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Program ELIESE-3; Program for Calculation of the  
Nuclear Cross Sections by Using Local and  
Non-Local Optical Models and Statistical Model

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# Program ELIESE-3; Program for Calculation of the Nuclear Cross Sections by Using Local and Non-local Optical Models and Statistical Model.\*

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## Summary

Program ELIESE-3 has been prepared in order to calculate nuclear cross sections and polarizations for particles with spin 0, 1/2 and 1. Non-local optical potentials, their equivalent local potentials and conventional spherical local potentials are adopted in this program. Cross section for excitation of discrete levels and/or overlapping levels of residual nucleus is calculated by using the statistical model.

In ELIESE-3, automatic search for potential parameters can be performed in elastic scattering stage; fifteen parameters at maximum are looked for simultaneously. Curve plotting of the angular distributions of the cross sections and polarizations is possible by using the CALCOMP plotter.

Program ELIESE-3 is composed of a main program and 42 sub-programs. Core-memory used for this program is less than about 80K words.

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\* This work was performed as one of the project of the Japanese Nuclear Data Committee.

## プログラム ELIESE-3; 局所形および非局所形光学模型を使って原子核の断面積を計算するためのプログラム\*

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1972年8月10日 受理

### 要　　旨

プログラム ELIESE-3 はスピンが 0, 1/2 および 1 の粒子に対する原子核の断面積と粒子の偏極を計算するために作られた。非局所ポテンシャルとそれに等価な局所ポテンシャルおよび通常の球形ポテンシャルを使用している。統計模型を使って、残留核の離散レベルおよび連続レベルの励起断面積を計算することが出来る。

ELIESE-3 では、弹性散乱についてポテンシャルパラメータの自動探索が出来るが、この時のパラメータ数は一度に 15 箇まで探すことが出来る。CALCOMP プロッターを使うことにより、断面積の角度分布、偏極の角度分布をプロットすることが出来る。

ELIESE-3 は主プログラムと 42 箇の部分プログラムから成っており、プログラムの使用に必要な計算機のコア記憶容量は 80K 語以下である。

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\* この仕事はシグマ専門／研究委員会の作業の一部として行ったものである。

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## 1. Introduction

The programs ELIESE-1<sup>1)</sup> and ELIESE-2<sup>2)</sup> have been prepared to calculate elastic and inelastic scattering cross sections, and some types of reaction cross sections concerning a particle with spin 0 or 1/2 by means of the optical model and Hauser-Feshbach's method<sup>3)</sup>. ELIESE-2, for example, was able (1) to calculate the elastic scattering cross section and its angular distribution, the inelastic scattering cross section for each discrete nuclear level and its angular distribution, the total inelastic scattering cross section and the cross section for compound nucleus formation, (2) to calculate the reaction cross sections, such as  $(n, \alpha)$ ,  $(p, \alpha)$  and  $(n, p)$ , (3) to take account of the effects of the competing processes whose cross sections cannot be calculated by using ELIESE-2, (4) to search for the potential parameters automatically in the calculation of the shape elastic scattering stage, and (5) to make punched-cards for calculated cross-section values, transmission coefficients and Legendre coefficients of the angular distributions. ELIESE-2 was written for an IBM-7090 computer, which had no room left in the core-memory when the program was loaded into the computer.

Recent development of large, high-speed computers makes it possible to extend the program to treat many complicated nuclear reaction processes. A new program ELIESE-3 has been made to calculate the following problems in addition to what were treated by ELIESE-2. (1) The calculations of the elastic and inelastic scattering cross sections and their angular distributions are performed for a particle with spin 1. (2) The reaction cross sections can be calculated concerning absorption and emission of the particles with spin 0, 1/2 and 1; for example  $(n, d)$ ,  $(d, p)$  and  $(d, \alpha)$  reactions through the compound nucleus. (3) Moldauer's method<sup>4)5)6)</sup> can be used in the calculations of the compound nuclear process. (4) Hauser-Feshbach's method<sup>3)</sup> is extended to calculate the cross section for the excitation of the overlapping levels of the residual nucleus. (5) One of the characteristics in ELIESE-3 is that non-local optical potential<sup>7)8)</sup> can be used. Two non-local kernels are available; Gaussian type and Yukawan type. Equivalent local potential to each non-local potential can be used instead of the non-local potential. (6) Polarization, asymmetry, rotation, depolarization and tensor polarization of scattered particles can be calculated. (7) Angular distributions of the cross sections and polarizations can be plotted on the graphs by using CALCOMP plotter. (8) Method of automatic search for the potential parameters is improved in ELIESE-3. This function of the automatic parameter search is available only in the elastic scattering calculation.

As mentioned above, ELIESE-3 has a lot of functions of the calculations. Following sections of this report will be devoted in order to understand the contents of the program. Section 2 is devoted to the description of the mathematical formulae of the cross sections and polarizations. Descriptions of the potential forms and parameters are given in section 3. The non-local potential and its equivalent local potential are described in detail in this section. In section 4, method of obtaining the numerical solutions of the wave functions is given. Section 5 is devoted to the presentation of some basic quantities, such as the level density, phase shift of the Coulomb scattering, and Legendre coefficients of the differential cross sections. Method of the automatic search for potential parameter is also presented in section 5. Sections 2 to 5 will be of help for understanding the program description, and input and output descriptions given in sections 6 to 8. Explanations of the input data are given in section 7, with input and output data-form in Fig. 2. Some examples of input and output are given in section 8 with figures. How to use

this program will be caught by careful reading of these two sections.

This program ELIESE-3 is composed of a main (control) program and 42 sub-programs. Roles of each sub-program will be explained in section 6, and a flow-chart of the main program is shown in Fig. 1. The program ELIESE-3 is written for IBM 360/75 and FACOM 230-60 computers originally. There may be, however, no problem for any other computer which has larger memory than 80K words available for the program. One temporary device (magnetic tape, disk, or drum) is needed in the calculation, of which logical number in Fortran statement is 15.

## 2. Cross Section and Polarization Formulae

This section is devoted to the description of the mathematical formulae which are used in the calculations of the nuclear cross sections, on the basis of the optical model and statistical model. The optical model provides many important quantities which are used in analysing and understanding the nuclear process. In ELIESE-3, these quantities play very important roles. Therefore, descriptions in this section will be started from obtaining these quantities by using the optical model.

### 2.1 Cross sections and polarizations for shape elastic scattering

Basic radial Schroedinger equation, in the center of mass system, is

$$\left\{ \frac{d^2}{dr^2} - \frac{l(l+1)}{r^2} + k^2 + C\mathcal{V}_c(r) + [j(j+1) - l(l+1) - s(s+1)]C\mathcal{V}_{so}(r) - C\mathcal{V}_{Coul}(r) \right\} \varphi_l^{(j)}(r) = 0, \quad (2.1)$$

where

$$|l-s| \leq j \leq l+s .$$

Non-local optical potential is considered as well as local optical potential in this program. Schroedinger equation, Eq. (2.1), is replaced by the following integro-differential equation<sup>7,8)</sup>:

$$\left\{ \frac{d^2}{dr^2} - \frac{l(l+1)}{r^2} + k^2 \right\} \varphi_l^{(j)}(r) + \int_0^\infty [C\mathcal{V}_c(r') + [j(j+1) - l(l+1) - s(s+1)]C\mathcal{V}_{so}(r') - C\mathcal{V}_{Coul}(r')] h_l(r, r') \varphi_l^{(j)}(r') dr' = 0, \quad (2.1')$$

where  $C\mathcal{V}_c(r)$ ,  $C\mathcal{V}_{so}(r)$  and  $C\mathcal{V}_{Coul}(r)$  are the central, spin-orbit and Coulomb potentials, respectively. Function  $h_l(r, r')$  is the  $l$ -th component of the non-local kernel. The wave function  $\varphi_l^{(j)}(r)$  is the radial wave function corresponding to angular momentum quantum number  $j$  which is composed of orbital angular momentum  $l$  and intrinsic spin  $s$  of incident particles. In ELIESE-3, any particle with spin 0, 1/2 or 1 can be treated as an incident particle or emitted particle. Therefore, there need three components of the wave functions for the particle with spin 1, two components for the particle with spin 1/2 and one component for the particle with spin 0, respectively. Wave number  $k$  in Eqs. (2.1) or (2.1') is defined by

$$k = (2\mu E/\hbar^2)^{1/2}, \quad (2.2)$$

where  $\mu$  and  $E$  are reduced mass and relative energy between an incident particle and a target nucleus, respectively. They are given as follows:

$$\mu = \frac{mM}{m+M}, \quad (2.3)$$

and

$$E = \frac{M}{m+M} E_0, \quad (2.4)$$

where  $m$  and  $M$  are masses of incident particle and target nucleus, and  $E_0$  the energy in laboratory system.

The wave function,  $\varphi_l^{(j)}(r)$ , has an asymptotic form in the region where nuclear potential becomes negligibly small in comparison with the incident energy. The asymptotic form of the wave function is written as

$$\varphi_l^{(j)}(r) \rightarrow u_l^{(j)}(\rho) = u_l^{(-)}(\rho) - \eta_l^{(j)} u_l^{(+)}(\rho). \quad (2.5)$$

The wave functions  $u_l^{(-)}(\rho)$  and  $u_l^{(+)}(\rho)$  stand for the incoming and outgoing waves, respectively, and they are written as

$$u_l^{(\pm)}(\rho) = G_l(\rho) \pm iF_l(\rho). \quad (2.6)$$

For neutron, wave functions  $G_l(\cdot)$  and  $F_l(\cdot)$  are the spherical Neumann function and the spherical Bessel function multiplied by their argument  $\rho (=kr)$ , respectively.

Coefficient of the outgoing wave,  $\eta_l^{(j)}$ , is an important quantity and is related with scattering phase shift  $\delta_l^{(j)}$ :

$$\eta_l^{(j)} = \exp(2i\delta_l^{(j)}). \quad (2.7)$$

This quantity,  $\eta_l^{(j)}$ , is obtained by joining the wave function  $\varphi_l^{(j)}(r)$  to its asymptotic wave function  $u_l^{(j)}(\rho)$  smoothly at  $\rho_M = kr_M$  which is called matching radius. (Definition of the matching radius in ELIESE-3 will be given in the next section.) The quantity,  $\eta_l^{(j)}$ , is given by the following formula:

$$\eta_l^{(j)} = \frac{f_l^{(j)} - (\Delta_l - is_l) u_l^{(-)}(\rho_M)}{f_l^{(j)} - (\Delta_l + is_l) u_l^{(+)}(\rho_M)}, \quad (2.8)$$

where  $f_l^{(j)}$  is the logarithmic derivative of the wave function  $\varphi_l^{(j)}(r)$  at the matching radius,  $r_M$ :

$$f_l^{(j)} = r_M \left[ \frac{d\varphi_l^{(j)}}{dr} \Big|_{r=r_M} \right]. \quad (2.9)$$

Corresponding quantity for the incoming or outgoing wave functions in the asymptotic region is

$$\Delta_l \pm is_l = \rho_M \left[ \frac{du_l^{(\pm)}}{d\rho} \Big|_{\rho=\rho_M} \right]. \quad (2.10)$$

(i) For neutron, elastic scattering cross section and its differential cross section formulae are written by using the quantity  $\eta_l^{(j)}$  as follows, in unit of milli-barns:

$$\sigma_{el} = \frac{\pi}{k^2} \sum_{l=0}^{\infty} [(l+1)|1-\eta_l^{(l+1)}|^2 + l|1-\eta_l^{(l-1)}|^2] \times 10, \quad (2.11)$$

and

$$\frac{d\sigma_{el}}{d\Omega} = \{|A(\theta)|^2 + |B(\theta)|^2\} \times 10, \quad (2.12)$$

where

$$A(\theta) = \frac{i}{2k} \sum_{l=0}^{\infty} [(l+1)(1-\eta_l^{(l+1)}) + l(1-\eta_l^{(l-1)})] P_l(\cos\theta), \quad (2.13)$$

and

$$B(\theta) = \frac{1}{2k} \sum_{l=0}^{\infty} [\eta_l^{(l-1)} - \eta_l^{(l+1)}] P_l^1(\cos\theta). \quad (2.14)$$

Legendre function  $P_l(\cos\theta)$  and its associated function  $P_l^1(\cos\theta)$  are used. Cross section for compound nucleus formation and total cross section are calculated by the formulae:

$$\sigma_c = \frac{\pi}{k^2} \sum_{l=0}^{\infty} [(l+1)T_l^{(l+1)} + lT_l^{(l-1)}] \times 10, \quad (2.15)$$

and

$$\sigma_t = \sigma_{el} + \sigma_c, \quad (2.16)$$

where the quantity  $T_l^{(j)}$  is called transmission coefficient and is related to the quantity  $\eta_l^{(j)}$ :

$$T_l^{(j)} = 1 - |\eta_l^{(j)}|^2. \quad (2.17)$$

In ELIESE-3, polarization of the scattered particles is calculated. For neutron, the polarization, asymmetry and rotation are obtained by the following formulae<sup>9), 10), 11)</sup>:

$$P_{ol} = \frac{A(\theta)^* B(\theta) + A(\theta) B(\theta)^*}{|A(\theta)|^2 + |B(\theta)|^2}, \quad (2.18)$$

$$A_{sy} = \frac{(|A(\theta)|^2 - |B(\theta)|^2) \sin\theta + i(A(\theta)^* B(\theta) - A(\theta) B(\theta)^*) \cos\theta}{|A(\theta)|^2 + |B(\theta)|^2}, \quad (2.19)$$

and

$$R_{el} = \frac{(|A(\theta)|^2 - |B(\theta)|^2) \cos \theta - i(A(\theta)^* B(\theta) - A(\theta) B(\theta)^*) \sin \theta}{|A(\theta)|^2 + |B(\theta)|^2}. \quad (2.20)$$

(ii) For proton or charged particles with spin 1/2, the same equations as those for neutron are obtained, except for the total cross section and the elastic scattering cross section. The differential elastic scattering cross section is written by the same formula as Eq. (2.12), but the quantities  $A(\theta)$  and  $B(\theta)$  are somewhat different from Eqs. (2.13) and (2.14). They are defined by using phase shift of Coulomb scattering  $\sigma_t$  [cf. section 5] :

$$A(\theta) = f_c(\theta) + \frac{i}{2k} \sum_{l=0}^{\infty} e^{2i\sigma_t} \{ (l+1)(1-\eta_l^{(l+1)}) + l(1-\eta_l^{(l-1)}) \} P_l(\cos \theta), \quad (2.21)$$

and

$$B(\theta) = \frac{1}{2k} \sum_{l=0}^{\infty} e^{2i\sigma_t} \{ \eta_l^{(l-1)} - \eta_l^{(l+1)} \} P_l^1(\cos \theta), \quad (2.22)$$

where  $f_c(\theta)$  is Coulomb scattering amplitude :

$$f_c(\theta) = \frac{-\eta}{2k \sin^2(\theta/2)} \exp \left[ -i\eta \ln(\sin^2(\theta/2)) + 2i\sigma_0 \right]. \quad (2.23)$$

Cross section of the Rutherford scattering is given by using the amplitude  $f_c(\theta)$  :

$$\left( \frac{d\sigma_{el}}{d\Omega} \right)_R = |f_c(\theta)|^2 \times 10. \quad (2.24)$$

Quantity  $\eta$  is Coulomb parameter which is defined by

$$\eta = \mu Z Z' e^2 / \hbar^2 k. \quad (2.25)$$

Cross section for compound nucleus formation, polarization, asymmetry and rotation are given by the same formulae as for neutron.

(iii) For alpha-particle or charged particles with spin 0, the total angular momentum  $j$  is equal to the orbital angular momentum  $l$ . Therefore, the quantity  $\eta_l^{(l)}$  depends only on the orbital angular momentum  $l$  and the quantities  $A(\theta)$  and  $B(\theta)$  are

$$A(\theta) = f_c(\theta) + \frac{i}{2k} \sum_{l=0}^{\infty} e^{2i\sigma_t} (2l+1)(1-\eta_l^{(l)}) P_l(\cos \theta), \quad (2.26)$$

and

$$B(\theta) = 0. \quad (2.27)$$

No polarization of the scattered particles exists in this case.

(iv) For deuteron or charged particles with spin 1, the differential elastic scattering cross section is written as follows :

$$\frac{d\sigma_{el}}{d\Omega} = \frac{1}{3} \{ |A(\theta)|^2 + 2(|B(\theta)|^2 + |C(\theta)|^2 + |D(\theta)|^2 + |E(\theta)|^2) \} \times 10, \quad (2.28)$$

where

$$A(\theta) = f_c(\theta) + \frac{i}{2k} \sum_{l=0}^{\infty} e^{2i\sigma_t} \{ (l+1)(1-\eta_l^{(l+1)}) + l(1-\eta_l^{(l-1)}) \} P_l(\cos \theta), \quad (2.29)$$

$$B(\theta) = f_c(\theta) + \frac{i}{4k} \sum_{l=0}^{\infty} e^{2i\sigma_t} \{ (l+2)(1-\eta_l^{(l+1)}) \\ + (2l+1)(1-\eta_l^{(l)}) + (l-1)(1-\eta_l^{(l-1)}) \} P_l(\cos \theta), \quad (2.30)$$

$$C(\theta) = \frac{i}{2\sqrt{2}k} \sum_{l=1}^{\infty} e^{2i\sigma_t} \{ \eta_l^{(l-1)} - \eta_l^{(l+1)} \} P_l^1(\cos \theta), \quad (2.31)$$

$$D(\theta) = \frac{i}{2\sqrt{2}k} \sum_{l=1}^{\infty} e^{2i\sigma_t} \frac{1}{l(l+1)} \{ l(l+2)(1-\eta_l^{(l+1)}) \\ - (2l+1)(1-\eta_l^{(l)}) - (l^2-1)(1-\eta_l^{(l-1)}) \} P_l^1(\cos \theta), \quad (2.32)$$

and

$$E(\theta) = \frac{i}{4k} \sum_{l=2}^{\infty} e^{2i\sigma_t} \frac{1}{l(l+1)} \{ l(l-1)(1-\eta_l^{(l+1)}) \\ - (2l+1)(1-\eta_l^{(l)}) + (l+1)(1-\eta_l^{(l-1)}) \} P_l^2(\cos \theta). \quad (2.33)$$

The cross section for the compound nucleus formation is given by the formula :

$$\sigma_c = \frac{\pi}{3k^2} \sum_{l=0}^{\infty} \sum_{j=[l-1]}^{l+1} (2j+1) T_l^{(j)} \times 10. \quad (2.34)$$

The polarization of the scattered deuteron is written by the use of the quantities defined in Eqs. (2.29) to (2.33)<sup>9), 10), 11)</sup> :

$$P_{el} = \frac{\sqrt{8}}{3} \operatorname{Im} [A(\theta)C(\theta)^* + B(\theta)D(\theta)^* + D(\theta)E(\theta)^*] \times 10 \left| \left( \frac{d\sigma_{el}}{d\Omega} \right) \right|. \quad (2.35)$$

The asymmetry, rotation and depolarization of the scattered deuteron are similarly defined :

$$A_{sy} = - \{ \sqrt{2} \operatorname{Re}(B(\theta)^*D(\theta) + D(\theta)^*E(\theta)) \cos \theta \\ + (|B(\theta)|^2 - |E(\theta)|^2) \sin \theta \} \times 10 \left| \left( \frac{d\sigma_{el}}{d\Omega} \right) \right|_{Asy}, \quad (2.36)$$

$$R_{st} = \{ \operatorname{Re}(A(\theta)^*B(\theta) + A(\theta)^*E(\theta)) \cos \theta \\ - \sqrt{2} \operatorname{Re}(B(\theta)^*C(\theta) + E(\theta)^*C(\theta)) \sin \theta \} \times 10 \left| \left( \frac{d\sigma_{el}}{d\Omega} \right) \right|_{Rot}, \quad (2.37)$$

and

$$D_{ep} = \{ \operatorname{Re}(A(\theta)^*B(\theta) + 2C(\theta)^*D(\theta) - A(\theta)^*E(\theta)) \\ + \sqrt{2} \operatorname{Im}(C(\theta)^*A(\theta) + D(\theta)^*B(\theta) + E(\theta)^*D(\theta)) \} \times 10 \left| \left( \frac{d\sigma_{el}}{d\Omega} \right) \right|_{Dep}. \quad (2.38)$$

Components of the tensor polarization are also taken into account in the program. Since spin tensor for the first rank is proportional to the usual vector polarization, components for the second rank tensor are only calculated. They are expressed in terms of the Eqs. (2.29) to (2.33)<sup>11)</sup> :

$$T_{2,0} = \frac{1}{\sqrt{2}} \left[ 1 - \frac{(|A(\theta)|^2 + 2|D(\theta)|^2) \times 10}{\left| \left( \frac{d\sigma_{el}}{d\Omega} \right) \right|} \right], \quad (2.39)$$

$$T_{2,1} = -T_{2,-1} = \sqrt{\frac{2}{3}} \operatorname{Re} \{ B(\theta)^*D(\theta) - D(\theta)^*E(\theta) - A(\theta)^*C(\theta) \} \times 10 \left| \left( \frac{d\sigma_{el}}{d\Omega} \right) \right|, \quad (2.40)$$

and

$$T_{2,2} = T_{2,-2} = \frac{1}{\sqrt{3}} \{ 2 \operatorname{Re} B(\theta)^*E(\theta) - |C(\theta)|^2 \} \times 10 \left| \left( \frac{d\sigma_{el}}{d\Omega} \right) \right|, \quad (2.41)$$

respectively.

## 2.2 Cross sections for compound nuclear reaction

Differential cross section for the compound nuclear reaction is written as the following formula :

$$\frac{d\sigma_{cc}}{dQ_c} (I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') = \sum_L B_L (I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') P_L (\operatorname{ccs} \theta_c). \quad (2.42)$$

This formula means that the incident particle with energy  $E$ , spin  $s$  and parity  $\pi_s$ , collides with the target nucleus with spin  $I$  and parity  $\pi_I$ , and forms the compound nucleus with spin  $J$  and parity  $\Pi$  before emitting a particle with energy  $E'$ , spin  $s'$  and parity  $\pi_{s'}$  leaving a residual nucleus in a state with spin  $I'$  and parity  $\pi_{I'}$ . Coefficient  $B_L (I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E')$  is expressed in terms of the Hauser-Feshbach formula<sup>9)</sup> :

$$B_L (I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') \\ = \frac{1}{4k^2} \frac{(-)^{I'-I+s-s'}}{(2s+1)(2I+1)} \sum_{J\Pi} \frac{(2J+1)^2}{\sigma_{J\Pi}} \sum_J \omega_{II} (\pi_I, \pi_s, l) \\ \times \tau_{I'} (E, I, \pi_I, s, \pi_s, J, L) \sum_{J'P} \omega_{II} (\pi_{I'}, \pi_{s'}, l') \tau_{I'} (E', I', \pi_{I'}, s', \pi_{s'}, J, L) \times 10, \quad (2.43)$$

where

$$\omega_{II} (\pi_I, \pi_s, l) = \frac{1}{2} [\Pi + \pi_I \times \pi_s \times (-)^l], \quad (2.44)$$

$$\tau_{l'}(E, I, \pi_I, s, \pi_s, J, L) = T_{l'}^{(j)}(E, I, \pi_I, s, \pi_s) \cdot Z(ljlj; sL) \cdot W(jJjJ; IL), \quad (2.45)$$

and

$$\sigma_{JII} = \sum_{E' I' \pi_{I'} s' \pi_{s'} l' j'} \omega_{II}(\pi_{I'}, \pi_{s'}, l') \cdot T_{l'}^{(j')} (E', I', \pi_{I'}, s', \pi_{s'}) / (1 - \alpha_{JII}). \quad (2.46)$$

The transmission coefficient,  $T_{l'}^{(j)}(E, I, \pi_I, s, \pi_s)$ , is calculated by the use of Eq. (2.17). Parameter  $\alpha_{JII}$  plays a role of correction factor of the branching ratio<sup>2), 12)</sup>. It corrects the effects of the competing processes, such as  $(n, \gamma)$  or fission, whose transmission coefficients cannot be calculated by using this program.

In Eq. (2.42), levels of the residual nucleus are all discrete, and their energies, spins and parities are well defined. In ELIESE-3, this formula is extended to include the overlapping levels of the residual nucleus. In this case, Eq. (2.42) must be rewritten as follows:

$$\frac{d^2\sigma(c, c')}{dE_c d\Omega_c} = \sum_{I' \pi_{I'}} B_L(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') \rho(U', I', \pi_{I'}) P_L(\cos \theta_{c'}), \quad (2.42')$$

where  $\rho(U', I', \pi_{I'})$  is level density of the residual nuclear state which has excitation energy  $U'$ , spin  $I'$  and parity  $\pi_{I'}$ . Eq. (2.46) is also rewritten as

$$\begin{aligned} \sigma_{JII} = & \left\{ \sum_{E' I' \pi_{I'} s' \pi_{s'} l' j'} \omega_{II}(\pi_{I'}, \pi_{s'}, l') T_{l'}^{(j')} (E', I', \pi_{I'}, s', \pi_{s'}) + \sum_{I' \pi_{I'} s' \pi_{s'} l' j'} \omega_{II}(\pi_{I'}, \pi_{s'}, l') \right. \\ & \left. \times \int_{E_c + Q'}^{E + Q'} dU' \cdot \rho(U', I', \pi_{I'}) T_{l'}^{(j')} (E', I', \pi_{I'}, s', \pi_{s'}) \right\} / (1 - \alpha_{JII}), \end{aligned} \quad (2.46')$$

where  $Q'$  means  $Q$ -value of the reaction concerned here and  $E_c$  is a critical energy above which nuclear levels are assumed to be overlapping.

By integrating Eq. (2.42) over angles, cross section for the compound nuclear process is given by  $B_0(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E')$ . Explicite formula of the cross section is

$$\sigma_{cc}(E, I, \pi_I \rightarrow E', I', \pi_{I'}) = 4\pi B_0(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E'), \quad (2.47)$$

where

$$\begin{aligned} B_0(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') = & \frac{1}{4\pi} \frac{1}{(2s+1)(2I+1)} \\ & \times \sum_{JII} \frac{2J+1}{\sigma_{JII}} \sum_{jl} \omega_{II}(\pi_I, \pi_s, l) T_l^{(j)}(E, I, \pi_I, s, \pi_s) \\ & \times \sum_{j'l'} \omega_{II}(\pi_{I'}, \pi_{s'}, l') T_{l'}^{(j')} (E', I', \pi_{I'}, s', \pi_{s'}) \times 10. \end{aligned} \quad (2.48)$$

Similar expression is given in the case of Eq. (2.42'). Then, total reaction cross section via compound nucleus is

$$\begin{aligned} \sigma_r(E, I, \pi_I) = & 4\pi \sum_{I' \pi_{I'}} \left\{ \sum_{E'} B_0(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') \right. \\ & \left. + \int_0^{E-E_c} \rho(U', I', \pi_{I'}) B_0(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') dE' \right\}. \end{aligned} \quad (2.49)$$

In the Moldauer formula<sup>4), 5), 6)</sup>, the coefficient,  $B_L(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E')$ , is defined as the fluctuation part of the cross section and is given by the formula:

$$\begin{aligned} B_L(I, \pi_I, s, \pi_s, E \rightarrow I', \pi_{I'}, s', \pi_{s'}, E') = & \frac{1}{4k^2} \frac{1}{(2s+1)(2I+1)} \\ & \times \sum_{JII} (2J+1)^2 \left\{ \frac{(-)^{I'-I+s-s'}}{\sigma_{JII}} \sum_{jl} \omega_{II}(\pi_I, \pi_s, l) \cdot \tau_{lj}^{JII}(E, I, \pi_I, s, \pi_s, J, L) \right. \\ & \times \sum_{j'l'} \omega_{II}(\pi_{I'}, \pi_{s'}, l') \cdot \tau_{l'j'}^{JII}(E', I', \pi_{I'}, s', \pi_{s'}, J, L) \cdot S_{cc}^{JII}(E, I, s, j, l; E', I', s', j', l') \\ & + \delta_{EI\pi_I, E'I'\pi_{I'}} \sum_{j'l'lp} (1 - \delta_{j, j'} \cdot \delta_{l, l'}) \cdot (1 + b^*_{EI\pi_I j l} \cdot b_{E'I'\pi_{I'} j' l'}) \\ & \left. \times \frac{1}{\sigma_{JII}} \omega_{II}(\pi_I, \pi_s, l) \cdot \omega_{II}(\pi_{I'}, \pi_{s'}, l') [Z(ljlj'; sL) \cdot W(jJjJ'; IL)]^2 \right\} \end{aligned}$$

$$\begin{aligned} & \times \Theta_{l,j}^{J\pi}(EI\pi_I s\pi_s) \cdot \Theta_{l',j'}^{J\pi}(EI\pi_I s\pi_s) \cdot S_{cc}^{J\pi}(E, I, s, j, l; E, I, s, j', l') \\ & - \frac{1}{2} \delta_{EI\pi_I, E'I'\pi_{s'}} \sum_{jljl'} b^*_{EI\pi_I j} b_{EI\pi_I j'l'} [Z(ljlj; sL) \cdot W(JjJj'; IL)]^2 \\ & \times \left[ 1 - \Phi_0(\sigma_{J\pi}) \right] \cdot \omega_{ll'}(\pi_I, \pi_s, l) \cdot \omega_{ll'}(\pi_{I'}, \pi_{s'}, l') \cdot \Theta_{l,j}^{J\pi}(EI\pi_I s\pi_s) \\ & \times \Theta_{l',j'}^{J\pi}(EI\pi_I s\pi_s) \} \times 10, \end{aligned} \quad (2.50)$$

where

$$\tau_{l,j}^{J\pi}(E, I, \pi_I, s, \pi_s, J, L) = \Theta_{l,j}^{J\pi}(EI\pi_I s\pi_s) Z(ljlj; sL) W(JjJj; IL). \quad (2.51)$$

The quantities  $\Theta_{l,j}^{J\pi}(EI\pi_I s\pi_s)$  and  $T_l^{(j)}(EI\pi_I s\pi_s)$  are combined with each other by the following formula<sup>4), 5), 6)</sup> :

$$T_l^{(j)} = \Theta_{l,j}^{J\pi} - \frac{1}{4} Q_{l,j}^{J\pi} \times [\Theta_{l,j}^{J\pi}]^2, \quad (2.52)$$

where

$$Q_{l,j}^{J\pi} = 2 \times [1 - \Phi_0(\sigma_{J\pi})], \quad (2.53)$$

and

$$\sigma_{J\pi} = \sum_{E'I'\pi_I, s\pi_s, j'l'} \omega_{ll'}(\pi_I, \pi_s, l') \cdot \Theta_{l',j'}^{J\pi}(E'I'\pi_I s' \pi_{s'}) / (1 - \alpha_{J\pi}). \quad (2.54)$$

The quantity  $\Theta_{l,j}^{J\pi}$  is solved by the iterative method<sup>4), 5), 6), 13)</sup>. Function  $\Phi_0$  gives an interference effect between resonance levels, and is defined as follows :

$$\Phi_0(2x) = 1 - \frac{1}{x} \left[ 1 - \frac{1}{x} e^{-x} \sinh x \right] - \frac{1}{x} Ei(-x) \left[ \cosh x - \frac{1}{x} \sinh x \right], \quad (2.55)$$

where

$$Ei(-x) = - \int_x^\infty \frac{e^{-t}}{t} dt = \log x + \gamma + \sum_{n=1}^{\infty} \frac{(-x)^n}{n \cdot n!}, \quad (2.56)$$

and  $\gamma$  is the Euler's constant,

$$\gamma = 0.5772157. \quad (2.57)$$

Quantity  $b_{EI\pi_I j l}$  in Eq. (2.50) is defined in this program by the following formula :

$$b_{EI\pi_I j l} = \exp[2i \arg(\phi_l^{(j)}(r_M))]. \quad (2.58)$$

It is assumed here that the averaged value of the reduced width amplitude is proportional to the value of the optical model wave function at  $r=r_M$ . Effect of the fluctuations of the resonance level widths is taken into account by the quantity  $S_{cc}^{J\pi}(E, I, s, j, l; E', I', s', j', l')$ :

$$S_{cc}^{J\pi}(E, I, s, j, l; E', I', s', j', l') = \int_0^\infty \frac{1 + \frac{2}{\nu_c} \delta(E, I, s, j, l; E', I', s', j', l') dt}{f_c(EIsjl) \cdot f_c(E'I's'j'l') \prod_i f_i^{\nu_i/2}}, \quad (2.59)$$

where

$$f_i(EIsjl) = 1 + \frac{2\Theta_{jl}^{J\pi}(EI\pi_I s\pi_s) \cdot t}{\nu_i \sigma_{J\pi}}, \quad (2.60)$$

assuming a  $\chi^2$ -distribution with  $\nu_i$  degrees of freedom for  $\Theta_{jl}^{J\pi}$ .

Expression similar to Eq. (2.48) is given also in this case. Since Moldauer effect is only important near threshold energy of reaction process, an extension like Eq. (2.42') is not carried out in this program.

### 3. Description of Potential Forms

In usual optical model, nuclear potential is divided into three parts; central potential, spin-orbit potential and Coulomb potential. In this section, the forms of these potentials are discussed as well as several parameters included in the potentials. The non-local potential and its equivalent local potential are also described in this section.

#### 3.1 Central potential

The central potential is written as

$$\mathcal{V}_C(r) = \mathcal{V}_{CR}(r) + i\mathcal{W}_{CI}(r), \quad (3.1)$$

where  $\mathcal{V}_{CR}(r)$  is the real part and  $\mathcal{W}_{CI}(r)$  the imaginary part. The real potential  $\mathcal{V}_{CR}(r)$  is assumed to have Woods-Saxon form factor and is represented as follows:

$$\mathcal{V}_{CR}(r) = \frac{2\mu}{\hbar^2} V_C \cdot \mathcal{F}_{CR}(r), \quad (3.2)$$

where  $\mathcal{F}_{CR}(r)$  is the Woods-Saxon form factor and is written as

$$\mathcal{F}_{CR}(r) = \frac{1}{1 + \exp \{(r - R_0)/a_0\}}, \quad (3.3)$$

and  $V_C$  is the potential strength (or potential well depth) parameter. The parameter  $V_C$  is expressed in the present program as

$$V_C = V_{C,0} + V_{C,1} \left( E - V_{Coul} \frac{ZZ' e^2}{R_C} \right) + V_{C,2} \cdot E^2 + V_{sym} \frac{(N-Z) \cdot (N'-Z')}{A \cdot A'}, \quad (3.4)$$

where  $A$ ,  $Z$  and  $N$  are mass number, proton number and neutron number of the target nucleus, respectively. Prime means quantity on the incident particle. Energy dependent form of Eq. (3.4) reflects non-local character of the optical potential<sup>[14]</sup>. When the non-local optical potential is used in the calculation, energy independent form should be selected from Eq. (3.4). Last term of Eq. (3.4) stands for the symmetric term. It means  $z$ -component of isospin interaction and therefore such form as in Eq. (3.4) is rather general.

Parameter  $R_0$  in Eq. (3.3) is defined in this program as

$$R_0 = r_0 A^{1/3} \text{ or } r_0 \cdot (A^{1/3} + A'^{1/3}). \quad (3.5)$$

Additional term  $r_0 A'^{1/3}$  means radius of the incident particle. Adoption of this term is managed by an input data. Parameter  $R_C$  in Eq. (3.4) means Coulomb radius and is given as

$$R_C = r_C A^{1/3} \text{ or } r_C \cdot (A^{1/3} + A'^{1/3}). \quad (3.6)$$

Parameters  $r_0$ ,  $r_C$  and diffuseness parameter  $a_0$  in Eq. (3.3) are given as input data in the present program.

The imaginary potential  $\mathcal{W}_{CI}(r)$  consists of nuclear surface part and nuclear interior part, and is expressed as

$$\mathcal{W}_{CI}(r) = \frac{2\mu}{\hbar^2} \{ W_S \mathcal{F}_{CS}(r) + W_I \mathcal{F}_{CI}(r) \}. \quad (3.7)$$

The form factor of the surface part,  $\mathcal{F}_{CS}(r)$ , is assumed to be Gaussian type or derivative Woods-Saxon type. Either type of the form factor is selected by the input data in this program. On the other hand, the form factor of the interior part,  $\mathcal{F}_{CI}(r)$ , is assumed to be Woods-Saxon form. These three types of the form factor are given as the following forms:

$$\mathcal{F}_{CI}(r) = \frac{1}{1 + \exp \{(r - R_I)/a_I\}} ; \text{ interior}, \quad (3.8)$$

and

$$\mathcal{F}_{CS}(r) = \begin{cases} \exp \{-(r - R_S)/b\}^2 ; & \text{Gaussian,} \\ \frac{4 \exp \{(r - R_S)/b\}}{\{1 + \exp \{(r - R_S)/b\}\}^2} ; & \text{derivative Woods-Saxon.} \end{cases} \quad (3.9)$$

$$\mathcal{F}_{CS}(r) = \begin{cases} \exp \{-(r - R_S)/b\}^2 ; & \text{Gaussian,} \\ \frac{4 \exp \{(r - R_S)/b\}}{\{1 + \exp \{(r - R_S)/b\}\}^2} ; & \text{derivative Woods-Saxon.} \end{cases} \quad (3.10)$$

Potential strength  $W_I$  and  $W_S$  are assumed to be quadratic form of the energy:

$$W_I = W_{I,0} + W_{I,1} \cdot E + W_{I,2} \cdot E^2, \quad (3.11)$$

and

$$W_S = W_{S,0} + W_{S,1} \cdot E + W_{S,2} \cdot E^2, \quad (3.12)$$

respectively. Radial parameters  $R_I$  and  $R_S$  are defined in the same way as  $R_0$  and  $R_C$ . They are given as follows:

$$R_I = r_I A^{1/3} \text{ or } r_I \cdot (A^{1/3} + A'^{1/3}), \quad (3.13)$$

and

$$R_S = r_S A^{1/3} \text{ or } r_S \cdot (A^{1/3} + A'^{1/3}), \quad (3.14)$$

respectively.

### 3.2 Spin-orbit potential

Spin-orbit potential is assumed to be Thomas-Fermi type and is expressed as

$$CV_{SO}(r) = \frac{2\mu}{\hbar^2} C_{SO} \frac{1}{r} (V_{SO} + iW_{SO}) \frac{1}{a_{SO}} \frac{\exp \{(r - R_{SO})/a_{SO}\}}{\{1 + \exp \{(r - R_{SO})/a_{SO}\}\}^2}, \quad (3.15)$$

where  $C_{SO}$  is given by using  $\pi$ -meson mass  $m_\pi$  and the light velocity  $c$ :

$$C_{SO} = \left( \frac{\hbar}{m_\pi c} \right)^2. \quad (3.16)$$

Potential strength  $V_{SO}$  and  $W_{SO}$  are defined in the same way as in Eqs. (3.11) and (3.12):

$$V_{SO} = V_{SO,0} + V_{SO,1} \cdot E + V_{SO,2} \cdot E^2, \quad (3.17)$$

and

$$W_{SO} = W_{SO,0} + W_{SO,1} \cdot E + W_{SO,2} \cdot E^2. \quad (3.18)$$

Same definition as  $R_0$ ,  $R_I$  or  $R_S$  is given to the radial parameter  $R_{SO}$ :

$$R_{SO} = r_{SO} A^{1/3} \text{ or } r_{SO} \cdot (A^{1/3} + A'^{1/3}). \quad (3.19)$$

### 3.3 Coulomb potential

Coulomb potential in the interior region is defined as follows:

$$CV_{Coul}(r) = \frac{2\mu}{\hbar^2} \frac{ZZ'e^2}{2R_C} \left( 3 - \frac{r^2}{R_C^2} \right), \quad r \leq R_C, \quad (3.20)$$

where charge distribution is assumed to be uniform. In the external region, the Coulomb potential is given as usual:

$$CV_{Coul}(r) = \frac{2\mu}{\hbar^2} \frac{ZZ'e^2}{r}, \quad r > R_C. \quad (3.21)$$

As mentioned in section 2, internal and external wave functions are smoothly joined with each other at matching radius  $r_M$ . This matching radius  $r_M$  is defined as the minimum value of those radii which satisfy the following conditions simultaneously:

$$\frac{1}{\hbar^2} CV_{CR}(r) \leq 10^{-4}, \quad (3.22)$$

$$\frac{1}{k^2} \mathcal{W}_{Cl}(r) \leq 10^{-4}, \quad (3.23)$$

$$\frac{1}{k^2} CV_{\text{so}}(r) \leq 10^{-4}, \quad (3.24)$$

and

$$\frac{1}{k^2} CV_{\text{Coul}}(r) \leq 10^{-4}. \quad (3.25)$$

### 3.4 Non-local kernel and equivalent local potential

The  $l$ -th component of the non-local kernel,  $h_l(r, r')$  in Eq. (2.1'), is defined as

$$h_l(r, r') = 2\pi rr' \int_0^\infty H(|\vec{r} - \vec{r}'|) P_l(\cos \theta) \sin \theta \cdot d\theta. \quad (3.26)$$

Here, a separable form is assumed for the non-local potential to facilitate the numerical calculation. Some approximations are taken here after Perey and Buck's ones<sup>11</sup>. The function  $H(|\vec{r} - \vec{r}'|)$  is chosen to be a Gaussian form or a Yukawan form. In the case of the Gaussian form, the function  $h_l(r, r')$  has a following form :

$$h_l(r, r') = \frac{1}{\sqrt{\pi} \beta} \left\{ Q_l(\xi) \exp \left[ -\left( \frac{r-r'}{\beta} \right)^2 \right] + (-)^{l+1} Q_l(-\xi) \exp \left[ -\left( \frac{r+r'}{\beta} \right)^2 \right] \right\}, \quad (3.27)$$

where  $\beta$  is a non-local parameter and  $\xi = 2rr'/\beta^2$ . Function  $Q_l(\xi)$  is defined as a finite polynomial in  $(1/\xi)$  and is given by

$$Q_l(\xi) = \sum_{n=0}^l A_n(l) (-\xi)^{-n}, \quad (3.28)$$

where

$$\left. \begin{aligned} A_n(l) &= \frac{l(l+1)-n(n-1)}{2n} A_{n-1}(l), \\ A_0(l) &= 1. \end{aligned} \right\} \quad (3.29)$$

For small  $\xi$ , Eq. (3.27) is expanded as a power series in  $\xi$ ,

$$h_l(r, r') = \frac{1}{\sqrt{\pi} \beta} \exp \left[ -\frac{r^2+r'^2}{\beta^2} \right] \frac{2}{(2l+1)!} \xi^{l+1} \sum_{n=0}^{\infty} B_n(l) \xi^n, \quad (3.30)$$

where

$$\left. \begin{aligned} B_n(l) &= \frac{1}{n(n+2l+1)} B_{n-2}(l), \\ B_0(l) &= 1, \quad B_1(l) = 0. \end{aligned} \right\} \quad (3.31)$$

In the case of the Yukawan form for  $H(|\vec{r} - \vec{r}'|)$ , the kernel function is

$$h_l(r, r') = \frac{4}{\beta^2} \sqrt{rr'} I_{l+1/2} \left( \frac{2r'}{\beta} \right) K_{l+1/2} \left( \frac{2r}{\beta} \right), \quad 0 < r' < r. \quad (3.32)$$

The modified Bessel functions,  $I_{l+1/2}(x)$  and  $K_{l+1/2}(x)$ , are subject to a differential equation :

$$\frac{d^2 X_n}{dx^2} - \left\{ 1 + \frac{1}{r^2} \left( n^2 - \frac{1}{4} \right) \right\} X_n = 0, \quad (3.33)$$

where  $X_n$  stands for  $\sqrt{x} I_n(x)$  or  $\sqrt{x} K_n(x)$ . Recurrence relations of  $I_n(x)$  and  $K_n(x)$  are as follows :

$$\left. \begin{aligned} I_{n+1}(x) &= I_{n-1}(x) - \frac{2n}{x} I_n(x), \\ K_{n+1}(x) &= K_{n-1}(x) + \frac{2n}{x} K_n(x). \end{aligned} \right\} \quad (3.34)$$

and  
The lowest two functions of them are given as

$$\left. \begin{aligned} I_{1/2}(x) &= \sqrt{\frac{2}{\pi x}} \sinh x, \\ I_{3/2}(x) &= \sqrt{\frac{2}{\pi x}} \left( \cosh x - \frac{1}{x} \sinh x \right), \\ K_{1/2}(x) &= \sqrt{\frac{\pi}{2x}} e^{-x}, \\ K_{3/2}(x) &= \sqrt{\frac{\pi}{2x}} \left( 1 + \frac{1}{x} \right) e^{-x}, \end{aligned} \right\} \quad (3.35)$$

and

respectively. Two functions must satisfy a following Wronskian condition :

$$I_n(x)K_{n+1}(x) + I_{n+1}(x)K_n(x) = \frac{1}{x}. \quad (3.36)$$

The function  $K_n(x)$  is an increasing function with increasing  $n$  value, while  $I_n(x)$  is a decreasing function. Therefore, a sequence of the  $K_n(x)$ -function is obtained by using Eqs. (3.34) and (3.35) with increasing order. On the other hand, a sequence of the  $I_n(x)$ -function is made by using the recurrence relation, Eq. (3.34), with decreasing order and each  $I_n(x)$  is normalized to Eq. (3.36). This procedure is similar one as in the case of obtaining the wave functions in the asymptotic region (see next section). In ELIESE-3, this procedure is applied in order to obtain the values of the functions,  $K_n(x)$  and  $I_n(x)$ .

The equivalent local potentials are used as the local optical potentials which are effectively equivalent to the non-local optical potentials. Relation between the non-local potential and its equivalent local potential is given as follows :

$$CV_L(\vec{r}) = CV_N(\vec{r}) G\left(\frac{2\mu}{\hbar^2}[E + CV_L(\vec{r})]\right), \quad (3.37)$$

where  $CV_L(\vec{r})$  and  $CV_N(\vec{r})$  are local and non-local potentials respectively, and

$$G(k^2) = \int d\vec{s} H(s) \exp(-i\vec{k} \cdot \vec{s}). \quad (3.38)$$

For the Gaussian kernel, Eq. (3.37) is

$$CV_L(\vec{r}) = CV_N(\vec{r}) \exp\left[\frac{\mu}{2\hbar^2}\beta^2(E + CV_L(\vec{r}))\right]. \quad (3.39)$$

This transcendental equation is solved by the following coupled equations for the real and imaginary parts of the potential :

$$\left\{ \begin{aligned} W_L &= \left\{ (V_N^2 + W_N^2) \exp\left[\frac{\mu\beta^2}{\hbar^2}(E + V_L)\right] - V_L^2 \right\}^{1/2}, \\ \tan^{-1}\left(\frac{W_L}{V_L}\right) + \frac{\mu\beta^2}{2\hbar^2} W_L &= \tan^{-1}\left(\frac{W_N}{V_N}\right), \end{aligned} \right. \quad (3.40)$$

$$\left. \begin{aligned} \tan^{-1}\left(\frac{W_L}{V_L}\right) + \frac{\mu\beta^2}{2\hbar^2} W_L &= \tan^{-1}\left(\frac{W_N}{V_N}\right), \end{aligned} \right. \quad (3.41)$$

where  $V_N$  and  $V_L$  are real parts of the non-local and the local potentials respectively, while  $W_N$  and  $W_L$  stand for their imaginary parts.

For the Yukawan kernel, Eq. (3.37) is given as follows :

$$CV_L(\vec{r}) = CV_N(\vec{r}) \left/ \left[ 1 + \frac{\mu\beta^2}{2\hbar^2}[E + CV_L(\vec{r})] \right] \right., \quad (3.42)$$

and the solutions of the equivalent local potential are easily given by the following relations :

$$\left\{ \begin{aligned} V_L &= \frac{\hbar^2}{\mu\beta^2} \left[ \sqrt{A} \cos \frac{\theta}{2} - 1 - \frac{\mu\beta^2}{2\hbar^2} E \right], \\ W_L &= \frac{\hbar^2}{\mu\beta^2} \sqrt{A} \sin \frac{\theta}{2}, \end{aligned} \right. \quad (3.43)$$

$$\left. \begin{aligned} V_L &= \frac{\hbar^2}{\mu\beta^2} \left[ \sqrt{A} \cos \frac{\theta}{2} - 1 - \frac{\mu\beta^2}{2\hbar^2} E \right], \\ W_L &= \frac{\hbar^2}{\mu\beta^2} \sqrt{A} \sin \frac{\theta}{2}, \end{aligned} \right. \quad (3.44)$$

where

$$A^2 = \left[ \left( 1 + \frac{\mu\beta^2}{2\hbar^2} E \right)^2 + \frac{2\mu\beta^2}{\hbar^2} V_N \right]^2 + \left( \frac{2\mu\beta^2}{\hbar^2} W_N \right)^2, \quad (3.45)$$

and

$$\tan \theta = \frac{2\mu\beta^2}{\hbar^2} W_N / \left[ \left( 1 + \frac{\mu\beta^2}{2\hbar^2} E \right)^2 + \frac{2\mu\beta^2}{\hbar^2} V_N \right]. \quad (3.46)$$

## 4. Method of Obtaining the Wave Functions

In this section, method of obtaining the numerical solutions is described on the wave functions.

### 4.1 Wave functions in the asymptotic region

Asymptotic form of the wave function is given by Eq. (2.6). Function  $G_l(\rho)$  is subject to a recurrence relation<sup>15)</sup>:

$$G_{l+1}(\rho) = \frac{l+1}{\sqrt{\eta^2 + (l+1)^2}} \left[ (2l+1) \left( \frac{\eta}{l(l+1)} + \frac{1}{\rho} \right) G_l(\rho) - \frac{1}{l} \sqrt{\eta^2 + l^2} G_{l-1}(\rho) \right]. \quad (4.1)$$

It increases with increasing  $l$  value. Since nuclear penetrability is proportional to a quantity  $(G_l(\rho_M)^2 + F_l(\rho_M)^2)^{-1}$ , maximum angular momentum quantum number  $l_{\max}$  is defined by the condition:

$$[G_l(\rho_M)/G_0(\rho_M)]^2 > 10^6. \quad (4.2)$$

Then, the function  $G_l(\rho)$  is obtained at  $\rho_M$  by using Eq. (4.1), in the range of  $l$  from 0 to  $l_{\max}$ .

On the other hand, the function  $F_l(\rho)$  increases with decreasing  $l$  value. Therefore, the function  $F_l(\rho)$  is obtained by using the recurrence relation, Eq. (4.1), inversely. Actually, assuming

$$l^{(1)} = l_{\max} + 10, \quad (4.3)$$

$$F_{l^{(1)}+1}^{(1)} = 0, \quad (4.4)$$

and

$$F_{l^{(1)}}^{(1)} = 10^{-36}, \quad (4.5)$$

the function  $F_l^{(1)}(\rho_M)$  corresponding to lower  $l$ -value is calculated by the reverse relation to Eq. (4.1). For  $l=0$ , the normalization factor is obtained by means of Wronskian's rule as follows:

$$\alpha = (1 + \eta^2)^{1/2} (F_0^{(1)} G_1 - G_0 F_1^{(1)}). \quad (4.6)$$

The function  $F_l^{(1)}(\rho_M)$  is renormalized by using this factor:

$$F_l(\rho_M) = F_l^{(1)}(\rho_M) / \alpha. \quad (4.7)$$

If the function  $F_l(\rho_M)$  is correct, Wronskian's rule should be satisfied for  $l \leq l_{\max}$ :

$$F_l'(\rho_M) G_l(\rho_M) - F_l(\rho_M) G_l'(\rho_M) = 1. \quad (4.8)$$

If it is not correct, above method is repeated by resetting  $l^{(1)}$  as  $l^{(1)} + 5$ . (Prime means differentiation by  $\rho$  in the above and following equations for  $G_l(\rho)$  and  $F_l(\rho)$ .)

In order to use the recurrence relation, Eq. (4.1), the lowest two functions  $G_0(\rho_M)$  and  $G_1(\rho_M)$  are needed. For the neutron, the Coulomb parameter  $\eta$  is of course zero, and,

$$G_0(\rho_M) = \cos \rho_M, \quad (4.9)$$

and

$$G_1(\rho_M) = \frac{1}{\rho_M} [\cos \rho_M + \rho_M \cdot \sin \rho_M]. \quad (4.10)$$

For the charged particle,  $G_0(\rho_M)$  and  $G_0'(\rho_M)$  must be found at an asymptotic radius  $\rho_A$ , because  $G_0(\rho)$  and  $G_1(\rho)$  are not always obtained easily at  $\rho_M$ . The asymptotic radius  $\rho_A$  is defined by<sup>15)</sup>

$$\rho_A = 16 \quad \text{for } \eta \geq 15, \quad (4.11)$$

$$\rho_A = 2\eta \quad \text{for } 15 > \eta \geq 4, \quad (4.12)$$

$$\rho_A = 2\eta + 9 \quad \text{for } \eta < 4. \quad (4.13)$$

At  $\rho_A$ , the functions  $G_0$  and  $G_0'$  are calculated by means of the following formulae<sup>15)</sup>:

- i)  $\eta \geq 15$ , and  $\rho_A = 16$ ,

$$G_0(\rho_A) = \exp \{ \Psi(t, \eta) \}, \quad (4.14)$$

$$G_0'(\rho_A) = G_0(\rho_A) \frac{d\Psi}{dt} \Big|_{2\eta}, \quad (4.15)$$

where  $t = \rho_A/2\eta$  and

$$\Psi(t, \eta) = \sum_{n=0}^{\infty} (-2\eta)^{1-n} g_n. \quad (4.16)$$

Coefficients  $g_n$  (for  $n=0 \sim 7$ ) are

$$g_0 = \sqrt{t(1-t)} + \sin^{-1}(\sqrt{t}) - \frac{1}{2}\pi, \quad (4.17)$$

$$g_1 = \frac{1}{4} \ln\left(\frac{t}{1-t}\right), \quad (4.18)$$

$$g_2 = -\frac{8t^2 - 12t + 9}{48\sqrt{t(1-t)^3}}, \quad (4.19)$$

$$g_3 = \frac{8t - 3}{64t(1-t)^3}, \quad (4.20)$$

$$g_4 = \frac{2048t^6 - 9216t^5 + 16128t^4 - 13440t^3 - 12240t^2 + 7560t - 1890}{92160\sqrt{t^3(1-t)^9}}, \quad (4.21)$$

$$g_5 = \frac{3(1024t^3 - 448t^2 + 208t - 39)}{8192t^2(1-t)^6}, \quad (4.22)$$

$$g_6 = -\frac{(262144t^{10} - 1966080t^9 + 6389760t^8 - 11714560t^7 + 13178880t^6 - 9225216t^5 + 13520640t^4 - 3588480t^3 + 2487240t^2 - 873180t + 130977)/10321920\sqrt{t^5(1-t)^{15}}}{}, \quad (4.23)$$

and

$$g_7 = \frac{1105920t^5 - 55296t^4 + 314624t^3 - 159552t^2 + 45576t - 5697}{393216t^3(1-t)^9}. \quad (4.24)$$

Derivatives of these coefficients by  $t$  are given as follows,

$$g_0' = \sqrt{(1-t)/t}, \quad (4.25)$$

$$g_1' = \frac{1}{4t(1-t)}, \quad (4.26)$$

$$g_2' = -\frac{8t - 3}{32\sqrt{t^3(1-t)^5}}, \quad (4.27)$$

$$g_3' = \frac{3(8t^2 - 4t + 1)}{64t^2(1-t)^4}, \quad (4.28)$$

$$g_4' = -\frac{1536t^3 - 704t^2 + 336t - 63}{2048\sqrt{t^5(1-t)^{11}}}, \quad (4.29)$$

$$g_5' = \frac{3(2560t^4 - 832t^3 + 728t^2 - 260t + 39)}{4096t^3(1-t)^7}, \quad (4.30)$$

$$g_6' = \frac{-368640t^5 - 30720t^4 + 114944t^3 - 57792t^2 + 16632t - 2079}{65536\sqrt{t^7(1-t)^{17}}}, \quad (4.31)$$

and

$$g_7' = 3(860160t^6 + 196608t^5 + 308480t^4 - 177280t^3 + 73432t^2 - 17724t + 1899)/131072t^4(1-t)^{10}. \quad (4.32)$$

ii)  $15 > \eta \geq 4$ , and  $\rho_A = 2\eta$ ,

$$\begin{aligned} G_0(\rho_A) = & 1.223404016\eta^{1/6} [1 + 0.04959570165\eta^{-4/3} \\ & - 0.008888888886\eta^{-2} + 0.002455199181\eta^{-10/3} \\ & - 0.0009108958061\eta^{-4} + 0.0002534684115\eta^{-16/3}], \end{aligned}$$

and

$$G_0'(\rho_A) = -0.7078817734\eta^{-1/6} [1 - 0.1728260369\eta^{-2/3} + 0.0003174603174\eta^{-2}]$$

$$\begin{aligned} & -0.003581214850\eta^{-8/3} + 0.0003117824680\eta^{-4} \\ & -0.0009073966427\eta^{-14/3}. \end{aligned} \quad (4.34)$$

iii)  $\eta < 4$ , and  $\rho_A = 2\eta + 9$ ,  $(\varphi = \rho_A - \eta \cdot \ln(2\rho_A) + \sigma_0)$

$$G_0(\rho_A) = s \cdot \cos \varphi - t \cdot \sin \varphi, \quad (4.35)$$

and

$$G_0'(\rho_A) = S \cdot \cos \varphi - T \cdot \sin \varphi, \quad (4.36)$$

where

$$s = \sum s_n, \quad (4.37)$$

$$t = \sum t_n, \quad (4.38)$$

$$S = \sum S_n, \quad (4.39)$$

and

$$T = \sum T_n. \quad (4.40)$$

These  $s_n$ ,  $t_n$ ,  $S_n$  and  $T_n$  are obtained by using the following relations:

$$s_{n+1} = A_n s_n - B_n t_n, \quad (4.41)$$

$$t_{n+1} = A_n t_n + B_n s_n, \quad (4.42)$$

$$S_{n+1} = A_n S_n - B_n T_n - \frac{s_{n+1}}{\rho_A}, \quad (4.43)$$

and

$$T_{n+1} = A_n T_n + B_n S_n - \frac{t_{n+1}}{\rho_A}, \quad (4.44)$$

where

$$A_n = \frac{2n+1}{2(n+1)\rho_A} \eta, \quad (4.45)$$

$$B_n = \frac{\eta^2 - n(n+1)}{2(n+1)\rho_A}, \quad (4.46)$$

$$s_0 = 1, \quad (4.47)$$

$$t_0 = 0, \quad (4.48)$$

$$S_0 = 0, \quad (4.49)$$

and

$$T_0 = 1 - (\eta/\rho_A). \quad (4.50)$$

Quantities  $s$ ,  $t$ ,  $S$  and  $T$  should satisfy the Wronskian relation:

$$sT - St = 1. \quad (4.51)$$

If they do not satisfy the relation, calculation should be repeated by resetting  $\rho_A$  to  $\rho_A + 5.0$ .

When the functions  $G_0$  and  $G_0'$  are obtained at the asymptotic radius  $\rho_A$ , the wave function  $G_0$  is obtained numerically from  $\rho_A$  to the matching radius  $\rho_M$ . The wave equation for  $G_0$ ,

$$\frac{d^2 G_0}{d\rho^2} = \left( \frac{2\eta}{\rho} - 1 \right) G_0 \equiv f(\rho) G_0, \quad (4.52)$$

is integrated by means of Fox-Goodwin's method:

$$G_0(n+1) = \frac{\left( 2 + \frac{5}{6} h^2 f(n) \right) G_0(n) - \left( 1 - \frac{1}{12} h^2 f(n-1) \right) G_0(n-1)}{1 - \frac{1}{12} h^2 f(n+1)}, \quad (4.53)$$

where  $n$  stands for  $n$ -th mesh point in the numerical integration and  $h$  means step length of the integration. In this numerical method, initial values at initial two mesh points are needed. These initial values are calculated by means of Picard's five points method:

$$\begin{aligned} G_0(1) = G_0(0) - h G_0'(0) + \frac{h^2}{1440} [367f(0)G_0(0) \\ - 282f(2)G_0(2) + 116f(3)G_0(3) - 21f(4)G_0(4)], \end{aligned} \quad (4.54)$$

$$\begin{aligned} G_0(2) &= G_0(0) - 2hG_0'(0) + \frac{h^2}{1440} [848f(0)G_0(0) + 2304f(1)G_0(1) \\ &\quad - 480f(2)G_0(2) + 256f(3)G_0(3) - 48f(4)G_0(4)], \end{aligned} \quad (4.55)$$

$$\begin{aligned} G_0(3) &= G_0(0) - 3hG_0'(0) + \frac{h^2}{1440} [1323f(0)G_0(0) + 4212f(1)G_0(1) \\ &\quad + 486f(2)G_0(2) + 540f(3)G_0(3) - 81f(4)G_0(4)], \end{aligned} \quad (4.56)$$

$$\begin{aligned} G_0(4) &= G_0(0) - 4hG_0'(0) + \frac{h^2}{1440} [1792f(0)G_0(0) + 6144f(1)G_0(1) \\ &\quad + 1536f(2)G_0(2) + 2048f(3)G_0(3)]. \end{aligned} \quad (4.57)$$

These are simple algebraic equations and solved easily. Initial values for Fox-Goodwin's method, Eq. (4.53), are  $G_0(3)$  and  $G_0(4)$ . Derivative function  $G_0'$  at  $\rho_M$  is calculated by Lagrange's six points method :

$$\begin{aligned} G_0'(n) &= \frac{1}{h} \left\{ \frac{1}{60} (G_0(n+3) - G_0(n-3)) + \frac{3}{20} (G_0(n-2) - G_0(n+2)) \right. \\ &\quad \left. + \frac{3}{4} (G_0(n+1) - G_0(n-1)) \right\}. \end{aligned} \quad (4.58)$$

Using  $G_0(\rho_M)$  and  $G_0'(\rho_M)$ , the function  $G_1(\rho_M)$  is obtained by the relation :

$$G_1(\rho_M) = \frac{1}{\sqrt{1+\eta^2}} \left\{ \left( \eta + \frac{1}{\rho_M} \right) G_0(\rho_M) - G_0'(\rho_M) \right\}. \quad (4.59)$$

Then, the function  $G_l(\rho_M)$  and  $F_l(\rho_M)$  are all derivable from  $l=0$  to  $l_{\max}$ , and their derivatives are also calculated by the following relation :

$$X_l'(\rho_M) = \frac{1}{l+1} \left\{ \left( \frac{(l+1)^2}{\rho_M} + \eta \right) X_l(\rho_M) - \sqrt{(l+1)^2 + \eta^2} X_{l+1}(\rho_M) \right\}, \quad (4.60)$$

where  $X_l$  stands for  $G_l$  or  $F_l$ .

## 4.2 Wave functions in the interior region

The wave functions in the nuclear interior region are obtained by solving Eqs. (2.1) or (2.1'). In the case of Eq. (2.1'), the integro-differential equation can be rewritten by using the local optical potentials as follows :

$$\begin{aligned} \frac{d^2\varphi_l^{(j)}}{dr^2} - \left\{ \frac{l(l+1)}{r^2} - k^2 - V_L^{(j)}(r) \right\} \varphi_l^{(j)}(r) \\ - \left\{ V_L^{(j)}(r) \varphi_l^{(j)}(r) - \int_0^\infty V_N^{(j)}(r') h_l(r, r') \varphi_l^{(j)}(r') dr' \right\}, \end{aligned} \quad (4.61)$$

where  $V_L^{(j)}(r)$  and  $V_N^{(j)}(r)$  mean the local potential and the non-local potential, respectively. Eq. (2.1) is included in this general form of the Schroedinger equation, and then the following descriptions are performed with this equation, Eq. (4.61).

Eq. (4.61) is rewritten in an abbreviated form :

$$\frac{d^2\varphi_l^{(j)}}{dr^2} = Q_l^{(j)}(r) \varphi_l^{(j)}(r) + R_l^{(j)}(r). \quad (4.62)$$

This equation can be solved by using the Fox-Goodwin's method :

$$\begin{aligned} \varphi_l^{(j)}(n+1) &= \frac{1}{1 - \frac{1}{12} h^2 Q_l^{(j)}(n+1)} \left\{ \left( 2 + \frac{5}{6} h^2 Q_l^{(j)}(n) \right) \varphi_l^{(j)}(n) \right. \\ &\quad \left. - \left( 1 - \frac{1}{12} h^2 Q_l^{(j)}(n-1) \right) \varphi_l^{(j)}(n-1) \right. \\ &\quad \left. + \frac{1}{12} h^2 (R_l^{(j)}(n+1) + 10R_l^{(j)}(n) + R_l^{(j)}(n-1)) \right\}, \end{aligned} \quad (4.63)$$

where  $h$  is the step length of the numerical integration and  $n$  stands for the  $n$ -th mesh point. Derivative of the function is calculated by the same way as in Eq. (4.58).

The values of the wave function at the first two mesh points should be introduced as the starting values of this numerical integration, Eq. (4.63). The first point is an origin,  $r=0$ , and the second point is at  $r=h$ . Since the wave function is regular at  $r=0$ , then,

$$\varphi_l^{(j)}(0)=0, \quad (4.64)$$

for all values of  $l$ . However, for  $p$ -wave, a relation

$$Q_1^{(j)}(0)\varphi_1^{(j)}(0)=2, \quad (4.65)$$

should be noticed, because of the centrifugal force  $2/r^2$  for the  $p$ -wave and the values of the wave functions  $r^{l+1}$  for  $r \rightarrow 0$ . At  $r=h$ , the wave functions may be given as

$$\varphi_l^{(j)}(h)=h^{l+1}. \quad (4.66)$$

The non-local function  $\mathcal{R}_l^{(j)}(r)$  is calculated by the numerical integration, using the kernel function  $h_l(r, r')$  and the wave function  $\varphi_l^{(j)}(r)$ . Therefore, Eq. (4.63) should be solved by iterative procedure.

## 5. Description of Some Basic Quantities

In this section, some basic quantities used in the program are presented.

### 5. 1 Level density

The level density used in Eq. (2.42') has the following forms in this program<sup>16,17)</sup>.

$$\rho(U, I) = \begin{cases} \rho_c(U, I), & \text{for } U \geq U_0 \\ \rho_t(U, I), & \text{for } U < U_0, \end{cases} \quad (5.1)$$

where  $\rho_c(U, I)$  and  $\rho_t(U, I)$  are connected smoothly with each other at  $U = U_0$ . Critical excitation energy  $U_0$  is given as an input data. Functional form of  $\rho_c(U, I)$  is given as follows:

$$\rho_c(U, I) = \frac{(2I+1)}{C_0 U^2} e^{2\sqrt{\alpha}U - \frac{I(I+1)}{2\sigma_M}}, \quad (5.2)$$

where  $C_0$  is a constant and  $\sigma_M$  is a spin cut-off parameter. If a rigid body approximation is used, they are expressed as follows:

$$C_0 = 24\sqrt{2} (0.4\mu_0 r_0^2 A^{3/5}/\hbar^2 \sqrt{\alpha})^{5/2} \alpha^{1/4} \quad (5.3)$$

and

$$\sigma_M^2 = 0.4\mu_0 r_0^2 A^{5/3} U^{1/2}/\hbar^2 \sqrt{\alpha} \equiv \alpha U^{1/2}. \quad (5.4)$$

Quantities  $\alpha$ ,  $r_0$  and  $\mu_0$  are a level density parameter, a radial parameter in Eq. (3.5) and a nucleon unit mass. In ELIESE-3, another formula for  $\rho_c$ ,

$$\rho_c(U, I) = \frac{(2I+1)}{C_0 U^2} e^{2\sqrt{\alpha}U}, \quad (5.5)$$

is also usable.

Functional form  $\rho_t(U, I)$ , on the other hand, has the following formula:

$$\rho_t(U, I) = \rho_c(U_0, I) e^{(U-U_0)/T}, \quad (5.6)$$

where the nuclear temperature  $T$  is given as

$$\frac{1}{T} = \frac{1}{U_0} \{ \sqrt{\alpha U_0} - 2 \}, \quad (5.7)$$

which is obtained by using a continuous condition:

$$\left[ \frac{\partial}{\partial U} \ln \rho_t(U, I) \right]_{U=U_0} = \left[ \frac{\partial}{\partial U} \ln \rho_c(U, I) \right]_{U=U_0}. \quad (5.8)$$

Excitation energy  $U$  is defined by the pairing energy, the Q-value of the reaction and the difference between incident and emitted energies of the particles:

$$U = E - E' + Q - \delta. \quad (5.9)$$

Quantities  $\delta$  and  $\alpha$  are given as the input data in this program. Quantities  $C_0$  and  $\sigma_M$  are given not only as the input data, but also by Eqs. (5.3) and (5.4).

### 5. 2 Method of the automatic parameter search

A set of parameters which minimizes the value of chi-square is looked for in the program. The chi-square in this program is given by the following formula:

$$\chi^2 = \frac{1}{N} \sum_{i=1}^N \left( \frac{\sigma_{\text{exp}}^i - \sigma_{\text{cal}}^i}{\Delta \sigma_{\text{exp}}^i} \right)^2, \quad (5.10)$$

where  $\sigma_{\text{exp}}^i$ ,  $\Delta \sigma_{\text{exp}}^i$  and  $\sigma_{\text{cal}}^i$  are the experimental value, its error and the calculated value of the

differential elastic scattering cross sections at  $i$ -th angular point, respectively. It is also possible to add the chi-squares of the quantities concerned with the polarization.

Let central guess-values of the parameters  $\alpha_i$ 's be  $\alpha_i^0$ 's (expressed a vector  $\vec{\alpha}^0$ ). Normal equations for the deviations of the parameters are given as follows:

$$\sum_{i=1}^N \frac{1}{(\Delta\sigma_{\text{exp}}^i)^2} \frac{\partial\sigma_{\text{cal}}^i}{\partial\alpha_r^0} \sum_{s=1}^M \frac{\partial\sigma_{\text{cal}}^i}{\partial\alpha_s^0} \cdot \Delta\alpha_s = \sum_{i=1}^N \frac{(\sigma_{\text{exp}}^i - \sigma_{\text{cal}}^i) \partial\sigma_{\text{cal}}^i}{(\Delta\sigma_{\text{exp}}^i)^2}, \quad (5.11)$$

where  $M$  is the number of variable parameters, and

$$\frac{\partial\sigma_{\text{cal}}^i}{\partial\alpha_r^0} = \frac{1}{\delta_r} \{ \sigma_{\text{cal}}^i(\alpha_1^0, \alpha_2^0, \dots, \alpha_r^0 + \delta_r, \dots, \alpha_M^0) - \sigma_{\text{cal}}^i(\alpha_1^0, \alpha_2^0, \dots, \alpha_r^0, \dots, \alpha_M^0) \}. \quad (5.12)$$

In this program,  $\delta_r$  is taken to be one per-cent of  $\alpha_r^0$ .

Direction of the steepest descent in the parameter-space is given by a vector  $\vec{\Delta\alpha} = (\Delta\alpha_1, \Delta\alpha_2, \dots, \Delta\alpha_r, \dots, \Delta\alpha_M)$ . In numerical calculation, however, length of the vector is dependent on  $\delta_r$ 's. Therefore, a parameter  $z$  is needed for the control of the length. The parameter  $z$  is given, by using the largest value ( $\omega$ ) among  $(\Delta\alpha_r/\alpha_r^0)$ 's, as follows:

$$\left. \begin{array}{ll} z=1, & \text{for } |\omega| < 0.1, \\ z=0.5, & \text{for } 0.1 \leq |\omega| < 0.3, \\ z=0.2, & \text{for } 0.3 \leq |\omega| < 0.5, \\ z=0.1, & \text{for } 0.5 \leq |\omega| < 1, \\ z=0.05/|\omega|, & \text{for } 1 \leq |\omega|. \end{array} \right\} \quad (5.13)$$

A point at which the minimum value of the chi-square is expected is looked for by using a curve which passes through three points,  $\chi^2(\vec{\alpha}^0)$ ,  $\chi^2(\vec{\alpha}^0 + z \times \vec{\Delta\alpha})$  and  $\chi^2(\vec{\alpha}^0 + 2z \times \vec{\Delta\alpha})$ . The expected point ( $\vec{\alpha} \equiv \vec{\alpha}^0 + z_0 \times \vec{\Delta\alpha}$ ) is given so that the value of this quadratic curve is minimum. If the curve is concave and if  $0 \leq z_0 \leq 2z$ , the value of the chi-square is calculated at the point  $\vec{\alpha}$ . If  $z_0 < 0$ ,  $z_0$  is replaced by 0.0. If  $z_0 > 2z$ ,  $z_0$  is replaced by  $1.5z$ . If the curve is convex and  $\chi^2(\vec{\alpha}^0 + 2z \times \vec{\Delta\alpha})$  is less than  $\chi^2(\vec{\alpha}^0)$ ,  $z_0$  is redefined as  $3z$ . If  $\chi^2(\vec{\alpha}^0 + 2z \times \vec{\Delta\alpha})$  is greater than  $\chi^2(\vec{\alpha}^0)$ ,  $z_0$  is given as  $-z$ .

The condition of convergence for the chi-square value is defined in this program as follows; the curve mentioned above is concave and

$$|\chi^2(\vec{\alpha}) - \chi^2(\vec{\alpha}^0)| < \chi^2(\vec{\alpha}^0) \times 10^{-4}, \quad (5.14)$$

or

$$\chi^2(\vec{\alpha}) < \text{Max[NCHISQ, NCHIPL]} \times 0.1, \quad (5.15)$$

where NCHISQ and NCHIPL are given as input data (See next section).

### 5. 3 Phase shift of the Coulomb scattering

Phase shift of the Coulomb scattering,  $\sigma_l$ , is used in section 2. This quantity is obtained by the use of the following recurrence relation:

$$e^{2i\sigma_l} = \frac{(l+i\eta)(l-1+i\eta)\cdots(1+i\eta)}{(l-i\eta)(l-1-i\eta)\cdots(1-i\eta)} e^{2i\sigma_0} \quad (5.16)$$

where  $\eta$  is the Coulomb parameter defined by Eq. (2.25), and

$$\begin{aligned} \sigma_0 = & -\eta + \frac{\eta}{2} \ln(16+\eta^2) + 3.5 \tan^{-1}\left(\frac{\eta}{4}\right) - \left[ \tan^{-1}\eta + \tan^{-1}\frac{\eta}{2} + \tan^{-1}\frac{\eta}{3} \right] \\ & - \frac{\eta}{12(16+\eta^2)} \left\{ 1 + \frac{\eta^2-48}{30(16+\eta^2)^2} + \frac{\eta^4-160\eta^2+1280}{105(16+\eta^2)^4} \right\}. \end{aligned} \quad (5.17)$$

Relation given by Eq. (5.16) is separated into real and imaginary parts as follows:

$$\cos(2\sigma_{l+1}) = \left[ \frac{(l+1)^2 - \eta^2}{(l+1)^2 + \eta^2} \cos(2\sigma_l) \right] - \left[ \frac{2\eta(l+1)}{(l+1)^2 + \eta^2} \sin(2\sigma_l) \right], \quad (5.18)$$

and

$$\sin(2\sigma_{l+1}) = \left[ \frac{(l+1)^2 - \eta^2}{(l+1)^2 + \eta^2} \sin(2\sigma_l) \right] + \left[ \frac{2\eta(l+1)}{(l+1)^2 + \eta^2} \cos(2\sigma_l) \right]. \quad (5.19)$$

#### 5. 4 Legendre coefficients of the shape elastic scattering cross section

Differential cross section of the shape elastic scattering is given by Eq. (2.12). On the other hand, the compound elastic scattering cross section is described by the Eq. (2.42), that is the formula of the Legendre expansion. Since the coefficient of the Legendre expansion is needed for reactor calculations, Eq. (2.12) is reformulated in the form of the Legendre expansion:

$$\frac{d\sigma_{el}}{d\Omega} = \sum_L B_L P_L(\cos\theta), \quad (5.20)$$

where

$$B_L = \frac{1}{8k^2} \sum_{l_1, l_2} \sum_{j_1, j_2} \left[ Z(l_1, j_1; l_2, j_2; \frac{1}{2}, L) \right]^2 \times \text{Re}[(1 - \eta_{l_1}^{(j_1)}) (1 - \eta_{l_2}^{(j_2)})^*] \times 10. \quad (5.21)$$

Z-coefficient in Eq. (5.21) is given by

$$Z(l_1, j_1; l_2, j_2; sL) = \sqrt{(2l_1 + 1)(2l_2 + 1)(2j_1 + 1)(2j_2 + 1)} \\ \times (l_1 l_2 00 | L0) W(l_1, j_1; l_2, j_2; sL), \quad (5.22)$$

where the usual Racah coefficient and Clebsch-Gordan coefficient are used.

#### 5. 5 Transformation of the cross sections from center of mass system (CMS) to laboratory system (LAB)

In this program, the differential cross sections are given in the center of mass system as well as in the laboratory system. Relations between the scattering angles in CMS and LAB are given as follows:

$$\cos\theta_L = \frac{\gamma + \cos\theta_C}{(1 + 2\gamma\cos\theta_C + \gamma^2)^{1/2}}, \quad (5.23)$$

or

$$\tan\theta_L = \frac{\sin\theta_C}{\gamma + \cos\theta_C}, \quad (5.24)$$

where L and C mean LAB and CMS, and

$$\gamma = \left( \frac{mm'}{MM'} \right)^{1/2} \left( \frac{E}{E'} \right)^{1/2}. \quad (5.25)$$

Quantities  $m$  and  $M$  are masses of the incident particle and the target nucleus, and  $E$  stands for the incident energy in CMS. Primed quantities are referred to those of final stage. By using these relations, the differential cross sections are related with each other between CMS and LAB as follows:

$$\left( \frac{d\sigma}{d\Omega} \right)_L = \frac{(1 + 2\gamma\cos\theta_C + \gamma^2)^{1/2}}{|1 + \gamma\cos\theta_C|} \left( \frac{d\sigma}{d\Omega} \right)_C. \quad (5.26)$$

Coefficients of Legendre expansion for  $(d\sigma/d\Omega)_L$  are given by using the coefficients in CMS. The differential cross sections in LAB and CMS can be expressed as

$$\left( \frac{d\sigma}{d\Omega} \right)_L = \sum_l D_l P_l(\cos\theta_L), \quad (5.27)$$

and

$$\left(\frac{d\sigma}{dQ}\right)_c = \sum_l B_l P_l(\cos\theta_c). \quad (5.28)$$

The coefficient  $D_l$  is given as follows:

$$D_l = \frac{2l+1}{2} \sum_{l'} \int_{-1}^1 d(\cos\theta_c) P_{l'}(\cos\theta_c) P_l(\cos\theta_c). \quad (5.29)$$

In this program, integrations in Eq. (5.29) are calculated by using the Gaussian method of the numerical integration.

### 5. 6 Definition of the maximum angular momentum

In section 4, maximum angular momentum quantum number  $l_{max}$  is defined through the process of obtaining the wave functions in the asymptotic region. The quantity  $l_{max}$  should satisfy the conditions described in Eqs. (4.2) and (4.8). These two, however, are not sufficient conditions for obtaining the cross sections.

In ELIESE-3, the quantity  $l_{max}$  is redefined in the process of obtaining the cross section for the compound nucleus formation. In Eq. (2.15), the cross section for the compound nucleus formation is described by a summation of partial cross sections for the compound nucleus formation. Therefore, if this summation is sufficiently convergent for the partial cross sections with the angular momentum quantum number  $l \leq l_{max}$ , the partial cross sections with  $l > l_{max}$  can be neglected in the summation. In the program, the quantity  $l_{max}$  is given by the following condition:

$$\sigma_c^{(l_{max})} / \sum_{l=0}^{l_{max}-1} \sigma_c^{(l)} \leq 10^{-4} \quad (5.30)$$

The  $l$ -th partial cross section for the compound nucleus formation is given by the formula

$$\sigma_c^{(l)} = \frac{\pi}{k^2} \sum_{j=|l-s|}^{l+s} \frac{2j+1}{2s+1} T_l^{(j)}, \quad (5.31)$$

where  $s$  is the spin quantum number of the incident particle.

### 5. 7 Basic constants used in the program

In this program, mass of  $^{12}\text{C}$  is used as a standard nuclear mass, and nuclear mass unit is taken as follows:<sup>18,19)</sup>

$$\mu_0 c^2 = 931.504 \text{ MeV}, \quad (5.32)$$

where  $\mu_0$  is unit mass. Planck's constant devided by  $2\pi$  is  $1.0545919 \times 10^{-27}$  erg. sec. and the light velocity is  $2.997925 \times 10^{10}$  cm/sec. Therefore, some basic constants used in the program are

$$\left(\frac{2\mu_0}{\hbar^2}\right)^{1/2} = 0.2187342 \times 10^{13} \text{ MeV}^{-1/2} \cdot \text{cm}^{-1}, \quad (5.33)$$

or

$$= (1.0/4.571759) \times 10^{13} \text{ MeV}^{-1/2} \cdot \text{cm}^{-1}, \quad (5.33')$$

$$\frac{2\mu_0 e^2}{\hbar^2} = 0.06889532 \times 10^{13} \text{ cm}^{-1}, \quad (5.34)$$

$$\sqrt{\frac{2\mu_0 e^2}{\hbar^2}} = 0.1574862 \text{ MeV}^{1/2} \quad (5.35)$$

and

$$\frac{2\mu_0}{\hbar^2} \left( \frac{\hbar}{m_e c} \right)^2 = 0.09786764 \text{ MeV}^{-1}. \quad (5.36)$$

## 6. Program Description

The program ELIESE-3 is written in the FORTRAN language for an IBM-360/75 and a FACOM-230-60 computers. The program is composed of a main-program (control-program) and 42 sub-programs. A flow-chart of the main-program is shown in Fig.1.

Actual calculations start by reading a Title card at the statement number 200 in the flow-chart (the statement numbers in the flow-chart are the same ones as in the FORTRAN-list of the main-program). In the Title card, the number of the discrete nuclear levels (NLEVEL) is given, which is identical to the number of calling INPUT in the program. Symbol LEV plays a role of counting of the discrete nuclear levels and energy-mesh in the continuum region of the nuclear excited state. The number of the mesh-points is given automatically in the program. A subroutine PREP, at the statement number 220, prepares this number. The nuclear levels having unreasonable excitation energy for the calculations are rejected in this subroutine. Symbol NSIGN controls an automatic parameter search. Maximum angular momentum  $l_{\max}$  is defined by Eq. (4.2). This value of the maximum angular momentum is redefined by the condition in Eq. (5.30). Symbol LMAXC means this redefined maximum angular momentum.

Descriptions of the subroutine INPUT will be given in the next section, because an input-routine is the most important part of the program and then it is better to set an independent section. In this section, descriptions of the subroutines, except for INPUT, are given, concerning their functions and characteristics.

### SUBROUTINE PREP

It prepares reduced mass, wave number, potential well-depth, matching radius, Coulomb parameter and other basic quantities used in the calculations. It includes some quantities which are set up in each step of LEV.

### SUBROUTINE ANGLE

It sets up angle points, angular variables and transformation parameters, Eq. (5.25), between the center of mass system and the laboratory system. It rearranges the angle points in good order, even if the order of the angle points were given at random in the INPUT.

### SUBROUTINE SPHBES

Functions  $G_i(\rho)$ ,  $F_i(\rho)$ ,  $G'_i(\rho)$  and  $F'_i(\rho)$  for neutrons are generated at the matching radius  $\rho_M$ . Maximum angular momentum  $l_{\max}$  is also determined. (See section 4).

### SUBROUTINE GZERO

Functions  $G_0(\rho_A)$  and  $G'_0(\rho_A)$  at  $\rho_A$  are generated for charged particles. Asymptotic radius  $\rho_A$  is defined by using the Coulomb parameter  $\eta$ . (See Eqs. (4.11), (4.12) and (4.13)).

### SUBROUTINE PICARD

Values of the initial four points of the function  $G_0$  are generated by using the values  $G_0(\rho_A)$  and  $G'_0(\rho_A)$  for the charged particles. (See Eqs. (4.54) to (4.57)).

**SUBROUTINE GOASMA**

Differential equation for the function  $G_0(\rho)$  is integrated from  $\rho_A$  to  $\rho_M$  by means of the Fox-Goodwin's method. Derivative function  $G'_0(\rho)$  is generated by the Lagrange's six-points method. (See Eqs. (4.53) and (4.58)).

**SUBROUTINE GFLMAX**

Functions  $G_i(\rho_M)$ ,  $F_i(\rho_M)$ ,  $G'_i(\rho_M)$  and  $F'_i(\rho_M)$  for the charged particles are generated. The maximum angular momentum  $l_{\max}$  is determined by the condition of Eq. (4.2).

**SUBROUTINE INTEG**

Internal wave functions are generated by means of the Fox-Goodwin's method. Derivatives of the wave functions at the matching radius  $\rho_M$  are obtained by the Lagrange's six-points method. As far as the non-local potentials are concerned, the equivalent local potentials are prepared before the calculations of the wave functions are started.

**SUBROUTINE RRGET**

Non-local kernel of the Gaussian type and the non-local term of Eq. (4.62),  $R_i^{(j)}(r)$ , are prepared.

**SUBROUTINE RRYET**

Non-local kernel of the Yukawan type and the non-local term of Eq. (4.62) are prepared.

**SUBROUTINE ETASIG**

Coefficient of the outgoing wave,  $\eta_i^{(j)}$ , transmission coefficient,  $T_i^{(j)}$ , shape elastic scattering cross section, total cross section and compound nucleus formation cross section are calculated. The maximum angular momentum,  $l_{\max}$ , is redefined by the condition of Eq. (5.30).

**SUBROUTINE AMPAB**

Amplitudes  $A(\theta)$ ,  $B(\theta)$ ,  $C(\theta)$ ,  $D(\theta)$  and  $E(\theta)$  are calculated. Differential cross sections of the shape elastic scattering are calculated.

**SUBROUTINE POLAR**

Quantities  $P_{oi}$ ,  $A_{sy}$ ,  $R_{oi}$ ,  $D_{cp}$ ,  $T_{2,0}$ ,  $T_{2,1}$  and  $T_{2,2}$  are calculated.

**SUBROUTINE RUTH**

Amplitudes and cross section of the Rutherford scattering are calculated.

**SUBROUTINE BLL**

Coefficients of the Legendre expansion are calculated for the angular distribution of the shape elastic scattering cross section of the neutron.

**SUBROUTINE LABRAT**

The differential cross sections and their Legendre-coefficients are transformed from the center of mass system to the laboratory system.

**SUBROUTINE FLCOMP**

Cross sections via compound nucleus are calculated by means of the Hauser-Feshbach's and

the Moldauer's methods. Final nuclear states with discrete levels are treated in this subroutine.

#### SUBROUTINE COMJP

Denominators of the branching ratio, Eqs. (2.46) and (2.54), are calculated. In the case of the Moldauer's method, the quantities,  $Q_{IJ}^{J''}$  in Eq. (2.53), are given in this subroutine.

#### SUBROUTINE CONTDN

Cross sections for final nuclear states with overlapping levels are calculated. Denominators of the branching ratio, Eq. (2.46'), are also calculated.

#### SUBROUTINE AUTOS

Optical potential parameters, up to 15 in one run, are searched for automatically, in order to obtain the values of the differential elastic scattering cross sections and/or polarizations which are best fitted to the experimental values.

#### SUBROUTINE CHISQS

Chi-square deviations for the differential elastic scattering cross sections are calculated.

#### SUBROUTINE CHISPL

Chi-square deviations for the polarizations are calculated.

#### SUBROUTINE LEGEND

Legendre functions and their associated functions of first order are generated by means of their recurrence relations.

#### FUNCTION GPHIO

Function  $\Phi_0(x)$  in Eq. (2.55) is calculated. Numerical integration of Gaussian method in 20-th order is used, if the argument  $x$  is greater than 3.5. If  $x$  is smaller than 3.5, polynomial expansion is used.

#### FUNCTION SFACT

Quantity  $S^{J''}$  in Eq. (2.59) is calculated by means of the Gaussian method.

#### FUNCTION ZETC

Square of the quantity  $\sqrt{(2l_1+1)(2l_2+1)(2j_1-1)(2j_2+1)} W(l_1 j_1 l_2 j_2; \frac{1}{2}L)$  in Z-coefficient in Eq. (5.20) is calculated.<sup>20)</sup>

#### FUNCTION WRACA

The Racah coefficient of a special form  $W(abab; ef)$  is calculated.

#### FUNCTION RACAH

The general form of the Racah coefficient  $W(abcd; ef)$  is calculated.

#### FUNCTION CLBGD

The Clebsch-Gordan coefficient of a special form  $(l_1 l_2 00 | L 0)$  is calculated.

**SUBROUTINE OFLOW**

It is called at the head and the exit of each subroutine to see whether an overflow and/or divide-check condition are filled or not.

**SUBROUTINE COORDN**

A graphic frame is made in order to plot the experimental data and the calculated cross section curves.

**SUBROUTINE GRAPH**

The curves of the calculated values are drawn by means of the graphic plotter.

**FUNCTION PLYNM**

A polynomial is prepared for representing the cross section curve. The polynomial is used in order to calculate the cross section value at an arbitrary angular point. This subroutine is called in the subroutine GRAPH.

**SUBROUTINE INLST1**

The lists are given for the input and some fundamental data as to an entrance channel.

**SUBROUTINE INLST2**

The lists are given for the input and some fundamental data as to exit channels.

**SUBROUTINE OUTPT1**

Lists of the calculated data are given for the shape elastic scattering.

**SUBROUTINE OUTPT2**

Lists of the calculated data are given for the compound nuclear process. In the continuum region of the excited state, the lists are given at each mesh-point for the energy-integration.

**SUBROUTINE OUTPT3**

Lists are given for the data concerning the polarizations.

**SUBROUTINE OUTPT4**

Lists are given for the calculated values of the phase-shift and the scattering amplitudes.

**SUBROUTINE PUNCH**

A part of the calculated values is given on punched cards.

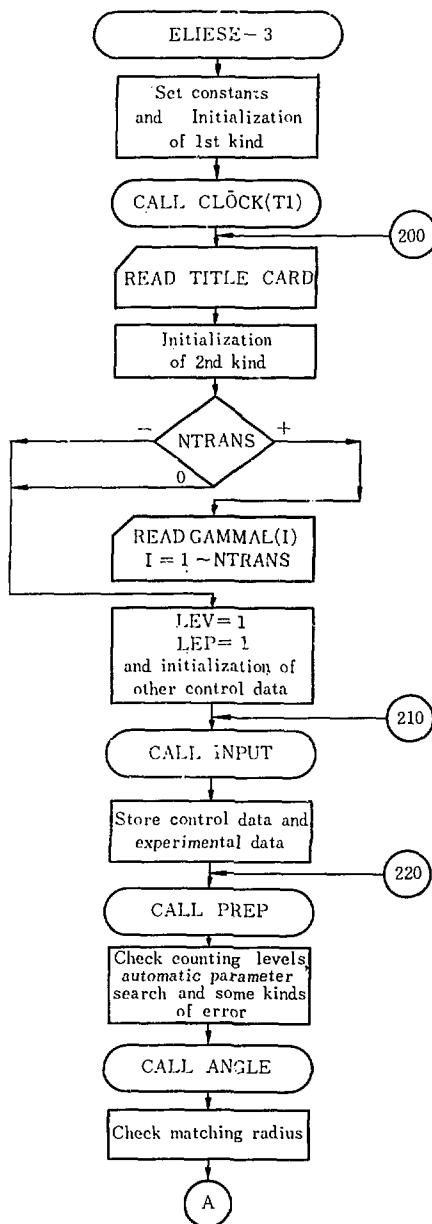


Fig. 1(1) Flow-chart of ELIESE-3.

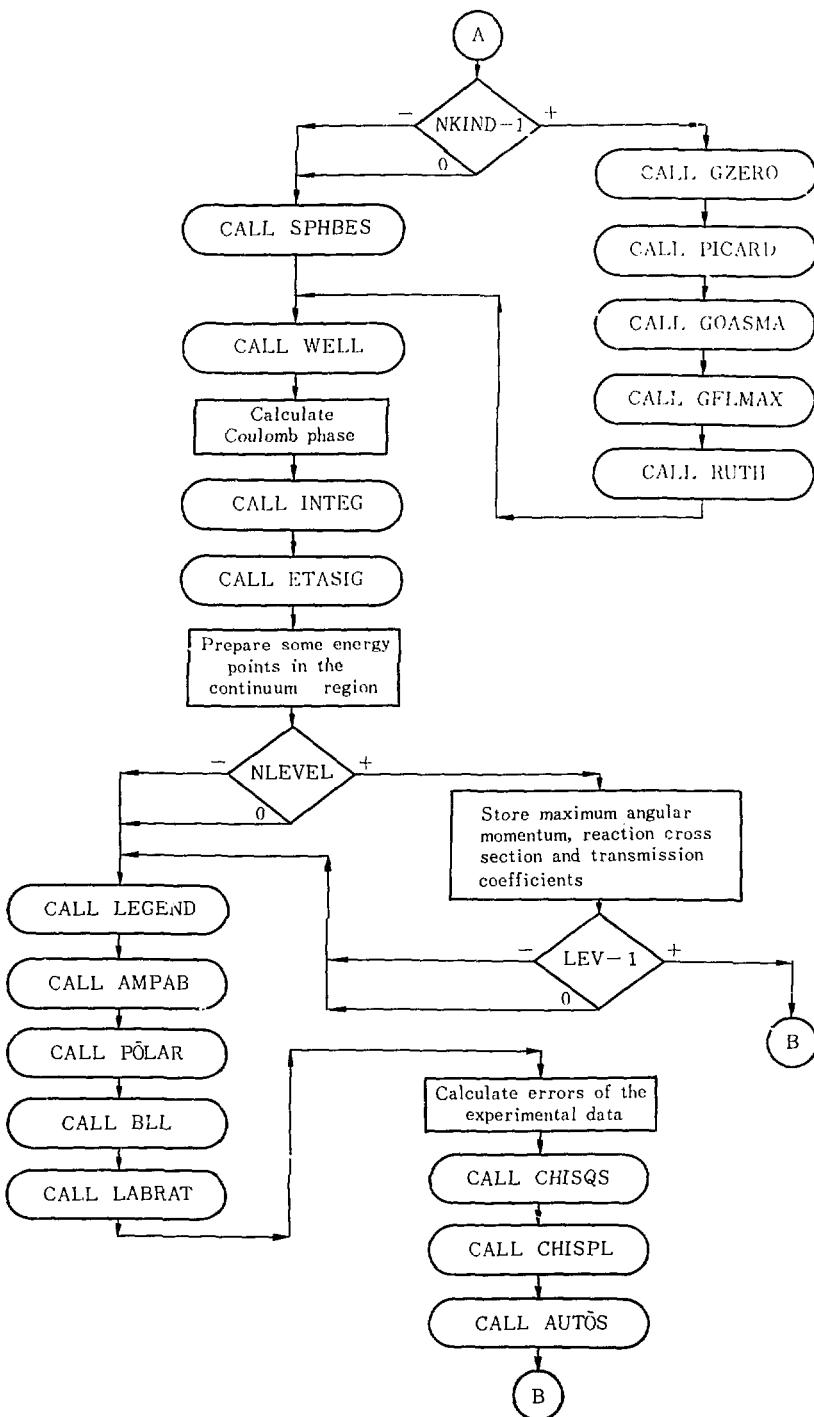


Fig. 1(2) Flow-chart of ELIESE-3.

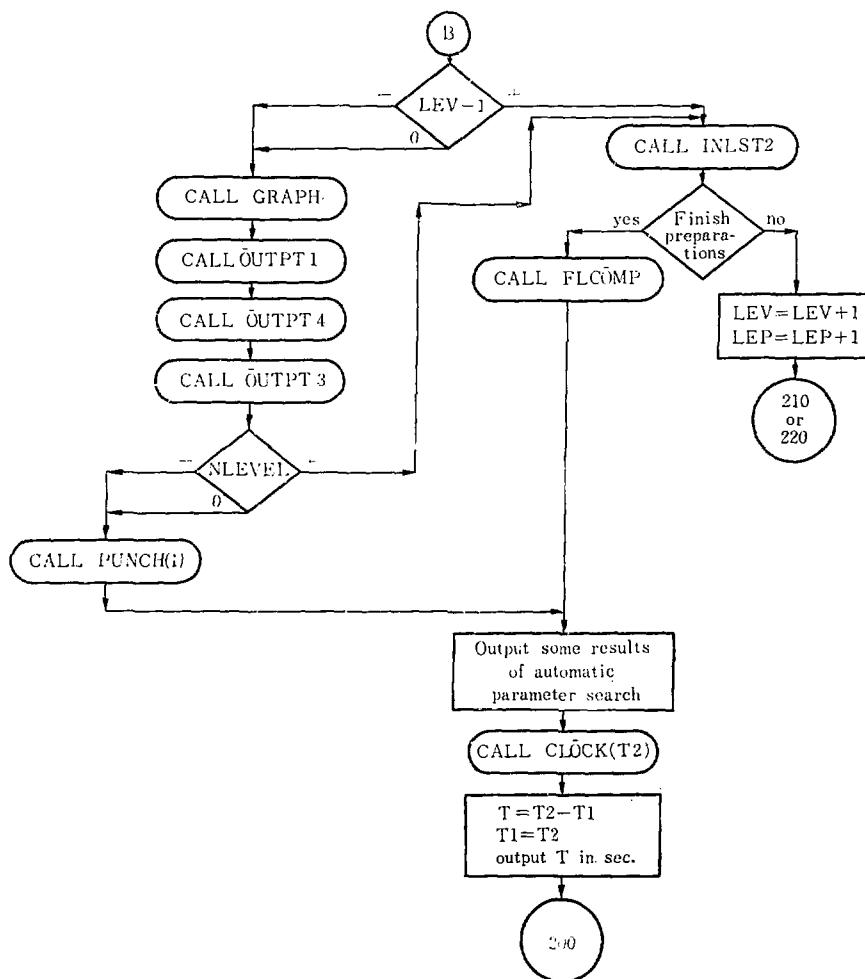


Fig. 1(3) Flow-chart of ELIESE-3.

## 7. Explanation of Input Data

In the same manner as the programs ELIESE-1 and ELIESE-2, the relative address is employed in ELIESE-3. For blank data, the "same as before" rule is applied, except for the data on "title card" and "supplementary transmission data". Input data of this program are composed of four parts; (1) data on the title card, (2) the supplementary transmission data, (3) fixed point data, and (4) floating point data. Compositions of the input data are shown in Fig.2. The fixed point data and the floating point data are needed for each discrete level of the residual nuclei. Some examples of the problems are shown in the next section, together with their input data.

### 7. 1 Title card (card No. 1) (315, 10A6)

**NLEVEL** Number of discrete levels used in the calculation. In this program, cross sections for the continuum region are also obtained above the energy region of the discrete levels specified by NLEVEL. For "shape elastic scattering calculation only", NLEVEL is zero.

Restriction ;  $0 \leq \text{NLEVEL} \leq 30$ .

**NAUTOS** Maximum number of iteration for automatic parameter search. This is the major control for the automatic parameter search, which is only available for elastic scattering calculations. If NAUTOS=0, no automatic parameter search is carried out. Variable range of the parameters is explained in Sample Problem 7.

**NTRANS** Number of supplementary transmission data.

Restriction ;  $0 \leq \text{NTRANS} \leq 30$  .

**TITLE** Arbitrary statements indicating the characteristics of the problem. These statements are printed out as the heading on each output sheet of the problem. First twelve characters, (16-27) columns, of the TITLE are written on a graph in which cross-section curve is drawn by a plotting machine, if an option for graph-plotting is selected. For specifications of output cards, characters on 16-25 columns may be used (see ref. 2).

### 7. 2 Supplementary transmission data cards (card No. 2~5) (8E10.4)

In Eqs. (2.46), (2.46') and (2.56), parameter,  $\alpha_{J\pi}$ , plays a role of correction factor of the branching ratio; corrections of the competing processes whose transmission coefficients are not calculable with this program.

A parameter  $\alpha_{J\pi}$  is related to the data GAMMAL(N), where N is connected to the spin J of the compound nuclear state by the relation;  $N=J-J_{\min}+1$ . The minimum value of the spin  $J_{\min}$  is 0 or 1/2. Relation between the parameter  $\alpha_{J\pi}$  and the data GAMMAL(N) is given as follows; (1) if GAMMAL(N) is given by  $0+\alpha_{J\pi}$  (numerical form 0.xxxxx), corrections in Eqs. (2.46), (2.46') or (2.56) are only accepted by the positive parity state of spin J. (2) If GAMMAL(N) is given by  $1+\alpha_{J\pi}$  (1.xxxxx), corrections are only accepted by the negative parity state of spin J. (3) If GAMMAL(N) is given by  $2+\alpha_{J\pi}$  (2.xxxxx), both parity states are corrected.

Note that the "same as before" rule cannot be applied for the blank data. If all GAMMA L(N)'s are the same as before, no input data are needed to put in repeatedly.

Restriction :  $0 \leq N \leq 30$ .

### 7. 3 Fixed point data cards (card No. 6, 7) (I2, I3, 1315)

In ELIESE-3, fixed point data play a role of the program control. They must be given for each discrete level of the residual nucleus, in principle. The "same as before" rule, however, is applicable for the fixed point data as well as floating point data (see 7.4). Therefore, some of them may be given only in the initial state.

**NCNTL** A card of card No. 7 in Fig. 2 is needed, if NCNTL $\neq$ 0. If NCNTL=0, no successive fixed point data card is required. In the program, fixed point data cards are required until NCNTL is zero on the preceding card.

**NDATA** Number of the floating point data cards relevant to the level.

NDATA is given only on the card of card No. 6.

**NKIND** Designation of the kind of an incident particle or emitted particles.

NKIND=1 for neutron,

=2 for charged particle with spin 1/2,

=3 for charged particle with spin 0,

=4 for charged particle with spin 1.

**NUMBER** Numbering for each discrete level of a residual nucleus. The numbering is made for each NKIND.

**NIMAG** Selection for the imaginary part of the optical potential.

	Volume part	Surface part
NIMAG=1;	none	Gaussian,
=2;	none	der. Woods-Saxon,
=3;	Woods-Saxon	none,
=4;	Woods-Saxon	Gaussian,
=5;	Woods-Saxon	der. Woods-Saxon.

**NOUTPT** Control for output of the cross sections.

NOUTPT=-1; No output for that level,

=0; print out on the line-printer,

=1; output on the punched cards as well as print out on the line-printer.

**NCHAGT** Atomic number of the target nucleus.

**NMASST** Mass number of the target nucleus.

**NCHAGI** The number of electric charge of the incident particle in a proton charge unit.

**NMASSI** Mass number of the incident particle.

**NTHETA** Control of angular points for calculated data. The number of the angular points must be smaller than 37. If NTHETA is positive, scattering angles are defined in the center of mass system. If NTHETA is negative, the scattering angles are given in the laboratory system. The scattering angles are given by THETA (see 4.7). NTHETA must be given in the entrance channel.

**NANGLE** Designation of the unit of angles.

NANGLE= 1 for degree,

= 0 for radian,

=-1 for cosine.

**NEXPTL** Indication of errors of the experimental data,  $\Delta\sigma_{exp}(\theta)$ 's. The errors,  $\Delta\sigma_{exp}(\theta)$ 's, are calculated in the program as

$$\Delta\sigma_{exp}(\theta) = \sigma_{exp}(\theta) \times NEXPTL/1000.$$

If  $\Delta\sigma_{\text{exp}}(\theta)$ 's are given in the input data, NEXPTL must be zero.

**NPHASE** Control for output of the phase shift factors.

NPHASE=0; no output.

$\neq 0$ ; print out on the line printer.

This control is only available for the shape elastic scattering.

**NCHISQ** Control for calculations of chi-square for angular distributions of the elastic scattering cross sections. If the automatic parameter search is needed, ten times of a target-value of the chi-square is given by NCHISQ. If NCHISQ=0, no calculations of the chi-square are made. (see Eqs. (5.10) and (5.15)).

**NRADII** Control for nuclear radius.

If NRADII=0, radial parameters are given by the radius of the target nucleus. If NRAD II $\neq 0$ , the radial parameters are defined by a sum of the radii of the target nucleus and the incident (or emitted) particle. (See Eqs. (3.5), (3.6), (3.13) and (3.14)).

**NPOLA** Control for the calculations and output of quantities concerning the polarization.

If NPOLA $\neq 0$ , the calculations and the output of the results are made. If NPOLA=0, they are not made.

**NCHIPL** Control for calculations of the chi-square for angular distributions of the quantities concerning the polarization. It plays a same role as NCHISQ for the cross section. Therefore, if the automatic parameter search is required for the polarization, NCHIPL should be set up as ten times of a target-value of the chi-square. (See Eqs. (5.10) and (5.15)).

**NEXPPL** Indication of errors of the experimental data for the quantities concerning the polarization. It plays a same role as NEXPTL for the cross section.

**NPLOT** Control for graphic plotting of the angular distributions of the cross sections and polarizations. Each column of columns 26 to 30 controls depolarization, rotation, asymmetry, polarization and cross section, respectively. For example, if every columns, except for column 29, are zero, only polarization is plotted by the graphic plotter. Column 30 plays some complicated roles in the case of NKIND $\geq 2$ ;

If column 30 is 1, cross section is plotted.

If it is 2, Rutherford ratio of the cross section is plotted.

If it is 3, cross section and Rutherford ratio are both plotted.

**NTENS** Control for graphic plotting of the angular distributions of the 2nd rank tensor polarization. Columns 33, 34 and 35 correspond to  $T_{2,0}$ ,  $T_{2,1}$  and  $T_{2,2}$  in Eqs. (2.39), (2.40) and (2.41), respectively. The quantities corresponding to the non-zero columns are plotted by the graphic plotter.

**NFLCR** Control for the calculations of the compound nuclear process. If NFLCR=0, Hauser-Feshbach method is adopted. If NFLCR $\neq 0$ , Moldauer's method is applied. Columns 39 and 40 are assigned to the data for degrees of freedom  $\nu_i$  in Eqs. (2.59) and (2.60). The data on the columns are given by ten times of real values of  $\nu_i$ .

Columns 36, 37 and 38 are assigned to the value of hundred times of parameter  $Q_{ij}^{JII}$  in Eq. (2.53). If these columns are zero, parameters  $Q_{ij}^{JII}$  are calculated in the program. If a negative value is given on these columns, all  $Q_{ij}^{JII}=0$ .

**NLVFIX** Control for fixing the input data, except for EIN (see 7.4) and NLVFIX itself. This control is efficient, when the calculations of the compound nuclear process are made with several incident energies. In the first case of such calculations, all the data needed are put in. If NLVFIX is set as non-zero in the second case corresponding to a new incident energy, those data read in the first case are all fixed through the following cases, and no data, except for EIN, are needed. This control is effective until NLVFIX is set to zero.

**NKERNL** Control for the non-local optical potentials. Columns 49 and 50 play a role of selection of the non-local kernel. The Gaussian kernel is selected, if the value on the columns is 1, and the Yukawan kernel is adopted, if it is 2.

Columns 46, 47 and 48 are assigned to the control for the spin-orbit force. If the value on these columns is zero, the spin-orbit force is not included in the non-local potential. If it is non-zero, the spin-orbit force is included in the non-local potential.

#### 7. 4 Floating point data cards (card No. 8-153) (5X, 15, 5 (1A, E9. 4))

Floating point data have their own addresses. The address of the first data on a card is given in the columns 6 to 10 in each card. The addresses of the other data on the card are assigned automatically in a successive order. For example, EMTARG has its address 1, SPIN has its address 3 and EIN has its address 5. Correspondence of each parameter to its address is shown in full in Fig.2.

Note on a data format of the parameter which is given as (1A, E9. 4). The first column is reserved for an indication of the parameter search. If a special character \* is given in the first column of the data for a potential parameter, its value is searched for automatically in the program.

**EMTARG** Mass of the target nucleus in a.m.u..

**EMIN** Mass of the incident particle in a.m.u.. Masses of the neutron, proton, deuteron and alpha-particle are set already in the program:

- 1. 0086652 for neutron,
- 1. 0072766 for proton,
- 2. 0140967 for deuteron,
- 4. 0025923 for alpha-particle.

If EMIN is read to be 0.0 (in the first case, blank is also permitted), they are adopted automatically. Any different values to be desired are surely permitted.

**SPIN** Spin of the incident or emitted particle. Its sign stands for its parity.

**SEPAR** Separation energy of the particle from the compound nucleus. This is required only in the calculation of the reaction process.

**EIN** Incident energy of the particle. It is only needed for the entrance channel. Positive sing indicates the energy in the center of mass system and negative sing in the laboratory system.

**RO** Nuclear radius parameter  $r_0$  for real potential (see Eq. (3.5)).

**RI** Nuclear radius parameter  $r_i$  for imaginary (volume type) potential (see Eq. (3.13)).

**RS** Nuclear radius parameter  $r_s$  for imaginary (surface type) potential (see Eq. (3.14)).

**RSO** Nuclear radius parameter  $r_{so}$  for spin-orbit force (see Eq. (3.19)).

**RC** Coulomb radius parameter  $r_c$  (see Eq. (3.6)).

**A0** Diffuseness parameter  $a_0$  for real potential (see Eq. (3.3)).

**A1** Diffuseness parameter  $a_i$  for imaginary (volume type) potential (see Eq. (3.8)).

**B** Diffuseness parameter  $b$  for imaginary (surface type) potential (see Eqs. (3.9) and (3.10)).

**ASO** Diffuseness parameter  $a_{so}$  for spin-orbit force (see Eq. (3.15)).

**BETA** Parameter  $\beta$  for non-locality of the potential (see Eqs. (3.27) and (3.32)). If BETA<0, an equivalent local potential is used. If BETA>0, the non-local potential is used.

**V, VE, VESQ, VSYM and VCOUL** They determine the strength of the real potential (see Eq. (3.4)):

$$V = V_{c,0},$$

$$VE = V_{c,1},$$

$$VESQ = V_{c,2},$$

$$\text{VSYM} = V_{sym},$$

and

$$\text{VCOUL} = V_{coul}.$$

**WI, WIE** and **WIESQ** They determine the strength of the imaginary potential (volume type) (see Eq. (3.11)):

$$\text{WI} = W_{I,0},$$

$$\text{WIE} = W_{I,1},$$

and

$$\text{WIESQ} = W_{I,2}.$$

**WS, WSE** and **WSESQ** They determine the strength of the imaginary potential (surface type) (see Eq. (3.12)):

$$\text{WS} = W_{S,0},$$

$$\text{WSE} = W_{S,1},$$

and

$$\text{WSESQ} = W_{S,2}.$$

**VSO, VSOE**, and **VSOESQ** They determine the strength of the real part of the spin-orbit force, (see Eq. (3.17)):

$$\text{VSO} = V_{SO,0},$$

$$\text{VSOE} = V_{SO,1},$$

and

$$\text{VSOESQ} = V_{SO,2}.$$

**WSO, WSOE**, and **WSOESQ** They determine the strength of the imaginary part of the spin-orbit force (see Eq. (3.18)):

$$\text{WSO} = W_{SO,0},$$

$$\text{WSOE} = W_{SO,1},$$

and

$$\text{WSOESQ} = W_{SO,2}.$$

**PMESH** Mesh interval for numerical integrations of the internal wave functions. If PMESH is given as blank in the initial case, it is set as 0.25 fm internally until any value is given. If any positive value is given, it is used as the mesh interval of the numerical integrations.

**PMESHc** Mesh interval for numerical integrations of the Coulomb wave functions. The same things mentioned above about PMESH are available for PMESHc.

**ELEV** Excitation energy of the level.

**SPINP** Spin and parity of the level. Parity is given by its sign.

**ECRITC** Critical energy  $E_c$  in Eq. (2.46'), above which the levels of the residual nucleus are regarded as the overlapping levels. The energy  $E_c$  is measured from the ground level of the target nucleus.

Note that the overlapping levels can be accounted for only one residual nucleus, even if several residual nuclei are treated. The nucleus with the overlapping levels is characterized by the last data of the discrete levels put in (see sample problems).

**DNPARA** Level density parameter  $\alpha$  in Eq. (5.2).

**SPINCT** Spin cut-off parameter in Eq. (5.2). If SPINCT=0, Eq. (5.5) is adopted, instead of Eq. (5.2). If SPINCT is any negative value, the spin cut-off parameter is calculated by using Eq. (5.4) regardless of the value of SPINCT. If SPINCT>0, its value is used as the spin cut-off parameter  $\sigma_M$ .

**PAIREN** Pairing energy  $\delta$  in Eq. (5.9).

**CNORM** Normalization factor  $C_0$  of the level density formula in Eq. (5.2). If CNORM=0, the

factor  $C_0$  is calculated by using Eq. (5.3). If CNORM $\neq 0$ , its value is used as the factor  $C_0$ . ECEX Critical excitation energy corresponding to the energy  $U_0$  in Eq. (5.1). Origin of the energy, in this case, is the energy of the ground level of the residual nucleus. Therefore, ECEX may be taken as an excitation energy of the residual nucleus. (See Fig.3).

**THETA(N)** Scattering angle. The number of THETA(N)'s are determined by NTHETA in the fixed point data card. These angles do not depend on whether experimental data are given at the angles or not. Moreover, order of their arrangement may be random. On the output lists, they are put in order. If the experimental data are put in, the number of THETA(N)'s must not be smaller than the number of the experimental data points.

**SIGELE(N)** Experimental data of the elastic scattering cross section at the angular point N. They must correspond to the angular points included in THETA(N)'s.

**DSIGEL(N)** Errors of the experimental data given above. Correspondent relation to THETA(N) is the same as SIGELE(N) to THETA(N).

**POLEX(N)** Experimental data of the polarization.

**DPOLEX(N)** Errors of the experimental data of the polarization.

**ASYMEX(N)** Experimental data of the asymmetry.

**DASYEX(N)** Errors of the experimental data of the asymmetry.

**ROTEX(N)** Experimental data of the rotation.

**DROTEX(N)** Errors of the experimental data of the rotation.

**DEPLEX(N)** Experimental data of the depolarization.

**DDPLEX(N)** Errors of the experimental data of the depolarization.

**TNEX20(N)** Experimental data of the second rank tensor polarization ( $T_{2,0}$ ).

**TNDX20(N)** Errors of the experimental data of  $T_{2,0}$ .

**TNEX21(N)** Experimental data of the second rank tensor polarization ( $T_{2,1}$ ).

**TNDX21(N)** Errors of the experimental data of  $T_{2,1}$ .

**TNEX22(N)** Experimental data of the second rank tensor polarization ( $T_{2,2}$ ).

**TNDX22(N)** Errors of the experimental data of  $T_{2,2}$ .

**SIGERE(N)** Experimental data of the Rutherford ratio of the elastic scattering cross section for the charged particles.

**DSIGRR(N)** Errors of the experimental data of the Rutherford ratio given above.

No.	1:2:3:4:5:6:7:8:9:10	11:12:13:14:15:16:17:18:19:20	21:22:23:24:25:26:27:28:29:30	31:32:33:34:35:36:37:38:39:40	41:42:43:44:45:46:47:48:49:50	51:52:53:54:55:56:57:58:59:60	61:62:63:64:65:66:67:68:69:70	71:72:73:74:75:76:77:78:79:80						
1	NLEVEL	NAUTOS	NTRANS	NTITLE										
2	GAMMAL11							GAMMAL11						
3	GAMMAL12							GAMMAL12						
4	GAMMAL13							GAMMAL13						
5	GAMMAL14							GAMMAL14						
6	* 1 * 2	NKIND	NUMBER	NIMAG	NOUTPT	SCHAG1	NMASS1	NCHAG1	NMASS1	NTHETA	NANGLE	NEXTITL	NPHASE	NCHISQ
7	NRAD1	NPDEA	NCHIPL	NEAPP1	SPLOT	NTENS	NFLCR	NLFIX1	NKERN1					
8		1	EMIANG			SHIN		SEPAR	EIN					* 1 = NCNTL
9		6	RO			BS		RSD	RC					* 2 2 = NDATA
10		11	AO			A1		ASD	BETA					
11		16	V			W1		VSO	WSO					
12		21	VE			W2		VSOE	WSDE					
13		26	VSQ			WESO		VSOESO	WSVSO					
14		31	VSYM			VCOL		PMESH	PMESH					
15		36	FLEV			SPINP								
16		41	ECRITC			DNPARA		SPINCT	PAIRN					
17		46	FACE						CNORM					
18		51	THETAI							THETAB1				
25		86	THETAB6											
26		91	SIGELB11								SIGELB11			
33		126	SIGELB1M											
34		131	DSIGEL11								DSIGEL11			
41		166	DSIGEL1M											
42		171	POLENU1								POLENU1			
49		206	POLENU6											

No.	1:2:3:4:5:6:7:8:9:10	11:12:13:14:15:16:17:18:19:20	21:22:23:24:25:26:27:28:29:30	31:32:33:34:35:36:37:38:39:40	41:42:43:44:45:46:47:48:49:50	51:52:53:54:55:56:57:58:59:60	61:62:63:64:65:66:67:68:69:70	71:72:73:74:75:76:77:78:79:80
50	211	DPLEX1					DPLEX1	
57	245	DPLEX10						
58	251	ASYMEND					ASYMEND	
65	286	ASYMEN6						
66	291	DASYEN1					DASYEN1	
73	326	DASYEN8			DASYEN2			
74	331	ROTEN1					ROTEN1	
81	366	ROTEN3			ROTEN2			
82	371	DROUTE1					DROUTE1	
89	406	DROUTE3			DROUTE2			
90	411	DEPLEX1					DEPLEX1	
97	446	DEPLEX3			DEPLEX3			
98	451	DPLEXEND					DPLEXEND	
105	486	DPLEXEND			DPLEXEND			
106	491	TNEV2011					TNEV2011	
113	516	TNEV2068			TNEV2068			
114	531	TNDX2011					TNDX2011	
121	566	TNDX2068			TNDX2068			
122	571	TNEV2011					TNEV2011	
129	606	TNEV2068			TNEV2068			
130	611	TNDX2011			TNDX2011			
137	646	TNDX2068			TNDX2068			
138	651	TNEV2211					TNEV2211	
145	686	TNEV2268			TNEV2268			

No.	1:2:3:4:5:6:7:8:9:10	11:12:13:14:15:16:17:18:19:20	21:22:23:24:25:26:27:28:29:30	31:32:33:34:35:36:37:38:39:40	41:42:43:44:45:46:47:48:49:50	51:52:53:54:55:56:57:58:59:60	61:62:63:64:65:66:67:68:69:70	71:72:73:74:75:76:77:78:79:80
146	611	TNDX2010					TNDX2010	
153	726	TNDX2206			TNDX2206			
154	731	SIGERE1					SIGERE1	
161	766	SIGERE6			SIGERE6			
162	771	DSIGER11					DSIGER11	
169	806	DSIGER6			DSIGER6			

Fig. 2 Input data form of ELIESE-3. Detailed description for the data is given in the text.

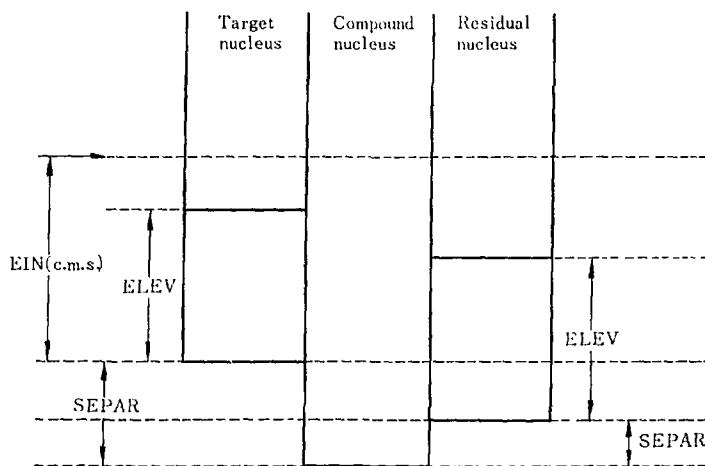


Fig. 3(1) Schematic representation of the relation among different energies which are put in as the input data.  
Incident energy is smaller than the critical energy  $E_c$  (see section 7).

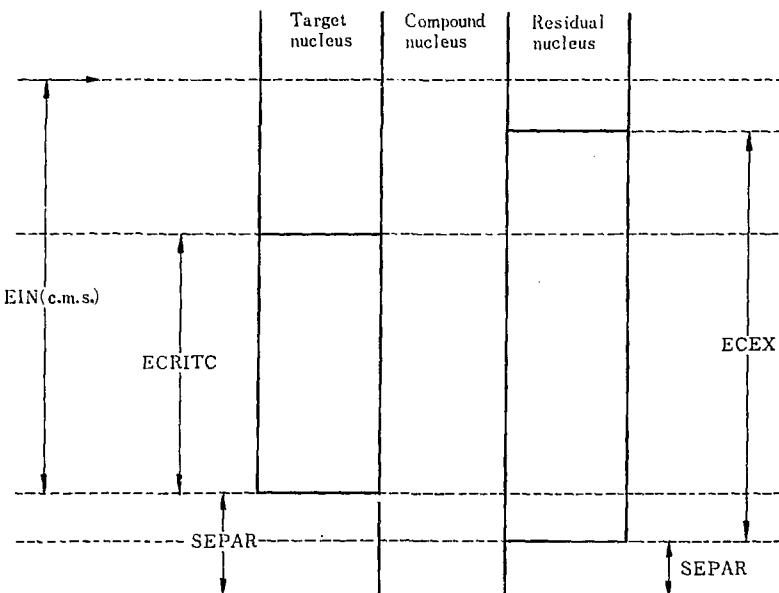


Fig. 3(2) Schematic representation of the relation among different energies which are put in as the input data.  
Incident energy is larger than the critical energy  $E_c$ .

TABLE 1 Table of cubic root of nuclear mass number. In ELIESE-3, nuclear radius is only given in the form  $rA^{1/3}$ . Therefore, this table will be convenient in conversion of the form  $r_0 A^{1/3} \div r_1$ , for example, to  $rA^{1/3}$ .

CUBIC ROOT OF MASS NUMBER											
A	A***(1/3)	A	A***(1/3)	A	A***(1/3)	A	A***(1/3)	A	A***(1/3)	A	A***(1/3)
1	1.0000	51	3.7084	101	4.6570	151	5.3251	201	5.8578	251	6.3080
2	1.2599	52	3.7325	102	4.6723	152	5.3368	202	5.8675	252	6.3164
3	1.4422	53	3.7563	103	4.6875	153	5.3485	203	5.8771	253	6.3247
4	1.5874	54	3.7790	104	4.7027	154	5.3601	204	5.8868	254	6.3330
5	1.7100	55	3.8030	105	4.7177	155	5.3717	205	5.8964	255	6.3413
6	1.8171	56	3.8259	106	4.7326	156	5.3832	206	5.9059	256	6.3496
7	1.9129	57	3.8485	107	4.7475	157	5.3947	207	5.9155	257	6.3579
8	2.0000	58	3.8709	108	4.7622	158	5.4061	208	5.9250	258	6.3661
9	2.0801	59	3.8930	109	4.7769	159	5.4175	209	5.9345	259	6.3743
10	2.1544	60	3.9149	110	4.7914	160	5.4288	210	5.9439	260	6.3825
11	2.2240	61	3.9365	111	4.8059	161	5.4401	211	5.9533	261	6.3907
12	2.2894	62	3.9579	112	4.8203	162	5.4514	212	5.9627	262	6.3988
13	2.3513	63	3.9791	113	4.8346	163	5.4626	213	5.9721	263	6.4070
14	2.4101	64	4.0000	114	4.8488	164	5.4737	214	5.9814	264	6.4151
15	2.4662	65	4.0207	115	4.8629	165	5.4848	215	5.9907	265	6.4232
16	2.5198	66	4.0412	116	4.8770	166	5.4959	216	6.0000	266	6.4312
17	2.5713	67	4.0615	117	4.8910	167	5.5069	217	6.0092	267	6.4393
18	2.6207	68	4.0817	118	4.9049	168	5.5178	218	6.0185	268	6.4473
19	2.6688	69	4.1016	119	4.9187	169	5.5288	219	6.0277	269	6.4553
20	2.7144	70	4.1213	120	4.9324	170	5.5397	220	6.0368	270	6.4633
21	2.7589	71	4.1408	121	4.9461	171	5.5505	221	6.0459	271	6.4713
22	2.8020	72	4.1602	122	4.9597	172	5.5613	222	6.0550	272	6.4792
23	2.6439	73	4.1793	123	4.9732	173	5.5721	223	6.0641	273	6.4872
24	2.8845	74	4.1983	124	4.9866	174	5.5828	224	6.0732	274	6.4951
25	2.9240	75	4.2172	125	5.0000	175	5.5934	225	6.0822	275	6.5030
26	2.9625	76	4.2358	126	5.0133	176	5.6041	226	6.0912	276	6.5108
27	3.0000	77	4.2543	127	5.0265	177	5.6147	227	6.1002	277	6.5187
28	3.0366	78	4.2727	128	5.0397	178	5.6252	228	6.1091	278	6.5265
29	3.0723	79	4.2908	129	5.0528	179	5.6357	229	6.1180	279	6.5343
30	3.1072	80	4.3089	130	5.0658	180	5.6462	230	6.1269	280	6.5421
31	3.1414	81	4.3267	131	5.0788	181	5.6567	231	6.1358	281	6.5499
32	3.1748	82	4.3445	132	5.0916	182	5.6671	232	6.1446	282	6.5577
33	3.2075	83	4.3621	133	5.1045	183	5.6774	233	6.1534	283	6.5654
34	3.2396	84	4.3795	134	5.1172	184	5.6877	234	6.1622	284	6.5731
35	3.2711	85	4.3968	135	5.1299	185	5.6980	235	6.1710	285	6.5808
36	3.3019	86	4.4140	136	5.1426	186	5.7083	236	6.1797	286	6.5885
37	3.3322	87	4.4310	137	5.1551	187	5.7185	237	6.1885	287	6.5962
38	3.3620	88	4.4490	138	5.1676	188	5.7287	238	6.1972	288	6.6039
39	3.3912	89	4.4647	139	5.1801	189	5.7388	239	6.2058	289	6.6115
40	3.4200	90	4.4814	140	5.1925	190	5.7489	240	6.2145	290	6.6191
41	3.4482	91	4.4979	141	5.2048	191	5.7590	241	6.2231	291	6.6267
42	3.4760	92	4.5144	142	5.2171	192	5.7690	242	6.2317	292	6.6343
43	3.5034	93	4.5307	143	5.2293	193	5.7790	243	6.2403	293	6.6419
44	3.5303	94	4.5468	144	5.2415	194	5.7890	244	6.2488	294	6.6494
45	3.5569	95	4.5629	145	5.2536	195	5.7989	245	6.2573	295	6.6569
46	3.5830	96	4.5789	146	5.2656	196	5.8088	246	6.2658	296	6.6644
47	3.6088	97	4.5947	147	5.2776	197	5.8186	247	6.2743	297	6.6719
48	3.6342	98	4.6104	148	5.2896	198	5.8285	248	6.2828	298	6.6794
49	3.6593	99	4.6261	149	5.3015	199	5.8383	249	6.2912	299	6.6869
50	3.6840	100	4.6416	150	5.3133	200	5.8480	250	6.2996	300	6.6943

## 8. Sample Problems

In this section, some sample problems are presented in order to make the problems clear for input data descriptions.

### 8. 1 Sample problem 1. (Figs. 4 (1) and 4 (2)).

Calculations are made only in the stage of the shape elastic scattering. Polarization, asymmetry and rotation are also calculated, that is, NPOLA=1. The incident energy is given in the laboratory system. The order of the angular points are random, including 11 points of the experimental values and 4 arbitrary points. Cross section values and their errors are correspondent to the experimental angular points at which they were measured. These are shown in Fig.4 (1).

List of the output in this case are given in Fig.4 (2). In PAGE 1 of the list, the input data are printed out. The experimental data are rearranged in good order as well as the angular points. In pages 2 to 4, results of the calculations are given. Chi-square values are given in the form of Eq. (5.10) as well as  $N$  times of the Eq. (5.10), where  $N$  is the number of the experimental data points. A quantity, stated by NORM in the list, means a normalization factor defined by the following formula<sup>1)</sup>:

$$\text{NORM} = \frac{\sum_i (\sigma_{\text{exp}}^i \times \sigma_{\text{cal}}^i / (\Delta\sigma_{\text{exp}}^i)^2)}{\sum_i (\sigma_{\text{exp}}^i / \Delta\sigma_{\text{exp}}^i)^2}$$

In PAGE 3, quantities given in Eq. (2.8) are printed out.

### 8. 2 Sample problem 2. (Figs. 5 (1) and 5 (2))

Inelastic scattering of neutron by  $^{238}\text{U}$  is taken in this case. Some competing processes are taken into account by using the quantity GAMMAL, that is  $\alpha_{J/\bar{J}}$  in Eq. (2.46). In this case, eight GAMMAL's are used and each of them corresponds to a compound state with  $J''=1/2^\pm$  to  $15/2^\pm$ . For example, GAMMAL(4)=2.035 means  $\alpha_{7/2^+}=\alpha_{7/2^-}=0.035$ .

Input data for the first and second excited states are the same as those of the entrance channel (ground state). Therefore, no data are needed for these excited states, except for excitation energy, spin and parity.

List of the output in this case are given in Fig.5(2). In PAGEs 3 and 4, the data used in the calculations of the compound nuclear process are printed out. In PAGEs 5 to 7, results of the calculations are given. Total inelastic scattering cross section is given as 1.1892 barns in PAGE 7. Compound elastic scattering cross section is 1.1335 barns (see in PAGE 5) and reaction cross section (cross section for compound nucleus formation) is 2.4231 barns (see in PAGE 2), so that  $2.4231 - (1.1335 + 1.1892) = 0.1004$  barns come from the contributions of the competing processes mentioned above.

### 8. 3 Sample Problem 3. (Figs. 6 (1) and 6 (2))

Examples in this case are devoted to explain a role of NLVFIX. PROB. 3-1, PROB. 3-2, PROB. 3-3 and PROB. 3-4 are successively processed. In PROB. 3-1, all data needed are prepa-

red, and the data, except EIN, are fixed in PROB. 3-2 and PROB. 3-3 by setting NLVFIX=1. PROB. 3-4 treats a different problem from PROB. 3-1 to PROB. 3-3, so that some input data must be changed. Therefore, NLVFIX is set to zero in order to exchange the data.

No information about the input data of the exit channels is printed out during NLVFIX≠0. In PROB. 3-2 and PROB. 3-3, there are no lists corresponding to the lists of PAGE 3 and PAGE 4 in PROB. 3-1.

In PROB. 3-4, neutron mass prepared in the program is adopted by setting EMIN=0.0.

#### 8. 4 Sample problem 4. (Figs. 7 (1) and 7 (2))

Calculations are performed for deuteron induced reaction with some competing processes. Emitted particles treated are deuteron, neutron, proton and alpha-particle. In deuteron channel, all the data needed are prepared, and some data are changed in the neutron, proton and alpha-particle channels, respectively. For example, the Coulomb radius parameter RC is given as 1.3 in the deuteron channel, and is changed to 0.0 in the neutron channel. It is further changed to 1.25 in the proton channel and 2.07 in the alpha-particle channel.

Lists of the output data are shown in Fig.7(2). In PAGE 8, total elastic scattering cross section and shape elastic scattering cross section are given as 0.0. This means that these two quantities cannot be defined in the deuteron channel or charged particle channel in general. Therefore, values given as 0.0 in the input or output lists must be read carefully whether they are truly zero or are undefined.

#### 8. 5 Sample problem 5. (Figs. 8 (1) and 8 (2))

Neutron inelastic scattering cross section of  $^{75}\text{As}$  is calculated by using the Hauser-Feshbach theory. Only the first excited level at 0.199 MeV is considered as a discrete level and the levels above 0.2 MeV are assumed to be overlapping levels (continuum region).

In PAGE 6 of Fig.8 (2), total inelastic scattering cross section for the discrete level is given. In PAGEs 7 to 12, information at some energy points in the continuum region is printed out and the inelastic scattering cross section for this region is given on the last line in PAGE 12. The energy points in the continuum region are set automatically in the program in order to integrate the differential cross section.

#### 8. 6 Sample problem 6. (Figs. 9 (1) and 9 (2))

In this example, inelastic scattering of neutron by  $^{56}\text{Fe}$  is considered. Proton emission is taken into account as a competing process. In neutron channel, continuum region of the residual nucleus is considered as well as two discrete levels at 0.847 and 2.085 MeV. Input data for second excited level at 2.085 MeV are placed at the end of the input data set, because the last data indicates the channel in which the calculation for the continuum region is performed.

#### 8. 7 Sample problem 7. (Figs. 10 (1) and 10 (2))

An example of automatic parameter search is given. Parameters looked for are  $r_s$ ,  $b$  and  $V_{C,0}$  (see Sec. 3). In PAGE 3 of Fig.10 (2), some information is printed out for each step of the

automatic search. Chi-squares at three points ( $\vec{a}^0$ ,  $\vec{a}^0 + z \times \Delta \vec{a}$ ,  $\vec{a}^0 + 2z \times \Delta \vec{a}$ ) are printed out as reference. The shape of the chi-square curve and the chi-square value at minimum point (or proper point) on the curve are shown as well as the solutions of the normal equation, Eq. (5.11), and the estimated values of the parameters. Parameters printed out are identified by their address numbers; for example,  $r_s$  is identified by 8. In the last page, chi-square values and the estimated values of the parameters are given again for convenience sake.

If NAUTOS>0, the parameters are searched for in parameter-range from 0.5 to 1.5 times of the initial values of the parameters. If this parameter-range is overleapt, the calculation is stopped with error message. If NAUTOS<0, no restriction is made in the parameter-range. If the solutions of the normal equations are not found, the calculation is stopped with error message.

#### 8. 8 Sample problem 8. (Figs. 11(1) and 11(2))

A sample calculation is given with non-local potential. In this case, spin-orbit potential is not included in the non-local potential but in local potential. Information for the non-local potential used is given in PAGE 1 of Fig.11 (2).

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Fig 4 (1)

```
PROB. 1+ Y(N,N) E=1.49MEV, SHAPE ELASTIC SCATTERING ONLY
1 14    1      2      39     89      1   15   -1      1   1
1
1  88.93
6  -0.22
11  0.68
16  48.0
21  -0.29
51  0.485
36  0.860
61  -0.65
91  380.0
95  700.0
101 110.0
131 20.0
136 100.0
141 15.0
      0.5      1.22
      0.47      0.65
      9.0      11.0
      -0.15
      0.7      -0.27
      0.99      -0.95
      -0.715      0.94
      350.0      140.0
      200.0      150.0
      100.0      645.0
      20.0      20.0
      25.0      40.0
      10.0      120.0
      -1.49
```

Fig 4 (2)

```
PROB. 1+ Y(N,N) E=1.49MEV, SHAPE ELASTIC SCATTERING ONLY          PAGE  1
TARGET INCIDENT PNESH = 2.500E-01 (FERMI)  MAXIMUM ANGULAR MOMENTUM  5
MASS ..... 88.93  1.008663  PNESHc = 2.500E-01 (FERMI)  CLASSICAL CUT-OFF MOMENTUM  4
MASS NO. ... 89      1      CMESH = 2.490E-01 (FERMI)  WAVE NUMBER .....
ATOMIC NO. ... 39      0      CMESHc= 0.0 (FERMI)  COULOMB PARAMETER (YETA)  0.265146
CMS ENERGY ... 1.473290 (MEV)
LAB ENERGY ... 1.490000 (MEV)  SEPARATION ENERGY ... 0.0 (MEV)

INCIDENT PARTICLE ..., NEUTRON
IMAGINARY POTENTIAL FORM          NNU-LNUAL PARAMETER = 0.0  L-S TERM
INTERNAL ..., SURFACE ABSCHPTION ONLY
SURFACE ... DIFF. WOODS-SAXON

POTENTIAL PARAMETER
FORM PARAMETER      WELL DEPTH PARAMETER (MEV)
(CFERMI)
RD = 1.220  V = 48.00  WI = 0.0  WS = 9.00  VSO = 11.00  WSO = 0.0  VSYM = 0.0
RI = 0.0  VE = -0.200  WIE = 0.0  WSE = 0.0  VSOE = -0.150  WSOE = 0.0  VCoul = 0.0
RS = 1.220  VESW = 0.0  WIEST = 0.0  WSESW = 0.0  VSOESW = 0.0  WSOESW = 0.0
RSO = 1.220  VESW = 0.0  WIEST = 0.0  WSESW = 0.0  VSOESW = 0.0  WSOESW = 0.0
A0 = 0.650  A1 = 0.0  VRE = 47.57  WIMJ = 0.0  WIMS = 9.00  VSP0 = 10.78  WSPO = 0.0  VSMM = 0.0
B = 0.470  ASO = 0.650

BRANCHING RATIO
0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
0.0

LEVEL DENSITY PARAMETER
EC = 0.0  A = 0.0  SGM = 0.0  EPR = 0.0  NOM = 0.0
0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

EXPERIMENTAL DATA      ( EXP. ERROR  **** INPUT )
ANGULAR DISTRIBUTION (COSINE)
ANGLE  ELASTIC  EXP. ERROR  ANGLE  ELASTIC  EXP. ERROR  ANGLE  ELASTIC  EXP. ERROR
0.990  0.0  0.0  0.250  2.4500E 02  4.0000E 01  -0.650  1.1000E 02  1.3000E 01
0.990  8.4200E 02  1.2000E 02  0.0  0.0  0.0  0.0  0.0  0.0
0.860  1.1000E 02  1.0000E 02  -0.270  2.0000E 02  2.5000E 01  -0.715  1.0000E 02  1.0000E 01
0.700  5.5000E 02  8.0000E 01  -0.270  1.4000E 02  2.0000E 01  -0.710  1.3000E 02  1.0000E 01
0.463  3.1800E 02  6.0000E 01  -0.510  1.1500E 02  2.0000E 01  -0.950  0.0  0.0
      1.1500E 02  2.0000E 01  -0.980  0.0  0.0
```

Fig 4 (2) continued

PRCB, 1+ Y(N+N) E=1.49MEV, SHAPE ELASTIC SCATTERING ONLY PAGE 2

TOTAL CROSS SECTION .....	4.2319E 03 (MILLI-BARN)	CHI SQUARE .....	NORM=1.000	NORM=0.333
SHAPE ELASTIC CROSS SECTION 1.936E 03 (MILLI-BARN)		CHI SQUARE PER PCINT	3.7592E 02	4.2951E 01
REACTION CROSS SECTION .....	2.2754E 03 (MILLI-BARN)		3.4274E 01	3.9046E 00

ANGULAR DISTRIBUTION (COSINE)

ANGLE	ELASTIC	ANGLE	ELASTIC	ANGLE	ELASTIC	ANGLE	ELASTIC	ANGLE	ELASTIC		
0.990	8.0774E 02	0.250	1.0795E 02	-0.650	2.2955E 01	0.990	8.2599E 02	0.261	1.1044E 02	-0.643	2.2619E 01
0.940	6.9273E 02	0.0	8.0947E 01	-0.715	1.7495E 01	0.981	7.0759E 02	0.011	8.0963E 01	-0.709	1.7214E 01
0.860	5.4062E 02	-0.010	8.0149E 01	-0.770	1.3820E 01	0.863	3.5124E 02	0.003	8.0146E 01	-0.765	1.3580E 01
0.700	3.2978E 02	-0.270	5.9809E 01	-0.950	1.2503E 01	0.706	3.3507E 02	-0.259	5.9494E 01	-0.949	1.2235E 01
0.483	1.7916E 02	-0.510	3.6767E 01	-0.980	1.4622E 01	0.494	1.6117E 02	-0.302	3.6348E 01	-0.980	1.4299E 01

COMPOUND FORMATION PROBABILITY														
L	2*J	T(+)	2*J	T(-)	L	2*J	T(+)	2*J	T(-)	L	2*J	T(+)	2*J	T(-)
0	1	5.4914E-01			2	5	1.9578E-01	3	3.0462E-01	4	9	1.8592E-03	7	2.3774E-03
1	3	9.1304E-01	1	6.6180E-01	3	7	1.7646E-01	5	4.4621E-02	5	11	1.4859E-04	9	5.7481E-05

A = COEFFICIENT (CMS)

LL	BL												
0	1.5570E 02	1	2.6412E 02	2	1.9887E 02	3	1.3426E 02	4	6.7757E 01	5	9.5965E 00	6	2.3314E 00
7	1.5294E-01	8	8.8364E-03	9	2.7175E-04	10	7.3342E-06	11	0.0				

B = COEFFICIENT (LAB)

LL	BL												
0	1.5570E 02	1	2.6414E 02	2	2.0354E 02	3	1.3866E 02	4	7.1932E-01	5	1.2153E 01	6	2.7854E 00
7	2.7323E-01	8	1.9769E-02	9	9.2732E-04	10	1.1618E-05	11	7.2967E-05				

PRCB, 1+ Y(N+N) E=1.49MEV, SHAPE ELASTIC SCATTERING ONLY PAGE 3

\*\*\*\*\* PHASE FACTOR ( EXP(2\*I\*PHASE SHIFT) ) .....

L+1	S(+).REAL	S(+).IMAG	S(-).REAL	S(-).IMAG	L+1	S(+).REAL	S(+).IMAG	S(-).REAL	S(-).IMAG
1	-6.0687E-01	2.8736E-01	0.0	0.0	4	9.0738E-01	1.9734E-02	9.7779E-01	1.7304E-02
2	2.9320E-01	-1.3738E-02	5.2900E-01	-2.4157E-01	5	9.9908E-01	1.9829E-03	9.9881E-01	-1.6319E-04
3	6.7368E-01	-2.0257E-01	7.6130E-01	-2.6311E-01	6	9.9993E-01	5.4104E-05	9.9997E-01	4.5725E-05

\*\*\*\*\* SCATTERING AMPLITUDES \*\*\*\*\*

ANGLE	A...REAL	A...IMAG	B...REAL	B...IMAG	ANGLE	A...REAL	A...IMAG	B...REAL	B...IMAG
0.990	-1.9287E 00	6.7981E 00	1.0678E-03	-1.0836E-01	-0.270	1.5877E 00	1.7789E 00	4.2652E-01	-3.3733E-01
0.940	-1.5551E 00	8.1667E 00	2.3362E-01	-2.5502E-01	-0.510	1.1175E 00	1.4044E 00	6.3740E-01	-2.2174E-01
0.860	-1.1375E 00	7.2468E 00	2.9575E-01	-3.6532E-01	-0.650	6.3643E-01	1.1515E 00	7.3611E-01	-1.4933E-01
0.700	-3.6248E-01	5.7045E 00	2.9067E-01	-4.6971E-01	-0.715	3.5953E-01	1.0141E 00	7.0059E-01	-1.1320E-01
0.483	5.1685E-01	4.1636E 00	2.2262E-01	-5.1357E-01	-0.770	9.7824E-02	8.8478E-01	7.6282E-01	-8.7454E-02
0.250	1.1634E 00	3.0346E 00	1.8608E-01	-4.9931E-01	-0.950	-9.3711E-01	5.5366E-01	4.9694E-01	-1.1398E-02
0.0	1.1768E 00	2.2857E 00	2.4566E-01	-4.3972E-01	-0.980	-1.1567E 00	2.4600E-01	5.3111E-01	-5.7478E-03
-0.010	1.6253E 00	2.2627E 00	2.5037E-01	-4.3658E-01					

PROB, 1+ Y(N+N) E=1.49MEV, SHAPE ELASTIC SCATTERING ONLY PAGE 4

EXPERIMENTAL DATA FOR POLARIZATION

NO EXPERIMENTAL DATA

CALCULATED DATA FOR POLARIZATION

ANGLE	POL.	ANGLE	POL.	ANGLE	ASYM.	ANGLE	ASYM.	ANGLE	ROT+	ANGLE	ROT.
0.990	0.0254	-0.2710	-0.0258	0.990	-0.1392	-0.270	-0.7508	0.990	0.9864	-0.2124	-0.0000
0.940	0.0706	-0.5110	-0.0710	0.940	-0.2512	-0.5320	-0.7509	0.940	0.9810	-0.4110	-0.2183
0.860	0.1104	-0.6720	-0.2549	0.860	-0.3611	-0.6360	-0.1473	0.860	0.8203	-0.4320	-0.0266
0.700	0.1689	-0.7155	-0.1740	0.700	-0.7641	-0.7155	0.4381	0.700	0.6226	-0.7155	-0.8809
0.483	0.2259	-0.7700	0.0040	0.483	-0.9042	-0.7700	0.6680	0.483	0.3516	-0.7700	-0.7442
0.250	0.2347	-0.9200	0.7514	0.250	-0.9716	-0.9500	0.0617	0.250	0.0301	-0.9200	-0.6264
0.0	0.1501	-0.9800	0.5161	0.0	-0.9373	-0.9800	-0.0657	0.0	-0.3145	-0.9800	-0.8540
-0.010	0.4900			-0.010	-0.9336			-0.010	-0.3278		

RUNNING TIME ..... 2.24 SEC.

Fig 5 (1)

3 EPROB= 2 U238(N=N), E=300 KEV  
 2.045 2.04 2.03 2.035 2.0 2.045 2.05 2.06  
 8 1 1 2 92 238 1 19 1  
 1 236.05 1.32 1.32 1.32 0.5  
 6 1.32 1.32 1.32 0.5  
 11 0.4 0.47 0.47 0.4  
 16 40.5 9.0 9.0 15.0  
 51 0.0 10.0 20.0 30.0 40.0  
 56 50.0 60.0 70.0 80.0 90.0  
 61 100.0 110.0 120.0 130.0 140.0  
 66 150.0 160.0 170.0 180.0  
 1  
 36 0.0447 2.0  
 1 3  
 36 0.148 4.0

Fig 5 (2)

PROB. 2 U238(N,N), E=300 KEV PAGE 1  
 TARGET INCIDENT PMESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 4  
 MASS ..... 238.05 1.008665 PMESHc = 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 2  
 MASS NO. .... 238 1 CMESH = 2.502E-01 (FERMI) WAVE NUMBER \*\*\*\*\* 0.120069  
 ATOMIC NO. ... 92 0 CMESHc = 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.0  
 CMS ENERGY ... 0.300000 (MEV)  
 LAB ENERGY ... 0.301271 (MEV) SEPARATION ENERGY ... 0.0 (MEV)  
 INCIDENT PARTICLE .... NEUTRON  
 IMAGINARY POTENTIAL FORM NUN=LOCAL PARAMETER = 0.0 ( L-S TERM )  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... DIFF: WOODS-SAXON  
 POTENTIAL PARAMETER  
 FORM PARAMETER WELL DEPTH PARAMETER (MEV)  
 (FSRMI) R0 = 1.320 V = 40.50 WI = 0.0 WS = 9.00 VSO = 15.00 WSO = 0.0 VSYM = 0.0  
 RI = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSQE = 0.0 WSOE = 0.0 VCDUL = 0.0  
 RC = 0.0 RS = 1.320 VES0 = 0.0 WI50 = 0.0 WSE50 = 0.0 VSQ50 = 0.0 WSO50 = 0.0  
 R50 = 1.320 A0 = 0.400 A1 = 0.0 VRE = 40.50 WIMI = 0.0 WIMS = 9.00 VSP0 = 15.00 WSP0 = 0.0 VSYMM = 0.0  
 B = 0.470 ASO = 0.00  
 BRANCHING RATIO  
 2.045 2.040 2.030 2.035 2.040 2.045 2.050 2.060 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 LEVEL DENSITY PARAMETER  
 E- = 0.0 A = 0.0 SGM = 0.0 EPR = 0.0 NOM = 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0  
 NO EXPERIMENTAL DATA  
 PROB. 2 U238(N,N), E=300 KEV PAGE 2  
 TOTAL CROSS SECTION ..... 9.2001E 03 (MILLI-BARN)  
 SHAPE ELASTIC CROSS SECTION 6.7770E 03 (MILLI-BARN)  
 REACTION CROSS SECTION ... 2.4231E 03 (MILLI-BARN)  
 ANGULAR DISTRIBUTION (DEGREE)  
 CENTER OF MASS \*\*\*\*\* LABORATORY \*\*\*\*\*  
 ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC  
 0.0 1.3266E 03 70.0 6.1002E 02 140.0 2.4650E 02 0.0 1.337E 03 69.8 6.1100E 02 139.8 2.4490E 02  
 10.0 1.3024E 03 80.0 5.0924E 02 120.0 2.3393E 02 10.0 1.3133E 03 79.6 5.1000E 02 139.6 2.3218E 02  
 20.0 1.2531E 03 90.0 4.2880E 02 160.0 2.2533E 02 19.9 1.2429E 03 89.8 4.2881E 02 159.9 2.2356E 02  
 30.0 1.1279E 03 100.0 3.6729E 02 170.0 2.2033E 02 29.9 1.1362E 03 99.8 3.6676E 02 170.0 2.1832E 02  
 40.0 1.0204E 03 110.0 3.2164E 02 180.0 2.1871E 02 39.8 1.0062E 03 109.8 3.2013E 02 180.0 2.1408E 02  
 50.0 8.5268E 02 120.0 2.8483E 02 190.0 2.1781E 02 49.8 8.5268E 02 119.8 2.8162E 02 190.0 2.1364E 02  
 60.0 7.2952E 02 130.0 2.5683E 02 200.0 2.1711E 02 59.8 7.2952E 02 129.8 2.5744E 02

COMPOUND FORMATION PROBABILITIES				L 2@J T(+) 2@J T(-)				L 2@J T(+) 2@J T(-)						
L	2@J	T(+)	2@J	T(-)	L	2@J	T(+)	2@J	T(-)	L	2@J	T(+)	2@J	T(-)
0	1	3.1520E-01			2	5	2.1462E-02	3	4.9122E-02	4	9	2.0462E-05	7	3.1068E-05

LL B = COEFFICIENT (CM/S) LL BL LL BL LL BL LL BL LL BL LL BL LL BL

Fig 5 (2) continued

```

PROB. 2 U238(N,N)+ E=300 KEV          PAGE  3

INELASTIC SCATTERING ..... INPUT DATA .....,.

TOTAL LEVELS ..... 3

*** GROUND STATE (N = N)

SPIN-PARITY ..... 0+.

TARGET INCIDENT PMESH = 2.5D0E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM +
MASS NO. .... 231      1 PHESH = 2.5D0E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM +
ATOMIC NO. ... 92       0 CMESH = 2.5D0E-01 (FERMI) WAVE NUMBER .....,.
CHS ENERGY ... 0.300000 (MEV) COULOMB PARAMETER (YETA) 0.0
LAB ENERGY ... 0.301271 (MEV) SEPARATION ENERGY ... 0.0 (MEV)

INCIDENT PARTICLE .... NEUTRON

IMAGINARY POTENTIAL FORM      NON-LOCAL PARAMETER = 0.0 < L-S TERM >
INTERNAL ..... SURFACE ABSORPTION ONLY
SURFACE ..... DIFF. WOODS-SAXON

POTENTIAL PARAMETER

FORM PARAMETER      WELL DEPTH PARAMETER (MEV)
(FERMI)           R0 = 1.320   V = 40.50    W3 = 0.0    WS = 9.00    VSO = 15.00    WSO = 0.0    VS0M = 0.0
R1 = 0.0           VE = 0.0     W1E = 0.0    WSE = 0.0     VSOE = 0.0    WSOE = 0.0    VCOUL = 0.0
RC = 0.0           R5 = 1.320   VES0 = 0.0   W1ES0 = 0.0   WSES0 = 0.0   VSOES0 = 0.0   WSOES0 = 0.0
RS0 = 1.320         A0 = 0.400   VRE = 40.50   W1MI = 0.0    WIMS = 9.00    VSP0 = 15.00    WSP0 = 0.0    VS0MH = 0.0
A1 = 0.0           B = 0.470   VRE = 40.50   W1MI = 0.0    WIMS = 9.00    VSP0 = 15.00    WSP0 = 0.0    VS0MMH = 0.0
ASD = 0.400

BRANCHING RATIO
2.045 2.040 2.030 2.035 2.040 2.045 2.050 2.060 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0

LEVEL DENSITY PARAMETER
EC = 0.0          A = 0.0     SGH = 0.0     EPR = 0.0     NOM = 0.0
V,0              0.0          0.0          0.0          0.0

PROB. 2 U238(N,N)+ E=300 KEV          PAGE  4

*** FIRST EXCITED STATE (N = N)

SPIN-PARITY ..... 2+
EXCITATION ENERGY .... 0.046700 (MEV)
POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

*** SECOND EXCITED STATE (N = N)

SPIN-PARITY ..... 0+
EXCITATION ENERGY .... 0.148000 (MEV)
POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

```

Fig 5 (2) continued

PRCB. 2 U238(N-Na), E=300 KEV

PAGE 3

## CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

## HAUSER-FESHBACH-WOLFENSTEIN THEORY USED

### GROUND STATE ( $n = N$ )

SPIN-PARITY ....., 0+

COMPOUND ELASTIC SCATTERING CROSS SECTION ..... 1.1935E 03 (MILLI-BARN)  
SHAPE ELASTIC SCATTERING CROSS SECTION ..... 6.7770E 03 (MILLI-BARN)  
TOTAL ELASTIC SCATTERING CROSS SECTION ..... 7.9105E 03 (MILLI-BARN)

REGULAR DISTRIBUTION (DEGREE)

***** CENTER OF MASS *****				***** LABORATORY *****			
ANGLE	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)	ANGLE	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)
0.0	1.3266E 03	1.2447E 02	1.4510E 03	0.0	1.3378E 03	1.2553E 02	1.4633E 03
10.0	1.3024E 03	1.2286E 02	1.4225E 03	10.0	1.3133E 03	1.2389E 02	1.4371E 03
20.0	1.2331E 03	1.1835E 02	1.3533E 03	19.9	1.2492E 03	1.1920E 02	1.3621E 03
30.0	1.1279E 03	1.1120E 02	1.2931E 03	29.9	1.1362E 03	1.1210E 02	1.2853E 03
40.0	9.9667E 02	1.0284E 02	1.2032E 03	39.8	9.8351E 02	1.0531E 02	1.1963E 03
50.0	8.4099E 02	9.4067E 02	1.1062E 03	49.8	8.7450E 02	9.0000E 02	1.0984E 03
60.0	7.9553E 02	8.6355E 02	9.5474E 02	59.8	7.9274E 02	8.4201E 02	8.8984E 02
70.0	6.1002E 02	7.9261E 02	6.1928E 02	69.8	6.1180E 02	7.9492E 02	6.9130E 02
80.0	5.0944E 02	7.5009E 02	5.8422E 02	79.8	5.1000E 02	7.1122E 02	5.4512E 02
90.0	4.2880E 02	7.3540E 02	5.0234E 02	89.8	4.2881E 02	7.3544E 02	5.0235E 02
100.0	3.6729E 02	7.5009E 02	4.4123E 02	99.8	3.6676E 02	7.4901E 02	4.4166E 02
110.0	3.2166E 02	7.9261E 02	4.0092E 02	109.8	3.2073E 02	7.9033E 02	3.9977E 02
120.0	2.8833E 02	8.5835E 02	3.7417E 02	119.8	2.8712E 02	8.5474E 02	3.7229E 02
130.0	2.6410E 02	9.4008E 02	3.5180E 02	129.8	2.6266E 02	9.3498E 02	3.5161E 02
140.0	2.4360E 02	1.0246E 02	3.4933E 02	139.8	2.4490E 02	3.1708E 02	3.4708E 02
150.0	2.2370E 02	1.1120E 02	3.4710E 02	149.8	2.2500E 02	3.1046E 02	3.4265E 02
160.0	2.0389E 02	1.2015E 02	3.4490E 02	159.8	2.0399E 02	3.0406E 02	3.3804E 02
170.0	2.0203E 02	1.2247E 02	3.4332E 02	170.0	2.1852E 02	3.1218E 02	3.4036E 02
180.0	2.1871E 02	1.2848E 02	3.4118E 02	180.0	2.1664E 02	3.1234E 02	3.4082E 02

PRGB. 2 U238(N,N=), E=300 KEV

PAGE 6

## CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

## HAUSER-FESHBACH-WOLFENSTEIN THEORY USED

### FIRST EXCITED STATE ( $\zeta_{N-N}$ )

EXCITATION ENERGY ..... 0.0447000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.2553000 (MEV)  
                           (LAB) ... 0.2563818 (MEV)  
 SPIN-PARITY ..... 2+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.4362E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 1.1621E 03 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)				LABORATORY			
ANGLE	DIFF.-C.S.	CENTER	MASS	ANGLE	DIFF.-C.S.	ANGLE	DIFF.-C.S.
0.0	7.6597E 01	100.0	9.9416E 01	0.0	7.7116E 01	99.7	9.9460E 01
10.0	7.9331E 01	110.0	9.7609E 01	10.0	7.7920E 01	99.8	9.8076E 01
20.0	7.9354E 01	120.0	8.5110E 01	19.9	8.0040E 01	119.8	9.4078E 01
30.0	8.2597E 01	130.0	9.0669E 01	29.9	8.3256E 01	129.8	9.0136E 01
40.0	8.6532E 01	140.0	8.6532E 01	39.8	8.7145E 01	139.8	8.5925E 01
50.0	9.0669E 01	150.0	8.2597E 01	49.8	9.1207E 01	149.9	8.1942E 01
60.0	9.4516E 01	160.0	7.9354E 01	59.8	9.4947E 01	159.9	8.5870E 01
70.0	9.7096E 01	170.0	7.7219E 01	69.8	9.7918E 01	170.0	8.7632E 01
80.0	9.9416E 01	180.0	7.6475E 01	79.7	9.9778E 02	180.0	7.5774E 01

```

B = COEFFICIENT (CM5)
          (LAB)           TRANSMISSION COEFFICIENT
          LL      BL          L    2*J   T(<>)    2*J   T(>)
          LL      BL
          0     9.2479E-01   0   9.2479E-01   0   1   2.9813E-01
          1     -1.5806E-01   1   8.7859E-01   1   3   1.9486E-01   1   1.3443E-01
          2     -1.9424E-01   2   -1.5804E-01   2   5   1.5521E-02   3   5.5858E-02
          3     -3.3943E-03   3   -1.7305E-01   3   7   2.1209E-03   5   7.3960E-04
          4     -7.7538E-08   4   -1.9511E-01   4   9   1.0135E-05   7   1.5650E-05

```

Fig 5 (2) continued

PRCB, 2 U23d(N,Ne), E=300 KEV  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHBACH-WOLFENSTEIN THEORY USED  
 SECOND EXCITED STATE (N - N)  
 EXCITATION ENERGY .... 0.1480000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.1520000 (MEV)  
 (LAB) ... 0.1526441 (MEV)  
 SPIN-PARITY ..... 4+  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.5122E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 2.7068E 01 (MILLI-BARN)  
 ANGULAR DISTRIBUTION (DEGREE)  
 \*\*\*\*\* CENTER OF MASS \*\*\*\*\*  

ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.
0.0	1.7919E 00	100.0	2.3020E 00	0.0	2.1422E 00	99.7	2.3004E 00
10.0	1.8095E 00	110.0	2.3020E 00	9.9	1.4505E 00	109.7	2.2552E 00
20.0	1.8619E 00	120.0	2.2023E 00	19.9	1.8828E 00	119.7	2.1893E 00
30.0	1.9393E 00	130.0	2.3212E 00	29.8	1.9594E 00	129.7	2.1020E 00
40.0	2.0299E 00	140.0	2.0299E 00	39.8	2.0480E 00	139.8	2.0155E 00
50.0	2.1212E 00	150.0	1.9593E 00	49.7	2.1375E 00	149.8	1.9194E 00
60.0	2.2223E 00	160.0	1.8619E 00	59.7	2.2155E 00	159.9	1.8411E 00
70.0	2.2653E 00	170.0	1.8095E 00	69.7	2.2747E 00	161.9	1.7884E 00
80.0	2.3050E 00	180.0	1.7910E 00	79.7	2.3099E 00	180.0	1.7697E 00
90.0	2.3185E 00			89.7	2.3186E 00		

 \*\*\*\*\* LABORATORY \*\*\*\*\*  

B = COEFFICIENT (CMS)	(LAB)	TRANSMISSION COEFFICIENT	T(+)	T(-)
LL	BL	L	2*J	2*J
0	2.1540E 00	0	2.1540E 00	0
2	-5.4313E-01	1	2.6462E-02	1
4	-1.9316E-02	2	-3.4304E-01	2
6	-5.6369E-04	3	-4.7487E-03	3

 INELASTIC CROSS SECTION ..... 1.1892E 03 (MILLI-BARN)  
 RUNNING TIME .... 5.19 SEC.

Fig 6 (1)

```

      3   PROB. 3-1: FE56-N, E=3.0 MEV , MOLDAUER THEORY , Q=1, NU=1.5
      1   7   1   1   1   26   56   0   1   13   1
      1   36.0   1.009   0.5   10015
      6   1.265
      11  0.62
      16  4.60
      31  0.0
      56  50.0   70.0   90.0   120.0   140.0
      61  159.0   160.0   170.0   175.0   180.0
      1   2
      36  0.6469   2.0
      3   9
      36  2.085   4.0
      3   PROB. 3-2: FE56-N, E=2.0 MEV , MOLDAUER THEORY , Q=1, NU=1.5
      1   1
      1   3
      2   2.0
      1   PROB. 3-3: FE56-N, E=1.0 MEV , MOLDAUER THEORY , Q=1, NU=1.5
      1   5   1.0
      1   PROB. 3-4: FE56-N, E=2.0 MEV , MOLDAUER THEORY
      2   1
      2   0.10   0
      2   0.0
      36  0.0
      1   2
      36  0.85   0.0

```

Fig 6 (2)

PROB. 3-1, F5E6-N, E=3.0 MEV + MOLDAUFER THEORY + B1+ NU=1.5 PAGE 2  
 TOTAL CROSS SECTION ..... 3.5523E 03 (MILLI-BARN)  
 SHAPE ELASTIC CROSS SECTION 2.1945E 03 (MILLI-BARN)  
 REACTION CROSS SECTION ... 1.3576E 03 (MILLI-BARN)  
 ANGULAR DISTRIBUTION (DEGREE)  
 ..... CENTER OF MASS .....  
 ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC LABORATORY ANGLE ELASTIC  
 0.0 1.4220E 03 35.0 2.9409E 02 150.0 3.747E 01 0.0 1.4737E 03 49.2 2.6520E 02 149.5 3.6298E 01  
 5.0 1.4012E 03 76.0 2.9335E 01 140.0 3.7205E 01 4.9 1.4519E 03 65.0 1.3526E 01 139.6 3.1604E 01  
 10.0 1.3403E 03 90.0 2.5931E 01 170.0 3.2346E 01 9.8 1.4335E 03 85.0 1.0444E 01 139.6 2.5604E 01  
 20.0 1.1326E 03 120.0 7.4811E 01 175.0 3.2622E 01 19.7 1.3462E 03 119.1 7.3474E 01 174.9 3.1491E 01  
 30.0 8.1756E 02 140.0 5.8612E 01 180.0 3.2794E 01 29.5 8.4337E 01 139.1 4.7291E 01 180.0 3.1623E 01

				COMPOUND FORMATION PROBABILITY										
L	2*J	T(+)	2*J	T(-)	L	2*J	T(+)	2*J	T(-)	L	2*J	T(+)	2*J	T(-)
0	1	9.8566E-01			2	5	7.5070E-01			4	9	1.3137E-02	7	3.0233E-02
1	3	1.3337E-01	1	1.3726E-01	3	7	1.1349E-01	5	3.4132E-02	5	11	1.6780E-03	9	4.7421E-04

Fig. 6 (2) continued

PRCB, 3-1, FES6-N, E=3.0 MEV + MOLDAUER THEORY : Q=1, NU=1.5  
 INELASTIC SCATTERING ..... INPUT DATA .....

TOTAL LEVELS ..... 3

\*\*\* GROUND STATE (N = N)

SPIN-PARITY ..... 0+

MASS ..... TARGET INCIDENT PMESH = 2.500E-01 (FERMI)  
 MASS NO. .... 56 1 CMESH = 2.500E-01 (FERMI)  
 ATOMIC NO. ... 26 0 CMESH = 0.0 (FERMI)

CMS ENERGY ... 3.000000 (MEV)  
 LAB ENERGY ... 3.054050 (MEV) SEPARATION ENERGY ... 0.0 (MEV)

INCIDENT PARTICLE ..... NEUTRON

IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 ( L-S TERM )  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... GAUSS

POTENTIAL PARAMETER

FORM PARAMETER	WELL DEPTH PARAMETER (MEV)
(FERMI)	
RD = 0.265	V = 46.00
R1 = 0.1	VI = 0.0
RC = 0.0	VE = 0.0
RS = 1.400	VI = 0.0
RS0 = 1.263	VE\$W = 0.0
AD = 0.620	VI\$EW = 0.0
A1 = 0.0	VE\$E = 0.0
B = 0.300	VI\$M = 0.0
As0 = 0.620	VE\$M = 0.0

BRANCHING RATIO

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0																			

LEVEL DENSITY PARAMETER

EC = 0.0	A = 0.0	SQM = 0.0	EPR = 0.0	NOM = 0.0
0.0	0.0	0.0	0.0	0.0

PRCB, 3-1, FES6-N, E=3.0 MEV + MOLDAUER THEORY : Q=1, NU=1.5  
 PAGE 4

\*\*\* FIRST EXCITED STATE (N = N)

SPIN-PARITY ..... 2+  
 EXCITATION ENERGY .... 0.846900 (MEV)

POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

\*\*\* SECOND EXCITED STATE (N = N)

SPIN-PARITY ..... 4+  
 EXCITATION ENERGY .... 2.085000 (MEV)

POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

PRCB, 3-1, FES6-N, E=3.0 MEV + MOLDAUER THEORY : Q=1, NU=1.5  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 MOLDAUER THEORY USED G-FACTOR ... 1.0000 DEG. OF FREEDOM ... 1.50  
 GROUND STATE (N = N)

SPIN-PARITY ..... 0+

COMPOUND ELASTIC SCATTERING CROSS SECTION ..... 3.2270E 02 (MILLI-BARN)  
 SHAPE ELASTIC SCATTERING CROSS SECTION ..... 2.1945E 03 (MILLI-BARN)  
 TOTAL ELASTIC SCATTERING CROSS SECTION ..... 2.5172E 03 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	LAB	TRANSMISSION COEFFICIENT	
ELASTIC(S)	ELASTIC(C)	ELASTIC(T)	L T(0) T(1)	
0.0	1.4220E 03	5.6040E 01	1.4781E 03	0.0 1.4737E 03 3.8079E 01 1.9338E 03
5.0	1.4013E 03	5.4278E 01	1.4965E 03	4.9 1.4519E 03 3.7242E 01 1.5032E 03
10.0	1.3403E 03	5.3020E 01	1.3933E 03	9.8 1.3880E 03 3.6984E 01 1.4632E 03
20.0	1.1185E 03	4.5552E 01	1.1641E 03	19.7 1.1568E 03 4.7110E 01 1.2039E 03
30.0	8.1756E 02	3.6563E 01	8.5412E 02	29.3 8.4357E 02 3.7718E 01 8.8109E 02
50.0	2.5919E 02	2.4132E 01	2.8524E 02	49.2 2.6520E 02 2.4722E 01 2.8992E 02
70.0	1.2150E 02	2.0135E 01	3.5730E 02	69.0 1.2000E 02 2.0000E 01 3.6230E 02
90.0	2.3931E 01	1.4725E 01	4.4225E 01	88.0 2.3944E 01 1.9000E 01 4.4600E 01
120.0	7.4831E 01	2.1535E 01	9.6350E 01	119.1 7.3497E 01 2.1160E 01 9.6657E 01
140.0	4.6614E 01	2.9027E 01	7.7631E 01	139.5 4.7294E 01 2.8228E 01 7.5518E 01
150.0	3.7454E 01	3.6563E 01	7.4017E 01	149.5 3.6299E 01 3.3433E 01 7.1734E 01
160.0	3.2700E 01	4.3552E 01	7.8251E 01	159.6 3.1604E 01 4.4029E 01 7.3628E 01
170.0	3.2394E 01	5.3020E 01	8.3428E 01	169.8 3.1209E 01 5.1216E 01 8.2924E 01
175.0	3.2622E 01	5.3278E 01	8.7631E 01	174.9 3.1494E 01 5.3312E 01 8.4805E 01
180.0	3.2794E 01	5.6041E 01	8.6836E 01	180.0 3.1623E 01 5.4040E 01 8.5865E 01

B - COEFFICIENT (CMS)

LL	BL-(S)	BL-(C)	BL-(T)	BL-(L)	TRANSMISSION COEFFICIENT	L T(0)	T(1)	
0	1.7463E 02	2.3680E 01	2.0031E 02	2.0051E 02	0	9.8566E-01	0.0	0.0
1	3.2545E 02	3.2545E 02	5.2754E 02		1	1.5397E-01	0.0	1.5372E-01
2	4.0255E 02	1.8621E 01	4.2113E 02	4.2723E 02				
3	3.5214E 02	9.1401E 00	1.5338E 02	3.6648E 02	2	7.5070E-01	0.0	8.7510E-01
4	1.4468E 02		1.7174E 02					
5	1.2235E 02		1.8233E 01	2.7523E 01	3	1.1349E-01	0.0	3.4132E-02
6	5.0577E-01		8.0546E-01	9.5481E-01				
8	7.1470E-02	2.1304E-02	9.6075E-02	1.8420E-01	4	1.3437E-02	0.0	3.0233E-02
9	1.2159E-02		2.1259E-02	2.5181E-02				
10	8.8819E-04	7.1633E-03	8.0515E-03	9.5347E-03	5	1.6784E-03	0.0	4.7421E-04

Fig. 6 (2) continued

PRCB. 3-1, Fe56-N, E=3.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5 PAGE 6

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

MOLDAUER THEORY USED Q-FACTOR ... 1.000 DEG. OF FREEDOM ... 1.50

FIRST EXCITED STATE (N = N)

EXCITATION ENERGY ....	0.8469000 (MEV)
EMITTED ENERGY (CMS) ...	2.1531000 (MEV)
(LAB) ...	2.1918942 (MEV)
SPIN-PARITY .....	2+
COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ....	1.5424E 03 (MILLI-BARN)
TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL .....	8.8879E 02 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREES)

ANGLE .....	CENTER OF MASS .....	LABORATORY .....			
ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.
0.0	6.4948E 01	120.0	7.1046E 01	0.0	6.7740E 01
5.0	6.5116E 01	140.0	7.1094E 01	4.9	6.7905E 01
10.0	6.5603E 01	150.0	6.9376E 01	9.8	6.8381E 01
20.0	6.7300E 01	160.0	6.7300E 01	19.6	7.0023E 01
30.0	6.9376E 01	170.0	6.5603E 01	29.4	7.1967E 01
50.0	7.1973E 01	175.0	6.5116E 01	49.1	7.3985E 01
70.0	7.1398E 01	180.0	6.4948E 01	68.9	7.2484E 01
90.0	7.0504E 01			88.8	7.0592E 01

B ~ COEFFICIENT (CMS)	(LAB)	TRANSMISSION COEFFICIENT				
LL	BL	L	Z+j	T(+)	Z-j	T(-)
0	7.0728E 01	0	7.0728E 01	0	1	7.9738E-01
2	-2.1131E 00	1	3.0265E 00	1	3	1.1182E-01
4	-3.5274E 00	2	-2.0808E 00	2	5	6.7518E-01
6	-1.3802E-01	3	-7.9057E-03	3	7	3.7091E-02
8	-9.6626E-04	4	-3.5220E 00	4	9	3.3257E-03
10	-2.8683E-05	5	-2.4306E-01	5	11	2.6678E-04

PRCB. 3-1, Fe56-N, E=3.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5 PAGE 7

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

MOLDAUER THEORY USED Q-FACTOR ... 1.000 DEG. OF FREEDOM ... 1.50

SECOND EXCITED STATE (N = N)

EXCITATION ENERGY ....	2.0890000 (MEV)
EMITTED ENERGY (CMS) ...	0.9150000 (MEV)
(LAB) ...	0.9314864 (MEV)
SPIN-PARITY .....	4+
COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ....	1.7211E 03 (MILLI-BARN)
TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL .....	1.4627E 02 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREES)

ANGLE .....	CENTER OF MASS .....	LABORATORY .....			
ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.
0.0	1.0133E 01	120.0	1.1876E 01	0.0	1.0805E 01
5.0	1.0159E 01	140.0	1.1291E 01	4.8	1.0831E 01
10.0	1.0235E 01	150.0	1.0894E 01	9.7	1.0904E 01
20.0	1.0312E 01	160.0	1.0512E 01	19.4	1.1139E 01
30.0	1.0391E 01	170.0	1.0159E 01	29.1	1.1322E 01
50.0	1.1631E 01	175.0	1.0159E 01	48.8	1.2135E 01
70.0	1.2024E 01	180.0	1.0133E 01	68.5	1.2311E 01
90.0	1.2117E 01			88.2	1.2136E 01

B ~ COEFFICIENT (CMS)	(LAB)	TRANSMISSION COEFFICIENT				
LL	BL	L	Z+j	T(+)	Z-j	T(-)
0	1.1640E 01	0	1.1640E 01	0	1	7.7538E-01
2	-1.1855E 00	1	7.7694E-01	1	3	6.8469E-02
4	-3.1362E-01	2	-1.1714E 00	2	5	2.6707E-01
6	-6.6798E-03	3	-7.9135E-02	3	7	1.8718E-03
8	-4.9422E-05	4	-5.1540E-01	4	9	2.5607E-04

INELASTIC CROSS SECTION ..... 1.0351E 03 (MILLI-BARN)

RUNNING TIME ..... 15.87 SFC.

Fig 6 (2) continued

PROB. 3-2, FE56-N, E=2.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5

PAGE 1

MASS ..... TARGET 56.00 INCIDENT 1.009000  
 MASS NO. .... 56 PHESH = 2.500E-02 (FERMI)  
 ATOMIC NO. ... 26 CMESH = 2.499E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 3  
 CMS ENERGY ... 2.000000 (MEV) CMESH = 0.0 CLASSICAL CUT-OFF MOMENTUM 4  
 LAB ENERGY ... 2.036056 (MEV) CMESH = 0.0 WAVE NUMBER ..... 0.307964  
 INCIDENT PARTICLE .... NEUTRON COULOMB PARAMETER (YETA) 0.0  
 IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 < L-S TERM >  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... GAUSS

POTENTIAL PARAMETER

FORM PARAMETER	WELL DEPTH PARAMETER (MEV)
(FERMI)	
RD = 1.263	V = 46.00
R1 = 0.0	WI = 0.0
RE = 3.0	WIE = 0.0
RS = 0.000	WSE = 0.0
RSOM = 1.263	VEG6 = 0.0
AD = 0.420	WIES0 = 0.0
A1 = 0.0	WSES0 = 0.0
B = 0.500	WIM5 = 14.00
AS0 = 0.620	VSPO = 7.00
	VSPOD = 0.0
	VSYM = 0.0
	VCOLM = 0.0

BRANCHING RATIO

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LEVEL DENSITY PARAMETER

EC = 0.0	A = 0.0	SQM = 0.0	EPR = 0.0	NOM = 0.0
0.0	0.0	0.0	0.0	0.0

NO EXPERIMENTAL DATA

PROB. 3-2, FE56-N, E=2.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5

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TOTAL CROSS SECTION ..... 3.873E 03 (MILLI-BARN)  
 SHAPE ELASTIC CROSS SECTION 1.8767E 03 (MILLI-BARN)  
 REACTION CROSS SECTION ... 1.5806E 03 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	ELASTIC										
0.0	1.0141E 02	50.0	2.4231E 02	150.0	9.2984E 01	0.0	1.0510E 03	49.2	2.4803E 02	149.3	8.9728E 01
5.0	1.0014E 02	70.0	9.1281E 01	160.0	1.0185E 02	4.9	1.0376E 03	69.0	3.1681E 02	159.6	9.8439E 01
10.0	9.6473E 02	90.0	1.2364E 00	170.0	1.0481E 02	9.8	9.9856E 02	89.0	7.7226E 02	169.8	1.0737E 02
20.0	8.2809E 02	120.0	6.3377E 02	180.0	1.1132E 02	19.3	8.6134E 02	119.0	6.2264E 01	179.9	1.0737E 02
30.0	6.3259E 02	140.0	0.3522E 02	180.0	1.1205E 02	29.5	6.5259E 02	139.3	8.1248E 01	180.0	1.0805E 02

L	2*J	T(<)	2*J	T(>)	L	2*J	FORMATION PROBABILITY	L	2*J	T(<)	2*J	T(>)		
0	1	9.9844E-01	1	1.3728E-01	2	5	5.4900E-01	3	6.4785E-01	4	9	4.2462E-03	7	6.8507E-03
1	3	1.0780E-01	3	2.8747E-02	5	5	5.5262E-03	5	11	1.7749E-04	9	5.5234E-05		

LL B = COEFFICIENT (CM5)  
 LL BL  
 0 1.4934E 02 1 2.3224E 02 2 3.3898E 02 3 2.1474E 02 4 7.3798E 01 5 3.9190E 00 6 9.3132E-01  
 7 6.7834E-02 8 4.6976E-03 9 4.2780E-04 10 2.2510E-05 11 0.0

PROB. 3-2, FE56-N, E=2.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5

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CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 MOLDAUER THEORY USED Q-FACTOR ... 1.000 DEG. OF FREEDOM ... 1.90

GROUND STATE (N - N)

SPIN-PARITY ..... 0+  
 COMPOUND ELASTIC SCATTERING CROSS SECTION ..... 6.3839E 02 (MILLI-BARN)  
 SHAPE ELASTIC SCATTERING CROSS SECTION ..... 1.8767E 03 (MILLI-BARN)  
 TOTAL ELASTIC SCATTERING CROSS SECTION ..... 2.5153E 03 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	ELASTIC(CS)	ANGLE	ELASTIC(CC)	ANGLE	ELASTIC(CS)	ANGLE	ELASTIC(CC)	ANGLE	ELASTIC(CC)
0.0	1.0141E 03	1.0140E 02	1.1157E 03	0.0	1.0510E 03	1.0529E 02	1.1567E 03	1.0510E 03	1.0529E 02
5.0	1.0014E 03	1.0005E 02	1.1019E 03	4.9	1.0376E 03	1.0416E 02	1.1414E 03	1.0376E 03	1.0416E 02
10.0	9.6473E 02	9.7404E 01	1.0114E 03	9.8	9.9856E 02	1.0089E 02	1.0993E 03	9.9856E 02	1.0089E 02
20.0	8.2809E 02	8.6511E 01	9.1239E 02	19.7	8.6134E 02	8.9267E 01	9.4360E 02	8.6134E 02	8.9267E 01
30.0	6.3259E 02	7.1989E 01	7.0458E 02	29.5	6.5259E 02	7.4226E 01	7.2883E 02	6.5259E 02	7.4226E 01
50.0	2.4231E 02	4.8394E 01	2.9067E 02	49.2	2.4803E 02	4.4949E 01	2.7214E 02	2.4803E 02	4.4949E 01
70.0	1.2364E 02	2.3720E 01	3.0102E 02	69.0	1.2264E 02	1.6181E 01	4.0490E 01	7.2144E 01	1.6181E 01
90.0	7.2343E 02	3.9235E 01	4.46472E 01	89.0	7.2399E 00	7.9253E 00	6.6494E 01	7.2399E 00	7.9253E 00
120.0	6.3371E 01	4.2473E 01	1.0582E 02	119.1	6.2264E 01	4.1727E 01	1.0397E 02	6.2264E 01	4.1727E 01
140.0	8.3321E 01	5.9437E 01	1.4196E 02	139.3	8.1248E 01	5.6447E 01	1.3809E 02	8.1248E 01	5.6447E 01
150.0	9.2584E 01	7.1988E 01	1.6457E 02	149.5	8.9727E 01	6.9789E 01	1.5930E 02	8.9727E 01	6.9789E 01
160.0	1.0921E 02	8.7040E 01	1.8195E 02	159.6	1.0953E 02	9.9491E 01	1.7143E 02	1.0953E 02	9.9491E 01
170.0	1.0921E 02	9.7404E 01	1.0546E 02	169.8	1.0537E 02	9.3979E 01	1.9933E 02	1.0537E 02	9.3979E 01
175.0	1.1132E 02	1.0059E 02	2.1132E 02	178.9	1.0736E 02	9.6947E 01	2.0431E 02	1.0736E 02	9.6947E 01
180.0	1.1203E 02	1.0160E 02	2.1352E 02	180.0	1.0805E 02	9.7956E 01	2.0602E 02	1.0805E 02	9.7956E 01

B = COEFFICIENT (CM5)  
 LL BL-(CS) BL-(CC) (LAB) BL-(L) TRANSMISSION COEFFICIENT  
 0 1.4934E 02 5.0817E 01 2.0016E 02 2.0016E 01 0 9.9844E 01 0.0 0.0  
 1 2.3224E 02 2.3224E 02 2.5322E 02 2.5322E 02 1 1.0700E 01 0.0 1.3220E 01  
 2 3.3898E 02 3.4041E 01 3.7764E 02 3.7764E 02 2 6.4900E 01 0.0 6.4783E 01  
 3 2.1474E 02 2.1474E 02 2.2843E 02 2.2843E 02 3 2.8747E 02 0.0 2.8526E 02  
 4 7.3798E 01 1.0494E 01 8.9238E 01 1.0037E 02 4 6.4900E 01 0.0 6.4783E 01  
 5 3.9190E 00 5.9390E 00 9.4469E 00 9.4469E 00 5 2.8747E 02 0.0 2.8526E 02  
 6 9.1349E 01 1.0037E 00 2.1436E 00 2.5599E 00 6 2.8747E 02 0.0 2.8526E 02  
 7 1.0494E 02 1.0494E 02 4.6224E 02 4.6224E 02 7 2.8747E 02 0.0 2.8526E 02  
 8 4.6478E 03 4.6478E 02 4.6224E 02 4.7948E 02 8 4.2442E 03 0.0 4.1507E 03  
 9 4.2780E 04 4.2780E 04 4.7242E 04 4.7242E 04 9 4.2442E 03 0.0 4.1507E 03  
 10 2.2510E 05 3.8701E 03 3.8924E 03 3.9292E 03 10 3.17749E 04 0.0 3.5234E 05

Fig 6 (2) continued

PRCb. 3-2, F=56-N, E=2.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 MOLDAUER THEORY USE: L-FACTOR ... 1.0000 DEG. OF FREEDOM ... 1.50  
 FIRST EXCITED STATE (N = N)  
 INITIATION ENERGY .... 0.8469000 (MEV)  
 EMITTED ENERGY (C+S) ... 1.1531000 (MEV)  
 (LAB) ... 1.1737764 (MEV)  
 SPIN-PAIR RITY ..... 2+  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (UNIVERSE PROCESS) ..... 1.7189E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 9.4198E 02 (MILLI-BARN)  
 ANGULAR DISTRIBUTION (DEGREE)  
 ANGLE \*\*\*\*\* CENTER OF MASS \*\*\*\*\* ANGLE \*\*\*\*\* LABORATORY \*\*\*\*\* ANGLE \*\*\*\*\* DIFF-C.S.  
 0.0 7.059E 01 120.0 7.6005E 01 0.0 7.3942E 01 118.6 7.4260E 01  
 5.0 7.0688E 01 140.0 7.5473E 01 4.9 7.4070E 01 139.1 7.2781E 01  
 10.0 7.1076E 01 150.0 7.4102E 01 9.8 7.4438E 01 149.3 7.1103E 01  
 20.0 7.2434E 01 160.0 7.2434E 01 19.5 7.5708E 01 159.5 6.9247E 01  
 30.0 7.4102E 01 170.0 7.1076E 01 29.3 7.7194E 01 169.8 6.7794E 01  
 50.0 7.6130E 01 175.0 7.0688E 01 49.0 7.8508E 01 174.9 6.7386E 01  
 70.0 7.5390E 02 180.0 7.0554E 02 68.7 7.8664E 02 180.0 6.7245E 01  
 90.0 7.4446E 02  
 B - COEFFICIENT (CMS) LL LL (LAB) TRANSMISSION COEFFICIENT  
 NL NL L 2\*J T(<>) 2\*J T(>)  
 0 7.4760E 01 0 7.4960E 01 0 1 9.8874E-01  
 2 -1.2763E 00 2 3.5698E 00 1 2 7.9890E-02  
 4 -3.0979E 00 2 -1.3343E 00 2 3 2.8890E-01  
 6 -3.1660E-02 3 2.3223E-02 3 7 4.2061E-03  
 8 -6.8481E-04 4 -3.0410E 00 4 9 6.2532E-04  
 INELASTIC CROSS SECTION ..... 9.4198E 02 (MILLI-BARN)  
 RUNNING TIME ..... 7.47 SEC.

PRCb. 3-2, F=56-N, E=1.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5  
 TARGET INCIDENT PNESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 4  
 MASS ..... 56.00 1.009000 PNLSHC = 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 3  
 MASS NO. ... 56 1 CSHC = 2.835E-01 (FERMI) WAVE NUMBER ..... 0.217763  
 ATOMIC NO. ... 26 0 CHSCH = 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.0  
 CHD ENERGY ... 1.000000 (MEV)  
 LAB ENERGY ... 1.018018 (MEV) SEPARATION ENERGY ... 0.0 (MEV)  
 INCIDENT PARTICLE ..... NEUTRON  
 IMAGINARY POTENTIAL FORM L-S TERM  
 INTERNAL ..... SURFACE ABSORPTION ONLY ..... 0.0 ( )  
 SURFACE ..... GAUSS ..... 0.0 ( )  
 POTENTIAL PARAMETER:  
 FORM PARAMETER WELL DEPTH PARAMETER (MEV)  
 (FERMI)  
 RD = 1.265 V = 46.00 WI = 0.0 WS = 14.00 VSO = 7.00 WSO = 0.0 VSYM = 0.0  
 RI = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOUL = 0.0  
 RS = 1.00 VESM = 0.0 WIERSQ = 0.0 WSSESQ = 0.0 VSOESQ = 0.0 WSOESQ = 0.0  
 RBSM = 1.265 VSYM = 0.0 WIERSQ = 0.0 WSSESQ = 0.0 VSOESQ = 0.0 WSOESQ = 0.0  
 AO = 0.620 A1 = U.L VRE = 46.00 WIIM = 0.0 WIMS = 14.00 VSPD = 7.00 WSPO = 0.0 VSMM = 0.0  
 B1 = U.R WS = 0.500 ASM = 0.020  
 BRANCHING RATIO  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 LEVEL DENSITY PARAMETER  
 EC = 0.0 A = 0.0 SGH = 0.0 EPR = 0.0 NOM = 0.0  
 D,0  
 NO EXPERIMENTAL DATA

PROB. 3-3, F=56-N, E=1.0 MEV + MOLDAUER THEORY + Q=1, NU=1.5  
 TOTAL CROSS SECTION ..... 3.2572E 03 (MILLI-BARN)  
 SHAPE ELASTIC CROSS SECTION 1.5364E 03 (MILLI-BARN)  
 REACTION CROSS SECTION ... 1.7209E 03 (MILLI-BARN)  
 ANGULAR DISTRIBUTION (DEGREE)  
 ANGLE \*\*\*\*\* CENTER OF MASS \*\*\*\*\* ANGLE ELASTIC ANGLE ELASTIC \*\*\*\*\* LABORATORY \*\*\*\*\* ANGLE ELASTIC  
 ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC  
 0.0 5.0100E 02 50.0 2.0335E 02 150.0 1.2981E 02 0.0 5.1930E 02 49.2 2.0815E 02 149.5 1.2981E 02  
 5.0 4.9678E 02 70.0 7.9581E 01 160.0 1.5165E 02 4.9 5.1477E 02 69.0 8.0397E 01 159.6 1.4657E 02  
 10.0 4.8407E 02 90.0 2.7264E 01 170.0 1.6630E 02 9.8 5.0141E 02 89.0 2.7277E 01 169.8 1.6045E 02  
 20.0 4.3813E 02 120.0 5.3461E 01 175.0 1.7015E 02 19.5 4.5109E 02 119.1 5.2521E 01 174.9 1.4410E 02  
 30.0 3.6564E 02 140.0 1.0393E 02 180.0 1.7146E 02 29.3 3.7718E 02 139.3 1.0111E 02 180.0 1.6533E 02  
 L 2\*J T(<>) 2\*J T(>) L 2\*J T(<>) 2\*J T(>) L 2\*J T(<>) 2\*J T(>)  
 0 1 9.8116E-01 1 1.0368E-01 2 5 3.0872E-01 3 2 1.2183E-01 4 9 3.6253E-01 7 2.1404E-01  
 1 3 7.2629E-02  
 B - COEFFICIENT (CMS) LL RL LL BL LL BL LL BL LL BL LL BL  
 0 1.2226E 02 1 1.1923E 02 2 2.0023E 02 3 4.3510E 01 4 1.3714E 01 5 2.6716E 01 6 4.0398E 02  
 7 7.3291E-04 8 2.0403E-05 9 0.0

Fig. 6 (2) continued

PROB. 3-3, F156-N, E=1.0 MEV + MOLDAUER THEORY, Q=1, NUM=1.5  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 MOLDAUER THEORY USED W-FACTOR ... 1.000 DEG. OF FREEDOM ... 1.50  
 GROUND STATE (N = N)  
 SPIN-PARITY ... 0+  
 CUSPCD ELASTIC SCATTERING CROSS SECTION ..... 1.2088E 03 (MILLI-BARN)  
 SHAPE ELASTIC SCATTERING CROSS SECTION ..... 1.3584E 03 (MILLI-BARN)  
 TOTAL ELASTIC SCATTERING CROSS SECTION ..... 2.7452E 03 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)			LABORATORY		
ANGLE	CENTER OF MASS	ELASTIC(S)	ANGLE	ELASTIC(S)	ELASTIC(T)
	ELASTIC(C)	ELASTIC(T)		ELASTIC(C)	ELASTIC(T)
0.0	5.010RE U2	1.6023E U2	6.6130E 02	0.0	5.1930E 02
>0	4.9678E U2	1.5894E 02	6.5573E 02	4.9	5.1477E 02
10.0	4.8407E U2	1.5517E 02	6.3925E 02	9.8	5.0141E 02
20.0	4.3613E U2	1.4166E 02	5.7773E 02	19.7	4.5105E 02
30.0	3.6564E U2	1.2358E 02	4.8922E 02	29.5	3.7718E 02
50.0	2.0355E U2	9.2576E 01	2.9593E 02	49.2	2.0815E 02
70.0	7.9301E U1	6.2139E 01	1.6152E 02	69.0	8.0397E 01
90.0	2.7205E U1	4.2235E 01	1.1635E 02	89.0	2.7205E 01
120.0	5.3801E U1	0.9000E 01	1.3847E 02	119.3	5.2521E 01
140.0	1.0393E U2	1.0598E 02	2.0991E 02	139.3	1.0211E 02
150.0	1.2981E U2	1.2353E 02	2.7239E 02	149.5	1.2581E 02
160.0	1.5162E U2	1.4160E 02	2.9326E 02	159.6	1.4657E 02
170.0	1.6663E U2	1.5517E 02	3.2147E 02	169.8	1.6045E 02
175.0	1.7015E U2	1.5894E 02	3.2909E 02	174.9	1.6410E 02
180.0	1.7146E U2	1.6023E 02	3.3168E 02	180.0	1.6533E 02
					1.5450E 02
					3.1984E 02

B - COEFFICIENT (CMS)				TRANSMISSION COEFFICIENT	
LL	BL- (S)	BL- (C)	BL- (T)	L	T(+) T(-)
0	1.2226E 04	9.6194E 01	2.1845E 02	2.1845E 02	0 9.6194E-01 0.0 D+0
1	1.1923L 02	1.1923E 02	1.2253E 02		1 7.2823E-02 0.0 1.0308E-01
<	2.0029L 02	4.3101E 01	2.4384E 02	2.4700E 02	
3	4.9110L 01	4.9310E 01	5.5208E 01		2 3.0872E-01 0.0 2.1283E-01
>	1.3714L 01	2.0603E 01	3.4317E 01	3.6767E 01	
5	2.7167E-01	2.6716E-01	2.3732E-01	2.3732E-01	
6	4.0398E-04	2.1907E-01	2.5297E-01	3.3300E-01	
7	7.2291E-04	7.3291E-04	2.2975E-02	3.2975E-02	
8	2.0403L-05	1.8914E-02	1.8934E-02	1.9390E-02	
					4 3.6239E-04 0.0 2.1404E-04

PROB. 3-3, F156-N, E=1.0 MEV + MOLDAUER THEORY, Q=1, NUM=1.5  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 MOLDAUER THEORY USED W-FACTOR ... 1.000 DEG. OF FREEDOM ... 1.50  
 FIRST EXCITED STATE (N = N)  
 EXCITATION ENERGY .... 0.8469000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.1531000 (MEV)  
 (LAB) ... 0.1535858 (MEV)  
 SPIN-PARITY ..... 2+

CUSPCD NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 3.3827E 03 (MILLI-BARN)

TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 5.1205E 02 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)			LABORATORY		
ANGLE	CENTER OF MASS	DIFF.C-S.	ANGLE	DIFF.C-S.	ANGLE
	DIFF.C-S.	ANGLE		DIFF.C-S.	ANGLE
0.0	4.0593E 01	120.0	4.0769E 01	D-0	4.4362E 01
5.0	4.0584E 01	140.0	4.0760E 01	4.0	4.3620E 01
10.0	4.0561E 01	160.0	4.0675E 01	9.6	4.3327E 01
20.0	4.0416E 01	180.0	4.0631E 01	19.1	4.1421E 01
30.0	4.0375E 01	170.0	4.0561E 01	28.7	4.4016E 01
50.0	4.0774E 01	175.0	4.0547E 01	48.0	4.3300E 01
70.0	4.0785E 02	180.0	4.0543E 01	67.6	4.2194E 01
90.0	4.0770E 01			87.4	4.0900E 01

TRANSMISSION COEFFICIENT			TRANSMISSION COEFFICIENT		
LL	BL	LL	BL	Z+j	T(+) T(-)
0	4.0748E 01	0	4.0748E 01	0	1 7.2250E-01
<	-1.1301L-01	1	3.7548E 00	1	3.0933E-02 1 1.7832E-02
4	-9.2460E-02	2	-2.6354E-02	2	5 4.8518E-03 3 2.4482E-03

INELASTIC CROSS SECTION ..... 5.1205E 02 (MILLI-BARN)

RUNNING TIME .... 4.92 SEC.

Fig. 6 (2) continued

PROB. 3-4, F5E6=N: E=2.0 MEV + MOLDAUER THEORY PAGE 1

TARGET INCIDENT PMESH = 2.300E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 5  
MASS ..... 56.00 PMESHc = 2.300E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 4  
MASS NO. .... 5 PMESH = 2.300E-01 (FERMI) WAVE NUMBER ..... 0.307914  
ATOMIC NO. .. 26 CMESHc = 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.0

CHS ENERGY ... 2.00000 (MEV)  
LAB ENERGY ... 2.036024 (MEV) SEPARATION ENERGY ... 0.0 (MEV)

INCIDENT PARTICLE ..... NEUTRON

IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 ( L-S TERM )  
INTERNAL ..... SURFACE ABSORPTION ONLY  
SURFACE ..... GAUSS

POTENTIAL PARAMETER

FORM PARAMETER (FERMI)	WELL DEPTH PARAMETER (MEV)	
RO = 1.265	V = 46.00 WI = 0.0 WS = 14.00 VSO = 7.00 WS0 = 0.0 VSym = 0.0	
RI = 0.4	VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WS0E = 0.0 VCOUL = 0.0	
RC = 0.0	RS = 1.400	RS0 = 1.265 VESB = 0.0 WIESB = 0.0 WSES0B = 0.0 VSOESB = 0.0 WS0ESB = 0.0
AD = 0.620	AL = 0.0 VRE = 46.00 WIMI = 0.0 WIMS = 14.00 VSPD = 7.00 WSPO = 0.0 VSyMh = 0.0	
B = 0.500	ASD = 0.620	

BRANCHING RATIO

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LEVEL DENSITY PARAMETER

EC = 0.0	A = 0.0	SgM = 0.0	EPR = 0.0	NOM = 0.0
0.0	0.0	0.0	0.0	0.0

NO EXPERIMENTAL DATA

PROB. 3-4, F5E6=N: E=2.0 MEV + MOLDAUER THEORY PAGE 2

TOTAL CROSS SECTION ..... 3.1392E 03 (MILLI=BARN)  
SHAPE ELASTIC CROSS SECTION 1.8779E 03 (MILLI=BARN)  
REACTION CROSS SECTION ... 1.5814E 03 (MILLI=BARN)

ANGULAR DISTRIBUTION (DEGREES)

ANGLE	ELASTIC										
0.0	1.0146E 03	50.0	2.4263E 02	130.0	9.2677E 01	0.0	1.0915E 03	49.2	2.4439E 02	149.5	8.9820E 01
5.0	1.0019E 03	70.0	3.1392E 01	160.0	0.0199E 02	4.9	1.0382E 03	69.0	3.1791E 01	159.6	8.9767E 01
10.0	9.6453E 02	90.0	7.1669E 00	170.0	1.0938E 02	9.8	9.9907E 02	89.0	7.1704E 00	169.8	1.0554E 02
20.0	8.2657E 02	120.0	6.3292E 01	175.0	1.1150E 02	19.7	8.5483E 02	119.1	6.2106E 01	174.9	1.0759E 02
30.0	8.3304E 02	140.0	6.3554E 01	180.0	1.1225E 02	29.3	8.5530E 02	139.3	6.1281E 01	180.0	1.0822E 02

L 2=J T(+/-) 2=J T(-) L 2=J T(+/-) 2=J T(-) L 2=J T(+/-) 2=J T(-)

COMPOUND FORMATION PROBABILITY													
0	1	9.9852E-02	2	5	6.4963E-01	3	6.4738E-01	4	9	4.2623E-03	7	4.8373E-03	
1	3	1.0784E-01	1	1.3261E-01	3	7	2.8626E-02	5	8.4931E-03	9	1.7693E-04	9	5.3103E-03

LL B = COEFFICIENT (CM5:  
BL LL BL LL BL LL BL LL BL LL BL LL BL

0	1	4.944E 02	1	2.3253E 02	2	3.3928E 02	3	2.1466E 02	4	7.3760E 01	5	3.9228E 00	6	9.3447E 01	
7	6.7681E-02	8	6.6803E-03	9	2.2609E-04	10	2.2425E-05	11	0.0						

PROB. 3-4, F5E6=N: E=2.0 MEV + MOLDAUER THEORY PAGE 3

INELASTIC SCATTERING ..... INPUT DATA .....

TOTAL LEVELS ..... 2

\* GROUND STATE (N = N)

SPIN-PARITY ..... 0+

TARGET INCIDENT PMESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 5  
MASS ..... 56.00 PMESHc = 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 4  
MASS NO. .... 5 PMESH = 2.500E-01 (FERMI) WAVE NUMBER ..... 0.307914  
ATOMIC NO. .. 26 CMESHc = 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.0

CHS ENERGY ... 2.00000 (MEV)  
LAB ENERGY ... 2.036024 (MEV) SEPARATION ENERGY ... 0.0 (MEV)

INCIDENT PARTICLE ..... NEUTRON

IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 ( L-S TERM )  
INTERNAL ..... SURFACE ABSORPTION ONLY  
SURFACE ..... GAUSS

POTENTIAL PARAMETER

FORM PARAMETER (FERMI)	WELL DEPTH PARAMETER (MEV)	
RO = 1.265	V = 46.00 WI = 0.0 WS = 14.00 VSO = 7.00 WS0 = 0.0 VSym = 0.0	
RI = 0.4	VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WS0E = 0.0 VCOUL = 0.0	
RC = 0.0	RS = 1.400	RS0 = 1.265 VESB = 0.0 WIESB = 0.0 WSES0B = 0.0 VSOESB = 0.0 WS0ESB = 0.0
AD = 0.620	AL = 0.0 VRE = 46.00 WIMI = 0.0 WIMS = 14.00 VSPD = 7.00 WSPO = 0.0 VSyMh = 0.0	
B = 0.500	ASD = 0.620	

BRANCHING RATIO

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LEVEL DENSITY PARAMETER

EC = 0.0	A = 0.0	SgM = 0.0	EPR = 0.0	NOM = 0.0
0.0	0.0	0.0	0.0	0.0

Fig. 6 (2) continued

PROB. 3-4, FE56-N, E=2.0 MEV + MOLDAUER THEORY

PAGE 4

\*\*\* FIRST EXCITED STATE (N - N)

SPIN-PARITY ..... 0+  
EXCITATION ENERGY ..... 0.850000 (MEV)

POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

PROB. 3-4, FE56-N, E=2.0 MEV + MOLDAUER THEORY

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CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

MOLDAUER THEORY USED DEG. OF FREEDOM ... 1.00

GROUND STATE (N - N)

SPIN-PARITY ..... 0+

COMPUND ELASTIC SCATTERING CROSS SECTION ..... 1.206E 03 (MILLI-BARN)  
SHAPE ELASTIC SCATTERING CROSS SECTION ..... 1.877E 03 (MILLI-BARN)  
TOTAL ELASTIC SCATTERING CROSS SECTION ..... 3.083E 03 (MILLI-BARN)

## ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	(LAB)	ANGLE	CENTER OF MASS	(LAB)	ANGLE	CENTER OF MASS	(LAB)
0.0	1.0146E 03	2.2056E 02	0.0	1.2391E 03	2.2391E 02	0.0	1.2800E 03	2.2800E 02
3.0	1.0049E 03	2.1787E 02	3.0	1.2176E 03	2.2176E 02	3.0	1.2576E 03	2.2576E 02
6.0	9.8610E 02	2.1007E 02	6.0	1.1802E 03	2.1802E 02	6.0	1.2187E 03	2.2187E 02
10.0	8.4637E 02	1.9252E 02	10.0	1.0021E 03	1.9821E 02	10.0	1.0483E 03	1.9483E 02
20.0	6.3354E 02	1.4725E 02	20.0	7.8050E 02	1.5953E 02	20.0	8.5302E 02	1.5191E 02
30.0	6.3354E 02	1.4725E 02	30.0	7.8050E 02	1.5953E 02	30.0	8.5302E 02	1.5191E 02
50.0	2.4243E 02	8.9674E 01	50.0	3.3230E 02	49.2	2.4835E 02	1.7178E 01	3.4013E 02
70.0	3.1390E 01	6.9529E 01	70.0	1.0092E 02	69.0	3.1791E 01	7.0419E 01	1.0221E 02
90.0	7.1669E 00	6.8259E 01	90.0	7.5420E 01	89.0	7.1704E 00	6.8287E 01	7.5457E 01
120.0	6.3292E 01	7.5449E 01	120.0	1.3878E 02	119.1	6.2180E 01	7.4120E 02	1.3630E 02
140.0	8.3554E 00	1.1148E 02	140.0	1.9773E 02	139.3	8.1281E 01	1.1107E 02	1.9236E 02
160.0	9.2477E 01	1.4726E 02	160.0	2.3994E 02	149.5	8.9820E 01	1.4272E 02	2.3234E 02
180.0	1.0199E 02	1.8252E 02	180.0	2.6481E 02	159.6	9.8376E 01	1.7640E 02	2.7490E 02
190.0	1.0198E 02	2.1007E 02	190.0	3.1946E 02	159.8	1.0354E 02	2.0669E 02	3.1822E 02
195.0	1.1113E 02	2.1787E 02	195.0	3.2937E 02	174.9	1.0753E 02	2.1012E 02	3.1766E 02
200.0	1.1223E 02	2.2056E 02	200.0	3.3279E 02	180.0	1.0822E 02	2.1268E 02	3.2091E 02

B	Coefficient (CMS)	(LAB)	TRANSMISSION COEFFICIENT	T(0)	T(-)			
0	LL	BL-(S)	BL-(C)	BL-(T)	BL-(L)			
1	1.4949E 03	9.5957E 01	2.4540E -02	2.9340E 02	0	9.9052E -01	0.0	0.0
2	2.3293E 02	2.3293E 02	2.3293E 02	2.3293E 02	1	1.0784E -01	0.0	1.3261E 01
3	3.2292E 02	8.2638E 01	4.1101E 02	4.2687E 02	2	6.4963E -01	0.0	6.4730E -01
4	2.1466E 02	2.1466E 02	2.3011E 02	2.3011E 02	3	2.8026E 02	0.0	8.4931E 03
5	9.3228E 00	3.8528E 01	1.1229E 02	1.2337E 02	4	4.2623E 03	0.0	4.8375E 03
6	3.9549E 00	3.0200E 00	3.9549E 00	4.4043E 00	5	1.7693E 04	0.0	5.5105E 05
7	6.7681E -02	6.7681E -02	3.6283E -01	3.6283E -01				
8	4.6802E -03	3.8592E -01	3.9060E -01	4.0360E -01				
9	4.2609E -04	4.2609E -04	3.6457E -02	3.6457E -02				
10	2.2425E -05	1.7673E -02	1.7662E -02	1.8977E -02				

PROB. 3-4, FE56-N, E=2.0 MEV + MOLDAUER THEORY

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CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

MOLDAUER THEORY USED DEG. OF FREEDOM ... 1.00

FIRST EXCITED STATE (N - N)

EXCITATION ENERGY ..... 0.850000 (MEV)  
EMITTED ENERGY (CMS) ... 1.150000 (MEV)  
(LAB) ... 1.170713 (MEV)

SPIN-PARITY ..... 0+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.7199E 03 (MILLI-BARN)

TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 3.7541E 02 (MILLI-BARN)

## ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	(LAB)	ANGLE	CENTER OF MASS	(LAB)	ANGLE	CENTER OF MASS	(LAB)
0.0	6.2239E 01	120.0	2.4213E 01	0.0	6.5230E 01	118.8	6.3659E 01	118.8
3.0	5.2293E 02	140.0	3.1675E 01	4.0	6.4223E 01	139.1	5.3656E 01	139.1
10.0	5.2293E 02	150.0	4.1613E 01	9.8	6.4223E 01	149.5	4.3713E 01	149.5
20.0	5.2648E 02	160.0	5.2468E 01	19.5	5.2064E 01	159.5	5.0363E 01	159.5
30.0	4.5530E 02	170.0	5.9638E 01	29.3	4.5334E 01	169.8	5.6842E 01	169.8
50.0	2.8001E 01	175.0	6.1574E 01	49.0	2.8877E 01	174.9	5.8695E 01	174.9
70.0	2.2861E 02	180.0	6.2239E 01	68.7	2.3251E 01	180.0	5.9317E 01	180.0
90.0	2.2934E 01			88.6	2.2953E 01			

B	Coefficient (CMS)	(LAB)	TRANSMISSION COEFFICIENT	T(0)	T(-)
0	2.9874E 01	0	2.9874E 01	1	9.8863E -01
2	2.1613E 01	1	2.2139E 01	3	7.9872E -02
4	1.0466E 01	2	2.1615E 01	5	3.7964E -01
6	2.3576E -02	3	0.9996E -01	7	4.192E -03
8	2.9413E -02	4	1.0488E 01	9	6.2096E -04

INELASTIC CROSS SECTION ..... 3.7541E 02 (MILLI-BARN)

RUNNING TIME ..... 7.39 SEC.

Fig. 7 (1)

PROB. AT C(D-D N PA)				REACTION, E=1.856 MEV + H-F THEORY			
7	4	1	2	6	12	1	2 19 1
9	4	12.0	0.0		1.0	10.625	-1.850
	1	1.005			1.005	1.005	1.3
	6						
	11	0.9			0.42	0.9	
	16	122.0			14.0	9.0	
	24	-0.15					
	51		10.0		20.0	30.0	40.0
	56	50.0	60.0		70.0	80.0	90.0
	61	100.0	110.0		120.0	130.0	140.0
	66	150.0	160.0		170.0	180.0	
5	1			7	13	0	1
	1	13.0	0.0		0.5	10.5336	
	6	1.25			1.25	1.25	0.0
	11	0.65			0.65	0.65	
	16	45.0			7.0	8.0	
	37	-0.5					
3	2			6		1	
	2	0.0				7.5507	
	10	1.25					
	16	50.0					
1	2						
1	36	3.09	0.5				
1	36	3.68	-1.5				
'1	4						
6	36	3.85	2.5				
	1	1.0	0.0	5	10	2	4
	6	2.07			2.07	0.0	4.07
	11	0.55			0.3	0.0	
	16	80.0			4.0	0.0	
	24	0.0					
	36	0.0	3.0				

Fig 7 (2)

```

PROB. = C(L=0 N=0 A) REACTION E=1.856 MEV + HF THEORY PAGE 1
          TARGET INCIDENT PMESH= 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 4
MASS ... 14.00 P01A097 CMESH= 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 4
MASS ... 12 ? CMESH= 2.499E-01 (FERMI) WAVE NUMBER ..... 0.362128
ATOMIC NO. ... 6 1 CMESH= 2.497E-01 (FERMI) COULOMB PARAMETER (YETA) 0.983340

CMB ENERGY ... 1.584257 (MEV)
LAB ENERGY ... 1.856000 (MEV) SEPARATION ENERGY ... 10.2625 (MEV)

INCIDENT PARTICLE .... DEUTERON

IMMAGINARY POTENTIAL FORM NON-LUCAL PARAMETER = 0.0 L-S TERM >
INTERNAL ..... SURFACE ABSORPTION ONLY
SURFACE ..... DIFF. WOODS-SAXON

POTENTIAL PARAMETERS

FORM PARAMETER WELL DEPTH PARAMETER (MEV)
(FERMI) V = -122.00 W1 = 0.0 WS = 14.00 VSO = 9.0U WSO = 0.0 VSYM = 0.0
R0 = 1.00D V = 0.0 WIE = 0.0 WSE = 0.0 VSOE = -0.150 WSOE = 0.0 VCOULE = 0.0
R1 = 0.000 V = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOULE = 0.0
RC = 1.30U V = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOULE = 0.0
RS = 1.00S V = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOULE = 0.0
RSW = 1.00D VESW = 0.0 WIE50 = 0.0 WSE50 = 0.0 VSOESW = 0.0 WSOESW = 0.0 VCOULE = 0.0
AD = U.900 VRE = 122.00 WIMJ = 0.0 WIMS = 14.00 VSP0 = 8.76 WSP0 = 0.0 VSYPMM = 0.0
AI = U.000 VRE = 122.00 WIMJ = 0.0 WIMS = 14.00 VSP0 = 8.76 WSP0 = 0.0 VSYPMM = 0.0
B = U.42U ASW = U.900

BRANCHING RATIOS
0.u 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.b
0.u 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.u

LEVEL DENSITY PARAMETER
EL = -0.0 A = 0.0 SGM = 0.0 EPR = 0.0 NOM = 0.0
      0.0           0.0           0.0           0.0           0.0

```

REACTION CROSS SECTION ... 8.9971E 02 (MILLI-BARN)										PAGE	2	
ANGULAR DISTRIBUTION (DEGREE)												
ANGLE	ELASTIC	RUTHERFORD	CENTER	OF MASS	ANGLE	ELASTIC	RUTHERFORD	ANGLE	ELASTIC	LABORATORY	ANGLE	ELASTIC
5.0	5.1470E 00	1.0008E 00	100.0	2.1681E 01	4.0420E 01			4.3	7.0137E 06	90.3	2.1335E 01	
10.0	3.1932E 05	9.9393E-01	110.0	1.3947E 01	3.3995E 01			8.6	4.3484E 05	100.5	1.2915E 01	
20.0	1.7874E 04	8.7987E-01	120.0	1.2205E 01	3.7166E 01			17.2	2.4045E 04	111.0	1.0632E 01	
30.0	3.3275E 03	8.0384E-01	130.0	1.3042E 01	4.7636E 01			23.6	4.4005E 03	121.8	1.0705E 01	
40.0	1.3580E 03	8.5785E-01	140.0	1.4547E 01	5.0700E 01			34.5	1.4992E 02	132.9	1.1302E 01	
50.0	2.2154E 02	8.9840E-01	150.0	1.5840E 01	5.7452E 01			43.4	8.0700E 02	143.8	1.1822E 01	
60.0	3.2472E 02	9.4788E-01	160.0	1.6680E 01	8.5320E 01			54.4	3.5232E 02	156.1	1.2809E 01	
70.0	5.1594E 01	9.1573E-01	170.0	1.6498E 01	9.0418E 01			64.5		144.0	1.1837E 01	
80.0	8.0981E 01	9.4422E-01	180.0	1.7053E 01	9.2319E 01			70.9	8.9110E 01	160.0	1.1809E 01	
90.0	4.1040E 01	9.5343E-01						80.5	4.2747E 01			

L	T(+) T(0) T(-)	L	COMMUNICATIVE FORMATION PROBABILITY T(+) T(0) T(-)	L	T(+) T(0) T(-)
0	7.049E-01	2	1.7135E-01 1.3290E-01 3.0349E-01	4	2.4000E-04 2.0126E-04 3.9184E-05

Fig. 7 (2) continued

PRCB. 4: C(D,D N P A) REACTION, E=1.856 MEV + H-F THEORY  
 INELASTIC SCATTERING ..... INPUT DATA .....

TOTAL LEVEL: \*\*\*\*\* 7

\*\*\* GROUND STATE (D - D)  
 SPIN-PARTITY: \*\*\*\*\* 0+

TARGET	INCIDENT	PMESS = 2.500E-01 (FERMI)	MAXIMUM ANGULAR MOMENTUM	4
MASS .....	12 000 2-01A097	PMESSC = 2.500E-01 (FERMI)	CLASSICAL CUT-OFF MOMENTUM	4
MASS NO. ....	12	CMESS = 2.499E-01 (FERMI)	WAVE NUMBER .....	0.362128
ATOMIC NO. ....	6 1	CMESSC = 2.497E-01 (FERMI)	COULOMB PARAMETER (YETA)	0.984340

CMS ENERGY ... 1.859257 (MEV)  
 LAB ENERGY ... 1.856000 (MEV) SEPARATION ENERGY ... 10.2623 (MEV)

INCIDENT PARTICLE: \*\*\*\*\* DEUTERON  
 IMAGINARY POTENTIAL FORM  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... DIFF. WOODS-SAXON  
 NUM-LOCAL PARAMETER = 0.0      L-S TERM >

POTENTIAL PARAMETER  
 FORM PARAMETER      WELL DEPTH PARAMETER (MEV)  
 (FERMI)  
 RD = 1.000      V = 122.00      WI = 0.0      WS = 14.00      VSO = 9.00      WSO = 0.0      VSYM = 0.0  
 RI = 0.0      VE = 0.0      WIE = 0.0      WSE = 0.0      VSOE = -0.150      WSOE = 0.0      VCOUL = 0.0  
 RC = 1.000      VRE = 122.00      WIESO = 0.0      WSESO = 0.0      VSOESO = 0.0      WSOESO = 0.0  
 RS = 0.003      VESW = 0.0      WIESW = 0.0      WSESW = 0.0      VSOESW = 0.0      WSOESW = 0.0  
 RSO = 1.003      VSOE = 0.0      WIESOE = 0.0      WSESOE = 0.0      VSOESOE = 0.0      WSOESOE = 0.0  
 AD = 0.800      VSOESW = 0.0      WIESOE = 0.0      WSESOE = 0.0      VSOESOE = 0.0      WSOESOE = 0.0  
 AI = 0.0      VRE = 122.00      WIMI = 0.0      WIMS = 14.00      VSPD = 8.74      WSPD = 0.0      VSMM = 0.0  
 B = 0.420      ASO = 0.900

BRANCHING RATIO  
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0  
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0  
 0.0

LEVEL DENSITY PARAMETER  
 EC = 0.0      A = 0.0      SGH = 0.0      EPR = 0.0      NOM = 0.0

PRCB. 4: C(D,D N P A) REACTION, E=1.856 MEV + H-F THEORY  
 PAGE 4

\*\*\* GROUND STATE (D - N)  
 SPIN-PARTITY: \*\*\*\*\* 1/2-  
 EXCITATION ENERGY ... 0.0 (MEV)

TARGET	INCIDENT	PMESS = 2.500E-01 (FERMI)	MAXIMUM ANGULAR MOMENTUM	4
MASS .....	13 00 1-008665	PMESSC = 2.500E-01 (FERMI)	CLASSICAL CUT-OFF MOMENTUM	3
MASS NO. ....	13	CMESS = 2.495E-01 (FERMI)	WAVE NUMBER .....	0.242967
ATOMIC NO. ....	7 0	CMESSC = 0.0 (FERMI)	COULOMB PARAMETER (YETA)	0.0

CMS ENERGY ... 1.318157 (MEV)  
 LAB ENERGY ... 1.420432 (MEV) SEPARATION ENERGY ... 10.5336 (MEV)

EMITTED PARTICLE: \*\*\*\*\* NEUTRON  
 IMAGINARY POTENTIAL FORM  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... DIFF. WOODS-SAXON  
 NUM-LOCAL PARAMETER = 0.0      L-S TERM >

POTENTIAL PARAMETER  
 FORM PARAMETER      WELL DEPTH PARAMETER (MEV)  
 (FERMI)  
 RD = 1.250      V = 45.00      WI = 0.0      WS = 7.00      VSO = 8.00      WSO = 0.0      VSYM = 0.0  
 RI = 1.0      VE = 0.0      WIE = 0.0      WST = 0.0      VSOE = -0.150      WSOE = 0.0      VCOUL = 0.0  
 RC = 1.0      VRE = 45.00      WIESO = 0.0      WSESW = 0.0      VSOESW = 0.0      WSOESW = 0.0  
 RS = 1.250      VESW = 0.0      WIESOE = 0.0      WSESOE = 0.0      VSOESOE = 0.0      WSOESOE = 0.0  
 RSO = 1.250      VSOE = 0.0      WIESOE = 0.0      WSESOE = 0.0      VSOESOE = 0.0      WSOESOE = 0.0  
 AD = 0.650      VSOESW = 0.0      WIESOE = 0.0      WSESOE = 0.0      VSOESOE = 0.0      WSOESOE = 0.0  
 AI = 0.0      VRE = 45.00      WIMI = 0.0      WIMS = 7.00      VSPD = 7.80      WSPD = 0.0      VSMM = 0.0  
 B = 0.650      ASO = 0.650

BRANCHING RATIO  
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0  
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0  
 0.0

LEVEL DENSITY PARAMETER  
 EC = 0.0      A = 0.0      SGH = 0.0      EPR = 0.0      NOM = 0.0

Fig. 7 (2) continued

PROB. 4: C(1D N P A) REACTION: E=1.836 MEV + H-F THEORY PAGE 5

\*\*\* GROUND STATE (D - P)

SPIN-PARITY ..... 1/2- EXCITATION ENERGY .... 0.0 (MEV)

TARGET INCIDENT PNESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 5 MASS ..... 13.00 1.007277 PNESHc = 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 4 MASS NU. .... 13 1 CMESH = 2.517E-01 (FERMI) WAVE NUMBER ..... 0.438650 ATOMIC NO. ... 6 1 CMESHc = 2.498E-01 (FERMI) COULOMB PARAMETER (YETA) 0.440530

CHS ENERGY ... 0.301057 (MEV) LAB ENERGY ... 0.331315 (MEV) SEPARATION ENERGY ... 7.5507 (MEV)

EMITTED PARTICLE .... PROTON

IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 < L-S TERM >  
INTERNAL ..... SURFACE ABSORPTION ONLY  
SURFACE ..... DIFF: WOODS-SAXON

POTENTIAL PARAMETER

FORM PARAMETER WELL DEPTH PARAMETER (MEV)  
(FERMI)  
R0 = 1.250 V = 54.00 WI = 0.0 WS = 7.00 VSO = 8.00 WSO = 0.0 VSYM = 0.0  
RI = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = -0.150 WSOE = 0.0 VCoul = 0.0  
RC = 1.250 RS = 0.0 RSe = 0.0 WSES = 0.0 WSOES = 0.0 WSOESe = 0.0  
RSu = 1.250 RSeu = 0.0 WSESu = 0.0 WSOESu = 0.0 WSOESeu = 0.0  
AD = 0.650 A1 = 0.0 VRE = 54.00 WIMI = 0.0 WIMS = 7.00 VSP0 = 7.35 WSP0 = 0.0 VSYMh = 0.0  
A1 = 0.0 B = 0.650 ASu = 0.650

BRANCHING RATIO  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0

LEVEL DENSITY PARAMETER  
EC = V0 A = 0.0 SGM = 0.0 EPR = 0.0 NOM = 0.0

PROB. 4: C(1D N P A) REACTION: E=1.836 MEV + H-F THEORY PAGE 6

\*\*\* FIRST EXCITED STATE (D - P)

SPIN-PARITY ..... 1/2+ EXCITATION ENERGY .... 3.090000 (MEV)

POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

\*\*\* SECOND EXCITED STATE (D - P)

SPIN-PARITY ..... 3/2- EXCITATION ENERGY .... 3.680000 (MEV)

POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

\*\*\* THIRD EXCITED STATE (D - P)

SPIN-PARITY ..... 5/2- EXCITATION ENERGY .... 3.450000 (MEV)

POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

PROB. 4: C(1D N P A) REACTION: E=1.836 MEV + H-F THEORY PAGE 7

\*\*\* GROUND STATE (D - A)

SPIN-PARITY ..... 3- EXCITATION ENERGY .... 0.0 (MEV)

TARGET INCIDENT PNESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 4 MASS ..... 10.00 4.002392 PNESHc = 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 0 MASS NU. .... 10 4 CMESH = 2.495E-01 (FERMI) WAVE NUMBER ..... 0.180250 ATOMIC NO. ... 5 2 CMESHc = 2.512E-01 (FERMI) COULOMB PARAMETER (YETA) 0.453748

CHS ENERGY ... 0.288357 (MEV) LAB ENERGY ... 0.337762 (MEV) SEPARATION ENERGY ... 11.6324 (MEV)

EMITTED PARTICLE .... ALPHA-PARTICLE

IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 < L-S TERM >  
INTERNAL ..... SURFACE ABSORPTION ONLY  
SURFACE ..... DIFF: WOODS-SAXON

POTENTIAL PARAMETER

FORM PARAMETER WELL DEPTH PARAMETER (MEV)  
(FERMI)  
R0 = 2.070 V = 40.00 WI = 0.0 WS = 4.00 VSO = 0.0 WSO = 0.0 VSYM = 0.0  
RI = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCoul = 0.0  
RC = 2.070 RS = 0.0 RSe = 0.0 WSES = 0.0 WSOES = 0.0 WSOESe = 0.0  
RSu = 0.0 RSeu = 0.0 WSESu = 0.0 WSOESu = 0.0 WSOESeu = 0.0  
AD = 0.350 A1 = 0.0 VRE = 40.00 WIMI = 0.0 WIMS = 4.00 VSP0 = 0.0 WSP0 = 0.0 VSYMh = 0.0  
A1 = 0.0 B = 0.350 ASu = 0.0

BRANCHING RATIO  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0

LEVEL DENSITY PARAMETER  
EC = V0 A = 0.0 SGM = 0.0 EPR = 0.0 NOM = 0.0

( D - N ) CROSS SECTION ..... 1.7147E 02 (MILLI-BARN)

Fig. 7 (2) continued

Fig. 7 (2) continued

PROB. 4: C(D+D N P A) REACTION, E=1.856 MEV + H-F THEORY  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHMACH-WOLFENSTEIN THEORY USED  
 GROUND STATE (D - P)

EXCITATION ENERGY ..... 0.0 (MEV)  
 EMITTED ENERGY (CMS) ... 4.6310570 (MEV)  
 (LAB) ... 4.6310510 (MEV)  
 SPIN-PARTY ..... 1/2-

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 7.8074E 02 (MILLI-BARN)  
 TOTAL REACTION CROSS SECTION TO THIS LEVEL ..... 3.2642E 02 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

CENTER OF MASS			LABORATORY			
ANGLE	DIFF.C.S.	ANGLE	ANGLE	DIFF.C.S.	ANGLE	
5.0	3.4794E 01	100.0	2.2599E 01	4.7	3.9768E 01	96.0
10.0	3.4410E 01	110.0	2.2460E 01	9.7	3.7446E 01	106.2
20.0	3.2250E 01	120.0	2.1933E 01	18.7	3.1744E 01	116.4
30.0	3.0946E 01	130.0	2.6533E 01	28.1	3.4828E 01	126.8
40.0	2.8683E 01	140.0	2.8683E 01	37.6	3.1895E 01	137.3
50.0	2.6532E 01	150.0	3.0946E 01	47.1	2.7062E 01	147.9
60.0	2.4731E 01	160.0	3.2981E 01	56.7	2.6609E 01	158.5
70.0	2.3403E 01	170.0	3.4410E 01	66.4	2.4675E 01	169.3
80.0	2.2399E 01	180.0	3.4923E 01	76.1	2.3305E 01	180.0
90.0	2.2331E 01			86.0	2.2492E 01	

B = COEFFICIENT (CMS)  
 LL BL LL LAB TRANSMISSION COEFFICIENT  
 0 2.5974E 01 0 2.5974E 01 0 1 4.721E-01  
 2 7.9250E 00 1 3.3816E 00 1 3 6.3862E-01  
 4 9.3392E-01 2 8.0218E 00 2 3 3.4961E-01  
 6 6.0304E-02 3 1.2330E 00 3 7 4.3074E-02  
 8 1.6798E-03 4 1.0101E 00 4 9 1.9077E-03  
 1U 0.0 5 2.0782E-01 5 11 1.2274E-04 9 1.1676E-04

PROB. 4: C(D+D N P A) REACTION, E=1.856 MEV + H-F THEORY  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHMACH-WOLFENSTEIN THEORY USED  
 FIRST EXCITED STATE (D - P)

EXCITATION ENERGY ..... 3.0900000 (MEV)  
 EMITTED ENERGY (CMS) ... 1.2110570 (MEV)  
 (LAB) ... 1.3048931 (MEV)  
 SPIN-PARTY ..... 3/2+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 4.7075E 02 (MILLI-BARN)  
 TOTAL REACTION CROSS SECTION TO THIS LEVEL ..... 6.4393E 01 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

CENTER OF MASS			LABORATORY			
ANGLE	DIFF.C.S.	ANGLE	ANGLE	DIFF.C.S.	ANGLE	
5.0	5.4393E 00	100.0	4.8803E 00	4.4	7.4592E 00	92.5
10.0	5.4053E 00	110.0	4.9278E 00	8.8	7.3996E 00	102.7
20.0	5.6800E 00	120.0	5.0149E 00	17.1	7.1772E 00	113.1
30.0	5.3043E 00	130.0	5.1460E 00	26.6	6.8557E 00	123.8
40.0	5.2110E 00	140.0	5.1510E 00	35.6	6.4944E 00	134.7
50.0	5.1460E 00	150.0	5.3504E 00	44.7	6.1240E 00	145.8
60.0	5.0149E 00	160.0	5.6800E 00	53.9	5.7800E 00	157.1
70.0	4.9278E 00	170.0	5.8D33E 00	63.3	5.4988E 00	168.5
80.0	4.8803E 00	180.0	5.8509E 00	72.8	5.2259E 00	180.0
90.0	4.8653E 00			82.6	4.9906E 00	

B = COEFFICIENT (CMS)  
 LL BL LL LAB TRANSMISSION COEFFICIENT  
 0 5.1242E 00 0 5.1242E 00 0 1 5.8796E-01  
 2 6.0531E-01 1 1.3076E 00 1 3 6.3559E-02  
 4 1.1904E-01 2 6.7832E-01 2 5 1.3495E-02  
 6 2.1726E-03 3 1.6741E-01 3 7 1.6352E-04 5 1.1380E-04

PROB. 4: C(D+D N P A) REACTION, E=1.856 MEV + H-F THEORY  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHMACH-WOLFENSTEIN THEORY USED  
 SECOND EXCITED STATE (D - P)

EXCITATION ENERGY ..... 3.6800000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.6210570 (MEV)  
 (LAB) ... 0.6691782 (MEV)  
 SPIN-PARTY ..... 3/2-

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.3440E 02 (MILLI-BARN)  
 TOTAL REACTION CROSS SECTION TO THIS LEVEL ..... 3.6170E 01 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

CENTER OF MASS			LABORATORY			
ANGLE	DIFF.C.S.	ANGLE	ANGLE	DIFF.C.S.	ANGLE	
5.0	3.0300E 00	100.0	2.4181E 00	4.4	4.2330E 00	89.3
10.0	3.0257E 00	110.0	2.4331E 00	8.5	4.1232E 00	99.5
20.0	3.0257E 00	120.0	3.0257E 00	17.0	4.1133E 00	110.1
30.0	2.9675E 00	130.0	2.8888E 00	25.5	4.0138E 00	121.0
40.0	2.9266E 00	140.0	2.9266E 00	34.1	3.8623E 00	132.2
50.0	2.8888E 00	150.0	2.9637E 00	42.9	3.6910E 00	143.8
60.0	2.8588E 00	160.0	3.0000E 00	51.8	3.5092E 00	155.7
70.0	2.8351E 00	170.0	3.0237E 00	60.6	3.3270E 00	167.8
80.0	2.8142E 00	180.0	3.0324E 00	70.1	3.1374E 00	180.0
90.0	2.8142E 00			79.7	2.9358E 00	

B = COEFFICIENT (CMS)  
 LL BL LL LAB TRANSMISSION COEFFICIENT  
 0 2.8783E 00 0 2.8783E 00 0 1 1.8424E-01  
 2 1.3922E-01 1 1.0403E 00 1 3 6.7304E-03 1 6.2624E-03  
 4 1.4499E-02 2 2.2840E-01 2 5 6.1496E-04 3 3.8183E-04  
 6 3.2709E-05 3 5.6140E-02 3 7 5.0821E-06 5 3.6204E-06

Fig 7 (2) continued

PROB. 4: C(U-D N P A) REACTION: E=1.856 MEV + H-F THEORY  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHBACH-WOLFENSTEIN THEORY USED  
 THIRD EXCITED STATE (D - P)  
 EXCITATION ENERGY ..... 3.8500000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.4510570 (MEV)  
 (LAB) ... 0.4860061 (MEV)  
 SPIN-PARITY ..... 3/2+  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.1079E 04 (MILLI-BARN)  
 TOTAL REACTION CROSS SECTION TO THIS LEVEL ..... 2.3727E 01 (MILLI-BARN)  
 ANGULAR DISTRIBUTION (DEGREE)  
 \*\*\*\*\* CENTER OF MASS \*\*\*\*\*  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 5.0 1.9320E 00 100.0 1.8574E 00 4.1 2.0476E 00 87.7 1.8571E 00  
 10.0 1.9320E 00 110.0 1.8733E 00 8.2 2.0368E 00 97.6 1.7241E 00  
 20.0 1.9261E 00 120.0 1.8823E 00 16.5 2.7944E 00 108.3 1.5990E 00  
 30.0 1.9164E 00 130.0 1.8935E 00 24.6 2.7264E 00 119.2 1.4833E 00  
 40.0 1.9055E 00 140.0 1.9055E 00 33.3 2.6359E 00 130.7 1.3863E 00  
 50.0 1.8935E 00 150.0 1.9168E 00 41.8 2.5272E 00 142.5 1.3051E 00  
 60.0 1.8823E 00 160.0 1.9261E 00 50.5 2.4045E 00 154.8 1.2447E 00  
 70.0 1.8723E 00 170.0 1.9323E 00 59.4 2.2723E 00 167.5 1.2075E 00  
 80.0 1.8674E 00 180.0 1.9344E 00 68.5 2.1346E 00 180.0 1.1944E 00  
 90.0 1.8654E 00 77.0 1.9951E 00  
 B = COEFFICIENT (CMS)  
 LL BL LL BL L 2^J T(+) 2^J T(-)  
 0 1.8882E 00 0 1.0882E 00 0 1 6.5303E-02  
 2 4.5819E-02 1 8.0459E-01 1 3 1.7612E-03 1 1.6666E-03  
 4 4.0268E-04 2 1.2496E-01 2 5 1.6716E-04 3 7.6414E-05  
 (D - P) CROSS SECTION ..... 4.5071E 02 (MILLI-BARN)

PROB. 4: C(D-D N P A) REACTION: E=1.856 MEV + H-F THEORY  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHBACH-WOLFENSTEIN THEORY USED  
 GROUND STATE (D - A)  
 EXCITATION ENERGY ..... 0.0 (MEV)  
 EMITTED ENERGY (CMS) ... 0.2383570 (MEV)  
 (LAB) ... 0.3337616 (MEV)  
 SPIN-PARITY ..... 3+  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.3038E-05 (MILLI-BARN)  
 TOTAL REACTION CROSS SECTION TO THIS LEVEL ..... 3.7014E-07 (MILLI-BARN)  
 ANGULAR DISTRIBUTION (DEGREE)  
 \*\*\*\*\* CENTER OF MASS \*\*\*\*\*  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 5.0 4.1150E-08 100.0 2.4281E-08 3.0 1.1452E-07 63.3 3.6817E-08  
 10.0 4.0720E-08 110.0 2.5724E-08 6.0 1.1291E-07 70.6 3.2867E-08  
 20.0 3.9638E-08 120.0 2.7931E-08 12.0 1.0680E-07 78.9 2.8864E-08  
 30.0 3.6646E-08 130.0 3.0222E-08 18.0 9.7861E-08 85.0 2.4821E-08  
 40.0 3.3558E-08 140.0 3.3773E-08 24.1 8.6430E-08 91.6 1.9800E-08  
 50.0 3.0707E-08 150.0 3.6644E-08 30.3 7.5339E-08 111.3 1.3523E-08  
 60.0 2.7951E-08 160.0 3.9088E-08 36.5 6.4915E-08 128.3 8.7307E-09  
 70.0 2.5724E-08 170.0 4.0720E-08 42.9 5.5070E-08 151.2 5.5406E-09  
 80.0 2.4281E-08 180.0 4.1295E-08 49.4 4.7383E-08 180.0 4.5166E-09  
 90.0 2.3781E-08 56.2 4.1434E-08  
 B = COEFFICIENT (CMS)  
 LL BL LL BL L 2^J T(+) 2^J T(-)  
 0 2.9455E-08 0 2.9455E-08 0 0 3.5406E-10  
 2 1.1229E-08 1 3.7517E-08 1 2 3.7045E-10  
 4 2.7121E-10 2 1.6733E-08 2 4 1.6086E-11  
 6 4.5509E-11 3 1.2015E-08 3 6 1.9705E-12  
 8 2.6233E-13 4 9.8195E-09 4 8 1.9735E-14  
 (D - A) CROSS SECTION ..... 3.7014E-07 (MILLI-BARN)  
 RUNNING TIME .... 11.83 SEC.

Fig 8 (1)

```

2      PRCH: 5: AS75(N=N), E=1.0 MEV, EC=0.2U MLV
10     1      1      5      33    75    0      1      10      1
      1    74.92   5          0.5
      6    1.302   1.302   1.421   1.302
      11   0.62    0.62    0.30    0.62
      14   46.0    14.0    14.0    7.0
      21   -3.25   0.125   -0.2
      27   -3.0    -4
      37   -1.3
      41   0.2     8.72    -1.45
      51   0.0     10.0    30.0    60.0    90.0
      56   120.0   150.0   170.0   180.0   110.0
1      2      36    0.199   -0.5

```

Fig 8 (2)

```

PRCB. 5. AS75(N+N) * E=1.0 MEV * EC=0.20 MEV PAGE 1
                                         TARGET INCIDENT PMESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 4
MASS ..... 74.92 1.003865 PMESHc = 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 3
MASS NO. .... TD 1 CMESH = 2.513E-01 (FERMI) RAVE NUMBER .....** 0.218216
ATOMIC NO. ... 33 0 CMESHc = 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.0

CMS ENERGY *** 1.000000 (MEV)
LAB ENERGY *** 1.013463 (MEV) SEPARATION ENERGY *** 0.0 (MEV)

INCIDENT PARTICLE .... NEUTRON

IMAGINARY POTENTIAL FORM NNU-LOCAL PARAMETER = 0.0 ( L=5 TERM )
INTERNAL ..... Woods-Saxon
SURFACE ..... DIFF. Woods-Saxon

```

## POTENTIAL PARAMETERS

```

FORM PARAMETER      WELL DEPTH PARAMETER (INCHES)
(FORM#1)
RU = 1.302          V = 46.00        WI = 0.4        WS = 14.00        VSO = 7.00        WSO = 0.0        VSYM = 0.0
RJ = 1.302
RC = 0.0            VE = -0.250       WIE = 0.125       WSE = -0.200       VSOE = 0.0        WSOE = 0.0        VCOUL = 0.0
RSI = 1.421
RSUW = 0.302        VESW = 0.0        WIESW = -0.000       WSESQ = 0.0        VSOESW = 0.0        WSOESQ = 0.0
AU = 0.400
A1 = 0.624          VRE = 45.75       WIMI = 0.12        WIMS = 13.00        VSPD = 7.00        WSPD = 0.0        VSYMM = 0.0
B = 0.300
ASUW = 0.629

```

### **BRANCHING RATIO**

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

LEVEL DENSITY PARAMETER  
EC = 0.20

$\epsilon_0 = 0.20$     $\mu = 0.12$     $S_{GM} = 0.0$     $LFR = -1.5$     $NDF = 0.0$   
 $\epsilon_0 = 0.0$     $\mu = 0.0$     $S_{GM} = 0.0$     $LFR = 0.0$     $NDF = 0.0$

## NO EXPERIMENTAL DATA

PRCB. 5. AS75(N+N\*) , E=1.0 MEV , EC=0.20 MEV

PAGE 2

TOTAL CROSS SECTION ..... 4.4269E 03 (MILLI-BARN)  
SHAPE ELASTIC CROSS SECTION 2.4252E 03 (MILLI-BARN)  
REACTION CROSS SECTION ... 2.0017E 03 (MILLI-BARN)

**ANGULAR DISTRIBUTION (DEGREE)**

CENTER OF MASS				LABORATORY			
ANGLE	ELASTIC	ANGLE	ELASTIC	ANGLE	ELASTIC	ANGLE	ELASTIC
0.0	7.0702E 02	90.0	1.2426E 02	170.0	3.0223E 01	89.2	1.2424E 02
10.0	6.8603E 02	110.0	8.3505E 01	180.0	2.9562E 01	99.9	6.0435E 02
30.0	5.4462E 02	120.0	6.8460E 01			29.6	5.5436E 02
60.0	2.6677E 02	150.0	3.7183E 01			59.3	2.7043E 02

#### COMPOUND FORMATION PROBABILITY

L	2+J	T(+)	2+J	T(-)	L	2+J	T(+)	2+J	T(-)	L	2+J	T(+)	2+J	T(-)
0	1	5.1279E-01	1	-1.2594E-01	2	9	9.1208E-02	3	1.5737E-01	4	9	2.2304E-04	7	2.6532E-04

```

L B = COEFFICIENT (CMS)
          LL      BL      LL      BL      LL      DL      LL      BL      LL      DL      LL      BL
  0  1.9495E-02   1  2.6345E-02   2  1.3355E-02   3  7.4580E-03   4  2.1578E-02   5  6.9226E-01   6  1.7268E-01

```

Fig. 8 (2) continued

PROB. 5. AS75(N+N) \* E=1.0 MEV \* EC=0.20 MEV PAGE 3

INELASTIC SCATTERING ..... INPUT DATA .....

TOTAL LEVELS ..... 2

\*\*\* GROUND STATE (N = N)

SPIN-PARITY ..... 3/2-

MASS .....	TARGET	INCIDENT	PMESH = 2.500E-01 (FERMI)	MAXIMUM ANGULAR MOMENTUM	4
MASS NO. ....	74	92	PMSHC = 2.500E-01 (FERMI)	CLASSICAL CUT-OFF MOMENTUM	3
ATOMIC NO. ...	30	1	CMSHC = 2.513E-01 (FERMI)	WAVE NUMBER .....	0.218216
			CMSHCA = 0.0 (FERMI)	COULOMB PARAMETER (YETA)	0.0

CMS ENERGY ... 1.000000 (MEV)

LAD ENERGY ... 1.013463 (MEV) SEPARATION ENERGY ... 0.0 (MEV)

INCIDENT PARTICLE ..... NEUTRON

IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 ( L=5 TERM )

INTERNAL ..... WOODS-SAXON

SURFACE ..... DIFF-WOODS-SAXON

POTENTIAL PARAMETERS

FORM PARAMETER	WELL DEPTH PARAMETER (MEV)					
(FERMI)						
R0 = 1.302	V = 46.00	W1 = 0.0	W5 = 14.00	VSO = 7.00	WSO = 0.0	VSYM = 0.0
R1 = 1.304				VSOE = 0.0	WSOE = 0.0	VCOUL = 0.0
R2 = 1.306	VE = -0.250	WIE = 0.125	WSE = -0.200			
R3 = 1.421				VSOEB = 0.0	WSOEB = 0.0	
R5O = 1.302	VESS = 0.0	WIESB = -0.000	WSES = 0.0			
A0 = 0.620				VSOESB = 0.0	WSOESB = 0.0	
A1 = 0.620	VRE = 45.75	WIMI = 0.12	WIMS = 13.80	VSP0 = 7.00	WSPO = 0.0	VSYMWW = 0.0
B = 0.300						
ASO = V+6.0						

BRANCHING RATIO

0-U	0.0														
0-U	0.0														
0-U	0.0														

LEVEL DENSITY PARAMETER

EC = 0.20	A = 8.72	SGM = 0.0	EPR = 1.45	NOM = 0.0
U,0	0.0	0.0	0.0	0.0

PROB. 5. AS75(N+N) \* E=1.0 MEV \* EC=0.20 MEV PAGE 4

\*\*\* FIRST EXCITED STATE (N = N)

SPIN-PARITY ..... 1/2+

EXCITATION ENERGY ..... 0.199000 (MEV)

POTENTIAL FORM AND PARAMETER ..... SAME AS BEFORE

PROB. 5. AS75(N+N) \* E=1.0 MEV \* EC=0.20 MEV PAGE 5

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

HAUSER-FESHBACH-WOLFENSTEIN THEORY USED

GROUND STATE (N = N)

SPIN-PARITY ..... 3/2-

COMPOUND ELASTIC SCATTERING CROSS SECTION .....	9.9495E 02 (HILLI-BARN)
SHAPE ELASTIC SCATTERING CROSS SECTION .....	2.4222E 03 (HILLI-BARN)
TOTAL ELASTIC SCATTERING CROSS SECTION .....	3.4202E 03 (HILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)	ANGLE	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)
0.0	7.0702E U2	1.0000E 02	8.0707E 02	0.0	7.2618E 02	1.0277E 02	8.2895E 02	
10.0	6.8603E 02	9.8879E 01	7.8491E 02	9.9	7.0435E 02	1.0152E 02	8.0387E 02	
20.0	5.4242E 02	9.1068E 01	6.4242E 02	29.6	5.5635E 02	9.5206E 02	6.4745E 02	
40.0	2.6571E 02	7.4303E 01	3.4533E 02	59.3	2.6730E 02	7.4303E 02	3.4533E 02	
80.0	1.2424E 02	6.9874E 01	1.9413E 02	89.2	1.2424E 02	6.9893E 01	1.9413E 02	
110.0	0.3587E 01	7.3019E 01	1.5661E 02	109.3	0.3587E 01	7.2365E 01	1.5520E 02	
120.0	6.8460E 01	7.6563E 01	1.4502E 02	119.3	6.7555E 01	7.5555E 01	1.4311E 02	
150.0	3.7183E 01	9.1064E 01	1.2825E 02	149.6	3.6322E 01	8.8959E 01	1.2528E 02	
170.0	3.0223E 01	9.8879E 01	1.2910E 02	169.9	2.9427E 01	9.6275E 01	1.2570E 02	
180.0	2.9562E 01	1.0000E 02	1.2962E 02	180.0	2.8772E 01	9.7379E 01	1.2612E 02	

B = COEFFICIENT (CM<sup>5</sup>)

LL	BL-(S)	BL-(C)	BL-(T)	LAB	BL-(L)	TRANSMISSION COEFFICIENT		
0	1.9299E 02	7.9176E 01	2.7217E 02	2.7217E 02	0	5.1279E-01	0.0	0.0
1	2.6345E 02	2.6345E 02	2.6982E 02	2.6982E 02	1	6.3709E-01	0.0	4.8734E-01
<	1.5355E 01	1.9237E 01	1.7278E 02	1.7902E 02	2	9.1508E-02	0.0	1.5717E-01
>	7.4598E 01	7.4598E 01	7.9792E 01	7.9792E 01	3	3.0640E-02	0.0	1.5750E-02
>	2.1578E 01	1.2075E 00	2.2186E 01	2.2186E 01	4	2.2308E-04	0.0	2.8532E-04
>	6.9259E-01	6.0845E-01	7.9468E 00	7.9468E 00				
>	6.1058E-01	4.3543E-01	6.0845E-01	6.6467E-01				
>	4.3733E-03	4.3733E-03	4.0643E-02	4.0643E-02				
>	-1.0225E-03	1.0446E-07	-1.0121E-05	1.0375E-03				

Fig. 8 (2) continued

PRCB. 5+ ASTD(N+N) + E=1.0 MEV + EC=0.20 MEV PAGE 6

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

HAUSER-FESHbach-WOLFENSTEIN THEORY USED

FIRST EXCITED STATE (N - N)

EXCITATION ENERGY .....	0.1990000 (MEV)
EMITTED ENERGY (CMS) ...	0.8010000 (MEV)
(LAB) ...	0.8117840 (MEV)
SPIN-PARITY .....	1/2+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) .....	2.0640E 03 (MILLI-BARN)
TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL .....	3.5248E 02 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	ANGLE	DIFF-C.S.	ANGLE	DIFF-C.S.	ANGLE	DIFF-C.S.
0.0	2.8529E 01	110.0	2.7935E 01	0.0	2.9188E 01	109.2	2.6539E 01
10.0	2.8529E 01	120.0	2.7935E 01	9.9	2.9188E 01	119.2	2.7531E 01
30.0	2.8527E 01	130.0	2.8273E 01	29.6	2.9187E 01	149.6	2.7540E 01
60.0	2.7943E 01	170.0	2.8334E 01	59.3	2.8312E 01	169.8	2.7501E 01
90.0	2.7948E 01	180.0	2.8329E 01	89.1	2.7998E 01	180.0	2.7483E 01

B - COEFFICIENT (CMS)	LL	LAB	TRANSMISSION COEFFICIENT	L	2*J	T(+)	2*J	T(-)
BL	BL	BL						
0	2.8030E 01	0	2.8030E 01	0	1	4.8586E-01		
2	2.8204E-01	1	8.4220E-01	1	3	5.5449E-01	1	4.1269E-01
4	1.1339E-01	2	2.8811E-01	2	5	6.4024E-02	3	1.1291E-01
6	-1.1797E-01	3	7.6710E-03	3	7	1.4679E-02	5	7.3490E-03
8	-2.9413E-08	4	1.1525E-01	4	9	0.4189E-05	7	1.1834E-04

\*INELASTIC CROSS SECTION ..... 3.5248E 02 (MILLI-BARN)

PRCB. 5+ ASTD(N+N) + E=1.0 MEV + EC=0.20 MEV PAGE 7

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

HAUSER-FESHbach-WOLFENSTEIN THEORY USED

SECOND EXCITED STATE (N - N)

EXCITATION ENERGY .....	0.2000000 (MEV)
EMITTED ENERGY (CMS) ...	0.8000000 (MEV)
(LAB) ...	0.8107706 (MEV)

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) .....	2.0643E 03 (MILLI-BARN)
TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL .....	1.1246E 03 (MILLI-BARN/MEV)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	ANGLE	DIFF-C.S.	ANGLE	DIFF-C.S.	ANGLE	DIFF-C.S.
0.0	8.9494E 01	110.0	8.9494E 01	0.0	9.2208E 01	109.2	8.6020E 01
10.0	8.9494E 01	120.0	8.9494E 01	9.9	9.2168E 01	119.2	8.8175E 01
30.0	8.9494E 01	130.0	8.9494E 01	29.6	9.1820E 01	149.6	8.7185E 01
60.0	8.9494E 01	170.0	8.9494E 01	59.3	9.0886E 01	169.8	8.6661E 01
90.0	8.9494E 01	180.0	8.9494E 01	89.1	8.9524E 01	180.0	8.6620E 01

B - COEFFICIENT (CMS)	LL	LAB	TRANSMISSION COEFFICIENT	L	2*J	T(+)	2*J	T(-)
BL	BL	BL						
0	8.9494E 01	0	8.9494E 01	0	1	4.4550E-01		
2	0.0	1	2.6492E 00	1	3	2.5402E-01	1	4.1228E-01
4	0.0	2	2.0278E-02	2	5	6.3868E-02	3	1.1219E-01
6	0.0	3	3.7717E-06	3	7	1.1481E-02	5	7.3184E-03
8	0.0	4	-3.2168E-05	4	9	0.3736E-05	7	1.1772E-04

PRCB. 5+ ASTD(N+N) + E=1.0 MEV + EC=0.20 MEV PAGE 8

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

HAUSER-FESHbach-WOLFENSTEIN THEORY USED

THIRD EXCITED STATE (N - N)

EXCITATION ENERGY .....	0.3520000 (MEV)
EMITTED ENERGY (CMS) ...	0.4448200 (MEV)
(LAB) ...	0.6494272 (MEV)

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) .....	2.1211E 03 (MILLI-BARN)
TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL .....	1.1012E 03 (MILLI-BARN/MEV)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	ANGLE	DIFF-C.S.	ANGLE	DIFF-C.S.	ANGLE	DIFF-C.S.
0.0	8.7630E 01	110.0	8.7630E 01	0.0	9.0507E 01	109.1	8.6190E 01
10.0	8.7630E 01	120.0	8.7630E 01	9.8	9.0558E 01	119.2	8.7109E 01
30.0	8.7630E 01	130.0	8.7630E 01	29.5	9.0211E 01	149.5	8.7109E 01
60.0	8.7630E 01	170.0	8.7630E 01	59.2	8.9138E 01	169.8	8.4752E 01
90.0	8.7630E 01	180.0	8.7630E 01	89.0	8.7667E 01	180.0	8.4707E 01

B - COEFFICIENT (CMS)	LL	LAB	TRANSMISSION COEFFICIENT	L	2*J	T(+)	2*J	T(-)
BL	BL	BL						
0	8.7630E 01	0	8.7630E 01	0	1	4.5691E-01		
2	0.0	1	2.1976E 00	1	3	4.7042E-01	1	3.4177E-01
4	0.0	2	2.4788E-02	2	5	4.3088E-02	3	7.6882E-02
6	0.0	3	3.8598E-06	3	7	6.9172E-03	5	3.4702E-03
8	0.0	4	-3.1980E-05	4	9	3.1458E-05	7	4.7803E-05

Fig 8 (2) continued

PROB. 5: ASTD(N+N) + E=1.0 MEV + EC=0.20 MEV  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHMACH-WOLFENSTEIN THEORY USED  
 4-TH EXCITED STATE (N - N)  
 EXCITATION ENERGY .... 0.518E000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.4816E000 (MEV)  
 (LAB) ... 0.4880E039 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.1830E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 1.0127E 03 (MILLI-BARN/MEV)

PAGE 9

ANGULAR DISTRIBUTION (DEGREE)				CENTER OF MASS				LABORATORY			
ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.				
0.0	8.0591E 01	110.0	8.0592E 01	0.0	8.3749E 01	108.9	7.9515E 01				
10.0	8.0591E 01	120.0	8.0591E 01	9.8	8.3702E 01	119.0	7.9070E 01				
30.0	8.0591E 01	150.0	8.0593E 01	29.3	8.3334E 01	149.4	7.7913E 01				
60.0	8.0591E 01	170.0	8.0591E 01	59.0	8.2197E 01	269.8	7.7543E 01				
90.0	8.0591E 01	180.0	8.0591E 01	88.9	8.0637E 01	180.0	7.7495E 01				

B = COEFFICIENT (CMS)				TRANSMISSION COEFFICIENT				LABORATORY			
LL	BL	LL	BL	L	2*J	T(<)	2*J	T(<)	2*J	T(<)	
0	8.0591E 01	0	8.0591E 01	0	1	4.1928E-01					
2	0.0	1	3.1270E 00	1	3	3.6772E-01	1	2.6051E-01			
4	0.0	2	3.0334E-02	2	5	2.4794E-02	3	4.4833E-02			
6	0.0	3	4.7219E-06	3	7	2.6119E-03	5	1.3152E-03			
8	0.0	4	-3.1635E-05	4	9	0.0	7	0.0			

PROB. 5: ASTD(N+N) + E=1.0 MEV + EC=0.20 MEV  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHMACH-WOLFENSTEIN THEORY USED  
 5-TH EXCITED STATE (N - N)  
 EXCITATION ENERGY .... 0.677E000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.4224E000 (MEV)  
 (LAB) ... 0.3261E005 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.2483E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 8.3010E 02 (MILLI-BARN/MEV)

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ANGULAR DISTRIBUTION (DEGREE)				CENTER OF MASS				LABORATORY			
ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.	ANGLE	DIFF-C,S.				
0.0	6.6058E 01	110.0	6.6058E 01	0.0	6.9227E 01	108.7	6.4542E 01				
10.0	6.6058E 01	120.0	6.6058E 01	9.8	6.9125E 01	118.8	6.4542E 01				
30.0	6.6058E 01	150.0	6.6058E 01	29.3	6.8812E 01	149.3	6.3388E 01				
60.0	6.6058E 01	170.0	6.6058E 01	59.8	6.7675E 01	169.8	6.3010E 01				
90.0	6.6058E 01	180.0	6.6058E 01	88.6	6.6113E 01	180.0	6.2962E 01				

B = COEFFICIENT (CMS)				TRANSMISSION COEFFICIENT				LABORATORY			
LL	BL	LL	BL	L	2*J	T(<)	2*J	T(<)	2*J	T(<)	
0	6.6138E 01	0	6.6058E 01	0	1	3.6640E-01					
2	0.0	1	3.1326E 00	1	3	2.4440E-01	1	1.6894E-01			
4	0.0	2	3.7142E-02	2	5	1.0862E-02	3	1.9458E-02			
6	0.0	3	1.7309E-06	3	7	6.3556E-04	5	3.3226E-04			
8	0.0	4	-2.9813E-05	4	9	0.0	7	0.0			

Fig. 8 (2) continued

PROB. 5, AST3(N+N) \* E=1.0 MEV \* EC=0.20 MEV PAGE 11  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED  
 6-TH EXCITED STATE (N = N)  
 EXCITATION ENERGY ..... 0.0368000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.1652000 (MEV)  
 (LAB) ... 0.1655972 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.3702E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 5.2622E 02 (MILLI-BARN/MEV)  
 ANGULAR DISTRIBUTION (DEGREE)  
 CENTER OF MASS .....  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 0° 4.1875E 01 100.0 4.1875E 01 0.0 4.4731E 01 108.2 4.0988E 01  
 10.0 4.1875E 01 120.0 4.1875E 01 9.7 4.4671E 01 118.3 4.0564E 01  
 30.0 4.1875E 01 150.0 4.1875E 01 29.1 4.4345E 01 149.0 3.9511E 01  
 60.0 4.1875E 01 170.0 4.1875E 01 58.4 4.3335E 01 169.7 3.9131E 01  
 90.0 4.1875E 01 180.0 4.1875E 01 88.1 4.1955E 01 180.0 3.9131E 01  
 B - COEFFICIENT (CMS)  
 LL BL LL BL TRANSMISSION COEFFICIENT  
 L 2\*J T(<) 2\*J T(>)  
 0 4.1875E 01 0 4.1875E 01 0 1 2.4346E 01  
 2 0.0 1 2.7911E 00 1 3 1.0733E 01 1 7.2752E 02  
 4 0.0 2 4.6518E 02 2 5 2.2672E 03 3 4.1541E 03  
 6 0.0 3 3.7762E 06 3 7 6.1987E 05 5 3.1546E 05  
 8 0.0 4 -2.1364E 05 4 9 0.0 7 0.0

PROB. 5, AS/2(N+N) \* E=1.0 MEV \* EC=0.20 MEV PAGE 12  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED  
 7-TH EXCITED STATE (N = N)  
 EXCITATION ENERGY ..... 0.0960000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.0040000 (MEV)  
 (LAB) ... 0.0040538 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 8.8201E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 5.6948E 01 (MILLI-BARN/MEV)  
 ANGULAR DISTRIBUTION (DEGREE)  
 CENTER OF MASS .....  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 0° 4.5318E 00 110.0 4.5318E 00 0.0 6.6466E 00 7.8 4.1711E 00  
 10.0 4.5318E 00 120.0 4.5318E 00 8.2 6.6403E 00 108.3 3.8919E 00  
 30.0 4.5318E 00 150.0 4.5318E 00 24.9 6.4338E 00 142.6 3.0922E 00  
 60.0 4.5318E 00 170.0 4.5318E 00 50.3 5.7604E 00 167.3 2.8402E 00  
 90.0 4.5318E 00 180.0 4.5318E 00 78.0 4.8433E 00 180.0 2.8077E 00  
 B - COEFFICIENT (CMS)  
 LL BL LL BL TRANSMISSION COEFFICIENT  
 L 2\*J T(<) 2\*J T(>)  
 0 4.5318E 00 0 4.5318E 00 0 1 5.2198E 02  
 2 0.0 1 1.9294E 00 1 3 4.9246E 04 1 3.3303E 04  
 4 0.0 2 2.0571E 01 2 5 0.0 3 0.0  
 6 0.0 3 5.1246E 07 3 7 0.0 5 0.0  
 8 0.0 4 -1.3647E 03 4 9 0.0 7 0.0  
 INELASTIC CROSS SECTION ..... 6.5426E 02 (MILLI-BARN)  
 RUNNING TIME ..... 11.41 SEC.

Fig. 9 (1)

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      PROB. 6.FE56(N+N,P) , E=3.2MEV + EC=2.1 MEV
      1   1   1   26   56   1   10   1
      1   36+0   0.5   7.646   3.2
      1   1-27   1.4   1.28
      6   0.62   0.95   2.62
      16  4.0   9.0   7.0
      41  2.1   6.8   3.1
      46  3.5   6.8   1.94
      51  10.0   20.0   30.0   60.0   90.0
      56  120.0   150.0   160.0   170.0   180.0
      1   2
      36  0.847   2.0
      3   2   1   25   1
      2   0.0
      10  1.25
      36  0.0   3.0
      1   2
      36  0.026   2.0
      3   1   3
      2   0.0
      10  0.0
      36  2.085   4.0

```

Fig. 9 (2)

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PRCB, 6.FE56(N+N,P) , E=3.2MEV + EC=2.1 MEV PAGE 1
TARGET  INCIDENT PMESH = 2.500E-01 (FERMI) MAX(MUM ANGULAR MOMENTUM 3
MASS ..... 56.00 1.008665 PMESHG= 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 5
MASS NO. .... 56 1 CMESH = 2.449E-01 (FERMI) WAVE NUMBER ..... 0.389483,
ATOMIC NO. ... 26 0 CMESHG= 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.0
CHS ENERGY ... 3.200000 (MEV)
LAB ENERGY ... 3.257638 (MEV) SEPARATION ENERGY ... 7.6460 (MEV)
INCIDENT PARTICLE ..... NEUTRON
IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 < L-S TERM >
INTERNAL ..... SURFACE ABSORPTION ONLY
SURFACE ..... GAUSS
POTENTIAL PARAMETERS
FORM PARAMETER WELL DEPTH PARAMETER (MEV)
(FERMI) V W1 WS VSO WSO VSYM
RD = 2.70 V = 46.00 W1 = 0.0 WS = 9.00 VSO = 7.00 WSO = 0.0 VSYM = 0.0
RI = 0.0
RC = 0.0 VE = 0.0 W1E = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOUL = 0.0
RS = 1.400 RSO = 1.240 VESW = 0.0 WIESW = 0.0 WSESW = 0.0 VSOESW = 0.0 WSOESW = 0.0
AQ = 0.420 AI = 0.50 VRE = 46.00 W1M1 = 0.0 W1MS = 9.00 VSPD = 7.00 WSPD = 0.0 VSYMM = 0.0
A1 = 0.50 B = 0.550 ASO = 0.620
BRANCHING RATIO
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0
LEVEL DENSITY PARAMETER
EC = 2.10 A = 6.80 SGH= 3.10 EPR= 1.54 NOM= 0.0
3.50
NO EXPERIMENTAL DATA

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PAGE 2

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PROB. 6.FE56(N+N,P) , E=3.2MEV + EC=2.1 MEV
TOTAL CROSS SECTION ..... 3.7299E 03 (MILLI-BARN)
SHAPE ELASTIC CROSS SECTION 2.1464E 03 (MILLI-BARN)
REACTION CROSS SECTION ... 1.2835E 03 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)
ANGLE ELASTIC CENTER OF MASS ANGLE ELASTIC ANGLE ELASTIC LABORATORY ANGLE ELASTIC
ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC
10.0 1.5230E 03 90.0 4.7057E 01 170.0 4.2943E 01 9.0 1.5776E 03 69.0 4.7080E 01 169.0 4.1433E 01
20.0 1.2599E 03 129.0 6.4731E 01 180.0 4.6326E 01 16.7 1.3030E 03 119.1 8.3243E 01 180.0 4.4662E 01
30.0 9.0572E 02 150.0 3.4034E 01 180.0 4.6326E 01 29.3 9.3420E 02 149.3 3.2987E 01
40.0 8.7133E 01 160.0 3.6221E 01 180.0 4.6326E 01 39.1 8.8742E 02 159.6 3.5008E 01

```

L	2J	T(+)	2J	T(-)	L	2J	T(+)	2J	T(-)	L	2J	T(+)	2J	T(-)
0	1	$9.1159E-01$	1	$1.2134E-01$	2	3	$7.1482E-03$	3	$9.7774E-01$	4	5	$1.1301E-02$	7	$4.4123E-02$
1	3	$1.2134E-01$	1	$1.1406E-01$	3	7	$1.1593E-03$	3	$5.4713E-02$	5	11	$2.2513E-03$	9	$5.2622E-03$

B = COEFFICIENT (CM5)

LL	BL												
0	$1.9468E-02$	1	$3.5592E-02$	2	$4.3721E-02$	3	$4.0898E-02$	4	$1.9474E-02$	5	$2.0470E-01$	6	$6.7740E-02$
T	$1.4602E-02$	8	$8.3558E-02$	9	$3.0619E-02$	10	$1.9794E-03$	11	0.0				

Fig. 9 (2) continued

PROB. 6\*FE56(N,N=0,P) + E=3.2MEV + EC=2.1 MEV PAGE 3  
 INELASTIC SCATTERING ..... INPUT DATA .....  
 TOTAL LEVELS ..... 5  
 \*\* GROUND STATE ( N = N )  
 SPIN=PARITY ..... 0+  
 TARGET INCIDENT PMESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 5  
 MASS ..... 56.00 1.008665 PMESHc= 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 5  
 MASS NO. .... 56 1 CMESH = 2.494E-01 (FERMI) WAVE NUMBER ..... 0.389483  
 ATOMIC NO. ... 26 0 CMESHc= 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.0  
 CMS ENERGY \*\*\* 3.200000 (MEV)  
 LAB ENERGY \*\*\* 3.257463 (MEV) SEPARATION ENERGY ... 7.6460 (MEV)  
 INCIDENT PARTICLE .... NEUTRON  
 IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 < L-S TERM  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... GAUSS  
 POTENTIAL PARAMETER  
 FORM PARAMETER WELL DEPTH PARAMETER (MEV)  
 (FERMI) (FERMI)  
 R0 = 1.270 V = 46.00 WI = 0.0 WS = 9.00 VSO = 7.00 WSO = 0.0 VSym = 0.0  
 RI = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOUL = 0.0  
 RC = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOUL = 0.0  
 RS = 1.400 VESw= 0.0 WIEsw= 0.0 WSEsw= 0.0 VSOEsW= 0.0 WSOEsW= 0.0  
 AO = 0.620 VRE = 46.00 WIMI = 0.0 WIMS = 9.00 VSPD = 7.00 WSPD = 0.0 VSymH = 0.0  
 AI = 0.620 VRE = 46.00 WIMI = 0.0 WIMS = 9.00 VSPD = 7.00 WSPD = 0.0 VSymH = 0.0  
 B = 0.550 ASO = 0.620  
 BRANCHING RATIO  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 U.U  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 U.U  
 0.0  
 LEVEL DENSITY PARAMETER  
 EC = 2.10 A = 6.80 SGM= 3.10 EPR= 1.54 NOM= 0.0 PAGE 4  
 3.50 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 U.U

PROB. 6\*FE56(N,N=0,P) + E=3.2MEV + EC=2.1 MEV PAGE 5  
 \*\* FIRST EXCITED STATE ( N = N )  
 SPIN=PARITY ..... 2+  
 EXCITATION ENERGY .... 0.847000 (MEV)  
 POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE  
 PROB. 6\*FE56(N,N=0,P) + E=3.2MEV + EC=2.1 MEV PAGE 5  
 \*\* GROUND STATE ( N = P )  
 SPIN=PARITY ..... 3+  
 EXCITATION ENERGY .... 0.0 (MEV)  
 TARGET INCIDENT PMESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 3  
 MASS ..... 56.00 1.007277 PMESHc= 2.500E-01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 0  
 MASS NO. .... 56 1 CMESH = 2.495E-02 (FERMI) WAVE NUMBER ..... 0.113461  
 ATOMIC NO. ... 25 1 CMESHc= 2.486E-01 (FERMI) COULOMB PARAMETER (YETA) 7.380221  
 CMS ENERGY \*\*\* 0.281800 (MEV)  
 LAB ENERGY \*\*\* 0.286665 (MEV) SEPARATION ENERGY ... 10.5644 (MEV)  
 EMITTED PARTICLE .... PROTON  
 IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 < L-S TERM  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... GAUSS  
 POTENTIAL PARAMETER  
 FORM PARAMETER WELL DEPTH PARAMETER (MEV)  
 (FERMI) (FERMI)  
 R0 = 1.270 V = 46.00 WI = 0.0 WS = 9.00 VSO = 7.00 WSO = 0.0 VSym = 0.0  
 RI = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOUL = 0.0  
 RC = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCOUL = 0.0  
 RS = 1.400 VESw= 0.0 WIEsw= 0.0 WSEsw= 0.0 VSOEsW= 0.0 WSOEsW= 0.0  
 AO = 0.620 VRE = 46.00 WIMI = 0.0 WIMS = 9.00 VSPD = 7.00 WSPD = 0.0 VSymH = 0.0  
 AI = 0.620 VRE = 46.00 WIMI = 0.0 WIMS = 9.00 VSPD = 7.00 WSPD = 0.0 VSymH = 0.0  
 B = 0.550 ASO = 0.620  
 BRANCHING RATIO  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 U.U  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 U.U  
 0.0  
 LEVEL DENSITY PARAMETER  
 EC = 2.10 A = 6.80 SGM= 3.10 EPR= 1.54 NOM= 0.0

Fig. 9 (2) continued

PRCB, 6,FE56(N+N+P) + E=3.2MEV + EC=2.1 MEV

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## \*\*\* FIRST EXCITED STATE (N - P)

SPIN-PARITY ..... 2+  
 EXCITATION ENERGY ..... 0.026000 (MEV)  
 POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

PRCB, 6,FE56(N+N+P) + E=3.2MEV + EC=2.1 MEV

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## \*\*\* SECOND EXCITED STATE (N - N)

SPIN-PARITY ..... 4+  
 EXCITATION ENERGY ..... 2.085000 (MEV)

MASS .....	TARGET	INCIDENT	FMESH = 2.500E-01 (FERMI)	MAXIMUM ANGULAR MOMENTUM	4
MASS NO. ....	26.00	1.0C8665	FMESHC = 2.500E-01 (FERMI)	CLASSICAL CUT-OFF MOMENTUM	3
ATOMIC NO. ...	25	1	CMESSH = 2.576E-01 (FERMI)	WAVE NUMBER .....	0.229906
CHS ENERGY ...	1.112000 (MEV)		CMESH = 0.0 (FERMI)	COULOMB PARAMETER (YETA)	0.0

LAB ENERGY ...	1.135083 (MEV)		SEPARATION ENERGY ...	T.6460 (MEV)
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EMITTED PARTICLE ..... NEUTRON

IMAGINARY POTENTIAL FORM	INTERNAL ..... SURFACE ABSORPTION ONLY	NON-LOCAL PARAMETER = 0.0	L=5 TERM	3
SURFACE .....	GAUSS			

## POTENTIAL PARAMETER

FORM PARAMETER	WELL DEPTH PARAMETER (MEV)	(FERMI)				
R0 = 1.270	V = 46.00	W1 = 0.0	WS = 9.00	VSO = 7.00	WSO = 0.0	VSYM = 0.0
R1 = 0.0			WSE = 0.0	VSOE = 0.0	WSOE = 0.0	VCOUL = 0.0
RC = 0.0	VE = 0.0	WIE = 0.0	VSSE = 0.0	VSOESE = 0.0	WSOESO = 0.0	
RS = 1.400			VSSESE = 0.0	VSOCSE = 0.0	WSOESO = 0.0	
R50 = 1.260	VESW = 0.0	WIESW = 0.0	VSOCSE = 0.0	VSOCSE = 0.0	WSOESW = 0.0	
A0 = 0.620			VSPO = 7.00	NSPC = 0.0	VSYMHH = 0.0	
A1 = 0.0	VRE = 46.00	WIM1 = 0.0	VSPO = 7.00	NSPC = 0.0	VSYMHH = 0.0	
B = 0.350						
ASD = 0.620						

## BRANCHING RATIO

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

## LEVEL DENSITY PARAMETER

EC = 2.10	A = 6.80	SGM = 3.10	EPR = 1.54	NOM = 0.0
3.30	0.0	0.0	0.0	0.0

PRCB, 6,FE56(N+N+P) + E=3.2MEV + EC=2.1 MEV

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## CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

## HAUSEN-FESMBACH-WOLFENSTEIN THEORY USED

## GROUND STATE (N - N)

SPIN-PARITY ..... 0+

COMPOUND ELASTIC SCATTERING CROSS SECTION .....	1.9084E 02	(MILLI-BARN)
SHAPE ELASTIC SCATTERING CROSS SECTION .....	2.4464E 03	(MILLI-BARN)
TOTAL ELASTIC SCATTERING CROSS SECTION .....	2.6373E 03	(MILLI-BARN)

## ANGULAR DISTRIBUTION (DEGREE)

ANGLE .....	CENTER OF MASS .....	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)	ANGLE .....	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)
10.0	1.5730E 03	3.2200E 01	1.3593E 03	9.8	1.5774E 03	3.2352E 01	1.4610E 03	
20.0	1.2897E 03	2.7694E 01	1.2775E 03	19.7	1.3030E 03	2.8802E 01	1.3334E 03	
30.0	9.0572E 02	2.4210E 01	9.2795E 02	29.5	9.3430E 02	2.2912E 01	9.5721E 02	
40.0	8.7133E 01	1.2717E 01	9.9851E 01	59.1	8.8742E 01	1.2492E 01	1.0164E 02	
50.0	4.7057E 01	1.0605E 01	5.7663E 01	89.0	4.7080E 01	1.0610E 01	5.7691E 01	
60.0	8.4731E 01	1.2717E 01	9.7449E 01	119.1	8.5243E 01	1.2494E 01	9.5737E 01	
70.0	3.4036E 01	2.2211E 01	3.6247E 01	149.5	3.2974E 01	2.3526E 01	5.4513E 01	
80.0	3.6221E 01	2.7656E 01	6.3678E 01	159.6	3.5008E 01	2.6730E 01	6.1737E 01	
90.0	4.2945E 01	3.2200E 01	7.5143E 01	169.8	4.1435E 01	3.1069E 01	7.2502E 01	
100.0	4.6316E 01	3.3983E 01	8.0299E 01	180.0	4.4662E 01	3.2770E 01	7.7432E 01	

## B = COEFFICIENT (CMS)

LL	BL- (S)	BL- (C)	BL- (T)	BL ~ (L)	(LAB)	TRANSMISSION COEFFICIENT	T(+) T(0) T(-)	
0	1.9464E 02	1.5187E 01	2.0987E 02	2.0987E 02	0	9.1153E 01	0.0	0.0
1	3.5592E 02	3.5592E 02	3.6021E 02					
2	4.3711E 02	1.2017E 01	4.4913E 02	4.5535E 02	1	1.2136E 01	0.0	1.1406E-01
3	4.0895E 02		4.0899E 02	4.2339E 02				
4	1.9464E 02	5.1523E 00	1.9989E 02	2.1421E 02	2	7.1802E 01	0.0	9.7776E-01
5	2.4070E 02		2.4070E 02	2.5774E 01				
6	6.7740E 00	1.6182E 00	1.3922E 00	1.0061E 01	3	1.1995E 01	0.0	3.4713E-02
7	3.4620E 00		2.5862E 00	2.5223E 00				
8	8.3538E-02	5.4603E-03	8.9018E-02	2.3765E-01	4	1.1301E-02	0.0	4.4123E-02
9	3.0619E-02		3.0619E-02	4.4043E-02				
10	1.8794E-03	2.8353E-03	4.8347E-03	8.1419E-03	5	2.2513E-05	0.0	5.2622E-04

Fig. 9 (2) continued

PRCB, 6+Fe56(N+N+P) + E=3.2MEV + EC=2.1 MEV PAGE 9

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

HAUSER-FESHbach-WOLFENSTEIN THEORY USED

FIRST EXCITED STATE (N - N)

EXCITATION ENERGY ..... 0.8470000 (MEV)  
 EMITTED ENERGY (CMS) ... 2.3530000 (MEV)  
       (LAB) ... 2.3953819 (MEV)  
 SPIN-PARITY ..... 2+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.5266E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 4.619E 02 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.
10.0	5.4*89E 01	120.0	3.7278E 01	9.8	3.2931E 01	116.9	3.6517E 01
20.0	3.5575E 01	150.0	3.6403E 01	19.6	3.2788E 01	149.4	3.5097E 01
30.0	3.6703E 01	180.0	3.6448E 01	29.4	3.7715E 01	169.6	3.6999E 01
60.0	3.7276E 01	170.0	3.4489E 01	59.0	3.8089E 01	169.8	3.1077E 01
90.0	3.6353E 01	180.0	3.4139E 01	86.8	3.6377E 01	180.0	3.2720E 01

B = COEFFICIENT (CMS)

LL	BL	LL	BL	L	2J	T(=)	2J	T(=)
v	3.6725E 01	0	3.6725E 01	0	1	9.4573E-01		
1	-5.3424E 00	1	1.3424E 00	1	3	9.0446E-02	1	1.0000E-01
2	-1.0046E 01	2	-1.1206E 01	2	5	7.1722E-01	3	8.7293E-01
3	-1.7141E-01	3	2.4593E-02	3	7	4.0750E-02	5	1.2401E-02
4	-6.0728E-04	4	-1.4628E 00	4	9	5.3524E-03	7	1.0088E-02
1v	-2.7408E-05	5	-1.2223E-01	5	11	3.9048E-04	9	1.0314E-04

PRCB, 6+Fe56(N+N+P) + E=3.2MEV + EC=2.1 MEV PAGE 10

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

HAUSER-FESHbach-WOLFENSTEIN THEORY USED

GROUND STATE (N - P)

EXCITATION ENERGY ..... 0.0 (MEV)  
 EMITTED ENERGY (CMS) ... 0.2816001 (MEV)  
       (LAB) ... 0.2866652 (MEV)  
 SPIN-PARITY ..... 3+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.6427E-11 (MILLI-BARN)  
 TOTAL REACTION CROSS SECTION TO THIS LEVEL ..... 1.5120E-12 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.
10.0	1.0756E-13	120.0	1.2194E-13	9.4	1.2081E-13	116.9	1.1521E-13
20.0	1.0292E-13	150.0	1.1195E-13	18.9	1.2217E-13	148.2	1.0064E-13
30.0	1.1495E-13	180.0	1.0929E-13	28.3	1.2421E-13	158.7	9.7250E-14
60.0	1.2199E-13	170.0	1.0756E-13	57.1	1.3001E-13	169.4	9.5104E-14
90.0	1.2702E-13	180.0	1.0690E-13	86.5	1.2772E-13	180.0	9.4574E-14

B = COEFFICIENT (CMS)

LL	BL	LL	BL	L	2J	T(=)	2J	T(=)
0	1.2032E-13	0	1.2032E-13	0	1	2.8923E-16		
2	-1.3391E-14	1	1.4925E-14	1	3	2.5898E-15	1	1.3700E-15
4	1.7034E-17	2	-1.2870E-14	2	5	2.7458E-17	3	1.5505E-17
6	1.0982E-17	3	1.1949E-15	3	7	1.7929E-18	5	3.8106E-18

PRCB, 6+Fe56(N+N+P) + E=3.2MEV + EC=2.1 MEV PAGE 11

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

HAUSER-FESHbach-WOLFENSTEIN THEORY USED

FIRST EXCITED STATE (N - P)

EXCITATION ENERGY ..... 0.0260000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.2556001 (MEV)  
       (LAB) ... 0.2601976 (MEV)  
 SPIN-PARITY ..... 2+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.7942E-12 (MILLI-BARN)  
 TOTAL REACTION CROSS SECTION TO THIS LEVEL ..... 1.6422E-13 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE	CENTER OF MASS	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.
10.0	1.4594E-14	120.0	1.2870E-14	9.4	1.6485E-14	116.7	1.2122E-14
20.0	1.4144E-14	150.0	1.4073E-14	18.8	1.6173E-14	148.1	1.1522E-14
30.0	1.4473E-14	180.0	1.4339E-14	28.3	1.5690E-14	158.7	1.12729E-14
60.0	1.2470E-14	170.0	1.4394E-14	56.9	1.3762E-14	169.3	1.12824E-14
90.0	1.2261E-14	180.0	1.4665E-14	86.4	1.2335E-14	180.0	1.12657E-14

B = COEFFICIENT (CMS)

LL	BL	LL	BL	L	2J	T(=)	2J	T(=)
0	1.3048E-14	0	1.3048E-14	0	1	2.8585E-17		
2	1.6082E-15	1	1.6238E-15	1	3	2.5744E-16	1	1.3584E-16
4	-1.0349E-17	2	1.6209E-15	2	5	2.7106E-18	3	1.5318E-18
6	-7.4072E-19	3	2.4591E-16	3	7	1.7894E-19	5	3.6907E-19

(N - P) CROSS SECTION ..... 1.6762E-12 (MILLI-BARN)

Fig. 9 (2) continued

PROB. 6+FE56(N,N+,P) + E=3.2MEV + EC=2+1 MEV  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED

SECOND EXCITED STATE (N = N)

EXCITATION ENERGY ..... 2.0850000 (MEV)  
 EMITTED ENERGY (CMS) ... 1.1150000 (MEV)  
 (LAB) ... 1.1350833 (MEV)  
 SPIN-PARITY ..... ++

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.9212E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 1.2385E 02 (MILLI-BARN)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE			CENTER OF MASS			ANGLE			LABORATORY		
	DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE
10.0	8.6631E 00	120.0	1.0040E 01	9.7	9.2132E 00	118.5	9.7467E 00				
20.0	8.0202E 00	130.0	9.4255E 00	19.4	9.4255E 00	149.1	8.7296E 00				
30.0	9.2048E 00	140.0	8.9024E 00	29.1	9.7024E 00	159.4	8.4008E 00				
40.0	1.0040E 01	170.0	8.6831E 00	59.3	1.0359E 01	169.7	8.1695E 00				
90.0	1.0303E 01	180.0	8.4028E 00	88.3	1.0318E 01	180.0	8.0858E 00				

B - COEFFICIENT (CMS)

LL	BL	LL	BL	L	2*J	T(<)	2*J	T(>)
0	9.8539E 00	0	9.8539E 00	0	1	9.5153E-01		
2	-1.0385E 00	1	6.1412E-01	1	3	6.3097E-02	1	8.4077E-02
4	-2.0200E-01	2	-1.0282E 00	2	5	4.4661E-01	3	3.0724E-02
6	-1.2287E-02	3	-6.7818E-02	3	7	2.9929E-03	5	9.8130E-04
8	-2.4491E-03	4	-2.0356E-01	4	9	4.9171E-04	7	3.1837E-04

INELASTIC CROSS SECTION ..... 5.6536E 02 (MILLI-BARN)

PROB. 6+FE56(N,N+,P) + E=3.2MEV + EC=2+1 MEV  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED

THIRD EXCITED STATE (N = N)

EXCITATION ENERGY ..... 2.1000000 (MEV)  
 EMITTED ENERGY (CMS) ... 1.1000000 (MEV)  
 (LAB) ... 1.1198130 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.9226E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 5.3922E 02 (MILLI-BARN/MEV)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE			CENTER OF MASS			ANGLE			LABORATORY		
	DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE
10.0	4.3654E 01	120.0	4.2812E 01	9.7	4.6337E 01	118.5	4.1552E 01				
20.0	4.3551E 01	150.0	4.3395E 01	19.4	4.6109E 01	149.1	4.1132E 01				
30.0	4.3399E 01	180.0	4.3351E 01	29.1	4.5750E 01	159.4	4.1080E 01				
40.0	4.2412E 01	170.0	4.3654E 01	59.3	4.4182E 01	169.7	4.1054E 01				
90.0	4.2523E 01	180.0	4.3689E 01	88.2	4.2533E 01	180.0	4.1046E 01				

B - COEFFICIENT (CMS)

LL	BL	LL	BL	L	2*J	T(<)	2*J	T(>)
0	4.2910E 01	0	4.2910E 01	0	1	9.9553E-01		
2	7.7620E-01	1	2.8269E 00	1	3	6.2508E-02	1	8.3492E-02
4	3.4778E-03	2	8.1555E-01	2	5	5.5727E-01	3	2.9879E-01
6	5.5210E-07	3	5.7048E-02	3	7	5.8543E-03	5	9.3720E-04
8	7.2520E-10	4	5.3284E-03	4	9	4.6824E-04	7	2.9935E-04

PROB. 6+FE56(N,N+,P) + E=3.2MEV + EC=2+1 MEV  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED

4-TH EXCITED STATE (N = N)

EXCITATION ENERGY ..... 2.4791459 (MEV)  
 EMITTED ENERGY (CMS) ... 0.7208940 (MEV)  
 (LAB) ... 0.7359380 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 1.7935E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 5.0989E 02 (MILLI-BARN/MEV)

ANGULAR DISTRIBUTION (DEGREE)

ANGLE			CENTER OF MASS			ANGLE			LABORATORY		
	DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE		DIFF.C.S.	ANGLE
10.0	4.0232E 01	120.0	4.0508E 01	9.6	4.4223E 01	118.3	3.9093E 01				
20.0	4.2020E 01	150.0	4.0912E 01	19.3	4.4911E 01	148.9	3.9471E 01				
30.0	4.5912E 01	180.0	4.1023E 01	28.4	4.3448E 01	159.2	3.8157E 01				
40.0	4.0508E 01	170.0	4.0426E 01	59.2	4.2124E 01	169.6	3.8080E 01				
90.0	4.0308E 01	180.0	4.1114E 01	87.8	4.0395E 01	180.0	3.8055E 01				

B - COEFFICIENT (CMS)

LL	BL	LL	BL	L	2*J	T(<)	2*J	T(>)
0	4.0274E 01	0	4.0274E 01	0	1	9.7903E-01		
2	5.3781E-01	1	3.0734E 00	1	3	4.2216E-02	1	6.4244E-02
4	8.4430E-02	2	5.7505E-02	2	5	2.3912E-02	3	1.2530E-02
6	1.4108E-07	3	4.8408E-02	3	7	6.5034E-04	5	2.1301E-04
8	2.0122E-10	4	4.3886E-03	4	9	9.4473E-05	7	4.3958E-05

Fig. 9 (2) continued

PRCB. 6,FF56(N,N+,P) + E=3.2MEV + EC=2.1 MEV PAGE 15  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED  
 5-TH EXCITED STATE (N = N)  
 EXCITATION ENERGY .... 2.7191427 (MEV)  
 EMITTED ENERGY (CMS) ... 0.4806573 (MEV)  
 (LAB) ... 0.4895184 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.0360E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 4.6188E 02 (MILLI-BARN/MEV)  
 ANGULAR DISTRIBUTION (DEGREE)  
 \*\*\*\*\* CENTER OF MASS \*\*\*\*\*  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 30.0 3.7391E 01 120.0 3.6878E 01 9.6 4.0676E 01 117.6 3.5274E 01  
 20.0 3.7133E 01 130.0 3.7095E 01 19.1 4.0482E 01 148.6 3.4199E 01  
 30.0 3.7095E 01 160.0 3.7135E 01 28.7 4.0170E 01 159.0 3.3993E 01  
 60.0 3.6678E 01 170.0 3.7191E 01 57.7 3.4701E 01 169.5 3.3869E 01  
 90.0 3.6770E 01 180.0 3.7204E 01 87.3 3.4890E 01 180.0 3.3827E 01  
 B - COEFFICIENT (CMS) (LAB) TRANSMISSION COEFFICIENT  
 LL BL LL BL L 2^J T(+) 2^J T(-)  
 0 3.6914E 01 0 3.6914E 01 0 1 9.1421E-01  
 2 2.8856E-01 1 3.4251E 01 1 3 3.1250E-02 1 4.4329E-02  
 4 1.2882E-03 2 3.6731E-01 2 5 1.0405E-01 3 4.2916E-02  
 6 2.6048E-08 3 3.2046E-02 3 7 1.5777E-04 5 5.6140E-03  
 8 0.0 4 2.8394E-03 4 9 0.0 7 0.0

PRCB. 6,FE56(N,N+,P) + E=3.2MEV + EC=2.1 MEV PAGE 16  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED  
 6-TH EXCITED STATE (N = N)  
 EXCITATION ENERGY .... 2.9042900 (MEV)  
 EMITTED ENERGY (CMS) ... 0.2957100 (MEV)  
 (LAB) ... 0.3016963 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 2.5443E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 4.4299E 02 (MILLI-BARN/MEV)  
 ANGULAR DISTRIBUTION (DEGREE)  
 \*\*\*\*\* CENTER OF MASS \*\*\*\*\*  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 10.0 3.4322E 01 120.0 3.4397E 01 9.4 3.6449E 01 117.0 3.2336E 01  
 20.0 3.4304E 02 130.0 3.4329E 01 18.7 3.4252E 01 148.2 3.0900E 01  
 30.0 3.4304E 02 140.0 3.4300E 01 28.4 3.4257E 01 158.8 3.0814E 01  
 60.0 3.4397E 01 170.0 3.4322E 01 57.1 3.6389E 01 167.4 3.0434E 01  
 90.0 3.4393E 01 180.0 3.4327E 01 86.6 3.4335E 01 180.0 3.0379E 01  
 B - COEFFICIENT (CMS) (LAB) TRANSMISSION COEFFICIENT  
 LL BL LL BL L 2^J T(+) 2^J T(-)  
 0 3.4212E 01 0 3.4212E 01 0 1 9.4312E-01  
 2 1.2447E-02 1 4.0525E 00 1 3 1.4670E-02 1 2.4723E-02  
 4 4.8301E-04 2 2.3621E-01 2 5 3.3463E-02 3 1.2754E-02  
 6 5.5589E-09 3 1.6227E-02 3 7 2.8010E-03 5 1.0415E-03  
 8 0.0 4 1.4380E-03 4 9 0.0 7 0.0

Fig. 9 (2) continued

PROB. 6+FE56(N+N,P) + E=3.2MEV + EC=2.1 MEV PAGE 17  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED  
 T=TH EXCITED STATE (N = N)  
 EXCITATION ENERGY .... 3.0591717 (MEV)  
 EMITTED ENERGY (CMS) ... 0.1453583 (MEV)  
 (LAB) ... 0.1453546 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 4.1729E 03 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 3.9191E 02 (MILLI-BARN/MEV)  
 ANGULAR DISTRIBUTION (DEGREE)  
 \*\*\*\*\* CENTER OF MASS \*\*\*\*\*  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 10.0 3.1212E 01 120.0 3.1184E 01 9.2 3.6723E 01 113.6 2.8823E 01  
 20.0 3.1202E 01 140.0 3.1202E 01 18.4 3.6488E 01 147.3 2.6822E 01  
 30.0 3.1205E 01 160.0 3.1208E 01 27.7 3.6102E 01 158.2 2.6416E 01  
 40.0 3.1184E 01 170.0 3.1212E 01 55.9 3.4176E 01 169.1 2.6167E 01  
 90.0 3.1175E 01 180.0 3.1213E 01 85.1 3.3520E 01 180.0 2.6083E 01  
 B - COEFFICIENT (CMS)  
 LL BL LL BL TRANSMISSION COEFFICIENT  
 L 2\*J T(<+) 2\*J T(>)  
 0 3.1187E 01 0 3.1187E 01 0 1 8.3943E 01  
 2 2.5292E 02 1 3.3546E 00 1 3 7.5452E 03 1 1.2036E 02  
 4 8.8594E 03 2 2.5515E 01 2 5 7.4122E 03 3 1.9870E 03  
 6 0.0 3 5.1725E 03 3 7 0.0 5 0.0  
 8 0.0 4 3.0755E 04 4 9 0.0 7 0.0

PROB. 6+FE56(N+N,P) + E=3.2MEV + EC=2.1 MEV PAGE 18  
 CALCULATED DATA OF COMPOUND NUCLEAR PROCESS  
 HAUSER-FESHbach-WOLFENSTEIN THEORY USED  
 B=TH EXCITED STATE (N = N)  
 EXCITATION ENERGY .... 3.1945000 (MEV)  
 EMITTED ENERGY (CMS) ... 0.0055000 (MEV)  
 (LAB) ... 0.0055990 (MEV)  
 COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 3.4897E 04 (MILLI-BARN)  
 TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 1.4454E 02 (MILLI-BARN/MEV)  
 ANGULAR DISTRIBUTION (DEGREE)  
 \*\*\*\*\* CENTER OF MASS \*\*\*\*\*  
 ANGLE DIFF.C.S. ANGLE DIFF.C.S. ANGLE DIFF.C.S.  
 10.0 1.1502E 01 120.0 1.1502E 01 7.0 2.3549E 01 94.3 9.6235E 00  
 20.0 1.1502E 01 140.0 1.1502E 01 14.0 2.3174E 01 130.8 5.1235E 00  
 30.0 1.1502E 01 160.0 1.1502E 01 21.0 2.2802E 01 145.9 4.4149E 00  
 60.0 1.1502E 01 170.0 1.1502E 01 42.4 1.9842E 01 162.5 3.8638E 00  
 90.0 1.1502E 01 180.0 1.1502E 01 66.9 1.4908E 01 180.0 3.6788E 00  
 B - COEFFICIENT (CMS)  
 LL BL LL BL TRANSMISSION COEFFICIENT  
 L 2\*J T(<+) 2\*J T(>)  
 0 1.1502E 01 0 1.1502E 01 0 1 2.8935E 01  
 2 7.5841E 05 1 9.9947E 00 1 3 7.1661E 03 1 1.1869E 04  
 4 0.0 2 2.2388E 00 2 5 0.0 3 0.0  
 6 0.0 3 6.9105E 05 3 7 0.0 5 0.0  
 8 0.0 4 -6.5287E 02 4 9 0.0 7 0.0  
 INELASTIC CROSS SECTION ..... 5.0726E 02 (MILLI-BARN)  
 RUNNING TIME .... 32.22 SEC.

Fig 10 (1)

```

      3   10    PROB. 7: U238-N: E=250 KEV + AUTOMATIC PARAMETER SEARCH
      8   1     1   2   92   238   1   9   -1   30   10
      1   238.05   0.45   -0.25
      6   1.32   * 1.32   1.32
     11   0.47   * 0.47   0.47
     14* 42.00   9.00   15.00
     51   0.85   0.67   0.43   0.20   0.0
     56   -0.05   -0.32   -0.35   -0.46
     93 1255.00 1035.00 891.00 665.00 571.00
     96 373.00 456.00 437.00 437.00
      1   2
      36   0.0477  2.0
      1   3
      36   0.148   4.0

```

Fig 10 (2)

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PROB. 7: U238-N: E=250 KEV + AUTOMATIC PARAMETER SEARCH PAGE 1
INELASTIC SCATTERING ..... INPUT DATA .....
TOTAL LEVELS ..... 3
*** GROUND STATE (N - N)
SPIN-PARITY ..... 0+
TARGET INCIDENT PHESH = 2.500E+01 (FERMI) MAXIMUM ANGULAR MOMENTUM 3
MASS NO.: 238 1 PMESHc = 2.500E+01 (FERMI) CLASSICAL CUT-OFF MOMENTUM 2
ATOMIC NO.: 92 0 CMESH = 2.487E+01 (FERMI) WAVE NUMBER ..... 0.109376
CMS ENERGY ... 0.248945 (MEV) CMESHc = 0.0 (FERMI) COULOMB PARAMETER (YETA) ... 0.0
LAB ENERGY ... 0.250000 (MEV) SEPARATION ENERGY ... 0.0 (MEV)
INCIDENT PARTICLE ..... NEUTRON
IMAGINARY POTENTIAL FORM NON-LOCAL PARAMETER = 0.0 ( L-S TERM ) 0
INTERNAL ..... SURFACE ABSORPTION ONLY
SURFACE ..... DIFF., WOODS-SAXON
POTENTIAL PARAMETER
FORM PARAMETER WELL DEPTH PARAMETER (MEV)
(FERMI)
R0 = 1.920 V = 42.00 WI = 0.0 WS = 9.00 VSO = 15.00 NSO = 0.0 VS0M = 0.0
R1 = 0.0 VE = 0.0 WIE = 0.0 WSE = 0.0 VSQE = 0.0 NSOE = 0.0 VC0ULE = 0.0
RC = 0.0 VSE = 0.0 WIEg = 0.0 WSEg = 0.0 VSQESg = 0.0 NSOESg = 0.0
RS = 1.320 VSEg = 0.0 WIEg = 0.0 WSEg = 0.0 VSQESg = 0.0 NSOESg = 0.0
RS0 = 1.320 VSE = 0.0 WIE = 0.0 WSE = 0.0 VSQE = 0.0 NSQE = 0.0 VS0M = 0.0
A0 = 0.470 VRE = 42.00 WIg = 0.0 WIm = 9.00 VSPO = 15.00 NSPO = 0.0 VSYM = 0.0
A1 = 0.0 VRE = 0.0 WIg = 0.0 WIm = 0.0 VSPO = 0.0 NSPO = 0.0 VSYM = 0.0
B = 0.470 AS0 = 0.470
AS0 = 0.470
BRANCHING RATIO
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0
LEVEL DENSITY PARAMETER
EC = 0.0 A = 0.0 SGK = 0.0 EPR = 0.0 NOM = 0.0 PAGE 2
PROB. 7: U238-N: E=250 KEV + AUTOMATIC PARAMETER SEARCH
*** FIRST EXCITED STATE (N - N)
SPIN-PARITY ..... 2+
EXCITATION ENERGY ..... 0.047700 (MEV)
POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE
*** SECOND EXCITED STATE (N - N)
SPIN-PARITY ..... 4+
EXCITATION ENERGY ..... 0.148000 (MEV)
POTENTIAL FORM AND PARAMETER .... SAME AS BEFORE

```

Fig 10 (2) continued

PROB. 7: U238-N: E=250 KEV + AUTOMATIC PARAMETER SEARCH

PAGE 3

NO. OF ITERATION ... 1  
 REFERENCE VALUES OF CHI-SQUARES AT ... 0.0 0.06768 0.09536 CHI-SQ. AT ... 0.03775  
 CHI-SQUARES 1.623E 01 1.426E 01 1.759E 01 1.623E 01  
 SHAPE OF CHI-SQUARE-CURVE ... CONCAVE  
 SOLUTIONS OF NORMAL EQUATION  
 PARAMETERS ESTIMATED -9.072E-01 4.928E-01 5.497E 00  
 8 1.309 -0.0191 13 0.4886 0.0186 16 42.2076 0.2076

NO. OF ITERATION ... 2  
 REFERENCE VALUES OF CHI-SQUARES AT ... 0.0 0.10000 0.20000 CHI-SQ. AT ... 0.11864  
 CHI-SQUARES 1.623E 01 1.497E 01 1.555E 01 1.496E 01  
 SHAPE OF CHI-SQUARE-CURVE ... CONCAVE  
 SOLUTIONS OF NORMAL EQUATION  
 PARAMETERS ESTIMATED -2.470E-01 4.733E-01 -1.749E 00  
 8 1.2713 -0.0293 13 0.5448 0.0562 16 42.0001 -0.2075

NO. OF ITERATION ... 3  
 REFERENCE VALUES OF CHI-SQUARES AT ... 0.0 0.10000 0.20000 CHI-SQ. AT ... 0.12460  
 CHI-SQUARES 1.495E 01 1.404E 01 1.673E 01 1.403E 01  
 SHAPE OF CHI-SQUARE-CURVE ... CONCAVE  
 SOLUTIONS OF NORMAL EQUATION  
 PARAMETERS ESTIMATED -9.859E-02 4.0009E-01 -9.2607E 00  
 8 1.2593 -0.0123 13 0.5946 0.0499 16 41.3446 -0.6559

NO. OF ITERATION ... 4  
 REFERENCE VALUES OF CHI-SQUARES AT ... 0.0 0.01967 0.03936 CHI-SQ. AT ... 0.0  
 CHI-SQUARES 1.403E 01 1.497E 01 1.673E 01 1.403E 01  
 SHAPE OF CHI-SQUARE-CURVE ... CONCAVE  
 SOLUTIONS OF NORMAL EQUATION  
 PARAMETERS ESTIMATED -1.597E 00 1.511E 00 9.324E 00  
 8 1.2593 0.0 13 0.5946 0.0 16 41.3446 0.0

PROB. 7: U238-N: E=250 KEV + AUTOMATIC PARAMETER SEARCH

PAGE 4

MASS ..... TARGET ..... INCIDENT ..... PNEHC = 2.500E-01 (FERMI) ..... MAXIMUM ANGULAR MOMENTUM ..... 4  
 MASS NO. .... 238 ..... 1.008665 ..... PNEHC = 2.500E-01 (FERMI) ..... CLASSICAL CUT-OFF MOMENTUM ..... 2  
 ATOMIC NO. .... 92 ..... 1 ..... CHESH = 2.498E-03 (FERMI) ..... WAVE NUMBER ..... 0.109376  
 RHO = 1.290 ..... CHESHC = 0.0 (FERMI) ..... COULOMB PARAMETER (YETA) ..... 0.0

CMS ENERGY ... 0.248945 (MEV)  
 LAB ENERGY ... 0.250000 (MEV) SEPARATION ENERGY ... 0.0 (MEV)

INCIDENT PARTICLE ..... NEUTRON

IMAGINARY POTENTIAL FORM  
 INTERNAL ..... SURFACE ABSORPTION ONLY  
 SURFACE ..... DIFF: WOODS-SAXON

NON-LOCAL PARAMETER = 0.0 (

L=5 TERM

&gt;

## POTENTIAL PARAMETER

FORM PARAMETER	WELL DEPTH PARAMETER (MEV)
(FERMI)	
R0 = 1.290	V = 41.34
R1 = 0.0	WI = 0.0
RC = 0.0	WE = 0.0
RS = 1.259	WIE = 0.0
R50 = 1.290	WSE = 0.0
AD = 0.470	WSES = 0.0
A1 = 0.0	WSE0 = 0.0
B = 0.595	WSES0 = 0.0
ASD = 0.470	WSE0S = 0.0

BRANCHING RATIO  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

LEVEL DENSITY PARAMETER  
 EC = 0.0 A = 0.0 SGH = 0.0 EPR = 0.0 NOM = 0.0

## EXPERIMENTAL DATA (EXP. ERROR ..... 5.0 PERCENT )

ANGULAR DISTRIBUTION (COSINE)			
ANGLE	ELASTIC	EXP. ERROR	ANGLE
0.850	1.735E 03	6.275E 01	0.200
0.670	1.053E 03	5.149E 01	0.0
0.430	8.520E 02	4.235E 01	-0.050

ANGLE	ELASTIC	EXP. ERROR	ANGLE	ELASTIC	EXP. ERROR
0.850	1.735E 03	6.275E 01	0.200	6.650E 02	3.423E 01
0.670	1.053E 03	5.149E 01	0.0	5.710E 02	2.855E 01
0.430	8.520E 02	4.235E 01	-0.050	5.730E 02	2.865E 01

Fig. 10 (2) continued

PROB. 7+ U238-N+ E=250 KEV + AUTOMATIC PARAMETER SEARCH PAGE 5

TOTAL CROSS SECTION .....	1.0371E 04 (MILLI-BARN)	CHI SQUARE .....	NORM=1.000	NORM=0.794
SHAPE ELASTIC CROSS SECTION 7.1372E 03 (MILLI-BARN)		CHI SQAURE PER POINT	2.0125E 02	4.8713E 01
REACTION CROSS SECTION ... 3.2340E 03 (MILLI-BARN)			2.2362E 01	5.4125E 00

ANGULAR DISTRIBUTION (COSINE)

***** CENTER OF MASS *****				***** LABORATORY *****							
ANGLE	ELASTIC	ANGLE	ELASTIC	ANGLE	ELASTIC	ANGLE	ELASTIC				
0.450	1.1451E 03	0.200	5.8234E 02	-0.320	3.4604E 02	0.451	1.1534E 03	0.204	5.8334E 02	-0.316	3.4511E 02
0.670	9.4932E 02	0.0	4.7490E 02	-0.350	2.7804E 02	0.672	9.5473E 02	0.004	4.7491E 02	-0.547	2.7679E 02
0.450	7.5957E 02	-0.050	4.5139E 02	-0.480	2.4652E 02	0.453	7.5747E 02	-0.046	4.5141E 02	-0.678	2.4511E 02

COMPOUND FORMATION PROBABILITY														
L	2+J	T(+)	2-J	T(-)	L	2+J	T(+)	2-J	T(-)					
0	1	2.9709E-01			2	5	1.9459E-02	3	3.1987E-02	4	9	1.5619E-05	7	1.6679E-05
1	3	2.9902E-01	1	1.9955E-01	3	7	2.8768E-03	5	9.4038E-03					

B = COEFFICIENT (CM5)											
LL	BL	LL	BL	LL	BL	LL	BL	LL	BL	LL	BL
0	5.6796E 02	1	5.3753E 02	2	1.8908E 02	3	3.8899E 01	4	3.9353E 00	5	1.3851E 01
7	9.4692E-05	8	9.9736E-07	9	0.0					6	6.3026E-03

PROB. 7+ U238-N+ E=250 KEV + AUTOMATIC PARAMETER SEARCH PAGE 6

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

MOLDAUER THEORY USED DEG. OF FREEDOM ... 1.00

GROUND STATE (N = N)

SPIN-PARITY ..... 0+

COMPOUND ELASTIC SCATTERING CROSS SECTION .....	2.1754E 03 (MILLI-BARN)	CHI SQUARE (WITHOUT EXP. ERROR) ....	1.4051E 01	NORM=1.000
SHAPE ELASTIC SCATTERING CROSS SECTION .....	7.1372E 03 (MILLI-BARN)	CHI SQAURE PER POINT	1.3590E 00	3.9782E 00
TOTAL ELASTIC SCATTERING CROSS SECTION .....	9.3129E 03 (MILLI-BARN)			4.4202E-01

ANGULAR DISTRIBUTION (COSINE)

***** CENTER OF MASS *****				***** LABORATORY *****			
ANGLE	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)	ANGLE	ELASTIC(S)	ELASTIC(C)	ELASTIC(T)
0.450	1.1451E 03	2.2348E 02	1.1405E 03	0.451	1.1534E 03	2.3507E 02	1.1578E 03
0.670	9.4932E 02	1.8699E 02	1.1363E 03	0.672	9.5473E 02	1.8804E 02	1.1428E 03
0.450	7.5957E 02	1.3554E 02	9.1012E 02	0.453	7.5747E 02	1.5614E 02	9.1561E 02
0.200	6.8254E 02	1.3556E 02	7.1719E 02	0.204	5.8334E 02	1.3558E 02	7.1914E 02
0.0	4.7490E 02	1.3073E 02	6.0563E 02	0.004	4.7491E 02	1.3074E 02	6.0565E 02
-0.050	4.5139E 02	1.3103E 02	5.8262E 02	-0.046	4.5141E 02	1.3098E 02	5.8239E 02
-0.320	3.4604E 02	1.4317E 02	4.8921E 02	-0.316	3.4511E 02	1.4278E 02	4.8789E 02
-0.520	2.7804E 02	1.6814E 02	4.4622E 02	-0.547	2.7679E 02	1.6736E 02	4.4415E 02
-0.680	2.4652E 02	1.8876E 02	4.3524E 02	-0.678	2.4511E 02	1.6768E 02	4.3279E 02

B = COEFFICIENT (CM5)				(LAB)				TRANSMISSION COEFFICIENT			
LL	BL-(S)	BL-(C)	BL-(T)	BL-(L)	BL-(R)	BL-(T)	BL-(R)	L	T(+)	T(0)	T(-)
0	5.6796E 02	1.7313E 02	7.4109E 02	T+109E 02	0	2.9709E-01	0.0				
1	5.3753E 02	5.3753E 02	5.3334E 02		1	2.9902E-01	0.0				
2	1.8908E 02	6.6837E 01	2.7592E 02	2.0033E 02							
3	3.8899E 01	3.8899E 01	4.6863E 01								
4	3.9353E 00	2.7833E 00	4.7123E 02	1.2303E 02	2	1.9459E-02	0.0				
5	1.3851E-01	1.3851E-01	2.3505E-01								
6	6.3026E-03	7.5159E-02	8.1458E-02	8.3592E-02	3	2.8766E-03	0.0				
7	9.4692E-05	9.4692E-05	1.2518E-03								
8	5.9736E-07	1.2327E-05	1.2924E-05	-6.7733E-04	4	1.5619E-05	0.0				

Fig. 10 (2) continued

PROB. T+ U238-N+ E=250 KEV + AUTOMATIC PARAMETER SEARCH PAGE 7

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

MOLDAUER THEORY USED DEG. OF FREEDOM ... 1.00

FIRST EXCITED STATE (N - N)

EXCITATION ENERGY .... 0.0477000 (MEV)  
EMITTED ENERGY (CMS) ... 0.2012422 (MEV)  
(LAB) ... 0.2020979 (MEV)  
SPIN-PARITY ..... 2+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 3.2633E 03 (MILLI-BARN)  
TOTAL INELASTIC SCATTERING CROSS SECTION TO THIS LEVEL ..... 1.0329E 03 (MILLI-BARN)

ANGULAR DISTRIBUTION (COSINE)

ANGLE	CENTER OF MASS	LABORATORY					
ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.		
0.000	7.291AE 01	-0.050	8.9989E 01	0.851	7.3500E 01	-0.045	8.9950E 01
0.470	7.9579E 01	-0.320	8.7706E 01	0.673	8.0079E 01	-0.316	8.7446E 01
0.450	8.5391E 01	-0.350	8.3052E 01	0.454	8.5756E 01	-0.347	8.2623E 01
0.200	8.9135E 01	-0.680	7.9251E 01	0.205	8.9306E 01	-0.677	7.8745E 01
0.0	9.0046E 01			0.005	9.0049E 01		

B - COEFFICIENT (CMS)

LL	BL	LL	BL	L	TRANSMISSION COEFFICIENT	Z-J	T(+)	Z-J	T(-)
0	8.2199E 01	0	8.2199E 01	0	1	2.7382E-01			
2	-1.5935E 01	1	8.0479E-01	1	3	2.4257E-01	1	1.6044E-01	
4	-3.2405E-01	2	-1.5933E 01	2	5	1.2359E-02	3	2.0251E-02	
6	-4.3016E-03	3	-1.7820E-01	3	7	1.3932E-03	5	4.5789E-04	

PROB. T+ U238-N+ E=250 KEV + AUTOMATIC PARAMETER SEARCH PAGE 8

CALCULATED DATA OF COMPOUND NUCLEAR PROCESS

MOLDAUER THEORY USED DEG. OF FREEDOM ... 1.00

SECOND EXCITED STATE (N - N)

EXCITATION ENERGY .... 0.1480000 (MEV)  
EMITTED ENERGY (CMS) ... 0.1009452 (MEV)  
(LAB) ... 0.1013729 (MEV)  
SPIN-PARITY ..... 4+

COMPOUND NUCLEUS FORMATION CROSS SECTION (INVERSE PROCESS) ..... 3.3579E 03 (MILLI-BARN)  
TOTAL INELASTIC SCATTERING CROSS SECTION TO TH'S LEVEL ..... 2.3591E 01 (MILLI-BARN)

ANGULAR DISTRIBUTION (COSINE)

ANGLE	CENTER OF MASS	LABORATORY					
ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.	ANGLE	DIFF.C.S.		
0.000	1.8128E 00	-0.050	2.1896E 00	0.852	1.8334E 00	-0.043	2.1882E 00
0.470	1.9688E 00	-0.320	2.1437E 00	0.674	1.9866E 00	-0.314	2.1347E 00
0.450	2.0958E 00	-0.350	2.0498E 00	0.455	2.1048E 00	-0.342	2.0309E 00
0.200	2.1726E 00	-0.680	1.9616E 00	0.206	2.1785E 00	-0.676	1.9439E 00
0.0	2.1907E 00			0.007	2.1908E 00		

B - COEFFICIENT (CMS)

LL	BL	LL	BL	L	TRANSMISSION COEFFICIENT	Z-J	T(+)	Z-J	T(-)
0	2.0206E 00	0	2.0206E 00	0	1	2.0446E-01			
2	-3.5833E-01	1	2.7444E-02	1	3	1.1123E-01	1	7.2392E-02	
4	-2.4463E-02	2	-3.5422E-01	2	5	2.9877E-03	3	4.3855E-03	
6	-4.1535E-04	3	-5.5052E-03	3	7	1.2935E-04	5	4.3094E-05	

INELASTIC CROSS SECTION ..... 1.0583E 03 (MILLI-BARN)

PROB. T+ U238-N+ E=250 KEV + AUTOMATIC PARAMETER SEARCH

NO.	CHI-SQUARE
0	1.681E 01
1	1.625E 01
2	1.497E 01
3	1.403E 01
4	1.403E 01

0.1.3200 0.0 13 0.4700 0.0 16 42.0000 0.0  
1.1.3009 -0.0193 13 0.4886 0.0186 16 42.2076 0.2076  
2.1.2715 -0.0293 13 0.5448 0.0462 16 42.0001 -0.2075  
3.1.2593 -0.0323 13 0.5946 0.0499 16 41.3446 -0.6055  
4.1.2593 0.0 13 0.5946 0.0 16 41.3446 0.0

RUNNING TIME ..... 95.71 SEC.

Fig 11 (1)

```
PRCB, 8+NON-LOCAL POTENTIAL, FE56-N, E=7.0 MEV
 1 8 1   1 26 36   1 19 1
      1 56.0    0.3    7.0
      6 1.25    1.25    1.25
     11 0.65    0.65    0.65
     16 7.0    7.0    10.0
     51 0.0    10.0   20.0   30.0   40.0
     56 30.0    60.0   70.0   80.0   90.0
     61 100.0   110.0  120.0  130.0  140.0
     66 150.0   160.0  170.0  180.0
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Fig 11 (2)

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PRCB, 8+NON-LOCAL POTENTIAL, FE56-N, E=7.0 MEV PAGE 1
TARGET 36.00 INCIDENT PMESH = 2.500E-01 (FERMI) MAXIMUM ANGULAR MOMENTUM 6
MASS NO. 36 PMESHc = 2.500E-02 (FERMI) CLASSICAL CUT-OFF MOMENTUM 7
ATOMIC NO. 1 CESH = 2.493E-01 (FERMI) WAVE NUMBER .....
CESHc = 0.0 (FERMI) COULOMB PARAMETER (YETA) 0.576053
0.0
CM ENERGY ... 7.000000 (MEV)
LAB ENERGY ... 7.126083 (MEV) SEPARATION ENERGY ... 0.0 (MEV)
INCIDENT PARTICLE ..... NEUTRON
IMAGINARY POTENTIAL FORM INTERNAL ..... SURFACE ABSORPTION ONLY NUN-LOCAL PARAMETER = 0.800(GAUSSIAN L-5 TERM EXCLUDED)
SURFACE ..... GAUSS
POTENTIAL PARAMETER
FORM PARAMETER WELL DEPTH PARAMETER (MEV)
(FERMI) V = 70.00 WI = 0.0 WS = 7.00 VSO = 10.00 WSO = 0.0 VSYM = 0.0
RI = 0.0 VE = 0.0 WI/E = 0.0 WSE = 0.0 VSOE = 0.0 WSOE = 0.0 VCoul = 0.0
RC = 1.250 VESW = 0.0 WI/ESW = 0.0 WSE/SW = 0.0 VSO/ESW = 0.0 WSO/ESW = 0.0
RSW = 1.250 A0 = 0.450 A1 = 0.0 VRE = 70.00 WI/HI = 0.0 WIMS = 7.00 VSPO = 10.00 WSP0 = 0.0 VSYM0 = 0.0
B = 0.450 ASW = 0.650
BRANCHING RATIO
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
LEVEL DENSITY PARAMETER
EC =  $\frac{v_0}{v_0}$  A = 0.0 SGM = 0.0 EPR = 0.0 NDM = 0.0
NO EXPERIMENTAL DATA
PRCB, 8+NON-LOCAL POTENTIAL, FE56-N, E=7.0 MEV PAGE 2
TOTAL CROSS SECTION ..... 4.1367E 03 (MILLI-BARN)
SHAPE ELASTIC CROSS SECTION 3.5369E 03 (MILLI-BARN)
REACTION CROSS SECTION ... 7.5983E 02 (MILLI-BARN)
ANGULAR DISTRIBUTION (DEGREES)
CENTER OF MASS ..... ELASTIC ANGLE ELASTIC ANGLE ELASTIC LABORATORY ANGLE ELASTIC
ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC ANGLE ELASTIC
0.0 3.5999E 03 70.0 9.3000E 01 140.0 5.2206E 01 0.0 3.7307E 03 69.0 9.4190E 01 139.3 5.0864E 01
10.0 5.1973E 03 80.0 1.0505E 02 190.0 9.2133E 01 9.8 3.3118E 03 79.0 1.0576E 02 149.5 8.9294E 01
20.0 7.2235E 03 90.0 1.4034E 01 180.0 1.3399E 02 19.3 3.2999E 03 89.0 8.8554E 02 159.6 1.2950E 02
30.0 1.1487E 03 100.0 6.4034E 01 170.0 1.3240E 02 29.3 1.2175E 03 99.0 6.4442E 01 169.8 1.4704E 02
40.0 4.5635E 02 110.0 5.8223E 01 180.0 1.5457E 02 39.3 4.6912E 02 109.0 4.7240E 01 180.0 1.4906E 02
50.0 1.3222E 02 120.0 4.9833E 01 180.0 1.5457E 02 49.2 1.3554E 02 119.1 4.8550E 01
60.0 6.8820E 01 130.0 4.0972E 01 180.0 1.5457E 02 59.1 7.0090E 01 129.2 4.0040E 01
COMPOUND FORMATION PROBABILITY
L 2=J T(+)
2=J T(-) L 2=J T(+)
2=J T(-) L 2=J T(+)
2=J T(-) L 2=J T(+)
2=J T(-)
0 1 4.4105E-01 3 7 3.9074E-01 5 9.4827E-02 6 13 2.7641E-03 11 3.6389E-04
1 3 1.4714E-01 1 1.4877E-01 4 9 5.7831E-02 7 3.7553E-01
2 3 3.8664E-01 3 5.6705E-01 5 11 2.15232E-01 9 1.8538E-02
L L = COEFFICIENT (CMS)
BL LL BL LL BL LL BL LL BL LL BL LL BL
0 2.6534E 02 1 5.1937E 02 2 7.1245E 02 3 6.8864E 02 4 6.27785E 02 5 4.1734E 02 6 2.2849E 02
7 8.0686E 01 8 1.3399E 01 9 1.6913E 01 10 -7.2672E-01 11 9.4400E-02 12 3.0786E-02 13 0.0
L L = COEFFICIENT (LAB)
BL LL BL LL BL LL BL LL BL LL BL LL BL
0 2.6554E 02 1 5.2377E 02 2 7.2041E 02 3 7.0343E 02 4 6.7932E 02 5 4.4725E 02 6 2.5348E 02
7 9.0223E 01 8 2.0043E 01 9 1.6053E 01 10 1.0360E 00 11 9.4535E-02 12 4.0074E-02 13 4.5200E-03
RUNNING TIME .... 108.54 SEC.
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