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－Statistical Model Calculation for Neutron Cross Sections and Gamma Ray Spectrum－

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Program CASTHY
—Statistical Model Calculation for Neutron Cross Sections and Gamma Ray Spectrum—

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Abstract

Program CASTHY has been utilized as a tool for nuclear data evaluations. It is used to calculate neutron cross sections of total, shape elastic scattering and compound nucleus formation with the optical model, and compound elastic, inelastic and capture cross sections by the statistical model. The other cross sections such as the $(n, 2n)$, (n, p), (n, f) reactions, etc. are treated as cross sections of competing processes, and their sum is given through input data. This program calculates also capture γ-ray spectra. Branching ratio for primary transition can be treated in a particular way, if necessary.

This program CASTHY was originally prepared for cross-section evaluation of fission-product nuclides, and was used to calculate cross sections for fission products in JENDL-1. It was expanded later on so that it could be applicable to nuclear data evaluation for JENDL-2 and JENDL-3. During these periods of the work for JENDL, some versions of this code including tentatives have been independently made up by users. Hence, this report puts them in order, establishes its complete version, and describes how to use it. The code CASTHY consists of 25 subroutines and 9 functions, together with a main routine and a block-data table. Short descriptions on these as well as how to prepare input data are presented.

Keywords: Statistical Model, Nuclear Data Evaluation, Cross Sections, Neutron, Gamma-Ray, Code, JENDL

*) Nuclear Energy Data Center

プログラム CASTHY

－中性子断面積及びガンマ線スペクトル計算用統計模型計算プログラム－

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(1990年9月1日受理)

要 旨

本プログラムCASTHYは核データ評価用として作られた計算コードで，光学模型を用いて中性子入射の全断面積，形状弾性散乱断面積，複合核形成断面積を，また，統計模型を用いて複合核弾性散乱断面積，非弾性散乱断面積及び捕獲断面積を計算する。これら以外の，例えば $(n, 2n)$，(n, p)，(n, f) などの反応の断面積は競争過程のデータとしてそれらの和が入力データで与えられる。このプログラムはまたガンマ線のスペクトルの計算も行うが，必要な場合には，一次遷移の分岐比が特別に扱われる。

このプログラムは，初め核分裂生成物（FP）核種の核データ評価のために作られ，JENDL－1のFPデータの計算に用いられた。その後，JENDL－2，JENDL－3の核データ評価にも使えるように拡張されてきたが，JENDLの作業期間中には必要に応じていくつかの改訂版が作られ，それぞれ独立に使われてきた。このレポートでは，それらを整理し，本版としてまとめ，その使用法を示す。

CASTHYは25個のサブルーチンと9個の関数，1個の主プログラム及び1個のブロックデータテーブルからなっているが，これらの簡単な説明と入力データの作り方も示す。

*) (財)原子力データセンター

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1. Introduction

Plans for this program CASTHY were originally made in the early nineteen seventies to calculate nuclear cross sections for fission products (FP). It was mainly based on the Hauser–Feshbach theory[1], and was requested to work for many nuclei in the wide energy range. For this purpose, it was required that the calculations could be done for plural points of the incident energy during a running computer time, total cross section should be equal to the sum of the partial cross sections including neutron capture cross section that was the most important for FP, the capture cross section could be adjusted to an appropriate experiment, etc.

Most computer codes for nuclear cross section calculations, in that era, were made for the specific cross section and the angular distribution at an energy point, because of slow computer time and limited memory size. To overcome these limitations, it was taken in this code that repetition of the same calculations done at the previous energy point was avoided, the interpolation method was adopted, for instance, for obtaining transmission coefficients. The cross sections for competing processes unable to calculate with this code were introduced through input data. Under such requirements cross–section formulas were modified[2] so that the calculations might be done faster with reasonable accuracy. Although CASTHY has some simplified methods, it can take several interesting options to treat quantities such as resonance level interference and width fluctuation, Legendre coefficients for angular distributions of scattered neutrons, etc. The original version of CASTHY had been made with these functions, and used to evaluate fission–product nuclear data[3,4,5].

In the middle of the nineteen seventies, Japanese Nuclear Data Committee (JNDC) started its work for Japanese Evaluated Nuclear Data Library (JENDL) and members of JNDC tried to use CASTHY to calculate cross sections in their work for nuclear data evaluations. As their evaluation work advanced, they have requested the original version of the code to be added such functions and options as photon production cross–section calculations, transfer of calculated results to a data base with the ENDF/B format, calculation of cross sections at threshold energies of inelastic scattering, selection on level densities and their parameters, etc. Responding to these requests, a new version has been made with some modifications added to the original one. It has accepted the requests as much as possible, so that the users could facilitate the evaluation work for JENDL.

The third version of JENDL, JENDL–3[6], was released in 1989. Hence, on this occasion, it would be the right time to release CASTHY that has concerned deeply with the evaluation work on JENDL. This report has been made, in this sense, in order that CASTHY might be widely used as well as JENDL–3 in the future.

In the next Chapter, cross–section formulas with the competing processes mentioned above are presented. The total transmission coefficient is modified so that the total reaction cross section obtained by using the optical model may be conserved. The transmission coefficients for neutrons and γ–rays are rewritten by considering an effect of $(n, \gamma n')$ process, though the effect has been treated still approximately. Correction factors for the resonance width fluctuation and level interference are also explained. These factors are expressed in the transmission coefficients modified from those obtained with the optical model by taking into consideration of the effect of the resonance level interference. Options on the optical model potential, level density and profile functions for the El giant resonance are also described briefly.

In Chapter 3, description on the calculation of branching ratios, population probability, spectra and multiplicities for γ–rays is shortly presented. Branching ratio of the primary transition for the E1 γ–rays is taken into account in this program. As this branching ratio is given as the input data, the relation between the input and calculated branching ratios and their treatment are explained.

CASTHY has 25 subroutines and 9 functions. Brief descriptions on their role are presented in Chapter 4. A main routine manages them all to perform the calculations consistently by joining them each other. It prepares initial values for some variables at its start together with constants and default values given in **BLOCKD**.

Chapter 5 is devoted to explanation of the input data. They have a card–image form, and are classified into Title, Normalization, Fixed–point, Floating–point and Gamma–ray data cards. The Fixed– and Floating–point data are set equal to zero at the beginning of calculation. They have their own address in the card, and obey "the same as before rule". Because of the rule, they can take their previous value, when they are given blank data in a running calculation. Detailed explanation on these rules will be also presented. Several examples on typical calculations are shown in Chapter 6. These may be helpful to users to make input data and to test their transferred version.

2. Cross Sections

This Chapter is devoted to description of the cross sections which can be calculated with this code, and of the relation between those given by input data and calculations. Total cross section σ_{tot}, shape elastic scattering cross section $\sigma_{el,s}$ and total reaction cross section σ_R are calculated by using the optical model, as usual. Compound elastic ($\sigma_{el,c}$), inelastic (σ_{in}) and capture ($\sigma_{n,\gamma}$) cross sections are given by the statistical model based on the Hauser–Feshbach theory[1]. The other reaction cross sections such as (*n, 2n*), (*n, p*), (*n, f*), etc. are not calculated with this code. Hence, they are prepared as input so that the total reaction cross section can be divided into partial cross sections reasonably.

In this report, the cross sections given by the input data are shown as $\Delta\sigma$ which means the sum of the partial reaction cross sections which this code is unable to calculate. Hereafter, mathematical expressions used in the previous papers[2, 7] are adopted, in general, in this report.

2.1 Transmission Coefficients of Neutrons and γ–rays

Neutron transmission coefficient $T_{njl}^{J\Pi}$ of a channel $(njlJ\Pi)$ is calculated in a usual way with the optical model. The total reaction cross section is expressed by using the neutron transmission coefficients in the entrance channel of neutron energy E_n:

$$\sigma_R=\frac{\pi}{k_n^2}\sum_{J\Pi jl} g^J \mathring{T}_{njl}^{J\Pi} \tag{2.1}$$

This must be conserved through calculations of the cross sections.

Assuming the E1 absorption, two kinds of γ–ray transmission coefficients[2] are used in this code for the cross–section calculations:

$$T_{\gamma 1}^{J\Pi}(E_n)=C_0^{J\Pi}\sum_{J'=|J-1|}^{J-1}\int_{E_n}^{E_n+B_n} d\varepsilon\ \varepsilon^3 f_\gamma(\varepsilon)\rho_c^{J'}(E_n+B_n-\varepsilon), \tag{2.2}$$

$$T_{\gamma 2}^{J\Pi}(E_n)=C_0^{J\Pi}\sum_{J'=|J-1|}^{J+1}\int_{0}^{E_n+B_n} d\varepsilon\ \varepsilon^3 f_\gamma(\varepsilon)\rho_c^{J'}(E_n+B_n-\varepsilon), \tag{2.3}$$

where $f_\gamma(\varepsilon)$ is a profile function[8,9] of the giant resonance for the E1 absorption and ρ_c^J is a level density function for a compound nucleus. Although a symbol for parity is not given explicitly in the level density, its conservation law is considered in the present code.

The two γ–ray transmission coefficients, Eqs. (2.2) and (2.3), correspond to the transitions to only the states below neutron separation energy B_n and to all the states below E_n+B_n, respectively. Coefficient $C_0^{J\Pi}$ is given as a normalization factor for the calculated cross section to be fitted to experimental data, or is calculated by the following formula

$$C_0^{J\Pi}=(2\pi\Gamma_\gamma^{J\Pi}/D_{J\Pi})_{B_n}\Big/\sum_{J'=|J-1|}^{J+1}\int_0^{B_n} d\varepsilon\ \varepsilon^3 f_\gamma(\varepsilon)\rho_c^{J'}(B_n-\varepsilon). \tag{2.4}$$

Neglecting J–dependence of the γ–ray width $\Gamma_\gamma^{J\Pi}$, the γ–ray strength function $(2\pi\Gamma_\gamma^{J\Pi}/D_{J\Pi})_{B_n}$ for s–wave neutron resonances is calculated by using the observed level spacing D_{obs} and γ–ray width $\Gamma_{\gamma,obs}$;

$$(2\pi\Gamma_\gamma^{J\Pi}/D_{J\Pi})_{B_n}=(\rho_c^J(B_n)\Big/\sum_{J'=|I-\frac{1}{2}|}^{I+\frac{1}{2}}\rho_c^{J'}(B_n))\cdot(2\pi\Gamma_{\gamma,obs}/D_{obs}), \tag{2.5}$$

where I is the spin of a target nucleus. The γ–ray width $\Gamma_\gamma^{J\Pi}$ is given by using $T_{\gamma 2}^{J\Pi}$ as follows :

$$\Gamma_{\gamma}^{J\Pi}(E_n)=(\pi/2)\,T_{\gamma 2}^{J\Pi}(E_n)/\rho_c^J(E_n+B_n), \tag{2.6}$$

and the observed γ–ray width is written as

$$\Gamma_{\gamma,obs}=\{I\Gamma^{I-\frac{1}{2}}+(I+1)\Gamma^{I+\frac{1}{2}}\}\Big/(2I+1). \tag{2.7}$$

Here, a quantity $\Delta T_{\gamma}^{J\Pi}$ is defined as the difference between $T_{\gamma 2}^{J\Pi}$ and $T_{\gamma 1}^{J\Pi}$:

$$\Delta T_{\gamma}^{J\Pi}=T_{\gamma 2}^{J\Pi}-T_{\gamma 1}^{J\Pi}. \tag{2.8}$$

This corresponds to the net strength for the neutron and γ–ray emissions through transitions of γ–rays to the levels of compound states above the neutron separation energy B_n. Using this quantity, contribution from this process to each exit channel can be written:

$$\Delta T_{n'j'l'}^{J\Pi}=\Delta T_{\gamma}^{J\Pi}\cdot \mathring{T}_{n'j'l'}^{J\Pi}/\mathring{T}^{J\Pi}, \tag{2.9}$$

$$\Delta T_{\gamma 1}^{J\Pi}=\Delta T_{\gamma}^{J\Pi}\cdot T_{\gamma 2}^{J\Pi}/\mathring{T}^{J\Pi}, \tag{2.10}$$

where

$$\mathring{T}^{J\Pi}=\sum_{n'j'l'}\mathring{T}_{n'j'l'}^{J\Pi}+T_{\gamma 2}^{J\Pi}. \tag{2.11}$$

Hence, new definitions of the neutron and γ–ray transmission coefficients are made in this code as follows:

$$T_{n'j'l'}^{J\Pi}=\mathring{T}_{n'j'l'}^{J\Pi}+\Delta T_{n'j'l'}^{J\Pi}, \tag{2.12}$$

$$T_{\gamma}^{J\Pi}=T_{\gamma 1}^{J\Pi}+\Delta T_{\gamma 1}^{J\Pi}. \tag{2.13}$$

It is easily seen that the new transmission coefficients satisfy Eq.(2.11) by summing them up.

If levels of residual nucleus are dense and overlapping with each other (region in continuum), the summation in Eq.(2.11) turns into an integral formula with the level density. Hence, the expression in Eq.(2.11) should be interpreted as inclusion of the levels in continuum above a critical energy E_c. Although explicit expressions for the excitation energy, spin and parity of the levels are not presented here, the subscript n' in Eqs. (2.11) and (2.12) may include these quantities as well as emitted neutrons.

2.2 Cross Section Formulas

As mentioned above, the partial reaction cross sections which cannot be calculated by this code are treated as those for processes competing with the calculated ones. They are given the input data ($\Delta\sigma$). Therefore, the data for competitors may be included in the total reaction cross section $\sigma_R(E_n)$ given in Eq.(2.1). For this reason, a new total transmission coefficient should be defined instead of the coefficient given by Eq.(2.11). It may be

$$T^{J\Pi}\equiv \mathring{T}^{J\Pi}/(1-\alpha), \tag{2.14}$$

where $\alpha=\Delta\sigma/\sigma_R$. It is easily seen that this definition ensures the relation

$$\sigma_{tot}=\sigma_{el,s}+\sigma_R=\sigma_{el,s}+\sigma_{el,c}+\sigma_{in}+\sigma_{n,\gamma}+\Delta\sigma. \tag{2.15}$$

Since the total, shape elastic scattering and reaction cross sections are calculated as usual, their formulas are not given here explicitly.

The compound elastic and inelastic scattering cross sections are given as follows;

$$\sigma_{n,n'}(E_n)=\frac{\pi}{k_n^2}\sum_{J\Pi jlj'l'} g^J\left\{\frac{\mathring{\Theta}^{J\Pi}_{njl}\cdot\mathring{\Theta}^{J\Pi}_{n'j'l'}}{}S^{J\Pi}_{njl;n'j'l'}\left(1+\frac{\Delta\Theta^{J\Pi}}{\mathring{\Theta}^{J\Pi}}\right)\right.$$

$$\left.-\delta_{njl;n'j'l'}\frac{1}{4}(1-\alpha)Q^{J\Pi}(\Theta)\cdot(\mathring{\Theta}^{J\Pi}_{njl})^2\right\}. \quad (2.16)$$

As mentioned above, the subscript n' denotes the inclusion of the energy, spin and parity for the levels of the residual nucleus together with the emitted neutrons. Hence, it should be also understood that the summation on the levels includes the overlapping ones. The capture cross section, in the same manner as in the neutron cross section, is written as

$$\sigma_{n,\gamma}(E_n)=\frac{\pi}{k_n^2}\sum_{J\Pi jl} g^J\frac{\mathring{\Theta}^{J\Pi}_{njl}}{\Theta^{J\Pi}}\left\{\Theta^{J\Pi}_{\gamma1}+\Theta^{J\Pi}_{\gamma2}\cdot\left[\frac{\Delta\Theta^{J\Pi}_{\gamma}}{\mathring{\Theta}^{J\Pi}}\cdot S^{J\Pi}_{njl;\gamma2}-(1-S^{J\Pi}_{njl;\gamma2})\right]\right\}. \quad (2.17)$$

Since Eqs.(2.16) and (2.17) are given by taking account of the resonance width fluctuation[10,11] and level interference[12,13,14,15], they are general formulas of the cross sections for the statistical model including the original Hauser–Feshbach formula.

Modified transmission coefficients are calculated by using a correction factor $Q^{J\Pi}(\Theta^{J\Pi})$ which represents the effect of the interference between resonance levels,

$$\mathring{\Theta}^{J\Pi}_{njl}-\frac{1}{4}Q^{J\Pi}(\Theta^{J\Pi})(\mathring{\Theta}^{J\Pi}_{njl})^2=\mathring{T}^{J\Pi}_{njl}, \quad (2.18)$$

$$\Theta^{J\Pi}_{\gamma i}-\frac{1}{4}Q^{J\Pi}(\Theta^{J\Pi})(\Theta^{J\Pi}_{\gamma i})^2=T^{J\Pi}_{\gamma i}, \quad (2.19)$$

for neutrons and γ-rays, respectively. Subscript i in Eq.(2.19) stands for 1 and 2, corresponding to Eqs. (2.2) and (2.3). The total transmission coefficient $T^{J\Pi}$ and the quantity $\Delta T^{J\Pi}_{\gamma}$ are replaced with the following formulas respectively,

$$\Theta^{J\Pi}=\mathring{\Theta}^{J\Pi}/(1-\alpha)=\left\{\sum_{n'j'l'}\mathring{\Theta}^{J\Pi}_{n'j'l'}+\Theta^{J\Pi}_{\gamma2}\right\}/(1-\alpha), \quad (2.20)$$

$$\Delta\Theta^{J\Pi}_{\gamma}=\Theta^{J\Pi}_{\gamma2}-\Theta^{J\Pi}_{\gamma1}. \quad (2.21)$$

Formula of the correction factor for the resonance level interference is given as follows,[13,14,15]

$$Q(\Theta)=2\{1-\Phi_0(\Theta/2\pi)\}, \quad (2.22)$$

where

$$\Phi_0(\Theta/2\pi)=1-(1/x)\{1-(1/x)e^{-x}\sinh x\}$$
$$-(1/x)Ei(-x)\{\cosh x-(1/x)\sinh x\}, \quad (2.23)$$

is a function of variable $x=\Theta/2$. Ei-function in Eq.(2.23) is defined by using an integral form;

$$Ei(-x)=-\int_x^{\infty}\frac{e^{-t}}{t}dt. \quad (2.24)$$

The correction factors for the level-width fluctuations are described by the following integral forms,[10,11]

$$S_{njl;n'j'l'}=\int_0^{\infty}dt(1+(2/\nu_n)\delta_{njl;n'j'l'})\cdot exp(-\Theta_{\gamma2}t/\mathring{\Theta})$$

$$\times\{(1+(2/\nu_n)\mathring{\Theta}_{njl}t/\mathring{\Theta})(1+(2/\nu_{n'})\mathring{\Theta}_{n'j'l'}t/\mathring{\Theta})\cdot\prod_{c\neq\gamma}(1+(2/\nu_c)\mathring{\Theta}_c t/\mathring{\Theta})^{\nu_c/2}\}^{-1}, \quad (2.25)$$

for neutrons, and

$$S_{njl;\gamma 2}=\int_0^\infty dt\ exp(-\Theta_{\gamma 2}t/\mathring{\Theta})\cdot\{(1+(2/\nu_n)\mathring{\Theta}_{njl}t/\mathring{\Theta})\cdot\prod_{c\neq\gamma}(1+(2/\nu_c)\mathring{\Theta}_c t/\mathring{\Theta})^{\nu_c/2}\}^{-1}, \tag{2.26}$$

for γ-rays, respectively. The spin and parity (J, Π) are not explicitly given in these two expressions for simplicity, but they are adopted in the code.

2.3 Optical Model Potential

The optical potential used in this code has the following form,

$$V(r)=V\cdot f(r,r_0,a_0)+iW_I\cdot f(r,r_I,a_I)+iW_S\cdot g(r,r_S,a_S)$$
$$+(V_{SO}+iW_{SO})\cdot(\hbar m_\pi c)^2\frac{1}{r}\left|\frac{d}{dr}f(r,r_{SO},a_{SO})\right|\cdot(\vec{\sigma}\cdot\vec{l}), \tag{2.27}$$

where $f(r,x,a)$ is

$$f(r,x,a)=\{1+exp[(r-xA^{1/3})/a]\}^{-1}, \tag{2.28}$$

and $g(r,r_s,a_s)$ is

$$g(r,r_s,a_s)=4a_s\left|\frac{d}{dr}f(r,r_s,a_s)\right|, \tag{2.29}$$

or

$$g(r,r_s,a_s)=exp[-((r-r_sA^{1/3})/a_s)^2]. \tag{2.30}$$

Strength of each term in Eq.(2.27) is assumed to be an energy dependent form, as follows;

$$\begin{aligned}V&=V_0+V_1E+V_2E^2+V_S(N-Z)/A,\\ W_I&=W_{I0}+W_{I1}E+W_{I2}E^2,\\ W_S&=W_{S0}+W_{S1}E+W_{S2}E^{1/2},\\ V_{SO}&=V_{SO0}+V_{SO1}E+V_{SO2}E^2,\end{aligned} \tag{2.31}$$

and

$$W_{SO}=W_{SO0}+W_{SO1}E+W_{SO2}E^2.$$

In this code, the energy dependence of the potential strength can be changed at E_r for V and at E_i for W_I and W_S. This corresponds to a case where two functions

$$y=a_0x^2+b_0x+c_0, \qquad x<x_0 \tag{2.32}$$

and

$$y=ax^2+bx+c, \qquad x\geq x_0 \tag{2.33}$$

are joined at x_0, and a constant c is uniquely defined. A new function

$$y=a_0x_0^2+b_0x_0+c_0+a(x^2-x_0^2)+b(x-x_0), \tag{2.34}$$

is made instead of Eq.(2.32). Hence, only two coefficients a and b are needed, if Eq.(2.33) is joined to Eq.(2.32) at x_0. Detailed explanation about the other parameters is given in Chapter 5 for input data.

2.4 Level Density

The level density must be considered above a critical excitation energy U_c which is related with E_c

both for residual and compound nuclear states. The level density in this code has the form of Fermi gas model[16] above an excitation energy U_0 and of constant temperature model[16] below U_0. They are written as follows[11,16] with energy, spin and parity terms,

$$\rho_G^{J\Pi}(U)=((2J+1)/C_0U^2)\cdot exp\{2\sqrt{aU}-(J(J+1))/2\sigma_M^2\}\cdot\rho_{G,p}(\Pi), \tag{2.35}$$

for the Fermi gas model, and

$$\rho_T=\rho_{T,E}(U)\cdot\rho_{T,s}(J)\cdot\rho_{T,p}(\Pi), \tag{2.36}$$

with

$$\rho_{T,E}(U)=C\cdot exp(U/T), \tag{2.37}$$

for the constant temperature model with temperaure T, respectively.

In Eq.(2.35), the parity term $\rho_{G,p}(\Pi)=1/2$ is taken reasonably, because the levels are highly excited enough. Apparent excitation energy U is related with pairing energy Δ and real excitation energy E,

$$U=E-\Delta. \tag{2.38}$$

The joint energy U_0 and the critical energy U_c are defined respectively by using this relation with the given energies E_0 and E_c. Normalization factor C_0 is an input data in the present code, but it can be also calculated by using the formula,

$$C_0=24\sqrt{2}a^{1/4}U^{5/4}\sigma_M^3/U^2, \tag{2.39}$$

if it is necessary. Here, a is level density parameter and σ_M^2 is spin cutoff factor which depends on the excitation energy U;

$$\sigma_M^2=\alpha_M U^{1/2}. \tag{2.40}$$

The parameters a and α_M are also given as the input data, but the spin cutoff parameter α_M is calculated by the formula,

$$\alpha_M=0.4\,\mu_0 r_0^2A^{5/3}/(a^{1/2}\hbar^2), \tag{2.41}$$

assuming the nucleus to be a rigid body with its mass number A and radius parameter r_0. A factor μ_0 in Eq.(2.41) is a nucleon unit mass. The spin term in Eq.(2.35) is an exponential form, but the present code has also an option of the spin term depending on only $(2J+1)$.

In some cases, it is convenient to use an observable level density[16] for the energy term in Eq.(2.35);

$$\rho_{G,obs}(U)=\sum_{J\Pi}\rho_G^{J\Pi}(U)\sim(2\sigma_M^2/C_0U^2)e^{2\sqrt{aU}}. \tag{2.42}$$

Using this formula, Eq.(2.35) is rewritten as follows,

$$\rho_G^{J\Pi}(U)=\rho_{G,obs}(U)\cdot((2J+1)/2\sigma_M^2)\cdot exp(-J(J+1)/2\sigma_M^2)\cdot\rho_{G,p}(\Pi). \tag{2.43}$$

It should be noticed that the spin term in Eq.(2.43) is different from the corresponding term in Eq.(2.35).

The level density of the constant temperature model, Eq.(2.36), must be joined smoothly to Eq.(2.35) or Eq.(2.43). If Eq.(2.35) is taken,

$$\rho_{T,E}(U)=exp\{2\sqrt{aU_0}+(U-U_0)/T\}/C_0U_0^2, \tag{2.44}$$

$$\rho_{T,s}(J)=(2J+1)\cdot exp\{-J(J+1)/2\sigma_T^2\}, \tag{2.45}$$

with the nuclear temperature

$$T=U_0/\{\sqrt{aU_0}-2\}, \tag{2.46}$$

are obtained. If Eq.(2.43) is selected for the Fermi gas model, each term of the constant temperature model is given below,

$$\rho_{T,E}(U)=2\sigma_M^2(U_0)exp\{2\sqrt{aU_0}+(U-U_0)/T\}/C_0U_0^2, \tag{2.47}$$

$$\rho_{T,s}(J)=((2J+1)/2\sigma_T^2)\cdot exp\{-J(J+1)/2\sigma_T^2\}, \tag{2.48}$$

with

$$T=U_0/\{\sqrt{aU_0}-3/2\}. \tag{2.49}$$

The parity term in Eq.(2.36) is defined tentatively as[2],

$$\rho_{T,p}(\Pi)=\{N_+ +0.5exp[(U-U_\chi)/D]\}/\{1+exp[(U-U_\chi)/D]\}, \tag{2.50}$$

where N_+ is the fraction of positive parity states in the discrete levels,

$$U_\chi=(U_0+U_c)/2, \tag{2.51}$$

and

$$D=|U_0-U_c|/8. \tag{2.52}$$

Four kinds of the spin cutoff factor for the constant temperature model are defined[17,18]. They are

$$\sigma_T^2(U)=\sigma_M^2(U), \tag{2.53}$$

$$\sigma_T^2(U)=\sigma_M^2(U_0), \tag{2.54}$$

$$\sigma_T^2(U)=\sigma_T^2(0)+[\sigma_M^2(U_0)-\sigma_T^2(0)]\,U/U_0, \tag{2.55}$$

and

$$\sigma_T^2(U)=\sigma_T^2(0), \tag{2.56}$$

where

$$\sigma_T^2(0)=\begin{cases}\sum_{i=1}^{N_0} I_i(I_i+1)/2N_0, & \text{for residual nucleus} \quad (2.57)\\ (2J_{min}+3)^2/8, & \text{for compound nucleus} \quad (2.58)\end{cases}$$

with the number of the discrete levels N_0. This factor, σ_T^2 (0), is given also as input data.

2.5 Profile Functions for E1 Giant Resonance

The present code has three kinds of the profile function for the E1 giant resonance. They are Lane–Lynn type, Brink–Axel type and Berman type.

(i) Lane–Lynn type[8]:

$$f_\gamma(\varepsilon_\gamma)=C/[(\varepsilon_\gamma-E_R)^2+\Gamma_R^2/4]\cdot\{\eta(\varepsilon_\gamma-E_R)+\eta(E_R-\varepsilon_\gamma)e^{a(\varepsilon_\gamma-E_R)}$$
$$-\eta(\varepsilon_\gamma-2E_R)+\eta(\varepsilon_\gamma-2E_R)e^{-b(\varepsilon_\gamma-2E_R)^2}\}, \tag{2.59}$$

where

$$\eta(x)=\begin{cases}1; & x>0,\\ 0; & x\leqq 0.\end{cases}$$

Parameters E_R and Γ_R are resonance energy and its width, and a and b are adjustable parameters.

(ii) Brink–Axel type[9,11]:

$$f_\gamma(\varepsilon_\gamma)=(2\Gamma_{Ri}/\pi)\cdot\varepsilon_\gamma\Big/\{(\varepsilon_\gamma^{\,2}-E_R^{\,2})^2+(\varepsilon_\gamma\cdot\Gamma_R)^2\}. \tag{2.60}$$

In the Lane–Lynn type and the Brink–Axel type, the total reaction cross section for the E1 photon absorption is taken as

$$\sigma_\gamma^{(E1)}(\varepsilon_\gamma)=2\pi^2\hbar e^2(NZ/A)\cdot((1+0.8y)/m_n c)\cdot\varepsilon_\gamma f_\gamma(\varepsilon_\gamma), \tag{2.61}$$

and the profile function is normalized;

$$\int_0^\infty \varepsilon_\gamma f_\gamma(\varepsilon_\gamma)d\varepsilon_\gamma=1. \tag{2.62}$$

Normalization factor C in Eq.(2.59) is fixed by using Eq.(2.62).

(iii) Berman type[19]:

$$f_\gamma(\varepsilon_\gamma)=\sum_{i=1}^{2}\varepsilon_\gamma\sigma_{Ri}\Gamma_{Ri}\Big/\{(\varepsilon_\gamma^{\,2}-E_{Ri}^{\,2})^2+(\varepsilon_\gamma\cdot\Gamma_{Ri})^2\}. \tag{2.63}$$

In this case, the total reaction cross section for the E1 photon absorption is defined as

$$\sigma_\gamma^{(E1)}(\varepsilon_\gamma)=\varepsilon_\gamma f_\gamma(\varepsilon_\gamma), \tag{2.64}$$

with two peaks of the resonances.

3. Spectra of γ-rays

The present code CASTHY treats only the E1 component of γ-rays in the cross-section calculations. In case of calculations for the capture γ-ray spectra, M1 and E2 components as well as the E1 component are obtainable. Besides, transitions from overlapping (continuous) to discrete levels and between the discrete levels in the compound nucleus are considered, in addition to the transitions between the continuous levels.

In this Chapter, short descriptions on the branching ratios of the γ-transitions, population probabilities of the excited levels and spectra of the γ-rays are presented. Since the M1 and E2 components are taken into account in this part of the code, the transmission coefficients presented in the previous Chapter must be enlarged. A special option for the E1 primary transition considered in the code is also explained.

3.1 Branching Ratio

The γ-ray transmission coefficient of the E1 component, Eq.(2.3), should be expanded so as to include the transitions to the discrete levels. This may be written as

$$T_\gamma^{J\Pi}(E)=\sum_{J'\Pi'}\Delta(J,1,J')\cdot\delta_{\Pi',-\Pi}\cdot C_0^{J\Pi}\cdot\int_{E_c}^{E}dE'(E-E')^3 f_\gamma(E-E')\rho_c^{J'\Pi'}(E')$$
$$+\sum_{k=1}^{k_0}\Delta(J,1,J_k)\cdot\delta_{\Pi_k,\ \Pi}\cdot C_0^{J\Pi}(E-E_k)^3 f_\gamma(E-E_k), \qquad (3.1)$$

with the following spin conservation factor;

$$\Delta(J',s,J)=1\ ; \qquad |J'-s|\leqq J\leqq J'+s,$$
$$=0\ ; \qquad \text{otherwise.} \qquad (3.2)$$

In Eq.(3.1), the number of the discrete levels is counted as k_0. Using this definition, the branching ratio for the E1 transition from a state (E', J', Π') to a state (E, J, Π) is given as follows,

$$B_\gamma(E',J',\Pi'\rightarrow E,J,\Pi)=B_\gamma(E',J',\Pi')\cdot\mathfrak{B}_\gamma(E',J',\Pi'\rightarrow E,J,\Pi)$$
$$=\Delta(J',1,J)\cdot\delta_{\Pi',-\Pi}\cdot C_0^{J'\Pi'}\cdot\varepsilon_\gamma^{\ 3}\cdot f_\gamma(\varepsilon_\gamma)\cdot\rho_c^{J\Pi}(E)/T^{J'\Pi'}(E'). \qquad (3.3)$$

Since emission of particles from the compound states is also included, the denominator $T^{J\Pi}(E)$ can be enlarged as

$$T^{J\Pi}(E)=\sum_{njl}T_{njl}^{J\Pi}(E)+T^{J\Pi}(E). \qquad (3.4)$$

In Eq.(3.3), the first factor $B_\gamma(E', J', \Pi')$ is the total branching ratio for the γ-ray emission, and is described as

$$B_\gamma(E',J',\Pi')=T_\gamma^{J'\Pi'}(E')/T^{J'\Pi'}(E'). \qquad (3.5)$$

Hence, the second factor $\mathfrak{B}_\gamma$ $(E', J', \Pi'\rightarrow E, J, \Pi)$ in Eq.(3.3) is the partial branching ratio of the transition between the states (E', J', Π') and (E, J, Π). Explicit expression of the partial branching ratio for the E1 transition is

$$\mathfrak{B}_\gamma(E',J',\Pi'\rightarrow E,J,\Pi)$$
$$=\Delta(J',1,J)\cdot\delta_{\Pi',-\Pi}\cdot C_0^{J'\Pi'}\cdot\varepsilon_\gamma^{\ 3}\cdot f_\gamma(\varepsilon_\gamma)\cdot\rho_c^{J\Pi}(E)/T_\gamma^{J'\Pi'}(E'). \qquad (3.6)$$

If the final state is discrete, the level density function in Eq.(3.6) is set to unity.

For the convenience of adjusting the strength function, the numerator in Eq.(3.6) is expressed with an adjustable factor $a(E1)$;

$$B(E1)=a(E1)\Delta(J',1,J)\cdot\delta_{\Pi',-\Pi}\cdot C_0^{J'\Pi'}\cdot\varepsilon_\gamma^{\ 3}\cdot f_\gamma(\varepsilon_\gamma). \tag{3.7}$$

In the same way as in Eq.(3.7), the numerators of the branching ratios for the M1 and E2 transitions are defined in the present code, using single particle model[11,20,21], as follows;

$$B(M1)=a(M1)\Delta(J',1,J)\delta_{\Pi',\Pi}C_0^{J\Pi}(E'-E)^3\cdot 2.072\times10^{-2}/C_f, \tag{3.8}$$

$$B(E2)=a(E2)\Delta(J',2,J)\delta_{\Pi',\Pi}C_0^{J\Pi}(E'-E)^5\cdot 4.790\times10^{-8}A^{4/3}/C_f, \tag{3.9}$$

where $a(M1)$ and $a(E2)$ are adjustable factors for the M1 and E2 components, and C_f in the denominator is

$$C_f=2\pi^2\hbar e^2[NZ/A][(1+0.8y)/m_nc]10^6/3\pi^2(\hbar c)^2. \tag{3.10}$$

The denominator in Eq.(3.6) is extended so as to include these components.

The present code has a special option with which input data can be put in for the primary E1 transition to some discrete levels. The number of levels taken into account in this option is limited to five. Using a simplified expression, Eq.(3.6) is presented as

$$B_i=F_i/T_0, \tag{3.11}$$

where $T_0=\Sigma F_i$, and index i stands for the final levels. If the branching ratio for the primary transition β_k is given, the denominator T_0 is changed so that the additional branching ratios can be included, and new one is made;

$$T=T_0-\Sigma(F_k-F_k'). \tag{3.12}$$

The additional branching ratios are given with the new denominator T,

$$\beta_k=F_k'/T. \tag{3.13}$$

Using these relations, the new denominator

$$T=(T_0-\Sigma F_k)/(1-\Sigma\beta_k) \tag{3.14}$$

is obtained, and the branching ratio of the primary transition to level i is rewritten as

$$B_i=F_i(1-\Sigma\beta_k)/(T_0-\Sigma F_k). \tag{3.15}$$

In this procedure, the branching ratio β_k is given to the final discrete levels, but no initial compound states are specified. Since, in general, three spin states in an initial compound state corresponding to one of the β_k's are possible for the E1 transition, the branching ratio β_k must be shared with these spin states. In the code, the branching ratio β_k given to a level k is shared evenly with the corresponding initial spin states.

Continuous calculation for some incident neutron energies can be carried out with this code. But the calculation with β_k is restricted to a given energy E_g, even though plural incident energies are concerned in. Therefore, E_g should be an incident energy for calculation of one energy point or one of the energies for the continuous calculations.

3.2 Population Probability and γ-ray Spectrum

The population probability for an excited state with (E, J, Π) is

$$P_{J_0\Pi_0}(E,J,\Pi)=\delta(E_0-E)R(J_0,\Pi_0)+R(J_0,\Pi_0)\cdot B_\gamma(E_0,J_0,\Pi_0\rightarrow E,J,\Pi)$$

$$+\sum_{J'\Pi'}\int_E^{E_0}dE' P_{J_0\Pi_0}(E',J',\Pi')\cdot B_\gamma(E',J',\Pi'\rightarrow E,J,\Pi), \qquad (3.16)$$

where $R(J_0, \Pi_0)$ is the ratio of creating a specific state (J_0, Π_0) to all the compound nuclear states with energy E_0, excited by an incident energy $E_n(E_0=E_n+B_n)$:

$$R(J_0,\Pi_0)=\sum_{jl} g^{J_0}T_{njl}^{J_0\Pi_0}(E_n)\Big/\sum_{J\Pi jl} g^J T_{njl}^{J\Pi}(E_n). \qquad (3.17)$$

The third term in Eq.(3.16) should include discrete levels, when they are taken into account in the calculation.

Since Eq.(3.16) presents a partial population created through successive transition process starting from a specific compound state, the net population should be given by

$$P(E,J,\Pi)=\sum_{J_0\Pi_0} P_{J_0\Pi_0}(E,J,\Pi). \qquad (3.18)$$

Using the net population and the branching ratio, the spectrum of γ-ray with an energy ε_γ can be calculated;

$$\Psi(\varepsilon_\gamma)=\sum_{J\Pi J'\Pi'}\int_{E_c+\varepsilon_\gamma}^{E_0} dE\, P(E,J,\Pi)\cdot B_\gamma(E,J,\Pi\rightarrow E-\varepsilon_\gamma,J',\Pi')$$

$$+\sum_{J\Pi}\sum_{k=1}^{k_0} P(E_k+\varepsilon_\gamma,J,\Pi)\cdot B_\gamma(E_k+\varepsilon_\gamma,J,\Pi\rightarrow E_k,J_k,\Pi_k)$$

$$+\sum_{k=1}^{k_0}\sum_{k'=k+1}^{k_0} P(E_k,J_k,\Pi_k)\cdot B_\gamma(E_{k'},J_{k'},\Pi_{k'}\rightarrow E_k,J_k,\Pi_k)\delta(E_{k'}-E_k-\varepsilon_\gamma). \qquad (3.19)$$

Three terms in Eq.(3.19) stand for the frequencies of transitions with the energy ε_γ from the continuous to continuous states, from the overlapping to the discrete levels, and between the discrete levels, respectively.

The total energy of the emitted γ-rays is obtained from the spectrum;

$$E_\gamma=\int_0^{E_0} d\varepsilon_\gamma\, \varepsilon_\gamma \Psi(\varepsilon_\gamma). \qquad (3.20)$$

Multiplicity and average energy of the γ-rays are also calculated by using the total energy and spectrum. They are

$$M_\gamma=\int_0^{E_0} d\varepsilon_\gamma \Psi(\varepsilon_\gamma), \qquad (3.21)$$

$$\bar{\varepsilon}_\gamma=E_\gamma/M_\gamma. \qquad (3.22)$$

4. Program Description

The present code consists of a main routine, 25 subroutines, 9 functions and a table of block–data. In this Chapter, their brief descriptions are presented in rough alphabetical order.

The **MAIN ROUTINE** controls the program. Initial values of some variables used in the calculation are set in the main routine when the code starts. Constants and some default values which are frequently used in the program are given in the table **BLOCKD**.

4.1 Subroutines

BRNCHD prepares the branching ratios for the γ–ray transitions between the discrete levels. Both calculated and input values of the branching ratios are given in this subroutine.

COMDNM gives the denominators in the decay rate of the compound nuclear state. This calls **CONTNM** which calculates the transmission coefficients for the states in continuum of the residual nucleus, if they are needed. These two subroutines are called in **CRSECT** which carries out statistical model calculations. It calls **ELEGND** to calculate the Legendre coefficients for angular distributions of scattered neutrons. **ELEGND** prepares also the coefficients for the differential shape elastic scattering cross section.

ETASIG calculates the phase–shift of outgoing waves scattered by the optical potential, neutron transmission coefficients and cross section of compound nucleus formation (total reaction cross section). Maximum angular momentum quantum number is defined automatically by cutting off the partial waves whose contributions to the compound nucleus formation cross section are less than 10^{-4} times of the total reaction cross section[7].

GAMTRN calculates the E1 component of the transmission coefficients and γ–ray widths. They are given by using Eqs. (2.2), (2.3), (2.6) and (2.7). The normalization factor $C_0^{J\Pi}$ mentioned in Chapter 2 is set in **RENORM** so that the calculated capture cross section can be adjusted to the experimental data. The profile functions for the E1 giant resonance are made by **PROFIL**. Three types of the profiles are available in the code.

Input data for cross–section calculations are put in through **INPUT**. They are listed in **INLIST** together with some calculated data. Details on input data are presented in the next Chapter.

The Schroedinger equation for radial wave function of each partial wave is solved in **INTEG** to provide the neutron wave function and its derivative with the method of Fox–Goodwin. Mesh size for the numerical calculations is taken around 0.25fm automatically, if no input data for the mesh size is given. Matching radius between internal and external wave functions is determined by defining the external region where potential tails are less than 10^{-4} times of the incident energy and are cut off[7]. The external wave functions are given by **SPHBES**.

Subroutines and functions of this code check whether overflow and zero divide errors occur before or during action. **OFLOW** plays this role in the subroutines and functions.

There are six subroutines working for output of calculated data. **OUTMGT** stores the data in magnetic disks tentatively so as to transfer the data to a data base of ENDF/B format[22]. Neutron capture cross section, elastic and inelastic scattering cross sections, compound nucleus formation cross section, total cross section, average cosine of scattering angles, s– and p–wave capture cross sections are put out with **OUTPT1**. Neutron transmission coefficients for s– to f–waves, neutron strength functions, two kinds of γ–ray transmission coefficients mentioned in the previous Chapter, and γ–ray widths are printed out by **OUTPT2**, together with the shape elastic scattering, compound nucleus formation and toal cross sections. Energy points printed out in this subroutine, in addition to the input ones, are those used for interpolation of the neutron transmission coefficients. **OUTPT3** gives the inelastic scattering cross sections for every discrete and overlapping level. This output may be useful to test the calculations. **OUTPT4** lists the population probabilities of the levels occupied through γ–ray transitions, the multiplicity and spectrum of γ–rays. **OUTPT5** provides the modified transmission coefficients, correction factors for the level interference and width fluctuation, etc. These must be also useful to test the calculations.

The population probabilities mentioned above are calculated by **POPROB**, and the multiplicity and spectrum of γ–rays are made by **SPECTG**. Number of artificial levels set in the continuous region to calculate the population probability is determined by assuming it to be dependent on the energy of the compound state. The largest spin of each excited state in the continuum is limited so that the γ–ray transitions can be joined reasonably to the discrete levels.

Optical model potentials are prepared in **POTWEL**. They are provided to **INTEG** and **ETASIG** to solve the Schroedinger equation, to obtain the scattering amplitudes, transmission coefficients, total, shape elastic scattering and compound nucleus formation cross sections, to define the maximum angular momentum quantum number, etc. **PREPEN** prepares energy points at which the transmission coefficients and cross sections are calculated. The energies provided through **INPUT** are transformed from laboratory to center of mass systems and vice versa, rearrangement of the energies in order, etc. are also made in **PREPEN**. These subroutines are organized by **TRANCE**, which calculates also the matching radius, mesh size, strength functions, etc.

4.2 Functions

BRANCH gives the branching ratios of the γ–ray transitions from levels to levels in continuum and to discrete levels. Subroutines **POPROB** and **SPECTG** call this function and calculate the branching ratios of E1, M1 and E2 components. The primary branching ratios mentioned in Chapter 3 are taken into account in this function.

CASCFC calculates the correction defined by Eqs. (2.9) and (2.10). It is only rough approximation of the $(n, \gamma n')$ process, and is still incomplete.

CLBGD is a function which calculates the Clebsch–Gordan coefficient. It is called in a function **ZCOEF** to compose the Z–coefficient. **ZCOEF** is used in the subroutine **ELEGND** together with a function **RACAH** which calculates the Racah–coefficient.

Level densities are prepared by using a function **ENLDNS**. It provides the level density for the compound nuclear states with an index N of 1, 2, and 4, while for the residual nucleus with $N=3$.

The correction factors about the resonance level interference and width fluctuation are calculated with **GPHIO** and **SFACT**, respectively. They correspond to Eqs. (2.23), (2.25) and (2.26).

It is sometimes needed to make interpolation of functions, coefficients, etc. A function **VINTPL** is used for such purposes.

5. Input Data Table

Input data of CASTHY have the card–image form, and are divided into Title, Normalization, Fixed–point data, Floating–point data, and Gamma–ray data cards (see Table 1). The Fixed–point data and the Floating–point data are set equal to zero automatically at the beginning of calculation. Built–in data are used when the corresponding input data are given in blank. "The same as before rule" is adopted for the Fixed–point and Floating–point data. The Floating–point data are treated with relative address fashion. Address of the first data of each card is given in cols. 8 to 10.

Units of the data used are MeV, fm, mb, and amu, if no special notice is made. Symbol, format, and short description for each data are given below. They are shown in a tabular form also at the end of this report (Appendix).

5.1 Title Card

In a case when an element of several isotopes is treated, the Fixed–point data and Floating–point data are needed for each isotope. The Title card must be prepared for a set of these data cards.

NISOTP : **I5** ; Number of isotopes taken in a calculation for natural element. It is set to unity in a calculation for single isotope: $\leqq 10$.

NOMLIZ : **I5** ; Option on decision of $2\pi\Gamma_{\gamma, obs}/D_{obs}$ in Eq.(2.5).

$=0$······Normalization of the capture cross section to an experimental data (SIGNRN) for natural element.

$\neq 0$······Normalization of the capture cross section to an experimental data (SIGNRN) or use of the strength function itself for individual isotope.

Energy of the experimental data is requested to be in a set of incident neutron energies (ENERGY).

NOUTPT : **I5** ; Selection of output.

$\leqq 0$······Storage of the calculated results on MT, to transfer them to a data base of the ENDF/B format[22]. For a new MT, an appropriate negative number should be selected. Writing procedure must be done isotope by isotope.

$\neq 0$······Each column manages an output subroutine.

col. 11; controls subroutine OUTPT5 which prints out transmission coefficients for γ–ray $\Theta_{\gamma i}^{J\Pi}$ and neutron $\mathring{\Theta}_{njl}^{J\Pi}$, resonance level interference factor $Q^{J\Pi}$, resonance level–width fluctuation factor $S_{cc'}^{J\Pi}$, etc. for the first excited level.

col. 12; controls subroutine OUTPT4 for output data on population probability of the levels excited through γ–ray transitions, γ–ray spectrum, multiplicity, energy, etc. This plays also a role of reading γ–ray spectrum data card in subroutine BRNCHD.

$=1$······prints out only the total spectrum of γ–ray.

$=2$······prints out partial spectra of γ–ray.

col. 13; controls subroutine OUTPT3 for output data on inelastic scattering cross section for each level.

col. 14; controls subroutine OUTPT2 for output data on neutron transmission coefficients, strength functions, total cross sections, shape elastic scattering cross sections, compound nucleus formation cross sections, γ–ray widths and transmission coefficients at all neutron energies concerned in the calculation.

col. 15; controls subroutine OUTPT1 which gives outputs of calculated data on capture, elastic and inelastic scattering, compound nucleus formation and total cross sections, average cosine of scattering angles, s- and p- wave components of the capture cross section at neutron incident energies given as input data. Subroutine CRSECT is called by giving this non-zero.

NFOLLW : **I5** ; Rearrangement of input data in the successive calculation.

$\leqq 0$······For NISOTP>1, part of the input data for the previous isotope are used. Only the data with new input data are renewed, while others take the previous data, in accordance with "the same as before rule" on input data. Zero or blank is taken, if no successive calculation is done.

>0······After calculation for the given input-energies is over, the calculation continues to run for level-energies of the target nucleus, regarding them as input. Results are printed out for both of them.

TITLE : **A60** ; Title of the problem. It is requested for every set of data cards, when calculations are performed for an element of several isotopes.

5.2 Normalization Card

This is needed only for natural element (NOMLIZ$=0$). When this is taken, ENORML, SIGNRN and RATIO in the Floating-point data card are discarded.

ENORM : **E10.4** ; Energy E_x of the experimental capture cross section $\sigma^{(Exp)}(E_x)$ that is used for normalization. This should be one of the input data ENERGY.

SIGNRN : **E10.4** ; Experimental capture cross section; $\sigma^{(Exp)}(E_x)$.

RATIO : **E10.4** ; Permissible range of relative difference between calculated and experimental capture cross sections for normalization;

$$|\sigma^{(Exp)}-\sigma^{(Cal)}|/\sigma^{(Exp)}<\mathrm{RATIO}$$

5.3 Fixed-point Data Card

To this type of data cards, "the same as before rule" is available.

NODATA : **I5** ; Number of Floating-point data cards.

NCHAGT : **I5** ; Atomic number Z for target nucleus.

NMASST : **I5** ; Mass number A for target nucleus.

NABUND : **I5** ; Natural abundance of the isotope concerned. It is given by 10 times of abundance ratio (%). If blank or $\leqq 0$ is given, a default value of 1000 ($=100\%$) is taken.

NLEVEL : **I5** ; Number of levels for residual nucleus ($\leqq 30$), including the ground state.

NIMAG : **I5** ; Selection of imaginary part of the optical potential.

$=1$······Gaussian form for surface absorption.

$=2$······Derivative Woods-Saxon form for surface absorption.

$=3$······Woods-Saxon form for volume absorption.

$=4$······Sum of Gaussian form for surface absorption and Woods-Saxon form for volume absorption.

$=5$······Sum of derivative Woods-Saxon form for surface absorption and Woods-Saxon form for volume absorption.

NPROF : **I5** ; Selection of profile function for the E1 giant resonance.

$=0$······Lane-Lynn type; Eq.(2.59).

$=1$······Brink-Axel type; Eq.(2.60).

$=2$······Berman type; Eq.(2.63).

NFLCR : **I5** ; Selection of correction factors for the resonance level interference and level-width fluctuation.

Representing this as

NFLCR = 100·M + N,

M selects the factor for the resonance level interference and N for the level-width fluctuation.

M should occupy the first 3 cols. and N the last 2 cols.

M \ N	=0	<10	≧10
<0	$S=1$ $Q=0$ (H−F)	$S=1$ $Q=0$ (H−F)	$S=$Cal. $Q=0$ (Fluc.)
=0	$S=1$ $Q=0$ (H−F)	$S=1$ $Q=$Cal. (Int.)	$S=$Cal. $Q=$Cal. (Fluc. +Int.)
>0	$S=1$ $Q=$M/100 (Int.)	$S=1$ $Q=$M/100 (Int.)	$S=$Cal. $Q=$M/100 (Fluc. +Int.)

S; Correction factor for resonance level-width fluctuation.

Q; Correction factor for resonance level interference.

H−F; Hauser-Feshbach.

Fluc.; Fluctuation of resonance level-widths.

Int.; Interference of resonance levels.

Cal.; Calculated values.

The correction factor for the level-width fluctuation is calculated, in the case of N≧10. Degrees of freedom for the decay of the levels through each channel is assumed to be N/10. Usually, it may take 1; that is N=10.

NLEVCM : **I5** ; Number of levels for compound nucleus (≦30), including the ground state. This is needed for γ-ray spectrum calculations.

NCASCD : **I5** ; Selection of cascade processes.

=0······selects an approximation. Only this option is available at present.

≠0······selects a rigorous method (not yet available).

NEMESH : **I5** ; Number of energy points of the incident neutron (≦50).

>0······gives energies in center of mass system.

<0······gives energies in laboratory system.

=0······adopts the following 15 default values:

1.0, 2.0, 5.0, 10.0, 20.0, 30.0, 50.0, 70.0, 100.0, 200.0, 300.0, 500.0, 700.0, 1000.0, 2000.0 (keV)

NLVDNT : **I5** ; Selection of level density parameters for residual nucleus.

NLVDNC : **I5** ; Selection of level density parameters for compound nucleus.

These two have the same function on the respective nuclei;

≧10······adopts Eq.(2.49) for nuclear temperature.

<10······adopts Eq.(2.46) for nuclear temperature.

=0 or 10······adopts Eq.(2.53) for spin cutoff factor.

=1 or 11······adopts Eq.(2.54) for spin cutoff factor.

=2 or 12······adopts Eq.(2.55) for spin cutoff factor.

=3 or 13······adopts Eq.(2.56) for spin cutoff factor.

NPMFIX : **I5** ; Function to make use of the transmission coefficients of the previous case, when successive problems are taken.
=0······does not use the previous ones.
=1······uses the previous ones of neutrons.
=2······uses the previous ones of γ-rays.
=3······uses both of them.

NCOMPT : **I5** ; Option for adoption of competing processes.
=0······does not take them into account.
≠0······takes them into account.

NTEMP1 : **I5** ; Number for identification (ID) of the data which are stored on MT. It is used to identify the data together with Z and A, when NOUTPT≦0 is taken. The data with the same Z, A and ID are replaced with the new ones. If ID<0, the old data whose ID is the same as the absolute value of this ID are deleted from the MT. If ID ≧10, all the data on the MT are printed out. Otherwise, only new data are put out.

5.4 Floating-point Data Card

As mentioned above, this data card has the fashion of "the same as before rule" and of the relative address. Address of the first data of each card must be given in cols. 8 to 10 of the card.

EMTARG: **E10.4** ; Mass of target nucleus (in amu).

EMIN : **E10.4** ; Mass of neutron (in amu).
Default value of 1.0086652 is built-in.

SEPAR : **E10.4** ; Separation energy (in MeV) of a neutron from the compound nucleus.

R0EXP : **E10.4** ; Experimental nuclear radius parameter. Default value of 1.4 fm is built-in.
This is used, when calculated neutron penetration factors are replaced with their experimental values for neutron strength functions.

PMESH : **E10.4** ; Mesh size for solving the Schroedinger equation. Default value of 0.25 fm is given.

R0 : **E10.4** ; Radius parameter for real part of the optical model potential.

RI : **E10.4** ; Radius parameter for volume absorption term in imaginary part of the optical model potential.

RS : **E10.4** ; Radius parameter for surface absorption term in imaginary part of the opical model potential.

RSO : **E10.4** ; Radius parameter for the spin-orbit potential.

TEMP1 : **E10.4** ; Turning point of energy E_r (in MeV) for potential strength of real part. See Section 2.3 in Chapter 2.

A0 : **E10.4** ; Diffuseness parameter for real part of the optical model potential.

A1 : **E10.4** ; Diffuseness parameter for volume abosrption term in imaginary part of the optical model potential.

B : **E10.4** ; Diffuseness parameter for surface absorption term in imaginary part of the optical model potential.

ASO : **E10.4** ; Diffuseness parameter for the spin-orbit potential.

TEMP2 : **E10.4** ; Turning point of energy E_i (in MeV) for potential strength of imaginary part.
See Section 2.3 in Chapter 2.

V : **E10.4** ; Constant term V_0 in Eq.(2.31) for real part of the optical model potential.

WI : **E10.4** ; Constant term W_{I0} in Eq.(2.31) for volume term in imaginary part of the optical model potential.

WS : **E10.4** ; Constant term W_{S0} in Eq.(2.31) for surface term in imaginary part of the optical model potential.

VSO : **E10.4** ; Constant term V_{SO0} in Eq.(2.31) for real part of the spin–orbit potential.

WSO : **E10.4** ; Constant term W_{SO0} in Eq.(2.31) for imaginary part of the spin–orbit potential.

VE : **E10.4** ; Coefficient of E–term V_1 in Eq.(2.31) for real part of the optical model potential.

WIE : **E10.4** ; Coefficient of E–term W_{I1} in Eq.(2.31) for volume absorption term in imaginary part of the optical potential.

WSE : **E10.4** ; Coefficient of E–term W_{S1} in Eq.(2.31) for surface absorption term in imaginary part of the optical potential.

VSOE : **E10.4** ; Coefficient of E–term V_{SO1} in Eq.(2.31) for real part of the spin–orbit potential.

WSOE : **E10.4** ; Coefficient of E–term W_{SO1} in Eq.(2.31) for imaginary part of the spin–orbit potential.

VESQ : **E10.4** ; Coefficient of E^2–term V_2 in Eq.(2.31) for real part of the optical model potential.

WIESQ : **E10.4** ; Coefficient of E^2–term W_{I2} in Eq.(2.31) for volume absorption term in imaginary part of the optical potential.

WSESQ : **E10.4** ; Coefficient of $E^{1/2}$–term W_{S2} in Eq.(2.31) for surface absorption term in imaginary part of the optical potential.

VSOESQ : **E10.4** ; Coefficient of E^2–term V_{SO2} in Eq.(2.31) for real part of the spin–orbit potential.

WSOESQ: **E10.4** ; Coefficient of E^2–term W_{SO2} in Eq.(2.31) for imaginary part of the spin–orbit potential.

VSYM : **E10.4** ; Coefficient of symmetric term V_S in Eq.(2.31) for real part of the optical model potential.

ECRITC : **E10.4** ; Critical energy E_c for energy–levels of residual nucleus, mentioned in Section 2.1 in Chapter 2. This is the lowest energy of excited states in continuum above which levels are assumed to be overlapping.

RATIO : **E10.4** ; Permissible range of relative difference between calculated and experimental capture cross sections for normalization. This can be given to individual isotopes. (See Normalization Card).

SPCTIN : **E10.4** ; Spin cutoff factor $\sigma_T^2(0)$ in Eqs.(2.55) and (2.56) for residual nucleus. If Eq.(2.57) is taken, input data should be $\leqq 0.0$.

SPCCIN : **E10.4** ; Spin cutoff factor $\sigma_T^2(0)$ in Eqs.(2.55) and (2.56) for compound nucleus. If Eq.(2.58) is taken, input data should be $\leqq 0.0$.

ELESPN : **E10.4** ; Energy, spin and parity for discrete level of residual nucleus. Data in address of 36 must be those of the target state. If the target is in a meta stable state, its data should be in the address of 36 and its energy turns to zero. Energies of the other levels are shifted on the basis of the energy–shift of the target state. Number of levels is given by NLEVEL($\leqq 30$). Order of the levels in input may be arbitrary. In each data field, the first seven cols. are alloted to energy, the eighth col. is assigned to parity and the last two to spin. For odd nucleus, two times of spins are put in, while for even nucleus, spin values themselves are given

DNPART : **E10.4** ; Level density parameter a in Eq.(2.35) of residual nucleus.

SPINCT : **E10.4** ; Spin cutoff factor α_M in Eq.(2.40) of residual nucleus.

>0.0······input data itself is used.

$=0.0$······Eq.(2.41) is adopted.

<0.0······Spin dependence of the level density is limited to only $2J+1$.

PAIRNT : **E10.4** ; Pairing energy Δ in Eq.(2.38) of residual nucleus.

CNORMT: **E10.4** ; Normalization factor C_0 for level density of residual nucleus. If no input data is given, Eq.(2.39) is adopted.

EJOINT : E10.4 ; Joint energy $E_0(=U_0+\Delta)$ between the Fermi gas model and the constant temperature model for level density of residual nucleus.

DNPARC : E10.4 ; Level density parameter a in Eq.(2.35) of compound nucleus.

SPINCC : E10.4 ; Spin cutoff factor α_M in Eq.(2.40) of compound nucleus.
>0.0······input data itself is used.
$=0.0$······Eq.(2.41) is adopted.
<0.0······Spin dependence of the level density is limited to only $2J+1$.

PAIRNC : E10.4 ; Pairing energy Δ in Eq.(2.38) of compound uncleus.

CNORMC: E10.4 ; Normalization factor C_0 for level density of compound nucleus. If no input data is given, Eq.(2.39) is adopted.

EJOINC : E10.4 ; Joint energy $E_0(=U_0+\Delta)$ between the Fermi gas model and the constant temperature model for level density of compound nucleus.

ENORML: E10.4 ; Energy E_x of the experimental data $\sigma^{(Exp)}(E_x)$ used to normalize the calculated capture cross section for individual isotope. See ENORM in Normalization card.

SIGNRN : E10.4 ; Experimental data $\sigma^{(Exp)}(E_x)$ for individual isotope used to normalize the calculated capture cross section.

TGMNRN: E10.4 ; γ-ray transmission coefficient of individual isotope used for normalization;
$T=(2\pi\Gamma_{\gamma,\,obs}/D_{obs})_{B_n}$.

DOBSRN : E10.4 ; $D_{obs}(eV)$ used for normalization.

WDGMRN: E10.4 ; $\Gamma_{\gamma,\,obs}(eV)$ used for normalization.
If ENORML$\neq$0.0, SIGNRN has a top priority.
If ENORML$=$0.0, TGMNRN has priority over DOBSRN and WDGMRN.
If TGMNRN$=$0.0, transmission coefficients T are constructed with DOBSRN and WDGMRN for each isotope. If no data are given for both of them, lacking ones are calculated internally.

EGIANT : E10.4 ; Energy E_R for the E1 giant resonance in Eqs.(2.59) and (2.60), for Lane–Lynn type (NPROF=0) and Brink–Axel type (NPROF=1), respectively. For Berman type (NPROF=2), this corresponds to E_{R1} in Eq.(2.63). Default values[9] are
$E_R=40.7\cdot(A+1)^{-1/5}$······NPROF=0.
$E_R=80.7\cdot(A+1)^{-1/3}$······NPROF=1.

WGIANT : E10.4 ; Level width Γ_R for the E1 giant resonance in Eqs.(2.59) and (2.60), for Lane–Lynn type and Brink–Axel type, respectively. For Berman type, this is Γ_{R1}. Default values[9] are
$\Gamma_R=6.0$······NPROF=0.
$\Gamma_R=5.0$······NPROF=1.

PARA1 : E10.4 ; Parameter a in Eq.(2.59).

PARA2 : E10.4 ; Parameter b in Eq.(2.59).

EXCHNG: E10.4 ; Parameter in exchange force; $0.8y$ in Eq.(2.61).

EGBERM : E10.4 ; Resonance energy E_{R2} in Eq.(2.63).

WGBERM: E10.4 ; Resonance width Γ_{R2} in Eq.(2.63).

SIGBM1 : E10.4 ; Resonance strength σ_{R1} in Eq.(2.63).

SIGBM2 : E10.4 ; Resonance strength σ_{R2} in Eq.(2.63).

ECCRIT : E10.4 ; Critical energy E_c for energy levels of compound nucleus, mentioned in Section 2.1. This is the lowest energy of excited states in continuum above which levels are assumed to be overlapping.

TEMX(1) : E10.4 ; Nuclear temperature T in $\rho_{T.E}(U)=C\,exp(U/T)$, which is used as a constant temperature model of level density instead of Eq.(2.47) for residual nucleus.

TEMX(2) : E10.4 ; Normalization factor C in $\rho_{T,E}(U)=C\,exp(U/T)$. It is used instead of Eq.(2.47) for residual nucleus.

TEMX(3) : E10.4 ; Renewed value of VE; coefficient of E–term in Eq.(2.31) for $E>E_r$, metioned in Section 2.3.

TEMX(4) : E10.4 ; Renewed value of WIE for $E>E_i$.

TEMX(5) : E10.4 ; Renewed value of WSE for $E>E_i$.

TEMX(6) : E10.4 ; Nuclear temperature T in $\rho_{T,E}(U)=C\,exp(U/T)$, which is used as a constant temperature model of level density instead of Eq.(2.47) for compound nucleus.

TEMX(7) : E10.4 ; Normalization factor C in $\rho_{T,E}(U)=C\,exp(U/T)$. It is used instead of Eq.(2.47) for compound nucleus.

TEMX(8) : E10.4 ; Renewed value of VESQ for $E>E_r$.

TEMX(9) : E10.4 ; Renewed value of WIESQ for $E>E_i$.

TEMX(10): E10.4 ; Renewed value of WSESQ for $E>E_i$.

ENERGY : E10.4 ; Incident neutron energies ($\leqq 50$). Order of the input data may be arbitrary. Even then, output data are rearranged in order.

COMPET : E10.4 ; Sum of the partial cross sections $\Delta\sigma$ unable to calculate with this code CASTHY. The data should be put in with arrangement of the same order as that of the corresponding data in ENERGY ($\leqq 50$). Difference between the addresses of the corresponding data in COMPET and ENERGY is 50.

CLESPN : E10.4 ; Energy, spin and parity for discrete level of compound nucleus. Except the ground state allotted to the address of 201, order of the levels in input may be optional. In each data field, the first seven cols. are allotted to energy, the eighth col. is assigned to parity and the last two to spin. Number of the levels is given by NLEVCM ($\leqq 30$). For odd nucleus, two times of spins are put in, while for even nucleus, spin values themselves are given.

5.5 Gamma–ray Spectrum Data Card

This type of data card is requested in the calculation of γ–ray spectra. They are not needed, if calculations are limited to the cross sections. Besides, they are free from the fashions of relative address and "the same as before rule".

NBRNCH : I10 ; This card is always required, when calculations for the γ–ray spectrum are performed. If all levels taken in the calculation are assumed to be in continuum, this data must be put in blank.

col. 7; selects option on output for branching ratios between discrete levels.

=0······No data are put out.

=1······Data are printed out.

col. 8; selects option on input of branching ratios β_k for the primary transitions, mentioned in Section 3.1.

=0······No branching ratios are put in.

$\neq$0······Branching ratio data are put in.

Number of the final discrete levels to which the primary transitions occure is put in.

col. 9; selects option on input for branching ratios between discrete levels.

=0······No branching ratios are put in.

=1······Branching ratios are put in.

col. 10; selects option on calculations of branching ratios between discrete levels.

=0······No calculations are carried out.

=1······Calculations are performed.

ICARD : **I10** ; Number of branching ratio data cards (≦20) for transitions between discrete levels.

ENHE1 : **E10.4** ; Adjustable factor for E1 component of branching ratio; $a(E1)$ mentioned in Chapter 3.
<0.0··················$a(E1)=0.0$ is given internally.
=0.0 or blank······ $a(E1)=1.0$ is reset.

ENHM1 : **E10.4** ; Adjustable factor for M1 component of branching ratio; $a(M1)$ mentioned in Chapter 3.
<0.0··················$a(M1)=0.0$ is given interally.
=0.0 or blank······ $a(M1)=1.0$ is reset.

ENHE2 : **E10.4** ; Adjustable factor for E2 component of branching ratio; $a(E2)$ mentioned in Chapter 3.
<0.0··················$a(E2)=0.0$ is given internally.
=0.0 or blank······ $a(E2)=1.0$ is reset.

ENHSHR : **E10.4** ; Selects option on output for component spectra of E1, M1 and E2.
=0.0······No output is printed out.
≠0.0······Output data are given.

BIN : **E10.4** ; Energy bin for output of average γ–ray spectra. Default value of 0.25 MeV is built–in.

LEVH : **I5** ; Number of the upper levels (≦60). Transition between two discrete levels rises from this level, and populates the lower level with its level number LEVL. Level number must be given with the same manner as that in CLEVEL. It is necessary that every level corresponds with one in CLEVEL.

LEVL : **I5** ; Number of the lower levels (≦60). Transition between two discrete levels rises from the upper level LEVH, and populates this. Level number must be assigned with the same manner as that in CLEVEL.

BRANCH : **E10.4** ; Branching ratio between levels of LEVH and LEVL. Number of the data set consisting of LEVH, LEVL and BRANCH is ≦60.

LEVB : **5I2** ; Number of the assigned discrete levels for which a special option about the primary γ–ray transitions is taken into account. The levels should correspond with those in CLEVEL.

BRNCP : **5E10.4** ; Branching ratios, β_k's in Eq.(3.13), of the primary transition to the levels given by LEVB.

ENGBC : **E10.4** ; Incident neutron energy E_g, mentioned in Chapter 3, at which the primary transition is considered. It must correspond with some one in ENERGY.

6. Examples

This Chapter is devoted to some examples of typical calculations which may be helpful to users of this code.

6.1 Example-1

Calculation for cross sections of ^{184}W selecting Hauser-Feshbach option. Optical model potential with volume absorption of Woods-Saxon and surface absorption of derivative Woods-Saxon (NIMAG=5) is selected. Coefficient $C_0^{J\Pi}$ for the transmission coefficient $T_{\gamma i}^{J\Pi}$ is calculated by using D_{obs} and $\Gamma_{\gamma, obs}$ which are given as input data. On page 1 of the output sheets, the calculated strength function $2\pi\Gamma_{\gamma, obs}/D_{obs}$ is shown as T.GAM. In this case, it is the same as NORMALIZATION FACTOR, because experimental data SIGNRN is not taken as the normalization factor.

Constant temperature model for the level density given in Eqs.(2.46) and (2.54) is taken. Hence SPCTIN, SPCCIN, SPCTEX and SPCCEX are not needed. On page 1 of the output sheets, they are shown as zero. Symbols TEMPLT and TEMPLC stand for the nuclear temperature given in Eqs.(2.46) or (2.49). In input data sheet, the symbols TEMX(1) and TEMX(6) correspond to TEMPLT and TEMPLC, respectively. (Figs. 1-a and 1-b)

6.2 Example-2

Except for NFLCR and NOUTPT, this has the same input data as Example-1. In this case, the resonance level-width fluctuation correction is selected: NFLCR$=-110$. Structure of NFLCR is divided into M$=-1$ and N$=10$. Hence, Q-factor for the resonance level interference is zero, and the degree of freedom for fluctuation is unity.

On pages 2 and 3 of the output sheets, results of the calculations with the optical model and γ-ray transmission coefficients are shown at 35 energy points. Since input energy points are 20 in this example, 15 energy points are generated internally in order to interpolate the neutron transmission coefficients for the calculations of inelastic scattering cross sections. Symbols T.G.1 and T.G.2 are the γ-ray transmission coefficients given in Eqs.(2.2) and (2.3), respectively, with the minimum value of spin J. These agree with T.GAM when neutron energy approaches zero. G.WIDTH is defined as an average of the γ-ray width Γ; $\{I\Gamma^{I-(1/2)}+(I+1)\Gamma^{I+(1/2)}\}/(2I+1)$. This corresponds to T.GAM$\cdot D/2\pi$, but with ρ^{-1} instead of D. With this relation, T.G.2 is given as $2\pi\rho$G.WIDTH.

Neutron strength functions SNl(1) and SNl(2) are defined as follows,

$$\mathrm{SN}l(1)=\{(l+1)T_l^{(+)}+l\,T_l^{(-)}\}/2\pi(2l+1)v_l\sqrt{E}\,,$$

$$\mathrm{SN}l(2)=\{(l+1)T_l^{(+)}+l\,T_l^{(-)}\}/2\pi(2l+1)2P_l\,,$$

where $P_l(x)=xv_l(x)$, and $v_l(x)$ is a quantity defined in Ref. 20). While SNl(1) is used as the neutron strength function for the analysis of experimental data, SNl(2) is defined as the pole strength function theoretically. (Figs. 2-a and 2-b)

6.3 Example-3

In this example, calculation is done at threshold energies for inelastic scattering, after the calculation at input energies is over. Since the energy is given in laboratory system, results for the threshold energies are also shown at energies of the laboratory system. They are printed out on page 4 of the output sheets.

Resonance level interference is taken into account in this case. NFLCR=1 consists of M=0 and N =1. This means that the degree of freedom for the level–width fluctuation is zero, with which no fluctuation is considered, while Q–factor for the level interference is calculated. Since the obtained Q–factors are variable depending on variety of the transmission coefficients for the related channels, they are not shown in the output sheets. (Figs. 3–a and 3–b)

6.4 Example–4

Cross sections for the competing processes mentioned in Section 2.2 are taken as input data above 800 keV. It must be kept in mind that COMPET(I) given in millibarns should be put in the right address corresponding with ENERGY(J), and NCOMPT$\neq$0.

In this example, both resonance interference and level–width fluctuation are calculated with NFLCR =10. The calculated Q–factors are not shown, with the same reason as mentioned above. (Figs. 4–a and 4–b)

6.5 Example–5

Experimental capture cross section of 8.867 millibarns at 50 keV is used for normalization. The obtained capture cross section at 50 keV is 8.8672 millibarns with good accuracy. Profile function of the Berman type is adopted in this calculation.

Normalization factors C_0's for the level density in Eq.(2.35) are calculated internally for both residual and compound nuclei, and CNORMT and CNORMC on page 1 of the output sheets are left zero. Since this page 1 is devoted to the list of the input data, they are left unchanged. Some data calculated internally are also shown on this page. (Figs. 5–a and 5–b)

6.6 Example–6

Cross sections of natural silver are obtained, after those for ^{107}Ag and ^{109}Ag are calculated. Experimental capture cross section of 0.174 barn at 800 keV is used for normalization. Results of the calculations for natural element are printed out on the last page. The calculated capture cross section at 800 keV is 0.1694 barn which agrees well within 3% with the experimental data. In this example, a common set of parameters of the optical potential is adopted for both isotopes, but, in general, it is also available to use different sets for different isotopes. (Figs. 6–a and 6–b)

6.7 Example–7

Well–depth parameters of the imaginary potential are changed at 6.0 MeV. Since the option of surface and volume absorption is adopted in this case, all of WIE, WSE, WIESQ and WSESQ are changed simultaneously. Hence, unchanged parameters must also be put in to reserve their values. In this example, only WSE of 0.074 below 6.0 MeV is replaced with −0.325 above 6.0 MeV, but WIE above 6.0 MeV is also put in the same value of 0.253 as that below 6.0 MeV. Since the other two parameters are zero and blank is also zero, they are left free. For the real part, as no parameters are changed, any data are not renewed. On page 1 of the output sheets, parameters of the real part are also printed out for information. Statement "ABOVE 0.0 MEV" means "no parameters change". (Figs. 7–a and 7–b)

6.8 Example-8

Calculation of γ-ray spectra for ^{238}U is performed at 0.02 eV. A part of the branching ratios between discrete levels of the compound nucleus ^{239}U are put in, and the rest are calculated. The former values are indicated with * on page 2 of the output sheets. Primary transition to the 16th and 17th levels is taken into account, respectively, with the branching ratios of 0.1 and 0.5. Population probability for continuous and discrete levels, partial and total spectra of γ-rays, etc. are printed out. Released energy of 4.8038 MeV for the total γ-ray is obtained, and it agrees well with the neutron separation energy of 4.803 MeV.

It should be noted that the ground-state spin and parity for the target and compound nuclei must be given as input in such a case as this calculation of γ-ray spectra, even if they have zero spin. (Figs. 8-a and 8-b)

6.9 Example-9

All branching ratios between discrete levels are calculated internally, and primary transition is considered, in this example. Total released energy of γ-rays is 4.8049 MeV which agrees well with the neutron separation energy within 0.04%. In this example, only information about total spectra is printed out. (Figs. 9-a and 9-b)

6.10 Example-10

Calculation of γ-ray spectra for ^{93}Nb is carried out at three points of neutron energy. Primary transitions to the 9th, 10th and 16th levels are taken into account at 0.0253 eV. Total released γ-ray energies for the three points of neutron incident energy are in good agreement with the neutron separation energy of 7.2289 MeV within 0.65%. (Figs. 10-a and 10-b)

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Appendix

Symbols used in the code are selectively tabulated for users' sake in this appendix. They are roughly arranged in an alphabetical order.

Symbol	Description
A(I)	Coefficients for Gaussian integration.
ADUM(I)	Temporary variables for arrangement of input data.
AVEGME	Averaged energy of total released γ-ray.
BDUM(I)	Temporary variables for arrangement of input data.
BFACT(I,J,K)	Phase factor of wave function[7]; $\exp(2i\,arg\,\phi_l^j(r_{mat}))$.
BIN	Energy bin for averaged γ-ray spectrum. Default value is 0.25MeV.
BLCMS(I,J)	Legendre coefficient B_L.
BYDNG(I,J)	Sum of the transmission coefficients for the primary γ-ray transition; ΣF_k in Eq.(3.14).
CEK	$\hbar^2/2\mu_0=20.90098$ MeV·fm^2
CENTFG(I)	$1/r^2$.
CLEVEL(I)	Energies of discrete levels for compound nucleus.
CM(I)	Temporary storage for Floating-point input data.
CMESH	Mesh size for solving wave functions; Δr.
CMSH2	$\mathrm{CMESH}^2=(\Delta r)^2$.
CMS12	$\mathrm{CMESH}^2/12=(\Delta r)^2/12$.
CNPROF	Normalization factor of profile function; C in Eq.(2.59).
COMPIN(I)	Temporary storage for COMPET(I) given in input.
CPRITY(I)	Parity of discrete levels for compound nucleus.
CPTRT	Rate of positive parity states for compound nucleus.
CSPO	Square of pion Compton wave length $(\hbar/m_\pi c)^2=2.04553$ fm^2.
CYDNG(I,J)	Sum of branching ratios for the primary γ-ray transitions; $\Sigma\beta_k$ in Eq.(3.15).
DBRNCH(I,J)	Branching ratios between discrete levels.
DENOM(I,J,K)	Denominator of transition rate in the Hauser-Feshbach formula.
DGFCM(I,J)	Integration of continuous levels. It is used to obtain an effective degree of freedom for resonance level-width fluctuation calculation.
DINTST(I)	Intensity of γ-rays emitted through transition between discrete levels.
DNMCJ0(I,J)	Denominator for normalization factor $C_0^{J\Pi}$ in Eq.(2.4).
DOBSCL	Calculated level spacing. It is used to obtain γ-ray strength function.
DPHI(I,J)	Derivatives of wave functions.
ECM	Neutron energy in center of mass system.
ECMAX	Maximum energy for generating tentative energy points internally for neutron transmission coefficients.
ECMS(I)	Neutron energies in center of mass system derived from input data.
ECMX(I)	Neutron energies in center of mass system including internally generated energy points.

Symbol	Description
ELAB(I)	Neutron energies in laboratory system derived from input data.
ELEVEL(I)	Energies of discrete levels for target nucleus.
EMAXGM(I)	Maximum energy of an interval in the continuous region in which γ-ray transition is calculated.
EMBAR(I)	Average cosine of scattering angle for differential elastic scattering cross section in laboratory system.
EMINGM(I)	Minimum energy of an interval in the continuous region in which γ-ray transition is calculated.
EMRED	Reduced mass of neutron.
ENDATA(I)	Default values of incident neutron energy.
ENEGW(I)	Temporary variables for rearranging incident energies in ascending order.
ENGAMR(I)	Default values of γ-ray energies for calculation of continuous spectra.
ENGSUM(I)	Released energy of continuous γ-rays in each interval.
ENGYIN(I)	Temporary storage for incident energies.
ENUEX(I)	Energy points for calculating population probabilities in continuum.
EWMIN	Minimum energy for generating tentative energy points internally for neutron transmission coefficients.
F(I)	Spherical Bessel function multiplied by its argument.
FACTSG	Coefficient $2\pi^2\hbar e^2(NZ/A)((1+0.8y)/m_nc)$ in Eq.(2.61).
FCHAGT	Atomic number of target nucleus.
FMASST	Mass number of target nucleus.
FP(I)	Derivative function of F(I).
FT(I)	Spherical Bessel function multiplied by its argument. This is used for calculation of pole strength function with a different argument from that of F(I), which is used for calculation of experimental strength function.
G(I)	Spherical Neumann function multiplied by its argument.
GAMENG(I)	Released energy of γ-rays emitted through transitions between discrete levels.
GAMSUM(I)	Integrated population probability of continuous γ-ray transitions in each interval.
GP(I)	Derivative function of G(I).
GT(I)	Spherical Neumann function multiplied by its argument. This is used for calculation of pole strength function with a different argument from that of G(I), which is used for calculation of experimental strength function.
HBARC2	$(\hbar c)^2=389386.9$ (MeV$^2\cdot$mb).
HCENM	$\hbar ce^2/m_nc^2=3.024231$ (MeV$\cdot$mb).
ICMAX	Two times of the maximum spin values of discrete levels in compound nucleus.
ICRITC	Indicator for inclusion or exclusion of overlapping levels in residual states.
IDENG(I)	Numbering of ascending order of ENERGY(I).
IDENTR(I)	Indicator for identification of input energy. If ECMX(I)=ECMS(J), IDENTR(I)=J. Otherwise, IDENTR(I)=0.
IDGCM(I,J)	Number of channels in residual nuclear states in continuum.
IEGMAX	Number of energy point for γ-ray spectrum calculation.

Symbol	Description
IELEV	Number of levels including tentative ones in continuum. This is used for counting levels at which transmission coefficients for inverse processes are calculated.
IENERG	Number of energy points for incident neutrons.
IENTRC	Number of energy points at which neutron transmission coefficients are calculated.
IJP(I,J)	Flag for calculation of Q–factor. If it is zero, no calculation is done. If non–zero, calculation is done.
IPNEN(I,J,K)	Number of incident energy points for use of interpolation of transmission coefficients.
IDJMX(I)	Two times of the maximum spin at a temporary state I in continuum.
JMAX	Two times of the maximum total spin J.
JJMAX	Two times of the maximum total spin J. These two are used as mutual supporters.
JMIN	Two times of the minimum total spin J. For even nucleus, it is unity, and for odd nucleus, it is zero.
JOUTPT(I)	Control index for calling subroutines OUTPT1～5.
KIBRD(I,J)	Index on branching ratios for γ–ray transition between discrete levels I and J. If it is zero, no input data are given. If it is non–zero, input data are given.
LEV	Number of discrete levels in residual nucleus for which cross–section calculations are possible.
LEV0	Number of levels for cross–section calculations.
LEVN	Number of levels including overlapping region for which inelastic scattering cross sections are calculated.
LMAX	Maximum angular momentum quantum number for calculation of the spherical Bessel and Neumann functions.
LMAXC	Maximum angular momentum quantum number for calculation of cross sections.
MAXDLI	Maximum number of discrete γ–ray transitions.
MAXSUM	Maximum number of γ–ray transitions in continuum.
MESHIN	Tentative storage for energy index NEMESH. It is taken in the second run at threshold energies for an isotope.
NENOT	Number of energy points in continuum for calculation of population probability.
NINT	Number of mesh points for integration of wave equation.
NINTG	Number of mesh points for generating wave functions and their derivatives.
NMASSC	Mass number of compound nucleus.
NPARTY	Number of positive parity states in discrete levels of residual nucleus.
OUTNGN(I,J)	Tentative storage for calculated cross sections of natural element.
PARITY(I)	Parity of discrete levels in residual nucleus.
PENN(I,J,K)	Interpolated values of transmission coefficients.
PENOM(I,J)	Temporary storage for denominator in transition rates.
PHI(I,J,K)	Wave functions near matching radius.
PHIJ(I,J)	Wave functions.

Symbol	Description
POPULD(I)	Population probability for discrete levels.
POPULP(I,J,K)	Population probability for levels in continuum.
PSLMAX(I)	Maximum angular momentum quantum number at energies for interpolation.
PENNOV(I,J,K,L)	Transmission coefficients for overlapping levels.
QFACT(I,J)	Q–factor for resonance level interference.
REACT(I)	Reaction cross section σ_R.
RENFCT(I)	Renormalization coefficient $C_0^{J\Pi}$ in Eq.(2.4), or γ–ray strength function.
ROHMA	Matching radius R_{mat} times wave number k.
RIMI	RI times $A^{1/3}$.
RIMS	RS times $A^{1/3}$.
RMAT	Matching radius R_{mat}.
RRE	R0 times $A^{1/3}$.
RRSO	RSO times $A^{1/3}$.
SIGAMM(I)	Storage for capture cross section.
SIGEL(I)	Storage for shape elastic scattering cross section.
SIGELC(I)	Storage for compound elastic scattering cross section.
SIGELS	Shape elastic scattering cross section.
SIGGAM	Capture cross section.
SIGSP(I,J)	s– and p–wave components of capture cross section.
SINELA(I)	Storage for inelastic scattering cross section.
SINELL(I)	Excitation function given in Eq.(2.16).
SJMAX0	Maximum value of total spin.
SLMAX(I)	Storage for the maximum angular momentum quantum number.
SPCCEX	Equivalent to SPCCIN in Eqs.(2.55), (2.56) and (2.58).
SPCTEX	Equivalent to SPCTIN in Eqs.(2.55), (2.56) and (2.57).
SPCTGM(I)	Intensity of γ–rays emitted from transitions betweem artificial levels in continuum.
SPIN	Spin of neutron.
SPINC(I)	Spin of discrete levels in compound nucleus.
SPINCG	Spin cutoff factor used in constant temperature model.
SPINEC	Spin cutoff factor $\sigma_M^2\ (U_0)$ in Eqs.(2.54) and (2.55).
SPINL(I)	Spin of discrete levels in residual nucleus.
SPINRM(I,J)	$\rho_c^J\,(B_n) \Big/ \sum_{J'=\lvert I-1\rvert}^{I+1} \rho_c^{J'}(B_n)$.
SSIGR	Compound nucleus formation cross section.
STRFNC(I,J,K)	Neutron strength function.
SYMELM(I)	Symbol of element.
TENN(I,J,K)	Neutron transmission coefficients.
TGMNCL	Calculated γ–ray strength function. It is used for normalization.
THETA(I,J,K)	Modified neutron transmission coefficients defined in Eq.(2.18).
THGAM(I,J)	Modified γ–ray transmission coefficients with $i=1$ in Eq.(2.19).
THGAMD(I,J)	Modified γ–ray transmission coefficients with $i=2$ in Eq.(2.19).
TNRATE(I)	Cross section $\Delta\sigma$ of competing processes shown in Eq.(2.15).
TRGAM(I,J,K)	γ–ray transmission coefficients defined in Eqs.(2.2) and (2.3).
VSPO	Strength of real spin–orbit potential.

Symbol	Description
VRE	Strength of real optical potential.
WDGMCL	Calculated γ–ray width for normalization.
WIMI	Strength of volume term in imaginary potential.
WIDGAM(I)	Averaged γ–ray width.
WIMS	Strength of surface term in imaginary potential.
WSPO	Strength of imaginary spin–orbit potential.
WVNO	Wave number k.
WVNOSQ	Square of wave number.
YETAI(I,J)	Imaginary part of scattering amplitude; $-Im(\eta_l^j)$.
YETAR(I,J)	Real part of scattering amplitude; $1-Re(\eta_l^j)$.

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Table 1. A tabular form of input data. Descriptions of variables are explained in Chapter 5.

5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
NISOTP	NOMLIZ	NOUTPT	NFOLLW					TITLE							
ENORM		SIGNRN		RATIO											
NODATA	NCHAGT	NMASST	NABUND	NLEVEL	NIMAG	NPROF	NFLCR	NLEVCM	NCASCD	NEMESH	NLVDNT	NLVDNC	NPMFIX	NCOMPT	NTEMPI
	1	EMTARG		EMIN		SEPAR		R0EXP		PMESH					
	6	R0		RI		RS		RSO		TEMP1					
	11	A0		A1		B		ASO		TEMP2					
	16	V		WI		WS		VSO		WSO					
	21	VE		WIE		WSE		VSOE		WSOE					
	26	VESQ		WIESQ		WSESQ		VSOESQ		WSOESQ					
	31	VSYM		ECRITC		RATIO		SPCTIN		SPCCIN					
	36	ELESPN(1) →													
	⟆														
	61									→ ELESPN(30)					
	66	DNPART		SPINCT		PAIRNT		CNORMT		EJOINT					
	71	DNPARC		SPINCC		PAIRNC		CNORMC		EJOINC					
	76	ENORML		SIGNRN		TGMNRN		DOBSRN		WDGMRN					
	81	EGIANT		WGIANT		PARA1		PARA2		EXCHNG					
	86	EGBERM		WGBERM		SIGBM1		SIGBM2		ECCRIT					
	91	TEMX(1) →													
	96									→ TEMX(10)					
	101	ENERGY(1) →													
	⟆														
	146									→ ENERGY(50)					
	151	COMPET(1) →													
	⟆														
	196									→ COMPET(50)					
	201	CLESPN(1) →													
	⟆														
	226									→ CLESPN(30)					
NBRNCH		ICARD		ENHE1		ENHM1		ENHE2		ENHSHR		BIN			
	1	LEVH(1)	LEVL(1) →									LEVH(6)	LEVL(6)		
	1	BRANCH(1) →										BRANCH(6)			
	⟆														
	10										→	LEVH(60)	LEVL(60)		
	10										→	BRANCH(60)			
LEVB		BRNCP(1) →								→ BRNCP(5)		ENGBC			

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
    1    1    1       EXAMPLE-1, W-184 CROSS SECTION, E=1KEV TO 10MEV
   17   74  184          13    5    1                  -20    1    1
         1 184.0                  5.7497
         6  1.26      1.28        1.28       1.26
        11  0.63      0.47        0.47       0.63
        16 46.79      3.365       8.7        6.0
        21 -0.25      0.4        -1.87
        32  2.0
        36  0.0   + 0 0.1112+ 2 0.3641+ 4 0.7483+ 6 0.9033+ 2
        41 1.1214+ 2 1.2213- 3 1.2523+ 8 1.2850- 5 1.3863+ 2
        46 1.4310+ 2 1.5015- 7 1.8613+10
        66 21.0508    13.1803   1.30      3478.81   4.6152
        71 21.1312    13.2533   0.72      3511.09   4.0308
        79 95.5       0.081
        85 0.4
       101 0.001      0.005     0.01      0.03      0.05
       106 0.08       0.1       0.2       0.3       0.5
       111 0.6        0.7       0.8       1.0       2.0
       116 3.0        5.0       6.0       8.0      10.0
```

Fig. 1–a The input data of calculation for cross sections of ^{184}W selecting Hauser–Feshbach option (Example–1).

```
EXAMPLE-1, W-184 CROSS SECTION, E=1KEV TO 10MEV                                                             PAGE    1

 TARGET NUCLEUS ... W  184      NUCLEAR MASS ... 184.000      SEPARATION ENERGY ...   5.7497  MEV

  HAUSER-FESHBACH THEORY USED
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

             .......... POTENTIAL PARAMETERS ..........                                  .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.260   RI    = 1.280   RS    = 1.280   RSO    = 1.260                         DNPART =  21.0508    DNPARC =  21.1312
  AO  =  0.630   A1    = 0.470   B     = 0.470   ASO    = 0.630                         SPINCT =  13.1803    SPINCC =  13.2533
  V   = 46.790   WI    = 3.365   WS    = 8.700   VSO    = 6.000   WSO    = 0.0          PAIRNT =   1.3000    PAIRNC =   0.7200
  VE  = -0.250   WIE   = 0.400   WSE   =-1.870   VSOE   = 0.0     WSOE   = 0.0          CNORMT =3478.8100    CNORMC =3511.0900
  VESQ=  0.0     WIESQ= 0.0      WSESQ= 0.0      VSOESQ= 0.0      WSOESQ= 0.0           EJOINT =   4.6152    EJOINC =   4.0308
  VSYM=  0.0                                                                            SPCTIN =   0.0       SPCCIN =   0.0
                 NIMAG ... 5                                                            NLVDNT .....  1      NLVDNC .....  1

                                                                                        TEMPLT =   0.5218    TEMPLC =   0.5202
                                                                                        TNORMT =   3.2608    TNORMC =   4.9780
                                                                                        SPCTEX =   0.0       SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.0     MEV   CROSS SECTION=   0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0         D.OBS. =    95.50 EV  GAM.WIDTH =  0.0810 EV
   CALCULATED ONES  ... T.GAM= 5.329D-03   D.CAL. =     0.0  EV  GAM.WIDTH =  0.0    EV   NORMALIZATION FACTOR ... 5.3292D-03

  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BRINK
   ENERGY = 14.04 MEV   WIDTH = 5.000 MEV   PARA1 = 0.0     PARA2 = 0.0     EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN   PARITY      NO    ENERGY   SPIN   PARITY      NO    ENERGY   SPIN   PARITY
    0   0.0        0.0     +          1   0.11120    2.0     +          2   0.36410    4.0     +
    3   0.74830    6.0     +          4   0.90330    2.0     +          5   1.12140    2.0     +
    6   1.22130    3.0     -          7   1.25230    8.0     +          8   1.28500    5.0     -
    9   1.38630    2.0     +         10   1.43100    2.0     +         11   1.50150    7.0     -
   12   1.86130   10.0     +

  LEVELS ABOVE 2.000MEV ARE ASSUMED TO BE OVERLAPPING

  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    1.0000D-03  5.0000D-03  1.0000D-02  3.0000D-02  5.0000D-02  8.0000D-02  1.0000D-01  2.0000D-01  3.0000D-01  5.0000D-01
    6.0000D-01  7.0000D-01  8.0000D-01  1.0000D+00  2.0000D+00  3.0000D+00  5.0000D+00  6.0000D+00  8.0000D+00  1.0000D+01
```

Fig. 1–b The output of Example-1.

```
EXAMPLE-1, W-184 CROSS SECTION, E=1KEV TO 10MEV                                                    PAGE    2

  TARGET NUCLEUS ... W  184

 CALCULATED CROSS SECTIONS IN MILLI-BARNS

 RUNNING TIME .....     7.24  SEC.
```

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
1.0000D-03	3.3771D+03	4.1749D+04	0.0	3.6030D+04	4.5126D+04	3.9868D-03	3.2004D+03	1.7671D+02
5.0000D-03	1.0313D+03	2.3614D+04	0.0	1.5893D+04	2.4645D+04	6.5547D-03	6.7729D+02	3.5205D+02
1.0000D-02	7.6417D+02	1.8963D+04	0.0	1.1241D+04	1.9727D+04	1.0754D-02	3.4596D+02	4.1275D+02
3.0000D-02	5.0278D+02	1.4033D+04	0.0	6.7314D+03	1.4536D+04	3.0443D-02	1.2125D+02	3.5417D+02
5.0000D-02	4.0608D+02	1.2403D+04	0.0	5.4749D+03	1.2810D+04	5.0657D-02	7.5853D+01	2.7507D+02
8.0000D-02	3.5252D+02	1.1104D+04	0.0	4.6588D+03	1.1456D+04	7.9214D-02	5.0322D+01	2.0499D+02
1.0000D-01	3.3922D+02	1.0531D+04	0.0	4.3646D+03	1.0871D+04	9.6627D-02	4.1859D+01	1.7673D+02
2.0000D-01	1.1376D+02	8.1692D+03	9.5215D+02	3.7551D+03	9.2351D+03	1.7866D-01	2.5036D+01	7.1193D+01
3.0000D-01	9.0328D+01	6.9042D+03	1.4156D+03	3.5725D+03	8.4101D+03	2.4150D-01	1.9152D+01	4.6816D+01
5.0000D-01	8.4841D+01	5.5594D+03	1.9051D+03	3.4667D+03	7.5493D+03	3.3087D-01	1.3997D+01	3.5301D+01
6.0000D-01	8.6964D+01	5.1677D+03	2.0431D+03	3.4417D+03	7.2978D+03	3.6567D-01	1.2735D+01	3.4162D+01
7.0000D-01	9.0872D+01	4.8796D+03	2.1399D+03	3.4171D+03	7.1103D+03	3.9659D-01	1.1972D+01	3.4168D+01
8.0000D-01	9.6466D+01	4.6639D+03	2.2084D+03	3.3910D+03	6.9688D+03	4.2450D-01	1.1566D+01	3.4874D+01
1.0000D+00	1.0264D+02	4.3150D+03	2.3630D+03	3.3355D+03	6.7807D+03	4.7953D-01	1.1453D+01	3.5229D+01
2.0000D+00	1.3360D+02	3.6948D+03	2.8189D+03	3.1955D+03	6.6473D+03	6.7438D-01	9.4124D+00	2.6799D+01
3.0000D+00	4.8203D+01	3.5032D+03	3.0864D+03	3.1620D+03	6.6378D+03	7.8877D-01	2.5590D+00	8.2633D+00
5.0000D+00	5.5013D+00	2.9794D+03	3.1513D+03	3.1572D+03	6.1362D+03	8.4740D-01	1.9038D-01	5.8721D-01
6.0000D+00	1.8480D+00	2.6582D+03	3.1205D+03	3.1224D+03	5.7805D+03	8.5061D-01	5.5484D-02	1.7124D-01
8.0000D+00	2.5672D-01	2.3205D+03	3.0099D+03	3.0101D+03	5.3306D+03	8.5472D-01	6.3377D-03	1.9726D-02
1.0000D+01	5.6255D-02	2.2679D+03	2.9541D+03	2.9542D+03	5.2221D+03	8.7961D-01	1.1718D-03	3.6373D-03

Fig. 1-b The output of Example-1 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
   1    1   11      EXAMPLE-2, W-184 CROSS SECTION, E=1KEV TO 10MEV
  17   74  184         13    5    1 -110               -20    1    1
         1 184.0                 5.7497
         6  1.26       1.28       1.28      1.26
        11  0.63       0.47       0.47      0.63
        16 46.79       3.365      8.7       6.0
        21 -0.25       0.4       -1.87
        32  2.0
        36  0.0    + 0 0.1112+ 2 0.3641+ 4 0.7483+ 6 0.9033+ 2
        41 1.1214+ 2 1.2213- 3 1.2523+ 8 1.2850- 5 1.3863+ 2
        46 1.4310+ 2 1.5015- 7 1.8613+10
        66 21.0508    13.1803    1.30      3478.81    4.6152
        71 21.1312    13.2533    0.72      3511.09    4.0308
        79 95.5       0.081
        85 0.4
       101 0.001      0.005      0.01      0.03      0.05
       106 0.08       0.1        0.2       0.3       0.5
       111 0.6        0.7        0.8       1.0       2.0
       116 3.0        5.0        6.0       8.0      10.0
```

Fig. 2–a The input data with resonance level–width fluctuation option (Example 2).

```
EXAMPLE-2, W-184 CROSS SECTION, E=1KEV TO 10MEV                                                              PAGE    1

 TARGET NUCLEUS ... W  184     NUCLEAR MASS ... 184.000     SEPARATION ENERGY ...   5.7497  MEV

  MOLDAUER THEORY USED           DEG. OF FREEDOM ...   1.00           Q-FACTOR ...   0.0
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

                .......... POTENTIAL PARAMETERS ..........                                        .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.260    RI    = 1.280    RS    = 1.280    RSO    = 1.260                        DNPART =  21.0508    DNPARC =  21.1312
  AO  =  0.630    A1    = 0.470    B     = 0.470    ASO    = 0.630                        SPINCT =  13.1803    SPINCC =  13.2533
  V   = 46.790    WI    = 3.365    WS    = 8.700    VSO    = 6.000   WSO    = 0.0         PAIRNT =   1.3000    PAIRNC =   0.7200
  VE  = -0.250    WIE   = 0.400    WSE   =-1.870    VSOE   = 0.0     WSOE   = 0.0         CNORMT =3478.8100   CNORMC =3511.0900
  VESQ=  0.0      WIESQ= 0.0       WSESQ= 0.0       VSOESQ= 0.0      WSOESQ= 0.0          EJOINT =   4.6152   EJOINC =   4.0308
  VSYM=  0.0                                                                              SPCTIN =   0.0      SPCCIN =   0.0
                  NIMAG ... 5                                                             NLVDNT .....  1     NLVDNC .....  1

                                                                                          TEMPLT =    0.5218  TEMPLC =    0.5202
                                                                                          TNORMT =    3.2608  TNORMC =    4.9780
                                                                                          SPCTEX =    0.0     SPCCEX =    0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.0     MEV   CROSS SECTION=    0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0          D.OBS. =     95.50 EV  GAM.WIDTH =  0.0810 EV
   CALCULATED ONES  ... T.GAM= 5.329D-03    D.CAL. =      0.0  EV  GAM.WIDTH =  0.0    EV   NORMALIZATION FACTOR ... 5.3292D-03


  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BRINK
   ENERGY = 14.04 MEV    WIDTH = 5.000 MEV    PARA1 = 0.0      PARA2 = 0.0      EXCHNG = 0.400
  LEVEL PARAMETERS
   NO     ENERGY   SPIN   PARITY       NO     ENERGY   SPIN   PARITY       NO     ENERGY   SPIN   PARITY
    0   0.0         0.0     +           1   0.11120    2.0     +           2   0.36410    4.0     +
    3   0.74830     6.0     +           4   0.90330    2.0     +           5   1.12140    2.0     +
    6   1.22130     3.0     -           7   1.25230    8.0     +           8   1.28500    5.0     -
    9   1.38630     2.0     +          10   1.43100    2.0     +          11   1.50150    7.0     -
   12   1.86130    10.0     +

   LEVELS ABOVE 2.000MEV ARE ASSUMED TO BE OVERLAPPING


  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    1.0000D-03  5.0000D-03  1.0000D-02  3.0000D-02  5.0000D-02  8.0000D-02  1.0000D-01  2.0000D-01  3.0000D-01  5.0000D-01
    6.0000D-01  7.0000D-01  8.0000D-01  1.0000D+00  2.0000D+00  3.0000D+00  5.0000D+00  6.0000D+00  8.0000D+00  1.0000D+01
```

Fig. 2–b The output of Example–2.

EXAMPLE-2, W-184 CROSS SECTION, E=1KEV TO 10MEV PAGE 2

TARGET NUCLEUS ... W 184

***** NEUTRON TRANSMISSION COEFFICIENTS *****

ENERGY	SIG.T.	SIG.E.S.	SIG.C.	TO	T1(+)	T1(-)	T2(+)	T2(-)	T3(+)	T3(-)
1.023D-04	1.2357D+05	9.2800D+03	1.1429D+05	1.7756D-02	3.0443D-06	2.8162D-06	1.7854D-10	1.7649D-10	1.1934D-15	9.3331D-16
3.228D-04	7.3181D+04	9.2136D+03	6.3968D+04	3.1321D-02	1.7052D-05	1.5774D-05	3.1562D-09	3.1202D-09	6.6376D-14	5.1888D-14
9.641D-04	4.5807D+04	9.1015D+03	3.6705D+04	5.3514D-02	8.7892D-05	8.1299D-05	4.8642D-08	4.8091D-08	3.0489D-12	2.3824D-12
1.000D-03	4.5126D+04	9.0966D+03	3.6030D+04	5.4473D-02	9.2833D-05	8.5870D-05	5.3290D-08	5.2687D-08	3.4643D-12	2.7069D-12
2.727D-03	3.0534D+04	8.9166D+03	2.1617D+04	8.8342D-02	4.1613D-04	3.8487D-04	6.5308D-07	6.4583D-07	1.1565D-10	9.0334D-11
5.000D-03	2.4645D+04	8.7518D+03	1.5893D+04	1.1773D-01	1.0273D-03	9.4998D-04	2.9672D-06	2.9351D-06	9.6420D-10	7.5295D-10
7.300D-03	2.1759D+04	8.6186D+03	1.3140D+04	1.4045D-01	1.8017D-03	1.6658D-03	7.6259D-06	7.5460D-06	3.6230D-09	2.8288D-09
1.000D-02	1.9727D+04	8.4857D+03	1.1241D+04	1.6234D-01	2.8681D-03	2.6513D-03	1.6701D-05	1.6532D-05	1.0885D-08	8.4975D-09
1.851D-02	1.6516D+04	8.1519D+03	8.3639D+03	2.1415D-01	7.0604D-03	6.5235D-03	7.7142D-05	7.6449D-05	9.3503D-08	7.2955D-08
3.000D-02	1.4536D+04	7.8043D+03	6.7314D+03	2.6424D-01	1.4136D-02	1.3054D-02	2.5509D-04	2.5320D-04	5.0465D-07	3.9346D-07
4.441D-02	1.3183D+04	7.4538D+03	5.7289D+03	3.1161D-01	2.4515D-02	2.2624D-02	6.7008D-04	6.6645D-04	1.9799D-06	1.5423D-06
5.000D-02	1.2810D+04	7.3346D+03	5.4749D+03	3.2713D-01	2.8857D-02	2.6627D-02	8.9577D-04	8.9162D-04	2.9902D-06	2.3284D-06
8.000D-02	1.1456D+04	6.7972D+03	4.6588D+03	3.9423D-01	5.4054D-02	4.9838D-02	2.8074D-03	2.8065D-03	1.5292D-05	1.1885D-05
1.000D-01	1.0871D+04	6.5061D+03	4.3646D+03	4.2905D-01	7.1845D-02	6.6220D-02	4.7949D-03	4.8073D-03	3.3104D-05	2.5695D-05
1.009D-01	1.0848D+04	6.4938D+03	4.3537D+03	4.3051D-01	7.2667D-02	6.6977D-02	4.9000D-03	4.9134D-03	3.4162D-05	2.6514D-05
2.000D-01	9.2351D+03	5.4800D+03	3.7551D+03	5.4745D-01	1.6106D-01	1.4843D-01	2.4005D-02	2.4428D-02	3.5858D-04	2.7649D-04
2.171D-01	9.0596D+03	5.3507D+03	3.7089D+03	5.6220D-01	1.7556D-01	1.6182D-01	2.8814D-02	2.9397D-02	4.7417D-04	3.6519D-04
3.000D-01	8.4101D+03	4.8376D+03	3.5725D+03	6.2127D-01	2.4136D-01	2.2269D-01	5.7757D-02	5.9640D-02	1.4185D-03	1.0863D-03
4.421D-01	7.7362D+03	4.2517D+03	3.4845D+03	6.9202D-01	3.3650D-01	3.1120D-01	1.2355D-01	1.2997D-01	5.1719D-03	3.9218D-03
5.000D-01	7.5493D+03	4.0826D+03	3.4667D+03	7.1397D-01	3.6962D-01	3.4219D-01	1.5381D-01	1.6288D-01	7.7473D-03	5.8509D-03
6.000D-01	7.2978D+03	3.8560D+03	3.4417D+03	7.4570D-01	4.2051D-01	3.9001D-01	2.0781D-01	2.2225D-01	1.3994D-02	1.0495D-02
7.000D-01	7.1103D+03	3.6933D+03	3.4171D+03	7.7148D-01	4.6465D-01	4.3172D-01	2.6155D-01	2.8203D-01	2.2866D-02	1.7035D-02
8.000D-01	6.9688D+03	3.5779D+03	3.3910D+03	7.9285D-01	5.0326D-01	4.6841D-01	3.1313D-01	3.3987D-01	3.4699D-02	2.5685D-02
8.525D-01	6.9087D+03	3.5322D+03	3.3765D+03	8.0265D-01	5.2165D-01	4.8595D-01	3.3893D-01	3.6895D-01	4.2178D-02	3.1122D-02
1.000D+00	6.7807D+03	3.4451D+03	3.3355D+03	8.2603D-01	5.6757D-01	5.2999D-01	4.0594D-01	4.4471D-01	6.8081D-02	4.9828D-02

***** NEUTRON STRENGTH FUNCTIONS *****

ENERGY	T.G.1	T.G.2	G.WIDTH	SNO(1)	SNO(2)	SN1(1)	SN1(2)	SN2(1)	SN2(2)	SN3(1)	SN3(2)
1.023D-04	5.330D-03	5.330D-03	9.406D-02	2.802D-04	3.018D-02	2.142D-05	2.308D-03	0.0	0.0	0.0	0.0
3.228D-04	5.332D-03	5.332D-03	9.407D-02	2.782D-04	3.104D-02	2.305D-05	2.571D-03	0.0	0.0	0.0	0.0
9.641D-04	5.339D-03	5.339D-03	9.408D-02	2.750D-04	3.175D-02	2.493D-05	2.877D-03	0.0	0.0	0.0	0.0
1.000D-03	5.339D-03	5.339D-03	9.408D-02	2.749D-04	3.177D-02	2.500D-05	2.889D-03	0.0	0.0	0.0	0.0
2.727D-03	5.357D-03	5.357D-03	9.413D-02	2.700D-04	3.224D-02	2.731D-05	3.261D-03	0.0	0.0	0.0	0.0
5.000D-03	5.381D-03	5.381D-03	9.419D-02	2.657D-04	3.237D-02	2.925D-05	3.563D-03	8.800D-06	1.072D-03	0.0	0.0
7.300D-03	5.404D-03	5.404D-03	9.425D-02	2.623D-04	3.237D-02	3.080D-05	3.801D-03	9.355D-06	1.154D-03	0.0	0.0
1.000D-02	5.433D-03	5.433D-03	9.432D-02	2.591D-04	3.232D-02	3.238D-05	4.039D-03	9.881D-06	1.233D-03	0.0	0.0
1.851D-02	5.522D-03	5.522D-03	9.454D-02	2.512D-04	3.202D-02	3.657D-05	4.660D-03	1.116D-05	1.422D-03	0.0	0.0
3.000D-02	5.645D-03	5.645D-03	9.484D-02	2.435D-04	3.156D-02	4.129D-05	5.353D-03	1.253D-05	1.624D-03	0.0	0.0
4.441D-02	5.803D-03	5.803D-03	9.523D-02	2.360D-04	3.103D-02	4.641D-05	6.102D-03	1.406D-05	1.848D-03	0.0	0.0
5.000D-02	5.866D-03	5.866D-03	9.538D-02	2.335D-04	3.083D-02	4.821D-05	6.367D-03	1.463D-05	1.931D-03	0.0	0.0
8.000D-02	6.213D-03	6.213D-03	9.618D-02	2.224D-04	2.989D-02	5.667D-05	7.614D-03	1.764D-05	2.370D-03	1.652D-06	2.220D-04
1.000D-01	6.456D-03	6.456D-03	9.673D-02	2.165D-04	2.934D-02	6.138D-05	8.316D-03	1.967D-05	2.665D-03	1.820D-06	2.465D-04
1.009D-01	6.467D-03	6.467D-03	9.675D-02	2.163D-04	2.931D-02	6.158D-05	8.346D-03	1.976D-05	2.678D-03	1.827D-06	2.477D-04
2.000D-01	7.815D-03	7.816D-03	9.953D-02	1.954D-04	2.717D-02	7.775D-05	1.081D-02	3.045D-05	4.235D-03	2.700D-06	3.755D-04
2.171D-01	8.074D-03	8.075D-03	1.000D-01	1.926D-04	2.687D-02	7.969D-05	1.112D-02	3.237D-05	4.516D-03	2.866D-06	4.000D-04
3.000D-01	9.453D-03	9.457D-03	1.025D-01	1.810D-04	2.558D-02	8.685D-05	1.227D-02	4.173D-05	5.896D-03	3.771D-06	5.329D-04
4.421D-01	1.236D-02	1.238D-02	1.069D-01	1.661D-04	2.383D-02	9.348D-05	1.341D-02	5.683D-05	8.153D-03	5.762D-06	8.266D-04
5.000D-01	1.378D-02	1.381D-02	1.087D-01	1.611D-04	2.323D-02	9.496D-05	1.369D-02	6.230D-05	8.981D-03	6.750D-06	9.731D-04
6.000D-01	1.659D-02	1.667D-02	1.121D-01	1.536D-04	2.231D-02	9.650D-05	1.401D-02	7.059D-05	1.025D-02	8.710D-06	1.265D-03
7.000D-01	1.994D-02	2.011D-02	1.156D-01	1.472D-04	2.150D-02	9.715D-05	1.420D-02	7.736D-05	1.131D-02	1.099D-05	1.606D-03
8.000D-01	2.389D-02	2.424D-02	1.192D-01	1.415D-04	2.079D-02	9.724D-05	1.429D-02	8.272D-05	1.215D-02	1.358D-05	1.996D-03
8.525D-01	2.624D-02	2.673D-02	1.211D-01	1.387D-04	2.044D-02	9.713D-05	1.431D-02	8.501D-05	1.252D-02	1.506D-05	2.219D-03
1.000D+00	3.399D-02	3.514D-02	1.269D-01	1.318D-04	1.955D-02	9.641D-05	1.430D-02	8.983D-05	1.332D-02	1.960D-05	2.906D-03

Fig. 2–b The output of Example-2 (continued).

EXAMPLE-2, W-184 CROSS SECTION, E=1KEV TO 10MEV PAGE 3

TARGET NUCLEUS ... W 184

***** NEUTRON TRANSMISSION COEFFICIENTS *****

ENERGY	SIG.T.	SIG.E.S.	SIG.C.	TO	T1(+)	T1(-)	T2(+)	T2(-)	T3(+)	T3(-)
1.556D+00	6.6241D+03	3.3982D+03	3.2260D+03	8.7928D-01	6.8899D-01	6.4838D-01	5.8661D-01	6.4876D-01	2.2589D-01	1.6281D-01
2.000D+00	6.6473D+03	3.4518D+03	3.1955D+03	8.9997D-01	7.5122D-01	7.1059D-01	6.7072D-01	7.4169D-01	3.9188D-01	2.8457D-01
2.690D+00	6.6651D+03	3.4922D+03	3.1729D+03	9.1315D-01	8.1584D-01	7.7701D-01	7.4402D-01	8.1884D-01	6.3455D-01	4.7781D-01
3.000D+00	6.6378D+03	3.4758D+03	3.1620D+03	9.1451D-01	8.3674D-01	7.9912D-01	7.6360D-01	8.3789D-01	7.2139D-01	5.5475D-01
4.401D+00	6.3327D+03	3.1807D+03	3.1521D+03	9.0222D-01	8.9434D-01	8.6350D-01	8.0310D-01	8.6656D-01	9.3731D-01	7.9120D-01
5.000D+00	6.1362D+03	2.9789D+03	3.1572D+03	9.0097D-01	9.1167D-01	8.8430D-01	8.1685D-01	8.7162D-01	9.6885D-01	8.4978D-01
6.000D+00	5.7805D+03	2.6581D+03	3.1224D+03	9.1095D-01	9.3756D-01	9.1595D-01	8.4664D-01	8.8705D-01	9.9006D-01	9.1491D-01
6.818D+00	5.5467D+03	2.4747D+03	3.0720D+03	9.1872D-01	9.5216D-01	9.3462D-01	8.6685D-01	8.9817D-01	9.9480D-01	9.4553D-01
8.000D+00	5.3306D+03	2.3205D+03	3.0101D+03	9.2923D-01	9.6647D-01	9.5384D-01	8.9121D-01	9.1245D-01	9.9454D-01	9.7032D-01
1.000D+01	5.2221D+03	2.2679D+03	2.9542D+03	9.4486D-01	9.7998D-01	9.7331D-01	9.2281D-01	9.3267D-01	9.8993D-01	9.8771D-01

***** NEUTRON STRENGTH FUNCTIONS *****

ENERGY	T.G.1	T.G.2	G.WIDTH	SNO(1)	SNO(2)	SN1(1)	SN1(2)	SN2(1)	SN2(2)	SN3(1)	SN3(2)
1.556D+00	8.405D-02	9.679D-02	1.511D-01	1.125D-04	1.699D-02	9.150D-05	1.382D-02	9.451D-05	1.427D-02	3.959D-05	5.979D-03
2.000D+00	1.596D-01	2.128D-01	1.737D-01	1.016D-04	1.550D-02	8.715D-05	1.330D-02	9.154D-05	1.397D-02	5.476D-05	8.359D-03
2.690D+00	3.825D-01	6.975D-01	2.145D-01	8.886D-05	1.374D-02	8.092D-05	1.251D-02	8.425D-05	1.303D-02	7.079D-05	1.094D-02
3.000D+00	5.443D-01	1.173D+00	2.351D-01	8.426D-05	1.309D-02	7.840D-05	1.218D-02	8.088D-05	1.256D-02	7.479D-05	1.162D-02
4.401D+00	2.143D+00	1.101D+01	3.463D-01	6.863D-05	1.084D-02	6.879D-05	1.087D-02	6.763D-05	1.068D-02	7.738D-05	1.222D-02
5.000D+00	3.558D+00	2.733D+01	4.033D-01	6.430D-05	1.022D-02	6.572D-05	1.044D-02	6.373D-05	1.013D-02	7.483D-05	1.189D-02
6.000D+00	7.759D+00	1.178D+02	5.120D-01	5.935D-05	9.508D-03	6.166D-05	9.878D-03	5.926D-05	9.494D-03	6.975D-05	1.117D-02
6.818D+00	1.408D+01	3.709D+02	6.143D-01	5.615D-05	9.049D-03	5.872D-05	9.463D-03	5.633D-05	9.077D-03	6.566D-05	1.058D-02
8.000D+00	3.208D+01	1.821D+03	7.850D-01	5.243D-05	8.512D-03	5.501D-05	8.931D-03	5.286D-05	8.582D-03	6.041D-05	9.808D-03
1.000D+01	1.239D+02	2.303D+04	1.142D+00	4.768D-05	7.824D-03	4.988D-05	8.184D-03	4.834D-05	7.931D-03	5.343D-05	8.766D-03

Fig. 2-b The output of Example-2 (continued).

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EXAMPLE-2, W-184 CROSS SECTION, E=1KEV TO 10MEV                                    PAGE    4

  TARGET NUCLEUS ... W  184

 CALCULATED CROSS SECTIONS IN MILLI-BARNS
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ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
1.0000D-03	2.5948D+03	4.2531D+04	0.0	3.6030D+04	4.5126D+04	3.9806D-03	2.4218D+03	1.7297D+02
5.0000D-03	8.5013D+02	2.3795D+04	0.0	1.5893D+04	2.4645D+04	6.5317D-03	5.4701D+02	3.0118D+02
1.0000D-02	6.0663D+02	1.9121D+04	0.0	1.1241D+04	1.9727D+04	1.0693D-02	2.8637D+02	3.1481D+02
3.0000D-02	3.7170D+02	1.4164D+04	0.0	6.7314D+03	1.4536D+04	3.0191D-02	1.0358D+02	2.4172D+02
5.0000D-02	3.0555D+02	1.2504D+04	0.0	5.4749D+03	1.2810D+04	5.0275D-02	6.5513D+01	1.9020D+02
8.0000D-02	2.6944D+02	1.1187D+04	0.0	4.6588D+03	1.1456D+04	7.8649D-02	4.3794D+01	1.4675D+02
1.0000D-01	2.5792D+02	1.0613D+04	0.0	4.3646D+03	1.0871D+04	9.5910D-02	3.6525D+01	1.2896D+02
2.0000D-01	1.1817D+02	8.5296D+03	5.8733D+02	3.7551D+03	9.2351D+03	1.7124D-01	2.1147D+01	5.6303D+01
3.0000D-01	9.9910D+01	7.4333D+03	8.7687D+02	3.5725D+03	8.4101D+03	2.2453D-01	1.5169D+01	4.0300D+01
5.0000D-01	8.9962D+01	6.2485D+03	1.2108D+03	3.4667D+03	7.5493D+03	2.9472D-01	1.0634D+01	3.2164D+01
6.0000D-01	9.0317D+01	5.8840D+03	1.3234D+03	3.4417D+03	7.2978D+03	3.2153D-01	9.7620D+00	3.1340D+01
7.0000D-01	9.3390D+01	5.6046D+03	1.4123D+03	3.4171D+03	7.1103D+03	3.4569D-01	9.3244D+00	3.1354D+01
8.0000D-01	9.8743D+01	5.3868D+03	1.4832D+03	3.3910D+03	6.9688D+03	3.6795D-01	9.1711D+00	3.1877D+01
1.0000D+00	1.0318D+02	4.9818D+03	1.6957D+03	3.3355D+03	6.7807D+03	4.1576D-01	9.3396D+00	3.1122D+01
2.0000D+00	1.3187D+02	4.0402D+03	2.4752D+03	3.1955D+03	6.6473D+03	6.1699D-01	7.9862D+00	2.4488D+01
3.0000D+00	4.7366D+01	3.5552D+03	3.0353D+03	3.1620D+03	6.6378D+03	7.7729D-01	2.4363D+00	7.9626D+00
5.0000D+00	5.4952D+00	2.9802D+03	3.1504D+03	3.1572D+03	6.1362D+03	8.4716D-01	1.8973D-01	5.8578D-01
6.0000D+00	1.8480D+00	2.6582D+03	3.1205D+03	3.1224D+03	5.7805D+03	8.5061D-01	5.5484D-02	1.7124D-01
8.0000D+00	2.5672D-01	2.3205D+03	3.0099D+03	3.0101D+03	5.3306D+03	8.5472D-01	6.3377D-03	1.9726D-02
1.0000D+01	5.6255D-02	2.2679D+03	2.9541D+03	2.9542D+03	5.2221D+03	8.7961D-01	1.1718D-03	3.6373D-03

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 RUNNING TIME .....      8.02   SEC.
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Fig. 2–b The output of Example–2 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
   1    1    1    1EXAMPLE-3, NB-93 CROSS SECTION, E=1KEV TO 10MEV
  17   41   93         13    2    1    1              -20    1    1
        1 92.91                  7.2289
        6 1.23                  1.29       1.11
       11 0.69                  0.52       0.56
       16 52.56                 3.23       6.0
       21 -0.3                  0.271      -0.015
       31 -16.5       1.34
       36 0.0     + 9 0.0304- 1 0.6860- 3 0.744 + 7 0.8087+ 5
       41 0.8101- 3 0.9499+13 0.9791+11 1.0826+ 9 1.2900- 3
       46 1.2974+ 9 1.3156+ 5 1.3351+17
       66 10.8949   6.0165    0.72       910.02     4.8329
       71 11.6068   6.2544               979.91     4.0957
       79 35.0      0.15
       85 0.4
      101 0.001     0.005     0.01       0.03       0.05
      106 0.08      0.1       0.2        0.3        0.5
      111 0.6       0.7       0.8        1.0        2.0
      116 3.0       5.0       6.0        8.0       10.0
```

Fig. 3–a The input data of calculating cross sections at threshold energies for inelastic scattering and with resonance level interference option (Example–3).

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EXAMPLE-3, NB-93 CROSS SECTION, E=1KEV TO 10MEV                                                     PAGE    1

 TARGET NUCLEUS ... NB  93     NUCLEAR MASS ...  92.910     SEPARATION ENERGY ...  7.2289  MEV

  MOLDAUER THEORY USED          DEG. OF FREEDOM ...   0.0
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

                .......... POTENTIAL PARAMETERS ..........                                   .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.230  RI    = 0.0    RS    = 1.290   RSO    = 1.110                              DNPART =  10.8949   DNPARC =  11.6068
  AO  =  0.690  A1    = 0.0    B     = 0.520   ASO    = 0.560                              SPINCT =   6.0165   SPINCC =   6.2544
  V   = 52.560  WI    = 0.0    WS    = 3.230   VSO    = 6.000   WSO    = 0.0               PAIRNT =   0.7200   PAIRNC =   0.0
  VE  = -0.300  WIE   = 0.0    WSE   = 0.271   VSOE   =-0.015   WSOE   = 0.0               CNORMT = 910.0200   CNORMC = 979.9100
  VESQ=  0.0    WIESQ= 0.0     WSESQ= 0.0      VSOESQ= 0.0      WSOESQ= 0.0                EJOINT =   4.8329   EJOINC =   4.0957
  VSYM=-16.500                                                                             SPCTIN =   0.0      SPCCIN =   0.0
                NIMAG ... 2                                                                NLVDNT .....  1     NLVDNC .....  1

                                                                                           TEMPLT =   0.8762   TEMPLC =   0.8367
                                                                                           TNORMT =   4.1590   TNORMC =   5.6164
                                                                                           SPCTEX =   0.0      SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.0     MEV   CROSS SECTION=    0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0         D.OBS. =     35.00 EV  GAM.WIDTH =  0.1500 EV
   CALCULATED ONES  ... T.GAM= 2.693D-02   D.CAL. =      0.0  EV  GAM.WIDTH =  0.0    EV   NORMALIZATION FACTOR ... 2.6928D-02


  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BRINK
   ENERGY = 17.59 MEV    WIDTH = 5.000 MEV    PARA1 = 0.0      PARA2 = 0.0      EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN   PARITY      NO     ENERGY   SPIN   PARITY      NO     ENERGY   SPIN   PARITY
    0   0.0        4.5      +         1   0.03040    0.5      -          2   0.68600    1.5      -
    3   0.74400    3.5      +         4   0.80870    2.5      +          5   0.81010    1.5      -
    6   0.94990    6.5      +         7   0.97910    5.5      +          8   1.08260    4.5      +
    9   1.29000    1.5      -        10   1.29740    4.5      +         11   1.31560    2.5      +
   12   1.33510    8.5      +

   LEVELS ABOVE 1.340MEV ARE ASSUMED TO BE OVERLAPPING


  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    1.0000D-03  5.0000D-03  1.0000D-02  3.0000D-02  5.0000D-02  8.0000D-02  1.0000D-01  2.0000D-01  3.0000D-01  5.0000D-01
    6.0000D-01  7.0000D-01  8.0000D-01  1.0000D+00  2.0000D+00  3.0000D+00  5.0000D+00  6.0000D+00  8.0000D+00  1.0000D+01
```

Fig. 3-b The output of Example-3.

EXAMPLE-3, NB-93 CROSS SECTION, E=1KEV TO 10MEV   PAGE   2

TARGET NUCLEUS ... NB 93

CALCULATED CROSS SECTIONS IN MILLI-BARNS

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
1.0000D-03	3.9978D+03	7.1404D+03	0.0	5.9500D+03	1.1138D+04	6.5187D-03	3.3149D+03	6.8289D+02
5.0000D-03	2.0992D+03	6.9761D+03	0.0	3.9251D+03	9.0753D+03	4.5578D-03	1.0207D+03	1.0786D+03
1.0000D-02	1.5525D+03	7.4617D+03	0.0	3.8950D+03	9.0142D+03	3.7833D-03	5.8707D+02	9.6545D+02
3.0000D-02	7.4147D+02	9.0998D+03	0.0	4.7809D+03	9.8413D+03	9.4505D-03	2.3429D+02	5.0594D+02
5.0000D-02	4.8818D+02	1.0110D+04	1.4760D-01	5.5306D+03	1.0598D+04	2.2168D-02	1.5159D+02	3.3415D+02
8.0000D-02	3.3077D+02	1.1086D+04	4.7549D-01	6.2558D+03	1.1417D+04	4.7526D-02	1.0182D+02	2.2396D+02
1.0000D-01	2.7671D+02	1.1511D+04	7.5027D-01	6.5296D+03	1.1788D+04	6.6389D-02	8.4527D+01	1.8533D+02
2.0000D-01	1.7229D+02	1.2170D+04	3.1582D+00	6.5070D+03	1.2345D+04	1.6006D-01	4.8449D+01	1.0629D+02
3.0000D-01	1.4417D+02	1.1748D+04	7.3020D+00	5.6683D+03	1.1900D+04	2.3538D-01	3.5761D+01	8.0281D+01
5.0000D-01	1.2964D+02	1.0322D+04	2.1509D+01	4.1369D+03	1.0473D+04	3.3065D-01	2.5083D+01	6.1192D+01
6.0000D-01	1.2768D+02	9.6473D+03	3.1040D+01	3.6183D+03	9.8060D+03	3.5899D-01	2.2270D+01	5.7161D+01
7.0000D-01	1.2672D+02	9.0394D+03	4.3253D+01	3.2348D+03	9.2093D+03	3.7882D-01	2.0211D+01	5.4667D+01
8.0000D-01	1.1879D+02	8.2977D+03	2.6326D+02	2.9538D+03	8.6798D+03	4.0143D-01	1.7646D+01	5.0194D+01
1.0000D+00	8.4601D+01	6.6036D+03	1.1036D+03	2.6016D+03	7.7919D+03	4.6386D-01	1.4377D+01	3.2890D+01
2.0000D+00	2.2220D+01	3.2424D+03	2.0588D+03	2.2443D+03	5.3234D+03	5.3164D-01	1.9028D+00	5.9778D+00
3.0000D+00	1.1464D+01	2.2278D+03	1.9292D+03	1.9779D+03	4.1684D+03	4.9375D-01	6.2771D-01	2.4143D+00
5.0000D+00	5.1611D+00	1.9320D+03	1.6557D+03	1.6647D+03	3.5929D+03	5.1654D-01	1.7043D-01	7.7302D-01
6.0000D+00	3.3719D+00	2.1203D+03	1.7059D+03	1.7107D+03	3.8296D+03	5.8821D-01	9.0009D-02	4.1150D-01
8.0000D+00	1.1645D+00	2.5395D+03	1.7378D+03	1.7392D+03	4.2785D+03	7.3301D-01	2.6206D-02	1.0878D-01
1.0000D+01	4.2341D-01	2.7085D+03	1.6888D+03	1.6892D+03	4.3977D+03	8.1391D-01	9.1456D-03	3.3963D-02

Fig. 3–b The output of Example–3 (continued).

```
EXAMPLE-3, NB-93 CROSS SECTION, E=1KEV TO 10MEV                                                              PAGE    3

 TARGET NUCLEUS ... NB  93      NUCLEAR MASS ...  92.910      SEPARATION ENERGY ...   7.2289  MEV

  MOLDAUER THEORY USED           DEG. OF FREEDOM ...   0.0
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

              .......... POTENTIAL PARAMETERS ..........                                      .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.230   RI    = 0.0     RS    = 1.290   RSO    = 1.110                             DNPART =  10.8949    DNPARC =  11.6068
  AO  =  0.690   A1    = 0.0     B     = 0.520   ASO    = 0.560                             SPINCT =   6.0165    SPINCC =   6.2544
  V   = 52.560   WI    = 0.0     WS    = 3.230   VSO    = 6.000   WSO    = 0.0              PAIRNT =   0.7200    PAIRNC =   0.0
  VE  = -0.300   WIE   = 0.0     WSE   = 0.271   VSOE   =-0.015   WSOE   = 0.0              CNORMT = 910.0200    CNORMC = 979.9100
  VESQ=  0.0     WIESQ= 0.0      WSESQ= 0.0      VSOESQ= 0.0      WSOESQ= 0.0               EJOINT =   4.8329    EJOINC =   4.0957
  VSYM=-16.500                                                                               SPCTIN =   0.0       SPCCIN =   0.0
                 NIMAG ... 2                                                                 NLVDNT .....  1      NLVDNC .....  1

                                                                                             TEMPLT =   0.8762    TEMPLC =   0.8367
                                                                                             TNORMT =   4.1590    TNORMC =   5.6164
                                                                                             SPCTEX =   0.0       SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.0    MEV   CROSS SECTION=    0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0         D.OBS. =     35.00 EV  GAM.WIDTH =  0.1500 EV
   CALCULATED ONES  ... T.GAM= 2.693D-02   D.CAL. =      0.0  EV  GAM.WIDTH =  0.0     EV    NORMALIZATION FACTOR ... 2.6928D-02

  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BRINK
   ENERGY = 17.59 MEV   WIDTH = 5.000 MEV   PARA1 = 0.0     PARA2 = 0.0     EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN  PARITY      NO    ENERGY   SPIN  PARITY      NO    ENERGY   SPIN  PARITY
    0   0.0        4.5    +          1   0.03040   0.5     -          2   0.68600   1.5     -
    3   0.74400    3.5    +          4   0.80870   2.5     +          5   0.81010   1.5     -
    6   0.94990    6.5    +          7   0.97910   5.5     +          8   1.08260   4.5     +
    9   1.29000    1.5    -         10   1.29740   4.5     +         11   1.31560   2.5     +
   12   1.33510    8.5    +

   LEVELS ABOVE 1.340MEV ARE ASSUMED TO BE OVERLAPPING

  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    3.0730D-02  6.9345D-01  7.5208D-01  8.1748D-01  8.1889D-01  9.6021D-01  9.8973D-01  1.0944D+00  1.3040D+00  1.3115D+00
    1.3299D+00  1.3496D+00  1.3545D+00
```

Fig. 3–b The output of Example 3 (continued).

EXAMPLE-3, NB-93 CROSS SECTION, E=1KEV TO 10MEV PAGE 4

TARGET NUCLEUS ... NB 93

CALCULATED CROSS SECTIONS IN MILLI-BARNS

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
3.0730D-02	7.2746D+02	9.1446D+03	0.0	4.8124D+03	9.8721D+03	9.8209D-03	2.2955D+02	4.9663D+02
6.9345D-01	1.2732D+02	9.0782D+03	4.0832D+01	3.2565D+03	9.2463D+03	3.7769D-01	2.0327D+01	5.4796D+01
7.5208D-01	1.2428D+02	8.7442D+03	5.7031D+01	3.0775D+03	8.9255D+03	3.8669D-01	1.9353D+01	5.3760D+01
8.1748D-01	1.1702D+02	8.1246D+03	3.5199D+02	2.9132D+03	8.5936D+03	4.0749D-01	1.7309D+01	4.8535D+01
8.1889D-01	1.1686D+02	8.1104D+03	3.5943D+02	2.9100D+03	8.5867D+03	4.0799D-01	1.7284D+01	4.8392D+01
9.6021D-01	1.0557D+02	6.9786D+03	8.6844D+02	2.6547D+03	7.9526D+03	4.4731D-01	1.5369D+01	3.6303D+01
9.8973D-01	9.0440D+01	6.7159D+03	1.0263D+03	2.6146D+03	7.8327D+03	4.5839D-01	1.5049D+01	3.4025D+01
1.0944D+00	6.2104D+01	5.8052D+03	1.5705D+03	2.5001D+03	7.4378D+03	5.0308D-01	1.2605D+01	2.2377D+01
1.3040D+00	4.8224D+01	4.8914D+03	1.8276D+03	2.3628D+03	6.7673D+03	5.3222D-01	9.1488D+00	1.3460D+01
1.3115D+00	4.8118D+01	4.8690D+03	1.8288D+03	2.3595D+03	6.7459D+03	5.3239D-01	9.0840D+00	1.3358D+01
1.3299D+00	4.7324D+01	4.8097D+03	1.8370D+03	2.3518D+03	6.6941D+03	5.3327D-01	8.6339D+00	1.3055D+01
1.3496D+00	4.6768D+01	4.7481D+03	1.8447D+03	2.3441D+03	6.6396D+03	5.3407D-01	8.3718D+00	1.2683D+01
1.3545D+00	4.6364D+01	4.7327D+03	1.8470D+03	2.3422D+03	6.6261D+03	5.3427D-01	8.3144D+00	1.2587D+01

RUNNING TIME ..... 41.17 SEC.

Fig. 3-b The output of Example 3 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
   1    1    1       EXAMPLE-4, NB-93 CROSS SECTION, E=1KEV TO 10MEV
  19   41   93          13    2    1   10               -20    1    1         1
         1 92.91                  7.2289
         6 1.23                  1.29       1.11
        11 0.69                  0.52       0.56
        16 52.56                 3.23       6.0
        21 -0.3                  0.271      -0.015
        31 -16.5       1.34
        36 0.0     + 9 0.0304- 1 0.6860- 3 0.744 + 7 0.8087+ 5
        41 0.8101- 3 0.9499+13 0.9791+11 1.0826+ 9 1.2900- 3
        46 1.2974+ 9 1.3156+ 5 1.3351+17
        66 10.8949   6.0165    0.72      910.02    4.8329
        71 11.6068   6.2544              979.91    4.0957
        79 35.0      0.15
        85 0.4
       101 0.001     0.005     0.01      0.03      0.05
       106 0.08      0.1       0.2       0.3       0.5
       111 0.6       0.7       0.8       1.0       2.0
       116 3.0       5.0       6.0       8.0       10.0
       163 34.2      62.7      123.2     274.3     318.6
       168 367.3     382.5     401.8
```

Fig. 4–a The input data including competing processes above 800 keV (Example–4).

```
EXAMPLE-4, NB-93 CROSS SECTION, E=1KEV TO 10MEV                                                          PAGE    1

 TARGET NUCLEUS ... NB  93      NUCLEAR MASS ...  92.910      SEPARATION ENERGY ...   7.2289  MEV

  MOLDAUER THEORY USED           DEG. OF FREEDOM ...    1.00
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

              .......... POTENTIAL PARAMETERS ..........                                    .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.230   RI    = 0.0     RS    = 1.290   RSO    = 1.110                           DNPART =  10.8949    DNPARC =  11.6068
  AO  =  0.690   A1    = 0.0     B     = 0.520   ASO    = 0.560                           SPINCT =   6.0165    SPINCC =   6.2544
  V   = 52.560   WI    = 0.0     WS    = 3.230   VSO    = 6.000   WSO    = 0.0            PAIRNT =   0.7200    PAIRNC =   0.0
  VE  = -0.300   WIE   = 0.0     WSE   = 0.271   VSOE   =-0.015   WSOE   = 0.0            CNORMT = 910.0200    CNORMC = 979.9100
  VESQ=  0.0     WIESQ= 0.0      WSESQ= 0.0      VSOESQ= 0.0      WSOESQ= 0.0             EJOINT =   4.8329    EJOINC =   4.0957
  VSYM=-16.500                                                                            SPCTIN =   0.0       SPCCIN =   0.0
                 NIMAG ... 2                                                              NLVDNT .....  1      NLVDNC .....  1

                                                                                          TEMPLT =   0.8762    TEMPLC =   0.8367
                                                                                          TNORMT =   4.1590    TNORMC =   5.6164
                                                                                          SPCTEX =   0.0       SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES    ENERGY AT 0.0      MEV   CROSS SECTION=    0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0          D.OBS. =     35.00 EV   GAM.WIDTH =   0.1500 EV
   CALCULATED ONES  ... T.GAM= 2.693D-02    D.CAL. =      0.0  EV   GAM.WIDTH =   0.0    EV    NORMALIZATION FACTOR ... 2.6928D-02

  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BRINK
   ENERGY = 17.59 MEV    WIDTH = 5.000 MEV    PARA1 = 0.0      PARA2 = 0.0     EXCHNG = 0.400
  LEVEL PARAMETERS
   NO     ENERGY   SPIN   PARITY        NO     ENERGY   SPIN   PARITY        NO     ENERGY   SPIN   PARITY
    0   0.0         4.5     +            1   0.03040    0.5     -            2   0.68600    1.5     -
    3   0.74400     3.5     +            4   0.80870    2.5     +            5   0.81010    1.5     -
    6   0.94990     6.5     +            7   0.97910    5.5     +            8   1.08260    4.5     +
    9   1.29000     1.5     -           10   1.29740    4.5     +           11   1.31560    2.5     +
   12   1.33510     8.5     +

   LEVELS ABOVE 1.340MEV ARE ASSUMED TO BE OVERLAPPING

  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    1.0000D-03  5.0000D-03  1.0000D-02  3.0000D-02  5.0000D-02  8.0000D-02  1.0000D-01  2.0000D-01  3.0000D-01  5.0000D-01
    6.0000D-01  7.0000D-01  8.0000D-01  1.0000D+00  2.0000D+00  3.0000D+00  5.0000D+00  6.0000D+00  8.0000D+00  1.0000D+01

  CROSS SECTIONS OF THE COMPETING PROCESSES
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         3.4200D+01  6.2700D+01  1.2320D+02  2.7430D+02  3.1860D+02  3.6730D+02  3.8250D+02  4.0180D+02
```

Fig. 4-b The output of Example-4.

```
EXAMPLE-4, NB-93 CROSS SECTION, E=1KEV TO 10MEV                                                        PAGE    2

  TARGET NUCLEUS ... NB  93

  CALCULATED CROSS SECTIONS IN MILLI-BARNS
```

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
1.0000D-03	3.0204D+03	8.1178D+03	0.0	5.9500D+03	1.1138D+04	6.6041D-03	2.3715D+03	6.4884D+02
5.0000D-03	1.5479D+03	7.5275D+03	0.0	3.9251D+03	9.0753D+03	4.7448D-03	6.9642D+02	8.5143D+02
1.0000D-02	1.1230D+03	7.8912D+03	0.0	3.8950D+03	9.0142D+03	3.9598D-03	3.9968D+02	7.2336D+02
3.0000D-02	5.6637D+02	9.2749D+03	0.0	4.7809D+03	9.8413D+03	9.3985D-03	1.6208D+02	4.0289D+02
5.0000D-02	3.8929D+02	1.0209D+04	1.0280D-01	5.5306D+03	1.0598D+04	2.2012D-02	1.0621D+02	2.8027D+02
8.0000D-02	2.7383D+02	1.1143D+04	3.6543D-01	6.2558D+03	1.1417D+04	4.7308D-02	7.2209D+01	1.9591D+02
1.0000D-01	2.3278D+02	1.1555D+04	5.9693D-01	6.5296D+03	1.1788D+04	6.6152D-02	6.0252D+01	1.6480D+02
2.0000D-01	1.5053D+02	1.2192D+04	2.6242D+00	6.5070D+03	1.2345D+04	1.5977D-01	3.4799D+01	9.7611D+01
3.0000D-01	1.2664D+02	1.1767D+04	5.9981D+00	5.6683D+03	1.1900D+04	2.3500D-01	2.5581D+01	7.4032D+01
5.0000D-01	1.1273D+02	1.0344D+04	1.6471D+01	4.1369D+03	1.0473D+04	3.2996D-01	1.7830D+01	5.5463D+01
6.0000D-01	1.1099D+02	9.6721D+03	2.2955D+01	3.6183D+03	9.8060D+03	3.5808D-01	1.5880D+01	5.1049D+01
7.0000D-01	1.1049D+02	9.0672D+03	3.1655D+01	3.2348D+03	9.2093D+03	3.7767D-01	1.4522D+01	4.8026D+01
8.0000D-01	1.0121D+02	8.3433D+03	2.0105D+02	2.9538D+03	8.6798D+03	3.9927D-01	1.2748D+01	4.1543D+01
1.0000D+00	7.4499D+01	6.8874D+03	7.6730D+02	2.6016D+03	7.7919D+03	4.4504D-01	1.0588D+01	2.6913D+01
2.0000D+00	2.1995D+01	3.3830D+03	1.7952D+03	2.2443D+03	5.3234D+03	5.0983D-01	1.8293D+00	5.6485D+00
3.0000D+00	1.0284D+01	2.2612D+03	1.6226D+03	1.9779D+03	4.1684D+03	4.8655D-01	5.7683D-01	2.0897D+00
5.0000D+00	4.1448D+00	1.9345D+03	1.3357D+03	1.6647D+03	3.5929D+03	5.1589D-01	1.3234D-01	6.1695D-01
6.0000D+00	2.5942D+00	2.1201D+03	1.3396D+03	1.7107D+03	3.8296D+03	5.8827D-01	6.8498D-02	3.1634D-01
8.0000D+00	8.8827D-01	2.5395D+03	1.3556D+03	1.7392D+03	4.2785D+03	7.3302D-01	1.9916D-02	8.2725D-02
1.0000D+01	3.3769D-01	2.7085D+03	1.2871D+03	1.6892D+03	4.3977D+03	8.1392D-01	7.2542D-03	2.6943D-02

```
  RUNNING TIME .....    37.25   SEC.
```

Fig. 4–b The output of Example-4 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
    1    1    1     EXAMPLE-5, CR-52 CROSS SECTION, E=1KEV TO 15MEV
   20   24   52        24    2    2   10            -20   11   11         0    0
         1 51.94                   7.9405
         6   1.30                  1.40       1.30
        11   0.48                  0.40       0.48
        16  50.05                  4.87       7.0
        21  -0.262                 0.352
        32   4.816
        36 0.0     + 0 1.4341+ 2 2.3696+ 4 2.6470+ 0 2.7677+ 4
        41 2.9648+ 2 3.1138+ 6 3.1617+ 2 3.4152+ 4 3.4722+ 3
        46 3.6158+ 5 3.7000+ 2 3.7717+ 2 3.9460+ 4 3.9512+ 1
        51 4.0154+ 5 4.0380+ 4 4.5630- 3 4.6270+ 5 4.7060+ 2
        56 4.7410+ 2 4.7507+ 8 4.7940+ 0 4.8045+ 6
        66 5.88      3.21      1.05      0.0       5.1
        71 6.06      3.36      0.14      0.0       5.1
        76 0.05      8.8672
        81 16.62     4.24                          0.4
        86 19.91     4.16     47.4      44.9
       101 0.001     0.005     0.01      0.03      0.05
       106 0.1       0.3       0.5       0.8       1.0
       111 2.0       3.0       4.0       5.0       6.0
       116 7.0       8.0      10.0      12.0      15.0
```

Fig. 5–a The input data using the capture normalization cross section of 8.8672 mb at 50 keV (Example-5).

```
EXAMPLE-5, CR-52 CROSS SECTION, E=1KEV TO 15MEV                                                              PAGE    1

 TARGET NUCLEUS ... CR  52     NUCLEAR MASS ...  51.940     SEPARATION ENERGY ...  7.9405  MEV

  MOLDAUER THEORY USED          DEG. OF FREEDOM ...   1.00
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

             .......... POTENTIAL PARAMETERS ..........                                 .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.300   RI   = 0.0    RS   = 1.400   RSO   = 1.300                             DNPART =   5.8800   DNPARC =   6.0600
  AO  =  0.480   A1   = 0.0    B    = 0.400   ASO   = 0.480                             SPINCT =   3.2100   SPINCC =   3.3600
  V   = 50.050   WI   = 0.0    WS   = 4.870   VSO   = 7.000   WSO   = 0.0               PAIRNT =   1.0500   PAIRNC =   0.1400
  VE  = -0.262   WIE  = 0.0    WSE  = 0.352   VSOE  = 0.0     WSOE  = 0.0               CNORMT =   0.0      CNORMC =   0.0
  VESQ=  0.0     WIESQ= 0.0    WSESQ= 0.0     VSOESQ= 0.0     WSOESQ= 0.0               EJOINT =   5.1000   EJOINC =   5.1000
  VSYM=  0.0                                                                            SPCTIN =   0.0      SPCCIN =   0.0
                 NIMAG ... 2                                                            NLVDNT ..... 11     NLVDNC ..... 11

                                                                                        TEMPLT =   1.1982   TEMPLC =   1.2455
                                                                                        TNORMT =   0.6364   TNORMC =   0.8931
                                                                                        SPCTEX =   0.0      SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.050000MEV   CROSS SECTION=   8.867MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0        D.OBS. =     0.0  EV  GAM.WIDTH =  0.0   EV
   CALCULATED ONES  ... T.GAM= 0.0        D.CAL. =     0.0  EV  GAM.WIDTH =  0.0   EV   NORMALIZATION FACTOR ... 7.2285D-05


  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BERMAN
   ENERGY = 16.62 MEV   WIDTH = 4.240 MEV   PARA1 = 0.0      PARA2 = 0.0      EXCHNG = 0.400
   ENERGY2= 19.91 MEV   WIDTH2=  4.16 MEV   SIGBM1=  47.400 MB   SIGBM2=  44.900 MB
  LEVEL PARAMETERS
   NO    ENERGY   SPIN   PARITY      NO    ENERGY   SPIN   PARITY      NO    ENERGY   SPIN   PARITY
    0  0.0        0.0     +           1  1.43410   2.0      +           2  2.36960   4.0     +
    3  2.64700    0.0     +           4  2.76770   4.0      +           5  2.96480   2.0     +
    6  3.11380    6.0     +           7  3.16170   2.0      +           8  3.41520   4.0     +
    9  3.47220    3.0     +          10  3.61580   5.0      +          11  3.70000   2.0     +
   12  3.77170    2.0     +          13  3.94600   4.0      +          14  3.95120   1.0     +
   15  4.01540    5.0     +          16  4.03800   4.0      +          17  4.56300   3.0     -
   18  4.62700    5.0     +          19  4.70600   2.0      +          20  4.74100   2.0     +
   21  4.75070    8.0     +          22  4.79400   0.0      +          23  4.80450   6.0     +

   LEVELS ABOVE 4.816MEV ARE ASSUMED TO BE OVERLAPPING


  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    1.0000D-03  5.0000D-03  1.0000D-02  3.0000D-02  5.0000D-02  1.0000D-01  3.0000D-01  5.0000D-01  8.0000D-01  1.0000D+00
    2.0000D+00  3.0000D+00  4.0000D+00  5.0000D+00  6.0000D+00  7.0000D+00  8.0000D+00  1.0000D+01  1.2000D+01  1.5000D+01
```

Fig. 5–b The output of Example–5.

EXAMPLE-5, CR-52 CROSS SECTION, E=1KEV TO 15MEV PAGE 2

TARGET NUCLEUS ... CR 52

CALCULATED CROSS SECTIONS IN MILLI-BARNS

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
1.0000D-03	5.9165D+01	8.8532D+04	0.0	8.1205D+04	8.8591D+04	1.2984D-02	4.7652D+01	1.1513D+01
5.0000D-03	2.2062D+01	4.0498D+04	0.0	3.3691D+04	4.0519D+04	1.3321D-02	9.6261D+00	1.2435D+01
1.0000D-02	1.4577D+01	2.8990D+04	0.0	2.2564D+04	2.9004D+04	1.3932D-02	4.8430D+00	9.7341D+00
3.0000D-02	1.0935D+01	1.7027D+04	0.0	1.1470D+04	1.7037D+04	1.7223D-02	1.6473D+00	5.0307D+00
5.0000D-02	8.8672D+00	1.3228D+04	0.0	8.1991D+03	1.3236D+04	2.1068D-02	1.0075D+00	3.4423D+00
1.0000D-01	6.0025D+00	9.2857D+03	0.0	5.0964D+03	9.2916D+03	3.1098D-02	5.2795D-01	1.9921D+00
3.0000D-01	3.2584D+00	5.1649D+03	0.0	2.4735D+03	5.1682D+03	6.2728D-02	2.1176D-01	8.6611D-01
5.0000D-01	2.8374D+00	4.0253D+03	0.0	1.9704D+03	4.0282D+03	8.0999D-02	1.5248D-01	6.3641D-01
8.0000D-01	2.9640D+00	3.4101D+03	0.0	1.7786D+03	3.4130D+03	1.0329D-01	1.2476D-01	5.2630D-01
1.0000D+00	3.1324D+00	3.2572D+03	0.0	1.7353D+03	3.2603D+03	1.2229D-01	1.1909D-01	5.0370D-01
2.0000D+00	1.8017D+00	2.6675D+03	5.4854D+02	1.5262D+03	3.2179D+03	3.1032D-01	1.0198D-01	3.4575D-01
3.0000D+00	1.5205D+00	2.6163D+03	7.3153D+02	1.3142D+03	3.3493D+03	4.6895D-01	6.4362D-02	3.6722D-01
4.0000D+00	1.1587D+00	2.5137D+03	9.5871D+02	1.2311D+03	3.4735D+03	5.8674D-01	6.2734D-02	3.0696D-01
5.0000D+00	1.0085D+00	2.4663D+03	1.0699D+03	1.2138D+03	3.5372D+03	6.5896D-01	4.1754D-02	2.6342D-01
6.0000D+00	4.2743D-01	2.3529D+03	1.1730D+03	1.2110D+03	3.5264D+03	7.2505D-01	2.1454D-02	7.1914D-02
7.0000D+00	2.4362D-01	2.2471D+03	1.2044D+03	1.2048D+03	3.4518D+03	7.6820D-01	1.2104D-02	3.3316D-02
8.0000D+00	1.7286D-01	2.1390D+03	1.1887D+03	1.1889D+03	3.3278D+03	7.9182D-01	8.2003D-03	2.0681D-02
1.0000D+01	1.1679D-01	1.8649D+03	1.1513D+03	1.1514D+03	3.0163D+03	8.1670D-01	4.8518D-03	1.3694D-02
1.2000D+01	8.9367D-02	1.5847D+03	1.1470D+03	1.1471D+03	2.7318D+03	8.2110D-01	3.2152D-03	1.0292D-02
1.5000D+01	5.8538D-02	1.2542D+03	1.2010D+03	1.2010D+03	2.4552D+03	8.1376D-01	1.7003D-03	6.2385D-03

RUNNING TIME ..... 13.62 SEC.

Fig. 5–b The output of Example–5 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
    2         1     EXAMPLE-6, NATURAL AG  CROSS SECTION
  0.8      174.0     0.05
   14   47  107  518    7    5      1010            -10   11   11
         1 106.91               7.269
         6  1.286    1.286      1.39      1.286
        11  0.62     0.62       0.35      0.62
        16 46.0                 7.0       7.0
        21 -0.25     0.125
        27 -4.0  - 4
        32  1.0
        36  0.0  - 1 0.093 + 7 0.3244- 3 0.4225- 5 0.786 - 3
        41 0.922 + 5 0.9497- 5
        66 15.71      7.934    1.24      1510.1    5.142
        71 16.36      8.145              1586.5    3.889
        83 0.1       0.5       0.4
       101 0.1       0.5       0.8       1.0       2.0
       106 3.0       4.0       5.0       8.0      10.0
    7       109  482   13
         1 108.9               6.8094
        32 1.51
        36 0.0    - 1 0.0880+ 7 0.1328+ 9 0.3144- 3 0.4153- 5
        41 0.7019- 3 0.7244+ 3 0.7353+ 5 0.8394- 7 0.8627- 5
        46 0.8695+ 5 0.911  - 7 0.9123+ 3
        66 16.80     8.305     1.25      1644.4    5.126
        71 17.17     8.448               1696.7    3.864
```

Fig. 6–a The input data of calculating cross sections for natural silver (Example–6).

```
EXAMPLE-6, NATURAL AG  CROSS SECTION                                                                   PAGE    1

 TARGET NUCLEUS ... AG 107      NUCLEAR MASS ... 106.910      SEPARATION ENERGY ...   7.2690  MEV

  MOLDAUER THEORY USED           DEG. OF FREEDOM ...    1.00           Q-FACTOR ...   0.10
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ... 51.8  PER CENT

             .......... POTENTIAL PARAMETERS ..........                                .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.286   RI   = 1.286   RS   = 1.390   RSO    = 1.286                           DNPART =  15.7100   DNPARC =  16.3600
  AO  =  0.620   A1   = 0.620   B    = 0.350   ASO    = 0.620                           SPINCT =   7.9340   SPINCC =   8.1450
  V   = 46.000   WI   = 0.0     WS   = 7.000   VSO    = 7.000   WSO    = 0.0            PAIRNT =   1.2400   PAIRNC =   0.0
  VE  = -0.250   WIE  = 0.125   WSE  = 0.0     VSOE   = 0.0     WSOE   = 0.0            CNORMT =1510.1000   CNORMC =1586.5000
  VESQ=  0.0     WIESQ=-0.000   WSESQ= 0.0     VSOESQ= 0.0      WSOESQ= 0.0             EJOINT =   5.1420   EJOINC =   3.8890
  VSYM=  0.0                                                                            SPCTIN =   0.0      SPCCIN =   0.0
                 NIMAG ... 5                                                            NLVDNT ..... 11     NLVDNC ..... 11

                                                                                        TEMPLT =   0.6165   TEMPLC =   0.6005
                                                                                        TNORMT =   2.0548   TNORMC =   8.7352
                                                                                        SPCTEX =   0.0      SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR NATURAL    ENERGY AT 0.800000MEV   CROSS SECTION=  174.000MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0        D.OBS. =      0.0  EV  GAM.WIDTH =  0.0    EV
   CALCULATED ONES  ... T.GAM= 0.0        D.CAL. =      0.0  EV  GAM.WIDTH =  0.0    EV   NORMALIZATION FACTOR ... 6.9846D-02

  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... LANE
   ENERGY = 15.96 MEV   WIDTH = 6.000 MEV   PARA1 = 0.100   PARA2 = 0.500   EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN  PARITY     NO    ENERGY   SPIN  PARITY     NO    ENERGY   SPIN  PARITY
    0   0.0       0.5     -         1   0.09300   3.5     +         2   0.32440   1.5     -
    3   0.42250   2.5     -         4   0.78600   1.5     -         5   0.92200   2.5     +
    6   0.94970   2.5     -

   LEVELS ABOVE 1.000MEV ARE ASSUMED TO BE OVERLAPPING

   INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    1.0000D-01  5.0000D-01  8.0000D-01  1.0000D+00  2.0000D+00  3.0000D+00  4.0000D+00  5.0000D+00  8.0000D+00  1.0000D+01
```

Fig. 6–b The output of Example 6.

```
EXAMPLE-6, NATURAL AG  CROSS SECTION                                                                PAGE    2

  TARGET NUCLEUS ... AG 107

 CALCULATED CROSS SECTIONS IN MILLI-BARNS
```

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
1.0000D-01	7.0326D+02	7.9210D+03	5.8477D-01	3.7490D+03	8.6249D+03	1.6705D-01	1.2474D+02	5.6627D+02
5.0000D-01	2.3307D+02	7.0389D+03	8.0557D+02	2.8194D+03	8.0776D+03	4.2519D-01	3.9319D+01	1.4306D+02
8.0000D-01	2.0625D+02	6.1459D+03	1.0200D+03	2.3197D+03	7.3722D+03	4.8744D-01	2.9226D+01	9.5954D+01
1.0000D+00	1.9201D+02	5.5727D+03	1.1764D+03	2.1548D+03	6.9411D+03	5.1387D-01	2.3066D+01	7.5982D+01
2.0000D+00	1.7438D+02	3.5204D+03	1.5338D+03	1.9535D+03	5.2286D+03	5.7159D-01	1.1453D+01	4.7973D+01
3.0000D+00	1.2867D+02	2.3601D+03	1.7101D+03	1.8840D+03	4.1988D+03	5.9444D-01	6.4000D+00	2.4605D+01
4.0000D+00	1.9188D+02	1.9331D+03	1.7255D+03	1.9209D+03	3.8505D+03	5.8273D-01	4.3946D+00	2.7326D+01
5.0000D+00	2.0953D+02	1.9195D+03	1.7694D+03	1.9722D+03	3.8984D+03	6.0696D-01	6.7538D+00	3.1737D+01
8.0000D+00	1.3530D+02	2.4729D+03	1.7143D+03	1.8258D+03	4.3225D+03	7.6997D-01	4.6885D+00	1.3434D+01
1.0000D+01	1.2131D+02	2.7061D+03	1.7273D+03	1.8250D+03	4.5547D+03	8.3117D-01	3.4860D+00	8.9930D+00

Fig. 6-b The output of Example-6 (continued).

```
EXAMPLE-6, NATURAL AG  CROSS SECTION                                                                    PAGE    1

 TARGET NUCLEUS ... AG 109     NUCLEAR MASS ... 108.900     SEPARATION ENERGY ...   6.8094  MEV

  MOLDAUER THEORY USED           DEG. OF FREEDOM ...    1.00           Q-FACTOR ...   0.10
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ... 48.2  PER CENT

            .......... POTENTIAL PARAMETERS ..........                               .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.286   RI    = 1.286   RS    = 1.390   RSO    = 1.286                    DNPART =   16.8000    DNPARC =   17.1700
  AO  =  0.620   A1    = 0.620   B     = 0.350   ASO    = 0.620                    SPINCT =    8.3050    SPINCC =    8.4480
  V   = 46.000   WI    = 0.0     WS    = 7.000   VSO    = 7.000   WSO    = 0.0     PAIRNT =    1.2500    PAIRNC =    0.0
  VE  = -0.250   WIE   = 0.125   WSE   = 0.0     VSOE   = 0.0     WSOE   = 0.0     CNORMT =1644.4000    CNORMC =1696.7000
  VESQ=  0.0     WIESQ=-0.000    WSESQ= 0.0      VSOESQ= 0.0      WSOESQ= 0.0      EJOINT =    5.1260    EJOINC =    3.8640
  VSYM=  0.0                                                                       SPCTIN =    0.0       SPCCIN =    0.0
                 NIMAG ... 5                                                       NLVDNT ..... 11       NLVDNC ..... 11

                                                                                   TEMPLT =    0.5900    TEMPLC =    0.5815
                                                                                   TNORMT =    2.2785    TNORMC =   10.1267
                                                                                   SPCTEX =    0.0       SPCCEX =    0.0

  NORMALIZATION CARRIED OUT FOR NATURAL    ENERGY AT 0.800000MEV   CROSS SECTION=  174.000MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0        D.OBS. =      0.0  EV  GAM.WIDTH =  0.0    EV
   CALCULATED ONES  ... T.GAM= 0.0        D.CAL. =      0.0  EV  GAM.WIDTH =  0.0    EV    NORMALIZATION FACTOR ... 4.9431D-02

  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... LANE
   ENERGY = 15.90 MEV   WIDTH = 6.000 MEV   PARA1 = 0.100   PARA2 = 0.500   EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN   PARITY     NO    ENERGY   SPIN   PARITY     NO    ENERGY   SPIN   PARITY
    0   0.0        0.5     -         1   0.08800   3.5     +          2   0.13280   4.5     +
    3   0.31440    1.5     -         4   0.41530   2.5     -          5   0.70190   1.5     -
    6   0.72440    1.5     +         7   0.73530   2.5     +          8   0.83940   3.5     -
    9   0.86270    2.5     -        10   0.86950   2.5     +         11   0.91100   3.5     -
   12   0.91230    1.5     +

   LEVELS ABOVE 1.510MEV ARE ASSUMED TO BE OVERLAPPING

  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    1.0000D-01  5.0000D-01  8.0000D-01  1.0000D+00  2.0000D+00  3.0000D+00  4.0000D+00  5.0000D+00  8.0000D+00  1.0000D+01
```

Fig. 6–b The output of Example 6 (continued).

EXAMPLE-6, NATURAL AG CROSS SECTION PAGE 2

TARGET NUCLEUS ... AG 109

CALCULATED CROSS SECTIONS IN MILLI-BARNS

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
1.0000D-01	5.4893D+02	7.7502D+03	1.5872D+00	3.5299D+03	8.3008D+03	1.2247D-01	1.0348D+02	4.3303D+02
5.0000D-01	1.7343D+02	6.9066D+03	8.2131D+02	2.6709D+03	7.9013D+03	3.4420D-01	3.1498D+01	1.0350D+02
8.0000D-01	1.2974D+02	6.0308D+03	1.1569D+03	2.2373D+03	7.3174D+03	4.2310D-01	1.6942D+01	6.3587D+01
1.0000D+00	9.8656D+01	5.4828D+03	1.3597D+03	2.0994D+03	6.9412D+03	4.6185D-01	9.3082D+00	4.8841D+01
2.0000D+00	1.2336D+02	3.6042D+03	1.5803D+03	1.9343D+03	5.3079D+03	5.3766D-01	6.3070D+00	3.8689D+01
3.0000D+00	8.6644D+01	2.4168D+03	1.7659D+03	1.8896D+03	4.2694D+03	5.8571D-01	3.4431D+00	1.8444D+01
4.0000D+00	1.2670D+02	1.9577D+03	1.8273D+03	1.9541D+03	3.9116D+03	5.8316D-01	3.4453D+00	1.7765D+01
5.0000D+00	1.9065D+02	1.9203D+03	1.8201D+03	2.0020D+03	3.9310D+03	6.0969D-01	5.2932D+00	2.4658D+01
8.0000D+00	1.2757D+02	2.4516D+03	1.7421D+03	1.8451D+03	4.3213D+03	7.7766D-01	4.5450D+00	1.2036D+01
1.0000D+01	1.1394D+02	2.7053D+03	1.7729D+03	1.8621D+03	4.5922D+03	8.3877D-01	3.4407D+00	8.2564D+00

Fig. 6-b The output of Example-6 (continued).

EXAMPLE-6, NATURAL AG CROSS SECTION   PAGE 3

CROSS SECTIONS OF NATURAL AG (MILLI-BARNS)

ENERGY(MEV)	CAPTURE	INELASTIC	ELASTIC(C)	COMPOUND	ELASTIC(S)	ELASTIC	COMPETE	TOTAL
1.0000D-01	6.2887D+02	1.0679D+00	3.0135D+03	3.6434D+03	4.8253D+03	7.8387D+03	0.0	8.4686D+03
5.0000D-01	2.0432D+02	8.1316D+02	1.7303D+03	2.7478D+03	5.2448D+03	6.9752D+03	0.0	7.9926D+03
8.0000D-01	1.6937D+02	1.0860D+03	1.0246D+03	2.2800D+03	5.0658D+03	6.0904D+03	0.0	7.3458D+03
1.0000D+00	1.4701D+02	1.2648D+03	7.1628D+02	2.1281D+03	4.8131D+03	5.5294D+03	0.0	6.9412D+03
2.0000D+00	1.4979D+02	1.5562D+03	2.3821D+02	1.9442D+03	3.3226D+03	3.5608D+03	0.0	5.2669D+03
3.0000D+00	1.0841D+02	1.7370D+03	4.1314D+01	1.8867D+03	2.3461D+03	2.3874D+03	0.0	4.2328D+03
4.0000D+00	1.6047D+02	1.7745D+03	1.8921D+00	1.9369D+03	1.9430D+03	1.9449D+03	0.0	3.8799D+03
5.0000D+00	2.0043D+02	1.7938D+03	-7.6859D+00	1.9866D+03	1.9276D+03	1.9199D+03	0.0	3.9141D+03
8.0000D+00	1.3157D+02	1.7277D+03	-2.4166D+01	1.8351D+03	2.4868D+03	2.4627D+03	0.0	4.3219D+03
1.0000D+01	1.1776D+02	1.7493D+03	-2.4198D+01	1.8429D+03	2.7299D+03	2.7057D+03	0.0	4.5728D+03

RUNNING TIME ..... 21.85 SEC.

Fig. 6–b The output of Example 6 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
  1    1    1      EXAMPLE-7, FE-56 CROSS SECTION, E=850KEV TO 14MEV
 21   26   56          28    5    1   10             -15   11   11
       1 56.00                  7.646
       6 1.287       1.345     1.345       1.12
      11 0.56        0.47      0.47        0.47       6.0
      16 49.746      -0.207    6.053       6.2
      21 -0.4295     0.253     0.074
      26 -0.0003
      32  4.7         0.05     3.2766      3.4606
      36 0.0     + 0 0.8468+ 2 2.0851+ 4 2.6576+ 2 2.9417+ 0
      41 2.96    + 2 3.12    + 1 3.1229+ 4 3.3702+ 2 3.3884+ 6
      46 3.4454+ 3 3.4493+ 1 3.6009+ 2 3.6019+ 2 3.607  + 0
      51 3.748  + 2 3.7558+ 6 3.832  + 2 3.8565+ 3 4.094  + 3
      56 4.1003+ 3 4.12   + 4 4.2982+ 4 4.3020+ 0 4.3950+ 3
      61 4.401  + 2 4.4584+ 3 4.51   - 3
      66 6.355       3.2766    2.81        319.63     7.9886
      71 6.9232      3.4606    1.54        354.43     6.6716
      76 0.85        5.0
      85 0.4
      94 0.253       -0.325
     101 0.85        1.0       2.0         3.0        4.0
     106 5.0         6.0       7.0         8.0        9.0
     111 10.0        11.0      12.0        13.0       14.0
```

Fig. 7–a The input data changing well–depth parameters of the imaginary potential at 6 MeV (Example–7).

```
EXAMPLE-7, FE-56 CROSS SECTION, E=850KEV TO 14MEV                                                         PAGE    1

 TARGET NUCLEUS ... FE  56     NUCLEAR MASS ...  56.000     SEPARATION ENERGY ...   7.6460  MEV

  MOLDAUER THEORY USED          DEG. OF FREEDOM ...    1.00
  NO DISCRETE LEVELS OF COMPOUND NUCLEUS ARE TAKEN
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

               .......... POTENTIAL PARAMETERS ..........                          .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.287   RI   = 1.345   RS   = 1.345   RSO   = 1.120                       DNPART =   6.3550   DNPARC =    6.9232
  AO  =  0.560   A1   = 0.470   B    = 0.470   ASO   = 0.470                       SPINCT =   3.2766   SPINCC =    3.4606
  V   = 49.746   WI   =-0.207   WS   = 6.053   VSO   = 6.200   WSO    = 0.0        PAIRNT =   2.8100   PAIRNC =    1.5400
  VE  = -0.430   WIE  = 0.253   WSE  = 0.074   VSOE  = 0.0     WSOE   = 0.0        CNORMT = 319.6300   CNORMC =  354.4300
  VESQ= -0.000   WIESQ= 0.0     WSESQ= 0.0     VSOESQ= 0.0     WSOESQ= 0.0         EJOINT =   7.9886   EJOINC =    6.6716
  VSYM=  0.0                                                                       SPCTIN =   3.2766   SPCCIN =    3.4606
                 NIMAG ... 5                                                       NLVDNT ..... 11     NLVDNC ..... 11

  ABOVE  0.0  MEV,  VE=-0.430   VESQ=-0.000                                        TEMPLT =   1.2223   TEMPLC =    1.1505
  ABOVE  6.00 MEV, WIE= 0.253   WIESQ= 0.0                                         TNORMT =   0.2426   TNORMC =    0.3828
                   WSE=-0.325   WSESQ= 0.0                                         SPCTEX =   3.2766   SPCCEX =    3.4606

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.850000MEV   CROSS SECTION=   5.000MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0         D.OBS. =     0.0  EV  GAM.WIDTH =  0.0   EV
   CALCULATED ONES  ... T.GAM= 0.0         D.CAL. =     0.0  EV  GAM.WIDTH =  0.0   EV   NORMALIZATION FACTOR ... 1.2438D-04


  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BRINK
   ENERGY = 20.79 MEV    WIDTH = 5.000 MEV   PARA1 = 0.0     PARA2 = 0.0     EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN   PARITY      NO    ENERGY   SPIN   PARITY      NO    ENERGY   SPIN   PARITY
    0   0.0        0.0      +         1   0.84680   2.0      +          2   2.08510   4.0      +
    3   2.65760    2.0      +         4   2.94170   0.0      +          5   2.96000   2.0      +
    6   3.12000    1.0      +         7   3.12290   4.0      +          8   3.37020   2.0      +
    9   3.38840    6.0      +        10   3.44540   3.0      +         11   3.44930   1.0      +
   12   3.60090    2.0      +        13   3.60190   2.0      +         14   3.60700   0.0      +
   15   3.74800    2.0      +        16   3.75580   6.0      +         17   3.83200   2.0      +
   18   3.85650    3.0      +        19   4.09400   3.0      +         20   4.10030   3.0      +
   21   4.12000    4.0      +        22   4.29820   4.0      +         23   4.30200   0.0      +
   24   4.39500    3.0      +        25   4.40100   2.0      +         26   4.45840   3.0      +
   27   4.51000    3.0      -

   LEVELS ABOVE 4.700MEV ARE ASSUMED TO BE OVERLAPPING


  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    8.5000D-01  1.0000D+00  2.0000D+00  3.0000D+00  4.0000D+00  5.0000D+00  6.0000D+00  7.0000D+00  8.0000D+00  9.0000D+00
    1.0000D+01  1.1000D+01  1.2000D+01  1.3000D+01  1.4000D+01
```

Fig. 7-b The output of Example-7.

EXAMPLE-7, FE-56 CROSS SECTION, E=850KEV TO 14MEV PAGE 2

TARGET NUCLEUS ... FE 56

CALCULATED CROSS SECTIONS IN MILLI-BARNS

ENERGY(MEV)	CAPTURE	ELASTIC	INELASTIC	COMPOUND	TOTAL	MU-BAR	CAPTURE-S	CAPTURE-P
8.5000D-01	5.1729D+00	3.9115D+03	0.0	1.9147D+03	3.9167D+03	1.3299D-01	2.1999D-01	9.2345D-01
1.0000D+00	2.3664D+00	3.2939D+03	4.4194D+02	1.8992D+03	3.7382D+03	1.6462D-01	2.0145D-01	6.4893D-01
2.0000D+00	2.1788D+00	2.5458D+03	7.8500D+02	1.6623D+03	3.3329D+03	3.3603D-01	1.3413D-01	5.0495D-01
3.0000D+00	2.1885D+00	2.4563D+03	9.4289D+02	1.5104D+03	3.4014D+03	4.7290D-01	1.4164D-01	5.8028D-01
4.0000D+00	1.5613D+00	2.2939D+03	1.2585D+03	1.4925D+03	3.5540D+03	6.0706D-01	6.9097D-02	3.6687D-01
5.0000D+00	1.2740D+00	2.2522D+03	1.3924D+03	1.5119D+03	3.6459D+03	6.9098D-01	5.2111D-02	2.8272D-01
6.0000D+00	1.2112D+00	2.1892D+03	1.4492D+03	1.5195D+03	3.6397D+03	7.4988D-01	4.6919D-02	2.3971D-01
7.0000D+00	1.0328D+00	2.1049D+03	1.4607D+03	1.4975D+03	3.5666D+03	7.8992D-01	3.8943D-02	1.7924D-01
8.0000D+00	7.8589D-01	1.9859D+03	1.4529D+03	1.4703D+03	3.4396D+03	8.1607D-01	3.0268D-02	1.1672D-01
9.0000D+00	5.7846D-01	1.8476D+03	1.4337D+03	1.4418D+03	3.2819D+03	8.3058D-01	2.2675D-02	7.4836D-02
1.0000D+01	4.2676D-01	1.6980D+03	1.4149D+03	1.4153D+03	3.1133D+03	8.3814D-01	1.6603D-02	5.0758D-02
1.1000D+01	3.2009D-01	1.5560D+03	1.3926D+03	1.3929D+03	2.9489D+03	8.3681D-01	1.2250D-02	3.6322D-02
1.2000D+01	2.4700D-01	1.4237D+03	1.3753D+03	1.3756D+03	2.7993D+03	8.3109D-01	9.2620D-03	2.7283D-02
1.3000D+01	1.9670D-01	1.3070D+03	1.3626D+03	1.3628D+03	2.6698D+03	8.2210D-01	7.2273D-03	2.1334D-02
1.4000D+01	1.6107D-01	1.2092D+03	1.3535D+03	1.3536D+03	2.5629D+03	8.1089D-01	5.8024D-03	1.7199D-02

RUNNING TIME ..... 23.86 SEC.

Fig. 7-b The output of Example-7 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
    1    1 2        EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV
   15   92 238           1    1              22        -1         1
         1 238.051             4.803
         6  1.392              1.348     1.348
        11  0.47               1.0       0.470
        16 38.23               7.67     13.89
        36  0.0   + 0
        71 29.18     -18.47    0.69      6075.0    3.82
        79 18.0       0.0276
        81 13.61      6.0      0.1                 0.4
        90  0.955
       101  2.0   - 8
       201  0.0   + 5 0.043 + 7 0.097 + 9 0.133 + 1 0.1452+ 3
       206 0.165 +11 0.173 + 7 0.189 + 5 0.220 + 7 0.2291+ 9
       211 0.3   +11 0.3072+ 9 0.373 +13 0.6932+ 1 0.718 + 3
       216 0.7432+ 5 0.7423- 3 0.7541- 1 0.7986- 7 0.823 - 5
       221 0.894 -11 0.943 - 9
      1211         14
         1   17    1   17    4   17    5   17    8   17   14   17   15
         1 0.411      0.22        0.2064    0.1625   1.004-4   1.21  -5
         2   18    4   18    5   18   14   18   15   19    1   19    2
         2  0.5154    0.4841    4.239 -4  8.777 -5  0.2323    0.1947
         3   19    3   19    7   19    8   19    9   19   10   19   12
         3  0.1538    0.107     0.09862   0.08369   0.07962   0.05018
         4   19   16   20    1   20    2   20    5   20    7   20    8
         4  6.79  -5  0.2729    0.2298    0.1471    0.1288    0.1191
         5   20    9   20   15   20   16   21    3   21    6   21   10
         5  0.1017    4.754 -4  2.146 -4  0.2987    0.2247    0.1678
         6   21   11   21   12   21   13   22    2   22    3   22    6
         6  0.1176    0.1132    0.07795   0.2129    0.1744    0.1334
         7   22    7   22    9   22   10   22   11   22   12
         7  0.1291    0.1056    0.1014    0.07284   0.0703
 1718       0.1       0.5                                     2.0   -8
```

Fig. 8–a The input data including γ–ray spectra calculation (Example–8).

```
EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV                                                    PAGE    1

 TARGET NUCLEUS ... U  238     NUCLEAR MASS ... 238.051     SEPARATION ENERGY ...   4.8030  MEV

  HAUSER-FESHBACH THEORY USED
  NUMBER OF DISCRETE LEVELS OF COMPOUND NUCLEUS TAKEN IS  22
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

              .......... POTENTIAL PARAMETERS ..........                               .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.392   RI    = 0.0    RS    = 1.348   RSO    = 1.348                         DNPART =    0.0      DNPARC =  29.1800
  AO  =  0.470   A1    = 0.0    B     = 1.000   ASO    = 0.470                         SPINCT =    0.0      SPINCC = -18.4700
  V   = 38.230   WI    = 0.0    WS    = 7.670   VSO    =13.890   WSO    = 0.0          PAIRNT =    0.0      PAIRNC =   0.6900
  VE  =  0.0     WIE   = 0.0    WSE   = 0.0     VSOE   = 0.0     WSOE   = 0.0          CNORMT =    0.0      CNORMC =6075.0000
  VESQ=  0.0     WIESQ= 0.0     WSESQ= 0.0      VSOESQ= 0.0      WSOESQ= 0.0           EJOINT =    0.0      EJOINC =   3.8200
  VSYM=  0.0                                                                           SPCTIN =    0.0      SPCCIN =   0.0
                 NIMAG ... 1                                                           NLVDNT .....  0      NLVDNC .....  1

                                                                                       TEMPLT =    0.0      TEMPLC =   0.4142
                                                                                       TNORMT =    0.0      TNORMC = -10.8441
                                                                                       SPCTEX =    0.0      SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.0     MEV   CROSS SECTION=    0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0         D.OBS. =    18.00 EV  GAM.WIDTH =  0.0276 EV
   CALCULATED ONES  ... T.GAM= 9.634D-03   D.CAL. =     0.0  EV  GAM.WIDTH =  0.0    EV   NORMALIZATION FACTOR ... 9.63420-03


  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... LANE
   ENERGY = 13.61 MEV   WIDTH = 6.000 MEV   PARA1 = 0.100   PARA2 = 0.0    EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN   PARITY     NO    ENERGY   SPIN   PARITY     NO    ENERGY   SPIN   PARITY
    0   0.0        0.0     +


  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    2.0000D-08
```

Fig. 8–b The output of Example–8.

EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV

PAGE 2

LEVEL PARAMETERS (COMPOUND NUCLEUS)

0	0.0	2.5	+	1	0.04300	3.5	+	2	0.09700	4.5	+
3	0.13300	0.5	+	4	0.14520	1.5	+	5	0.16500	5.5	+
6	0.17300	3.5	+	7	0.18900	2.5	+	8	0.22000	3.5	+
9	0.22910	4.5	+	10	0.30000	5.5	+	11	0.30720	4.5	+
12	0.37300	6.5	+	13	0.69320	0.5	+	14	0.71800	1.5	+
15	0.74320	2.5	+	16	0.74230	1.5	-	17	0.75410	0.5	-
18	0.79860	3.5	-	19	0.82300	2.5	-	20	0.89400	5.5	-
21	0.94300	4.5	-								

LEVELS ABOVE 0.955MEV ARE ASSUMED TO BE OVERLAPPING

BRANCHING RATIOS FOR DISCRETE LEVELS ARE CALCULATED AND INPUT(*)
BRANCHING RATIO FOR PRIMARY TRANSITIONS ARE PUT IN

INITIAL	FINAL	BRANCHING RATIO	INITIAL	FINAL	BRANCHING RATIO	INITIAL	FINAL	BRANCHING RATIO
1	0	1.000D+00	2	0	1.870D-04	2	1	9.998D-01
3	0	1.000D+00	4	0	9.994D-01	4	1	1.248D-05
4	3	5.928D-04	5	1	2.946D-04	5	2	9.997D-01
6	0	6.627D-01	6	1	2.812D-01	6	2	5.618D-02
6	4	7.286D-09	6	5	1.438D-11	7	0	6.784D-01
7	1	3.127D-01	7	2	2.271D-06	7	3	1.897D-07
7	4	8.443D-03	7	6	4.116D-04	8	0	5.855D-01
8	1	3.049D-01	8	2	1.023D-01	8	4	4.414D-07
8	5	9.487D-08	8	6	5.708D-03	8	7	1.638D-03
9	0	2.354D-04	9	1	7.011D-01	9	2	2.507D-01
9	5	2.865D-02	9	6	1.920D-02	9	7	3.867D-08
9	8	8.196D-05	10	1	3.436D-04	10	2	7.479D-01
10	5	2.199D-01	10	6	1.013D-05	10	8	1.004D-06
10	9	3.186D-02	11	0	2.745D-04	11	1	5.397D-01
11	2	2.718D-01	11	5	8.414D-02	11	6	7.072D-02
11	7	2.315D-06	11	8	1.940D-02	11	9	1.394D-02
11	10	1.092D-05	12	2	5.845D-04	12	5	9.580D-01
12	9	2.252D-05	12	10	4.141D-02	12	11	4.502D-07
13	0	1.608D-03	13	3	5.153D-01	13	4	4.828D-01
13	7	3.274D-04	14	0	4.082D-01	14	1	5.289D-04
14	3	2.207D-01	14	4	2.071D-01	14	6	1.815D-04
14	7	1.631D-01	14	8	1.156D-04	14	13	1.679D-05
15	0	2.799D-01	15	1	2.340D-01	15	2	2.629D-04
15	3	1.974D-04	15	4	1.457D-01	15	6	1.263D-01
15	7	1.160D-01	15	8	9.755D-02	15	9	8.379D-05
15	11	3.676D-05	15	13	7.292D-10	15	14	1.089D-05
* 16	0	4.110D-01	* 16	3	2.200D-01	* 16	4	2.064D-01
* 16	7	1.625D-01	* 16	13	1.004D-04	* 16	14	1.210D-05
* 17	3	5.154D-01	* 17	4	4.841D-01	* 17	13	4.239D-04
* 17	14	8.777D-05	* 18	0	2.323D-01	* 18	1	1.947D-01
* 18	2	1.538D-01	* 18	6	1.070D-01	* 18	7	9.862D-02
* 18	8	8.369D-02	* 18	9	7.962D-02	* 18	11	5.018D-02
* 18	15	6.790D-05	* 19	0	2.729D-01	* 19	1	2.298D-01
* 19	4	1.471D-01	* 19	6	1.288D-01	* 19	7	1.191D-01
* 19	8	1.017D-01	* 19	14	4.754D-04	* 19	15	2.146D-04
* 20	2	2.987D-01	* 20	5	2.247D-01	* 20	9	1.678D-01
* 20	10	1.176D-01	* 20	11	1.132D-01	* 20	12	7.795D-02
* 21	1	2.129D-01	* 21	2	1.744D-01	* 21	5	1.334D-01
* 21	6	1.291D-01	* 21	8	1.056D-01	* 21	9	1.014D-01
* 21	10	7.284D-02	* 21	11	7.030D-02			

Fig. 8 b The output of Example 8 (continued).

```
PRIMARY TRANSITION ..... ENERGY AT 2.000D-08MEV
      BRANCHING RATIO FOR 2 LEVELS OF
      16   1.000D-01    17   5.000D-01

                         IN CONSIDERATION OF <  E1 TRANS.    M1 TRANS.    E2 TRANS. >
```

Fig. 8-b The output of Example-8 (continued).

EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV   PAGE 3

TARGET NUCLEUS ... U 238

GAMMA RAY SPECTRA AND POPULATION PROBABILITIES

INCIDENT ENERGY (CMS) ... 1.992D-08 MEV   SEPARATION ENERGY ... 4.803D+00 MEV

INCIDENT ENERGY (LAB) ... 2.000D-08 MEV

POPULATION PROBABILITIES OF DISCRETE LEVELS

NO.	ENERGY		P-PROB.	NO.	ENERGY		P-PROB.	NO.	ENERGY		P-PROB.
0	0.0	2.5 +	9.996D-01	1	0.04300	3.5 +	6.462D-02	2	0.09700	4.5 +	5.916D-03
3	0.13300	0.5 +	3.717D-01	4	0.14520	1.5 +	3.676D-01	5	0.16500	5.5 +	3.925D-04
6	0.17300	3.5 +	1.724D-02	7	0.18900	2.5 +	6.851D-02	8	0.22000	3.5 +	1.475D-02
9	0.22910	4.5 +	2.025D-03	10	0.30000	5.5 +	1.115D-04	11	0.30720	4.5 +	1.531D-03
12	0.37300	6.5 +	4.752D-06	13	0.69320	0.5 +	1.697D-02	14	0.71800	1.5 +	1.806D-02
15	0.74320	2.5 +	9.738D-03	16	0.74230	1.5 -	1.211D-01	17	0.75410	0.5 -	5.169D-01
18	0.79860	3.5 -	3.176D-03	19	0.82300	2.5 -	1.002D-02	20	0.89400	5.5 -	8.490D-06
21	0.94300	4.5 -	1.404D-04								

POPULATION PROBABILITIES OF CONTINUUM STATES

	2*J = 1		2*J = 3		2*J = 5		2*J = 7		2*J = 9		2*J =11	
ENERGY (MEV)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
4.8030D+00	1.000 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0
4.6491D+00	4.883 -4	9.383 -4	9.768 -4	1.877 -3	1.190 -7	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0
4.4952D+00	2.775 -3	5.529 -3	5.551 -3	1.106 -2	3.298 -6	1.015 -6	6.188-11	1.102-10	3.148-15	0.0 0	0.0 0	0.0 0
4.3412D+00	6.623 -3	1.368 -2	1.326 -2	2.735 -2	2.609 -5	1.179 -5	2.071 -9	3.364 -9	1.828-13	7.720-14	2.313-18	3.777-18
4.1873D+00	1.107 -2	2.364 -2	2.217 -2	4.728 -2	1.177 -4	6.993 -5	2.552 -8	3.924 -8	4.606-12	2.277-12	1.243-16	1.785-16
4.0334D+00	1.522 -2	3.350 -2	3.049 -2	6.701 -2	3.432 -4	2.275 -4	1.820 -7	2.609 -7	5.776-11	3.427-11	3.396-15	4.529-15
3.8795D+00	1.853 -2	4.182 -2	3.716 -2	8.364 -2	8.335 -4	5.733 -4	8.969 -7	1.214 -6	4.660-10	3.290-10	5.531-14	6.982-14
3.7256D+00	2.082 -2	4.779 -2	4.180 -2	9.558 -2	1.655 -3	1.194 -3	3.211 -6	4.194 -6	2.775 -9	2.110 -9	5.760-13	6.895-13
3.5716D+00	2.232 -2	5.143 -2	4.486 -2	1.029 -1	2.953 -3	2.135 -3	9.546 -6	1.210 -5	1.289 -8	1.047 -8	4.487-12	5.132-12
3.4177D+00	2.323 -2	5.291 -2	4.674 -2	1.058 -1	4.731 -3	3.457 -3	2.405 -5	2.964 -5	4.851 -8	4.067 -8	2.695-11	2.979-11
3.2638D+00	2.385 -2	5.256 -2	4.804 -2	1.051 -1	7.081 -3	5.086 -3	5.404 -5	6.470 -5	1.578 -7	1.343 -7	1.332-10	1.420-10
3.1099D+00	2.437 -2	5.072 -2	4.915 -2	1.015 -1	9.935 -3	7.005 -3	1.099 -4	1.268 -4	4.497 -7	3.820 -7	5.538-10	5.684-10
2.9560D+00	2.501 -2	4.779 -2	5.052 -2	9.570 -2	1.335 -2	9.033 -3	2.073 -4	2.287 -4	1.165 -6	9.705 -7	2.028 -9	1.986 -9
2.8020D+00	2.586 -2	4.409 -2	5.231 -2	8.836 -2	1.725 -2	1.109 -2	3.669 -4	3.811 -4	2.769 -6	2.223 -6	6.637 -9	6.134 -9
2.6481D+00	2.701 -2	3.996 -2	5.474 -2	8.022 -2	2.165 -2	1.298 -2	6.163 -4	5.961 -4	6.155 -6	4.679 -6	1.992 -8	1.716 -8
2.4942D+00	2.839 -2	3.571 -2	5.769 -2	7.186 -2	2.644 -2	1.466 -2	9.891 -4	8.794 -4	1.285 -5	9.138 -6	5.529 -8	4.397 -8
2.3403D+00	2.996 -2	3.167 -2	6.109 -2	6.396 -2	3.154 -2	1.607 -2	1.523 -3	1.240 -3	2.545 -5	1.681 -5	1.437 -7	1.051 -7
2.1864D+00	3.155 -2	2.807 -2	6.462 -2	5.698 -2	3.672 -2	1.730 -2	2.257 -3	1.686 -3	4.787 -5	2.946 -5	3.514 -7	2.374 -7
2.0324D+00	3.307 -2	2.509 -2	6.811 -2	5.128 -2	4.184 -2	1.846 -2	3.226 -3	2.239 -3	8.607 -5	4.987 -5	8.149 -7	5.147 -7
1.8785D+00	3.440 -2	2.275 -2	7.134 -2	4.693 -2	4.672 -2	1.971 -2	4.466 -3	2.925 -3	1.484 -4	8.230 -5	1.802 -6	1.082 -6
1.7246D+00	3.555 -2	2.105 -2	7.433 -2	4.393 -2	5.135 -2	2.118 -2	6.012 -3	3.786 -3	2.469 -4	1.334 -4	3.830 -6	2.225 -6
1.5707D+00	3.650 -2	1.990 -2	7.708 -2	4.214 -2	5.575 -2	2.300 -2	7.908 -3	4.868 -3	3.985 -4	2.130 -4	7.867 -6	4.492 -6
1.4168D+00	3.735 -2	1.925 -2	7.981 -2	4.147 -2	6.010 -2	2.525 -2	1.021 -2	6.228 -3	6.269 -4	3.357 -4	1.570 -5	8.920 -6
1.2628D+00	3.816 -2	1.904 -2	8.265 -2	4.182 -2	6.457 -2	2.802 -2	1.298 -2	7.926 -3	9.651 -4	5.218 -4	3.056 -5	1.740 -5
1.1089D+00	3.908 -2	1.925 -2	8.593 -2	4.321 -2	6.945 -2	3.145 -2	1.634 -2	1.004 -2	1.459 -3	8.000 -4	5.808 -5	3.330 -5
9.5500D-01	4.021 -2	1.991 -2	8.992 -2	4.565 -2	7.505 -2	3.566 -2	2.040 -2	1.266 -2	2.173 -3	1.210 -3	1.080 -4	6.242 -5

INTEGRATED POPULATION INCLUDING THAT FOR DISCRETE LEVELS ... 3.4112D+00

DISCRETE ... 2.6111D+00   CONTINUOUS ... 8.0001D-01

Fig. 8-b The output of Example-8 (continued).

EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV PAGE 4

GAMMA RAY SPECTRUM

LINE SPECTRUM ... PRIMARY + DISCRETE TO DISCRETE

ENERGY(MEV)	INTENSITY	ENERGY*INTENSITY
4.803D+00	5.153D-05	2.475D-04
4.670D+00	5.988D-04	2.797D-03
4.658D+00	6.384D-04	2.973D-03
4.614D+00	4.216D-05	1.945D-04
4.110D+00	4.082D-04	1.677D-03
4.085D+00	4.237D-04	1.731D-03
4.060D+00	2.223D-05	9.027D-05
4.061D+00	1.000D-01	4.061D-01
4.049D+00	5.000D-01	2.024D+00
4.300D-02	6.462D-02	2.778D-03
9.700D-02	1.293D-06	1.254D-07
5.400D-02	6.915D-03	3.734D-04
1.330D-01	3.717D-01	4.944D-02
1.452D-01	3.674D-01	5.334D-02
1.022D-01	4.587D-06	4.688D-07
1.220D-02	2.179D-04	2.658D-06
1.220D-01	1.156D-07	1.411D-08
6.800D-02	3.924D-04	2.668D-05
1.730D-01	1.142D-02	1.976D-03
1.300D-01	4.847D-03	6.301D-04
7.600D-02	9.684D-04	7.360D-05
2.780D-02	1.256D-10	3.491D-12
8.000D-03	2.478D-13	1.983D-15
1.890D-01	4.648D-02	8.784D-03
1.460D-01	2.142D-02	3.128D-03
9.200D-02	1.556D-07	1.431D-08
5.600D-02	1.300D-08	7.279D-10
4.380D-02	5.784D-04	2.533D-05
1.600D-02	2.819D-05	4.511D-07
2.200D-01	8.633D-03	1.899D-03
1.770D-01	4.496D-03	7.958D-04
1.230D-01	1.509D-03	1.856D-04
7.480D-02	6.508D-09	4.868D-10
5.500D-02	1.399D-09	7.694D-11
4.700D-02	8.417D-05	3.956D-06
3.100D-02	2.415D-05	7.487D-07
2.291D-01	4.767D-07	1.092D-07
1.861D-01	1.420D-03	2.643D-04
1.321D-01	5.079D-04	6.709D-05
6.410D-02	5.802D-05	3.719D-06
5.610D-02	3.890D-05	2.182D-06
4.010D-02	7.832D-11	3.141D-12
9.100D-03	1.660D-07	1.511D-09
2.570D-01	3.832D-08	9.847D-09
2.030D-01	8.339D-05	1.693D-05
1.350D-01	2.453D-05	3.311D-06
1.270D-01	1.129D-09	1.434D-10
8.000D-02	1.120D-10	8.959D-12
7.090D-02	3.552D-06	2.519D-07
3.072D-01	4.202D-07	1.291D-07
2.642D-01	8.262D-04	2.183D-04
2.102D-01	4.160D-04	8.745D-05
1.422D-01	1.288D-04	1.831D-05
1.342D-01	1.083D-04	1.453D-05

CONTINUUM SPECTRUM

ENERGY(MEV)	INTENSITY	ENERGY*INTENSITY
5.0000D-02	8.0752D-04	4.0376D-05
1.5000D-01	1.6632D-02	2.4948D-03
3.0000D-01	1.0042D-01	3.0127D-02
4.0000D-01	1.7698D-01	7.0793D-02
5.0000D-01	2.5899D-01	1.2950D-01
6.0000D-01	3.3727D-01	2.0236D-01
7.0000D-01	4.0791D-01	2.8554D-01
8.0000D-01	5.4099D-01	4.3280D-01
9.0000D-01	7.0608D-01	6.3547D-01
1.0000D+00	8.2039D-01	8.2039D-01
1.2000D+00	7.7369D-01	9.2843D-01
1.4000D+00	6.9206D-01	9.6889D-01
1.6000D+00	5.9287D-01	9.4860D-01
1.8000D+00	4.9036D-01	8.8266D-01
2.0000D+00	3.9366D-01	7.8733D-01
2.2000D+00	3.0823D-01	6.7810D-01
2.4000D+00	2.3595D-01	5.6627D-01
2.6000D+00	1.7705D-01	4.6033D-01
2.8000D+00	1.3078D-01	3.6617D-01
3.0000D+00	9.5336D-02	2.8601D-01
3.2000D+00	6.8737D-02	2.1996D-01
3.4000D+00	4.9034D-02	1.6672D-01
3.6000D+00	3.4467D-02	1.2408D-01
3.8000D+00	2.3695D-02	9.0042D-02
4.0000D+00	4.1793D-03	1.6717D-02
4.2000D+00	1.7270D-03	7.2534D-03
4.4000D+00	4.5708D-04	2.0111D-03
4.6000D+00	5.0325D-05	2.3150D-04
4.8000D+00	1.9258D-07	9.2436D-07
4.8025D+00	3.0717D-08	1.4752D-07

Fig. 8-b The output of Example-8 (continued).

```
EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV                                              PAGE    5

GAMMA RAY SPECTRUM

   LINE SPECTRUM ... PRIMARY + DISCRETE TO DISCRETE                 CONTINUUM SPECTRUM

      ENERGY(MEV)  INTENSITY   ENERGY*INTENSITY                         ENERGY(MEV)  INTENSITY   ENERGY*INTENSITY
       1.182D-01   3.543D-09   4.188D-10
       8.720D-02   2.970D-05   2.590D-06
       7.810D-02   2.134D-05   1.666D-06
       7.200D-03   1.672D-08   1.204D-10
       2.760D-01   2.778D-09   7.667D-10
       2.080D-01   4.553D-06   9.470D-07
       1.439D-01   1.070D-10   1.540D-11
       7.300D-02   1.968D-07   1.437D-08
       6.580D-02   2.139D-12   1.408D-13
       6.932D-01   2.729D-05   1.892D-05
       5.602D-01   8.743D-03   4.898D-03
       5.480D-01   8.193D-03   4.490D-03
       5.042D-01   5.556D-06   2.802D-06
       7.180D-01   7.372D-03   5.293D-03
       6.750D-01   9.551D-06   6.447D-06
       5.850D-01   3.985D-03   2.331D-03
       5.728D-01   3.740D-03   2.142D-03
       5.450D-01   3.277D-06   1.786D-06
       5.290D-01   2.946D-03   1.558D-03
       4.980D-01   2.088D-06   1.040D-06
       2.480D-02   3.032D-07   7.520D-09
       7.432D-01   2.725D-03   2.026D-03
       7.002D-01   2.279D-03   1.596D-03
       6.462D-01   2.560D-06   1.654D-06
       6.102D-01   1.922D-06   1.173D-06
       5.980D-01   1.419D-03   8.484D-04
       5.702D-01   1.230D-03   7.013D-04
       5.542D-01   1.129D-03   6.258D-04
       5.232D-01   9.499D-04   4.970D-04
       5.141D-01   8.159D-07   4.195D-07
       4.360D-01   3.580D-07   1.561D-07
       5.000D-02   7.100D-12   3.550D-13
       2.520D-02   1.060D-07   2.672D-09
       7.423D-01   4.978D-02   3.695D-02
       6.093D-01   2.665D-02   1.624D-02
       5.971D-01   2.500D-02   1.493D-02
       5.533D-01   1.968D-02   1.089D-02
       4.910D-02   1.216D-05   5.971D-07
       2.430D-02   1.466D-06   3.561D-08
       6.211D-01   2.664D-01   1.655D-01
       6.089D-01   2.502D-01   1.524D-01
       6.090D-02   2.191D-04   1.334D-05
       3.610D-02   4.537D-05   1.638D-06
       7.986D-01   7.378D-04   5.892D-04
       7.556D-01   6.184D-04   4.673D-04
       7.016D-01   4.885D-04   3.427D-04
       6.256D-01   3.399D-04   2.126D-04
       6.096D-01   3.132D-04   1.909D-04
       5.786D-01   2.658D-04   1.538D-04
       5.695D-01   2.529D-04   1.440D-04
       4.914D-01   1.594D-04   7.832D-05
       5.540D-02   2.157D-07   1.195D-08
       8.230D-01   2.735D-03   2.251D-03
       7.800D-01   2.303D-03   1.796D-03
```

Fig. 8–b The output of Example 8 (continued).

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EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV                                                        PAGE    6

 GAMMA RAY SPECTRUM

    LINE SPECTRUM ... PRIMARY + DISCRETE TO DISCRETE                  CONTINUUM SPECTRUM

        ENERGY(MEV)   INTENSITY    ENERGY*INTENSITY                       ENERGY(MEV)  INTENSITY    ENERGY*INTENSITY
          6.778D-01    1.474D-03    9.991D-04
          6.500D-01    1.291D-03    8.389D-04
          6.340D-01    1.193D-03    7.567D-04
          6.030D-01    1.019D-03    6.145D-04
          1.050D-01    4.764D-06    5.002D-07
          7.980D-02    2.150D-06    1.716D-07
          7.970D-01    2.536D-06    2.021D-06
          7.290D-01    1.908D-06    1.391D-06
          6.649D-01    1.425D-06    9.472D-07
          5.940D-01    9.984D-07    5.931D-07
          5.868D-01    9.610D-07    5.639D-07
          5.210D-01    6.618D-07    3.448D-07
          9.000D-01    2.989D-05    2.690D-05
          8.460D-01    2.448D-05    2.071D-05
          7.780D-01    1.873D-05    1.457D-05
          7.700D-01    1.812D-05    1.395D-05
          7.230D-01    1.482D-05    1.072D-05
          7.139D-01    1.423D-05    1.016D-05
          6.430D-01    1.022D-05    6.574D-06
          6.358D-01    9.868D-06    6.274D-06
```

Fig. 8–b The output of Example–8 (continued).

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        EXAMPLE-8, U-238 GAMMA-RAY SPECTRA AT 0.02EV                                                              PAGE    7

TOTAL GAMMA RAY SPECTRUM ( PHOTON /CAPTURE/ENERGY BINS)

  INCIDENT ENERGY (CMS) ... 1.992D-08 MEV
  INCIDENT ENERGY (LAB) ... 2.000D-08 MEV

        ENERGY BIN (MEV)          PHOTONS     ENERGY*PHOTONS          PHOTONS              SPECTRA
   (BIN WIDTH ... 2.500D-01)                                     (CONTINUUM  ONLY)     PER BIN (MEV)
     0.0       - 2.500D-01       9.193D-01       1.248D-01          4.471D-03            1.078D+00
     2.500D-01 - 5.000D-01       4.068D-02       1.620D-02          3.970D-02            4.773D-02
     5.000D-01 - 7.500D-01       7.780D-01       4.847D-01          8.878D-02            9.127D-01
     7.500D-01 - 1.000D+00       1.710D-01       1.511D-01          1.645D-01            2.006D-01
     1.000D+00 - 1.250D+00       2.007D-01       2.254D-01          2.007D-01            2.355D-01
     1.250D+00 - 1.500D+00       1.756D-01       2.408D-01          1.756D-01            2.060D-01
     1.500D+00 - 1.750D+00       1.450D-01       2.349D-01          1.450D-01            1.701D-01
     1.750D+00 - 2.000D+00       1.134D-01       2.120D-01          1.134D-01            1.330D-01
     2.000D+00 - 2.250D+00       8.490D-02       1.799D-01          8.490D-02            9.960D-02
     2.250D+00 - 2.500D+00       6.128D-02       1.451D-01          6.128D-02            7.189D-02
     2.500D+00 - 2.750D+00       4.285D-02       1.122D-01          4.285D-02            5.028D-02
     2.750D+00 - 3.000D+00       2.924D-02       8.384D-02          2.924D-02            3.431D-02
     3.000D+00 - 3.250D+00       1.958D-02       6.101D-02          1.958D-02            2.296D-02
     3.250D+00 - 3.500D+00       1.288D-02       4.337D-02          1.288D-02            1.511D-02
     3.500D+00 - 3.750D+00       8.616D-03       3.117D-02          8.616D-03            1.011D-02
     3.750D+00 - 4.000D+00       3.583D-03       1.375D-02          3.583D-03            4.203D-03
     4.000D+00 - 4.250D+00       6.015D-01       2.437D+00          6.248D-04            7.056D-01
     4.250D+00 - 4.500D+00       1.588D-04       6.889D-04          1.588D-04            1.863D-04
     4.500D+00 - 4.803D+00       1.344D-03       6.273D-03          1.341D-05            1.301D-03

AVERAGE GAMMA-RAY ENERGY ...  1.4089D+00 MEV
TOTAL RELEASED GAMMA RAY ENERGY ...  4.8038D+00 MEV
TOTAL PHOTON NUMBER ...  3.4096D+00

RUNNING TIME .....     6.13   SEC.
```

Fig. 8–b The output of Example–8 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
   1    1 1         EXAMPLE-9, U-238 GAMMA-RAY SPECTRA AT 0.02EV
  15   92  238           1    1               22        -1         1
        1 238.051                   4.803
        6  1.392                    1.348     1.348
       11  0.47                     1.0       0.470
       16 38.23                     7.67     13.89
       36  0.0   + 0
       71 29.18       -18.47       0.69       6075.0     3.82
       79 18.0         0.0276
       81 13.61        6.0         0.1                   0.4
       90  0.955
      101  2.0   - 8
      201  0.0   + 5 0.043 + 7 0.097 + 9 0.133 + 1 0.1452+ 3
      206 0.165 +11 0.173 + 7 0.189 + 5 0.220 + 7 0.2291+ 9
      211 0.3   +11 0.3072+ 9 0.373 +13 0.6932+ 1 0.718 + 3
      216 0.7432+ 5 0.7423- 3 0.7541- 1 0.7986- 7 0.823 - 5
      221 0.894 -11 0.943 - 9
     1001
```

Fig. 9 a The input data calculating all γ–ray branching ratios between discrete levels internally and considering no primary transition (Example–9).

```
EXAMPLE-9, U-238 GAMMA-RAY SPECTRA AT 0.02EV                                                                       PAGE    1

 TARGET NUCLEUS ... U  238     NUCLEAR MASS ... 238.051     SEPARATION ENERGY ...   4.8030  MEV

  HAUSER-FESHBACH THEORY USED
  NUMBER OF DISCRETE LEVELS OF COMPOUND NUCLEUS TAKEN IS  22
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

                .......... POTENTIAL PARAMETERS ..........                                      .... LEVEL DENSITY PARAMETERS ....

  RO   =  1.392   RI    = 0.0     RS    = 1.348   RSO    = 1.348                    DNPART =    0.0        DNPARC =  29.1800
  AO   =  0.470   A1    = 0.0     B     = 1.000   ASO    = 0.470                    SPINCT =    0.0        SPINCC = -18.4700
  V    = 38.230   WI    = 0.0     WS    = 7.670   VSO    =13.890   WSO    = 0.0     PAIRNT =    0.0        PAIRNC =   0.6900
  VE   =  0.0     WIE   = 0.0     WSE   = 0.0     VSOE   = 0.0     WSOE   = 0.0     CNORMT =    0.0        CNORMC =6075.0000
  VESQ=  0.0      WIESQ= 0.0      WSESQ= 0.0      VSOESQ= 0.0      WSOESQ= 0.0      EJOINT =    0.0        EJOINC =   3.8200
  VSYM=  0.0                                                                        SPCTIN =    0.0        SPCCIN =   0.0
                  NIMAG ... 1                                                       NLVDNT .....  0        NLVDNC .....  1

                                                                                    TEMPLT =    0.0        TEMPLC =   0.4142
                                                                                    TNORMT =    0.0        TNORMC = -10.8441
                                                                                    SPCTEX =    0.0        SPCCEX =   0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES   ENERGY AT 0.0     MEV   CROSS SECTION=    0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0          D.OBS. =     18.00 EV  GAM.WIDTH =  0.0276 EV
   CALCULATED ONES  ... T.GAM= 9.634D-03    D.CAL. =      0.0  EV  GAM.WIDTH =  0.0     EV   NORMALIZATION FACTOR ... 9.6342D-03

  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... LANE
   ENERGY = 13.61 MEV   WIDTH = 6.000 MEV   PARA1 = 0.100   PARA2 = 0.0    EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY   SPIN   PARITY     NO    ENERGY   SPIN   PARITY     NO    ENERGY   SPIN   PARITY
    0    0.0       0.0     +

  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    2.00000-08
```

Fig. 9–b The output of Example–9.

EXAMPLE-9, U-238 GAMMA-RAY SPECTRA AT 0.02EV PAGE 2

LEVEL PARAMETERS (COMPOUND NUCLEUS)

0	0.0	2.5	+	1	0.04300	3.5	+	2	0.09700	4.5	+
3	0.13300	0.5	+	4	0.14520	1.5	+	5	0.16500	5.5	+
6	0.17300	3.5	+	7	0.18900	2.5	+	8	0.22000	3.5	+
9	0.22910	4.5	+	10	0.30000	5.5	+	11	0.30720	4.5	+
12	0.37300	6.5	+	13	0.69320	0.5	+	14	0.71800	1.5	+
15	0.74320	2.5	+	16	0.74230	1.5	-	17	0.75410	0.5	-
18	0.79860	3.5	-	19	0.82300	2.5	-	20	0.89400	5.5	-
21	0.94300	4.5	-								

LEVELS ABOVE 0.955MEV ARE ASSUMED TO BE OVERLAPPING

BRANCHING RATIOS FOR DISCRETE LEVELS ARE CALCULATED DATA ONLY

INITIAL	FINAL	BRANCHING RATIO	INITIAL	FINAL	BRANCHING RATIO	INITIAL	FINAL	BRANCHING RATIO
1	0	1.000D+00	2	0	1.870D-04	2	1	9.998D-01
3	0	1.000D+00	4	0	9.994D-01	4	1	1.248D-05
4	3	5.928D-04	5	1	2.946D-04	5	2	9.997D-01
6	0	6.627D-01	6	1	2.812D-01	6	2	5.618D-02
6	4	7.286D-09	6	5	1.438D-11	7	0	6.784D-01
7	1	3.127D-01	7	2	2.271D-06	7	3	1.897D-07
7	4	8.443D-03	7	6	4.116D-04	8	0	5.855D-01
8	1	3.049D-01	8	2	1.023D-01	8	4	4.414D-07
8	5	9.487D-08	8	6	5.708D-03	8	7	1.638D-03
9	0	2.354D-04	9	1	7.011D-01	9	2	2.507D-01
9	5	2.865D-02	9	6	1.920D-02	9	7	3.867D-08
9	8	8.196D-05	10	1	3.436D-04	10	2	7.479D-01
10	5	2.199D-01	10	6	1.013D-05	10	8	1.004D-06
10	9	3.186D-02	11	0	2.745D-04	11	1	5.397D-01
11	2	2.718D-01	11	5	8.414D-02	11	6	7.072D-02
11	7	2.315D-06	11	8	1.940D-02	11	9	1.394D-02
11	10	1.092D-05	12	2	5.845D-04	12	5	9.580D-01
12	9	2.252D-05	12	10	4.141D-02	12	11	4.502D-07
13	0	1.608D-03	13	3	5.153D-01	13	4	4.828D-01
13	7	3.274D-04	14	0	4.082D-01	14	1	5.289D-04
14	3	2.207D-01	14	4	2.071D-01	14	6	1.815D-04
14	7	1.631D-01	14	8	1.156D-04	14	13	1.679D-05
15	0	2.799D-01	15	1	2.340D-01	15	2	2.629D-04
15	3	1.974D-04	15	4	1.457D-01	15	6	1.263D-01
15	7	1.160D-01	15	8	9.755D-02	15	9	8.379D-05
15	11	3.676D-05	15	13	7.292D-10	15	14	1.089D-05
16	0	4.110D-01	16	3	2.200D-01	16	4	2.064D-01
16	7	1.625D-01	16	13	1.004D-04	16	14	1.210D-05
17	3	5.154D-01	17	4	4.841D-01	17	13	4.239D-04
17	14	8.777D-05	17	16	1.639D-12	18	0	2.323D-01
18	1	1.947D-01	18	2	1.538D-01	18	6	1.070D-01
18	7	9.862D-02	18	8	8.369D-02	18	9	7.962D-02
18	11	5.018D-02	18	15	6.468D-05	18	16	3.926D-16
19	0	2.729D-01	19	1	2.298D-01	19	4	1.471D-01
19	6	1.288D-01	19	7	1.191D-01	19	8	1.017D-01
19	14	4.754D-04	19	15	2.074D-04	19	16	1.135D-10
19	17	1.150D-15	19	18	3.137D-12	20	2	2.987D-01
20	5	2.247D-01	20	9	1.678D-01	20	10	1.176D-01
20	11	1.132D-01	20	12	7.794D-02	20	18	7.096D-15
21	1	2.129D-01	21	2	1.744D-01	21	5	1.334D-01
21	6	1.291D-01	21	8	1.056D-01	21	9	1.014D-01
21	10	7.284D-02	21	11	7.030D-02	21	18	3.805D-10
21	19	1.078D-14	21	20	1.487D-11			

Fig. 9 b The output of Example–9 (continued).

```
IN CONSIDERATION OF <  E1 TRANS.    M1 TRANS.    E2 TRANS. >
```

Fig. 9–b The output of Example–9 (continued).

EXAMPLE-9, U-238 GAMMA-RAY SPECTRA AT 0.02EV   PAGE 3

TOTAL GAMMA RAY SPECTRUM (PHOTON /CAPTURE/ENERGY BINS)

INCIDENT ENERGY (CMS) ... 1.992D-08 MEV
INCIDENT ENERGY (LAB) ... 2.000D-08 MEV

ENERGY BIN (MEV) (BIN WIDTH ... 2.500D-01)	PHOTONS	ENERGY*PHOTONS	PHOTONS (CONTINUUM ONLY)	SPECTRA PER BIN (MEV)
0.0 - 2.500D-01	8.862D-01	1.159D-01	1.106D-02	8.648D-01
2.500D-01 - 5.000D-01	1.006D-01	4.008D-02	9.820D-02	9.821D-02
5.000D-01 - 7.500D-01	4.508D-01	2.834D-01	2.196D-01	4.399D-01
7.500D-01 - 1.000D+00	4.231D-01	3.738D-01	4.070D-01	4.128D-01
1.000D+00 - 1.250D+00	4.966D-01	5.577D-01	4.966D-01	4.846D-01
1.250D+00 - 1.500D+00	4.343D-01	5.958D-01	4.343D-01	4.238D-01
1.500D+00 - 1.750D+00	3.586D-01	5.811D-01	3.586D-01	3.500D-01
1.750D+00 - 2.000D+00	2.805D-01	5.244D-01	2.805D-01	2.737D-01
2.000D+00 - 2.250D+00	2.100D-01	4.450D-01	2.100D-01	2.050D-01
2.250D+00 - 2.500D+00	1.516D-01	3.590D-01	1.516D-01	1.479D-01
2.500D+00 - 2.750D+00	1.060D-01	2.775D-01	1.060D-01	1.035D-01
2.750D+00 - 3.000D+00	7.235D-02	2.074D-01	7.235D-02	7.060D-02
3.000D+00 - 3.250D+00	4.843D-02	1.509D-01	4.843D-02	4.726D-02
3.250D+00 - 3.500D+00	3.187D-02	1.073D-01	3.187D-02	3.110D-02
3.500D+00 - 3.750D+00	2.131D-02	7.712D-02	2.131D-02	2.080D-02
3.750D+00 - 4.000D+00	8.863D-03	3.401D-02	8.863D-03	8.649D-03
4.000D+00 - 4.250D+00	1.411D-02	5.736D-02	1.546D-03	1.377D-02
4.250D+00 - 4.500D+00	3.928D-04	1.704D-03	3.928D-04	3.833D-04
4.500D+00 - 4.803D+00	3.326D-03	1.552D-02	3.318D-05	2.678D-03

AVERAGE GAMMA-RAY ENERGY ... 1.1722D+00 MEV
TOTAL RELEASED GAMMA RAY ENERGY ... 4.8049D+00 MEV
TOTAL PHOTON NUMBER ... 4.0991D+00

RUNNING TIME ..... 6.16 SEC.

Fig. 9–b The output of Example–9 (continued).

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
    1    1 1        EXAMPLE10, NB-93 GAMMA-RAY SPECTRUM AT 3 ENERGIES
   16   41   93         1    2    1        17        -3          1
         1 92.91                    7.2289
         6 1.23                    1.29      1.11
        11 0.69                    0.52      0.56
        16 52.56                   3.23      6.0
        21 -0.3                    0.271     -0.015
        31 -16.5
        36 0.0    + 9
        71 11.6068   6.2544                  979.91    4.0957
        79 35.0      0.15
        85 0.4
        90 0.82
       101 2.53   - 8 1.0    - 6 1.0    - 3
       201 0.0    + 6 0.041  + 3 0.0587+ 4 0.0787+ 7 0.1134+ 5
       206 0.1404- 2 0.3016- 2 0.3119+ 4 0.3342+ 3 0.3963- 3
       211 0.4502- 3 0.6317+ 4 0.6409+ 5 0.6657+ 3 0.7849+ 3
       216 0.7929+ 3 0.8178- 3
      1301
101117     0.2         0.2        0.1                        2.53  - 8
```

Fig. 10-a The input data for calculation of γ-ray spectra for ^{93}Nb at three points of incident neutron energy (Example-10).

```
EXAMPLE10, NB-93 GAMMA-RAY SPECTRUM AT 3 ENERGIES                                                                        PAGE    1

 TARGET NUCLEUS ... NB  93     NUCLEAR MASS ...  92.910     SEPARATION ENERGY ...   7.2289  MEV

  HAUSER-FESHBACH THEORY USED
  NUMBER OF DISCRETE LEVELS OF COMPOUND NUCLEUS TAKEN IS  17
  CASCADE PROCESS IS EXCLUDED IN THE CALCULATION OF THE CROSS SECTIONS
  ABUNDANCE RATIO USED IN THIS CALCULATION ...100.0  PER CENT

                ......... POTENTIAL PARAMETERS ..........                                                .... LEVEL DENSITY PARAMETERS ....

  RO  =  1.230   RI   = 0.0     RS   = 1.290   RSO   = 1.110                                     DNPART =    0.0       DNPARC =  11.6068
  AO  =  0.690   A1   = 0.0     B    = 0.520   ASO   = 0.560                                     SPINCT =    0.0       SPINCC =    6.2544
  V   = 52.560   WI   = 0.0     WS   = 3.230   VSO   = 6.000   WSO    = 0.0                      PAIRNT =    0.0       PAIRNC =    0.0
  VE  = -0.300   WIE  = 0.0     WSE  = 0.271   VSOE  =-0.015   WSOE   = 0.0                      CNORMT =    0.0       CNORMC = 979.9100
  VESQ=  0.0     WIESQ= 0.0     WSESQ= 0.0     VSOESQ= 0.0     WSOESQ= 0.0                       EJOINT =    0.0       EJOINC =    4.0957
  VSYM=-16.500                                                                                   SPCTIN =    0.0       SPCCIN =    0.0
                 NIMAG ... 2                                                                     NLVDNT .....  0       NLVDNC .....  1

                                                                                                 TEMPLT =    0.0       TEMPLC =    0.8367
                                                                                                 TNORMT =    0.0       TNORMC =    5.6164
                                                                                                 SPCTEX =    0.0       SPCCEX =    0.0

  NORMALIZATION CARRIED OUT FOR ISOTOPES    ENERGY AT 0.0     MEV   CROSS SECTION=    0.0  MILLI-BARNS
   INPUT PARAMETERS ... T.GAM= 0.0         D.OBS. =    35.00 EV  GAM.WIDTH =  0.1500 EV
   CALCULATED ONES  ... T.GAM= 2.693D-02  D.CAL. =      0.0 EV  GAM.WIDTH =  0.0     EV    NORMALIZATION FACTOR ... 2.6928D-02


  PARAMETERS OF THE GIANT RESONANCE LEVEL
  SELECTED PROFILE FUNCTION ... BRINK
   ENERGY = 17.59 MEV   WIDTH = 5.000 MEV   PARA1 = 0.0     PARA2 = 0.0     EXCHNG = 0.400
  LEVEL PARAMETERS
   NO    ENERGY  SPIN  PARITY     NO    ENERGY  SPIN  PARITY     NO    ENERGY  SPIN  PARITY
    0   0.0           4.5     +


  INCIDENT ENERGY IN LAB. SYSTEM (MEV)
    2.5300D-08  1.0000D-06  1.0000D-03
```

Fig. 10–b The output of Example–10.

```
EXAMPLE10, NB-93 GAMMA-RAY SPECTRUM AT 3 ENERGIES                                        PAGE    2

 LEVEL PARAMETERS ( COMPOUND NUCLEUS )
   0   0.0       6.0    +        1   0.04100   3.0    +        2   0.05870   4.0    +
   3   0.07870   7.0    +        4   0.11340   5.0    +        5   0.14040   2.0    -
   6   0.30160   2.0    -        7   0.31190   4.0    +        8   0.33420   3.0    +
   9   0.39630   3.0    -       10   0.45020   3.0    -       11   0.63170   4.0    +
  12   0.64090   5.0    +       13   0.66570   3.0    +       14   0.78490   3.0    +
  15   0.79290   3.0    +       16   0.81780   3.0    -

   LEVELS ABOVE 0.820MEV ARE ASSUMED TO BE OVERLAPPING


 BRANCHING RATIOS FOR DISCRETE LEVELS ARE CALCULATED DATA ONLY
   BRANCHING RATIO FOR PRIMARY TRANSITIONS ARE PUT IN

   INITIAL FINAL  BRANCHING RATIO    INITIAL FINAL  BRANCHING RATIO    INITIAL FINAL  BRANCHING RATIO
      2      0      1.242D-04           2      1      9.999D-01           3      0      1.000D+00
      4      0      8.991D-01           4      1      1.212D-06           4      2      1.009D-01
      4      3      3.065D-08           5      1      1.000D+00           6      1      1.000D+00
      6      5      3.380D-06           7      0      6.637D-05           7      1      4.525D-01
      7      2      3.695D-01           7      4      1.780D-01           8      1      6.645D-05
      8      2      5.512D-05           8      4      1.367D-09           8      5      9.991D-01
      8      6      7.998D-04           8      7      2.923D-08           9      1      5.497D-01
      9      2      4.480D-01           9      5      2.150D-06           9      6      1.090D-07
      9      7      1.749D-03           9      8      5.126D-04          10      1      5.384D-01
     10      2      4.511D-01          10      5      2.124D-06          10      6      2.343D-07
     10      7      7.019D-03          10      8      3.474D-03          10      9      1.118D-08
     11      0      8.896D-08          11      1      1.845D-04          11      2      1.684D-04
     11      4      1.247D-04          11      7      2.928D-05          11      8      2.357D-05
     11      9      7.385D-01          11     10      2.610D-01          12      0      4.094D-01
     12      1      1.193D-04          12      2      3.068D-01          12      3      8.626D-05
     12      4      2.282D-01          12      7      5.536D-02          12      8      4.168D-06
     12     11      1.210D-06          13      1      8.963D-06          13      2      8.223D-06
     13      4      1.866D-09          13      5      7.530D-01          13      6      1.736D-01
     13      7      1.628D-06          13      8      1.339D-06          13      9      5.203D-02
     13     10      2.130D-02          13     11      1.445D-09          13     12      3.407D-16
     14      1      5.830D-06          14      2      5.424D-06          14      4      1.909D-09
     14      5      6.577D-01          14      6      2.077D-01          14      7      1.498D-06
     14      8      1.296D-06          14      9      8.678D-02          14     10      4.775D-02
     14     11      5.089D-08          14     12      8.659D-13          14     13      2.397D-08
     15      1      5.682D-06          15      2      5.290D-06          15      4      1.912D-09
     15      5      6.522D-01          15      6      2.094D-01          15      7      1.487D-06
     15      8      1.290D-06          15      9      8.887D-02          15     10      4.953D-02
     15     11      5.596D-08          15     12      1.071D-12          15     13      2.749D-08
     15     14      6.840D-12          16      1      4.453D-01          16      2      4.060D-01
     16      5      1.410D-06          16      6      6.240D-07          16      7      7.993D-02
     16      8      6.673D-02          16      9      3.397D-07          16     10      2.253D-07
     16     11      1.462D-03          16     13      6.521D-04          16     14      1.427D-06
     16     15      4.683D-07

 PRIMARY TRANSITION ..... ENERGY AT 2.530D-08MEV
       BRANCHING RATIO FOR 3 LEVELS OF
         9   2.000D-01      10   2.000D-01      16    1.000D-01

                        IN CONSIDERATION OF <  E1 TRANS.    M1 TRANS.    E2 TRANS. >
```

Fig. 10-b The output of Example–10 (continued).

```
EXAMPLE10, NB-93 GAMMA-RAY SPECTRUM AT 3 ENERGIES                                        PAGE   3

TOTAL GAMMA RAY SPECTRUM ( PHOTON /CAPTURE/ENERGY BINS)

  INCIDENT ENERGY (CMS) ... 2.503D-08 MEV
  INCIDENT ENERGY (LAB) ... 2.530D-08 MEV
```

ENERGY BIN (MEV) (BIN WIDTH ... 2.500D-01)	PHOTONS	ENERGY*PHOTONS	PHOTONS (CONTINUUM ONLY)	SPECTRA PER BIN (MEV)
0.0 - 2.500D-01	7.173D-01	5.903D-02	1.224D-03	7.970D-01
2.500D-01 - 5.000D-01	3.127D-01	1.066D-01	1.527D-02	3.475D-01
5.000D-01 - 7.500D-01	1.388D-01	8.508D-02	5.435D-02	1.543D-01
7.500D-01 - 1.000D+00	1.789D-01	1.549D-01	1.535D-01	1.988D-01
1.000D+00 - 1.250D+00	1.659D-01	1.867D-01	1.659D-01	1.844D-01
1.250D+00 - 1.500D+00	1.688D-01	2.322D-01	1.688D-01	1.876D-01
1.500D+00 - 1.750D+00	1.710D-01	2.779D-01	1.710D-01	1.900D-01
1.750D+00 - 2.000D+00	1.710D-01	3.206D-01	1.710D-01	1.900D-01
2.000D+00 - 2.250D+00	1.680D-01	3.570D-01	1.680D-01	1.867D-01
2.250D+00 - 2.500D+00	1.619D-01	3.845D-01	1.619D-01	1.800D-01
2.500D+00 - 2.750D+00	1.530D-01	4.014D-01	1.530D-01	1.700D-01
2.750D+00 - 3.000D+00	1.416D-01	4.069D-01	1.416D-01	1.574D-01
3.000D+00 - 3.250D+00	1.288D-01	4.023D-01	1.288D-01	1.432D-01
3.250D+00 - 3.500D+00	1.162D-01	3.920D-01	1.162D-01	1.292D-01
3.500D+00 - 3.750D+00	1.037D-01	3.758D-01	1.037D-01	1.153D-01
3.750D+00 - 4.000D+00	9.139D-02	3.539D-01	9.139D-02	1.015D-01
4.000D+00 - 4.250D+00	7.954D-02	3.278D-01	7.954D-02	8.838D-02
4.250D+00 - 4.500D+00	6.838D-02	2.989D-01	6.838D-02	7.598D-02
4.500D+00 - 4.750D+00	5.796D-02	2.679D-01	5.796D-02	6.440D-02
4.750D+00 - 5.000D+00	4.844D-02	2.360D-01	4.844D-02	5.383D-02
5.000D+00 - 5.250D+00	4.005D-02	2.051D-01	4.005D-02	4.450D-02
5.250D+00 - 5.500D+00	3.290D-02	1.767D-01	3.290D-02	3.656D-02
5.500D+00 - 5.750D+00	2.698D-02	1.516D-01	2.698D-02	2.997D-02
5.750D+00 - 6.000D+00	2.218D-02	1.302D-01	2.218D-02	2.464D-02
6.000D+00 - 6.250D+00	2.241D-02	1.372D-01	2.241D-02	2.490D-02
6.250D+00 - 6.500D+00	2.188D-02	1.399D-01	4.185D-03	2.432D-02
6.500D+00 - 6.750D+00	8.982D-03	5.917D-02	1.296D-04	9.981D-03
6.750D+00 - 7.229D+00	8.080D-02	5.559D-01	3.557D-05	4.687D-02

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AVERAGE GAMMA-RAY ENERGY ...  1.9955D+00 MEV
TOTAL RELEASED GAMMA RAY ENERGY ...  7.1832D+00 MEV
TOTAL PHOTON NUMBER ...  3.5997D+00
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Fig. 10-b The output of Example-10 (continued).

EXAMPLE10, NB-93 GAMMA-RAY SPECTRUM AT 3 ENERGIES   PAGE 4

TOTAL GAMMA RAY SPECTRUM (PHOTON /CAPTURE/ENERGY BINS)

INCIDENT ENERGY (CMS) ... 9.893D-07 MEV
INCIDENT ENERGY (LAB) ... 1.000D-06 MEV

ENERGY BIN (MEV) (BIN WIDTH ... 2.500D-01)	PHOTONS	ENERGY*PHOTONS	PHOTONS (CONTINUUM ONLY)	SPECTRA PER BIN (MEV)
0.0 - 2.500D-01	7.336D-01	6.230D-02	1.309D-03	7.978D-01
2.500D-01 - 5.000D-01	2.804D-01	9.369D-02	1.636D-02	3.050D-01
5.000D-01 - 7.500D-01	1.479D-01	9.078D-02	5.842D-02	1.609D-01
7.500D-01 - 1.000D+00	1.803D-01	1.572D-01	1.639D-01	1.961D-01
1.000D+00 - 1.250D+00	1.769D-01	1.990D-01	1.769D-01	1.924D-01
1.250D+00 - 1.500D+00	1.800D-01	2.475D-01	1.800D-01	1.957D-01
1.500D+00 - 1.750D+00	1.823D-01	2.963D-01	1.823D-01	1.983D-01
1.750D+00 - 2.000D+00	1.824D-01	3.419D-01	1.824D-01	1.983D-01
2.000D+00 - 2.250D+00	1.793D-01	3.808D-01	1.793D-01	1.949D-01
2.250D+00 - 2.500D+00	1.728D-01	4.103D-01	1.728D-01	1.879D-01
2.500D+00 - 2.750D+00	1.633D-01	4.285D-01	1.633D-01	1.776D-01
2.750D+00 - 3.000D+00	1.512D-01	4.346D-01	1.512D-01	1.645D-01
3.000D+00 - 3.250D+00	1.376D-01	4.298D-01	1.376D-01	1.497D-01
3.250D+00 - 3.500D+00	1.242D-01	4.188D-01	1.242D-01	1.350D-01
3.500D+00 - 3.750D+00	1.109D-01	4.016D-01	1.109D-01	1.206D-01
3.750D+00 - 4.000D+00	9.766D-02	3.782D-01	9.766D-02	1.062D-01
4.000D+00 - 4.250D+00	8.501D-02	3.504D-01	8.501D-02	9.245D-02
4.250D+00 - 4.500D+00	7.309D-02	3.195D-01	7.309D-02	7.948D-02
4.500D+00 - 4.750D+00	6.195D-02	2.863D-01	6.195D-02	6.738D-02
4.750D+00 - 5.000D+00	5.178D-02	2.522D-01	5.178D-02	5.631D-02
5.000D+00 - 5.250D+00	4.281D-02	2.192D-01	4.281D-02	4.656D-02
5.250D+00 - 5.500D+00	3.517D-02	1.889D-01	3.517D-02	3.824D-02
5.500D+00 - 5.750D+00	2.883D-02	1.621D-01	2.883D-02	3.136D-02
5.750D+00 - 6.000D+00	2.370D-02	1.392D-01	2.370D-02	2.578D-02
6.000D+00 - 6.250D+00	2.395D-02	1.466D-01	2.395D-02	2.605D-02
6.250D+00 - 6.500D+00	1.076D-02	6.858D-02	4.469D-03	1.170D-02
6.500D+00 - 6.750D+00	9.678D-03	6.375D-02	1.379D-04	1.053D-02
6.750D+00 - 7.229D+00	3.057D-02	2.144D-01	3.779D-05	1.736D-02

AVERAGE GAMMA-RAY ENERGY ... 1.9528D+00 MEV
TOTAL RELEASED GAMMA RAY ENERGY ... 7.1824D+00 MEV
TOTAL PHOTON NUMBER ... 3.6781D+00

Fig. 10-b The output of Example-10 (continued).

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     EXAMPLE10, NB-93 GAMMA-RAY SPECTRUM AT 3 ENERGIES                                          PAGE    5

TOTAL GAMMA RAY SPECTRUM ( PHOTON /CAPTURE/ENERGY BINS)

 INCIDENT ENERGY (CMS) ... 9.893D-04 MEV
 INCIDENT ENERGY (LAB) ... 1.000D-03 MEV

      ENERGY BIN (MEV)          PHOTONS     ENERGY*PHOTONS          PHOTONS             SPECTRA
  (BIN WIDTH ... 2.500D-01)                                    (CONTINUUM  ONLY)     PER BIN (MEV)
    0.0       - 2.500D-01      7.321D-01      6.226D-02           1.329D-03           7.992D-01
    2.500D-01 - 5.000D-01      2.764D-01      9.224D-02           1.628D-02           3.017D-01
    5.000D-01 - 7.500D-01      1.474D-01      9.048D-02           5.806D-02           1.609D-01
    7.500D-01 - 1.000D+00      1.796D-01      1.566D-01           1.637D-01           1.960D-01
    1.000D+00 - 1.250D+00      1.766D-01      1.988D-01           1.766D-01           1.928D-01
    1.250D+00 - 1.500D+00      1.795D-01      2.469D-01           1.795D-01           1.959D-01
    1.500D+00 - 1.750D+00      1.816D-01      2.952D-01           1.816D-01           1.983D-01
    1.750D+00 - 2.000D+00      1.814D-01      3.401D-01           1.814D-01           1.980D-01
    2.000D+00 - 2.250D+00      1.781D-01      3.784D-01           1.781D-01           1.944D-01
    2.250D+00 - 2.500D+00      1.716D-01      4.073D-01           1.716D-01           1.873D-01
    2.500D+00 - 2.750D+00      1.620D-01      4.251D-01           1.620D-01           1.769D-01
    2.750D+00 - 3.000D+00      1.500D-01      4.308D-01           1.500D-01           1.637D-01
    3.000D+00 - 3.250D+00      1.364D-01      4.259D-01           1.364D-01           1.489D-01
    3.250D+00 - 3.500D+00      1.231D-01      4.151D-01           1.231D-01           1.343D-01
    3.500D+00 - 3.750D+00      1.099D-01      3.980D-01           1.099D-01           1.199D-01
    3.750D+00 - 4.000D+00      9.684D-02      3.750D-01           9.684D-02           1.057D-01
    4.000D+00 - 4.250D+00      8.437D-02      3.478D-01           8.437D-02           9.209D-02
    4.250D+00 - 4.500D+00      7.265D-02      3.176D-01           7.265D-02           7.930D-02
    4.500D+00 - 4.750D+00      6.174D-02      2.854D-01           6.174D-02           6.740D-02
    4.750D+00 - 5.000D+00      5.179D-02      2.523D-01           5.179D-02           5.654D-02
    5.000D+00 - 5.250D+00      4.302D-02      2.203D-01           4.302D-02           4.696D-02
    5.250D+00 - 5.500D+00      3.552D-02      1.908D-01           3.552D-02           3.878D-02
    5.500D+00 - 5.750D+00      2.928D-02      1.646D-01           2.928D-02           3.196D-02
    5.750D+00 - 6.000D+00      2.419D-02      1.420D-01           2.419D-02           2.641D-02
    6.000D+00 - 6.250D+00      2.452D-02      1.501D-01           2.452D-02           2.676D-02
    6.250D+00 - 6.500D+00      1.095D-02      6.983D-02           4.618D-03           1.195D-02
    6.500D+00 - 6.750D+00      1.057D-02      6.963D-02           1.473D-04           1.154D-02
    6.750D+00 - 7.230D+00      3.335D-02      2.344D-01           4.132D-05           1.896D-02

AVERAGE GAMMA-RAY ENERGY ...  1.9602D+00 MEV
TOTAL RELEASED GAMMA RAY ENERGY ...  7.1829D+00 MEV
TOTAL PHOTON NUMBER ...  3.6644D+00

RUNNING TIME .....    29.09   SEC.
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Fig. 10–b The output of Example–10 (continued).