

Present Status of JENDL Project

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1. JENDL-3 revision 3 (JENDL-3.3: General Purpose File)

The second revised version of JENDL-3 (JENDL-3.2) was released in June 1994. It contains the data for 340 nuclides in the energy range from 10^{-5} eV to 20 MeV. The ENDF-6 format was adopted. The pointwise files were also constructed at 0 K and 300 K by using RESEND, RECENT, LINEAR and SIGMA1.

Though JENDL-3.2 gives much better evaluated data than JENDL-3.1, JENDL-3.2 has no covariance matrices. We recognize importance of the covariance matrices. A new working group has been organized in Japanese Nuclear Data Committee (JNDC) for studying of evaluation method of the covariance matrices. To meet the requests from FBR reactor projects, several materials have being compiled by this group.

The benchmark tests have shown that JENDL-3.2 gave much better prediction of various reactor characteristics than JENDL-3.1, though some problems have been pointed out. Up to now a lot of experiences has been piled up. To reflect these feedback information to JENDL-3.3, a new task force was organized to summarize the problems of JENDL-3.2 at April 1996. A report indicating the direction of revision for JENDL-3.2 was submitted to JNDC by the group after one year survey. It was approved by the steering committee of JNDC at March 1997.

The data improvement of JENDL-3.2 has been started at April 1997. JENDL3.3 will be published as a consolidated new version of JENDL by JAERI NDC (Nuclear Data center) with the cooperation of JNDC (Japanese Nuclear Data Committee) in FY2001. It's main features are followings:

- 1) Covariance data supplemented for major elements such as major actinides, structural materials and main coolants for the applications of FBR, LWR and Fusion reactors, to enable the estimation of quantitative contribution of nuclear data uncertainty to design accuracy or safety margin. No covariance data were supplied up to the JENDL-3.2.
- 2) New material evaluations such as Er for burnable poisons in LWR high burn-up applications.

- 3) Adoption of isotope evaluation policy rather than natural element evaluation policy. Up to JENDL-3.2 for natural elements JENDL was prepared by natural element evaluation policy, i.e., for the transport calculations in nuclear reactors, natural elements data are recommended to use and for the dosimetry or activation applications isotope evaluations are recommended to use. We want to keep this isotope evaluation policy as far as possible, for some elements, however, we have to make natural element file due to maintaining the evaluation accuracy.
- 4) Among others, addition of gamma-ray production data for the materials needed in Fusion applications.

5) Individual Evaluation

a. Heavy Nuclides (Modified Cross-sections)

A simultaneous evaluation of fission cross-section of U-233, U-235, U-238, Pu-239, Pu-240 and Pu-241 was made. A least squares method was applied to selected absolute and relative measurements on the fission cross sections. Covariance matrices of the experimental data were constructed from the uncertainty information reported in the references.

U-233: URR(Un-Resolved Resonance), (n,2n), (n,3n) and nu.

U-235: RR(Resolved Resonance) (Leal new evaluation), URR, (n,2n), (n,3n), (n,4n), nu and fission spectrum evaluated by multi-mode fission model.

U-238: (n,2n),(n,3n),(n,4n), capture in MeV range, partial level inelastic scattering.

Pu-240:RR, URR, (n,2n),(n,3n),(n,4n) and partial level inelastic scattering.

Pu-242:RR(fission width), (n,2n),(n,3n) and partial level inelastic scattering.

Problem of neutron emission spectrum is solved by GNASH+GAMFIL calculation.

Capture cross section in MeV range is calculated by newly developed code DSD calculating of Direct/Semi-Direct Capture cross-sections.

b. Medium Mass Nuclides

Na: inelastic cross section (Geel + TNG code calculation).

Ti-46,47,48,49,50: threshold reaction, gamma production, elastic scattering angular distributions.

V: RR, total cross section above 100 keV by Geel data and gamma production data.

Cr-50,52,53,54: RR and gamma production data.

Fe-54,56,57,58: RR, total, capture in MeV range calculated by TNG including pre-equilibrium capture.

Co-59: RR, total, gamma-production.

Ni-58,60,61,62,64: inelastic, threshold reaction, neutron emission spectra using SINCROS code.

Nb-93: capture gamma reflecting pre-equilibrium.

W-182,183,184,186: RR, threshold reaction, gamma production data.

Er-162,164,166,167,168,170: Complete new evaluation reflecting newly obtained measured data by TIT.

The data will be released after the review including vast range benchmarks for all of the reevaluated nuclides.

2. JENDL Special Purpose Files

The following special purpose files other than JENDL-3.3 general purpose file are being developed in Japan. Their status is given below.

JENDL Fusion File

JENDL Fusion File(JFF) was released at March 1996 to provide precise double-differential neutron and charged particle emission data by using MF6 representation of the ENDF-6 format. The evaluation was made for the data of H, D, Li, Be, C, N, O, ¹⁹F, ²⁷Al, Si, Ca, Ti, Cr, ⁵⁵Mn, Fe, ⁵⁹Co, Ni, Cu, ⁷⁵As, Zr, ⁹³Nb, Mo, Sn, Sb, W, Pb and ²⁰⁹Bi. For H, D, Li, N and O, the data of JENDL-3.2 are directly adopted. The revision works for the nuclides excepting the light mass ones have been performed by the SINCROS-II code system which consists of GNASH, DWUCK, CASTHY and several auxiliary programs. Those results are examined by comparing with DDX measured at Tohoku and Osaka Universities. For the data of light mass nuclei, individual evaluation has been done. A lot of nuclides are adopted as FENDL-2 from this file. Complete version of JFF96 was released in the FY98.

JENDL Actinide File

This file will provide the data of about 90 nuclei in the actinide region from 10^{-5} eV to 20 MeV. Data for about 60 nuclei will be taken from JENDL-3.2 with some modification. We need complete new evaluation work for about 30 nuclei. Up to now the evaluations have been completed for U-235, U-236, U-238, Np-235, Pu-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-244, Pu-246, Am-242, Am-242m, Am-243, Cm-240, Cm-241, Cm-242, Cm-243, Cm-244, Cm-245, Cm-246, Cm-247, Cm-248, Cm-249, Cm-250, Bk-247.

Since 1994, International Science and Technology Center (ISTC) project for Measurements and Evaluation of minor actinide nuclei has been started at Institute of Physics and Power Engineering (IPPE, Obninsk Russia, #304), V.I. Khlopin Radium Institute (KRI, St.Petersburg Russia, #183) and Radiation Physics and Chemistry Problem Institute (RPCPI, Minsk Belarus, #b-03). After that the forth project started to measure fission cross-sections of minor actinides in medium energy range, i.e., 1 to 200 MeV by St.Petersburg Nuclear Physics Institute (PNPI St.Petersburg, #609) And a new project of actinide nuclear data evaluation for Th cycle started this April (RPCPI, Minsk Belarus, #B-404). The results obtained by these projects will be reflected in JENDL Actinide File. The file release will be envisaged in FY2001 material-by-material bases. Summary record about ISTC is given in Appendix A.

JENDL Dosimetry File

The working group on dosimetry in JNDC which is working for JENDL Dosimetry File has been published a new file. The cross section data for more than 20 reactions was revised and their covariance matrices were replaced with new ones. Integral tests were also made. The file was released in FY99 as JENDL-D99 and the data are also released with a CD-ROM. Contents are 67 reactions with pointwise and 641 group structures data.

JENDL Activation Cross Section File

Evaluation and compilation work for JENDL Activation Cross Section File has been completed and released in March 1996 as JENDL-A96. This first version stores the data for 233 nuclei and 1246 reactions. Final report is under preparation. Revision of the files is foreseen near future for the feedback information from the ad hoc group for threshold reaction evaluation working group.

JENDL High Energy Files

The evaluation of data for high energy neutrons and protons has been initiated in JNDC. They will make data files for neutrons and protons up to 50 MeV and about 3 GeV.

The former files will be used for the IFMIF project which JAERI participates. The evaluation of neutron data up to 50 MeV has been made for almost all necessary nuclides. The evaluation results for neutron are being reviewed. After review, the data will be combined with JENDL Fusion File or JENDL-3.2 below 20 MeV. The file release will be envisaged in FY2000.

The latter files will be used for design of accelerators, transmutation systems of high-level waste, medical applications and so on. The evaluations of Al, Si, Cr, Ni, Cu, Pb and Bi isotopes were made for neutron and proton induced reactions up to 3 GeV. The neutron nuclear data for hydrogen are also completed. These data will be reviewed. The file release will be envisaged starting at FY2000.

JENDL PKA/KERMA File

This file stores the spectra of primary knock-on atoms (PKA) and KERMA factors. The data to be stored are created from the data files(JENDL High Energy File) up to 50 MeV made for the IFMIF project. A couple of processing codes to create the file from evaluated nuclear data file, by using the effective single particle emission approximation, have been developed and tested.

The test compilation has been performed from JENDL Fusion File for the 69 isotope data except light mass nuclei below 20 MeV. The file release will be made in FY2000.

JENDL Photonuclear Data File

The evaluation has been finished for 46 isotopes; ^2D , ^{12}C , ^{14}N , ^{16}O , ^{23}Na , $^{24,25,26}\text{Mg}$, ^{27}Al , $^{28,29,30}\text{Si}$, $^{40,48}\text{Ca}$, ^{46}Ti , ^{51}V , ^{52}Cr , ^{55}Mn , $^{54,56}\text{Fe}$, ^{59}Co , $^{58,60}\text{Ni}$, $^{63,65}\text{Cu}$, ^{90}Zr , ^{93}Nb , $^{92,94,96,98,100}\text{Mo}$, ^{133}Cs , ^{160}Gd , $^{182,183,184,186}\text{W}$, ^{197}Au , $^{206,207,208}\text{Pb}$, ^{209}Bi and $^{235,238}\text{U}$ in the gamma-ray energy range up to 140 MeV. Their compilation in the ENDF-6 format and the critical review are in progress. The file will be released in FY2000.

3. Other Activity Relating to Nuclear Data

1) The 1999 Symposium on Nuclear Data

The 1999 Symposium on Nuclear Data was held at Tokai Research Establishment, Japan Atomic Energy Research Institute (JAERI), on 18th and 19th of November 1999. Japanese Nuclear Data Committee and Nuclear Data Center, JAERI organized this symposium. In the oral sessions, presented were 18 papers on keynote address, nuclear data measurement for long-lived RI and in medium energy region, status of JENDL, international session and other topics. In the poster session, presented were 46 papers concerning experiments, evaluations, benchmark tests and on-line database on nuclear data. Those presented papers are compiled in the proceedings published as JAERI-conf 2000-005, INDC(JPN)-183/U (2000). Total of 157 attendees including 17 foreigners, 102 outside JAERI were gathered.

Fig.1 Expected Contents of JENDL Actinoid File

| | | | | | | | | | |
|---|-------------------|------|---|-------------------------------|----------|---|-------------------------------|---|------|
| | ²⁰⁸ Tl | K | | ²³⁴ U | J3 | ■ | ²⁴³ Cm | M | J33A |
| | ²¹⁰ Pb | K | ■ | ²³⁵ U | J33A | ■ | ²⁴⁴ Cm | L | J33A |
| | ²¹⁰ Bi | K | | ²³⁶ U | J33A | ■ | ²⁴⁵ Cm | M | J33A |
| | ²¹⁰ Po | K | | ²³⁷ U | TN, J3 | ■ | ²⁴⁶ Cm | M | J33A |
| | ²²² Rn | K | ■ | ²³⁸ U | J3.3A | | ²⁴⁷ Cm | L | J33A |
| | ²²³ Ra | J3 | | ²³⁴ Np | | | ²⁴⁸ Cm | L | J33A |
| | ²²⁴ Ra | J3 | | ²³⁵ Np | J33A | | ²⁴⁹ Cm | L | J33A |
| | ²²⁵ Ra | J3 | | ²³⁶ Np | TN, J3 | | ²⁵⁰ Cm | L | J33A |
| | ²²⁶ Ra | J3 | ■ | ²³⁷ Np | I J3 | | ²⁴⁵ Bk | L | |
| | ²²⁸ Ra | K | ■ | ²³⁸ Np | M TN, J3 | | ²⁴⁶ Bk | L | |
| | ²²⁵ Ac | J3 | | ²³⁹ Np | J3 | | ²⁴⁷ Bk | L | J33A |
| | ²²⁶ Ac | J3 | | ²³⁶ Pu | J3 | | ²⁴⁸ Bk | L | |
| | ²²⁷ Ac | J3 | | ²³⁷ Pu | N J33A | | ²⁴⁹ Bk | L | J3 |
| | ²²⁷ Th | J3 | ■ | ²³⁸ Pu | M J33A | | ²⁵⁰ Bk | | J3 |
| | ²²⁸ Th | J3 | ■ | ²³⁹ Pu | J33A | | ²⁴⁶ Cf | | |
| | ²²⁹ Th | J3 | ■ | ²⁴⁰ Pu | J3.3A | | ²⁴⁸ Cf | | |
| | ²³⁰ Th | J3 | ■ | ²⁴¹ Pu | J3.3A | | ²⁴⁹ Cf | L | J3 |
| | ²³¹ Th | K | ■ | ²⁴² Pu | M J3 | | ²⁵⁰ Cf | L | J3 |
| ■ | ²³² Th | J3.3 | | ²⁴⁴ Pu | N J33A | | ²⁵¹ Cf | L | J3 |
| | ²³³ Th | J3 | | ²⁴⁶ Pu | J33A | | ²⁵² Cf | L | J3 |
| | ²³⁴ Th | J3 | | ²⁴⁷ Pu | | | ²⁵³ Cf | | |
| | ²²⁹ Pa | K | ■ | ²⁴¹ Am | M J3 | | ²⁵⁴ Cf | | J3 |
| | ²³⁰ Pa | K | ■ | ²⁴² Am | M J33A | | ²⁵¹ Es | | |
| | ²³¹ Pa | J3 | ■ | ^{242^m} Am | M J33A | | ²⁵² Es | | |
| | ²³² Pa | J3 | ■ | ²⁴³ Am | M J33A | | ²⁵³ Es | | |
| | ²³³ Pa | J3 | ■ | ²⁴⁴ Am | J3 | | ²⁵⁴ Es | | J3 |
| | ²³⁰ U | | | ^{244^m} Am | J3 | | ^{254^m} Es | | |
| | ²³¹ U | | ■ | ²⁴⁰ Cm | L J33A | | ²⁵⁵ Es | | J3 |
| | ²³² U | J3 | | ²⁴¹ Cm | L J33A | | ²⁵⁵ Fm | | J3 |
| ■ | ²³³ U | J3.3 | ■ | ²⁴² Cm | L J33A | | | | |

- most important nuclide;
- important nuclide;
- J3 JENDL-3.2 data available;
- J3.3 JENDL-3.3;
- J33A JENDL-3.3 & Actinide File (Evaluation completed);
- M Maslov's evaluation;
- I Ignatyuk's evaluation;
- TN Nakagawa's evaluation;
- K Nakajima's evaluation;
- L Liu Tong and Nakagawa's evaluation.

Appendix A. Summary of ISTC project that JAERI participated with some funds, relating to the JENDL Actinide File

Objective: Improvement of minor actinide data for transmutation projects using actinide burner reactors or accelerator driven spallation neutron sources. The data needed are for $^{237, 238}\text{Np}$, $^{238, 242}\text{Pu}$, $^{241, 242g, 242m, 243}\text{Am}$ and $^{242, 243, 244, 245, 246}\text{Cm}$. The corresponding data for most important cross sections should be obtained on the basis of ISTC.

ISTC projects:

- “Measurements of the fission neutron spectra for minor actinides”. V.I.Khlopin Radium Institute (KRI St.Petersburg Russia, # 183-p), 1995-1997.

High precision measurements of the fission neutron spectra for spontaneous fission of Cm-244, -246, Pu-240 -242, and that for thermal induced fission of Cm-243, -245

- “Measurements and analysis of basic nuclear data for minor actinides”. Institute of Physics and Power Engineering (IPPE Obninsk, #304-p), 1995-1996.

Precise measurements of the fission cross sections of Cm-243, -244, -245, -246, -247, -248m, Am-242m, Pu-238.

Measurements of fission product yields for Np-237.

Measurements of inelastic scattering and prompt fission neutron spectra for Np-237.

Measurements of delayed neutron yields and it's 6-group constants for Np-237 fast neutron fission.

Critical comparison between evaluated data for BROND-2, JENDL-3 and ENDF/B-VI and deduction of recommended values.

- “Evaluation of actinide nuclear data”. Radiation Physics and Chemistry Problems Institute (RPCPIMinsk Belarus, # b-03), 1995-1998.

Complete new evaluations of neutron cross sections for Cm-243, -245 -246, Am-241, 242, 242m, 243, Np-238, Pu-238, -242.

- “Neutron induced fission cross-sections of some actinides heavy nuclei in energy region 1-200 MeV. Petersburg Nuclear Physics Institute (PNPI St.Petersburg, #609), 1996-1999.

Measurements of neutron fission cross-section of U-233, U-238, Np-237, Th-232, Pu-239, Pb and Bi in the energy range up to 200 MeV.

Relative measurements to U-235 fission with accuracy 3-10%.

Evaluation of above listed cross section for neutron and proton induced fissions in the energy range 20-200 MeV.

Other ISTC Project relating to Nuclear Data:

- “Benchmark Data on Gamma-ray Production For Fusion Application”, Institute of Physics and Power Engineering (IPPE Obninsk, #731), 1997-2000

Measurements and evaluations of the benchmark data on gamma-ray production cross section in the fast neutron induced reactions for materials that are most important for fusion power applications.

Measurements anticipated are 32 structure materials at 14 MeV. (For 1st year: Li-6,-7, B-10,-11, C, N, O, Al, Si, Fe, Cu, Mo,W, Pb were measured.). The data will be available in EXFOR

Format.

Evaluations in ENDF-6 Format will be made for most important 20 nuclides.

- “Experimental and Theoretical Study of the Yields of Residual Product Nuclei Produced In thin Targets Irradiated by 100-2600 MeV protons”, Federal Scientific Center of Russia Institute for Theoretical and Experimental Physics (ITEP Moscow, #839), 1997-2000.

Residual product nuclei measurements from spallation by high energy proton beam for thin targets of ^{182}W , ^{183}W , ^{184}W , ^{186}W , ^{232}Th , $^{\text{nat}}\text{U}$, ^{99}Tc , ^{59}Co , ^{63}Cu and ^{65}Cu . The proton energies are 100, 150, 200, 800, 1000, 1200, 1400, 1600 and 2600 MeV.

To get the reference data to check the simulation code such as LAHET, ALICE, QMD, etc.

- “Nuclear Physics Investigation Aimed at the Solution of Weapon Plutonium Conversion and Long-lived Radioactive Wastes Transmutation Problems”, Russia Federal Nuclear Center All-Russia Scientific Research of Experimental Physics (VNIIEF Sarov, #1145), 1998-2000.

Measurements of the cross sections necessary for the transmutation technologies and electro-nuclear energy production system on the basis of high-current proton accelerator.

Cross sections of a wide range of isotopes for minor actinides of Np, Pu, Am and Cm in the fast and intermediate neutron spectra.

Thermal cross section for neutron induced fission and radioactive capture of Np-238 ($T_{1/2} = 2.12$ d).

Spectra of fast fission neutrons from Th, U, Np and Pu by 40-200 MeV protons.

- “Evaluation of actinide nuclear data”, Radiation Physics and Chemistry Problems Institute (RPCPI Minsk Belarus, # B-404), 2000-2002.

Complete new evaluations of neutron cross sections for Th-232, Pa-231, Pa-233, U-232, U-233, U-234 up to 20 MeV.

New evaluations of neutron cross sections for U-238 and Pu-239 up to 150 MeV.