JENDL GAS-PRODUCTION CROSS SECTION FILE

May 1992

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The JENDL gas-production cross section file was compiled by taking cross-section data from JENDL-3 and by using the ENDF-5 format. The data were given to 23 nuclei or elements in light nuclei and structural materials. Graphs of the cross sections and brief description on their evaluation methods are given in this report.

Keywords: JENDL, Gas-production Cross Section, Graph, ENDF-5 Format
JENDLガス生成断面積ファイル

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JENDLガス生成断面積ファイルをENDF-5フォーマットを用い、JENDL-3のデータから編集した。データは軽核や構造材核種のうちの23種（または元素）に対して与えた。
本報では、断面積のグラフと評価手法に関する簡単な情報をまとめた。
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1. Introduction

The JENDL–3 general purpose file\textsuperscript{13} was released in 1989 with the data for 171 nuclides, and the JENDL–3 fission product nuclear data file\textsuperscript{9} was completed as a part of the JENDL–3 general purpose file in 1990. JENDL–3 contains the data for 324 nuclides which consist of cross sections, angular distributions and energy distributions of neutrons emitted from reactions, in the neutron energy region from $10^{-4}$ eV to 20 MeV. The data for $\gamma$-ray production were also evaluated for 53 nuclides, and given in the JENDL–3 general purpose file.

On the other hand, files with only data needed for a certain purpose are called as special purpose files. A plan of the JENDL special purpose files was proposed by Iijima et al.\textsuperscript{9}, and they are in progress\textsuperscript{9}. The JENDL gas-production cross section file was compiled as one of the JENDL special purpose files. This file contains cross sections of gas-production reactions of light and structural material nuclei, which are of importance for material damage study.

In the next chapter, the compilation of the file will be described and figures of the cross sections are given. In Chapter 3, descriptive information given in the JENDL gas–production cross section file is listed to show the evaluation methods of the data.

The present file which was completed in July 1991 is the first version of the JENDL gas–production cross section file. In the future, it will be updated by adding new materials and/or improving the present data.
2. Compilation of the File

The data were given for 23 materials listed in Table 1. The ENDF-5 format\(^5\) was used to compile the data. The file contains the following data.

MF
1  Descriptive information (listed in Chapter 3)
2  Resonance parameters (only scattering radius is given)
3  Gas-production cross sections for the MT numbers described below

In the MF=3, the cross-section data are given for the following gas-production reactions.

MT
203  H production
204  D production
205  \(^3\)H production
206  \(^3\)He production
207  \(^4\)He production

The data were adopted from JENDL-3, and summed up to the above gas-production cross sections. The summation equation for each reaction is given in the descriptive data in the file (MF=1, MT=451), and listed in Chapter 3 in this report. Curves of the cross sections are shown in Figs. 1 to 23.
3. Descriptive Information for Each Nuclide or Material

All the descriptive information given in MF=1 of the JENDL gas-production cross section file is given here.
3.1 Li-6

3-LI-6 JAERI EVAL-MAR85 S.CHIBA AND K.SHIBATA
JAERI-M 88-164 DIST-JUL91

HISTORY
83-12 NEWLY EVALUATED BY K.SHIBATA
85-03 MODIFIED BY S. CHIBA
DATA OF MF=3 (MT=59,63) AND MF=4 (MT=59,63) WERE ADDED.
PSUEDO-LEVEL REPRESENTATION WAS ADOPTED FOR THE
(N,N')ALPHA-D CONTINUUM (MT=51,52,54-56,58,60-62,64-86).
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
= MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
= SUM OF INELASTIC SCATTERING CROSS SECTIONS
MT=205 TRITIUM PRODUCTION CROSS SECTION
= MT105
MT=207 HE-4 PRODUCTION CROSS SECTION
= MT204 + MT205

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ***********************

MF=3 CROSS SECTIONS

MT=53 SIG-IN 2.185 MEV
BASED ON THE EXPERIMENTAL DATA /1,2,3,4,5/.
MT=57 SIG-IN 3.562 MEV
BASED ON THE EXPERIMENTAL DATA /6,7/.
MT=59 SIG-IN 4.31 MEV
BASED ON A COUPLED-CHANNEL CALCULATION. THE SYMMETRIC
ROTATIONAL MODEL WAS ASSUMED. THE COUPLING SCHEME WAS
1+(0.5) - 3+(2.185MEV) - 2+(4.31MEV) - 1+(5.7MEV).
THE POTENTIAL PARAMETERS WERE;
V = 45.0766 MEV, R = 1.1875 FM, A = 0.57335 FM
WS = 0.4432*EL-1.1631 MEV, RI = 1.6113 FM, AT = 0.26735 FM
VSO = 5.5 MEV,
RSO = 1.15 FM, ASO = 0.5 FM
BETA(2) = 1.1395,
WHERE EL MEANS THE INCIDENT NEUTRON ENERGY IN THE LAB.
SYSTEM (MEV).

MT=63 SIG-IN 5.7 MEV
BASED ON THE CC CALCULATION NORMALIZED TO THE EXPERIMENTAL
DATA /12/.
MT=51,52,54-56,58,60-62,64-86 (N,N')ALPHA-D CONTINUUM
REPRESENTED BY PSEUDO-LEVELS, BINNED IN 0.5 MEV INTERVALS.
THE (N,N')ALPHA-D CROSS SECTION WAS BASED ON THE
MEASUREMENT OF ROSEN AND STEWART /8/.
THE CONTRIBUTION FROM MT=53, 59 AND 63 WAS SUBTRACTED SO
THAT SIG-T MIGHT BE EQUAL TO THE SUM OF PARTIAL CROSS
SECTIONS. THE CROSS SECTION FOR EACH LEVEL WAS CALCULATED
BY THE 3-BODY PHASE-SPACE DISTRIBUTION WITH A CORRECTION
OF THE COULOMB INTERACTION IN THE FINAL STATE, ASSUMING
ISOTROPIC CENTER-OF-MASS DISTRIBUTIONS.

MT=103 (N,P)
BASED ON THE EXPERIMENTAL DATA /6,9/.

MT-105 (N,T)ALPHA
BELOW 1 MEV, R-MATRIX CALCULATION.
ABOVE 1 MEV, BASED ON THE EXPERIMENTAL DATA /10,11/.

REFERENCES
9) MERCHEZ F. ET AL.: NUCI. PHYS. A162 (1972) 428.
3.2 Li-7

3-L1-  7 JAERI   EVAL-DEC84 S.CHIBA AND K.SHIBATA
JAERI-M 88-164   DIST-JUL91

HISTORY
83-12 NEWLY EVALUATED BY K.SHIBATA
84-12 MODIFIED BY S.CHIBA
87-02 Li7(N,NT) CROSS SECTION WAS MODIFIED.
87-02 Li7(N,N) CROSS SECTION AND ANG. DIST. WERE MODIFIED.
Li7(N,NO) WAS ALSO MODIFIED SO AS TO GIVE THE TOTAL CROSS
SECTION WHICH IS EQUAL TO JENDL-3PR1. THE Li7(N,NI) ANG.
DIST. WAS ALSO MODIFIED. Li7(N,NT) CROSS SECTION WAS
FIXED TO 87-02 VERSION BY MODIFYING THE PSEUDO-LEVEL
CROSS SECTIONS. COMMENT WAS ALSO MODIFIED.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
   = MT104
MT=205 TRITIUM PRODUCTION CROSS SECTION
   = MT205 GIVEN IN JENDL-3
MT=207 HE-4 PRODUCTION CROSS SECTION
   = MT205

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3  ***************

MF=3 CROSS SECTIONS

MT=104 (N,D)
THE (N,D) CROSS SECTION WAS CALCULATED WITH DWBA.
NORMALIZATION WAS TAKEN SO THAT THE CALCULATED CROSS
SECTION MIGHT BE CONSISTENT WITH THE ACTIVATION DATA /1/.

MT=205 (N,N')ALPHA-T
BASED ON THE EXPERIMENTAL DATA /2,3,4,5,6,7/.

REFERENCES
1) BATTAT M.E. AND RIBE F.L.: PHYS. REV. 89 (1953) 80.
3) LISKIEN H. ET AL.: PROC. INT. CONF. NUCLEAR DATA FOR
5) TAKAHASHI A. ET AL.: PROC. 13TH SYMP. FUSION TECH.. VARESE,
3.3 Be-9

4-BE- 9 JAERI EVAL-AUG84 K.Shibata
JAERI-M 84-226 DIST-JUL91

HISTORY
84-08 REEVALUATED FOR JENDL-3 BY K.Shibata.
DETAILS OF THE EVALUATION ARE GIVEN IN REF/1/.
89-01 MODIFIED BY CONSIDERING NEUTRON EMISSION SPECTRA
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
   BY T.Narita AND T.Nakagawa

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION  
   = MT103.
MT=204 DEUTERIUM PRODUCTION CROSS SECTION  
   = MT104.
MT=205 TRITIUM PRODUCTION CROSS SECTION  
   = MT105.
MT=207 HE-4 PRODUCTION CROSS SECTION  
   = MT024 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ***************

THE STATISTICAL MODEL CALCULATION WAS MADE FOR THE CHARGED
PARTICLE EMISSION REACTIONS BY USING THE COMPUTER CODE
ELISEE-3/2/. OPTICAL MODEL PARAMETERS FOR NEUTRON WERE
TAKEN FROM AGEE AND ROSEN /3/.

\[
\begin{align*}
V &= 49.3 - 0.33E, \quad WS = 5.75, \quad VS0 = 5.5 \text{ (MEV)} \\
R &= 1.25, \quad RS = 1.25, \quad RSO = 1.25 \text{ (FM)} \\
A &= 0.65, \quad B = 0.70, \quad AS0 = 0.65 \text{ (FM)}
\end{align*}
\]

MT=24 (N,2N ALPHA)
THIS IS THE CROSS SECTION FOR THE (N,A1) REACTION. THE
1ST EXCITED LEVEL OF HE-6 DECAYS BY EMITTING 2 NEUTRONS.
THE (N,A1) CROSS SECTION WAS CALCULATED WITH THE
STATISTICAL MODEL.

ALPHA POTENTIAL PARAMETERS ARE THE FOLLOWING /4/:

\[
\begin{align*}
V &= 125.0, \quad WS = 15.0, \quad VS0 = 0.0 \text{ (MEV)} \\
R &= 1.56, \quad RS = 1.56, \quad RC = 1.22 \text{ (FM)} \\
A &= 0.50, \quad B = 0.11 \text{ (FM)}
\end{align*}
\]

THE CROSS SECTION WAS NORMALIZED TO THE DATA OF
PERROUD AND SELLEM /5/ AT 14 MEV.

MT=103 (N,P)
CALCULATED WITH THE STATISTICAL MODEL.
PROTON POTENTIAL PARAMETERS ARE THE FOLLOWING /6/:

\[
\begin{align*}
V &= 59.5 - 0.36E, \quad WS = 12.0 + 0.07E, \quad VS0 = 4.9 \text{ (MEV)} \\
R &= 1.24, \quad RS = 1.36, \quad RSO = 1.2 \text{ (FM)} \\
RC &= 1.3, \quad A = 0.63, \quad B = 0.35, \quad AS0 = 0.31 \text{ (FM)}
\end{align*}
\]

THE CROSS SECTION WAS NORMALIZED TO THE EXPERIMENTAL DATA
OF AUGUSTSON AND MENLOVE /7/, WHO MEASURED DELAYED
NEUTRONS, BY TAKING ACCOUNT OF THE BRANCHING RATIO
OF 49.5% FOR Li-8 \rightarrow Be-9* \rightarrow 2A + N.

MT=104 (N,D)
BASED ON THE EXPERIMENTAL DATA OF SCOBEL /8/.

MT=105 (N,T)
SUM OF MT=740 AND 741.
BASED ON THE EXPERIMENTAL DATA /4,5,9,10,11,12/.
MT=740, 741 (N,T0) AND (N,T1)
CALCULATED WITH THE STATISTICAL MODEL.
TRITON POTENTIAL PARAMETERS ARE THE FOLLOWING /13/:
\[ V = 140.0 \text{ MeV}, \quad W_S = 7.5, \quad V_S = 6.0 \]
\[ R = 1.20 \text{ fm}, \quad R_S = 2.69, \quad R_S = 1.20, \quad R_C = 1.30 \text{ fm} \]
\[ A = 0.45, \quad B = 0.36, \quad A_S = 0.7 \text{ fm} \]
NORMALIZATION WAS TAKEN SO THAT THE TOTAL (N,T) CROSS
SECTION MIGHT BE CONSISTENT WITH THE EXPERIMENTAL DATA
OF BOEDY ET AL./14/

REFERENCES
3.4 B-10

5-8 - 10 JAERI EVAL-MARB7 S.CHIBA
DIST-JUL91

HISTORY
87-03 NEWLY EVALUATED BY S.CHIBA (JAERI) FOR JENDL-3.
88-11 DATA FOR MF=3 (MT=1, 2, 3, 4, 51, 103, 107, 113, 780, 781) WERE
MODIFIED.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
= MT016 + MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
= MT104 + (SUM OF MT'S FROM 60 TO 89).
MT=205 TRITIUM PRODUCTION CROSS SECTION
= MT113
MT=207 HE-4 PRODUCTION CROSS SECTION
= MT016*2 + MT107 + MT113*2 + 2*(SUM OF MT'S FROM 60 TO
89)

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 **********************

THE 2200M/S AND 14 MEV CROSS SECTIONS ARE IN TABLE 1.

MF=3 NEUTRON CROSS SECTIONS
MT=16 (N,2N)
BASED ON THE EXPERIMENTAL DATA /1/. CROSS SECTION WAS
EXTRAPOLATED AS 0.0120*SQRT(E-ETH), WHERE E IS INCIDENT
NEUTRON ENERGY AND ETH THRESHOLD ENERGY IN MEV. NOTE
THAT THIS REACTION PRODUCES 1 PROTON AND 2 ALPHA
PARTICLES, I.E. (N,2NP)2ALPHA.

MT=51-69, 61, 62, 64-66. INELASTIC SCATTERING TO REAL LEVELS
CROSS SECTIONS WERE CALCULATED BY THE COLLECTIVE MODEL
DBA AND NORMALIZED TO THE EXPERIMENTAL DATA/2/ AT 14
MEV. CALCULATED LEVELS AND ASSUMED ORBITAL ANGULAR
MOMENTUM TRANSFERS (L) ARE SUMMARIZED IN TABLE 3. DATA
FOR MT=51 WAS NORMALIZED TO THE EXPERIMENTAL DATA/3/
BELOW 6MEV. ABOVE 6MEV, THE DEFORMATION PARAMETER
DEDUCED FROM (P,P') REACTION/4/ WAS USED.

MT=60, 63, 67-89 (N,N'D)2ALPHA CONTINUUM,
REPRESENTED BY PSEUDO-LEVELS, BINNED IN 0.5 MEV INTERVALS.
THE (N,N'D)2ALPHA CROSS SECTION WAS BASED ON THE
MEASUREMENT OF FRYE+ /5/. THE CROSS SECTION FOR EACH
LEVEL WAS CALCULATED BY THE 3-BODY PHASE SPACE
DISTRIBUTION, ASSUMING ISOTROPIC CENTER-OF-MASS
ANGULAR DISTRIBUTIONS.

MT=103 (N,P)
SUM OF MT = 700 TO 705.

MT=104 (N,D)
SUM OF MT = 720 AND 721.

MT=107 (N,ALPHA)
SUM OF MT = 780 AND 781. THE THERMAL CROSS SECTION OF
3837 BARN WAS ADOPTED/6/.

MT=113 (N,T)2ALPHA
BASED ON THE EXPERIMENTAL DATA 5,7,8,9,10,11,12,13,14/
MT=700 (N,P) TO THE GROUND STATE OF BE-10.
BELOW 100 KEV, ASSUMED TO BE 1/2. THE THERMAL CROSS
SECTION WAS ASSUMED TO BE 3MB/15/
FROM 100 KEV TO 500 KEV, ASSUMED TO BE CONSTANT.
FROM 500 KEV TO 1 MEV, LINEARLY INTERPOLATED.
ABOVE 1 MEV, THE STATISTICAL MODEL CALCULATION WAS
NORMALIZED BY A FACTOR OF 0.704. THE OPTICAL POTENTIAL,
LEVEL SCHEMES AND LEVEL DENSITY PARAMETERS USED IN THE
CALCULATION ARE SUMMARIZED IN TABLES 2, 3 AND 4.
MT=701-705 (N,P) TO THE LOW LYING EXCITED STATES OF BE-10.
THE STATISTICAL MODEL CALCULATION WAS NORMALIZED TO THE
EXPERIMENTAL DATA11/ AT 14 MEV.
MT=720 (N,DO)
BELOW 7.6 MEV, THE INVERSE REACTION CROSS SECTIONS/16,17/
WERE CONVERTED BY THE PRINCIPLE OF DETAILED BALANCE.
FROM 7.6 TO 14 MEV, INTERPOLATED LINEARLY.
ABOVE 14 MEV, DWBA CALCULATION WITH THE PROTON PICKUP
MECHANISM WAS NORMALIZED TO THE EXPERIMENTAL DATA
18, 19/ AT 14 MEV. THE D + BE-9 AND BOUND PROTON
POLENTIALS OF VALKOVIC+/19/ WERE USED. DEPTH OF THE
PROTON POTENTIAL WAS SEARCHED BY THE SEPARATION ENERGY
METHOD. THE POTENTIAL PARAMETERS ARE LISTED IN TABLE 2.
MT=721 (N,D2)
DWBA CALCULATION WITH THE PROTON PICKUP MECHANISM WAS
NORMALIZED TO THE EXPERIMENTAL DATA11,18,19/ AT 14
MEV. THIS IS REALLY THE (N,DO) REACTION TO THE SECOND
LEVEL OF BE-9.
MT=780 (N,ALPHAD)
BELOW 10 KEV, R-MATRIX CALCULATION.
FROM 10 KEV TO 800 KEV, BASED ON THE EXPERIMENTAL DATA
20,21/.
FROM 800 KEV TO 7.5 MEV, THE EXPERIMENTAL DATA22/ WERE
NORMALIZED BY A FACTOR OF 1.38 AND FITTED BY THE SPLINE
FUNCTION.
ABOVE 7 MEV, THE EXPERIMENTAL DATA22/ WERE ADOPTED.
MT=781 (N,ALPHA1)
BELOW 10 KEV, THE R-MATRIX CALCULATION.
FROM 10 KEV TO 100 KEV, BASED ON THE EXPERIMENTAL DATA
21, 23/.
FROM 100 KEV TO 2 MEV, RECOMMENDATION BY
LISKIEN AND WATTECamps24/ WAS ADOPTED.
FROM 2 TO 7.5 MEV, THE EXPERIMENTAL DATA22,23,24,25/
WERE NORMALIZED BY A FACTOR OF 1.38 AND FITTED BY THE
SPLINE FUNCTION.
ABOVE 7 MEV, THE EXPERIMENTAL DATA25/ WAS ADOPTED.

TABLE 1 THE 2200-M/S AND 14 MEV CROSS SECTIONS

<table>
<thead>
<tr>
<th></th>
<th>2200-M/S (B)</th>
<th>14 MEV (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELASTIC</td>
<td>2.144</td>
<td>0.943</td>
</tr>
<tr>
<td>(N,N')</td>
<td>-----</td>
<td>0.269</td>
</tr>
<tr>
<td>(N,P)</td>
<td>0.003</td>
<td>0.038</td>
</tr>
<tr>
<td>(N,O)</td>
<td>-----</td>
<td>0.047</td>
</tr>
<tr>
<td>(N,T)</td>
<td>0.012</td>
<td>0.095</td>
</tr>
<tr>
<td>(N,ALPHA)</td>
<td>3837.0</td>
<td>0.049</td>
</tr>
<tr>
<td>(N,2N)</td>
<td>-----</td>
<td>0.027</td>
</tr>
<tr>
<td>CAPTURE</td>
<td>0.50</td>
<td>0.000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3839.7</td>
<td>1.467</td>
</tr>
</tbody>
</table>
TABLE 2  OPTICAL POTENTIAL PARAMETERS

B-10 + N /26/
\[ V = 47.91 - 0.346E_N, \quad W_S = 0.657 + 0.810E_N, \quad V_S = 5.5 \quad (\text{MEV}) \]
\[ R = 1.387, \quad R_S = 1.336, \quad R_S = 1.15 \quad (\text{FM}) \]
\[ A = 0.464, \quad A_S = 0.278, \quad A_S = 0.5 \quad (\text{FM}) \]

BE-10 + P /27/
\[ V = 60.0 + 27.0(N-Z)/A - 0.3E_C \quad (\text{MEV}) \]
\[ W_S = 0.64E_C + 10.0(N-Z)/A, \quad (E_C < 13.8 \text{ MEV}) \quad (\text{MEV}) \]
\[ = 9.60 - 0.06E_C + 10.0(N-Z)/A, \quad (E_C > 13.8 \text{ MEV}) \quad (\text{MEV}) \]
\[ V_S = 5.5 \quad (\text{MEV}) \]
\[ R = R_S = R_S = 1.15 \quad (\text{FM}) \]
\[ A = A_S = 0.57, \quad A_S = 0.5 \quad (\text{FM}) \]

BE-9 + D /19/
\[ V = 80.0, \quad W_D = 30.0, \quad V_S = 6.0 \quad (\text{MEV}) \]
\[ R = 1.0, \quad R_D = 1.0, \quad R_S = 1.0, \quad R_C = 1.3 \quad (\text{FM}) \]
\[ A = 1.0, \quad A_D = 0.8, \quad A_S = 1.0 \quad (\text{FM}) \]

TABLE 3  LEVEL SCHEMES USED IN THE DWBA OR STATISTICAL MODEL CALCULATION

<table>
<thead>
<tr>
<th>MT</th>
<th>ENERGY (MEV)</th>
<th>JP</th>
<th>L</th>
<th>MT</th>
<th>ENERGY (MEV)</th>
<th>JP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.0</td>
<td>3+</td>
<td></td>
<td>700</td>
<td>0.0</td>
<td>0+</td>
</tr>
<tr>
<td>51</td>
<td>0.7183</td>
<td>1+</td>
<td>2</td>
<td>701</td>
<td>3.368</td>
<td>2+</td>
</tr>
<tr>
<td>52</td>
<td>1.7402</td>
<td>0+</td>
<td>4</td>
<td>702</td>
<td>5.958</td>
<td>2+</td>
</tr>
<tr>
<td>53</td>
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<td>2+</td>
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TABLE 4  LEVEL DENSITY PARAMETERS USED IN THE STATISTICAL MODEL CALCULATION

<table>
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<tr>
<th>A(1/MEV)</th>
<th>T(MEV)</th>
<th>C(1/MEV)</th>
<th>PAIR.(MEV)</th>
<th>EX(MEV)</th>
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REFERENCES
6) MUGHABGHAB, S.F. ET AL.: 'NEUTRON CROSS SECTIONS', VOL.1 PART A (ACADEMIC PRESS 1981, NEW YORK)
3.5 B-11

5-8 - 11 JAERI  EVAL-MAY88 T.FUKAHORI
JAERI-M 89-046  DIST-JUL91

HISTORY
87-03 NEWLY EVALUATED BY T.FUKAHORI (JAERI)
88-05 REVISED BY T.FUKAHORI (JAERI)
(N,D), (N,ND), (N,T), (N,NT) AND (N,N2A) ADDED.
DETAILS OF EVALUATION ARE GIVEN IN REF./1/.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
  = MT029 + MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
  = MT029 + MT104
MT=205 TRITIUM PRODUCTION CROSS SECTION
  = MT029 + MT033 + MT105
MT=207 HE-4 PRODUCTION CROSS SECTION
  = MT022 + MT029*2 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ***************

MF=3 CROSS SECTIONS
MT=22 (N,N' ALPHA) LI-7 CROSS SECTION
CALCULATED WITH GNASH/2/. THE OPTICAL POTENTIAL
PARAMETERS, THE LEVEL DENSITY PARAMETERS AND THE LEVEL
SCHEME ARE SHOWN IN TABLES 1-3, RESPECTIVELY.
MT=28 (N,N' P) BE-10 CROSS SECTION
BASED ON THE GNASH CALCULATION. THE PARAMETERS USED ARE
LISTED IN TABLES 1-3.
MT=29 (N,N' ALPHA) T CROSS SECTION
BASED ON (N,N') CROSS SECTION OF THE GNASH CALCULATION
AND NORMALIZED TO HE PRODUCTION CROSS SECTION OF KNEFF
ET AL. /3/.
MT=32 (N,N' D) BE-9 CROSS SECTION
BASED ON THE GNASH CALCULATION. THE PARAMETERS USED ARE
LISTED IN TABLES 1-3.
MT=33 (N,N' T) BE-8 CROSS SECTION
BASED ON THE GNASH CALCULATION. THE PARAMETERS USED ARE
LISTED IN TABLES 1-3.
MT=103 (N,P) BE-11 CROSS SECTION
BASED ON THE GNASH CALCULATION WITH BEING NORMALIZED TO
THE EXPERIMENTAL DATA OF STEPANIC ET AL. /4/.
THE PARAMETERS USED ARE SHOWN IN TABLES 1-3, RESPECTIVELY.
MT=104 (N,D) BE-10 CROSS SECTION
BASED ON THE GNASH CALCULATION.
MT=105 (N,T) BE-9 CROSS SECTION
BASED ON THE GNASH CALCULATION.
MT=107 (N,ALPHA) LI-8 CROSS SECTION
THE GNASH CALCULATION WAS PERFORMED, AND NORMALIZED TO THE
EXPERIMENTAL DATA OF ANTOLKOVIC ET AL. /5/ AND SCOBEL ET
AL. /6/.
THE PARAMETERS USED ARE SHOWN IN TABLES 1-3, RESPECTIVELY.
### TABLE 1 THE OPTICAL POTENTIAL PARAMETERS

<table>
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<tr>
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<th>V (MeV)</th>
<th>R0 (MeV)</th>
<th>A0 (MeV)</th>
<th>Ref.</th>
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<td>NEUTRON</td>
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<td></td>
<td>1.01E</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PROTON</td>
<td>66.1 - 0.273E</td>
<td>1.15</td>
<td>0.57</td>
<td>8/</td>
</tr>
<tr>
<td></td>
<td>1.50 + 0.581E</td>
<td>1.15</td>
<td>0.5</td>
<td></td>
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<tr>
<td>DEUTERON</td>
<td>80.0</td>
<td>R0</td>
<td>1.0</td>
<td></td>
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<tr>
<td></td>
<td>30.0</td>
<td>RI</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>TRITON</td>
<td>103.0 + 20.0E</td>
<td>0.85</td>
<td>0.70</td>
<td>10/</td>
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<td></td>
<td>1.49E</td>
<td>R0</td>
<td>2.06</td>
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<td>8.55</td>
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<td>0.72</td>
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<tr>
<td>ALPHA</td>
<td>285.2 - 2.40E</td>
<td>1.61</td>
<td>0.55</td>
<td>11/</td>
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<tr>
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<td>16.16 - 0.70E</td>
<td>R1</td>
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<td>A0</td>
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**NOTE:** E is incident neutron energy in LAB. SYSTEM. *MEANS THAT PARAMETER IS MODIFIED FROM ORIGINAL ONE.

### TABLE 2 THE LEVEL DENSITY PARAMETERS

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<th>A(1/MeV)</th>
<th>T(MeV)</th>
<th>PAIR(MeV)</th>
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<td>1.115</td>
<td>9.187</td>
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<tr>
<td>1.125</td>
<td>8.248</td>
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<td>1.419</td>
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<td>1.138</td>
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<td>1.115</td>
<td>8.170</td>
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### TABLE 3 THE LEVEL SCHEME (ENERGY(MeV), SPIN AND PARITY) /12,13/

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<th>GS 0.0</th>
<th>3+ 0.0</th>
<th>3/2- 0.0</th>
<th>0+ 0.0</th>
<th>1/2+ 0.0</th>
<th>3/2- 0.0</th>
<th>2+ 0.0</th>
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<tr>
<td>1.740</td>
<td>0+ 4.445</td>
<td>5/2- 5.998</td>
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<td>4.830</td>
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<td>2.154</td>
<td>1+ 5.020</td>
<td>3/2- 5.960</td>
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<td>3.587</td>
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<td>7/2- 6.179</td>
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<td>9.670</td>
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<tr>
<td>5.110</td>
<td>2+ 9.120</td>
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<td>5.180</td>
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<td>9.400</td>
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<td>5.926</td>
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<td>18</td>
<td>7.561</td>
<td>0+</td>
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REFERENCES
2) YOUNG P.G. ET AL.: GNASH, A PREEQUILIBRIUM,STATISTICAL
   NUCLEAR-MODEL CODE FOR CALCULATION OF CROSS SECTION AND
3) KNEFF D.W. ET AL.: NUCL. SCI. ENG. 92 (1986) 491
4) STEPANIC B.Z. ET AL.: BULL. INST. BORIS KIDRIC 17 (1966) 237
5) ANTOLOKOVIC B. ET AL.: NUCL. PHYS. A325 (1979) 199
6) SCOBEL W. ET AL.: ZEITSCHRIFT F. NATURFORSCHUNG, SECTION A
   25 (1970) 1406
7) GLENDINNING S.G. ET AL.: NUCL. SCI. ENG. 80 (1982) 256
8) WATSON B.A. ET AL.: PHYS. REV. 182 (1969) 977
9) MILJANIC D. ET AL.: NUCL. PHYS. A176 (1971) 110
12) AJZENBERG-SELOVE F.: NUCL. PHYS. A413 (1984) 1
13) AJZENBERG-SELOVE F.: IBID. A433 (1985) 1
3.6 C-12

6-C - 12 JAERI  EVAL-AUG83 K.Shibata
JAERI-M 83-221  DIST-JUL91
HISTORY
83-08 NEWLY EVALUATED BY K.Shibata
DETAILS OF THE EVALUATION ARE GIVEN IN REF./1/.
85-02 DATA OF MT=2, 3, 4, 53 OF MF=3 WERE REVISED ABOVE 10.45
MEV. ANGULAR DISTRIBUTIONS FOR MT=52, 53 WERE ALSO
REVISED.
88-07 DATA OF MT=1, 3, 4, 52 OF MF=3 WERE REVISED ABOVE 8.3 MEV.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.Narita and T.Nakagawa

MF=1  GENERAL INFORMATION
MT=491  DESCRIPTIVE DATA AND DICTIONARY

MF=2  RESONANCE PARAMETERS
MT=151  SCATTERING RADIUS ONLY

MF=3  NEUTRON CROSS SECTIONS
MT=203  HYDROGEN PRODUCTION CROSS SECTION
        = MT103
MT=204  DEUTERIUM PRODUCTION CROSS SECTION
        = MT104
MT=207  HE-4 PRODUCTION CROSS SECTION
        = (MT052 + MT053 + MT091)*3 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ***************

MF=3  CROSS SECTIONS
MT=52  SIG-IN  7.65 MEV LEVEL
THE CROSS SECTION WAS ESTIMATED SO THAT THE ELASTIC SCAT-
TERING CROSS SECTION GIVEN AS THE DIFFERENCE BETWEEN THE
TOTAL AND REACTION CROSS SECTIONS MIGHT BE CONSISTENT WITH
EXPERIMENTAL DATA. TAKING ACCOUNT OF THE MEASUREMENT /2/,
THE CROSS SECTION WAS MODIFIED BY MULTIPLYING A FACTOR OF
0.5.

MT=53  SIG-IN  9.63 MEV LEVEL
BASED ON THE EXPERIMENTAL DATA OF ANTOLKOVIC ET AL./3/.
TAKING ACCOUNT OF THE MEASUREMENT OF ONO ET AL./4/, THE
CROSS SECTION WAS MODIFIED BY A FACTOR OF 0.8.

MT=91  (N,N')3A
BASED ON THE EXPERIMENTAL DATA OF ANTOLKOVIC ET AL./3/.
TOTAL (N,N')3A CROSS SECTION IS THE SUM OF MT=52, 53
AND 91.

MT=103  (N,P)
BASED ON THE MEASUREMENT OF Rimmer and Fisher /5/.

MT=104  (N,D)
CALCULATED WITH DWBA.

MT=107  (N,A)
BASED ON THE EXPERIMENTAL DATA /6,7,8,9,10,11,12,13,14/.

REFERENCES
2) Takahashi A. et al.: Proc. the 1987 Seminar on Nuclear Data,
4) Ono M. et al.: Fall Mtg. of the Atomic Energy Society of
   Japan, 1984
13) VERBINSKI, V.V. ET AL.: PHYS. REV. 170 (1968) 916.
3.7 Natural N

7-N - 0 JNDC+ EVAL-JUN89 Y.KANDA(KYU), T.FUKAHORI(JAERI)+ DIST-JUL91

HISTORY
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
DATA WERE CALCULATED FROM THOSE OF N-14 AND N-15.
N-14 = 99.634 %
N-15 = 0.366 %

MT=203 HYDROGEN PRODUCTION CROSS SECTION
= MT028 + MT103

MT=204 DEUTERIUM PRODUCTION CROSS SECTION
= MT032 + MT104

MT=205 TRITIUM PRODUCTION CROSS SECTION
= MT033 + MT105

MT=207 HE-4 PRODUCTION CROSS SECTION
= MT022 + MT107 + MT108*2

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ***************

7-N - 14 JNDC EVAL-JUN89 Y.KANDA(KYU) T.MURATA(NAIG)+ DIST-SEP89

HISTORY
89-06 NEW EVALUATION FOR JENDL-3
WORKING GROUP ON EVALUATION OF N-14,
WORKING GROUP ON NUCLEAR DATA FOR FUSION,
JAPANESE NUCLEAR DATA COMMITTEE
IN CHARGE
SIG-T K.SHIBATA (JAERI)
SIG-EL T.ASAMI (JAERI), T.MURATA (NAIG)
SIG-EN T.ASAMI, T.MURATA
(N,2N),(N,P),(N,T),(N,A)
Y.KANDA(KYU)
(N,Na),(N,Np),(N,Nd),(N,D)
T.ASAMII
CAPTURE T.ASAMII
PHOTON PRODUCTION T.ASAMII

COMPILATION
EVALUATED DATA WERE COMPILED BY T.FUKAHORI.

MF=3 CROSS SECTIONS
MT=22 (N,W ALPHA)
CALCULATED WITH THE GNASH CODE/1/.

MT=28 (N,NP)
CALCULATED WITH THE GNASH CODE, AND NORMALIZED TO THE
EXPERIMENTAL DATA/2/.

MT=32 (N,ND)
CALCULATED WITH THE GNASH CODE.

MT=103 (N,P)
BELOW 7 MEV, BASED ON EXPERIMENTAL DATA /3,4,5,6,7,8/.
ABOVE 7 MEV, BASED ON THE CALCULATIONS WITH GNASH.

MT=104 (N,D)
Below 8.5 MeV, based on the experimental data/9/. Above 8.5 MeV, calculated with GNASH.

MT=105 (N,T)
Below 9 MeV, based on the experimental data/10/. Above 9 MeV, calculated with GNASH and normalized at 9 MeV.

MT=107 (N,\alpha\alpha)
Based on the experimental data/7,10/.

MT=108 (N,2\alpha\alpha)
Calculated with GNASH and normalized at 14.1 MeV to an average value among the experimental data/11,12/.

7-N - 15 EVAL-DEC88 T. FUKAHORI
JAERI-M 89-047 DIST-SEP89
HISTORY
88-12 Newly evaluated by T. FUKAHORI (JAERI)

MF=3 CROSS SECTIONS
MT=16,22,28,32,33,103,104,105,107 Calculated with GNASH /7/. The optical potential potential parameters, the level density parameters and the level scheme are shown in Tables 1-3, respectively.

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<thead>
<tr>
<th>TABLE 1</th>
<th>THE OPTICAL POTENTIAL PARAMETERS</th>
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<td>Neutron</td>
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<td>V</td>
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REFERENCE

5) CURE P. ET AL.: J. PHYS. RADIUM., 12, 6 (1951).
13) PEREY F. G.: PHYS. REV. 131 (1963) 745
14) BECCETTI J.R. F. D. AND GREENLEES G. W.: 'POLARIZATION
    PHENOMENA IN NUCLEAR REACTIONS', THE UNIVERSITY OF WISCONSIN
    PRESS (1971)
15) AJZENBERG-SELOVE F.: NUCL. PHYS. A460 (1986) 1
16) AJZENBERG-SELOVE F.: NUCL. PHYS. A449 (1986) 1
17) AJZENBERG-SELOVE F.: NUCL. PHYS. A433 (1985) 1
3.8 F-19

9-F - 19 JAERI EVAL-JUL89 T.SUGI
DIST-JUL91

HISTORY
83-11 EVALUATION FOR JENDL-2 WAS PERFORMED BY SUGI AND NISHIMURA (JAERI)/1/.
89-07 RESONANCE PARAMETERS AND TOTAL CROSS SECTION WERE RE-EVALUATED FOR JENDL-3.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
   = MT028 + MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
   = MT104
MT=205 TRITIUM PRODUCTION CROSS SECTION
   = MT105
MT=207 HE-4 PRODUCTION CROSS SECTION
   = MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 **********************

MF=3 NEUTRON CROSS SECTIONS
MT=22 (N,N' ALPHA) AND (N,ALPHA N') CROSS SECTIONS
   CALCULATED WITH A STATISTICAL MODEL BY USING PEARLSTEIN'S
   EMPIRICAL FORMULA/2/.

MT=28 (N,N P) AND (N,P N') CROSS SECTIONS
   CALCULATED WITH A STATISTICAL MODEL BY USING PEARLSTEIN'S
   EMPIRICAL FORMULA.

MT=103 (N,P) CROSS SECTION
   UP TO 9 MEV : BASED ON THE EXPERIMENTAL DATA OF BASS ET AL.
      /3/.
   9 MEV - 20 MEV : CALCULATED WITH THE STATISTICAL MODEL BY
      USING PEARLSTEIN' EMPIRICAL FORMULA.

MT=104 (N,D) CROSS SECTION
   CALCULATED WITH THE PEARLSTEIN'S EMPIRICAL FORMULA. THE
   CROSS SECTION WAS NORMALIZED TO 39.5 MILLI-BARNS AT 14.4
   MEV.

MT=105 (N,T) CROSS SECTION
   CALCULATED WITH THE PEARLSTEIN'S EMPIRICAL FORMULA. THE
   CROSS SECTION WAS NORMALIZED TO 15.0 MILLI-BARNS AT 14.4
   MEV.

MT=107 (N,ALPHA) CROSS SECTION
   BELOW 9 MEV, BASED ON THE FOLLOWING EXPERIMENTAL DATA:
   UP TO 4 MEV: DAVIS ET AL. /4/.
   4 MEV - 5.5 MEV: SMITH ET AL. /5/.
   5.5 MEV - 9 MEV: BASS ET AL. /3/.
   ABOVE 9 MEV, CALCULATED WITH THE PEARLSTEIN'S FORMULA.

REFERENCES
1) SUGI T. AND NISHIMURA K.: JAERI-M 7253 (1977), ENGLISH TRANS-
   LATION: ORNL-TR-4605.
3) BASS R. ET AL.: EANDC(E) 66-64.
3.9 Al-27

13-AL-27 TIT, JAERI EVAL-MAR88 Y. HARIMA, H. KITAZAWA, T. FUKAHORI
DIST-JUL91

HISTORY
88-03 NEW EVALUATION WAS PERFORMED FOR JENDL-3 BY HARIMA,
KITAZAWA (TOKYO INSTITUTE OF TECH.) AND FUKAHORI (JAERI).
DETAILS ARE GIVEN IN REF./1/.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T. NARITA AND T. NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
   = MT028 + MT103 + MT111

MT=207 HE-4 PRODUCTION CROSS SECTION
   = MT022 + MT107

***** ORIGINAL DESCRIPTIVE DATA IN JENDL-3  ***********************

MF=3 NEUTRON CROSS SECTIONS
MT=22 \{N,NA\} CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL, USING THE GNASH CODE./1,2/
   OPTICAL POTENTIAL FOR ALPHA-PARTICLES WAS DETERMINED, USING
   THE DISPERSION THEORY./3/

MT=28 \{N,NP\} CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL, USING THE GNASH CODE./1,2/

MT=103 \{N,P\} CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL, USING THE GNASH CODE./1,2/

MT=107 \{N,A\} CROSS SECTIONS
   OBTAINED BY AN EYE-GUIDE TO FOLLOW OBSERVED VALUES./4/.

MT=111 \{N,2P\} CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL, USING THE GNASH CODE./1,2 /

REFERENCES
1) KITAZAWA H. ET AL.: PROC. INT. CONF. NUCLEAR DATA FOR
3) KITAZAWA H. ET AL.: UNPUBLISHED.
4) VONACH H.: NUCLEAR DATA STANDARDS FOR NUCLEAR MEASUREMENTS,
3.10 Natural Si

14-SI- O TIT, JAERI EVAL-MAR88 H. KITAZAWA, Y. HARIMA, T. FUKAHORI
DIST-JUL91

HISTORY
88-03 NEW EVALUATION WAS PERFORMED FOR JENDL-3 BY KITAZAWA,
HARIMA (TOKYO INSTITUTE OF TECH.) AND FUKAHORI (JAERI).
DETAILS ARE GIVEN IN REF./1/.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T. NARITA AND T. NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
   = MT028 + MT103 + MT111*2
MT=207 HE-4 PRODUCTION CROSS SECTION
   = MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ***********************

MF=3 NEUTRON CROSS SECTIONS
MT=22 (N,NA) CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL USING THE GNASH CODE./1,2/
   OPTICAL POTENTIAL FOR ALPHA-PARTICLES WAS DETERMINED, USING
   THE DISPERSION THEORY./3/
MT=28 (N,NP) CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL USING THE GNASH CODE./1,2/
MT=103 (N,P) CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL USING THE GNASH CODE./1,2/
   THE IMAGINARY POTENTIAL STRENGTH OF THE PROTON SPHERICAL
   OPTICAL MODEL WAS MODIFIED FROM THAT IN REF./1/ TO BE
   W = 11.0 MEV BETWEEN 11 AND 20 MEV AND W = 8.8 + 0.2*E (MEV)
   BELOW 11 MEV.
MT=107 (N,A) CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL USING THE GNASH CODE./1,2/
   OPTICAL POTENTIAL FOR ALPHA-PARTICLES WAS DETERMINED, USING
   THE DISPERSION THEORY./3/
MT=111 (N,2P) CROSS SECTIONS
   CALCULATED BY THE STATISTICAL MODEL USING THE GNASH CODE./1,2/

REFERENCES
1) KITAZAWA H. ET AL.: PROC. INT. CONF. NUCLEAR DATA FOR
3) KITAZAWA H. ET AL.: UNPUBLISHED.
3.11 Natural Ti

22-TI- 0 KUR EVAL-SEPBB K.KOBAYASHI(KUR), H.HASHIKURA(TOK)
       DIST-JUL91

HISTORY
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
       BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
       = MT028 + MT103
MT=207 HE-4 PRODUCTION CROSS SECTION
       = MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3  **********************

MF=3 NEUTRON CROSS SECTIONS
MT=22 (N,NA)
       CALCULATED WITH THE GNASH CODE/1/ FOR ALL THE ISOTOPES.
MT=28 (N,NP)
       CALCULATED WITH THE GNASH CODE FOR TI-46, 48 AND 50, AND
       EVALUATED ON THE BASIS OF EXPERIMENTAL DATA FOR TI-47 AND 49.
MT=103 (N,P)
       COMPOSED FROM THE ISOTOPIC DATA EVALUATED FROM EXPERIMENTAL
       DATA.
MT=107 (N,A)
       CALCULATED WITH THE GNASH CODE FOR TI-48, AND EVALUATED ON THE
       BASIS OF EXPERIMENTAL DATA FOR TI-46, 47, 49 AND 50.

REFERENCES
3.12 V-51

23-V - 51 KHI EVAL-AUG88 T.WATANABE
DIST-JUL91

HISTORY
82-10 EVALUATION WAS MADE BY S.TANAKA(JAERI) FOR JENDL-2. DETAILS
ARE GIVEN IN REF.1/.
88-08 RE-EVALUATION WAS MADE BY T.WATANABE(KAWASAKI HEAVY
INDUSTRIES LTD.) FOR JENDL-3.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA.

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
    = MT028 + MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
    = MT104
MT=205 TRITIUM PRODUCTION CROSS SECTION
    = MT105
MT=207 HE-4 PRODUCTION CROSS SECTION
    = MT022 + MT107

**** DESCRIPTIVE DATA FOR JENDL-3 ***********************

MF=3 NEUTRON CROSS SECTIONS
DATA FOR MT'S=22, 28, 104 AND 105 WERE ADOPTED FROM THE
JENDL-2 EVALUATION/1/.

MT=22 (N,N'ALPHA)
    BASED ON THE DATA BY HILLMAN /2/.
MT=28 (N,N'P)
    GIVEN BY SUBTRACTING THE (N,P) CROSS SECTION (MT=103, FOR
JENDL-2) FROM THE (N, XP) CROSS SECTION CALCULATED BY
KITAZAWA AND ISOGAI /3/.
MT=103 (N,P)
    BASED ON THE EXPERIMENTAL DATA /4,5/.
MT=104 (N,D)
    CALCULATION BY GUENTHER ET AL. /6/.
MT=107 (N,ALPHA)
    BASED ON THE EXPERIMENTAL DATA /1,7,8,9/.

REFERENCES
1) TANAKA S.: JAERI-M 82-151 (1982).
3) KITAZAWA, H. AND ISOGAI, Y.: PRIVATE COMMUNICATION.
8) LU HAN-LIN, ET AL.: PHYSICA ENERGIAE FORTIS ET PHYSICA
9) ZUPRANSKA, E ET AL.: ACTA PHYSICA POLONICA SECTION B 11,
    853 (1980).
3.13 Natural Cr

24-CR-  O NEDAC  EVAL-MARB7 T.ASAM\nDIST-JUL91

HISTORY
87-03 NEW EVALUATION WAS MADE BY T.ASAMI.
88-12 MF/M=3/107 WAS MODIFIED.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
= MT028 + MT103
MT=207 HE-4 PRODUCTION CROSS SECTION
= MT022 + MT107

**** DESCRIPTIVE DATA FOR JENDL-3 **************************

MF=3 NEUTRON CROSS SECTIONS
ALL THE CROSS-SECTION DATA WERE DEDUCED FROM THE EVALUATED ONES
FOR FOUR STABLE ISOTOPES OF CR CONSIDERING THEIR ABUNDANCES IN
THE CR ELEMENT/1/.

MT=22 \( N,Na \)
FOR ALL ISOTOPES: CALCULATED WITH THE GNASH CODE/2/

MT=28 \( N,Np \)
FOR ALL ISOTOPES: CALCULATED WITH THE GNASH CODE/2/

MT=103 \( N,P \)
CR-50: CALCULATED WITH THE GNASH CODE/2/
CR-52: CALCULATED WITH THE GNASH CODE, AND NORMALIZED TO THE
RECOMMENDED VALUE OF FORREST /3/ AT 14.8 MEV.
CR-53: BELOW 9 MEV, EVALUATION WAS MADE ON THE BASIS OF THE
EXPERIMENTAL DATA OF SMITH /4/. ABOVE 9 MEV, CALCULATION
WITH THE GNASH CODE WAS NORMALIZED SO AS TO CONNECTED WITH
SMITH'S DATA /4/.
CR-54: CALCULATED WITH THE GNASH CODE AND NORMALIZED AT 14.7
MEV TO THE AVERAGE VALUE OF THE EXPERIMENTAL DATA /5,6,7/.

MT=107 \( N,A \)
THE DATA FOR ALL THE ISOTOPES NEAR THE THRESHOLD ENERGIES
WERE MODIFIED ON THE BASIS OF THE EXPERIMENTAL DATA FOR
CR-NAT(N,ALPHA) /8/.

CR-50: CALCULATED WITH THE GNASH CODE, AND NORMALIZED AT 14.8
MEV IN REFERING TO GRIMES' DATA /9/.
CR-52: CALCULATED WITH THE GNASH CODE, AND NORMALIZED TO THE
AVERAGE VALUE OF EXPERIMENTAL DATA /9, 10/ AT 14.8 MEV.
CR-53: CALCULATED WITH THE GNASH CODE, AND NORMALIZED TO THE
EXPERIMENTAL DATA /10/ AT 14.7 MEV.
CR-54: CALCULATED WITH THE GNASH CODE, AND NORMALIZED TO THE
AVERAGE VALUE OF EXPERIMENTAL DATA /6,7,11/ AT 14.8 MEV.

REFERENCES
1) HOLDEN N.E., MARTIN R.L. AND BARNES I.L.: PURE & APPL.
6) HUSAIN L. ET AL.: J. INORG. NUCL. CHEM., 29, 2665 (1967).
3.14 Mn-55

25-MN-55 JAERI,MAPI EVAL-MAR87 K.SHIBATA, T.HOJUYAMA
DIST-JUL91

HISTORY
87-03 RESONANCE PARAMETERS WERE EVALUATED BY T.HOJUYAMA (MAPI).
MULTISTEP HAUSER-FESHBACH CALCULATIONS WERE PERFORMED
BY K.SHIBATA (JAERI).
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY.

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
    = MT028 + MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
    = MT104
MT=205 TRITIUM PRODUCTION CROSS SECTION
    = MT105
MT=206 HE-3 PRODUCTION CROSS SECTION
    = MT106
MT=207 HE-4 PRODUCTION CROSS SECTION
    = MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ****************************

MF=3 NEUTRON CROSS SECTIONS
STATISTICAL-MODEL CALCULATIONS WERE PERFORMED USING THE
TNG CODE /1/. THE PRECOMPONUD PROCESS WAS CONSIDERED
ABOVE 5 MEV. THE OPTICAL POTENTIAL PARAMETERS USED ARE AS
FOLLOWS/2/ (IN THE UNITS OF MEV AND FM):

V = 49.747 - 0.42954E - 0.00034E**2  R0 = 1.287  A0 = 0.56
WS = 11.2 - 0.094E  RS = 1.345  AS = 0.47
VSO= 6.2  RS0= 1.120  ASO = 0.47

THE LEVEL SCHEME WAS TAKEN FROM REF./3/.

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25. 2.992 7/2 -
26. 3.006 3/2 -
27. 3.036 11/2 -
28. 3.038 1/2 -
29. 3.040 3/2 +

Levels above 3.046 MeV were assumed to be overlapping.

MT=22,28,103,107 (N,N'),(N,N'),(N,P) and (N,A) cross sections calculated with TNG. Global optical-potential parameters were employed for protons and alpha-particles /4,5/.

MT=104 (N,D) cross section
The excitation function of the (N,P) cross section calculated with TNG was used for the (N,D) reaction by shifting the threshold energy. The cross sections were normalized to the experimental datum at 14.1 MeV /6/.

MT=105 (N,T) cross section
The excitation function of the (N,P) cross section calculated with TNG was used for the (N,T) reaction by shifting the threshold energy. The cross sections were normalized to the experimental datum at 14.7 MeV /7/.

MT=106 (N,He-3) cross section
Based on the experimental data /8,9/.

References
3.15 Natural Fe

26-FE- 0 JNDC  EVAL-MAR87 S.IIJIMA, H.YAMAKOSHI  
DIST-JUL91

HISTORY
87-03 EVALUATION WAS PERFORMED FOR JENDL-3.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3  
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION  
= MT028 + MT103
MT=207 HE-4 PRODUCTION CROSS SECTION  
= MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3  ***********************

NATURAL IRON DATA CONSTRUCTED FROM FE-ISOTOPES.

MF=3 NEUTRON CROSS SECTIONS

MT=22,28 Calculated with GNASH /1/.

MT=103 Calculated with GNASH /1/ except for Fe-54 and 56.

FE-54
Below 2.5 MeV, based on the data of Paulsen and Widera /2/.
Between 2.5 and 10 MeV, based on the data of Smith and
Meadows /3/.
Above 10 MeV, calculated with GNASH.

FE-56
Below 7 MeV, based on the data of Smith and Meadows /3/.
7 - 13 MeV, taken from JENDL-2.
13 - 16 MeV, based on the data of Ikeda et al. /4/.
16 - 20 MeV, taken from JENDL-2.

MT=107 (n, alpha)
For Fe-56, the evaluation was made on the basis of
experimental data. For Fe-54, 57, 58, the GNASH calculation
was adopted.

REFERENCES
2) PAULSEN A. AND WIDER A.: CONF. CHEMICAL NUCLEAR DATA,
MEASUREMENTS AND APPLICATION, CANTERBURY, 1971.
3.16 Co-59

27-CO- 59 KHI  EVAL-AUG88 T.WATANABE
DIST-JUL91

HISTORY
88-08 NEWLY EVALUATED BY T.WATANABE
(KAWASAKI HEAVY INDUSTRIES, LTD.)
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
   = MT028 + MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
   = MT104
MT=207 HE-4 PRODUCTION CROSS SECTION
   = MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 **********************

MF=3 NEUTRON CROSS SECTIONS
MT=22, 28 (N,N'ALPHA), (N,N'P)
   YAMAMURO'S CALCULATION WITH THE MODIFIED GNASH /1/ WAS
   ADOPTED.
MT=103 (N,P)
   BASED ON THE EXPERIMENTAL DATA /2,3,4,5/.
MT=104 (N,D)
   YAMAMURO'S CALCULATION WITH THE MODIFIED GNASH /1/ WAS
   ADOPTED.
MT=107 (N,ALPHA)
   JENDL-2 DATA WHICH WERE EVALUATED FROM THE EXPERIMENTAL
   DATA OF SANTRY AND BUTLER /6/ WERE ADOPTED WITH SLIGHT
   MODIFICATION BASED ON EVAIN'S EVALUATION /7/ AND
   EXPERIMENTAL DATA /4,8/.

REFERENCES
3) WILLIAMS J.R. AND ALFORD, W.L.: PROC. INT. CONF. NUCLEAR
   DATA FOR BASIC AND APPLIED SCIENCE, SANTA FE, 1985,
3.17 Natural Ni

28-NI- O TOSHIBA EVAL-MAR87 S.IIJIMA DIST-JUL91

HISTORY
87-03 EVALUATION WAS PERFORMED FOR JENDL-3.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
= MT028 + MT103 + MT111*2
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
= MT104
MT=205 TRITIUM PRODUCTION CROSS SECTION
= MT105
MT=206 HE-3 PRODUCTION CROSS SECTION
= MT106
MT=207 HE-4 PRODUCTION CROSS SECTION
= MT022 + MT107

**** DESCRIPTIVE DATA FOR JENDL-3 ****************************

EVALUATION WAS REPORTED AT MITO CONFERENCE./1/

MF=3 NEUTRON CROSS SECTIONS

MT=22,28,103,104,105,106,107,111:
(N,N'),(N,N'P),(N,P),(N,D),(N,T),(N,HE-3),(N,A),(N,2P)
CROSS SECTIONS WERE CONSTRUCTED FROM THE DATA FOR EACH
ISOTOPE.

NI-58
MT=28,103 (N,N'P),(N,P)
BASED ON EXPERIMENTAL DATA.
MT=22,104,105,106,107,111 (N,N'),(N,D),(N,T),(N,HE-3),
(N,A),(N,2P)
THE CROSS SECTIONS WERE CALCULATED USING THE PEGASUS
CODE /2/ AND NORMALIZED TO EXPERIMENTAL DATA.

NI-60
MT=22,28,104,105,106,107,111: (N,N'),(N,N'P),(N,D),
(N,T),(N,HE-3),(N,A),(N,2P)
THE CROSS SECTIONS WERE CALCULATED WITH PEGASUS /2/.
AND NORMALIZED TO EXPERIMENTAL DATA.
MT=103 (N,P)
MOST OF DATA WERE TAKEN FROM JENDL-2.

NI-61
MT=22,28,103,104,105,106,107,111 (N,N'),(N,N'P),(N,P),
(N,D),(N,T),(N,HE-3),(N,A),(N,2P)
CALCULATED WITH PEGASUS /2/.

NI-62 AND NI-64
MT=22,28,103,104,105,106,111 (N,N'),(N,N'P),(N,P),(N,D),
(N,T),(N,HE-3),(N,2P)
CALCULATED WITH PEGASUS /2/.
MT=107 (N,A)
BASED ON EXPERIMENTAL DATA.

REFERENCES
3.18 Natural Cu

29-CU-  O NAIG, MAPI EVAL-MAR87 N. YAMAMURO, T. KAWAKITA
        DIST-JUL91

HISTORY
87-03 EVALUATION WAS PERFORMED FOR JENDL-3.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
        BY T. NARITA AND T. NAKAGAWA

MF=1  GENERAL INFORMATION
MT=451  DESCRIPTIVE DATA AND DICTIONARY

MF=2  RESONANCE PARAMETERS
MT=151  SCATTERING RADIUS ONLY

MF=3  NEUTRON CROSS SECTIONS
MT=203  HYDROGEN PRODUCTION CROSS SECTION
        = MT028 + MT103
MT=204  DEUTERIUM PRODUCTION CROSS SECTION
        = MT032 + MT104
MT=207  HE-4 PRODUCTION CROSS SECTION
        = MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3  **********************

MF=3  NEUTRON CROSS SECTIONS
MT=22, 28, 32, 103, 104 (N, N'A), (N, N'P), (N, N'D), (N, P) (N, D) CROSS
        SECTIONS
CALCULATED WITH GNASH /1/. OPTICAL POTENTIAL PARAMETERS
        WERE AS follows (IN THE UNITS OF MEV AND FM):
NEUTRON /2/
        V  = 51.725 - 0.447*E  RO  = 1.221  AO  = 0.683
        WS  = 8.44 + 0.055*E  RS  = 1.223  AS  = 0.507
        VS0= 8.0  RSO= 1.221  AS0= 0.683
PROTON /3/
        V  = 59.11 - 0.55*E  RO  = 1.25  AO  = 0.65
        WS  = 10.4  RS  = 1.25  AS  = 0.47
        VS0= 7.5  RSO= 1.25  AS0= 0.47
ALPHA-PARTICLE /4/
        V  = 164.7  RO  = 1.442  AO  = 0.52
        WV  = 22.4  RV  = 1.442  AV  = 0.52
        RC  = 1.30
DEUTERON /5/
        V  = 106.69  RO  = 1.05  AO  = 0.86
        WS  = 13.92  RS  = 1.43  AS  = 0.704
        VS0= 7.0  RSO= 0.75  AS0= 0.5
        RC  = 1.3
MT=107  (N, A) CROSS SECTION
CALCULATED CROSS SECTIONS OF CU-63 WERE NORMALIZED TO
        THE EXPERIMENTAL DATA /6/ AT 10 MEV. ABOVE 12 MEV, THE
        EXCITATION FUNCTION FOLLOWS THE DATA OF PAULSEN /7/.
        FOR CU-65, THE GNASH CALCULATION WAS EMPLOYED.

REFERENCES
1) YOUNG, P.G. AND ARTHUR, E.D.: "GNASH, A PREEQUILIBRIUM,
        STATISTICAL NUCLEAR-MODEL CODE FOR CALCULATION OF CROSS
        NEUTRON-INDUCED CROSS SECTIONS FOR CU-63, 65 FROM 1 TO 20 MEV
76, 30 (1980).
7) PAULSEN, A.: NUCLEONIK, 10, 91 (1967)
3.19 As-75

33-As-75 JNDC EVAL-Aug89 JNDC FP Nuclear Data W.G. DIST-jul91

History
89-08 NEW EVALUATION FOR JENDL-3 WAS COMPLETED BY JNDC FPND W.G./1/
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.MAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
= MT029 + MT103
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
= MT032 + MT104
MT=205 TRITIUM PRODUCTION CROSS SECTION
= MT033 + MT105
MT=206 HE-3 PRODUCTION CROSS SECTION
= MT106
MT=207 HE-4 PRODUCTION CROSS SECTION
= MT022 + MT107

**** DESCRIPTIVE DATA for JENDL-3 FP ***********************

MF = 3 Neutron cross sections
The threshold reaction cross sections were calculated with PEGASUS/2 standing on a quasiequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined to reproduce a systematic trend of the total cross section, changed from radii of Iijima and Kawai/3/. The OMP's for charged particles are as follows:
Proton = Perey/4/
Alpha = Huizenga and Igo/5/
Deuteron = Lohr and Heber/6/
Helium-3 and triton = Becchetti and Greenles/7/
Parameters for the composite level density formula of Gilbert and Cameron/8/ were evaluated by Iijima et al./9/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppeleer /10/.

MT = 22 (n,n') Cross Section
MT = 28 (n,n') Cross Section
MT = 32 (n,n') Cross Section
MT = 33 (n,n') Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section

These reaction cross sections were calculated with the quasiequilibrium and multi-step evaporation model code PEGASUS/2/.
The Kalbach's constant $K (= 83.0)$ was estimated by the formula derived from Kikuchi-Kawai's formalism\(^{(11)}\) and level density parameters.

Finally, the \((n,p)\) and \((n,\alpha)\) cross sections were normalized to the following values at 14.5 MeV:

\[
\begin{align*}
(n,p) & \quad 32.00 \text{ mb (recommended by Forrest/12/)} \\
(n,\alpha) & \quad 11.00 \text{ mb (recommended by Forrest/12/)}
\end{align*}
\]

Table 1  Neutron Optical Potential Parameters

<table>
<thead>
<tr>
<th>Depth (MeV)</th>
<th>Radius(fm)</th>
<th>Diffuseness(fm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V = 46.0$-0.25E</td>
<td>$R_0 = 5.7$</td>
<td>$a_0 = 0.62$</td>
</tr>
<tr>
<td>$W_s = 7.0$</td>
<td>$R_s = 6.2$</td>
<td>$a_s = 0.35$</td>
</tr>
<tr>
<td>$W_{so} = 7.0$</td>
<td>$R_{so} = 5.7$</td>
<td>$a_{so} = 0.62$</td>
</tr>
</tbody>
</table>

Table 2  Level Density Parameters

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>SYST</th>
<th>$a/(1/MeV)$</th>
<th>$T(1/MeV)$</th>
<th>$C(1/MeV)$</th>
<th>EX(MeV)</th>
<th>Pairing</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-Ga-71</td>
<td>$^*$</td>
<td>1.332E+01</td>
<td>9.155E-01</td>
<td>1.399E+01</td>
<td>9.613E+00</td>
<td>1.430E+00</td>
</tr>
<tr>
<td>31-Ga-72</td>
<td>$^*$</td>
<td>1.390E+01</td>
<td>9.028E-01</td>
<td>9.003E+01</td>
<td>8.399E+00</td>
<td>0.00</td>
</tr>
<tr>
<td>31-Ga-73</td>
<td>$^*$</td>
<td>1.269E+01</td>
<td>8.264E-01</td>
<td>1.933E+00</td>
<td>7.805E+00</td>
<td>1.880E+00</td>
</tr>
<tr>
<td>31-Ga-74</td>
<td>$^*$</td>
<td>1.350E+01</td>
<td>8.784E-01</td>
<td>5.236E+01</td>
<td>7.951E+00</td>
<td>0.00</td>
</tr>
<tr>
<td>32-Ge-72</td>
<td>$^*$</td>
<td>1.350E+01</td>
<td>9.028E-01</td>
<td>3.062E+00</td>
<td>1.086E+01</td>
<td>2.790E+00</td>
</tr>
<tr>
<td>32-Ge-73</td>
<td>$^*$</td>
<td>1.409E+01</td>
<td>8.904E-01</td>
<td>1.973E+00</td>
<td>9.644E+00</td>
<td>1.360E+00</td>
</tr>
<tr>
<td>32-Ge-74</td>
<td>$^*$</td>
<td>1.384E+01</td>
<td>8.784E-01</td>
<td>1.667E+00</td>
<td>1.106E+01</td>
<td>3.240E+00</td>
</tr>
<tr>
<td>32-Ge-75</td>
<td>$^*$</td>
<td>1.368E+01</td>
<td>8.667E-01</td>
<td>1.100E+00</td>
<td>8.810E+00</td>
<td>1.360E+00</td>
</tr>
<tr>
<td>33-As-73</td>
<td>$^*$</td>
<td>1.369E+01</td>
<td>8.904E-01</td>
<td>1.364E+01</td>
<td>9.389E+00</td>
<td>1.430E+00</td>
</tr>
<tr>
<td>33-As-74</td>
<td>$^*$</td>
<td>1.132E+01</td>
<td>9.475E-01</td>
<td>1.967E+00</td>
<td>7.033E+00</td>
<td>0.00</td>
</tr>
<tr>
<td>33-As-75</td>
<td>$^*$</td>
<td>1.250E+01</td>
<td>9.510E-01</td>
<td>6.830E+00</td>
<td>1.008E+01</td>
<td>1.880E+00</td>
</tr>
<tr>
<td>33-As-76</td>
<td>$^*$</td>
<td>1.330E+01</td>
<td>7.860E-01</td>
<td>1.900E+01</td>
<td>5.611E+00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

SYST: $^*$ = LDP's were determined from systematics.

Spin cutoff params were calculated as $0.146 \times \text{SQRT}(a) \times A^{2/3}$. In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 3.5 for As-75 and 5.0 for As-76.

References
3.20 Natural Se

34-Se-  0 JNDC  EVAL-Aug89 JNDC FP Nuclear Data W.G.
         DIST-Ju191

History
89-08  NEW EVALUATION FOR each isotope WAS COMPLETED BY JNDC FPND
       W.G./1/
91-07  GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
       BY T.NARITA AND T.NAKAGAWA

MF=1  GENERAL INFORMATION
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MF=2  RESONANCE PARAMETERS
MT=151  SCATTERING RADIUS ONLY

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MT=203  HYDROGEN PRODUCTION CROSS SECTION
        = MT028 + MT103 + mt111*2
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        = MT032 + MT104
MT=205  TRITIUM PRODUCTION CROSS SECTION
        = MT105
MT=206  HE-3 PRODUCTION CROSS SECTION
        = MT106
MT=207  HE-4 PRODUCTION CROSS SECTION
        = MT022 + MT107

**** DESCRIPTIVE DATA for JENDL-3 FP ***************

MF = 3 Neutron cross sections
The threshold reaction cross sections were calculated with
PEGASUS/2/ standing on a preequilibrium and multi-step
evaporation model. The OMP's for neutron given in Table 1 were
determined to reproduce a systematic trend of the total cross
section, changed from radii of Iijima and Kawai/3/. The OMP's
for charged particles are as follows:

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Alpha    = Huizenga and Igo/5/
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Helium-3 and triton = Becchetti and Greenlees/7/

Parameters for the composite level density formula of Gilbert
and Cameron/8/ were evaluated by Iijima et al./9/. More
extensive determination and modification were made in the
present work. Table 2 shows the level density parameters used
in the present calculation. Energy dependence of spin cut-off
parameter in the energy range below E-joint is due to Gruppelaar
/10/.

MT = 22  (n,n'a) Cross Section
MT = 28  (n,n'p) Cross Section
MT = 32  (n,n'd) Cross Section
MT =103  (n,p) Cross Section
MT =104  (n,d) Cross Section
MT =105  (n,t) Cross Section
MT =106  (n,He3) Cross Section
MT =107  (n,alpha) Cross Section

These reaction cross sections were calculated with the
preequilibrium and multi-step evaporation model code
PEGASUS/2/.

Finally, the (n,p) and (n,alpha) cross sections were
normalized to the following values at 14.5 MeV:

<table>
<thead>
<tr>
<th>Isotope</th>
<th>(n,p)/11/</th>
<th>(n,alpha)/11/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se- 74</td>
<td>135 mb</td>
<td>34.8 mb</td>
</tr>
<tr>
<td>Se- 76</td>
<td>79 mb</td>
<td>15.6 mb</td>
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<tr>
<td>Se- 77</td>
<td>35 mb</td>
<td>10.1 mb</td>
</tr>
<tr>
<td>Se- 78</td>
<td>18 mb</td>
<td>5.5 mb</td>
</tr>
<tr>
<td>Se- 80</td>
<td>16 mb</td>
<td>17 mb</td>
</tr>
<tr>
<td>Se- 82</td>
<td>2.4 mb</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 Neutron Optical Potential Parameters

<table>
<thead>
<tr>
<th>Depth (MeV)</th>
<th>Radius (fm)</th>
<th>Diffuseness (fm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V = 46.0-0.25E</td>
<td>R0 = 5.7</td>
<td>a0 = 0.62</td>
</tr>
<tr>
<td>Ws = 7.0</td>
<td>Rs = 6.2</td>
<td>as = 0.35</td>
</tr>
<tr>
<td>Wso = 7.0</td>
<td>Rso = 5.7</td>
<td>aso = 0.62</td>
</tr>
</tbody>
</table>

Table 2 Level Density Parameters

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>SYST a(1/MeV)</th>
<th>T(MeV)</th>
<th>C(1/MeV)</th>
<th>EX(MeV)</th>
<th>Pairing</th>
</tr>
</thead>
<tbody>
<tr>
<td>32-Ge- 70</td>
<td>1.236E+01</td>
<td>9.286E-01</td>
<td>1.710E+00</td>
<td>1.048E+01</td>
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<tr>
<td>32-Ge- 71</td>
<td>1.293E+01</td>
<td>9.155E-01</td>
<td>1.132E+01</td>
<td>9.208E+00</td>
<td>1.360E+00</td>
</tr>
<tr>
<td>32-Ge- 72</td>
<td>1.350E+01</td>
<td>9.028E-01</td>
<td>3.062E+00</td>
<td>1.086E+01</td>
<td>2.790E+00</td>
</tr>
<tr>
<td>32-Ge- 73</td>
<td>1.409E+01</td>
<td>8.904E-01</td>
<td>1.973E+01</td>
<td>9.644E+00</td>
<td>1.360E+00</td>
</tr>
<tr>
<td>32-Ge- 74</td>
<td>1.384E+01</td>
<td>8.784E-01</td>
<td>1.667E+00</td>
<td>1.106E+01</td>
<td>3.240E+00</td>
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<tr>
<td>32-Ge- 75</td>
<td>1.368E+01</td>
<td>8.667E-01</td>
<td>1.100E+01</td>
<td>8.810E+00</td>
<td>1.360E+00</td>
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<td>33-As- 71</td>
<td>1.254E+01</td>
<td>9.155E-01</td>
<td>7.299E+00</td>
<td>9.012E+00</td>
<td>1.500E+00</td>
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<tr>
<td>33-As- 72</td>
<td>1.311E+01</td>
<td>9.028E-01</td>
<td>5.047E+01</td>
<td>7.739E+00</td>
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</tr>
<tr>
<td>33-As- 73</td>
<td>1.399E+01</td>
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<td>1.364E+01</td>
<td>9.389E+00</td>
<td>1.430E+00</td>
</tr>
<tr>
<td>33-As- 74</td>
<td>1.132E+01</td>
<td>9.475E-01</td>
<td>1.967E+01</td>
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<tr>
<td>33-As- 75</td>
<td>1.250E+01</td>
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<td>1.008E+01</td>
<td>1.880E+00</td>
</tr>
<tr>
<td>33-As- 76</td>
<td>1.330E+01</td>
<td>7.860E-01</td>
<td>1.900E+01</td>
<td>5.611E+00</td>
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</tr>
<tr>
<td>33-As- 77</td>
<td>1.300E+01</td>
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<td>33-As- 82</td>
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<td>5.344E+00</td>
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<td>34-Se- 72</td>
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<td>9.028E-01</td>
<td>1.477E+00</td>
<td>1.034E+01</td>
<td>2.930E+00</td>
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<td>34-Se- 73</td>
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<td>8.250E-01</td>
<td>7.927E+00</td>
<td>8.206E+00</td>
<td>1.430E+00</td>
</tr>
<tr>
<td>34-Se- 74</td>
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<td>1.070E+00</td>
<td>9.612E+00</td>
<td>2.860E+00</td>
</tr>
<tr>
<td>34-Se- 75</td>
<td>1.391E+01</td>
<td>8.500E-01</td>
<td>9.741E+00</td>
<td>8.707E+00</td>
<td>1.430E+00</td>
</tr>
<tr>
<td>34-Se- 76</td>
<td>1.315E+01</td>
<td>8.900E-01</td>
<td>1.097E+00</td>
<td>1.082E+01</td>
<td>3.310E+00</td>
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<td>34-Se- 77</td>
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<td>8.000E-01</td>
<td>7.140E+00</td>
<td>8.015E+00</td>
<td>1.430E+00</td>
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<tr>
<td>34-Se- 78</td>
<td>1.287E+01</td>
<td>8.750E-01</td>
<td>1.163E+00</td>
<td>9.882E+00</td>
<td>2.900E+00</td>
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<tr>
<td>34-Se- 79</td>
<td>1.412E+01</td>
<td>8.000E-01</td>
<td>5.994E+00</td>
<td>7.842E+00</td>
<td>1.430E+00</td>
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<td>34-Se- 80</td>
<td>1.334E+01</td>
<td>8.130E-01</td>
<td>6.129E-01</td>
<td>9.138E+00</td>
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34-Se- 81  1.368E+01  7.490E-01  2.463E+00  6.614E+00  1.430E+00  34-Se- 82  1.299E+01  7.980E-01  3.563E-01  8.246E+00  2.890E+00  34-Se- 83  1.381E+01  7.500E-01  2.666E+00  6.700E+00  1.430E+00

SYST:  *= LDP's were determined from systematics.

Spin cutoff params were calculated as 0.146*SQR(a)*A**(2/3).

References
3.21 Natural Zr

40-2r- O JNDC EVAL-Aug89 JNDC FP Nuclear Data W.G.
DIST-Jul91

History
89-08 NEW EVALUATION FOR each isotope WAS COMPLETED BY JNDC FPND
W.G.1/
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
\[ \text{MT028 + MT103 + MT111} \]
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
\[ \text{MT032 + MT104} \]
MT=205 TRITIUM PRODUCTION CROSS SECTION
\[ \text{MT033 + MT105} \]
MT=206 HE-3 PRODUCTION CROSS SECTION
\[ \text{MT106} \]
MT=207 HE-4 PRODUCTION CROSS SECTION
\[ \text{MT022 + MT107} \]

**** DESCRIPTIVE DATA for JENDL-3 FP ***************

MF = 3 Neutron cross sections
The threshold reaction cross sections were calculated with
PEGASUS/2/ standing on a preequilibrium and multi-step
evaporation model. The OMP's for neutron given in Table 1 were
determined/3/ to reproduce a systematic trend of the total
cross section. The OMP's for charged particles are as follows:

Proton = Perey/4/
Alpha = Huizenga and Igo/5/
Deuteron = Lohr and Haebeler/6/
Tritium = Lohr and Greenlees/7

Parameters for the composite level density formula of Gilbert
and Cameron/8/ were evaluated by Iijima et al./9/. More
extensive determination and modification were made in the
present work. Table 2 shows the level density parameters used
in the present calculation. Energy dependence of spin cut-off
parameter in the energy range below E-joint is due to Gruppelaar
/10/.

MT = 22 (n,n') Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT = 33 (n,n't) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section
MT =111 (n,2p) Cross Section

These reaction cross sections were calculated with the
preequilibrium and multi-step evaporation model code
PEGASUS/2/.
The (n,p) and (n,α) cross sections were normalized to the following values at 14.5 MeV:

<table>
<thead>
<tr>
<th>Isotope</th>
<th>(n,p)/11/</th>
<th>(n,α)/11/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zr-90</td>
<td>40 mb/11/</td>
<td>10.0 mb/11/</td>
</tr>
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<td>29 mb/11/</td>
<td>8.51 mb/11/</td>
</tr>
<tr>
<td>Zr-92</td>
<td>22 mb/12/</td>
<td>10.1 mb/13.14/</td>
</tr>
<tr>
<td>Zr-94</td>
<td>10 mb/11/</td>
<td>4.8 mb/12/</td>
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<td>Zr-96</td>
<td>3.79 mb/11/</td>
<td>3.0 mb/11/</td>
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Table 1 Neutron Optical Potential Parameters

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<th>Parameter</th>
<th>Value</th>
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<td>V</td>
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</tr>
<tr>
<td>Ws</td>
<td>7.0</td>
</tr>
<tr>
<td>Wso</td>
<td>7.0</td>
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<tr>
<td>R0</td>
<td>5.893</td>
</tr>
<tr>
<td>Rs</td>
<td>6.393</td>
</tr>
<tr>
<td>Rso</td>
<td>5.893</td>
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<tr>
<td>a0</td>
<td>0.62</td>
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<tr>
<td>as</td>
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</tr>
<tr>
<td>aso</td>
<td>0.62</td>
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</table>

Table 2 Level Density Parameters

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<th>Nuclide</th>
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<th>a(1/MeV)</th>
<th>T(MeV)</th>
<th>C(1/MeV)</th>
<th>EX(MeV)</th>
<th>Pairing</th>
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<td>38-Sr-86</td>
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<td>8.900E-01</td>
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<td>2.700E+00</td>
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<tr>
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<td>1.030E+01</td>
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<td>1.240E+00</td>
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<tr>
<td>38-Sr-88</td>
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<td>8.288E-02</td>
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<td>3.795E-01</td>
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<tr>
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<td>5.625E+00</td>
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<tr>
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<td>1.273E+00</td>
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<td>2.497E+00</td>
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SYST: * = LDP's were determined from systematics.

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
References
3.22 Nb-93

41-NB-93 TOSHIBA EVAL-NOV88 M.KAWAI, N.YAMAMURO
DIST-JUL91

HISTORY
88-10 EVALUATION WAS PERFORMED.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1 GENERAL INFORMATION
MT=451 DESCRIPTIVE DATA AND DICTIONARY

MF=2 RESONANCE PARAMETERS
MT=151 SCATTERING RADIUS ONLY

MF=3 NEUTRON CROSS SECTIONS
MT=203 HYDROGEN PRODUCTION CROSS SECTION
MT=204 DEUTERIUM PRODUCTION CROSS SECTION
MT=207 HE-4 PRODUCTION CROSS SECTION

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3 ***************

MF=3 NEUTRON CROSS SECTIONS
MT=4,51-91 INELASTIC SCATTERING

THE INELASTIC SCATTERING CROSS SECTIONS TO DISCRETE LEVELS
WERE CALCULATED WITH THE STATISTICAL-MODEL CODE CASTHY/1/, CONSIDERING LEVEL FLUCTUATION, USING MODIFIED WALTER-GUSS
POTENTIAL PARAMETERS FOR NEUTRONS. THE COMPONENTS OF THE
DIRECT PROCESS WERE ADDED TO THE LEVELS OF MT=53,54,56,57,
58,60 BY USING THE DWUCK CODE /2/. THE CROSS SECTION TO
CONTINUUM WAS CALCULATED WITH THE THE GNASH CODE /3/
CONSIDERING PRE-EQUILIBRIUM.

THE LEVEL SCHEME IS GIVEN AS FOLLOWS:

NO. ENERGY(MEV) SPIN-PARITY
 6. 0.304 3/2 +
 7. 0.0304 1/2 -
 8. 0.6860 3/2 -
 9. 0.7440 7/2 +
10. 0.8087 5/2 +
11. 0.8101 3/2 -
12. 0.9499 13/2 +
13. 0.9791 11/2 +
14. 1.0826 9/2 +
15. 1.2900 3/2 -
16. 1.2974 9/2 +
17. 1.3156 5/2 +
18. 1.3351 17/2 +

LEVELS ABOVE 1.34 MEV WERE ASSUMED TO BE OVERLAPPING.

OPTICAL-MODEL PARAMETERS ARE AS FOLLOWS:
W=52.56-0.30*EN, WS=3.233+0.271*EN, VSO=6.004-0.015*EN
WSYM=-16.5, WI=-0.963+0.153*EN, WSO=0.291-0.018*EN
R0=1.229, RS=1.282, R1=1.42, RSO=1.103
A0=0.688, B=0.512, AI=0.509, ASO=0.56

THE LEVEL DENSITY PARAMETERS FOR GNASH AND CASTHY
CALCULATIONS ARE AS FOLLOWS:

A = EX, T = DS, GAMMA-G
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<th>(MEV)</th>
<th>(MEV)</th>
<th>(EV)</th>
<th>(EV)</th>
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<td>0.130</td>
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MT=22, 28, 103, 104, 107 (N,N' A), (N,N' P), (N,P) (N,D) AND (N,A) CROSS SECTIONS
CALCULATED WITH GNASH/3/. OPTICAL POTENTIAL PARAMETERS FOR PROTON, ALPHA-PARTICLE AND DEUTERON WERE TAKEN FROM THE WORKS OF PEREY/4/, LEMOS/5/, AND LOHR AND HAEVERLI/6/, RESPECTIVELY.

REFERENCES
1) IGARASI, S.: J. NUCL. SCI. TECHNOL., 12, 67 (1975).
3.23 Natural Mo

42-MO- 0 JNDC EVAL-MAR89 JNDC FPND W.G.
DIST-JUL91

HISTORY
89-03 DATA WERE COMPILED FROM ISOTOPE DATA EVALUATED BY JNDC FPND
W.G.
91-07 GAS-PRODUCTION DATA FILE WAS CREATED FROM JENDL-3
BY T.NARITA AND T.NAKAGAWA

MF=1  GENERAL INFORMATION
MT=451  DESCRIPTIVE DATA AND DICTIONARY

MF=3  NEUTRON CROSS SECTIONS
MT=203  HYDROGEN PRODUCTION CROSS SECTION
= MT028 + MT103 + MT111*2
MT=204  DEUTERIUM PRODUCTION CROSS SECTION
= MT032 + MT104
MT=205  TRITIUM PRODUCTION CROSS SECTION
= MT105
MT=206  HE-3 PRODUCTION CROSS SECTION
= MT106
MT=207  HE-4 PRODUCTION CROSS SECTION
= MT022 + MT107

**** ORIGINAL DESCRIPTIVE DATA IN JENDL-3  ***********************

MF = 3  NEUTRON CROSS SECTIONS
THE THRESHOLD REACTION CROSS SECTIONS WERE CALCULATED WITH
PEGASUS/1/ STANDING ON A PREEQUILIBRIUM AND MULTI-STEP
EVAPORATION MODEL. THE OMP'S FOR NEUTRON GIVEN IN TABLE 1 WERE
DETERMINED BY IJIMA ET AL.2/ TO REPRODUCE A SYSTEMATIC TRENDS
OF THE TOTAL CROSS SECTION. THE OMP'S FOR CHARGED PARTICLES ARE
AS FOLLOWS:
PROTON  = PEREY/3/
ALPHA = HUIZENGA AND IGO/4/
DEUTERON = LOHR AND HAEGERLI/5/
HELIUM-3 AND TRITON = BECCCHETTI AND GREENLEES/6/
PARAMETERS FOR THE COMPOSITE LEVEL DENSITY FORMULA OF GILBERT
AND CAMERON/7/ WERE EVALUATED BY IJIMA ET AL.8/ MORE
EXTENSIVE DETERMINATION AND MODIFICATION WERE MADE IN THE
PRESENT WORK. TABLE 2 SHOWS THE LEVEL DENSITY PARAMETERS USED
IN THE PRESENT CALCULATION. THE ENERGY DEPENDENCE OF SPIN
CUT-OFF PARAMETER IN THE ENERGY RANGE BELOW E-JOINT (EX) IS DUE
TO GRUPPELAAR/9/.

MT = 22,28,32,103,104,105,106,107,111
(N,N4A), (N,N4P), (N,N4D), (N,P), (N,D), (N,T), (N,H3),
(N,ALPHA) AND (N,2P) CROSS SECTIONS
THESE REACTION CROSS SECTIONS WERE CALCULATED WITH PEGASUS
/1/. THE KALBACH'S CONSTANTS WERE ESTIMATED BY THE FORMULA
DERIVED FROM KIKUCHI-KAWAI'S FORMALISM/10/ AND LEVEL DENSITY
PARAMETERS. THE (N,P) AND (N,ALPHA) CROSS SECTIONS WERE
NORMALIZED TO THE EXPERIMENTAL DATA OR SYSTEMATICS AT 14.5 MEV
AS FOLLOWS:

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<th>ISOLOPE</th>
<th>(N,P)</th>
<th>(N,ALPHA)</th>
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<td>MO- 92</td>
<td>116 MB/11/</td>
<td>24 MB/12/</td>
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<td>MO- 93</td>
<td>55.1 MB/11/</td>
<td>17.5 MB/11/</td>
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<td>MO- 94</td>
<td>38 MB/11/</td>
<td>13.5 MB/11/</td>
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TABLE 1 NEUTRON OPTICAL POTENTIAL PARAMETERS

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<tr>
<th>DEPTH (MEV)</th>
<th>RADIUS (FM)</th>
<th>DIFFUSINESS (FM)</th>
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<td>V = 46.0-0.25E</td>
<td>R0 = 5.893</td>
<td>A0 = 0.62</td>
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<tr>
<td>WS = 7.0</td>
<td>RS = 6.393</td>
<td>AS = 0.35</td>
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<tr>
<td>WSO = 7.0</td>
<td>RSO = 5.893</td>
<td>ASO = 0.62</td>
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TABLE 2 LEVEL DENSITY PARAMETERS

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<th>NUCL</th>
<th>SYST</th>
<th>A(/MEV)</th>
<th>T(MEV)</th>
<th>C(/MEV)</th>
<th>EX(MEV)</th>
<th>PAIRING</th>
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<td>7.386E-01</td>
<td>4.932E-01</td>
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<tr>
<td>40-ZR-89</td>
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<tr>
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SYST: * = LDP'S WERE DETERMINED FROM SYSTEMATICS.
SPIN CUT-OFF PARAMS WERE CALCULATED AS 0.146*SQRT(A)*A**(2/3).

REFERENCES
References


Table 1 Data in the JENDL-gas-production cross section file

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Fig. 1(a) Gas-production cross sections of $^{6}$Li
The $^{4}$He production cross section is equal to the $^{3}$H production
cross section below 1.75 MeV.
Fig. 1(b) Gas-production cross sections of $^6\text{Li}$
Fig. 2 Gas-production cross sections of $^6\text{Li}$
The $^4\text{He}$ production cross section is equal to the $^3\text{H}$ production cross section.
Fig. 3 Gas-production cross sections of $^9$Be
Fig. 4(b) Gas-production cross sections of $^{10}{B}$

Cross Section (barns)

Neutron Energy (eV)
Fig. 4(c) Gas-production cross sections of $^{10}$B
Fig. 5 Gas-production cross sections of $^{11}$B
Fig. 6  Gas-production cross sections of $^{12}$C
Fig. 7(a) Gas-production cross sections of N
Fig. 7(b) Gas-production cross sections of N
Fig. 8 Gas-production cross sections of $^{19}$F
Fig. 9  Gas-production cross sections of $^{27}\text{Al}$
Fig. 10 Gas-production cross sections of Si
Fig. 11 Gas-production cross sections of Ti
Fig. 12 Gas-production cross sections of $^{51}$V
Fig. 13 Gas-production cross sections of Cr
Fig. 14 Gas-production cross sections of $^{55}\text{Mn}$
Fig. 15 Gas-production cross sections of Fe
Fig. 16 Gas-production cross sections of $^{59}$Co
Fig. 17 Gas-production cross sections of Ni
Fig. 18 Gas-production cross sections of Cu
Fig. 19 Gas-production cross sections of $^{75}$As
Fig. 20 Gas-production cross sections of Se
Fig. 21 Gas-production cross sections of Zr
Fig. 22 Gas-production cross sections of $^{93}$Nb
Fig. 23 Gas-production cross sections of Mo