

# **NUCLEAR DATA SERVICES**

DOCUMENTATION SERIES OF THE IAEA NUCLEAR DATA SECTION

IAEA-NDS-200 Rev. 0 September 2003

# **POINT2003**

### A TEMPERATURE DEPENDENT ENDF/B-VI, RELEASE 8

### **Cross Section Library**

by

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Summary documentation (P. McLaughlin)

Abstract: The ENDF/B data library has recently been updated and is now freely available through the National Nuclear Data Center (NNDC), Brookhaven National Laboratory. This most recent library is identified as ENDF/B-VI, Release 8. Release 8 completely supersedes all preceding releases.

For use in applications this library has been processed into the form of temperature dependent cross sections at eight temperatures between 0 and 2100 Kelvin, in steps of 300 Kelvin. At each temperature the cross sections are tabulated and linearly interpolable in energy. The data package is available from the IAEA Nuclear Data Section on 3 CD-ROMs or online at: http://www-nds.iaea.org/point2003/

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#### **Citation guidelines:**

a) *citing the evaluation of one material* 

Author(s), "Neutron reaction data evaluation of ...", report ... (place, year) [or, if no report is available: Undocumented]. Data file ENDF/B-VI MAT 1234 Rev. 2 (date) by the U.S. National Nuclear Data Center on behalf of the Cross-Section Evaluation Working Group. Data received on tape (or retrieved online) from the IAEA Nuclear Data Section.

b) *citing the entire library* 

P.F. Rose (ed.), "ENDF/B-VI Summary Documentation", report BNL-NCS-17541 (ENDF-201), (Brookhaven National Laboratory 1991). Data Library ENDF/B-VI, update 1998, by the U.S. National Nuclear Data Center ... etc. as above.

V. McLane (ed.), "ENDF/B-VI Summary Documentation Supplement 1" "ENDF/HE-VI Summary Documentation", report BNL-NCS-17541 (ENDF-201), 4th Edition.12/96.

c) *citing the format* 

V. McLane, P.F. Rose, C.L. Dunford (ed.), "Data formats and procedures for the Evaluated Nuclear Data File ENDF-6", report BNL-NCS-44945 (ENDF-102) Rev 1/04 (Brookhaven National Laboratory 2001).



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Work performed under the auspices of the U. S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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### OR

Lawrence Livermore National Laboratory Technical Information Department's Digital Library <u>http://www.llnl.gov/tid/Library.html</u>

UCRL-ID-127776, Rev. 2

### POINT 2003 A Temperature Dependent ENDF/B-VI, Release 8 Cross Section Library

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#### May 22, 2003

### Introduction

The ENDF/B data library has recently been updated and is now freely available through the National Nuclear Data Center (NNDC), Brookhaven National Laboratory. This most recent library is identified as ENDF/B-VI, Release 8. Release 8 completely supersedes all preceding releases. Release 8 will be the last release of ENDF/B-VI; the next release of ENDF/B data will be for the new ENDF/B-VII library.

As distributed the ENDF/B-VI, Release 8 data includes cross sections represented in the form of a combination of resonance parameters and/or tabulated energy dependent cross sections, nominally at 0 Kelvin temperature.

For use in applications this library has been processed into the form of temperature dependent cross sections at eight temperatures between 0 and 2100 Kelvin, in steps of 300 Kelvin. At each temperature the cross sections are tabulated and linearly interpolable in energy.

All results are in the computer independent ENDF/B-VI character format [1], which allows the data to be easily transported between computers. In its processed form this

library is approximately 1.6 gigabyte in size and is distributed on three CDs.

### **Earlier Versions of ENDF/B-VI**

Between the original distribution (Release 0) and Release 2 libraries, 74 evaluations were updated and distributed in July 1994 (see, UCRL-ID-117797). Between Release 2 and 3 libraries, 18 evaluations were updated and distributed in January 1996 (see, UCRL-ID-124171). Between Release 0 and 3 no completely new evaluations were added to the library. Between Release 3 and 4(see, UCRL-ID-127776), 87 evaluations were updated and five completely new evaluations were added, namely for Gd<sup>152</sup>, Gd<sup>154</sup>, Ir<sup>191</sup>, Ir<sup>193</sup> and Pu<sup>236</sup>. In additional the evaluation for natural Cd was deleted and replaced by evaluations for the individual isotopes. Between Release 4 and 7, 68 materials were modified; mostly to extend the cross sections from 20 to 150 MeV, and three new evaluations were added (14-Si-28, 14-Si-29, 14-Si-30). The result was a library of 324 evaluations.

For details, see the above mentioned three reports: UCRL-ID-117797, UCRL-ID-124171, and UCRL-ID-127776.

### ENDF/B-VI, Release 8 Data

Between the last version of this library (POINT2000), which was based on release 7 data, and the current version (POINT2003), which is based on release 8 data, a direct cross section by cross section comparison will show minor (fraction of a %) differences in many cross sections, mainly due to improvements in the precision of the PREPRO2002 codes; these differences are not listed here. There are also many changes to the data that are not processed by PREPRO, this includes delayed neutron data, and neutron induced photon production data, that were not included in earlier versions of these evaluations; these changes are widespread throughout the library are also not listed here.

The following lists only significant changes to the evaluations cross sections (listed below in ascending ZA order),

#### Material Changes

4-Be-9	(n,t) 12 to 20 MeV
8-O-16	New cross sections
16-S-Nat	I removed bogus "fission widths" from resonance parameters
	(note that this is the same correction I made for Release 7???)
17-Cl-35	New evaluation
17-Cl-37	New evaluation
42-Mo-95	New elastic and capture
43-Tc-99	New elastic and capture
44-Ru-101	New elastic and capture
45-Rh-103	New elastic and capture

- 46-Pd-105 New elastic and capture
- 47-Ag-109 New elastic and capture
- 50-Sn-120 New above 10 keV
- 50-Sn-122 New above 10 keV
- 50-Sn-124 New above 10 keV
- 51-Sb-121 New elastic, capture and inelastic
- 51-Sb-123 New elastic, capture and inelastic
- 54-Xe-131 New elastic and capture
- 60-Nd-143 New elastic and capture
- 60-Nd-145 New elastic and capture
- 62-Sm-147 New elastic and capture
- 62-Sm-150 New elastic and capture
- 62-Sm-151 New elastic and capture
- 62-Sm-152 Minor changes at upper end of resolved resonance region
- 64-Gd-155 New elastic and capture
- 64-Gd-157 New elastic and capture
- 91-Pa-232 New evaluation
- 92-U-232 New elastic, inelastic, fission and capture
- 93-Np-236 New evaluation

The result is a library of 328 evaluations.

### PREPRO2002 Codes

In addition to the changes in the ENDF/B-VI evaluations, it should be noted that between the last version of this report, where the PREPRO2000 codes were used, and the current version, where the PREPRO2002 codes were used, there have been major improvements in the ENDF/B Pre-processing codes. The major improvements were both in terms of improving the basic methods used by the codes and in terms of incorporating the latest ENDF/B-VI Formats and Procedures used by the current evaluations. The result is more accurate cross section data throughout the POINT2003 library.

**WARNING** – due to recent changes in ENDF/B-VI Formats and Procedures only the latest version of the ENDF/B Pre-processing codes, namely PREPRO2002, can be used to accurately process all current ENDF/B-VI evaluations. If you fail to heed this warning and you use any earlier versions of these codes the results will be inaccurate.

The PREPRO2002 codes run on virtually any computer, and are now available FREE online from the Nuclear Data Section, IAEA, Vienna, Austria, website at,

http://www-nds.iaea.or.at/ndspub/endf/prepro/

#### **Requesting this Data**

Please do not contact the author of this report to request this data; I do not have the resources necessary to directly respond to requests for this data. This data has been distributed to and is Internationally available from nuclear data/code centers throughout the World,

- 1) Within the United States: contact the National Nuclear Data Center, Brookhaven National Laboratory, Vicki McLane at <a href="mailto:services@bnlnd2.dne.bnl.gov">services@bnlnd2.dne.bnl.gov</a>
- 2) Within Western Europe: contact the OECD Nuclear Energy Agency/ Data Bank (NEA/DB), Paris, France, Enrico Sartori at <u>sartori@nea.fr</u>
- 3) Otherwise: contact the Nuclear Data Section, international Atomic Energy Agency, Vienna, Austria, Vladimir Pronyaev at v.pronyaev@iaea.org

### **Data Processing**

As distributed the original evaluated data includes cross sections represented in the form of a combination of resonance parameters and/or tabulated energy dependent cross sections, nominally at 0 Kelvin temperature. For use in applications, this data has been processed using the 2002 version of the ENDF/B Pre-processing codes (PREPRO2001) to produce temperature dependent, linearly interpolable in energy, tabulated cross sections, in the ENDF/B-VI format.

Data is included for eight temperatures between 0 and 2100 Kelvin, in steps of 300 Kelvin.

The steps required and codes used to produce room temperature, linearly interpolable tabulated cross sections, in the ENDF/B-VI format, are described below (the name of each code in given in parenthesis; for details of each code see reference [2]).

Here are the steps, and PREPRO2002 codes, used to process the data, in the order in which the codes were used.

- 1) Linearly interpolable, tabulated cross sections (LINEAR)
- 2) Including the resonance contribution (**RECENT**)
- 3) Doppler broaden all cross sections to temperature (SIGMA1)
- 4) Check data, define redundant cross sections by summation (FIXUP)
- 5) Update evaluation dictionary in MF/MT=1/451 (**DICTIN**)

For the "cold" (0 Kelvin) data steps 1), 2) and 4), 5) were used. For the data at other temperatures, after steps 1) and 2), the data was Doppler broadened to each temperature using step 3), and the results were then made consistent with the ENDF/B formats and conventions using steps 4) and 5), to produce the final distributed data.

The result is linearly interpolable in energy, tabulated, temperature dependent cross sections, in the ENDF/B-VI format, ready to be used in applications.

**Note** - this processing only involved the energy dependent neutron cross sections. All other data in the evaluations, e.g., angular and energy distributions, was not affected by this processing, and is identical in all versions of the final results, i.e., it is the same in all of the directories, ORIGINAL, as well as K0 through K2100, on the CDs.

### **Accuracy of Results**

Each of the codes described above that was used to process data to obtain tabulated, linearly interpolable in energy cross sections, processed the data to within a user defined accuracy, or allowable uncertainty. The ENDF/B Pre-processing codes (PREPRO2002) are self-documenting, in the sense that the ENDF/B formatted output data that each code produces includes comments at the beginning of each evaluation defining the accuracy to which the cross sections were calculated. The combination of comments added by all of the codes defines the sequence and accuracy used by all of them. The accuracy is the same for all evaluations. Therefore, for exact details of the accuracy of the data, see the comments at the beginning of any evaluation.

The current results were generated using an energy dependent accuracy, to allow the low energy cross sections, where there are no narrow resonances, to be generated to much higher accuracy, without a significant increase in the overall size of the data base. This was done in order to improve the cross sections for use in thermal and slow neutron applications. Again, for details see the comments in any evaluation.

# **Contents of the Library**

This library **contains** all of the evaluations in the ENDF/B-VI general purpose library. The following table summarizes the contents of the ENDF/B-VI general purpose library. This library contains evaluations for 328 materials (isotopes or naturally occurring elemental mixtures of isotopes).

This library **does not contain** data from special purpose ENDF/B-VI libraries, such as fission products, thermal scattering, photon interaction data. To obtain any of these special purpose libraries contact the National Nuclear Data Center, Brookhaven National Laboratory,

#### ENDF@bnlnd2.dne.bnl.gov

In this library each evaluation is stored as a separate file. The following table defines each material and the corresponding filename. The entire library is in the computer independent ENDF/B-VI character format, which allows the data to be easily transported between computers. The entire library requires approximately 1.6 gigabyte of storage and is distributed on three CDs; see below for details of the CD contents.

This library contains data for some metastable materials, which are indicated by an "M"

at the end of their descriptions.

The majority of these evaluations are complete, in the sense that they include all cross sections over the energy range  $10^{-5}$  eV to at least 20 MeV. However, the following are only partial evaluations that either only contain single reactions and no total cross section (Mg<sup>24</sup>, K<sup>41</sup>, Ti<sup>46</sup>, Ti<sup>47</sup>, Ti<sup>48</sup>, Ti<sup>50</sup> and Ni<sup>59</sup>), or do not include energy dependent cross sections above the resonance region (Ar<sup>40</sup>, Mo<sup>92</sup>, Mo<sup>98</sup>, Mo<sup>100</sup>, In<sup>115</sup>, Sn<sup>120</sup>, Sn<sup>122</sup> and Sn<sup>124</sup>).

# **CD** Format and Layout

The CDs were written using ISO 9660 format that can be read on almost any computer. One restriction of the ISO 9660 format is that it is similar to DOS diskettes, in that it does not distinguish between upper and lower case characters. Therefore when the data is read from the CDs, on some computers the filenames will end up in upper case, and on other computers they will be lower case.

The three CDs are divided into ten directories,

CD # 1

DOCUMENT	- A copy of this report in various formats.
ORIGINAL	- The original ENDF/B data before it was processed
K0	- 0 Kelvin cross sections
K300	- 300 Kelvin cross sections
CD # 2	
K600	- 600 Kelvin cross sections
K900	- 900 Kelvin cross sections
K1200	- 1200 Kelvin cross sections
CD # 3	
K1500	- 1500 Kelvin cross sections
K1800	- 1800 Kelvin cross sections
K2100	- 2100 Kelvin cross sections

With the exception of DOCUMENT, each of these directories contains 328 files, one file for each evaluation. Each file is a complete ENDF/B "tape" [1], including a starting "tape" identification line, and ending with a "tape" end line [1]. In this form, each file can be used by a wide variety of available computer codes that treat data in the ENDF/B format, e.g., all of the PREPRO codes.

### The Effects of Temperature and Doppler Broadening

For those readers who are not familiar with the effects of temperature and Doppler broadening on neutron cross sections and transport, I suggest that you read references [3] and [4], listed below.

Users of neutron cross sections should be aware that there are several important effects of temperature and Doppler broadening,

1) There is the well known effect in the neutron resonance region, where as the temperature increases resonances become broader, hence the name Doppler broadening. Figure 1 illustrates the effect of temperature on the  $U^{238}$  capture cross section. From this figure we can see that as temperature increases the peaks of the resonances become lower, and the minima between resonances become higher. At extremely high temperature the entire resonance structure disappears and the cross sections approaches a simple 1/v (where v is the neutron speed) shape. This temperature effect will have a very important effect on resonance self-shielding in any neutron transport calculation.

2) Another, less well known, effect of Doppler broadening is at lower energies where as temperature increases the low energy constant scattering cross section increases, and at very low energies approaches a simple 1/v (where v is the neutron speed) shape; this effect is explained in detail in ref [3]. Figure 2 illustrates the effect of temperature on the hydrogen total cross section. From this figure we can see that starting from a "cold" (0 Kelvin) cross section that is constant at about 20 barns, as temperature increases the cross section increases. Compared to the "cold" 20 barn cross section, at thermal energy the Doppler broadened cross section is about 30 barns, i.e., 50 % higher. Note also from this figure that this effect extends well above thermal energy. For example, at 300 Kelvin the thermal energy is 0.0253 eV, but we can see this effect up to about 1 eV. From the lower half of figure 2 we can see that at very low energy the cross section approaches 1/v (where v is the neutron speed) and the cross sections at various temperatures become proportional to one another. This effect on the cross sections at low energy is very important for thermal and low energy neutron systems.

3) Yet another important effect of temperature is that at lower energies neutrons do not slow down in energy as quickly and neutron scatter can even result in the upscatter of neutrons, i.e., when neutrons scatter they can gain, rather than lose, energy. This is a well known effect at low energies, where thermal scattering law data or a free gas model is used to model the interaction of neutrons with target atoms that are moving about with thermal motion. This effect can also be important at higher energies, particularly near narrow resonances, where thermal motion of the target atoms can cause neutrons to slightly upscatter, but even slight upscatter can cause a neutron to scatter from below to above the energy of a very narrow resonance. See reference [4], below for a routine designed to be used in conjunction with the SIGMA1 method of Doppler broadening [3], to handle neutron thermal scattering. This routine [4] is completely compatible for use with the cross sections included here, since these cross sections were Doppler broadened using the SIGMA1 method [3].

The combination of SIGMA1 [3] Doppler broadened cross sections and THERMAL [4] to handle thermal scattering, is currently used in the TART Monte Carlo transport code [5].

### Acknowledgments

I thank Vicki McLane and Marion Blennau, of the National Nuclear Data Center (NNDC), Brookhaven National Laboratory, for supplying the original ENDF/B, Release 8 data, used in this project. I thank Vladimir Pronyaev and Kevin McLaughlin, of the Nuclear Data Section, International Atomic Energy Agency, for supplying the ENDF/B Pre-processing codes, PREPRO2002, used in this project. I thank Bob MacFarlane, Maurice Greene, and Mike Dunn, for benchmarking their cross section processing codes (NJOY and AMPX) against the PREPRO2002 codes. These comparisons have led to significant improvements in the accuracy and reliability of the results produced by all three codes (NJOY, AMPX, PREPRO).

### References

[1] Data Formats and Procedures for the Evaluated Nuclear Data File ENDF-6, BNL-NCS-44945, Rev. 11/95, edited by V. McLane, C.L. Dunford, P.F. Rose, National Nuclear Data Center, Brookhaven National Laboratory

[2] "PREPRO2002: The 2002 ENDF/B Pre-Processing Codes," by D.E. Cullen, Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria, IAEA-NDS-39, Rev. 11, April 1, 2002.

[3] "Exact Doppler Broadening of Tabulated Cross Sections," by D.E. Cullen and C.R. Weisbin, Nuclear Science and Engineering 60, p. 199 (1975)

[4] "THERMAL: A Routine Designed to Calculate Neutron Thermal Scattering," by D.E. Cullen, Lawrence Livermore National Laboratory, UCRL-ID-120560-Rev-1, Sept. 1995.

[5] "TART2002: A Coupled Neutron-Photon 3-D, Time Dependent, Combinatorial Geometry Monte Carlo Transport Code," by D.E. Cullen, Lawrence Livermore National Laboratory, UCRL-ID-126455, Rev. 4, November, 2002.

# ENDF/B-VI Release 8 Library (Z = 1 to 51) New Release 8 Evaluations in RED

Filename	Material	Filename	Material	Filename	Material
ZA001001	1-н -1	ZA028062	28-Ni-62	ZA042099	42-Mo-99
ZA001002	1-н -2	ZA028064	28-Ni-64	ZA042100	42-Mo-100
ZA001003	1-н -3	ZA029063	29-Cu-63	ZA043099	43-Tc-99
ZA002003	2-He-3	ZA029065	29-Cu-65	ZA044096	44-Ru-96
ZA002004	2-He-4	ZA031000	31-Ga-Nat	ZA044098	44-Ru-98
ZA003006	3-Li-6	ZA032072	32-Ge-72	ZA044099	44-Ru-99
ZA003007	3-Li-7	ZA032073	32-Ge-73	ZA044100	44-Ru-100
ZA004009	4-Be-9	ZA032074	32-Ge-74	ZA044101	44-Ru-101
ZA005010	5-в -10	ZA032076	32-Ge-76	ZA044102	44-Ru-102
ZA005011	5-B -11	ZA033075	33-As-75	ZA044103	44-Ru-103
ZA006000	6-C -Nat	ZA034074	34-Se-74	ZA044104	44-Ru-104
ZA007014	7-N -14	ZA034076	34-Se-76	ZA044105	44-Ru-105
ZA007015	7-N -15	ZA034077	34-Se-77	ZA044106	44-Ru-106
ZA008016	8-0 -16	ZA034078	34-Se-78	ZA045103	45-Rh-103
ZA008017	8-0 -17	ZA034080	34-Se-80	ZA045105	45-Rh-105
ZA009019	9-F -19	ZA034082	34-Se-82	ZA046102	46-Pd-102
ZA011023	11-Na-23	ZA035079	35-Br-79	ZA046104	46-Pd-104
ZA012000	12-Mg-Nat	ZA035081	35-Br-81	ZA046105	46-Pd-105
ZA012024	12-Mg-24	ZA036078	36-Kr-78	ZA046106	46-Pd-106
ZA013027	13-Al-27	ZA036080	36-Kr-80	ZA046107	46-Pd-107
ZA014000	14-Si-Nat	ZA036082	36-Kr-82	ZA046108	46-Pd-108
ZA014028	14-Si-28	ZA036083	36-Kr-83	ZA046110	46-Pd-110
ZA014029	14-Si-29	ZA036084	36-Kr-84	ZA047107	47-Ag-107
ZA014030	14-Si-30	ZA036085	36-Kr-85	ZA047109	47-Ag-109
ZA015031	15-P -31	ZA036086	36-Kr-86	ZA047111	47-Ag-111
ZA016000	16-S -Nat	ZA037085	37-Rb-85	ZA048106	48-Cd-106
ZA016032	16-S -32	ZA037086	37-Rb-86	ZA048108	48-Cd-108
ZA017000	17-Cl-Nat	ZA037087	37-Rb-87	ZA048110	48-Cd-110
ZA017035	17-C1-35	ZA038084	38-Sr-84	ZA048111	48-Cd-111
ZA017037	17-C1-37	ZA038086	38-Sr-86	ZA048112	48-Cd-112
ZA018040	18-Ar-40	ZA038087	38-Sr-87	ZA048113	48-Cd-113
ZA019000	19-K -Nat	ZA038088	38-Sr-88	ZA048114	48-Cd-114
ZA019041	19-K -41	ZA038089	38-Sr-89	ZA048115.M	48-Cd-115m
ZA020000	20-Ca-Nat	ZA038090	38-Sr-90	ZA048116	48-Cd-116
ZA021045	21-Sc-45	ZA039089	39-Y -89	ZA049000	49-In-Nat
ZA022000	22-Ti-Nat	ZA039090	39-Y -90	ZA049113	49-In-113
ZA022046	22-Ti-46	ZA039091	39-Y -91	ZA049115	49-In-115
ZA022047	22-T1-47	ZA040000	40-Zr-Nat	ZA050112	50-Sn-112
ZA022048	22-T1-48	ZA040090	40-Zr-90	ZA050114	50-Sn-114
ZA022050	22-T1-50	ZA040091	40-Zr-91	ZA050115	50-Sn-115
ZA023000	23-V -Nat	ZA040092	40-Zr-92	ZA050116	50-Sn-116
ZA024050	24-Cr-50	ZA040093	40-2r-93	ZA050117	50-Sn-117
ZA024052	24-Cr-52	ZA040094	40-2r-94	ZA050118	50-Sn-118
ZA024053	24-Cr-53	ZA040095	40-2r-95	ZA050119	50-Sn-119
ZAU24054	24-Cr-54	ZAU40096	40-2r-96	ZA050120	50-Sn-120
ZAU25055	25-Mn-55	ZAU41093	41-ND-93	ZAU50122	50-Sn-122
2AU26054	20-re-54 26 Ec 56	ZAU41094	41-ND-94	ZAUSUIZS	50-Sn-123
ZAU26056	20-Fe-50	ZA041095	41-ND-95	ZA050124	50-Sn-124
2AU20U3/	20-re-3/ 26-re 59	ZAU42000	42-Mo-Nat	ZAUDU125	50-Sn-125
2AU26058	20-re-50 27 Co 50	ZAU42U92	42-MO-92	ZAU5U126	50-Sn-120
2AUZ/U39	27-00-39 29-Ni 59	2AU42U94 77042005	42-Mo 05	2AU31121 7A051133	51-5D-121
2AU28U38	20-N1-30 20-N; 50	ZAU42095	42-MO-95	ZAUDII23 73051104	51-5D-123
2AU20039	20-N1-39 28-Ni-60	2AU42U90 73042097	42-MO-90	ZAUDIIZ4 73051125	51_9b_124
2AU28080	20-N1-00	2AU42U9/ 77042099	42-M0-9/	2AU31123	31-20-172
7407000T	70-NT-0T	44042030	4Z-MO-30		

# ENDF/B-VI Release 8 Library (Z = 51 to 99) New Release 8 Evaluations in RED

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ZA055135 $55-cs-135$ ZA065159 $65-rb-160$ ZA094240 $94-Pu-240$ ZA055136 $55-cs-136$ ZA065160 $65-rb-160$ ZA094241 $94-Pu-241$ ZA055137 $55-cs-137$ ZA066160 $66-Dy-160$ ZA094242 $94-Pu-242$ ZA056134 $56-Ba-134$ ZA066161 $66-Dy-161$ ZA094243 $94-Pu-244$ ZA056135 $56-Ba-135$ ZA066162 $66-Dy-162$ ZA094244 $94-Pu-244$ ZA056136 $56-Ba-136$ ZA066163 $66-Dy-163$ ZA095241 $95-Am-241$ ZA056137 $56-Ba-137$ ZA066164 $66-Dy-165$ ZA095242 $95-Am-242$ ZA056138 $56-Ba-138$ ZA067165 $67-Ho-165$ ZA095242 $95-Am-242$ ZA056140 $56-Ba-140$ ZA068166 $68-Er-166$ ZA095243 $95-Am-243$ ZA057139 $57-La-139$ ZA068167 $68-Er-167$ ZA096241 $96-Cm-241$ ZA058140 $58-ce-140$ ZA071175 $71-Lu-175$ ZA096242 $96-Cm-242$ ZA058141 $58-ce-140$ ZA072174 $72-Hf-Nat$ ZA096245 $96-Cm-246$ ZA058142 $58-ce-143$ ZA072176 $72-Hf-176$ ZA096245 $96-Cm-246$ ZA059141 $59-Pr-141$ ZA072177 $72-Hf-178$ ZA096246 $96-Cm-246$ ZA059141 $59-Pr-143$ ZA072178 $72-Hf-179$ ZA096247 $96-Cm-246$ ZA059143 $59-Pr-143$ ZA072179 $72-Hf-179$ ZA096248 $96-Cm-246$ ZA059143 $59-Pr-143$ ZA072179 $72-Hf-179$ ZA096248 $96-Cm-246$ </td <td>ZA055134</td> <td>55-Cs-134</td> <td>ZA064160</td> <td>64-Gd-160</td> <td>ZA094239</td> <td>94-Pu-239</td>	ZA055134	55-Cs-134	ZA064160	64-Gd-160	ZA094239	94-Pu-239
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ZA05613556-Ba-135ZA06616266-Dy-162ZA09424494-Pu-244ZA05613656-Ba-136ZA06616366-Dy-163ZA09524195-Am-241ZA05613756-Ba-137ZA06616466-Dy-164ZA09524295-Am-242ZA05613856-Ba-138ZA06716567-Ho-165ZA09524295-Am-242mZA05614056-Ba-140ZA06816668-Er-166ZA09524395-Am-243ZA05713957-La-139ZA06816768-Er-167ZA09624196-Cm-241ZA05714057-La-140ZA07117571-Lu-175ZA09624396-Cm-242ZA05814058-Ce-140ZA07117671-Lu-176ZA09624396-Cm-243ZA05814158-Ce-141ZA07200072-Hf-NatZA09624496-Cm-244ZA05814358-Ce-143ZA07217672-Hf-176ZA09624596-Cm-246ZA05814458-Ce-144ZA07217772-Hf-176ZA09624696-Cm-246ZA05814359-Pr-141ZA07217772-Hf-178ZA09624796-Cm-248ZA05914359-Pr-142ZA07217972-Hf-178ZA09624896-Cm-248ZA05914359-Pr-142ZA07217972-Hf-179ZA09624998-Cf-249ZA06014260-Nd-142ZA07318173-Ta-181ZA09825098-Cf-250ZA06014360-Nd-144ZA07400074-WNatZA09825198-Cf-252ZA06014460-Nd-144ZA07400074-WNatZA09825398-Cf-253ZA06014560-Nd-145ZA07418274-W182	ZA056134	56-Ba-134	ZA066161	66-Dy-161	ZA094243	94-Pu-243
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ZA060142         60-Nd-142         ZA073181         73-Ta-181         ZA098250         98-Cf-250           ZA060143         60-Nd-143         ZA073182         73-Ta-182         ZA098251         98-Cf-251           ZA060144         60-Nd-144         ZA074000         74-W -Nat         ZA098252         98-Cf-252           ZA060145         60-Nd-145         ZA074182         74-W -182         ZA098253         98-Cf-253           ZA060146         60-Nd-145         ZA074182         74-W -182         ZA098253         98-Cf-253	ZA059143	59-Pr-143	ZA072180	72-Hf-180	ZA098249	98-Cf-249
ZA060143         60-Nd-143         ZA073182         73-Ta-182         ZA098251         98-Cf-251           ZA060144         60-Nd-144         ZA074000         74-W -Nat         ZA098252         98-Cf-252           ZA060145         60-Nd-145         ZA074182         74-W -Nat         ZA098253         98-Cf-253           ZA060146         60-Nd-145         ZA074182         74-W -182         ZA098253         98-Cf-253	ZA060142	60-Nd-142	ZA073181	73-Ta-181	ZA098250	98-Cf-250
ZA060144         60-Nd-144         ZA074000         74-W -Nat         ZA098252         98-Cf-252           ZA060145         60-Nd-145         ZA074182         74-W -182         ZA098253         98-Cf-253           ZA060146         60-Nd-145         ZA074182         74-W -182         ZA098253         98-Cf-253	ZA060143	60-Nd-143	ZA073182	73-Ta-182	ZA098251	98-Cf-251
ZA060145 60-Nd-145 ZA074182 74-W -182 ZA098253 98-Cf-253	ZA060144	60-Nd-144	ZA074000	74-W -Nat	ZA098252	98-Cf-252
	ZA060145	60-Nd-145	ZA074182	74-W -182	ZA098253	98-Cf-253
ZAUDU140 DU-NQ-140 ZAU/4183 /4-W -183 ZAU99253 99-ES-253	ZA060146	60-Nd-146	ZA074183	74-w -183	ZA099253	99-Es-253
ZA060147 60-Nd-147 ZA074184 74-W -184	ZA060147	60-Nd-147	ZA074184	74-W -184		



#### Fig.1: Effect of Doppler Broadening on Resonance Cross Sections

#### Fig.2: Effect of Doppler Broadening on Low Energy Cross Sections



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