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# ANALYSIS OF NEUTRON CROSS SECTION OF N-14 AND O-16 WITH AN APPROXIMATE R-MATRIX THEORY

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Abstract: A simple many-channel multi-level resonance formula is derived on the assumption that the same spin-parity resonance levels have the same ratios of reduced width amplitude between different channels. The deduced formula are applied to neutron total cross section analysis of N-14 and O-16, and with obtained parameters, angular distributions of neutron elastic scattering from the nuclei are calculated for JENDL-3T.

( R-matrix, collision matrix, N-14, O-16, resonance analysis, neutron total cross section, neutron elastic scattering ang. distribution )

## Introduction

Light nuclei show resonance structure even in the incident neutron energy region higher than several MeV, where many reaction channel will open. To analyze the resonance structure in these region, the many-channel multi-level R-matrix theory is adopted generally. For the analysis, general R-matrix theory requires, however, cross section data of all related channels. For example, to analyze neutron elastic scattering cross section of N-14, the theory requires open channel data of the (n,p) reaction, the (n,a) reaction and so on in addition to the (n,n) reaction data itself. So, it is not practical, sometimes, applying the general R-matrix theory to cross section evaluation.

In order to avoid the difficulty, a simple multi-level many-channel resonance formula is presented in the present paper, based on the assumption that resonance levels of the same spin-parity have the same ratios of the reduced width amplitudes between each reaction channels. The assumption was applyed formerly to rather special case of the proton elastic scattering analysis by the author /1/.

## Theory

In general reaction theory, cross sections are described by the collision matrix, which relate wave function amplitudes of incident and outgoing channels.

The collision matrix U is expressed in the R-matrix theory as,

$$U^J = \Omega\left[1+\mathfrak{P}^{1/2}(1-R^JL^0)^{-1}R^J\mathfrak{P}^{1/2}w\right]\Omega$$

where notations are the same as those given in the review paper of Lane and Thomas /2/. Elements of the R-matrix Rcc' are given by

$$R^J_{cc'}(E)=\sum_\lambda \frac{\gamma_{\lambda c}\gamma_{\lambda c'}}{E_\lambda - E} .$$

The summation is taken over all resonance levels ( $\lambda$ ) of the indicated spin-parity (J).

Now, it is assumed that the same spin-parity resonance levels have the same ratios of reduced width amplitudes between each reaction channels. Then, the R-matrix elements have the relationships such as

$$R_{ik},\ R_{kj}=R_{ij},\ R_{kk}$$

and the R-matrix term including the matrix inversion shown in the collision matrix is reduced to simple form :

$$[(1-RL^0)^{-1}R]_{cc'}=\frac{R_{cc'}}{1-\sum_{c''}R_{c''c''}L_{c''}^0} .$$

So, the element of the collision matrix is given by

$$U_{cc'}=\exp i(\omega_c-\phi_c)\cdot$$

$$\left[\delta_{cc'}+\frac{\sum_\lambda i\Gamma_{\lambda c}^{1/2}\Gamma_{\lambda c'}^{1/2}/(E_\lambda-E)}{1+\sum_\lambda(\Delta_\lambda-i\Gamma_\lambda/2)/(E_\lambda-E)}\right]\exp i(\omega_{c'}-\phi_{c'}),$$

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This work was performed as a part of evaluation work for JENDL-3 by Working Group on Nuclear Data for Fusion, JNDC.

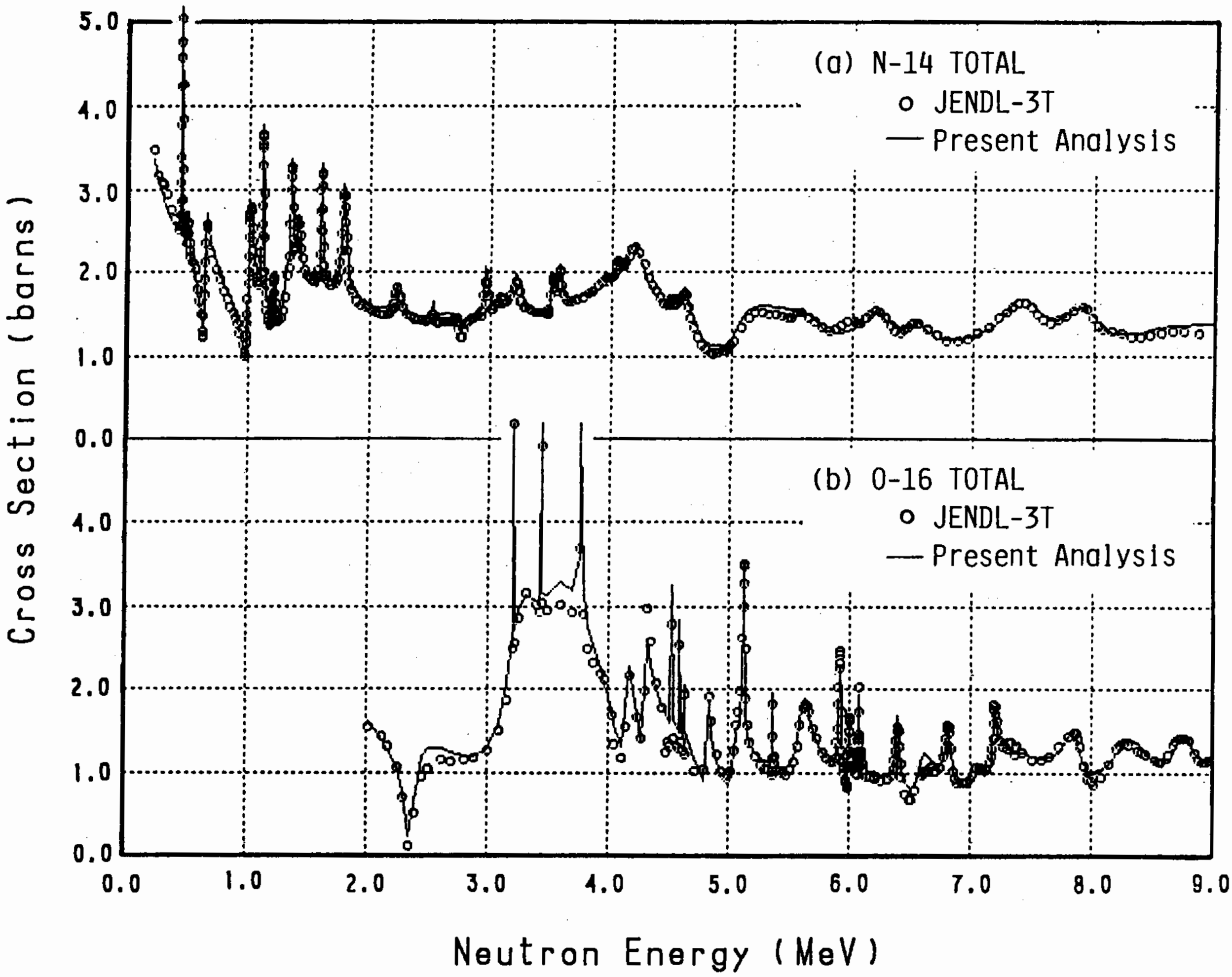


Fig. 1. Analysis of neutron total cross section of JENDL-3T for N-14 ( top ) and O-16 ( bottom ) with present approximation. The JENDL-3T evaluation was made by Shibata/3/ based on the experimental data of Heaton et al./4/ and Cierjacks et al./5/ for N-14 and O-16, respectively.

where $\Gamma_{c}$ , $\Gamma_{c'}$ and $\Gamma_{\lambda}$ are the partial width of incident channel c ,that of outgoing channel c' and the total width of the resonance level , respectively. Other notations are the same as those defined in reference /2/.

## Resonance Analysis

Neutron total cross section of N-14 and O-16 are analyzed with the above mentioned approximate R-matrix theory. Analyzed cross sections are evaluated data for JENDL-3 /3/, which are based on the experimental cross sections of Heaton et al./4/ for N-14 and Cierjacks et al./5/ for O-16.

Parameter search were made in dialogue style with a personal computer, starting from the resonance parameters recommended by Mughabghab et al./6/. Several large width resonances were required to reproduce the cross sections in some energy region, in addition to the resonances given in ref./6/.

For N-14, analysis were made in the incident neutron energy range of En = 0.2 - 9.0 MeV, and fitting parameters of 39 resonance levels including 3 negative levels are determined to reproduce the total cross section .

For O-16, total cross section in the energy range of En = 2.0 - 9.0 MeV were reproduced with 41 resonance levels including a negative level.

The calculated total cross sections are shown in Fig.1(a) for N-14 and in Fig.1(b) for O-16, comparing with each evaluated total cross sections for JENDL-3T.

With these resonance parameters, angular distributions of neutron elastic scattering are calculated using the formalism given by Blatt and Biedenharn /7/. The obtained relative angular distributions are stored in JENDL-3T. These results are compared with experimental data /8/ and evaluated data of ENDF/B-4. Some examples of the comparison are shown in Fig.2(a) for N-14 and in Fig.2(b) for O-16.

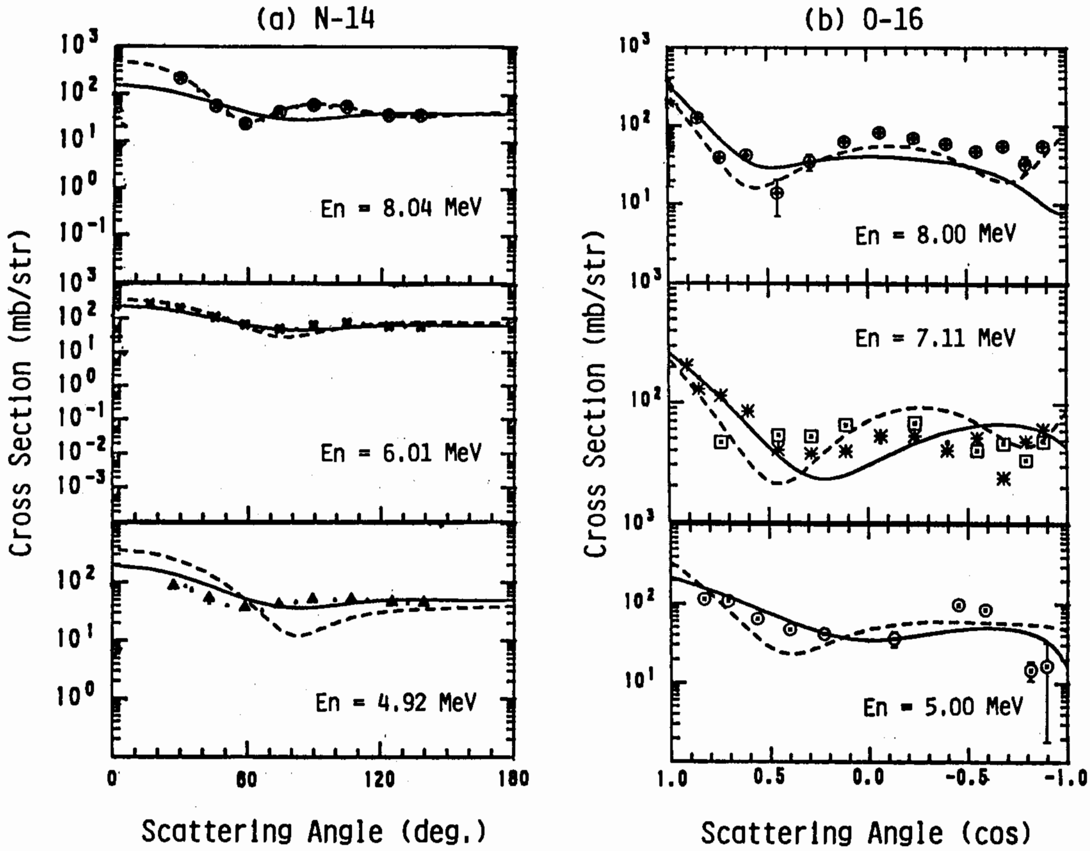


Fig. 2. Comparison of neuton elastic scattering differential cross sections for N-14 ( left ) and O-16 ( right ) : present calculation ( solid line ), experimental data /8/ ( dots ) and ENDF/B-4 evaluation ( dashed line ).

## Discussion

It is a general observation about resonance structures of many nuclei that the same spin-parity levels have tendency to exist in groups and may be originated in a simple state such as single particle state, doorway state or isobaric analog state. So, it is infered that the same spin-parity levels will have similar wave functions and have nearly the same ratios of reduced width amplitudes between each channels. Then, the present assumption seems not so unreasonable.

Though the resonance parameters determined presently are merely fitting parameters and would have a little physical meaning, the existence of large width resonances which are not recognized obviously in the structures of neutron total cross section are supported by other reaction cross section structures, such as O-17($\gamma$,n) reaction /9/ for the resonance analysis of O-16.

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