Present Status of CENDL Project

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1 General

CENDL is carried out by China Nuclear Data Center and China Nuclear Data Network, China Nuclear Data Committee assumes responsibility the management of CENDL project. The follows are the organization of the committee and the network

Committee Chair:	Dr. Zhao Zhixiang, CIAE
Technical working party:	Evaluation Working Party
	Measurements Working Party.
	Benchmark Working Party.
China Nuclear Data Network:	China Institute of Atomic Energy.
	Peking University,
	Sichuan University.
	Lanzhou University.
	Tsinghua University
	Nankai University,
	Jilin University
	Zhenzhou University ,
	Northwest University and et al

The progress and achievements in China nuclear data field are carried in the issue of Communication of Nuclear Data Progress (CNDP)

2 General purpose file

• CENDL-3.1

CENDL-3.1 includes comprehensive data evaluations for all neutron reactions in the energy range from 10^{-5}eV to 20MeV for 200 nuclides. The ENDF-6 format is adopted, the files 1, 2, 3, 4, 6, 12~15 are included for major fissile nuclide, structure material and light nuclide, files 1, 2, 3, 4, 5 are given for minor fissile and fission production nuclides.

The Nuclides of CENDL-3.1

Nucl.	Content
Light Elements	^{1,2,3}H, ^{3,4}He, ^{6,7}Li, ^{9}Be, ^{10,11}B, ^{12}C, ^{14}N, ^{16}O, ^{19}F, ^{23}Na, ^{nat}Mg, ^{27}Al, ^{nat}Si, ^{31}P, ^{nat}S, ^{nat}Cl, ^{nat}K, ^{nat}Ca
Structural Materials	^{nat}Ti, ^{nat}V, $^{50,52\sim54,nat}$Cr, ^{55}Mn, $^{54,56\sim58,nat}$Fe, ^{59}Co, $^{58,60\sim62,64,nat}$Ni, ^{63,65,nat}Cu, ^{nat}Zn
Fission Products & Medium Elements	^{69,71,nat}Ga, $^{83,84\sim86}$Kr, ^{85,87,nat}Rb, $^{88\sim90}$Sr, ^{89,91}Y, $^{90\sim96,nat}$Zr, ^{93,95}Nb, ^{95,97,98,100,nat}Mo, ^{99}Tc, $^{99\sim105}$Ru, ^{103}Rh, ^{105,108}Pd, ^{107,109,nat}Ag, ^{113,nat}Cd, ^{115,nat}In, ^{nat}Sn, ^{121,123,nat}Sb, ^{130}Te, ^{127}I, $^{124,129,131,132,134\sim136}$Xe, $^{133\sim135,137}$Cs, $^{130,132,134\sim138,nat}$Ba, ^{139}La, $^{140\sim142,144}$Ce, ^{141}Pr, $^{142\sim148,150,nat}$Nd, ^{147,148,149}Pm, $^{144,147\sim152,154,nat}$Sm, $^{151,153\sim155,nat}$Eu, $^{152,154\sim158,160,nat}$Gd, ^{164}Dy

Nucl.	Content
Heavy Elements	^{nat}Lu,^{nat}Hf,^{181}Ta,^{nat}W,^{197}Au,^{nat}Hg,^{nat}Ti,^{204,206,207,207,nat}Pb,
Actinides	^{233,234,235,236,238,239}U, ^{237}Np,^{238,239,240,241,242}Pu, ^{241,242}Am, ^{249}Bk,^{249}Cf

- **Data Validation**

CENDL-3.0 was was completed and distributed inside of China as an internal test version in 2001. The criticality benchmark testing had been carried out for various types of fast and thermal reactors and neutron leakage spectra experiments。The following material was tested: ^{9}Be, ^{12}C, ^{14}N, ^{16}O, Al, Si, Ti, Si, Fe, Cu, Nb, Mo, Zr, W, Pb, U, Pu, Np. The benchmark calculations generally were performed by using a continuous-energy Monte Carlo Code(MCNP). The benchmark testing for some fission product (FP) nuclides of CENDL-3.0 also had been done with the experiment performed on the CFRMF (Coupled Fast Reactivity Measurement Facility).

From the benchmark results, we can say CENDL-3.0 generally gives better k_{eff} values, compared with CENDL-2.1. As far as the neutron leakage spectra test of some nuclides, the test results show that underestimation of discretely inelastic scattering was observed, slightly overestimate for (n,2n) double differential cross sections and continuum inelastic cross-section were also found in the calculated results based on some nuclides of CENDL-3.0. According to the analysis of the test results, it can be seen that the evaluation of FP from CENDL-3.0 is better. This is because of the updated experimental data used in the CENDL-3.0 FP evaluations. Fig 1~5 and Table 1 show partial benchmarks test results

Validation of CENDL-3.0 for uranium isotope, plutonium isotope, beryllium and lead etc was done according to the benchmarks testing results.

However, further improvements of some nuclides data form CENDL-3.0 are expected to solve the following problems: 1) the systematic overestimated of k_{eff} values based on CENDL-3.0 for all ^{233}U solution thermal benchmarks. This may indicate either a problem with the ^{233}U capture cross section of CENDL-3.0 or with the harden neutron spectrum of ^{233}U from CENDL-3.0. 2) Underestimation of k_{eff} from CENDL-3.0 for critical assembly with zirconium hydride moderator, maybe the underestimated discrete inelastic scattering of CENDL-3.0 zirconium leads to higher average energy of neutron and smaller k_{eff}. For zirconium neutron leakage spectra experiment, underestimate relative to experiment from CENDL-3.0 zirconium is still existed though little improvement has been made. 3) Overestimation of continuum inelastic scattering and (n, 2n) reaction should be reduced in future revised version. Discrete inelastic scattering should also be paid attention. These are common problems for some nuclides neutron leakage spectra test. 4) The modification of elastic scattering angular distribution of some structure nuclides should be done in future revised version.

As far as some nuclides of CENDL-3.0, however, further test is necessary. Because the previous benchmark calculations were made only for limited integral experiments, and no further benchmarks test has been done after the modification of some nuclides was done.

Table 1 Integral Parameter Comparison

Lattices	Integral Parameter	Experiment	CENDL-3.0	ENDF/B6.2
	keff	1.0000 (~.30)	0.9975	0.98782
	ρ^{28}	1.32 (~1.6)	1.3608	1.377
TRX-1	δ^{25}	0.0987 (~1.0)	0.09803	0.0977

Lattices	Integral Parameter	Experiment	CENDL-3.0	ENDF/B6.2
	δ^{28}	0.0946 (~4.3)	0.09622	0.0974
	C*	**0.797 (~1.0)**	0.7922	0.808
TRX-2	keff	1.0000 (~.10)	0.99823	0.99015
	ρ^{28}	0.837 (~1.9)	0.8530	0.863
	δ^{25}	0.0614 (~1.3)	0.06201	0.0600
	δ^{28}	0.0693 (~5.1)	0.06811	0.0690
	C*	0.647 (~.93)	0.6387	0.650
BAPL-1	keff	1.0000 (~.10)	1.0023	0.99387
	ρ^{28}	1.390 (~.72)	1.3923	1.429
	δ^{25}	0.084 (~2.4)	0.08199	0.0824
	δ^{28}	0.078 (~5.1)	0.07362	0.0751
	C*	0.0000	0.7972	0.819
BAPL-2	keff	1.0000 (~.10)	1.00213	0.99399
	ρ^{28}	1.120 (~.89)	1.1602	1.188
	δ^{25}	0.068 (~1.5)	0.06695	0.0672
	δ^{28}	0.070 (~5.7)	0.06327	0.0645
	C*	0.0000	0.7274	0.746
BAPL-3	keff	1.0000 (~.10)	1.00209	0.99497
	ρ^{28}	0.906 (~1.1)	0.9130	0.933
	δ^{25}	0.052 (~1.9)	0.0515	0.0516
	δ^{28}	0.057 (~5.3)	0.05184	0.0528
	C*	0.0000	0.6511	0.666
BAPL-trx05	keff	1.0000 (~.05)	0.99925	0.99139
	ρ^{28}	0.0000	1.184	1.177
	δ^{25}	0.0000	0.0626	0.0625
	δ^{28}	0.0630 (~4.8)	0.0576	0.0611
	C*	0.0000	0.747	0.756
BAPL-trx06	keff	1.0000 (~.27)	0.99820	0.99110
	ρ^{28}	0.0000	0.995	0.988
	δ^{25}	0.0000	0.0513	0.0512
	δ^{28}	0.0540 (~5.6)	0.0497	0.0523
	C*	0.0000	0.687	0.696
Average	keff	1.0000	0.99996	0.9920

Note: Keff finite medium effective multiplication factor
ρ28 ratio of epithermal to thermal ^{238}U capture reaction rate,
δ25 ratio of epithermal to thermal ^{235}U fission reaction rate,
δ28 ratio of ^{238}U fission to ^{235}U fission reaction rate,
C* ratio of ^{238}U capture to ^{235}U fission reaction rate

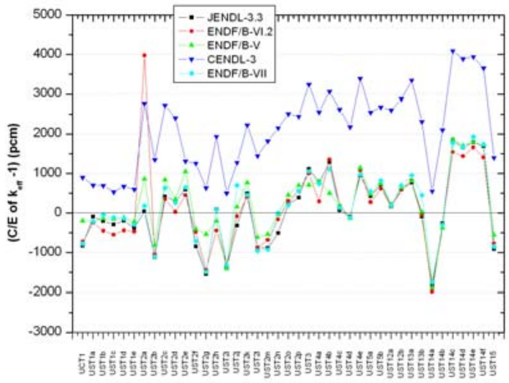

Fig.1 **^{233}U thermal benchmarks C/E-1 (dependence on ^{233}U data)**

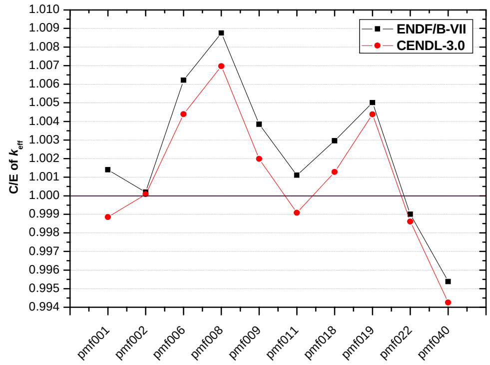

Fig. 2 **C/E values of k_{eff} for ^{239}Pu fast benchmarks**

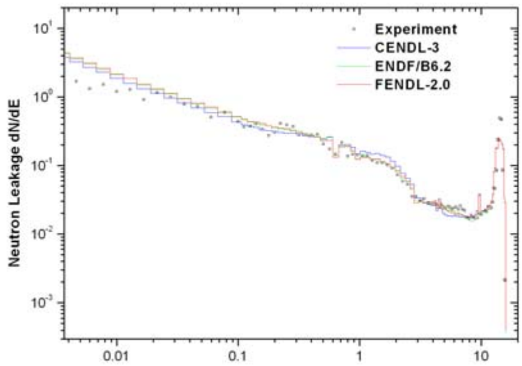

Fig.3 Leakage spectra from beryllium sphere (45.5mm)

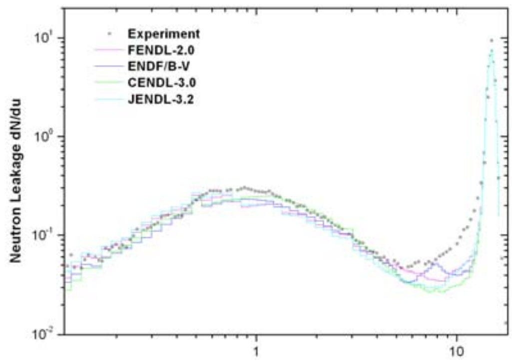

Fig.4 Neutron on leakage spectrum from W pile of 40 cm

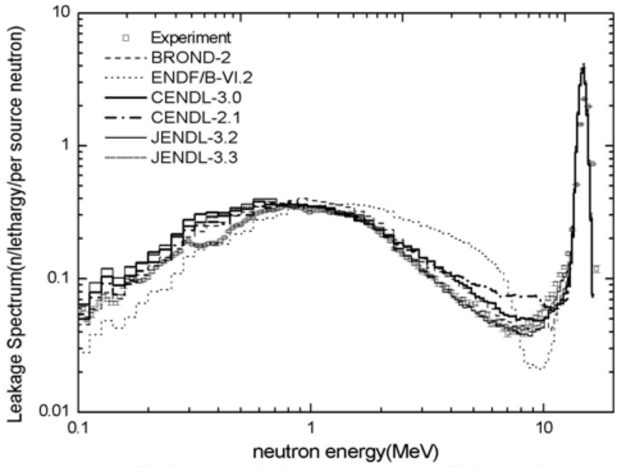

Fig.5 neutron leakage spectra from Zr 61cm pile

• New evaluations

30 new evaluations have been done in the past year. The range of nuclei contains light nuclides, structure material nuclides, fission product nuclides and actinides. The UNF code for nuclear data model calculations with the unified Hauser-Feshbach and exciton model are implemented in the evaluations. The APMN code was used for automatically searching a set of optimal optical potential parameter. A method to set up file-6 of light nuclei for evaluated neutron data in ENDF/B-6 format below 20 MeV has been established and the energy balance was strictly considered. The following shows the results of ^{16}O as an example.

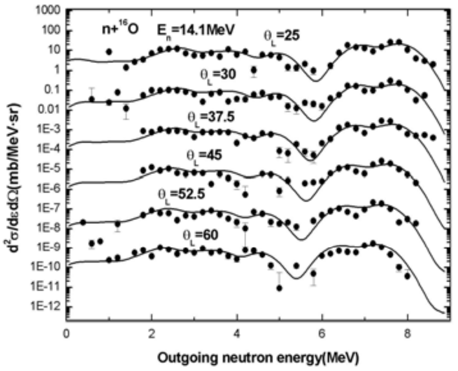

Fig. 6 The energy-angular spectra of 25°, 30°, 37.5°, 45°, 52.5° and 60° at E_n=14.1MeV.

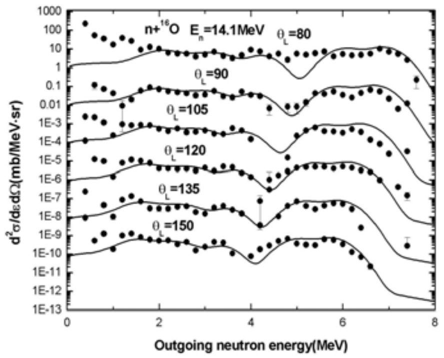

Fig. 7 The energy-angular spectra of 80°, 90°, 105°, 120°, 135° and 150° at E_n=14.1MeV.

• **Covariance**

The cross section covariance data were calculated with R-matrix code RAC for nuclides ^{6,7}Li and ^{10}B. The data are given in INDF/B-6 format and include main cross section: total, elastic, (n,α), (n,α_0), (n,α_1) cross section for ^{10}B, total, elastic, (n,t) cross section for ^{6}Li, total, elastic, (n,n't), inelastic to first and 4.63 MeV levels cross section for ^{7}Li.

A code for evaluating the covariance matrix of experimental data was developed. The covariance data are output in ENDF/B-6 format. The code together with the spline fitting code for multi-sets of correlative data was used to practically evaluate the covariance data for ^{58,60,61,62,64,nat}Ni , ^{63,65,nat}Cu and ^{27}AL , the reasonable results have been got.

3 Nuclear data for ADS

In order to satisfy the need of ADS project of China, a code MEND for calculating the nuclear data in medium energy region has been developed, The following nuclear data have been calculated and evaluated:

Nuclear data for incident neutron from 20 to 250MeV: ^{50,52,53,54}Cr, ^{54,56,57,58}Fe, ^{90,91,92,94,96}Zr, ^{180,182,183,184,186}W, ^{204,206,207,208}Pb, ^{238}U.

Nuclear data for incident proton from theshold energy to 250MeV: ^{54,56,57,58}Fe, ^{180,182,183,184,186}W, ^{204,206,207,208}Pb, ^{209}Bi, ^{238}U.

4 Structure and decay data

CNDC have taken permanent responsibility for evaluating and updating NSDD for A=51, 52 and 195-198.The mass chain A=51 and 67 have been revised using available experimental decay and reaction data, A=67 was published in NDS in 2005 and A=51 have been sent to NNDC in review. Now A=196 was being updated.

The decay data evaluation covers the following nuclides: ^{7}Be, ^{101}Mo, ^{175}Hf, ^{225}Ra, ^{231,232}Th, ^{231,233}Pa and ^{232,233,234,236}U. All evaluations including decay scheme were completed.

5 Fission yield

Based on the experimental data , the systematics on mass distribution of fission product nuclides and the systematics on independent yield were studied respectively. The systematics codes were developed and the parameters were determined by fitting experimental data. Using the codes, the chain yield and its uncertainty of any product nuclide with mass number A can be calculated in the energy region from thermal energy to 20 MeV for ^{235}U and from 1 MeV to 200 MeV for ^{238}U, the independent yield and its uncertainty of any product nuclide with mass number A can be calculated in the energy region from thermal energy to 20 MeV for ^{235}U and ^{239}Pu, from 1 MeV to 20 MeV for ^{238}U.

Cumulative yield data from ^{235}U and ^{238}U fission were evaluated for each about 50 fission product nuclides as a base of updating CENDL/FY and for some practical applications.

6 Nuclear physics basic database

The project is supported by Ministry of science and technology of china, it contains the following data base:

- Nuclear structure and Nuclear Decay database
- Nuclear Model Parameters and computing programs library
- Special Purpose database
- Exfor Database
- Evaluation Nuclear data library

7 International Co-operation:

At present, The scientists of CNDC participate in three IAEA Coordinated Research Projects: Evaluated Nuclear Data for Thorium-Uranium Fuel Cycle; Parameters for Calculation of Nuclear Reactions of Relevance to Non-energy Applications (RIPL-3); Updated Decay Data Library for Actinides.

8 The meeting and symposium

- The Technical Meeting of Nuclear Decay Data Measurement, May 25-30, 2005 Zhangjiajie, Hunan Province
- The symposium on Structure and decay data, July 23-27, 2005 Guiyang, Guizhou Province
- The Celebration Conference of 30^{th} Anniversary of China Nuclear Data Center and 2005 Nuclear Data Conference of China, 8-10 Aug. 2005 Xining Qinghai Province.

9 Future development

We will begin a new five years paln for the year 2006 to 2010, it has not been approved finally. The following is planned:

- New evaluation for some nuclides in the energy range from 10^{-5}eV to 30MeV.
- Revision and validation of the evaluations.
- Inclusion of more covariance data in the evaluations
- Evaluations for resonance parameters.