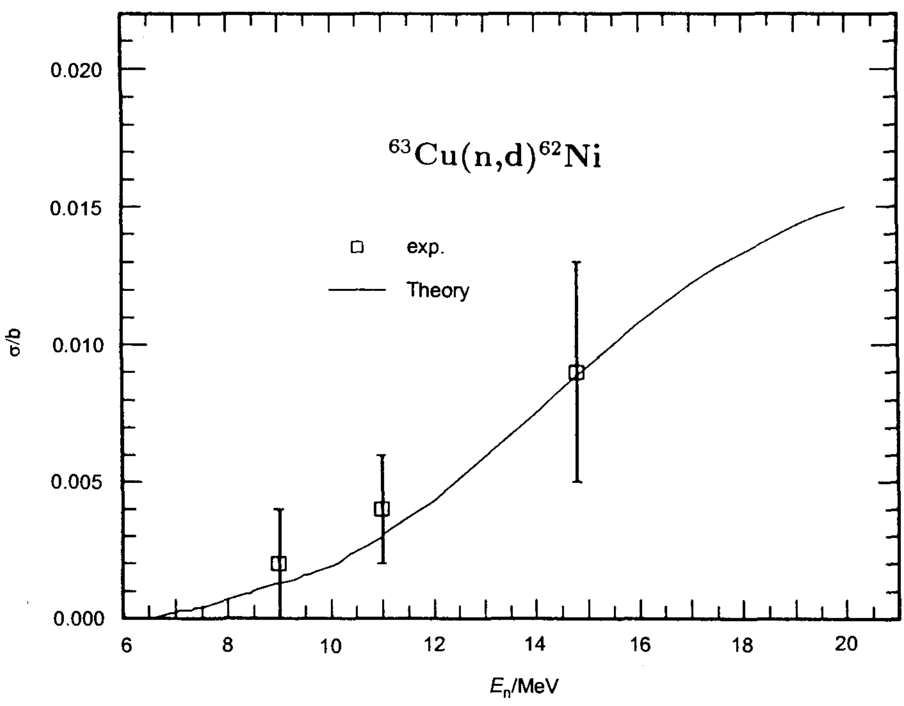

Fig. 7 The cross sections of $^{63}Cu(n,d)^{62}Ni$ reaction

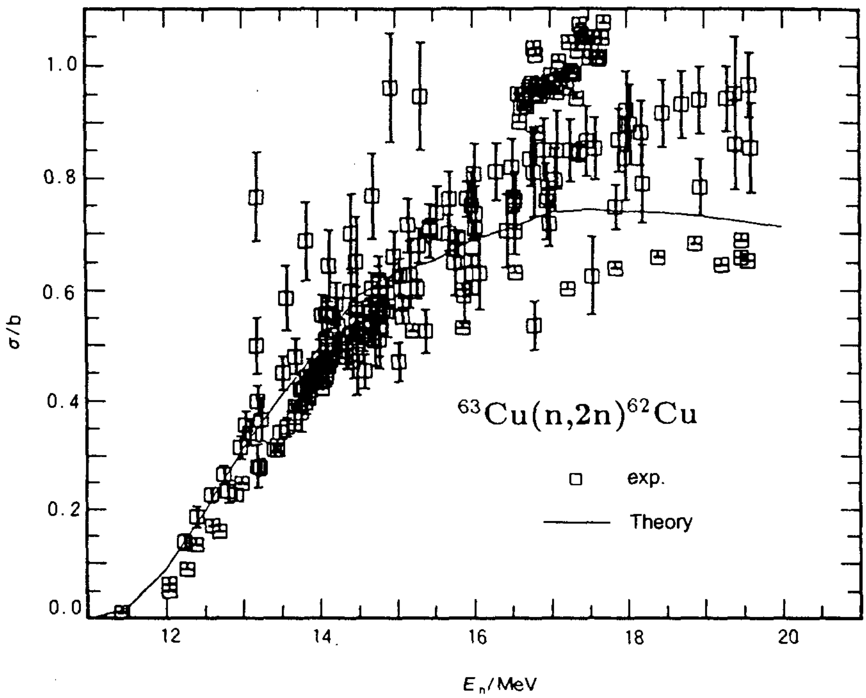

Fig. 8 The cross sections of $^{63}Cu(n,2n)^{62}Cu$ reaction

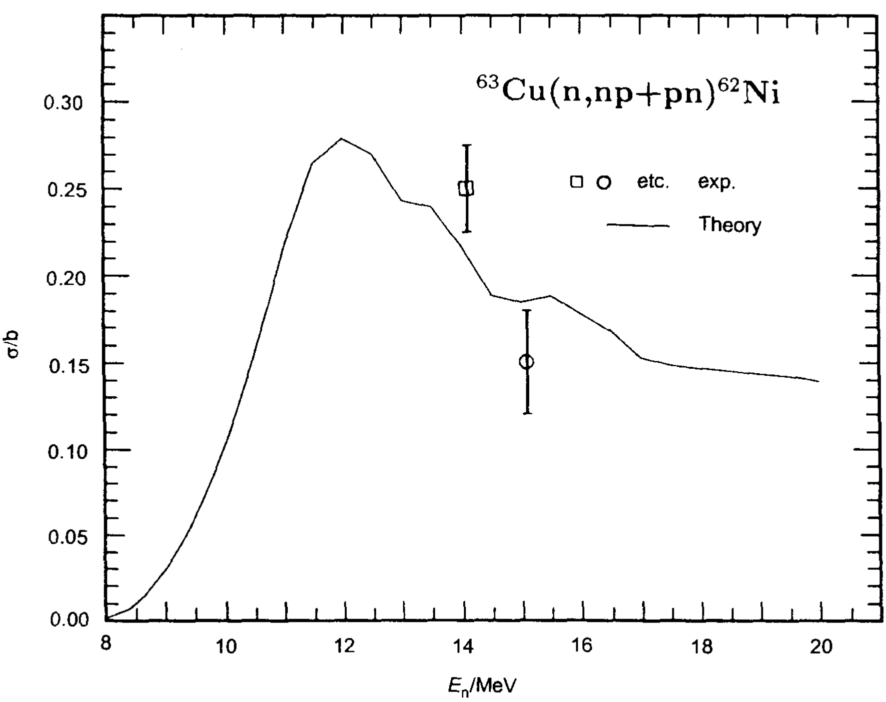

Fig. 9 The cross sections of $^{63}Cu(n,np+pn)^{62}Ni$ reaction

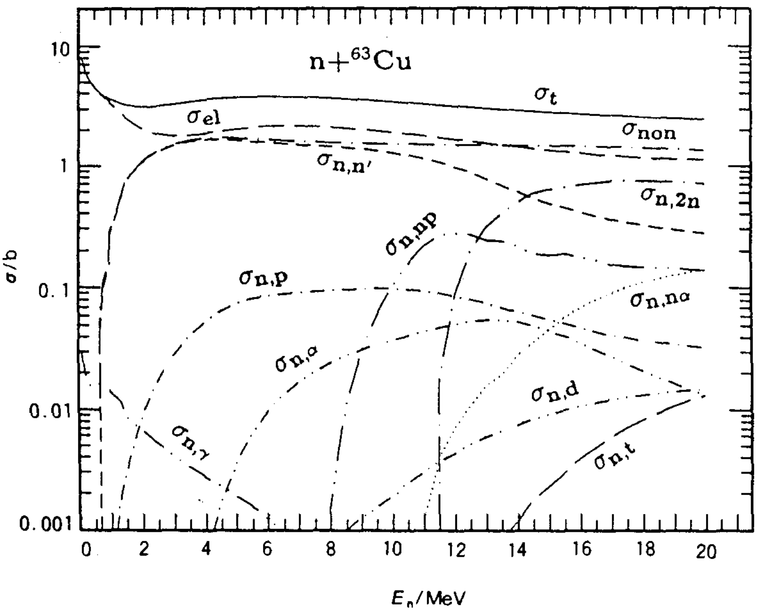

Fig. 10 The cross sections of n+^{63}Cu reaction

The comparison for calculated results and experimental data of ^{63}Cu(n,γ)^{64}Cu reaction cross sections is given in Fig.3. The calculated values are in agreement with experimental data in energy region 0.01 ~ 4 MeV, but for E_n = 14.5 MeV, the calculated value is lower than experimental data. Fig.4 and Fig.5 show the comparison of the calculated results and experimental data of ^{63}Cu(n,n')^{63}Cu[4~6] and ^{63}Cu(n,p)^{63}Ni[7,8] reaction cross sections, respectively. The calculated curves pass through the experimental data within error bars[5~7], at lower energy range and above 14 MeV, respectively. The comparison of calculated and experimental (n,α) reaction cross sections of ^{63}Cu is given in Fig.6. The calculated values fit the experimental data[9] very well. Fig.7 gives the comparison of calculated and experimental ^{63}Cu(n,d)^{62}Ni reaction cross section. The calculated curves pass through the experimental data. Figs.8 and 9 give the comparisons of calculated and experimental (n,2n) and (n,np) reaction cross sections of ^{63}Cu. The calculated results are in agreement with the experimental data. The calculated valves of (n,np) reaction is for (n,np)+(n,pn) reactions. All of the calculated results are consistent with the experimental data. Fig.10 illustrates all reaction cross sections of ^{63}Cu. The energy spectrum, angular distribution, double differential cross section and γ-production data were obtained at incident neutron energies below 20 MeV. Because the calculated results for many channels are in pretty agreement with existing experimental data, the predicted cross sections are reasonable.

3 Summary

Based on the experimental data of total and nonelastic scattering cross sections of ^{Nat}Cu reaction and the experimental data of elastic scattering cross section and angular distributions of ^{63,65,Nat}Cu reactions, a set of neutron optical potential parameters for ^{63,64}Cu was obtained. Then many nuclear data for n+^{63}Cu reactions were calculated based on optical model, unified model, and the pick-up mechanism of cluster pre-formation. Because the calculated results for many channels are in pretty agreement with existed experimental data, the predicted cross sections in the energy range where there are no any experimental data are reasonable and believable.

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Calculation of Neutron Induced Reactions on ^{105,108}Pd in Energy from 0.05 to 20 MeV

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Abstract

A set of neutron optical potential parameters for energy from 0.05 to 20 MeV is