4 Optical Model Parameters

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Summary

This chapter contains a description of the optical model Segment of the Reference Input Parameter Library. The Segment consists of some 293 optical model potentials for incident neutrons (76), protons (125), deuterons (6), tritons (26), ^{3}He (53), and ^{4}He (7). Global as well as nuclide-specific potentials are included that utilize spherical, vibrational, or rotational models. The optical model parameterizations in the Starter File are given in a very general format, which is described here in detail together with the conventions used for numbering the potentials. In general, it is recommended that nuclide-specific potentials be used for materials where careful analyses have been made. For cases where global parameterizations must be used, recommendations are included. The recommended file, which is the main RIPL optical potential file, is named **losalamos_omlib.dat**. Additionally, there are supplemental files that define the parameters and specify the format (**losalamos.readme**) and that include subroutines and short codes for accessing and summarizing the file (*losalamos_omcode.for*).

4.1 Introduction

The optical model provides the basis for many theoretical analyses and/or evaluations of nuclear cross sections that are used in providing nuclear data for applied purposes. In addition to offering a convenient means for calculation of reaction, shape elastic, and (neutron) total cross sections, optical model potentials are widely used in quantum-mechanical preequilibrium and direct-reaction theory calculations and, most importantly, in supplying particle transmission coefficients for Hauser-Feshbach statistical-theory analyses used in nuclear data evaluations. The importance of optical model parameterizations is made even more apparent by the worldwide diminution of experimental facilities for low-energy nuclear physics measurements and the consequent increased reliance on theoretical methods for providing nuclear data for applications. Therefore, the preservation of past work aimed at describing experimental results with optical model potentials is vital for future development of nuclear data bases.

The optical model Segment of the RIPL CRP is aimed at compiling and developing a Segment of optical model parameterizations that are useful in evaluations of nuclear data. The planned product of this activity is a Reference Input Parameter Library that will contain reliable, state-of-the-art parameterizations for conventional optical model codes used in calculations of nuclear data for applications. In addition to preserving optical model parameterizations for future activities, the Segment will offer a convenient means for present day evaluators to access a wide body of optical model information. Subroutines have been developed for reading and writing the data library, and eventually processing codes will be written that will permit direct interfacing of the Segment with selected optical model codes.

4.2 Optical Model Parameterization

One of the primary goals of the optical model Segment is to provide a format for optical model parameterizations that is general enough to cover all commonly used potential representations and that is easily expanded for additional types of optical potentials. For the present Starter

File we have focused on standard, Schrödinger-type forms of optical model potentials, and have included spherical, coupled-channel rotational, and simple vibrational models. Eventually, the Segment will be expanded to include more complex rotational/vibrational configurations, dispersive potentials, and perhaps even folding model potentials.

As presently formulated, potentials of the form

$$\begin{aligned} V(r) &= -V_R f_R(r) - iW_V f_V(r) + 4ia_D W_D \frac{\mathrm{d}}{\mathrm{d}r} f_D(r) \\ &+ \frac{\lambda_\pi^2}{r}\left[V_{SO}\frac{\mathrm{d}}{\mathrm{d}r} f_{VSO}(r) + iW_{SO}\frac{\mathrm{d}}{\mathrm{d}r} f_{WSO}(r)\right]\sigma\cdot l \end{aligned} \tag{4.1}$$

are allowed. In Eq. (4.1) V_R and W_V are the real and imaginary volume potential well depths, W_D is the well depth for the surface derivative term, V_{SO} and W_{SO} are the real and imaginary well depths for the spin-orbit potential, and λ_π^2 is the pion Compton wavelength squared ($\simeq 2$). The quantity $\sigma \cdot l$ is the scalar product of the intrinsic and orbital angular momentum operators and is given by

$$\begin{aligned} \sigma\cdot l &= l && \text{for } j = l + \frac{1}{2} \\ &= -(l+1) && \text{for } j = l - \frac{1}{2}. \end{aligned} \tag{4.2}$$

The $f_i(r)$ are radial-dependent form factors and are defined below.

Any incident particle is permitted by the format, but we have limited our initial file to incident neutrons, protons, deuterons, tritons, ^{3}He, and ^{4}He particles. Our approach is to supply a general form for optical model potentials that is an extension of the representation implemented in the SCAT2 optical model code [4.1] and that describes most of the parameterizations commonly used in the past. Additionally, three more specialized formats are formulated that describe particular, less common, forms of potentials but which offer promise of being important for applied purposes.

The general form of the optical model potential used here is the following:

$$\begin{aligned} V_i(E) &= \alpha_1 + \alpha_7\eta + \alpha_8\Delta_c + \alpha_9 A + \alpha_{10}A^{1/3} + \alpha_{11}A^{-2/3} + \alpha_{12}\Delta_{c'} \\ &\quad +(\alpha_2 + \alpha_{13}\eta + \alpha_{14}A)E + \alpha_3 E^2 + \alpha_4 E^3 + \alpha_6\sqrt{E} \\ &\quad +(\alpha_5 + \alpha_{15}\eta + \alpha_{16}E)\ln(E) + \alpha_{17}\Delta_c E^{-2}, \end{aligned} \tag{4.3}$$

where $V_i(E)$ designates the i^{th} term of the potential (for example, V_R, W_D, V_{SO}, etc.) at incident laboratory energy E, $\eta = (N-Z)/A$, N and Z are the neutron and proton numbers of the target nucleus, and A is the atomic mass of the target. Two different forms of correction terms for Coulomb repulsion with incident protons are provided:

$$\Delta_c = \frac{0.4Z}{A^{1/3}} \quad \text{and} \quad \Delta_{c'} = \frac{1.73Z}{R_c}, \tag{4.4}$$

where R_c is the Coulomb radius. Δ_c and $\Delta_{c'}$ are zero for incident neutrons. Each of the potential terms in Eq. (4.1) can be represented over any number of defined energy ranges using as many of the terms given in Eq. (4.3) as required, with the coefficients of the unused terms set to zero.

The first special form of the potential is used to represent the potential of Smith *et al.* [4.2] and to accommodate exponential forms included in the Engelbrecht and Fiedeldey potential [4.3]:

$$V_i(E) = \alpha_1 + \alpha_2\eta + \alpha_3\cos[2\pi(A-\alpha_4)/\alpha_5] + \alpha_6\exp(\alpha_7 E + \alpha_8 E^2) + \alpha_9 E\exp(\alpha_{10}E^{\alpha_{11}}). \tag{4.5}$$

This formulation is activated by setting $\alpha_{18} > 0$.

The second special form is necessary to represent the potential determined in an extensive analysis of proton scattering cross sections and polarizations by Varner *et al.* [4.4], as well as an exponential form permitted in the SCAT2 code [4.1]:

$$V_i(E) = \frac{\alpha_1 + \alpha_2\eta}{1 + \exp\left(\frac{\alpha_3 - E + \alpha_4\Delta_{c'}}{\alpha_5}\right)} + \alpha_6 \exp\left(\frac{\alpha_7 E - \alpha_8}{\alpha_6}\right). \tag{4.6}$$

The formulation in Eq. (4.6) is activated by setting $\alpha_{19} > 0$.

Finally, the third special form, which was developed by Delaroche, is activated by setting $\alpha_{20} > 0$ and is used by Koning, van Wijk, and Delaroche [4.5] in a recent analysis of neutron reactions with isotopes of Zr

$$\begin{aligned} V_i(E) = \alpha_1 + \alpha_2 E + \alpha_3 \exp\left[-\alpha_4(E - \alpha_5 E_f)\right] + \frac{\alpha_6 (E - E_f)^{\alpha_8}}{(E - E_f)^{\alpha_8} + (\alpha_7)^{\alpha_8}} \\ + \alpha_9 \exp[-\alpha_{10}(E - E_f)] \frac{(E - E_f)^{\alpha_{12}}}{(E - E_f)^{\alpha_{12}} + (\alpha_{11})^{\alpha_{12}}} \end{aligned} \tag{4.7}$$

where E_f is the Fermi energy in MeV and is given by

$$\begin{aligned} E_f &= -0.5\,[S_n(Z,A) + S_n(Z,A+1)] && \text{(for incident neutrons)} \\ &= -0.5\,[S_p(Z,A) + S_p(Z+1,A+1)] && \text{(for incident protons)}, \end{aligned} \tag{4.8}$$

where $S_n(Z,A)$ and $S_p(Z,A)$ are the neutron and proton separation energies for nucleus (Z,A).

Either Woods-Saxon or Gaussian form factors are permitted for the $f_i(r)$ terms in Eq. (4.1), that is,

$$f_i(r) = \frac{1}{1 + \exp\left(\frac{r - R_i}{a_i}\right)} \qquad \text{(Woods} - \text{Saxon form)} \tag{4.9}$$

or

$$f_i(r) = \exp\left(\frac{-(r - R_i)^2}{a_i^2}\right) \qquad \text{(Gaussian form)}. \tag{4.10}$$

The nuclear radius is given by $R_i = r_i A^{1/3}$ where r_i is given by

$$\begin{aligned} r_i(E) &= \beta_1 + \beta_2 E + \beta_3\eta + \beta_4 A^{-1} + \beta_5 A^{-1/2} + \beta_6 A^{2/3} + \beta_7 A \\ &\quad + \beta_8 A^2 + \beta_9 A^3 + \beta_{10} A^{1/3} + \beta_{11} A^{-1/3} \end{aligned} \tag{4.11}$$

and a similar form is used for the diffuseness, a_i,

$$\begin{aligned} a_i(E) &= \delta_1 + \delta_2 E + \delta_3\eta + \delta_4 A^{-1} + \delta_5 A^{-1/2} + \delta_6 A^{2/3} + \delta_7 A \\ &\quad + \delta_8 A^2 + \delta_9 A^3 + \delta_{10} A^{1/3} + \delta_{11} A^{-1/3}. \end{aligned} \tag{4.12}$$

Note that the $\beta_{11} A^{-1/3}$ term in Eq. (4.11) permits the inclusion of a constant (A-independent) quantity to the radius, that is, $R_i = r_o + r_i' A^{1/3} = \beta_{11} + r_i' A^{1/3}$, where r_i' includes terms in Eq. (4.11) through β_{10}.

The format also permits inputting of the relevant parameters for coupled-channel rotational, vibrational, and non-axial deformed models, including energies, spins and parities of vibrational and rotational states, deformation parameters, softness parameters, etc., that are required for the various models. At present the format is considered reasonably complete for spherical and rotational models, which permits calculations with codes like SCAT2 [4.1] for spherical models and ECIS94 [4.6] for rotational and vibrational models. Extensions to the format are needed for certain forms of vibrational and non-axial deformed models.

Details of the format for the optical model parameterizations are given in Annex A. The description in Annex A is included in the **losalamos.readme** file in the RIPL data base at the IAEA/NDS.

4.3 Contents of the Optical Model Segment

To date, some 293 optical model parameterizations are included in the Segment. These potentials have been selected mainly from analyses made at Los Alamos for various applied calculations [4.7, 4.8]; from a set of parameters supplied by workers from the Japan Atomic Energy Research Institute, from the Bhabha Atomic Research Institute; and others specifically for the RIPL Starter File; and from several well known global optical model parameterizations. There are several optical model potential compilations and/or general references available that are useful in compiling data on potentials. For example, Perey and Perey [4.9] and Young [4.10] for neutrons; Mehta and Kailas [4.11] for low-energy protons; Daehnick *et al.* [4.12] and Bojowald *et al.* [4.13] for deuterons; and Avrigeanu *et al.* [4.14] for alpha particles.

Each potential included in the RIPL is given a unique reference number, according to a numbering system that is described in Annex B. This system was adopted in order to separate the potentials for different incident particles into different reference number regions, and to provide approximate information on the sources of the various potentials by geographical region. The latter information might be used, for example, if one wished to use only potentials from a particular source for a given set of calculations (for example, JAERI). To be very useful, of course, many more potentials must be added to the Starter File, for example, from China, Japan, Russia, Bologna, and the JEFF and ENDF communities in general. In addition to the numbering rules given in Annex B, we are following an informal numbering convention for neutron and proton potentials that are related through isospin by means of the Lane model [4.15]; that is, we assign a 3-digit reference number to the potential and then add 3000 for incident neutrons and 5000 for incident protons.

An example of a complete entry for one reference in the Starter File is given in Annex C. The example follows the format given in Annex A and the numbering convention in Annex B. The reference number (600) indicates that the incident particle is a neutron and that the source of the potential is a former Soviet Union country.

Summary information on all the potentials compiled thus far is given in Annex D, together with references for each potential. To date, the Segment includes 76 optical model parameterizations for incident neutrons, 125 parameterizations for incident protons, 6 for incident deuterons, 26 for incident tritons, 53 for incident ^{3}He particles, and 7 parameterizations for incident alpha particles.

4.4 Files in the Optical Model Parameter Segment

As described above, the recommended optical model parameter file in the RIPL Starter File is the **losalamos_omlib.dat** file. The format, numbering convention, and file summary is included in the **losalamos.readme** file. In addition, a second file, *losalamos_omcode.for*, is included in the RIPL supplemental file area and is comprised of the following:

1. OMSUMRY — a Fortran code that reads the **losalamos_omlib.dat** file and produces a summary of the authors, reference, and descriptive information for the entire file;
2. OMTABLE — a Fortran code that makes an abbreviated summary of the **losalamos_omlib.dat** file together with a list of the references (see Annex D);
3. OMIN — a Fortran subroutine that reads a single reference from the **losalamos_omlib.dat** file;
4. OMOUT — a Fortran subroutine that writes a single reference in the format used by the **losalamos_omlib.dat** file.

In addition to the main optical potential file described here, two supplemental optical model potential files, one from China (*beijing.dat*) and one from Japan (*jaeri.dat*), are also included as supplemental files in the RIPL Starter File. These potentials, which are in different formats from the main file, will eventually be merged into the main RIPL file but are made available now for the convenience of interested users. Please note that there is some duplication of potentials between these two supplemental files and the main RIPL file.

4.5 Validation of the Optical Model Segment

Validation of the potentials in the Segment must be carried out at two levels: (1) ensuring that the potentials in the Segment are both complete and accurate, and (2) testing how well the potentials agree with the available experimental data base. Some effort has been directed at checking the accuracy of entries into the file by careful proofreading. Additional efforts are needed in this area and, in particular, a processing code should be developed that will retrieve information from the file and print it out in standard, easily readable form.

We have also began efforts to compare a few of the potentials with experimental data, as reported by Kumar *et al.* [4.16]. In this study neutron total, reaction, and elastic scattering cross sections are compared with experimental data for 6 global potentials and 5 regional or nuclide-specific potentials. Examples of the results of comparisons obtained by Kumar *et al.* are included in Fig. 4.1, which compares calculated and measured total neutron cross sections for ^{12}C, and Fig. 4.2, which compares measured and calculated neutron reaction cross sections for ^{27}Al. It should be noted that the Kumar calculations for global optical potentiuals in Figs. 4.1 and 4.2 exceed the energy ranges of validity for all the potentials considered, so caution should be exercised in interpreting these comparions.

Additionally, the volume integrals from global potentials can be compared with the ones obtained from "best-fit" potentials for specific target nuclei. This exercise enables identification of the global potential that is closest to the best-fit potential and, in combination with cross section comparisons as described above, can serve as a basis for parameter recommendations. An example is given in Fig. 4.3 where the volume integrals computed for the ^{208}Pb+n system are shown for well known global potentials and some best-fit potentials.

4.6 Conclusions and Recommendations

Because of the limited number of potentials included in the Segment thus far and, especially, because of the very limited testing done, it is not possible to make general recommendations for optical model potentials at present. However, some specific comments can be made. In every

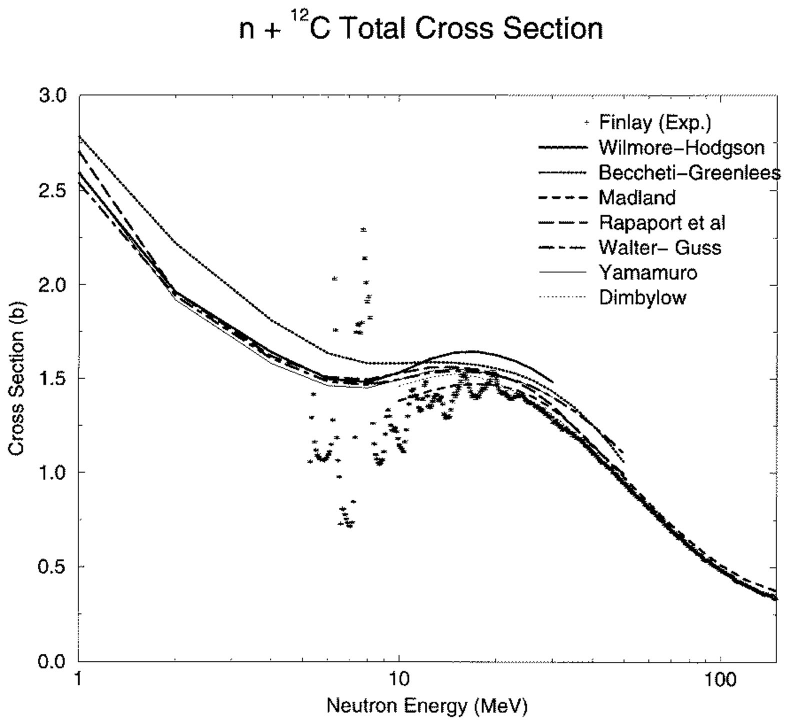

Figure 4.1: Calculated and measured neutron total cross sections for ^{12}C.

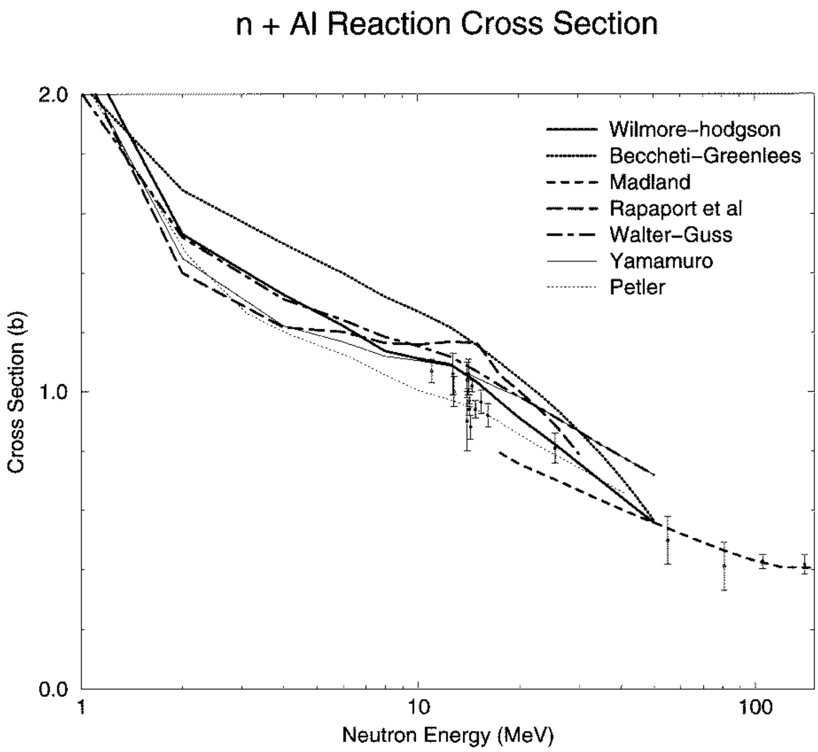

Figure 4.2: Calculated and measured neutron reaction cross sections for ^{27}Al.

case where local potentials were compared by Kumar *et al.* [4.16] to global potentials, the local parameterizations produced better agreement with the experimental data than did the global potentials. So one firm conclusion is that additional, carefully-chosen nuclide-specific potentials should be included in the RIPL Starter File. Also it was observed that, if a global optical

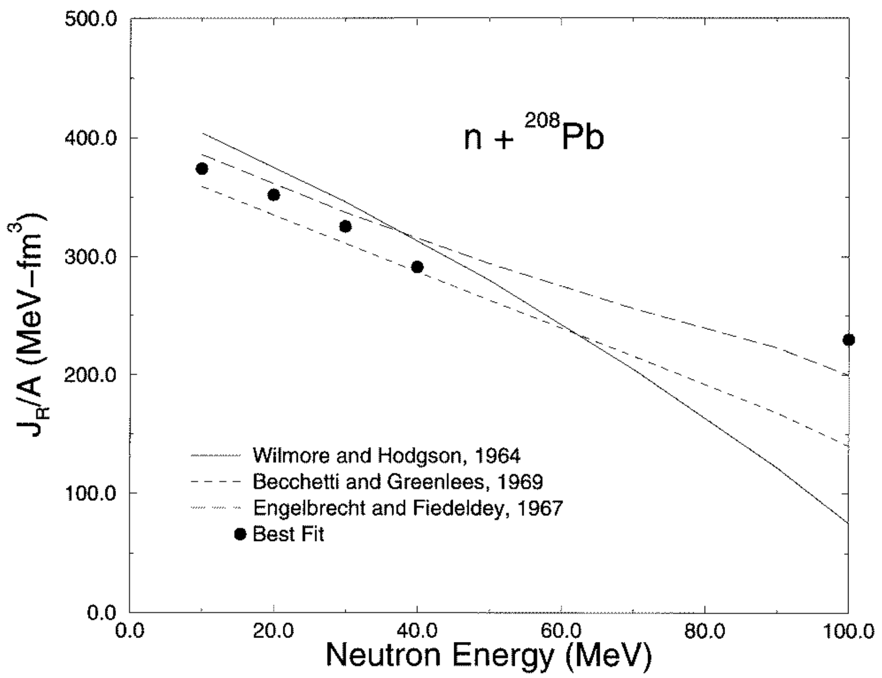

Figure 4.3: Comparison of volume integrals computed from global and "best-fit" optical model parameterizations for the ^{208}Pb+n system.

potential must be used for incident neutrons, then the Wilmore and Hodgson [4.17] potential often gave reasonable results below 30 MeV in the limited tests performed, and the Madland Semmering potential [4.18] usually gave reasonable results for both neutrons and protons from 30 to 200 MeV. These latter conclusions are particularly applicable for Hauser-Feshbach calculations where the reaction cross section is quite important. However, it should be again emphasized that the parameterizations included and the comparisons with experiment that have been made are very limited in scope and should be expanded.

The largest differences in the reaction cross sections calculated with the various potentials by Kumar *et al.* occurred at fairly low energies, which were not tested in the comparisons. To test the low energy reaction and elastic cross section predictions requires carrying out Hauser-Feshbach calculations. Such tests should clearly be performed.

In conclusion, it can be said that we have succeeded in developing an initial or Starter File of optical model parameterizations in a format that is easily expanded, together with initial codes and subroutines for handling the data. While the existing Starter File already promises to be useful, it is essential that follow-on activities occur to enhance its usefulness. A summary of improvements or areas where additional work is needed includes:

1. Additional potentials must be incorporated into the Segment. For example, potentials from programs in China, Japan, Russia, Bologna, and the JEFF and ENDF communities must be added.

2. Additional processing codes should be developed for checking, displaying, linking of the Segment to optical model codes, and comparing predictions from the parameter file with experimental data.

3. Extensive checking and validation of the Segment, especially when more processing codes become available.

As a final note, we should point out that most of the presently available optical model potentials have been derived over very limited energy and mass regions. For example, the Wilmore-Hodgson potential, which we recommend for use in certain circumstances, was derived at incident neutron energies between 1 and 15 MeV. Similarly, the recommended Madland Semering potential was derived over the energy range 50 MeV to 400 MeV. This obviously leaves a gap between 15 and 50 MeV where no potential is recommended. If, nonetheless, these two potentials are used over this energy range and are joined at, say, 30 MeV, then not only are they being used outside their range of validity but also a discontinuity results at 30 MeV. It is important that there be no such discontinuities in calculations of cross sections for applications.

The only potential having a truly broad energy range of validity in the present Segment is that of Koning, Wijk and Delaroche [4.5] for neutron reactions on ^{90}Zr (potential segment number 2404), which covers the neutron energy range from 0 to 220 MeV. Special mention should be made of the greatly advanced methodology used to derive this potential and the tremendous promise it offers for improved potentials in the future [4.19]. We are hopeful that in the coming years this methodology will be broadly applied over wide mass and energy ranges to produce greatly improved potentials for nuclear data calculations.

ANNEX A: Optical Model Parameter Format

```
iref
author
reference
summary
emin,emax
izmin,izmax
iamin,iamax
imodel,izproj,iaproj

       *****LOOP: i=1,5
jrange(i)
       *****LOOP j=1,jrange
epot(i,j)
(rco(i,j,k), k=1,11)
(aco(i,j,k), k=1,11)
(pot(i,j,k), k=1,20)
       *****END i AND j LOOPS

jcoul
       *****LOOP j=1,jcoul
ecoul(j),rcoul(j),rcoul0(j),beta(j)
       *****END j LOOP

    (1)*****SKIP TO (2)***** IF IMODEL NOT EQUAL TO 1

nisotopes
       *****LOOP n=1,nisotopes
iz(n),ia(n),ncoll(n),lmax(n),idef(n),bandk(n),[def(j,n),j=2,idef(n),2]
       *****LOOP k=1,ncoll(n)
ex(k,n),spin(k,n),ipar(k,n)
       *****END k AND n LOOPS

    (2)*****SKIP
TO (3)***** IF IMODEL NOT EQUAL TO 2

nisotopes
       *****LOOP n=1,nisotopes
iz(n),ia(n),nvib(n)
       *****LOOP k=1,nvib(n)
exv(k,n),spinv(k,n),iparv(k,n),nph(k,n),defv(k,n),thetm(k,n)
       *****END k LOOP
       *****END n LOOP

    (3)*****SKIP REMAINING LINES IF IMODEL NOT EQUAL TO 3

nisotopes
       *****LOOP n=1,nisotopes
iz(n),ia(n),beta0(n),gamma0(n),xmubeta(n)
       *****END n LOOP
```

Definitions

```
      iref  = unique fixed point reference number for this potential
    author  = authors for this potential (up to 80 characters, 1 line)
 reference  = reference for this potential (up to 80 characters, 1 line)
    summary = short description of the potential (320 characters, 4 lines)
 emin,emax  = minimum and maximum energies for validity of this potential
izmin,izmax = minimum and maximum Z values for this potential
iamin,iamax = minimum and maximum A values for this potential
    imodel  = 0 for spherical potential
            = 1 for coupled-channel, rotational model
            = 2 for vibrational model
            = 3 for non-axial deformed model
    izproj  = Z for incident projectile
    iaproj  = A for incident projectile
    index i = 1 real potential (Woods-Saxon)
            = 2 surface imaginary potential
            = 3 volume imaginary potential (Woods-Saxon)
            = 4 real spin-orbit potential
            = 5 imaginary spin-orbit potential
    jrange  = number of energy ranges over which the potential is specified
            = positive for potential strengths
            = negative for volume integrals
            = 0 if potential of type i not used
  epot(i,j) = upper energy limit for jth energy range for potential i
  rco(i,j,k)= coefficients for multiplying A**(1/3) for
              specification of radius R in fm where:

     R(i,j) = {abs[rco(i,j,1)] + rco(i,j,2)*E + rco(i,j,3)*eta
             + rco(i,j,4)/A + rco(i,j,5)/sqrt(A)
             + rco(i,j,6)*A**(2/3) + rco(i,j,7)*A
             + rco(i,j,8)*A**2  + rco(i,j,9)*A**3
             + rco(i,j,10)*A**(1/3)
             + rco(i,j,11)*A**(-1/3)} * [A**(1/3)]

and

if rco(2,j,1) >0.0: Woods-Saxon derivative surface potential
if rco(2,j,1) <0.0: Gaussian surface potential.

[Note that the A dependence of rco(i,j,11) cancels out so that
rco(i,j,11) is equivalent to adding a constant of that magnitude to
the radius R(i,j)].


 aco(i,j,k) = coefficients for specification of diffuseness a in

         fm where:

     a(i,j) = abs(aco(i,j,1)) + aco(i,j,2)*E + aco(i,j,3)*eta
                + aco(i,j,4)/A + aco(i,j,5)/sqrt(A)
                + aco(i,j,6)*A**(2/3) + aco(i,j,7)*A
                + aco(i,j,8)*A**2 + aco(i,j,9)*A**3
                + aco(i,j,10)*A**(1/3) + aco(i,j,11)*A**(-1/3)

 pot(i,j,k) = strength parameters, as follows:
```

```
if pot(i,j,k>17) .eq. 0, then

V(i,j) = pot(i,j,1) + pot(i,j,7)*eta + pot(i,j,8)*Ecoul
       + pot(i,j,9)*A + pot(i,j,10)*A**(1/3)
       + pot(i,j,11)*A**(-2/3) + pot(i,j,12)*Ecoul2
       + [pot(i,j,2) + pot(i,j,13)*eta + pot(i,j,14)*A]*E
       + pot(i,j,3)*E*E + pot(i,j,4)*E*E*E + pot(i,j,6)*sqrt(E)
       + [pot(i,j,5) + pot(i,j,15)*eta + pot(i,j,16)*E]*ln(E)
       + pot(i,j,17)*Ecoul/E**2

if pot(i,j,18) .ne. 0, then

V(i,j) = pot(i,j,1) + pot(i,j,2)*eta
       + pot(i,j,3)*cos[2*pi*(A - pot(i,j,4))/pot(i,j,5)]
       + pot(i,j,6)*exp[pot(i,j,7)*E + pot(i,j,8)*E*E]
       + pot(i,j,9)*E*exp[pot(i,j,10)*E**pot(i,j,11)]

if pot(i,j,19) .ne. 0, then

V(i,j) = [pot(i,j,1) + pot(i,j,2)*eta]/
       {1 + exp[(pot(i,j,3) - E + pot(i,j,4)*Ecoul2)/pot(i,j,5)]}
       + pot(i,j,6)*exp[(pot(i,j,7)*E - pot(i,j,8))/pot(i,j,6)]

if pot(i,j,20) .ne. 0, then

V(i,j) = pot(i,j,1) + pot(i,j,2)*E
       + pot(i,j,3)*exp[-pot(i,j,4)*(E - pot(i,j,5)*EF)]
       + pot(i,j,6)*[(E-EF)**pot(i,j,8)]/[(E-EF)**pot(i,j,8)
       + pot(i,j,7)**pot(i,j,8)]
       + pot(i,j,9)*exp[-pot(i,j,10)*(E-EF)]*[(E-EF)**pot(i,j,12)]
       /[(E-EF)**pot(i,j,12) + pot(i,j,11)**pot(i,j,12)]


where
     E      = projectile laboratory energy in MeV
     eta    = (N-Z)/A
     Ecoul  = 0.4Z/A**(1/3)
     Ecoul2 = 1.73*Z/RC
     EF     = Fermi energy in MeV
            = -0.5*[SN(Z,A) + SN(Z,A+1)]   (for incident neutrons)
            = -0.5*[SP(Z,A) + SP(Z+1,A+1)] (for incident protons)
    SN(Z,A) = the neutron separation energy for nucleus (Z,A)
    SP(Z,A) = the proton separation energy for nucleus (Z,A).

And, continuing the definitions:

    jcoul    = number of energy ranges for specifying coulomb
               radius and nonlocality range
   ecoul(j)  = maximum energy of coulomb energy range j
   rcoul(j), = coefficients to determine the coulomb radius,
   rcoul0(j)   RC, from the expression
                         RC = rcoul*A**(1/3) + rcoul0
    beta(j)  = nonlocality range.  Note that when beta(j).ne.0.,
               then the imaginary potential is pure derivative
               Woods-Saxon for energy range j.
  nisotopes  = number of isotopes for which deformation parameters
               and discrete levels are given
     iz,ia   = Z and A for the deformation parameters and discrete
               levels that follow
```

```
  ncoll   = number of collective states in the coupled-channel
            rotational model for this iz, ia
    lmax  = maximum l value for multipole expansion
    idef  = largest order of deformation
   bandk  = k for the rotational band
     def  = deformation parameters, l=2,4,6,...through lmax
      ex  = rotational level excitation energy (MeV)
    spin  = rotational level spin
    ipar  = rotational level parity
    nvib  = number of vibrational states in the model for this iz, ia
     exv  = vibrational level excitation energy (MeV)
   spinv  = vibrational level spin
   iparv  = vibrational level parity
     nph  = 1 for pure 1-photon state
          = 2 for pure 2-photon state
          = 3 for mixture of 1- and 2-photon states
    defv  = vibrational model deformation parameter
   thetm  = mixing parameter (degrees) for nph=3
   beta0  = beta deformability parameter
  gamma0  = gamma deformability parameter
 xmubeta  = non-axiality parameter
```

ANNEX B: Reference Numbering System

DEFINITION ===> IREF = 1000*I + JREF

Incident Particles (leading digit, I)

IREF	I	Particle
1 - 3999	0 - 3	Neutrons
4000 - 5999	4 - 5	Protons
6000 - 6999	6	Deuterons
7000 - 7999	7	Tritons
8000 - 8999	8	He-3
9000 - 9999	9	He-4

Geographic Indicators (trailing 3 digits, JREF)

JREF	Region
1- 99	Los Alamos National Laboratory (LANL)
100 - 199	Other U.S. laboratories, universities
200 - 299	Japan, JAERI
300 - 399	Russia
400 - 499	Western Europe, JEF community
500 - 599	China
600 - 649	Former Soviet Union
650 - 699	India, Pakistan
700 - 799	Others
800 - 999	Reserved

ANNEX C: Example of a Potential

```
  600
G. Vladuca, A. Tudora, M. Sin
Rom. J. Phys.,tome 41, no. 7-8 (1996) 515-526
Regional phenomenological deformed optical potential for neutron interactions
with actinides. Coupled-channels calculations performed with ECIS-95 code


     0.001    20.000
   90  103
  227  260
    1    0    1
    1
    20.000
     1.25600  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0
     0.62000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0
    51.32134 -5.70000-1  2.00000-2  0.00000+0  0.00000+0  0.00000+0 -2.40000+1
              0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0
    1
    20.000
     1.26000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0
     0.58000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0
     5.04567  4.00000-1  1.00000-3  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0
    0
    1
    20.000
     1.12000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0
     0.50000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0
     6.00000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
              0.00000+0
    0
    0
    7
   90  232    5    4    4  0.0  1.950E-01  8.200E-02
  0.00000000    0.0   1
  0.04936900    2.0   1
  0.16212000    4.0   1
  0.33320000    6.0   1
  0.55690000    8.0   1
   92  233    5    4    4  2.5  2.200E-01  7.000E-02
  0.00000000    2.5   1
  0.04035000    3.5   1
  0.09219000    4.5   1
```

```
0.15527000    5.5   1
0.22940000    6.5   1
 92  238    5    4    4  0.0  1.980E-01  5.700E-02
0.00000000    0.0   1
0.04491000    2.0   1
0.14841000    4.0   1
0.30721000    6.0   1
0.51830000    8.0   1
 94  239    5    4    4  0.5  2.200E-01  7.000E-02
0.00000000    0.5   1
0.00786100    1.5   1
0.05727600    2.5   1
0.07570600    3.5   1
0.16376000    4.5   1
 94  240    5    4    4  0.0  2.000E-01  7.000E-02
0.00000000    0.0   1
0.04282400    2.0   1
0.14169000    4.0   1
0.29431900    6.0   1
0.49752000    8.0   1
 94  242    5    4    4  0.0  2.180E-01  4.600E-02
0.00000000    0.0   1
0.04454000    2.0   1
0.14730000    4.0   1
0.30640000    6.0   1
0.51810000    8.0   1
 95  241    5    4    4  2.5  2.200E-01  3.600E-02
0.00000000    2.5  -1
0.04117600    3.5  -1
0.09365000    4.5  -1
0.15800000    5.5  -1
0.23400000    6.5  -1
```

ANNEX D: Summary of Entries and References

This annex contains a short summary of the optical model parameterizations that are included in the initial version of the RIPL optical potential data file. The results are given in tabular form (Table D-1), with each entry summarized in a single line and with a complete list of the references included in the Segment. The table and reference list were obtained using the OMTABLE computer code, which is included in the IAEA/NDS RIPL Starter File.

Table D-1. Summary of Optical Model Parameterizations Included in the RIPL Starter File.

Lib. No.	Inc. Part.	Model Type	Z-Range	A-Range	E-Range (MeV)	Ref. No.	First Author
1	n	CC rot.	93-93	237-237	0.0- 30.0	1	P.G.Young
2	n	vibra.	82-82	208-208	0.0-200.0	2	H.Vonach
3	n	CC rot.	92-92	235-235	0.0- 30.0	1	P.G.Young
4	n	CC rot.	92-92	237-237	0.0- 30.0	3	P.G.Young
5	n	CC rot.	92-92	238-238	0.0- 30.0	3	P.G.Young
6	n	CC rot.	94-94	242-242	0.0- 20.0	4	D.G.Madland
7	n	CC rot.	94-94	239-239	0.0- 30.0	3	P.G.Young
8	n	CC rot.	95-95	241-243	0.0- 30.0	5	P.G.Young
9	n	spher.	90-95	230-250	0.0- 10.0	6	D.G.Madland
10	n	spher.	26-26	54- 56	0.0- 52.0	7	E.D.Arthur
11	n	spher.	27-27	59- 59	0.0- 27.5	8	E.D.Arthur
12	n	spher.	30-30	57- 81	0.0- 20.0	9	P.G.Young
13	n	spher.	39-39	89- 89	0.0- 21.0	10	E.D.Arthur
14	n	spher.	40-40	90- 90	0.0- 20.0	10	E.D.Arthur
15	n	spher.	6- 6	12- 12	0.0- 65.0	11	M.B.Chadwick
16	n	spher.	7- 7	14- 14	0.0- 60.0	11	M.B.Chadwick
17	n	spher.	8- 8	16- 16	0.0- 50.0	11	M.B.Chadwick
100	n	spher.	20-92	40-238	10.0- 50.0	12	F.D.Becchetti
101	n	spher.	12-83	24-209	11.0- 11.0	13	J.C.Ferrer
102	n	spher.	82-82	206-208	5.0- 50.0	14	R.W.Finlay
103	n	spher.	26-26	56- 56	0.0-100.0	15	A.Prince
104	n	spher.	26-26	54- 54	0.0-100.0	15	A.Prince
105	n	spher.	26-26	57- 57	0.0-100.0	15	A.Prince
106	n	spher.	26-26	58- 58	0.0-100.0	15	A.Prince
107	n	spher.	28-28	58- 58	0.0-100.0	15	A.Prince
108	n	spher.	28-28	60- 60	0.0-100.0	15	A.Prince
109	n	spher.	28-28	61- 61	0.0-100.0	15	A.Prince
110	n	spher.	28-28	62- 62	0.0-100.0	15	A.Prince
111	n	spher.	28-28	64- 64	0.0-100.0	15	A.Prince
112	n	spher.	24-24	50- 50	0.0-100.0	15	A.Prince
113	n	spher.	24-24	53- 53	0.0-100.0	15	A.Prince
114	n	spher.	24-24	52- 52	0.0-100.0	15	A.Prince
115	n	spher.	24-24	54- 54	0.0-100.0	15	A.Prince
116	n	spher.	20-83	40-209	0.0- 5.0	16	P.A.Moldauer
117	n	spher.	13-13	27- 27	0.0- 60.0	17	J.Petler
118	n	spher.	39-51	85-125	0.0- 5.0	18	A.B.Smith
200	n	spher.	0-69	0-146	0.0- 20.0	19	S.Igarasi
201	n	spher.	69-95	147-999	0.0- 20.0	19	S.Igarasi
202	n	spher.	33-37	61-107	0.0- 20.0	20	JAERI NDC
203	n	spher.	38-42	69-116	0.0- 20.0	20	JAERI NDC
204	n	spher.	43-45	80-125	0.0- 20.0	20	JAERI NDC
205	n	spher.	46-48	89-134	0.0- 20.0	20	JAERI NDC
206	n	spher.	49-51	97-141	0.0- 20.0	20	JAERI NDC

207	n	spher.	52-54	103-150	0.0- 20.0	20	JAERI NDC
208	n	spher.	55-55	111-153	0.0- 20.0	20	JAERI NDC
209	n	spher.	56-56	112-154	0.0- 20.0	20	JAERI NDC
210	n	spher.	57-58	117-156	0.0- 20.0	20	JAERI NDC
211	n	spher.	59-59	119-160	0.0- 20.0	20	JAERI NDC
212	n	spher.	60-60	141-143	0.0- 20.0	20	JAERI NDC
213	n	spher.	60-60	144-148	0.0- 20.0	20	JAERI NDC
214	n	spher.	60-60	150-999	0.0- 20.0	20	JAERI NDC
215	n	spher.	61-61	147-999	0.0- 20.0	20	JAERI NDC
216	n	spher.	62-62	144-144	0.0- 20.0	20	JAERI NDC
217	n	spher.	62-62	147-147	0.0- 20.0	20	JAERI NDC
218	n	spher.	62-62	148-148	0.0- 20.0	20	JAERI NDC
219	n	spher.	62-62	149-149	0.0- 20.0	20	JAERI NDC
220	n	spher.	62-62	150-150	0.0- 20.0	20	JAERI NDC
221	n	spher.	63-63	151-999	0.0- 20.0	20	JAERI NDC
222	n	spher.	64-64	133-171	0.0- 20.0	20	JAERI NDC
223	n	spher.	65-65	138-175	0.0- 20.0	20	JAERI NDC
400	n	CC rot.	79-79	197-197	0.0- 57.0	21	J.P.Delaroche
401	n	spher.	20-92	40-238	0.0- 25.0	22	D.Wilmore
402	n	spher.	83-83	209-209	0.0- 30.0	23	O.Bersillon
403	n	spher.	74-74	182-186	0.0- 30.0	24	J.P.Delaroche
404	n	spher.	23-41	50- 95	0.0- 30.0	25	B.Strohmaier
600	n	CC rot.	90-**	227-260	0.0- 20.0	26	G.Vladuca
800	n	spher.	20-83	40-210	0.0-155.0	27	C.A.Engelbrecht
2001	n	spher.	13-82	12-208	50.0-400.0	28	D.G.Madland
2002	n	CC rot.	74-74	182-186	0.0-100.0	29	P.G.Young
2003	n	CC rot.	67-69	165-169	0.0-100.0	30	E.D.Arthur
2004	n	CC rot.	63-63	151-153	0.0- 20.0	31	R.Macklin
2005	n	CC rot.	75-75	185-187	0.0- 20.0	32	R.Macklin
2006	n	CC rot.	92-92	238-238	0.0-200.0	33	P.G.Young
2100	n	spher.	20-83	40-209	10.0- 26.0	34	R.L.Varner
2101	n	spher.	26-82	54-208	10.0- 80.0	35	R.L.Walter
2404	n	spher.	40-40	90- 90	0.0-200.0	36	A.J.Koning
4000	p	spher.	25-26	54- 56	0.0- 28.0	37	E.D.Arthur
4001	p	spher.	26-27	59- 59	0.0- 23.0	38	E.D.Arthur
4002	p	spher.	38-38	88- 89	0.0- 21.0	39	E.D.Arthur
4003	p	spher.	39-39	89- 89	0.0- 21.0	39	E.D.Arthur
4004	p	CC rot.	79-79	197-197	0.0- 57.0	40	P.G.Young
4015	p	spher.	6- 6	12- 12	0.0- 65.0	41	M.B.Chadwick
4016	p	spher.	7- 7	14- 14	0.0- 70.0	41	M.B.Chadwick
4017	p	spher.	8- 8	16- 16	0.0- 50.0	41	M.B.Chadwick
4100	p	spher.	16-49	30-100	0.0- 22.0	42	F.G.Perey
4101	p	spher.	20-83	40-209	10.0- 50.0	43	F.D.Becchetti
4102	p	spher.	6-82	12-208	30.0- 60.0	44	J.J.H.Menet
4103	p	spher.	26-26	56- 56	50.0- 50.0	45	G.S.Mani
4104	p	spher.	28-28	58- 58	100.0-100.0	46	K.Kwiatkowski
4105	p	spher.	40-40	90- 90	100.0-100.0	46	K.Kwiatkowski
4106	p	spher.	50-50	120-120	100.0-100.0	46	K.Kwiatkowski
4107	p	spher.	82-82	208-208	100.0-100.0	46	K.Kwiatkowski
4108	p	spher.	20-82	48-208	25.0- 45.0	47	D.M.Patterson
4109	p	spher.	39-39	89- 89	1.0- 7.0	48	C.H.Johnson
4110	p	spher.	41-41	93- 93	1.0- 7.0	48	C.H.Johnson
4111	p	spher.	45-45	103-103	1.0- 7.0	48	C.H.Johnson
4112	p	spher.	46-46	105-105	1.0- 7.0	48	C.H.Johnson
4113	p	spher.	47-47	107-107	1.0- 7.0	48	C.H.Johnson
4114	p	spher.	47-47	109-109	1.0- 7.0	48	C.H.Johnson
4115	p	spher.	48-48	110-110	1.0- 7.0	48	C.H.Johnson
4116	p	spher.	48-48	111-111	1.0- 7.0	48	C.H.Johnson
4117	p	spher.	48-48	113-113	1.0- 7.0	48	C.H.Johnson

4118	p	spher.	48-48	114-114	1.0- 7.0	48	C.H.Johnson
4119	p	spher.	49-49	115-115	1.0- 7.0	48	C.H.Johnson
4120	p	spher.	50-50	116-116	1.0- 7.0	48	C.H.Johnson
4121	p	spher.	50-50	122-122	1.0- 7.0	48	C.H.Johnson
4122	p	spher.	50-50	124-124	1.0- 7.0	48	C.H.Johnson
4123	p	spher.	52-52	128-128	1.0- 7.0	48	C.H.Johnson
4124	p	spher.	52-52	130-130	1.0- 7.0	48	C.H.Johnson
4125	p	spher.	40-40	92- 92	2.0- 7.0	49	D.S.Flynn
4126	p	spher.	40-40	94- 94	2.0- 7.0	49	D.S.Flynn
4127	p	spher.	40-40	96- 96	2.0- 7.0	49	D.S.Flynn
4128	p	spher.	42-42	95- 95	2.0- 7.0	49	D.S.Flynn
4129	p	spher.	42-42	98- 98	2.0- 7.0	49	D.S.Flynn
4130	p	spher.	42-42	100-100	2.0- 7.0	49	D.S.Flynn
4200	p	spher.	8- 8	16- 16	65.0- 65.0	50	H.Sagaguchi
4201	p	spher.	10-10	20- 20	65.0- 65.0	50	H.Sagaguchi
4202	p	spher.	12-12	24- 24	65.0- 65.0	50	H.Sagaguchi
4203	p	spher.	14-14	28- 28	65.0- 65.0	50	H.Sagaguchi
4204	p	spher.	18-18	40- 40	65.0- 65.0	50	H.Sagaguchi
4205	p	spher.	20-20	40- 40	65.0- 65.0	50	H.Sagaguchi
4206	p	spher.	20-20	44- 44	65.0- 65.0	50	H.Sagaguchi
4207	p	spher.	20-20	48- 48	65.0- 65.0	50	H.Sagaguchi
4208	p	spher.	22-22	46- 46	65.0- 65.0	50	H.Sagaguchi
4209	p	spher.	22-22	48- 48	65.0- 65.0	50	H.Sagaguchi
4210	p	spher.	22-22	50- 50	65.0- 65.0	50	H.Sagaguchi
4211	p	spher.	26-26	54- 54	65.0- 65.0	50	H.Sagaguchi
4212	p	spher.	26-26	56- 56	65.0- 65.0	50	H.Sagaguchi
4213	p	spher.	27-27	59- 59	65.0- 65.0	50	H.Sagaguchi
4214	p	spher.	28-28	58- 58	65.0- 65.0	50	H.Sagaguchi
4215	p	spher.	28-28	60- 60	65.0- 65.0	50	H.Sagaguchi
4216	p	spher.	28-28	62- 62	65.0- 65.0	50	H.Sagaguchi
4217	p	spher.	28-28	64- 64	65.0- 65.0	50	H.Sagaguchi
4218	p	spher.	39-39	89- 89	65.0- 65.0	50	H.Sagaguchi
4219	p	spher.	40-40	90- 90	65.0- 65.0	50	H.Sagaguchi
4220	p	spher.	42-42	98- 98	65.0- 65.0	50	H.Sagaguchi
4221	p	spher.	42-42	100-100	65.0- 65.0	50	H.Sagaguchi
4222	p	spher.	62-62	144-144	65.0- 65.0	50	H.Sagaguchi
4223	p	spher.	82-82	208-208	65.0- 65.0	50	H.Sagaguchi
4224	p	spher.	83-83	209-209	65.0- 65.0	50	H.Sagaguchi
4401	p	spher.	42-42	92- 92	22.3- 22.3	51	E.Cereda
4402	p	spher.	42-42	94- 94	22.3- 22.3	51	E.Cereda
4403	p	spher.	42-42	96- 96	22.3- 22.3	51	E.Cereda
4404	p	spher.	42-42	98- 98	22.3- 22.3	51	E.Cereda
4405	p	spher.	42-42	100-100	22.3- 22.3	51	E.Cereda
4406	p	spher.	44-44	102-102	22.3- 22.3	51	E.Cereda
4407	p	spher.	46-46	104-104	22.3- 22.3	51	E.Cereda
4408	p	spher.	46-46	106-106	22.3- 22.3	51	E.Cereda
4409	p	spher.	46-46	108-108	22.3- 22.3	51	E.Cereda
4410	p	spher.	46-46	110-110	22.3- 22.3	51	E.Cereda
4411	p	spher.	48-48	106-106	22.3- 22.3	51	E.Cereda
4412	p	spher.	48-48	110-110	22.3- 22.3	51	E.Cereda
4413	p	spher.	48-48	112-112	22.3- 22.3	51	E.Cereda
4414	p	spher.	48-48	116-116	22.3- 22.3	51	E.Cereda
4415	p	spher.	47-47	109-109	6.1- 6.1	52	A.Feigel
4650	p	spher.	21-21	45- 45	3.0- 5.0	53	S.Kailas
4651	p	spher.	20-20	48- 48	3.0- 5.0	53	S.Kailas
4652	p	spher.	23-23	51- 51	3.0- 5.0	53	S.Kailas
4653	p	spher.	24-24	54- 54	3.0- 5.0	53	S.Kailas
4654	p	spher.	27-27	59- 59	3.0- 5.0	53	S.Kailas
4655	p	spher.	28-28	61- 61	3.0- 5.0	53	S.Kailas

4656	p	spher.	29-29	65- 65	3.0- 5.0	53	S.Kailas
4657	p	spher.	31-31	71- 71	3.0- 5.0	53	S.Kailas
4658	p	spher.	33-33	75- 75	3.0- 5.0	53	S.Kailas
4659	p	spher.	34-34	80- 80	3.0- 5.0	53	S.Kailas
4660	p	spher.	19-19	41- 41	1.0- 7.0	54	Y.P.Viyogi
4661	p	spher.	21-21	45- 45	1.0- 7.0	54	Y.P.Viyogi
4662	p	spher.	20-20	48- 48	1.0- 7.0	54	Y.P.Viyogi
4663	p	spher.	22-22	49- 49	1.0- 7.0	54	Y.P.Viyogi
4664	p	spher.	23-23	51- 51	1.0- 7.0	54	Y.P.Viyogi
4665	p	spher.	25-25	55- 55	1.0- 7.0	54	Y.P.Viyogi
4666	p	spher.	27-27	59- 59	1.0- 7.0	54	Y.P.Viyogi
4667	p	spher.	28-28	61- 61	1.0- 7.0	54	Y.P.Viyogi
4668	p	spher.	29-29	65- 65	1.0- 7.0	54	Y.P.Viyogi
4669	p	spher.	30-30	68- 68	1.0- 7.0	54	Y.P.Viyogi
4670	p	spher.	31-31	71- 71	1.0- 7.0	54	Y.P.Viyogi
4671	p	spher.	33-33	75- 75	1.0- 7.0	54	Y.P.Viyogi
4672	p	spher.	34-34	80- 80	1.0- 7.0	54	Y.P.Viyogi
4673	p	spher.	39-39	89- 89	1.0- 7.0	54	Y.P.Viyogi
4674	p	spher.	41-41	93- 93	1.0- 7.0	54	Y.P.Viyogi
4675	p	spher.	42-42	96- 96	1.0- 7.0	54	Y.P.Viyogi
4676	p	spher.	42-42	98- 98	1.0- 7.0	54	Y.P.Viyogi
4677	p	spher.	45-45	103-103	1.0- 7.0	54	Y.P.Viyogi
4678	p	spher.	46-46	105-105	1.0- 7.0	54	Y.P.Viyogi
4679	p	spher.	47-47	107-107	1.0- 7.0	54	Y.P.Viyogi
4680	p	spher.	47-47	109-109	1.0- 7.0	54	Y.P.Viyogi
4681	p	spher.	48-48	110-110	1.0- 7.0	54	Y.P.Viyogi
4682	p	spher.	49-49	115-115	1.0- 7.0	54	Y.P.Viyogi
4683	p	spher.	50-50	120-120	1.0- 7.0	54	Y.P.Viyogi
4684	p	spher.	50-50	124-124	1.0- 7.0	54	Y.P.Viyogi
4685	p	spher.	52-52	128-128	1.0- 7.0	54	Y.P.Viyogi
4686	p	spher.	52-52	130-130	1.0- 7.0	54	Y.P.Viyogi
5001	p	spher.	13-82	12-208	50.0-400.0	28	D.G.Madland
5002	p	CC rot.	74-74	182-186	0.0-100.0	29	P.G.Young
5003	p	CC rot.	67-69	165-169	0.0-100.0	30	E.D.Arthur
5004	p	CC rot.	63-63	151-153	0.0- 20.0	31	R.Macklin
5005	p	CC rot.	75-75	185-187	0.0- 20.0	32	R.Macklin
5006	p	CC rot.	92-92	238-238	0.0-200.0	33	P.G.Young
5100	p	spher.	20-83	40-209	16.0- 65.0	34	R.L.Varner
5101	p	spher.	26-82	54-208	10.0- 80.0	55	R.L.Walter
5404	p	spher.	40-40	90- 90	0.0-200.0	36	A.J.Koning
6001	d	spher.	20-82	40-208	11.0- 27.0	56	C.M.Perey
6100	d	spher.	20-83	40-209	8.0- 13.0	57	J.M.Lohr
6300	d	spher.	22-22	48- 48	13.6- 13.6	58	O.P.Bilanyuk
6301	d	spher.	24-24	52- 52	13.6- 13.6	58	O.P.Bilanyuk
6302	d	spher.	24-24	54- 54	13.6- 13.6	58	O.P.Bilanyuk
6400	d	spher.	6-82	12-208	20.0-100.0	59	J.Bojowald
7001	t	spher.	20-20	40- 40	17.0- 17.0	60	R.Hardekopf
7002	t	spher.	22-22	46- 46	17.0- 17.0	60	R.Hardekopf
7003	t	spher.	22-22	48- 48	17.0- 17.0	60	R.Hardekopf
7004	t	spher.	26-26	54- 54	17.0- 17.0	60	R.Hardekopf
7005	t	spher.	26-26	56- 56	17.0- 17.0	60	R.Hardekopf
7006	t	spher.	28-28	58- 58	17.0- 17.0	60	R.Hardekopf
7007	t	spher.	28-28	60- 60	17.0- 17.0	60	R.Hardekopf
7008	t	spher.	30-30	68- 68	17.0- 17.0	60	R.Hardekopf
7009	t	spher.	40-40	90- 90	17.0- 17.0	60	R.Hardekopf
7010	t	spher.	40-40	94- 94	17.0- 17.0	60	R.Hardekopf
7011	t	spher.	50-50	116-116	17.0- 17.0	60	R.Hardekopf
7012	t	spher.	58-58	140-140	17.0- 17.0	60	R.Hardekopf
7013	t	spher.	82-82	208-208	17.0- 17.0	60	R.Hardekopf

7100	t	spher.	20-82	40-208	1.0- 40.0	61	F.D.Becchetti
7101	t	spher.	20-20	40- 40	20.0- 20.0	62	P.P.Urone
7102	t	spher.	24-24	52- 52	20.0- 20.0	62	P.P.Urone
7103	t	spher.	26-26	54- 54	20.0- 20.0	62	P.P.Urone
7104	t	spher.	28-28	62- 62	20.0- 20.0	62	P.P.Urone
7105	t	spher.	28-28	64- 64	20.0- 20.0	62	P.P.Urone
7106	t	spher.	40-40	90- 90	20.0- 20.0	62	P.P.Urone
7107	t	spher.	40-40	92- 92	20.0- 20.0	62	P.P.Urone
7108	t	spher.	40-40	94- 94	20.0- 20.0	62	P.P.Urone
7109	t	spher.	50-50	118-118	20.0- 20.0	62	P.P.Urone
7110	t	spher.	12-12	26- 26	17.0- 17.0	63	P.Schwandt
7111	t	spher.	13-13	27- 27	17.0- 17.0	63	P.Schwandt
7112	t	spher.	14-14	28- 28	17.0- 17.0	63	P.Schwandt
8100	3He	spher.	20-82	40-208	1.0- 40.0	61	F.D.Becchetti
8101	3He	spher.	20-20	40- 40	21.0- 84.0	64	H.H.Chang
8102	3He	spher.	28-28	58- 58	22.0- 84.0	64	H.H.Chang
8103	3He	spher.	28-28	60- 60	29.6- 29.6	65	C.B.Fulmer
8104	3He	spher.	28-28	60- 60	35.1- 35.1	65	C.B.Fulmer
8105	3He	spher.	28-28	60- 60	49.7- 49.7	65	C.B.Fulmer
8106	3He	spher.	28-28	60- 60	59.8- 59.8	65	C.B.Fulmer
8107	3He	spher.	28-28	60- 60	71.1- 71.1	65	C.B.Fulmer
8108	3He	spher.	20-20	40- 40	21.0- 21.0	66	P.P.Urone
8109	3He	spher.	24-24	52- 52	21.0- 21.0	66	P.P.Urone
8110	3He	spher.	26-26	54- 54	21.0- 21.0	66	P.P.Urone
8111	3He	spher.	28-28	62- 62	21.0- 21.0	66	P.P.Urone
8112	3He	spher.	28-28	64- 64	21.0- 21.0	66	P.P.Urone
8113	3He	spher.	40-40	90- 90	21.0- 21.0	66	P.P.Urone
8114	3He	spher.	40-40	92- 92	21.0- 21.0	66	P.P.Urone
8115	3He	spher.	40-40	94- 94	21.0- 21.0	66	P.P.Urone
8116	3He	spher.	50-50	118-118	21.0- 21.0	66	P.P.Urone
8200	3He	spher.	20-20	40- 40	109.2-109.2	67	M.Hyakutake
8201	3He	spher.	28-28	58- 58	109.2-109.2	67	M.Hyakutake
8202	3He	spher.	40-40	90- 90	109.2-109.2	67	M.Hyakutake
8203	3He	spher.	50-50	116-116	109.2-109.2	67	M.Hyakutake
8204	3He	spher.	28-28	58- 58	89.3- 89.3	67	M.Hyakutake
8205	3He	spher.	28-28	58- 58	118.5-118.5	67	M.Hyakutake
8400	3He	spher.	12-12	24- 24	130.0-130.0	68	A.Djaloeis
8401	3He	spher.	40-40	90- 90	130.0-130.0	68	A.Djaloeis
8402	3He	spher.	50-50	120-120	130.0-130.0	68	A.Djaloeis
8403	3He	spher.	82-82	208-208	130.0-130.0	68	A.Djaloeis
8404	3He	spher.	3- 3	6- 6	217.0-217.0	69	N.Willis
8405	3He	spher.	4- 4	9- 9	217.0-217.0	69	N.Willis
8406	3He	spher.	6- 6	12- 12	217.0-217.0	69	N.Willis
8407	3He	spher.	14-14	28- 28	217.0-217.0	69	N.Willis
8408	3He	spher.	20-20	40- 40	217.0-217.0	69	N.Willis
8409	3He	spher.	28-28	58- 58	217.0-217.0	69	N.Willis
8410	3He	spher.	39-39	89- 89	217.0-217.0	69	N.Willis
8411	3He	spher.	40-40	90- 90	217.0-217.0	69	N.Willis
8412	3He	spher.	50-50	120-120	217.0-217.0	69	N.Willis
8413	3He	spher.	82-82	208-208	217.0-217.0	69	N.Willis
8414	3He	spher.	5- 5	10- 10	41.0- 41.0	70	H.J.Trost
8415	3He	spher.	6- 6	12- 12	41.0- 41.0	70	H.J.Trost
8416	3He	spher.	6- 6	13- 13	41.0- 41.0	70	H.J.Trost
8417	3He	spher.	8- 8	16- 16	41.0- 41.0	70	H.J.Trost
8418	3He	spher.	8- 8	18- 18	41.0- 41.0	70	H.J.Trost
8419	3He	spher.	11-11	23- 23	41.0- 41.0	70	H.J.Trost
8420	3He	spher.	12-12	24- 24	41.0- 41.0	70	H.J.Trost
8421	3He	spher.	12-12	25- 25	41.0- 41.0	70	H.J.Trost
8422	3He	spher.	12-12	26- 26	41.0- 41.0	70	H.J.Trost

8423	3He	spher.	13-13	27- 27	41.0- 41.0	70	H.J.Trost
8424	3He	spher.	20-20	40- 40	41.0- 41.0	70	H.J.Trost
8425	3He	spher.	28-28	58- 58	41.0- 41.0	70	H.J.Trost
8650	3He	spher.	28-28	58- 58	270.0-270.0	71	P.P.Singh
8651	3He	spher.	40-40	90- 90	270.0-270.0	71	P.P.Singh
8652	3He	spher.	50-50	116-116	270.0-270.0	71	P.P.Singh
8653	3He	spher.	82-82	208-208	270.0-270.0	71	P.P.Singh
9000	4He	spher.	13-26	27- 56	1.0-100.0	72	E.D.Arthur
9001	4He	spher.	27-27	59- 59	1.0-100.0	73	E.D.Arthur
9100	4He	spher.	8-82	16-208	1.0- 25.0	74	L.McFadden
9101	4He	spher.	10-92	20-235	1.0- 46.0	75	J.R.Huizenga
9400	4He	spher.	20-45	40-100	1.0- 30.0	76	B.Strohmaier
9401	4He	spher.	22-30	37- 86	20.0- 30.0	77	O.F.Lemos
9600	4He	spher.	8-96	16-250	1.0- 73.0	78	V.Avrigeanu

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