JAERI-Data/Code
99-028

NEW OPTIONS OF COUPLED CHANNELS OPTICAL MODEL CODE OPTMAN VERSION 6 (1999)

May 1999

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編集兼発行　日本原子力研究所

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(Received April 9, 1999)

This report is a supplement to JAERI-Data/Code 98-019, describing new options of soft-rotator CC code OPTMAN installed on computers at JAERI Nuclear Data Center. Due to the new options, the code is now applicable for analysis of neutron and proton induced reactions simultaneously up to projectile energy of around 200 MeV.

Keywords: Nuclear Data, Optical Model, Coupled Channels Calculations, Soft-rotator Model, Nucleon Scattering, Relativistic Kinematics, Nucleus Mass Conservation, E=0.001 to 200 MeV

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チャンネル結合光学模型計算コードOPTMAN Version 6（1999年版）における新しいオプション

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（1999年4月9日受理）

このレポートはJAERI-Data/Code 98-019に対する補足であり、原研核データセンターの計算機にインストールされた、軟回転体模型に基づくチャンネル結合計算コードOPTMANに付与された新しい機能を説明するものである。本レポートで説明される機能により、本コードを用いて200MeV程度までの中性子と陽子入射により引き起こされる反応を同時に解析することが可能になった。

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1 Introduction

Coupled channels optical model code was installed at JAERI Nuclear Data Center two years ago. A manual describing algorithms, possible options, input and output examples was issued in 1998[1]. The code was intensively used for interpretation of experimental data for ^{12}C[2, 3], ^{58}Ni[4] and ^{238}U[5]. Such investigation led to a necessity for a development of new code options, taking account of some fundamental physical laws, such as nuclear mass conservation in nuclear shapes oscillations[6], effects of the relativistic kinematics, complex spin-orbit potential, and isospin dependence (Lane term) of optical potential. These additional options will make this code more applicable to solve a wider scope of existing problems.

This report is aimed at a description of the changes in the code input made after Ref. [1] is published to allow usage of the new code options.

2 New options of the code

2.1 Account of nuclear volume (mass) conservation

Deformed nuclear optical potential arises from deformed radius, representing the instant nuclear shape,

$$R(\theta', \varphi') = R_0 \left\{ 1 + \sum_{\lambda\mu} \beta_{\lambda\mu} Y_{\lambda\mu}(\theta', \varphi') \right\}, \tag{1}$$

with $\lambda \geq 2$, presented with evident dependences on the nuclear collective variables (deformations).

Recently we demonstrated [3] that account of nuclear charge conservation leads to a correct behavior in the multipole expansion of the Coulomb potential, spherical multipole term of which must be equal to $ZZ'e^2/r$. This solves the well-known problem of matching numerical CC-internal solutions for charged particles with the (outer) Coulomb functions[7] used to get the scattering matrix.

As in soft-rotator nuclear model we consider $\beta_{\lambda\mu}$ to be dynamical. Thus nuclear shape described in Eq. (1) will describe nuclei with non-conserving mass (number of particles). To conserve nuclear mass for uniform nuclear density case one must add a dynamic negative deformation β_{00} to the radial expansion given in Eq. (1)

$$\beta_{00} = -\sum_{\lambda} (-1)^{\lambda} \frac{\hat{\lambda}}{(4\pi)^{1/2}} \left(\beta_{\lambda} \otimes \beta_{\lambda}\right)_{00}, \tag{2}$$

where $\hat{\lambda} = \sqrt{2\lambda + 1}$. This is required as the condition to conserve the nuclear volume[8] which is equivalent to mass and nuclear charge conservation for uniform nuclear and nuclear charge density case adopted in Ref. [8]. So the radius describing shape of nuclei with constant volume becomes

$$R(\theta', \varphi') = R_0 \left\{ 1 + \beta_{00} Y_{00} + \sum_{\lambda\mu} \beta_{\lambda\mu} Y_{\lambda\mu}(\theta', \varphi') \right\} \tag{3}$$

Additional β_{00} deformation leads to additional zero nuclear potential multipole that couples levels with equal spin and parity I^{π}.

In case of nuclear density with diffuseness one must use another additional zero multipole deformation β'_{00} to conserve nuclear mass[6].

$$\beta'_{00} = -\frac{R_0}{2a}\beta_{00}\left[\int \frac{\partial^2 f(r,R,a)}{\partial x^2}\bigg|_{x_0} r^2 dr\right] / \left[\int \frac{\partial f(r,R,a)}{\partial x}\bigg|_{x_0} r^2 dr\right] \tag{4}$$

Here $f(r,R,a) = f(x)$ denotes the nuclear density form factor, $x = \frac{r-R}{a}$, and $x_0 = \frac{r-R_0}{a}$, Integrals in Eq.(4) are just constants, so we can write as

$$\beta'_{00} = C_\beta \beta_{00}. \tag{5}$$

In our code we use nuclear real potential form factor $f_R(r,R,a)$ instead of nuclear density form factor. As C_β appears to be close to unity, we take substitution of nuclear density form factor by real potential one as an acceptable approximation. Such an approximation leads to simultaneous conservation of nuclear volume and real potential volume integral in nuclear shape oscillations, so there is an additional reason to use it.

As usually we obtain multipoles of deformed nuclear potential, which determine coupling, by inserting deformed nuclear radius $R(\theta',\varphi') = R_0(1 + \beta'_{00}Y_{00} + \sum \beta_{\lambda\mu}Y_{\lambda\mu}(\theta',\varphi'))$ in potential form factors and expanding them in Taylor series, assuming $(\beta'_{00}Y_{00} + \sum \beta_{\lambda\mu}Y_{\lambda\mu})$ to be small:

$$V(R) \;=\; V_i f_i(R_0) \;+\; \sum_{t=1}^{max} \frac{\partial^t f_i}{\partial R^t}\bigg|_{R=R_0} \frac{R_0^t}{t!}(\beta'_{00}Y_{00} + \sum \beta_{\lambda\mu}Y_{\lambda\mu})^t \tag{6}$$

One can see that account of nuclear volume conservation leads to additional zero multipole term starting with the first nuclear potential derivative, which will additionally couple states with equal spins and parity $I^\pi$and themselves. This term $\beta'_{00}Y_{00}$ is proportional to $(\beta_{\lambda\mu})^2$ and must be taken into account, as account of terms up to $(\beta_{\lambda\mu})^4$ is necessary to get calculated values accurate enough to describe experimental data consistently[9].

2.2 Relativistic generalization of the non-relativistic Schrödinger formalism

As nucleon mass is ~1000 MeV, one must understand that for nucleon incident energies above 50 MeV accuracy of non-relativistic kinematics involved in non-relativistic Schrödinger formalism is worse than ~5%

Due to requests arising from nuclear data needs for transmutation and other applications it was decided to extend possible upper energy of incident particles at least up to 200MeV. So we included account of relativistic kinematics in the code.

It was done following relativistic generalization suggested by Elton[10], allowing relativistic corrections be easily incorporated in the usual non-relativistic formalism. This requested the following adding in the code:

1. Nucleon wave number k is calculated in the relativistic form:

$$(\hbar k)^2 = \left[E^2 - (M_p c^2)^2\right]/c^2 \tag{7}$$

where E denotes the total energy of projectile, M_p the projectile mass, and c the light velocity.

2. To allow non-relativistic motion of the target nucleus with mass M_T, incident particle mass M_p is changed by relativistic projectile energy E in reduced mass formulae, so that the quantity k^2 and optical potential values $U(r)$ must be both multiplied by coefficient:

$$\frac{1}{1+E/(M_T c^2)}. \tag{8}$$

3. Optical potentials depth values, excluding spin-orbit potential depth V_{SO}, are multiplied by ratio $E/(M_p c^2)$. Of course optical potential parameters can be in any case fitted to the experimental data, so that potential relativistic corrections can be included while fitting. However we agree with Elton[10] that "it is advantageous to separate out the known relativistic factor $E/(M_p c^2)$ in the central part of optical potential". This may allow successful extrapolation of optical potential from low incident projectile energy region to higher and vice versa.

One can see that for low energies all this factors have non-relativistic kinematic limit.

2.3 Account of imaginary spin-orbit optical potential

Account of imaginary spin-orbit optical potential was included for the same reasons, as we intend to extend applicable incident particle energies, while it is known that imaginary spin-orbit part of optical potential increases with incident projectile energy. In the present code, the optical potential has the form:

$$\begin{aligned} V(r) &= -V_R f_R(r) + i\left\{4W_D a_D \frac{d}{dr} f_D(r) - W_V\ f_V(r)\right\} \\ &+ \left(\frac{\hbar}{\mu_\pi c}\right)^2 (V_{SO} + iW_{SO})\,\frac{1}{r}\frac{d}{dr} f_{SO}(r)\hat{\sigma}\cdot\hat{L} + V_{Coul}(r), \end{aligned} \tag{9}$$

with linear dependence of imaginary spin-orbit potential strength from incident energy of nucleon:

$$W_{SO} = W_{SO}^0 + W_{SO}^1 E_p \tag{10}$$

where W_{SO}^0 and W_{SO}^1 are constant and linear terms of imaginary spin-orbit optical potential.

2.4 Account of isospin terms in optical potentials

Our experience showed that the most reliable results can be got if optical potential is adjusted on scattering experimental data base including neutron and proton data simultaneously, so this is the reason to include isospin terms $(-1)^{Z'+1}C_{viso}(A-2Z)/A$ and $(-1)^{Z'+1}C_{wiso}(A-2Z)/A$ in optical potentials, which in current version are:

$$\begin{aligned} V_R &= V_R^0 + V_R^1 E_p + V_R^2 E_p^2 + (-1)^{Z'+1}C_{viso}(A-2Z)/A + ZZ'/A^{1/3}C_{coul}, \\ W_D &= W_D^0 + W_D^1 E_p + (-1)^{Z'+1}C_{wiso}(A-2Z)/A, \\ W_V &= W_V^0 + W_V^1 E_p. \end{aligned} \tag{11}$$

The symbols Z', Z and A are charges of incident particle, nucleus and nucleus mass number, respectively, and potential slopes W_D^1 and W_V^1 may change at $E_p = E_{change}$. The last term in the right-hand side of V_R denotes the Coulomb correction term.

3 Changes in code input due to new options

Below we describe changes in input. For details of the card number, see Ref. [1]

Card 2 - FORMAT(20I2)

MEJOB, MEPOT, MEHAM, MECHA, MEPRI, MESOL, MECHA, MESHO, MEHAO, MEAPP, MEVOL, MEREL

Switches describing the options of the model are described in[1]. New switches MEVOL allows different options of nuclear mass (volume) conservation[6], MEREL - allows relativistic generalization of the non-relativistic Schrödinger formalism.

- MEVOL = 0 - without account of conservation, =1 - account of volume conservation in uniform nuclear density approximation[8], =2 - common case[6], presenting nuclear density distribution by real potential form factor.

- MEREL = 0 - Calculations using non-relativistic Schrödinger formalism, =1- account of relativistic kinematics.

Account of relativistic kinematics follows suggestions from Ref. [10]

Cards 11a, 11b, 11c, 11d, 11e, 11f, 11g -FORMAT(6e12.7)

Optical potential parameters

Card 11f -additional variables as comparing with the last version:

WDA1, WCA1,CCOUL, AZ, CISO,WCISO

AZ - diffuseness of nuclear charge distribution,

CISO - constant for real potential isospin term, C_{viso}

CWISO - constant for complex potential isospin term, C_{wiso}.

Card 11g -new card in input

WS0, WS1

WS0 - constant imaginary spin-orbit term W_{SO}^0,

WS1 - linear imaginary spin-orbit term W_{SO}^1

Card 13 - FORMAT(50I2) - a new input card format allowing adjustment of the new additional optical potential parameters

New flags allowing adjustment of additional optical parameters as comparing with previous code version:

- NPJ(36) - flag for nucleus charge density diffuseness a_Z adjustment AZ;
- NPJ(37) - flag for real optical potential isospin term C_{viso} adjustment CISO;
- NPJ(38) - flag for imaginary optical potential isospin term C_{wiso} adjustment WCISO;
- NPJ(39) - flag for real optical potential square term V_R^2 adjustment VR2;

- NPJ(40) - flag for imaginary spin-orbit optical potential constant term W^0_{SO} adjustment WS0;
- NPJ(41) - flag for imaginary spin-orbit optical potential linear term W^1_{SO} adjustment WS1;
- NPJ(42) - flag for adjustment of axial rigid-deformation β_{60} BET(6).

4 Other minor useful changes

4.1 Input

Card 6 : NST - possible number of energy points for which optical model calculations will be carried out (MEJOB=1), or number of experimental data energy points that will be used for optical potential parameter adjustment (MEJOB=2) is increased up to 30 (was 20 in previous code version).

Card 14 : NGN(I) and NGD(I) - number of groups of excited levels and groups of angular distributions with excitation of a group of levels must now be no more than 5 (it was 4 in previous code version).

Cards 6, 18 : MTET and MTD(I,K) - number of angles in which angular distributions are calculated (MEJOB=1) or adjusted (MEJOB=2) now can be up to 50 (it was 40 in previous code version).

4.2 Output

Now volume integrals of optical potential form factors and their first three derivatives are calculated in the code. They are printed for each soft-rotator case (MEPOT $\geq$ 2) CC calculation.

5 Examples

5.1 Input

Below we are giving an input including the described changes. In preparing input, one must follow detailed instructions given in Ref.[1] and this supplement.

```
U-238   SOFT-ROTATOR EXAMPLE INPUT
01020501000104020200020l
 .9881145+00 .2134703-00 .2882296+00 .1437403-00 .2290000-00 .4400000-01
 .2587913-01 .7455641-01 .7029708-00 .2144000-00 .3200000-02 .5608000-00
 .3500000-00 .2000000-02 .0000000-00 .1488000+02
060204041023456001
 .3400000+01 .6500000+02
0001
 .1000000-03 .5000000+01 .1000000+02 .1500000+02 .2500000+02 .3500000+02
 .5000000+02 .7000000+02 .1000000+03 .1800000+03
 .0000000-0000+101000000
 .4490000-0104+101000000
 .1490000-0008+101000000
 .6630000+0002-101000001
 .9930000+0000+101010000
 .1060300+0104+102000000
 .4840000+02-.3070000-00 .0004000+00 1.27040000  .6600000-00 .1700000-02
```

```
.4360000+01 .4670000-00 1.24180000  .4240000-00 .1560000-01 .0000000+01
.0000000-00 1.236800000 .4800000+00 .0000000-02 .1000000+01 .1000000+01
.0000000-00 .3920000+01 1.120000000 .4600000-00 .1000000-02 .1000000+01
.2380000+031.00866520   1.004900000 .9200000+02 .5000000-00 .1000000+02
-.095       .1420       .560        .440000     .1600000+02 .8000000+01
.20         -.01
```

5.2 Output

We are giving here the code output for the input shown above. So code user can check if the code is running correctly by making calculations with the suggested input and comparing with the one supplemented here.

The other reason for including example of output is to show volume integrals of optical potential form factors, that now are calculated for soft-rotator case and are included in output.

```
U-238   SOFT-ROTATOR EXAMPLE INPUT
      INTERACTION OF PARTICLE HAVING CHARGE = 1 AND SPIN =  .50
               WITH NUCLEI  A= 238.0000000
             COUPLED CHANNELS METHOD
        WITH AC. NONAXIAL HEXADECAPOLE DEFORMATIONS

        HAMILTONN-A SPAO       POTENTIAL EXPANDDED BY      BETO
        WITH AC. NONAXIAL OCTUPOLE       SOFT    DEFORMATIONS

             NUMBER OF COUPLED LEVELS 6      NPD = 4
            NUMBER OF TERMS IN POTENTIAL EXPANSION    4

             ENERGY     LEVEL'S SPIN*2    NTU        NNB        NNG        NNO        NPO

   1        .0000000E+00         0         1          0          0          0          1
   2        .4490000E-01         4         1          0          0          0          1
   3        .1490000E+00         8         1          0          0          0          1
   4        .6630000E+00         2         1          0          0          1         -1
   5        .9930000E+00         0         1          1          0          0          1
   6        .1060300E+01         4         2          0          0          0          1

                    PARAMETERS OF HAMILTONIAN
   HW=    .98811  AMBO=  .21347   AMGO=  .28823   GAMO=  .14374   BETO=  .22900
   BET4=    .04400   BB42=  .02588   GAMG=  .07456   DELG=  .70297
   BET3=    .21440   ETO=  .00320   AMUO=  .56080   HWO=  .35000   BB32=  .00200   GAMDE=  .00000   DPAR=14.88000
   GSHAPE=  .00000

 IO1=  1 IO2=  1 NNT=  1  FOLAR=   .0000000D+00 ANU1=   .6242140D+00  ANU2=   .6242140D+00
 IO1=  1 IO2=  1 NNT=  2  FOLAR=   .3957345D+01 ANU1=   .6242140D+00  ANU2=   .6242140D+00
 IO1=  1 IO2=  2 NNT=  1  FOLAR=   .1986251D+01 ANU1=   .6242140D+00  ANU2=   .2412730D+01
 IO1=  1 IO2=  2 NNT=  2  FOLAR=   .0000000D+00 ANU1=   .6242140D+00  ANU2=   .2412730D+01
 IO1=  2 IO2=  2 NNT=  1  FOLAR=   .0000000D+00 ANU1=   .2412730D+01  ANU2=   .2412730D+01
 IO1=  2 IO2=  2 NNT=  2  FOLAR=   .1077478D+02 ANU1=   .2412730D+01  ANU2=   .2412730D+01
 JU1= 1 JU2= 1 NNT= 1 FOV(JU1,JU2,     NNT)=   .1000000D+01  ANU1=   .6773400D-09  ANU2=   .6773400D-09
 JU1= 1 JU2= 1 NNT= 2 FOV(JU1,JU2,     NNT)=   .1022785D+01  ANU1=   .6773400D-09  ANU2=   .6773400D-09
 JU1= 1 JU2= 1 NNT= 3 FOV(JU1,JU2,     NNT)=   .1068354D+01  ANU1=   .6773400D-09  ANU2=   .6773400D-09
 JU1= 1 JU2= 1 NNT= 4 FOV(JU1,JU2,     NNT)=   .1138266D+01  ANU1=   .6773400D-09  ANU2=   .6773400D-09
 JU1= 1 JU2= 2 NNT= 1 FOV(JU1,JU2,     NNT)=   .1001868D+01  ANU1=   .6773400D-09  ANU2=   .4878343D-09
 JU1= 1 JU2= 2 NNT= 2 FOV(JU1,JU2,     NNT)=   .1026542D+01  ANU1=   .6773400D-09  ANU2=   .4878343D-09
 JU1= 1 JU2= 2 NNT= 3 FOV(JU1,JU2,     NNT)=   .1074070D+01  ANU1=   .6773400D-09  ANU2=   .4878343D-09
 JU1= 1 JU2= 2 NNT= 4 FOV(JU1,JU2,     NNT)=   .1146134D+01  ANU1=   .6773400D-09  ANU2=   .4878343D-09
 JU1= 1 JU2= 3 NNT= 1 FOV(JU1,JU2,     NNT)=   .1005467D+01  ANU1=   .6773400D-09  ANU2=   .2233772D-09
 JU1= 1 JU2= 3 NNT= 2 FOV(JU1,JU2,     NNT)=   .1034436D+01  ANU1=   .6773400D-09  ANU2=   .2233772D-09
 JU1= 1 JU2= 3 NNT= 3 FOV(JU1,JU2,     NNT)=   .1086431D+01  ANU1=   .6773400D-09  ANU2=   .2233772D-09
 JU1= 1 JU2= 3 NNT= 4 FOV(JU1,JU2,     NNT)=   .1163419D+01  ANU1=   .6773400D-09  ANU2=   .2233772D-09
 JU1= 1 JU2= 4 NNT= 1 FOV(JU1,JU2,     NNT)=   .1010760D+01  ANU1=   .6773400D-09  ANU2=   .1210580D-10
 JU1= 1 JU2= 4 NNT= 2 FOV(JU1,JU2,     NNT)=   .1060584D+01  ANU1=   .6773400D-09  ANU2=   .1210580D-10
 JU1= 1 JU2= 4 NNT= 3 FOV(JU1,JU2,     NNT)=   .1134611D+01  ANU1=   .6773400D-09  ANU2=   .1210580D-10
 JU1= 1 JU2= 4 NNT= 4 FOV(JU1,JU2,     NNT)=   .1236197D+01  ANU1=   .6773400D-09  ANU2=   .1210580D-10
 JU1= 1 JU2= 5 NNT= 1 FOV(JU1,JU2,     NNT)=   .1509463D+00  ANU1=   .6773400D-09  ANU2=   .1000000D+01
 JU1= 1 JU2= 5 NNT= 2 FOV(JU1,JU2,     NNT)=   .3018926D+00  ANU1=   .6773400D-09  ANU2=   .1000000D+01
 JU1= 1 JU2= 5 NNT= 3 FOV(JU1,JU2,     NNT)=   .4631567D+00  ANU1=   .6773400D-09  ANU2=   .1000000D+01
 JU1= 1 JU2= 5 NNT= 4 FOV(JU1,JU2,     NNT)=   .6450566D+00  ANU1=   .6773400D-09  ANU2=   .1000000D+01
 JU1= 1 JU2= 6 NNT= 1 FOV(JU1,JU2,     NNT)=   .1003245D+01  ANU1=   .6773400D-09  ANU2=   .1403811D-11
```

```
JU1= 1 JU2= 6 NNT= 2 FOV(JU1,JU2,     NNT)=   .1066716D+01  ANU1=    .6773400D-09  ANU2=    .1403811D-11
JU1= 1 JU2= 6 NNT= 3 FOV(JU1,JU2,     NNT)=   .1155472D+01  ANU1=    .6773400D-09  ANU2=    .1403811D-11
JU1= 1 JU2= 6 NNT= 4 FOV(JU1,JU2,     NNT)=   .1273822D+01  ANU1=    .6773400D-09  ANU2=    .1403811D-11
JU1= 2 JU2= 2 NNT= 1 FOV(JU1,JU2,     NNT)=   .1003896D+01  ANU1=    .4878343D-09  ANU2=    .4878343D-09
JU1= 2 JU2= 2 NNT= 2 FOV(JU1,JU2,     NNT)=   .1030461D+01  ANU1=    .4878343D-09  ANU2=    .4878343D-09
JU1= 2 JU2= 2 NNT= 3 FOV(JU1,JU2,     NNT)=   .1079959D+01  ANU1=    .4878343D-09  ANU2=    .4878343D-09
JU1= 2 JU2= 2 NNT= 4 FOV(JU1,JU2,     NNT)=   .1154196D+01  ANU1=    .4878343D-09  ANU2=    .4878343D-09
JU1= 2 JU2= 3 NNT= 1 FOV(JU1,JU2,     NNT)=   .1007858D+01  ANU1=    .4878343D-09  ANU2=    .2233772D-09
JU1= 2 JU2= 3 NNT= 2 FOV(JU1,JU2,     NNT)=   .1038720D+01  ANU1=    .4878343D-09  ANU2=    .2233772D-09
JU1= 2 JU2= 3 NNT= 3 FOV(JU1,JU2,     NNT)=   .1092712D+01  ANU1=    .4878343D-09  ANU2=    .2233772D-09
JU1= 2 JU2= 3 NNT= 4 FOV(JU1,JU2,     NNT)=   .1171924D+01  ANU1=    .4878343D-09  ANU2=    .2233772D-09
JU1= 2 JU2= 4 NNT= 1 FOV(JU1,JU2,     NNT)=   .1014875D+01  ANU1=    .4878343D-09  ANU2=    .1210580D-10
JU1= 2 JU2= 4 NNT= 2 FOV(JU1,JU2,     NNT)=   .1066637D+01  ANU1=    .4878343D-09  ANU2=    .1210580D-10
JU1= 2 JU2= 4 NNT= 3 FOV(JU1,JU2,     NNT)=   .1142816D+01  ANU1=    .4878343D-09  ANU2=    .1210580D-10
JU1= 2 JU2= 4 NNT= 4 FOV(JU1,JU2,     NNT)=   .1246899D+01  ANU1=    .4878343D-09  ANU2=    .1210580D-10
JU1= 2 JU2= 5 NNT= 1 FOV(JU1,JU2,     NNT)=   .1634637D+00  ANU1=    .4878343D-09  ANU2=    .1000000D+01
JU1= 2 JU2= 5 NNT= 2 FOV(JU1,JU2,     NNT)=   .3148677D+00  ANU1=    .4878343D-09  ANU2=    .1000000D+01
JU1= 2 JU2= 5 NNT= 3 FOV(JU1,JU2,     NNT)=   .4774146D+00  ANU1=    .4878343D-09  ANU2=    .1000000D+01
JU1= 2 JU2= 5 NNT= 4 FOV(JU1,JU2,     NNT)=   .6614654D+00  ANU1=    .4878343D-09  ANU2=    .1000000D+01
JU1= 2 JU2= 6 NNT= 1 FOV(JU1,JU2,     NNT)=   .1008456D+01  ANU1=    .4878343D-09  ANU2=    .1403811D-11
JU1= 2 JU2= 6 NNT= 2 FOV(JU1,JU2,     NNT)=   .1073917D+01  ANU1=    .4878343D-09  ANU2=    .1403811D-11
JU1= 2 JU2= 6 NNT= 3 FOV(JU1,JU2,     NNT)=   .1164952D+01  ANU1=    .4878343D-09  ANU2=    .1403811D-11
JU1= 2 JU2= 6 NNT= 4 FOV(JU1,JU2,     NNT)=   .1286006D+01  ANU1=    .4878343D-09  ANU2=    .1403811D-11
JU1= 3 JU2= 3 NNT= 1 FOV(JU1,JU2,     NNT)=   .1012641D+01  ANU1=    .2233772D-09  ANU2=    .2233772D-09
JU1= 3 JU2= 3 NNT= 2 FOV(JU1,JU2,     NNT)=   .1047811D+01  ANU1=    .2233772D-09  ANU2=    .2233772D-09
JU1= 3 JU2= 3 NNT= 3 FOV(JU1,JU2,     NNT)=   .1106361D+01  ANU1=    .2233772D-09  ANU2=    .2233772D-09
JU1= 3 JU2= 3 NNT= 4 FOV(JU1,JU2,     NNT)=   .1190664D+01  ANU1=    .2233772D-09  ANU2=    .2233772D-09
JU1= 3 JU2= 4 NNT= 1 FOV(JU1,JU2,     NNT)=   .1023592D+01  ANU1=    .2233772D-09  ANU2=    .1210580D-10
JU1= 3 JU2= 4 NNT= 2 FOV(JU1,JU2,     NNT)=   .1079776D+01  ANU1=    .2233772D-09  ANU2=    .1210580D-10
JU1= 3 JU2= 4 NNT= 3 FOV(JU1,JU2,     NNT)=   .1160880D+01  ANU1=    .2233772D-09  ANU2=    .1210580D-10
JU1= 3 JU2= 4 NNT= 4 FOV(JU1,JU2,     NNT)=   .1270690D+01  ANU1=    .2233772D-09  ANU2=    .1210580D-10
JU1= 3 JU2= 5 NNT= 1 FOV(JU1,JU2,     NNT)=   .1919110D+00  ANU1=    .2233772D-09  ANU2=    .1000000D+01
JU1= 3 JU2= 5 NNT= 2 FOV(JU1,JU2,     NNT)=   .3444648D+00  ANU1=    .2233772D-09  ANU2=    .1000000D+01
JU1= 3 JU2= 5 NNT= 3 FOV(JU1,JU2,     NNT)=   .5100360D+00  ANU1=    .2233772D-09  ANU2=    .1000000D+01
JU1= 3 JU2= 5 NNT= 4 FOV(JU1,JU2,     NNT)=   .6991041D+00  ANU1=    .2233772D-09  ANU2=    .1000000D+01
JU1= 3 JU2= 6 NNT= 1 FOV(JU1,JU2,     NNT)=   .1019696D+01  ANU1=    .2233772D-09  ANU2=    .1403811D-11
JU1= 3 JU2= 6 NNT= 2 FOV(JU1,JU2,     NNT)=   .1089709D+01  ANU1=    .2233772D-09  ANU2=    .1403811D-11
JU1= 3 JU2= 6 NNT= 3 FOV(JU1,JU2,     NNT)=   .1185966D+01  ANU1=    .2233772D-09  ANU2=    .1403811D-11
JU1= 3 JU2= 6 NNT= 4 FOV(JU1,JU2,     NNT)=   .1313233D+01  ANU1=    .2233772D-09  ANU2=    .1403811D-11
JU1= 4 JU2= 4 NNT= 1 FOV(JU1,JU2,     NNT)=   .1053915D+01  ANU1=    .1210580D-10  ANU2=    .1210580D-10
JU1= 4 JU2= 4 NNT= 2 FOV(JU1,JU2,     NNT)=   .1131951D+01  ANU1=    .1210580D-10  ANU2=    .1210580D-10
JU1= 4 JU2= 4 NNT= 3 FOV(JU1,JU2,     NNT)=   .1237697D+01  ANU1=    .1210580D-10  ANU2=    .1210580D-10
JU1= 4 JU2= 4 NNT= 4 FOV(JU1,JU2,     NNT)=   .1376470D+01  ANU1=    .1210580D-10  ANU2=    .1210580D-10
JU1= 4 JU2= 5 NNT= 1 FOV(JU1,JU2,     NNT)=   .3300813D+00  ANU1=    .1210580D-10  ANU2=    .1000000D+01
JU1= 4 JU2= 5 NNT= 2 FOV(JU1,JU2,     NNT)=   .4904199D+00  ANU1=    .1210580D-10  ANU2=    .1000000D+01
JU1= 4 JU2= 5 NNT= 3 FOV(JU1,JU2,     NNT)=   .6729964D+00  ANU1=    .1210580D-10  ANU2=    .1000000D+01
JU1= 4 JU2= 5 NNT= 4 FOV(JU1,JU2,     NNT)=   .8892670D+00  ANU1=    .1210580D-10  ANU2=    .1000000D+01
JU1= 4 JU2= 6 NNT= 1 FOV(JU1,JU2,     NNT)=   .1062916D+01  ANU1=    .1210580D-10  ANU2=    .1403811D-11
JU1= 4 JU2= 6 NNT= 2 FOV(JU1,JU2,     NNT)=   .1155604D+01  ANU1=    .1210580D-10  ANU2=    .1403811D-11
JU1= 4 JU2= 6 NNT= 3 FOV(JU1,JU2,     NNT)=   .1278179D+01  ANU1=    .1210580D-10  ANU2=    .1403811D-11
JU1= 4 JU2= 6 NNT= 4 FOV(JU1,JU2,     NNT)=   .1437067D+01  ANU1=    .1210580D-10  ANU2=    .1403811D-11
JU1= 5 JU2= 5 NNT= 1 FOV(JU1,JU2,     NNT)=   .1000000D+01  ANU1=    .1000000D+01  ANU2=    .1000000D+01
JU1= 5 JU2= 5 NNT= 2 FOV(JU1,JU2,     NNT)=   .1068354D+01  ANU1=    .1000000D+01  ANU2=    .1000000D+01
JU1= 5 JU2= 5 NNT= 3 FOV(JU1,JU2,     NNT)=   .1205063D+01  ANU1=    .1000000D+01  ANU2=    .1000000D+01
JU1= 5 JU2= 5 NNT= 4 FOV(JU1,JU2,     NNT)=   .1417913D+01  ANU1=    .1000000D+01  ANU2=    .1000000D+01
JU1= 5 JU2= 6 NNT= 1 FOV(JU1,JU2,     NNT)=   .4204871D+00  ANU1=    .1000000D+01  ANU2=    .1403811D-11
JU1= 5 JU2= 6 NNT= 2 FOV(JU1,JU2,     NNT)=   .5879991D+00  ANU1=    .1000000D+01  ANU2=    .1403811D-11
JU1= 5 JU2= 6 NNT= 3 FOV(JU1,JU2,     NNT)=   .7840570D+00  ANU1=    .1000000D+01  ANU2=    .1403811D-11
JU1= 5 JU2= 6 NNT= 4 FOV(JU1,JU2,     NNT)=   .1021136D+01  ANU1=    .1000000D+01  ANU2=    .1403811D-11
JU1= 6 JU2= 6 NNT= 1 FOV(JU1,JU2,     NNT)=   .1080936D+01  ANU1=    .1403811D-11  ANU2=    .1403811D-11
JU1= 6 JU2= 6 NNT= 2 FOV(JU1,JU2,     NNT)=   .1189012D+01  ANU1=    .1403811D-11  ANU2=    .1403811D-11
JU1= 6 JU2= 6 NNT= 3 FOV(JU1,JU2,     NNT)=   .1329758D+01  ANU1=    .1403811D-11  ANU2=    .1403811D-11
JU1= 6 JU2= 6 NNT= 4 FOV(JU1,JU2,     NNT)=   .1510826D+01  ANU1=    .1403811D-11  ANU2=    .1403811D-11

              POTENTIAL   PARAMETERS   V(R)

VRO=48.4000     VR1= -.3070     VR2=  .0004     RR= 1.2704     ARO=  .6600     AR1=  .0017
WDO= 4.3600     WD1=  .4670                     RD= 1.2418     ADO=  .4240     AD1=  .0156
WCO=  .0000     WC1=  .0000                     RC= 1.2368     ACO=  .4800     AC1=  .0000
                                                RW= 1.0000     AWO= 1.0000     AW1=  .0000
VSO= 3.9200                                     RS= 1.1200     ASO=  .4600     AS1=  .0010
ALF= 1.0000     ANEU= 1.0087                    RZ= 1.0049
BNDC=10.0000    WDA1= -.0950    WCA1=  .1420    CCOUL=  .5600     AZ=  .4400     CISO=16.0000
WCISO= 8.0000    WSO=  .2000    WS1= -.0100

                              NUCLEUS CHARGE 92.0000

 SPHERICAL VOLUME INTEGRALS OF REAL POTENTIAL F-FACTORS AND DERIVATIVES:
 VIRO= 174.139  VIR1= 499.457  VIR2= 487.976  VIR3= 162.657  CBETO=     .977
 SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WC) F-FACTORS AND DERIVATIVES:
 WICO= 155.901  WIC1= 456.082  WIC2= 450.273  WIC3= 150.087  CBETC=     .987
 SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WD) F-FACTORS AND DERIVATIVES:
 WIDO= 114.435  WID1= 226.013  WID2= 113.003  WID3=   -.003  CBETD=     .500
 SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WW) F-FACTORS AND DERIVATIVES:
 WIWO=    .000  WIW1=    .000  WIW2=    .000  WIW3=    .000  CBETW=     .000
```

ORB. MOMENT	TRANSITIONS	SR	SI
0	.4959137056	.3121624435	-.4455220537
1	.6025985753	-.0358565337	-.1706307317
2	.4786961777	-.4121870954	-.4230030615
3	.7838745707	.0239134350	-.1597656533
4	.3005656548	.7812800248	-.0527857984
5	.1811893615	.8898209683	-.0278486519
6	.0183023525	.9892912687	.0093458795
7	.0009590599	.9995126944	.0007473581
8	.0000717553	.4705446495	.0000550462
9	.0000000000	.0000000000	.0000000000
10	.0000000000	.0000000000	.0000000000
11	.0000000000	.0000000000	.0000000000
12	.0000000000	.0000000000	.0000000000
13	.0000000000	.0000000000	.0000000000
14	.0000000000	.0000000000	.0000000000

ANGULAR DISTRIBUTIONS OF SCATTERED PARTICLES

.100E-03	.713E+01	.991E-01	.207E-01	.106E-02	.699E-03	.296E-01
.500E+01	.687E+01	.974E-01	.206E-01	.125E-02	.694E-03	.294E-01
.100E+02	.612E+01	.926E-01	.203E-01	.178E-02	.682E-03	.290E-01
.150E+02	.502E+01	.856E-01	.197E-01	.251E-02	.663E-03	.282E-01
.250E+02	.257E+01	.693E-01	.181E-01	.373E-02	.626E-03	.255E-01
.350E+02	.802E+00	.559E-01	.165E-01	.363E-02	.622E-03	.207E-01
.500E+02	.491E-02	.456E-01	.160E-01	.205E-02	.708E-03	.113E-01
.700E+02	.136E+00	.456E-01	.164E-01	.405E-02	.730E-03	.139E-01
.100E+03	.244E-01	.304E-01	.110E-01	.200E-02	.774E-03	.155E-01
.180E+03	.410E-01	.665E-03	.975E-03	.430E-02	.645E-02	.126E-01

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.3426140E+00	.2826832E+00	.2290396E+00	.1806856E+00	.1414908E+00	.9692688E-01	.5169905E-01	.2179081E-01
.8419573E-02	.2065208E-02	.5211086E-03	.6411992E-04	.9169704E-05	.9504160E-06	.9464211E-07	.4540610E-08

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.3873495E-01	.7634065E-02	.1505103E-02	.9329252E-03	.5338102E-03	.2034686E-02	-.6909055E-03	.7123604E-04
.3428197E-03	-.1695966E-03	.8823892E-04	-.1514246E-04	.5534009E-05	-.2679490E-05	.1618558E-06	.5456252E-07

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.1205462E-01	.2631972E-02	-.4312401E-03	.1043029E-03	-.1416124E-04	.1591504E-03	.1329032E-03	-.2884473E-04
-.4638237E-04	-.1608627E-05	.6733203E-05	-.1214317E-05	.3377868E-06	-.1019368E-07	.2660714E-08	.7651176E-10

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.3310489E-02	-.1491621E-03	.1137081E-03	-.2094073E-03	.6809293E-04	.2200943E-03	-.1864236E-03	-.1406685E-03
.3089410E-04	-.1224599E-05	.4175169E-05	.1663386E-06	.1980592E-07	.1682135E-08	-.6532862E-09	-.3428964E-10

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.8646159E-03	-.1350608E-03	.7684075E-04	-.6550397E-04	.7440539E-04	-.9817197E-04	.9793947E-04	-.5366767E-04
.2113752E-04	-.6640882E-05	.1107709E-05	-.7051691E-07	.3617209E-07	.1102467E-08	.1519264E-09	.1946095E-11

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.1499458E-01	.1338726E-02	.5397430E-03	.2110343E-03	.1157855E-02	.4958847E-03	-.7963465E-03	-.1504840E-03
.1883873E-03	-.9361813E-05	.5778758E-05	-.2341649E-06	.1352410E-07	-.1351330E-09	.9312544E-10	.3355397E-11

NEUTRON ENERGY = 3.400000
TOTAL CR-SECT.= 8.102070
REACTION CR-SECT. = 2.917521

NMAX	CR-SECT. OF LEVEL EXCITATION
1	4.305415
2	.486758
3	.151483
4	.041601
5	.010865
6	.188427

STRENGTH FUNCTIONS

SF0= .4280423E-04 SF1= .5651124E-04 SF2= .5482083E-04

SPHERICAL VOLUME INTEGRALS OF REAL POTENTIAL F-FACTORS AND DERIVATIVES:
VIR0= 178.035 VIR1= 503.352 VIR2= 487.978 VIR3= 162.653 CBETO= .969
SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WC) F-FACTORS AND DERIVATIVES:
WIC0= 155.901 WIC1= 456.082 WIC2= 450.273 WIC3= 150.087 CBETC= .987
SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WD) F-FACTORS AND DERIVATIVES:
WID0= 139.964 WID1= 274.793 WID2= 137.396 WID3= .001 CBETD= .500
SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WW) F-FACTORS AND DERIVATIVES:
WIW0= .000 WIW1= .000 WIW2= .000 WIW3= .000 CBETW= .000

ORB. MOMENT	TRANSITIONS	SR	SI
0	.9766733374	-.1312721762	.0389157899
1	.9751059139	.1039109031	.0973538518
2	.9759394040	.1062574364	-.0891084049
3	.9738970165	-.0307777044	-.1430456996
4	.9734582507	-.1285873529	-.0688801521
5	.9719222493	-.1455580934	.0429100309
6	.9691534237	-.0935152051	.1271617803
7	.9681545446	.0006881496	.1587532048
8	.9652993848	.0946421954	.1346474585
9	.9635116732	.1522555085	.0525329950
10	.9591434038	.1524530929	-.0611538664
11	.9477544205	.1078713389	-.1399971810
12	.9422931763	.0542808437	-.1235927249
13	.9274169649	.0527181463	.0348822367
14	.7766473875	.2384984801	.2782643953
15	.4609750987	.5831547296	.3615728753
16	.2046374842	.8309976673	.2607951577
17	.0841025090	.9367296220	.1512121782
18	.0320915201	.9784166789	.0796701434
19	.0118897929	.9926835000	.0387967533
20	.0044321652	.9973383995	.0175904938
21	.0016775581	.9988696468	.0069746821
22	.0006323612	.9995227308	.0016029479

ANGULAR DISTRIBUTIONS OF SCATTERED PARTICLES

.100E-03	.418E+22	.256E+00	.151E-02	.614E-02	.691E-02	.419E-01
.500E+01	.613E+03	.128E+00	.119E-02	.721E-02	.225E-02	.232E-01
.100E+02	.315E+02	.115E+00	.201E-02	.491E-02	.138E-03	.113E-01
.150E+02	.150E+01	.899E-01	.439E-02	.131E-02	.507E-03	.962E-02
.250E+02	.790E-01	.633E-01	.868E-03	.321E-03	.408E-03	.509E-02
.350E+02	.872E-01	.203E-01	.167E-02	.135E-03	.213E-03	.137E-02
.500E+02	.804E-02	.769E-02	.610E-03	.125E-03	.120E-03	.770E-03
.700E+02	.186E-02	.106E-02	.294E-03	.140E-03	.106E-04	.263E-03
.100E+03	.220E-03	.196E-03	.591E-04	.191E-04	.205E-05	.425E-04
.180E+03	.859E-05	.134E-04	.111E-04	.479E-03	.117E-04	.110E-04

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.1678275E+00	.1460223E+00	.1177352E+00	.8864568E-01	.6228184E-01	.4079265E-01	.2507310E-01	.1503544E-01
.9677572E-02	.7369771E-02	.6575938E-02	.6318213E-02	.6112433E-02	.5737476E-02	.5152826E-02	.4383996E-02
.3296190E-02	.2338646E-02	.2693695E-02	.4947865E-02	.8607683E-02	.1262693E-01	.1597560E-01	.1795896E-01
.1830986E-01	.1714481E-01	.1485732E-01	.1198175E-01	.9039134E-02	.6410240E-02	.4290438E-02	.2717173E-02
.1628970E-02	.9222123E-03	.4901925E-03	.2423630E-03	.1102506E-03	.4597364E-04	.1787236E-04	.6498385E-05
.2069597E-05	.5032004E-06	.3834587E-07	-.5085922E-07	-.3429344E-07	-.9638750E-08	.3519865E-08	

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.5899556E-02	.5023932E-02	.3836600E-02	.2752341E-02	.1924487E-02	.1347048E-02	.9640510E-03	.7154470E-03
.5570876E-03	.4563546E-03	.3851574E-03	.3213348E-03	.2609132E-03	.2011112E-03	.1443058E-03	.9260688E-04
.4632929E-04	.4301914E-05	-.3467375E-04	-.7063933E-04	-.1061047E-03	-.1391562E-03	-.1699857E-03	-.1919522E-03
-.1764918E-03	-.8831531E-04	.6717220E-04	.2402040E-03	.3707810E-03	.4258670E-03	.4060321E-03	.3343602E-03
.2384626E-03	.1424507E-03	.6188307E-04	.4994583E-05	-.2667797E-04	-.3541823E-04	-.2625332E-04	-.1282165E-04
-.4372543E-05	.1455444E-06	.1943404E-05	.2287731E-05	.1879981E-05	.1138126E-05	.5718993E-06	

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.4297804E-03	.3099517E-03	.1826961E-03	.9329984E-04	.4410908E-04	.1919626E-04	.5243118E-05	-.4167034E-05
-.1121095E-04	-.1633845E-04	-.2019340E-04	-.2221078E-04	-.2304241E-04	-.2218182E-04	-.2031814E-04	-.1706994E-04
-.1304654E-04	-.8279261E-05	-.2907083E-05	.2427975E-05	.7982820E-05	.1253518E-04	.1587259E-04	.1803052E-04
.1775011E-04	.1272363E-04	.3751478E-05	-.5375115E-05	-.1113500E-04	-.1214869E-04	-.9476560E-05	-.5231017E-05
-.1267886E-05	.1389876E-05	.2656173E-05	.2866582E-05	.2469736E-05	.1763149E-05	.9992857E-06	.4576584E-06
.1818679E-06	.6363897E-07	.1849435E-07	.2838236E-08	.4497327E-09	-.2457490E-10	.5160593E-10	

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.2215854E-03	.1668565E-03	.1300985E-03	.9135077E-04	.7175638E-04	.5461927E-04	.4642810E-04	.3560452E-04
.3295817E-04	.2823283E-04	.2537190E-04	.2104075E-04	.1869349E-04	.1476572E-04	.1256392E-04	.8654051E-05
.7274300E-05	.4244092E-05	.2639103E-05	.7548687E-06	-.7360084E-06	-.1710707E-05	-.2177499E-05	-.3080567E-05
-.1506578E-05	.7640080E-06	.8546049E-06	-.2465302E-05	-.6610709E-05	-.1037644E-04	-.1048414E-04	-.9194095E-05
-.6120027E-05	-.2998172E-05	.4599078E-06	.2646180E-05	.4134777E-05	.3863362E-05	.3273128E-05	.1228218E-05
.2911317E-07	-.8630834E-06	-.7757298E-06	-.7999760E-06	-.3039771E-06	-.4096483E-06	.0000000E+00	

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

.5131597E-04	.3843131E-04	.2620716E-04	.1763655E-04	.1298225E-04	.1063330E-04	.9563951E-05	.8871493E-05
.8528115E-05	.8131119E-05	.7895962E-05	.7607028E-05	.7373688E-05	.7117099E-05	.6860153E-05	.6626209E-05
.6328896E-05	.6121972E-05	.5819552E-05	.5540297E-05	.5367803E-05	.4900492E-05	.4747189E-05	.4504904E-05
.3665541E-05	.2915786E-05	.3234529E-05	.4383171E-05	.5535659E-05	.6010092E-05	.5762215E-05	.4948866E-05
.3902121E-05	.2858931E-05	.1967261E-05	.1276952E-05	.7817872E-06	.4454079E-06	.2336711E-06	.1089419E-06
.4753320E-07	.1980519E-07	.8014815E-08	.3079856E-08	.1098949E-08	.3211100E-09	.8404114E-10	

LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS
ANGULAR DISTRIBUTIONS

```
  .6810649E-03   .5685514E-03   .4267672E-03   .3101934E-03   .2301653E-03   .1780301E-03   .1435943E-03   .1190611E-03
  .1011008E-03   .8750899E-04   .7615618E-04   .6573441E-04   .5610648E-04   .4713685E-04   .3905039E-04   .3208085E-04
  .2629209E-04   .2142573E-04   .1733812E-04   .1371606E-04   .9969905E-05   .5893483E-05   .1071480E-05  -.2305723E-05
  .1242238E-05   .1350063E-04   .2903013E-04   .4012465E-04   .4297068E-04   .3840787E-04   .2982949E-04   .2025572E-04
  .1175013E-04   .5157152E-05   .7175307E-06  -.1744648E-05  -.2582269E-05  -.2311413E-05  -.1406202E-05  -.5152915E-06
 -.1061565E-06   .4881347E-07   .9791397E-07   .9978109E-07   .7761308E-07   .4548255E-07   .2242581E-07

NEUTRON ENERGY = 65.000000
TOTAL  CR-SECT.=  4.504600
REACTION CR-SECT. =  2.304093

  NMAX                CR-SECT. OF LEVEL EXCITATION
   1                          2.108982
   2                           .074136
   3                           .005401
   4                           .002785
   5                           .000645
   6                           .008559

                              STRENGTH  FUNCTIONS
SFO=    .1928025E-04        SF1=    .1933368E-04        SF2=    .1952242E-04
```

In any case those who are interested in calculations using code OPTMAN are welcome to address for help to the authors if necessary.

6 Concluding remarks

The coupled-channels optical model code OPTMAN was extended to have new options which were added after the first version was published[1]. The main changes are inclusion of the (1) volume conservation option, (2) relativistic kinematics, (3) imaginary spin-orbit term, and (4) isospin dependence (Lane term) of the potential depth parameters. We hope the current code can be used for nuclear data evaluation and analyses of nucleon-induced reaction mechanisms up to projectile energy of 200 MeV.

Acknowledgments

The authors would like to thank Dr. Akira Hasegawa of JAERI nuclear data center for his support on this work

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国際単位系 (SI) と換算表

表1 SI基本単位および補助単位

量	名　称	記　号
長　　さ	メートル	m
質　　量	キログラム	kg
時　　間	秒	s
電　　流	アンペア	A
熱力学温度	ケルビン	K
物 質 量	モ　　ル	mol
光　　度	カンデラ	cd
平 面 角	ラジアン	rad
立 体 角	ステラジアン	sr

表2 SIと併用される単位

名　称	記　号
分，時，日	min, h, d
度，分，秒	°, ′, ″
リットル	l, L
ト　ン	t
電子ボルト	eV
原子質量単位	u

$1\ \mathrm{eV} = 1.60218 \times 10^{-19}\ \mathrm{J}$

$1\ \mathrm{u} = 1.66054 \times 10^{-27}\ \mathrm{kg}$

表5 SI接頭語

倍数	接頭語	記　号
10^{18}	エクサ	E
10^{15}	ペ　タ	P
10^{12}	テ　ラ	T
10^{9}	ギ　ガ	G
10^{6}	メ　ガ	M
10^{3}	キ　ロ	k
10^{2}	ヘクト	h
10^{1}	デ　カ	da
10^{-1}	デ　シ	d
10^{-2}	センチ	c
10^{-3}	ミ　リ	m
10^{-6}	マイクロ	μ
10^{-9}	ナ　ノ	n
10^{-12}	ピ　コ	p
10^{-15}	フェムト	f
10^{-18}	ア　ト	a

表3 固有の名称をもつSI組立単位

量	名　称	記号	他のSI単位による表現
周　波　数	ヘルツ	Hz	s^{-1}
力	ニュートン	N	$m{\cdot}kg/s^2$
圧力，応力	パスカル	Pa	N/m^2
エネルギー，仕事，熱量	ジュール	J	N·m
工率，放射束	ワット	W	J/s
電気量，電荷	クーロン	C	A·s
電位，電圧，起電力	ボルト	V	W/A
静電容量	ファラド	F	C/V
電気抵抗	オーム	Ω	V/A
コンダクタンス	ジーメンス	S	A/V
磁　　束	ウェーバ	Wb	V·s
磁束密度	テスラ	T	Wb/m^2
インダクタンス	ヘンリー	H	Wb/A
セルシウス温度	セルシウス度	℃	
光　　束	ルーメン	lm	cd·sr
照　　度	ルクス	lx	lm/m^2
放　射　能	ベクレル	Bq	s^{-1}
吸収線量	グレイ	Gy	J/kg
線量当量	シーベルト	Sv	J/kg

表4 SIと共に暫定的に維持される単位

名　称	記　号
オングストローム	Å
バ　ー　ン	b
バ　ー　ル	bar
ガ　　ル	Gal
キ ュ リ ー	Ci
レントゲン	R
ラ　　ド	rad
レ　　ム	rem

$1\ \text{Å} = 0.1\ \mathrm{nm} = 10^{-10}\ \mathrm{m}$

$1\ \mathrm{b} = 100\ \mathrm{fm}^2 = 10^{-28}\ \mathrm{m}^2$

$1\ \mathrm{bar} = 0.1\ \mathrm{MPa} = 10^5\ \mathrm{Pa}$

$1\ \mathrm{Gal} = 1\ \mathrm{cm/s^2} = 10^{-2}\ \mathrm{m/s^2}$

$1\ \mathrm{Ci} = 3.7 \times 10^{10}\ \mathrm{Bq}$

$1\ \mathrm{R} = 2.58 \times 10^{-4}\ \mathrm{C/kg}$

$1\ \mathrm{rad} = 1\ \mathrm{cGy} = 10^{-2}\ \mathrm{Gy}$

$1\ \mathrm{rem} = 1\ \mathrm{cSv} = 10^{-2}\ \mathrm{Sv}$

(注)

1. 表1〜5は「国際単位系」第5版，国際度量衡局 1985年刊行による。ただし，1 eV および 1 u の値は CODATA の1986年推奨値によった。
2. 表4には海里，ノット，アール，ヘクタールも含まれているが日常の単位なのでここでは省略した。
3. bar は，JISでは流体の圧力を表わす場合に限り表2のカテゴリーに分類されている。
4. EC閣僚理事会指令では bar，barn および「血圧の単位」mmHg を表2のカテゴリーに入れている。

換　　算　　表

力	N(=10^5dyn)	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

粘　度　1 Pa·s(N·s/m²)＝10 P(ポアズ)(g/(cm·s))

動粘度　1 m²/s＝10⁴St(ストークス)(cm²/s)

圧力	MPa(=10 bar)	kgf/cm²	atm	mmHg(Torr)	lbf/in²(psi)
	1	10.1972	9.86923	7.50062×10^3	145.038
	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	1.33322×10^{-4}	1.35951×10^{-3}	1.31579×10^{-3}	1	1.93368×10^{-2}
	6.89476×10^{-3}	7.03070×10^{-2}	6.80460×10^{-2}	51.7149	1

エネルギー・仕事・熱量	J(=10^7erg)	kgf·m	kW·h	cal(計量法)	Btu	ft·lbf	eV
	1	0.101972	2.77778×10^{-7}	0.238889	9.47813×10^{-4}	0.737562	6.24150×10^{18}
	9.80665	1	2.72407×10^{-6}	2.34270	9.29487×10^{-3}	7.23301	6.12082×10^{19}
	3.6×10^6	3.67098×10^5	1	8.59999×10^5	3412.13	2.65522×10^6	2.24694×10^{25}
	4.18605	0.426858	1.16279×10^{-6}	1	3.96759×10^{-3}	3.08747	2.61272×10^{19}
	1055.06	107.586	2.93072×10^{-4}	252.042	1	778.172	6.58515×10^{21}
	1.35582	0.138255	3.76616×10^{-7}	0.323890	1.28506×10^{-3}	1	8.46233×10^{18}
	1.60218×10^{-19}	1.63377×10^{-20}	4.45050×10^{-26}	3.82743×10^{-20}	1.51857×10^{-22}	1.18171×10^{-19}	1

1 cal = 4.18605 J (計量法)
= 4.184 J (熱化学)
= 4.1855 J (15 °C)
= 4.1868 J (国際蒸気表)

仕事率　1 PS (仏馬力)
= 75 kgf·m/s
= 735.499 W

放射能	Bq	Ci
	1	2.70270×10^{-11}
	3.7×10^{10}	1

吸収線量	Gy	rad
	1	100
	0.01	1

照射線量	C/kg	R
	1	3876
	2.58×10^{-4}	1

線量当量	Sv	rem
	1	100
	0.01	1

(86年12月26日現在)