Brief Note on the Statistical Calculation of Final Continuum Reaction Cross Sections of Light Nuclides

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1. Introduction

Statistical models are usually adopted for the calculation and evaluation of reaction cross sections to the final continuum state using the level density formula such as given by Gilbert and Cameron[1]. The level density parameters are determined to reproduce level structure and/or resonance level spacing of the nucleus. In the statistical compound nucleus model, cross sections to discrete levels decrease abruptly, and continuum level cross section increase strongly above the energy point where the continuum levels switched on. In the present study, for the nucleus which level scheme were well determined up to higher excitation energy more than 10 MeV, discrete level cross sections were calculated and summed up and compared with the cross section to the assumed continuum level corresponding to the discrete levels above several MeV excitation energy. Calculation of the (n,n') cross sections were made with CASTHY code[2] of Moldauer model option using level density parameters determined with former method[3]. It is shown that the assumed continuum cross section is fairly large compared with the summed up cross section. Origins of the discrepancy were discussed.

2. Calculation

1) Level Density Formula and Parameters

The level density formulae of Fermi gas type and constant temperature model given in CASTHY code are adopted. The level density parameters are determined to reproduce the stair-case plot of level schemes of target nucleus; ^{7}Li and ^{16}O. The stair-case plots are shown in Fig.1 for ^{7}Li and Fig.2 for ^{16}O comparing with integrated values of level density. The level density parameters are given in the figures. The parameters are T; nuclear temperature, a; Fermi gas constant, Ec; connection energy of constant temperature model and Fermi gas model, PE; pairing energy, Co; Fermi gas model normalization factor, SPC; spin cutoff factor and Uc=Ec-PE.

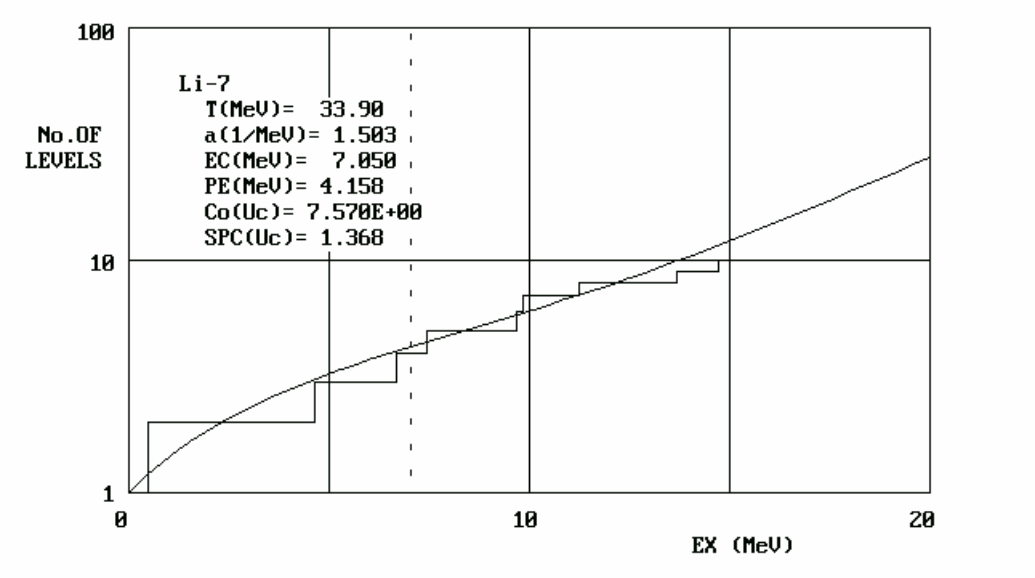

Fig.1. Staircase plot of ^{7}Li excited levels and determination of level density parameters of ^{7}Li.

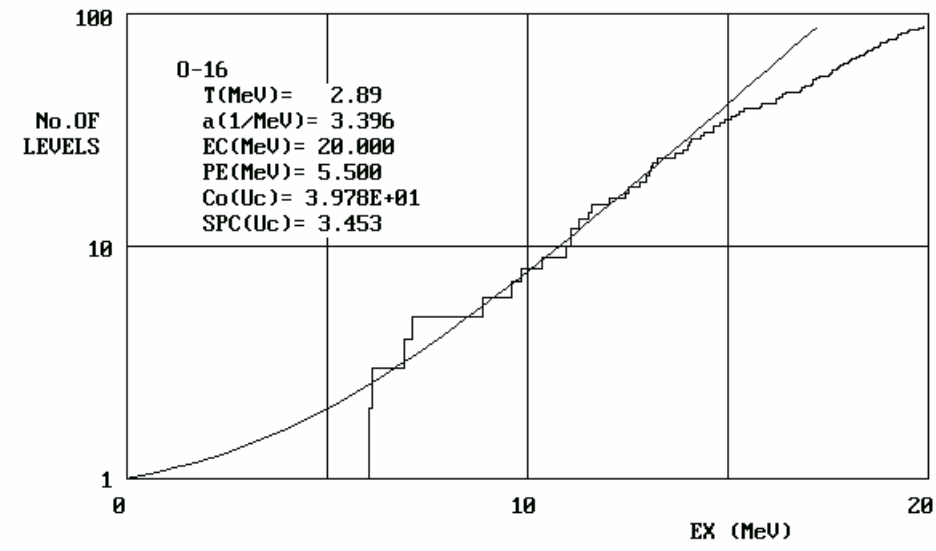

Fig. 2 . Staircase plot of ^{16}O excited levels and determination of level density parameters of ^{16}O

2) Cross Section Calculation

Neutron inelastic scattering cross sections to continuum state above some excitation energy (Ex>=6.50MeV for ^{7}Li and Ex>=6.92MeV for ^{16}O) were calculated at first using level density parameters determined in section 2.1. Then the inelastic scattering cross sections to discrete levels corresponding to the same excitation energy range were

calculated and summed up. Comparison between the continuum cross section and the summed up cross section is made in Fig.3 for ^{7}Li and in Fig.4 for ^{16}O. In the figures, dashed curve 1) is the cross section of final continuum state calculated with the level density parameters given in the above figures, dashed curve 2), same cross section calculated with spin cutoff factor 3 times as large as that of curve 1) and solid line represent the summed up discrete cross section.

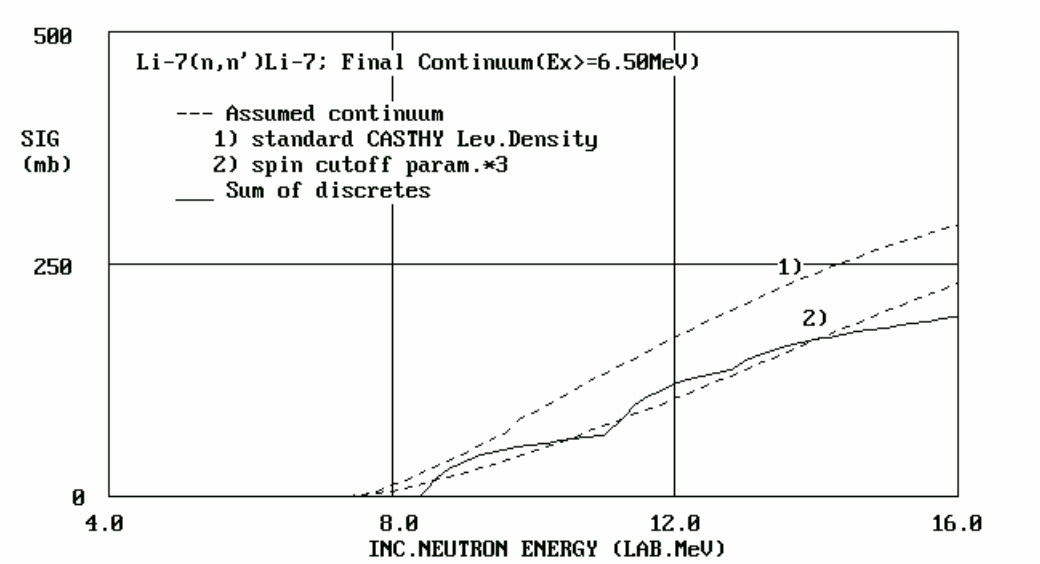

Fig.3. Calculated ^{7}Li(n,n') final continuum cross section comparison between sum of discrete levels (solid line) and assumed continuum state(dashed line).

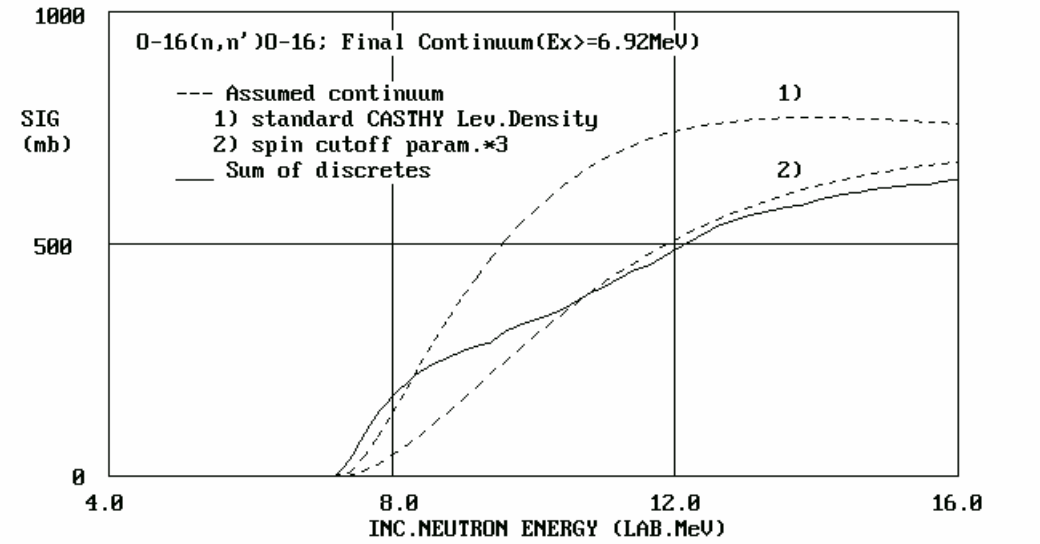

Fig.4. Calculated ^{16}O(n,n') final continuum cross section comparison between sum of discrete levels (solid line) and assumed continuum state(dashed line).

3. Discussion

As is shown in Fig.3 and Fig.4, the cross section to the assumed continuum state is larger about 1.5 times than the summed up cross sections. In each case, the 3 times larger spin cutoff factor (dashed curve 2) gives rather good agreement with the summed up cross sections. Larger spin cutoff factor suppresses number of low spin state, and will reduce the continuum cross section. So, there will be possibility that the formula of spin cutoff factor is inadequate. To check the calculated spin cutoff factor, spin distribution of ^{17}O was examined. The result is shown in Fig.5 and adequacy of the value is confirmed.

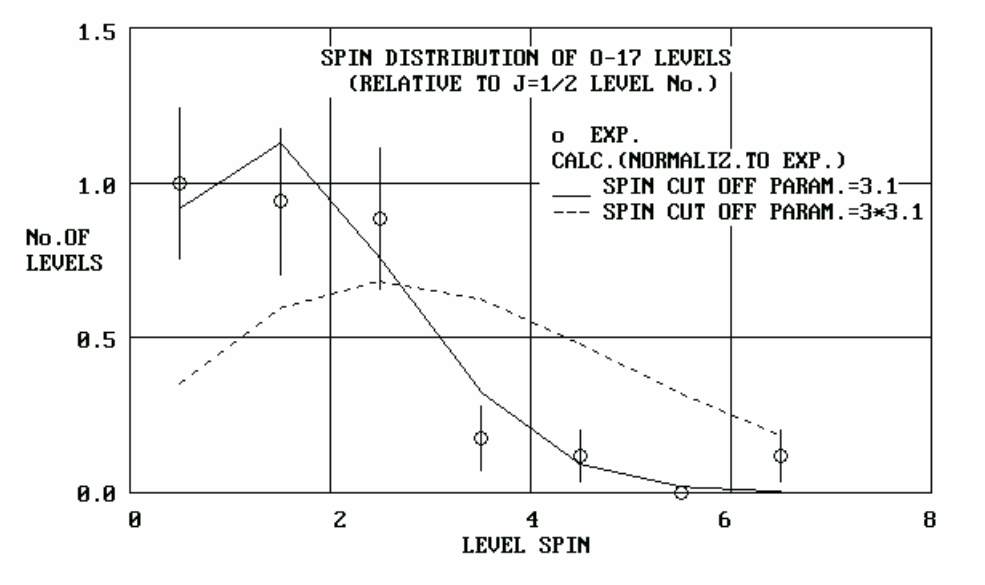

Fig.5. Spin distribution of ^{17}O excited levels and determination of the spin-cutoff parameter. Solid line is calculated with formula of spin cutoff factor given in CASTHY code. Dashed line shows the result with 3 times large factor.

There is possibility that the small differences in the stair-case plot between level scheme plot and level density integral values will cause large difference of the cross section. To check this, dummy level scheme easy to be reproduced by level density formulae was made for dummy ^{16}O nucleus. Spin-parity distribution was also made artificially to reproduce theoretical distribution. Stair-case plot of the dummy ^{16}O is shown in Fig.6 and cross section plot in Fig.7. The difference of the cross section was somewhat reduced but still remain same extent.

Other origins of the cross section discrepancy are

1) Some level density formula was applied to determine level density parameters inconsistent with that of cross section calculation. (Application error)
2) Spin parity distribution of the level scheme can not be described well by the

present level density formula.

3) The present discrepancy is in the range of statistical fluctuation, which is caused by spin-parity distribution fluctuation.
4) Present statistical model can not deal properly the competition between continuum state and discrete levels.

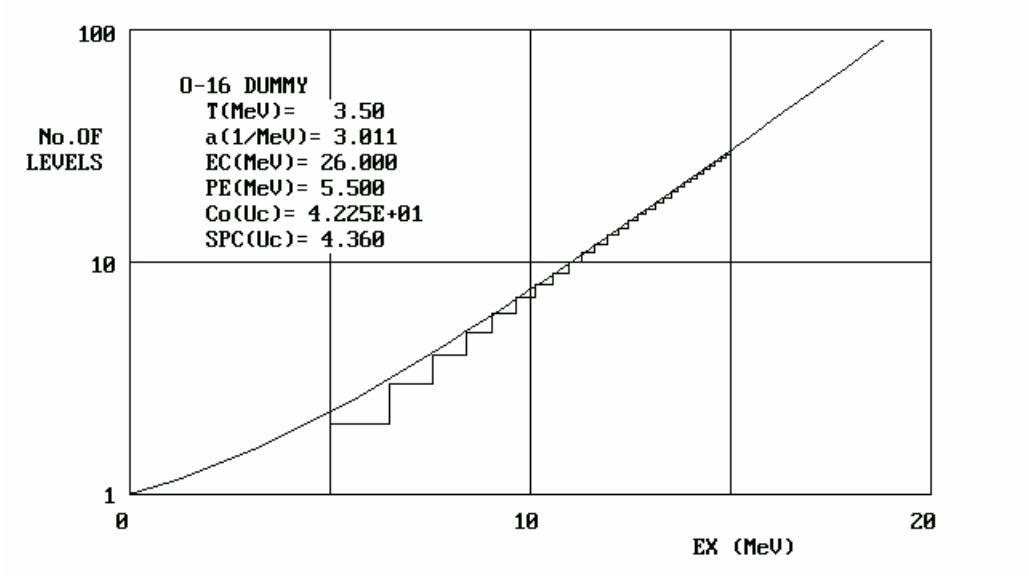

Fig.6. Staircase plot of dummy ^{16}O excited levels and determination of level density parameters of ^{16}O

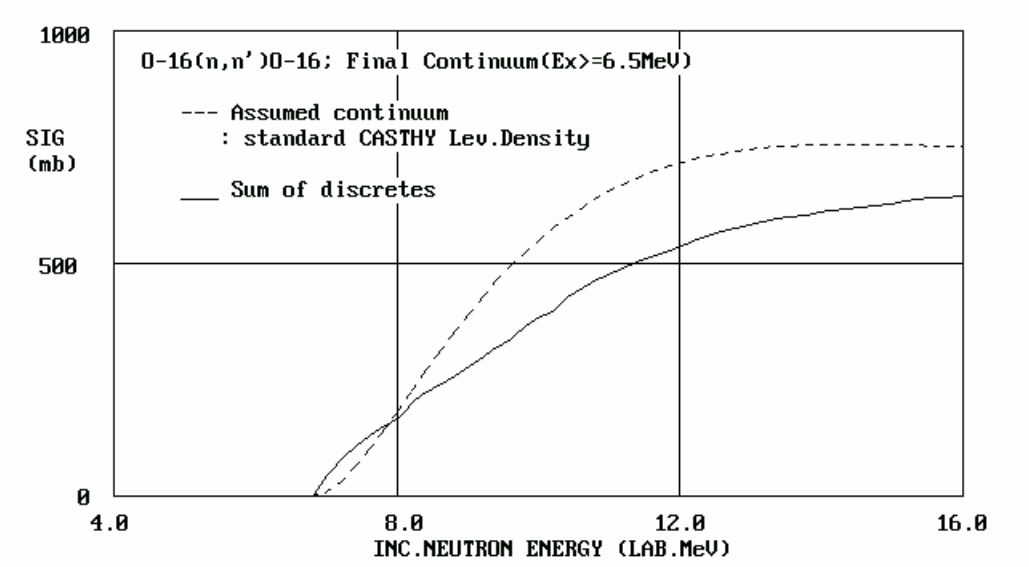

Fig.7. Calculated dummy $^{16}O(n,n')$ final continuum cross section comparison between sum of discrete levels (solid line) and assumed continuum state(dashed line).

4. Conclusions

The number of excited levels may be reproduced by level density formula, though the cross section depends on the spin-parity of the levels and the dependence on low spin states is rather large. The spin cutoff parameter calculated with a rigid body model gives large component of low spin states.

Present study was restricted in the framework of the statistical compound nucleus model. In the case of inclusion of pre-compound process, discrete level cross sections increase so much and continuum cross sections decrease.

For excited states of light nuclei, excitation energy below about 10 MeV or more, may not be treated as continuum state with simple level density parameter set.

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References

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[2] Igarasi, S., Fukahori, T. : JAERI 1321 (1991)

[3] Murata, T. : JAERI-Conf 2001-006 (2001), p.289