



JP9950397

JAERI-Data/Code

99-028



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

May 1999

Efrem Sh. SUKHOVITSKI<sup>II</sup>\* , Osamu IWAMOTO,  
Satoshi CHIBA and Keiichi SHIBATA

日本原子力研究所  
Japan Atomic Energy Research Institute

本レポートは、日本原子力研究所が不定期に公刊している研究報告書です。  
入手の問合せは、日本原子力研究所研究情報部研究情報課（〒319-1195 茨城県那珂郡東海村）あて、お申し越し下さい。なお、このほかに財団法人原子力弘済会資料センター（〒319-1195 茨城県那珂郡東海村日本原子力研究所内）で複写による実費領布を行っております。

This report is issued irregularly.  
Inquiries about availability of the reports should be addressed to Research Information Division, Department of Intellectual Resources, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195, Japan.

© Japan Atomic Energy Research Institute, 1999  
編集兼発行 日本原子力研究所

New Options of Coupled Channels Optical Model Code OPTMAN  
Version 6 (1999)

Efrem Sh. SUKHOVITSKII\*, Osamu IWAMOTO,  
Satoshi CHIBA<sup>+</sup> and Keiichi SHIBATA

Department of Nuclear Energy System  
Tokai Research Establishment  
Japan Atomic Energy Research Institute  
Tokai-mura, Naka-gun, Ibaraki-ken

(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

---

<sup>+</sup> Advanced Science Research Center

\* Radiation Physics and Chemistry Problems Institute

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

日本原子力研究所東海研究所エネルギー・システム研究部

Efrem Sh. SUKHOVITSKII\*・岩本 修・千葉 敏<sup>+</sup>・柴田 恵一

(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。

---

東海研究所：〒319-1195 茨城県那珂郡東海村白方白根2-4

+ 先端基礎研究センター

\* 放射線物理化学問題研究所

## Contents

1. Introduction .....	1
2. New Options of the Code .....	1
2.1 Account of Nuclear Volume (mass) Conservation .....	1
2.2 Relativistic Generalization of the Non-relativistic Schrödinger Formalism .....	2
2.3 Account of Imaginary Spin-orbit Optical Potential .....	3
2.4 Account of Isospin Terms in Optical Potentials .....	3
3. Changes in Code Input due to New Options .....	4
4. Other Minor Useful Changes .....	5
4.1 Input .....	5
4.2 Output .....	5
5. Examples .....	5
5.1 Input .....	5
5.2 Output .....	6
6. Concluding Remarks .....	10
Acknowledgments .....	10
References .....	11

## 目 次

1. 序 論 .....	1
2. コードの新しい機能 .....	1
2.1 原子核の体積（質量）保存 .....	1
2.2 非相対論的 Schrödinger 形式の相対論的拡張 .....	2
2.3 スピン・軌道項虚数部の導入 .....	3
2.4 光学ポテンシャルへのアイソスピン項の導入 .....	3
3. 新しい機能に伴う入力データの修正 .....	4
4. その他の修正事項 .....	5
4.1 入 力 .....	5
4.2 出 力 .....	5
5. 入出力例 .....	5
5.1 入 力 例 .....	5
5.2 出 力 例 .....	6
6. 結 論 .....	10
謝 辞 .....	10
参考文献 .....	11

## 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  $^{12}\text{C}$ [2, 3],  $^{58}\text{Ni}$ [4] and  $^{238}\text{U}$ [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,

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

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  $\beta_{00}$  to the radial expansion given in Eq. (1)

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

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

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

Additional  $\beta_{00}$  deformation leads to additional zero nuclear potential multipole that couples levels with equal spin and parity  $I^\pi$ .

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

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

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

$$\beta'_{00} = C_\beta \beta_{00}. \quad (5)$$

In our code we use nuclear real potential form factor  $f_R(r, R, a)$  instead of nuclear density form factor. As  $C_\beta$  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:

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

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  $\sim 1000$  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  $\sim 5\%$

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:

$$(\hbar k)^2 = [E^2 - (M_p c^2)^2] / c^2 \quad (7)$$

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:

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

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:

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

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

$$W_{SO} = W_{SO}^0 + W_{SO}^1 E_p \quad (10)$$

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:

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

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, MESH0, MEHA0, 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  $W_{SO}^0$  adjustment WS0;
- NPJ(41) - flag for imaginary spin-orbit optical potential linear term  $W_{SO}^1$  adjustment WS1;
- NPJ(42) - flag for adjustment of axial rigid-deformation  $\beta_{60}$  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
010205010001040202000201
.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= 238.000000
      COUPLED CHANNELS METHOD
      WITH AC. NONAXIAL HEXADECAPOLE DEFORMATIONS

HAMILTONN-A SPAO POTENTIAL EXPANDED 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
      1.000000E+00      0      1      0      0      0      1
      .4490000E-01      4      1      0      0      0      1
      .1490000E+00      8      1      0      0      0      1
      .6630000E+00      2      1      0      0      1      -1
      .9930000E+00      0      1      1      0      0      1
      .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 POLAR= .000000D+00 ANU1= .6242140D+00 ANU2= .6242140D+00
IO1= 1 IO2= 1 NNT= 2 POLAR= .3957345D+01 ANU1= .6242140D+00 ANU2= .6242140D+00
IO1= 1 IO2= 2 NNT= 1 POLAR= .1986251D+01 ANU1= .6242140D+00 ANU2= .2412730D+01
IO1= 1 IO2= 2 NNT= 2 POLAR= .0000000D+00 ANU1= .6242140D+00 ANU2= .2412730D+01
IO1= 2 IO2= 2 NNT= 1 POLAR= .0000000D+00 ANU1= .2412730D+01 ANU2= .2412730D+01
IO1= 2 IO2= 2 NNT= 2 POLAR= .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)= .6022785D+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)= .1019636D+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	AR0= .6600	ARI= .0017
WDO= 4.3600	WD1= .4670		RD= 1.2418	AD0= .4240	AD1= .0156
WCO= .0000	WC1= .0000		RC= 1.2368	AC0= .4800	AC1= .0000
VSO= 3.9200			RW= 1.0000	AWO= 1.0000	AW1= .0000
ALF= 1.0000	ANEU= 1.0087		RS= 1.1200	AS0= .4600	AS1= .0010
BNDC=10.0000	WDA1= -.0950	WCA1= .1420	CCOUL= .5600	AZ= .4400	CISO=16.0000
WCISO= 8.0000	WS0= .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

JAERI - Data/Code 99-028

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
.500E+01	.687E+01	.974E-01	.206E-01
.100E+02	.612E+01	.926E-01	.203E-01
.150E+02	.502E+01	.856E-01	.197E-01
.250E+02	.257E+01	.693E-01	.181E-01
.350E+02	.802E+00	.559E-01	.165E-01
.500E+02	.491E-02	.456E-01	.160E-01
.700E+02	.136E+00	.456E-01	.164E-01
.100E+03	.244E-01	.304E-01	.110E-01
.180E+03	.410E-01	.665E-03	.975E-03
LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS			
ANGULAR DISTRIBUTIONS			
.3426140E+00	.2826832E+00	.2290396E+00	.1806856E+00
.8419573E-02	.2065208E-02	.5211086E-03	.6411992E-04
LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS			
ANGULAR DISTRIBUTIONS			
.3873495E-01	.7634065E-02	.1505103E-02	.9329252E-03
.3428197E-03	-.1695966E-03	.8823892E-04	-.1514246E-04
LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS			
ANGULAR DISTRIBUTIONS			
.1205462E-01	.2631972E-02	-.4312401E-03	.1043029E-03
-.4638237E-04	-.1608627E-05	.6733203E-05	-.1214317E-05
LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS			
ANGULAR DISTRIBUTIONS			
.3310489E-02	-.1491621E-03	.1137081E-03	-.2094073E-03
.3089410E-04	-.1224599E-05	.4175169E-05	.1663386E-06
LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS			
ANGULAR DISTRIBUTIONS			
.8646159E-03	-.1350608E-03	.7684075E-04	-.6550397E-04
.2113752E-04	-.6640882E-05	.1107709E-05	-.7051691E-07
LEGENDR. COEFFICIENTS FOR SCATTERED NEUTRONS			
ANGULAR DISTRIBUTIONS			
.1499458E-01	.1338726E-02	.5397430E-03	.2110343E-03
.1883873E-03	-.9361813E-05	.5778758E-05	-.2341649E-06
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			
SFO= .4280423E-04	SF1= .5651124E-04	SF2= .5482083E-04	
SPHERICAL VOLUME INTEGRALS OF REAL POTENTIAL F-FACTORS AND DERIVATIVES:			
VIRO= 178.035	VIR1= 503.352	VIR2= 487.978	VIR3= 162.653
CBETO= .969			
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= 139.964	WID1= 274.793	WID2= 137.396	WID3= .001
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	S1				
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	-.139971810				
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	.1486732E-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	.58195652E-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

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

## References

- [1] E. Sh. Soukhovitskiĭ, Yu. V. Porodzinskii, O. Iwamoto, S. Chiba and K. Shibata, JAERI Data/Code 98-019 (1998)
- [2] S. Chiba, O. Iwamoto, Y. Yamanouti,, M. Sugimoto, M. Mizumoto, K. Hasegawa, E. Sh. Soukhovitskiĭ, Y.V. Porodzinskii and Y. Watanabe, Nucl. Phys. **A 624**, 305 (1997).
- [3] E. Sh. Soukhovitskiĭ, S. Chiba, O. Iwamoto and Y.V. Porodzinskii, Nucl. Phys. **A 640**, 147 (1998).
- [4] O. Iwamoto, E. Sh. Soukhovitskiĭ and S. Chiba, to be published.
- [5] E. Sh. Soukhovitskiĭ, O. Iwamoto and S. Chiba, to be published.
- [6] E. Sh. Soukhovitskiĭ, O. Iwamoto, S. Chiba, Nucl. Phys. **A 646**, 19 (1999).
- [7] J.Raynal, Phys.Rev. **C23**, 2571 (1980).
- [8] J.M. Eisenberg and W. Greiner, "Nuclear Models", North-Holland, Amsterdam (1970).
- [9] Y. Kikuchi, INDC(FR)-5/L (1972).
- [10] L. R. B. Elton, Nuovo Cimento **XLIII B**, 277 (1966)

This is a blank page.

# 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
光强度	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 <sup>-1</sup>
力	ニュートン	N	m·kg/s <sup>2</sup>
圧力、応力	パスカル	Pa	N/m <sup>2</sup>
エネルギー、仕事、熱量	ジュール	J	N·m
功率、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	ファラード	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 <sup>2</sup>
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	°C	
光束度	ルーメン	lm	cd·sr
照度	ルクス	lx	lm/m <sup>2</sup>
放射能	ベクレル	Bq	s <sup>-1</sup>
吸収線量	グレイ	Gy	J/kg
線量当量	シーベルト	Sv	J/kg

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

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

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

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
バーソル	b
バール	bar
ガル	Gal
キュリ	Ci
レントゲン	R
ラド	rad
レム	rem

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

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

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

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

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

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

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

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

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

(注)

- 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、1eVおよび1uの値はCODATAの1986年推奨値によった。
- 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。
- 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。
- 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 <sup>5</sup> dyn)	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

$$\text{粘度 } 1 \text{ Pa}\cdot\text{s}(N\cdot\text{s}/\text{m}^2) = 10 \text{ P(ポアズ)}(\text{g}/(\text{cm}\cdot\text{s}))$$

$$\text{動粘度 } 1 \text{ m}^2/\text{s} = 10^4 \text{ St(ストークス)}(\text{cm}^2/\text{s})$$

圧力	MPa(=10 bar)	kgf/cm <sup>2</sup>	atm	mmHg(Torr)	lbf/in <sup>2</sup> (psi)
力	1	10.1972	9.86923	$7.50062 \times 10^3$	145.038
	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	$1.33322 \times 10^{-4}$	$1.35951 \times 10^{-3}$	$1.31579 \times 10^{-3}$	1	$1.93368 \times 10^{-2}$
	$6.89476 \times 10^{-3}$	$7.03070 \times 10^{-2}$	$6.80460 \times 10^{-2}$	51.7149	1

エネルギー・仕事・熱量	J(=10 <sup>7</sup> erg)	kgf·m	kW·h	cal(計量法)	Btu	ft · lbf	eV	1 cal = 4.18605 J(計量法)
	1	0.101972	$2.77778 \times 10^{-7}$	0.238889	$9.47813 \times 10^{-4}$	0.737562	$6.24150 \times 10^{18}$	= 4.184 J(熱化学)
	9.80665	1	$2.72407 \times 10^{-6}$	2.34270	$9.29487 \times 10^{-3}$	7.23301	$6.12082 \times 10^{19}$	= 4.1855 J(15 °C)
	$3.6 \times 10^6$	$3.67098 \times 10^5$	1	$8.59999 \times 10^5$	3412.13	$2.65522 \times 10^6$	$2.24694 \times 10^{25}$	= 4.1868 J(国際蒸気表)
	4.18605	0.426858	$1.16279 \times 10^{-6}$	1	$3.96759 \times 10^{-3}$	3.08747	$2.61272 \times 10^{19}$	仕事率 1 PS(仏馬力)
	1055.06	107.586	$2.93072 \times 10^{-4}$	252.042	1	778.172	$6.58515 \times 10^{21}$	= 75 kgf·m/s
	1.35582	0.138255	$3.76616 \times 10^{-7}$	0.323890	$1.28506 \times 10^{-3}$	1	$8.46233 \times 10^{18}$	= 735.499 W
	$1.60218 \times 10^{-19}$	$1.63377 \times 10^{-20}$	$4.45050 \times 10^{-26}$	$3.82743 \times 10^{-20}$	$1.51857 \times 10^{-22}$	$1.18171 \times 10^{-19}$	1	

放射能	Bq	Ci
	1	$2.70270 \times 10^{-11}$
	$3.7 \times 10^{10}$	1

吸収線量	Gy	rad
	1	100
	0.01	1

照射線量	C/kg	R
	1	3876
	$2.58 \times 10^{-4}$	1

線量当量	Sv	rem
	1	100
	0.01	1

(86年12月26日現在)

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