The Benchmark Testing of ^{9}Be of CENDL-3

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【abstract】 *CENDL-3, the latest version of China Evaluated Nuclear Data Library was finished. The data of ^{9}Be were updated, and distributed for benchmark analysis recently. The calculated results were presented, and compared with the experimental data and the results based on other evaluated nuclear data libraries. The results show that CENDL-3 is better than others for most benchmarks.*

Introduction

The ^{9}Be data of CENDL-3 were updated again recently by Prof. ZHANG Jingshang et. al. by using a new approach[1]. In order to test the reliability of ^{9}Be data of CENDL-3, some benchmarks were used. In addition to the values of k_{eff} , the leakage spectrum of Be sphere was calculated. The data processing was carried out by using the NJOY[2] nuclear data processing code system. The calculations and analysis of benchmarks were done with Monte Carlo code MCNP[3]. The comparisons of calculated results with the results obtained with other evaluated nuclear data libraries were also performed. The aim of the comparison between different evaluated nuclear data libraries is to identify the source of the discrepancies with the experimental results.

1 Data Processing

The cross sections from CENDL-3, ENDF/B-6.4, JENDL-3.2 and CENDL-2.1 were processed with the NJOY97 code system in the MCNP-format of continuous-energy. The cross sections from the ENDF/B-5 in the MCNP-format of MCNP library [4] were also used for the benchmarks calculations.

2 Data Testing Calculations

The continuous energy Monte Carlo code MCNP was used to do the benchmark testing calculations. The characteristics of the benchmark assemblies are shown in Table 1 and Table 2 briefly. The benchmarks for the calculations of k_{eff} are given in the International Handbook of Evaluation Criticality Safety Benchmark Experiments[5]. The benchmark for the calculation of the leakage of Be sphere surface is a 50 cm radius beryllium sphere.[6] The calculated results of k_{eff} are given in Table 3 and Table 4. The leakage spectrum of Be sphere surface is given in Fig. 1.

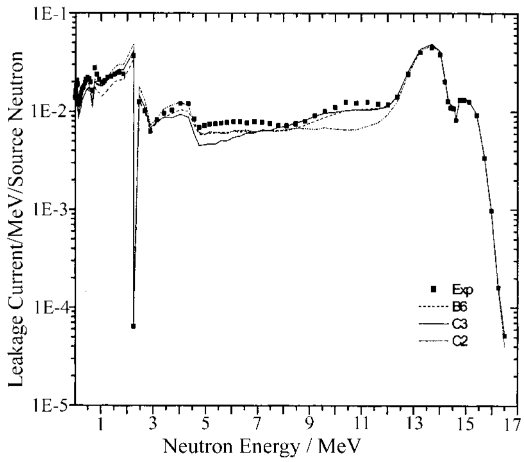

Fig.1 The leakage spectrum of Be sphere surface

3 Discussions

It can be seen that CENDL-3 shows good agreements with experiment for most assemblies. The calculated k_{eff} for the assembly of spheres of plutonium surrounded by highly enriched uranium and reflected by beryllium or beryllium oxide is slightly lower compared with other evaluated libraries; this may be due to the uranium data are from ENDF/B-5. While uranium data were used from CENDL-3, the calculated results would be better for the assembly. The calculated results based on CENDL-3 are significantly improved compared with the results based on CENDL-2.1, which is the old version of CENDL. ENDF/B-6 also gives better results for most assemblies.

It can be seen in the Fig.1 that CENDL-3 shows good agreement with the experiment, and the ENDF/B-6 is underestimated below 3 MeV. From 3~7.5 MeV, CENDL-3 is underestimated, maybe the original spectrum of Be is soften in the energy region. CENDL-3 also shows good agreement with the experiment above 7.5 MeV, but ENDF/B-6 and CENDL-2.1 are lower in this energy region.

Table 1 Composition of Isotopes (Atom/barn-cm)

Assembles	Core			Reflector		
	Isotope	Composition		Isotope	Composition	
1. A Delta-phase plutonium sphere reflected by beryllium	^{239}Pu	$3.7291*10^{-2}$		Beryllium	$1.1984*10^{-1}$	
	^{240}Pu	$1.9277*10^{-3}$		Oxygen	$1.3776*10^{-3}$	
	^{241}Pu	$1.2196*10^{-4}$				
	Gallium	$1.3628*10^{-3}$				
2. Sphere of plutonium reflected by beryllium	^{239}Pu	$3.3930*10^{-2}$		Be	$1.2081*10^{-1}$	
	^{240}Pu	$3.5043*10^{-3}$		O	$8.2064*10^{-3}$	
	^{241}Pu	$3.9189*10^{-4}$		C	$1.0020*10^{-4}$	
	Ga	$2.2105*10^{-3}$		Fe	$5.0939*10^{-5}$	
	C	$3.0246*10^{-4}$				
	Fe	$3.2525*10^{-4}$				
	W	$7.4100*10^{-5}$				
	Ni	$1.4187*10^{-3}$				
3a. Beryllium reflected cylinders of plutonium	^{239}Pu	$4.4422*10^{-2}$		Beryllium	$1.2099*10^{-1}$	
	^{240}Pu	$2.1326*10^{-3}$		Oxygen	$1.0449*10^{-3}$	
	^{241}Pu	$9.2538*10^{-5}$				
	C	$1.9515*10^{-4}$				
	Fe	$8.1943*10^{-5}$				
3b. Beryllium oxide reflected cylinders of plutonium	^{239}Pu	$4.4422*10^{-2}$		Beryllium	$6.9041*10^{-2}$	
	^{240}Pu	$2.1326*10^{-3}$		Oxygen	$6.9041*10^{-2}$	
	^{241}Pu	$9.2538*10^{-5}$				
	C	$1.9515*10^{-4}$				
	Fe	$8.1943*10^{-5}$				
4a. Highly enriched uranium-233 spheres reflected by beryllium	^{233}U	$4.7253*10^{-2}$		Beryllium	$1.1984*10^{-1}$	
	^{234}U	$5.2705*10^{-4}$		Oxygen	$1.3776*10^{-3}$	
	^{238}U	$3.2975*10^{-5}$				
4b. Highly enriched uranium-233 spheres reflected by beryllium	^{233}U	$4.7312*10^{-2}$		Beryllium	$1.1984*10^{-1}$	
	^{234}U	$5.2770*10^{-4}$		Oxygen	$1.3776*10^{-3}$	
	^{238}U	$3.3015*10^{-5}$				
5a,5b. Beryllium reflected and beryllium oxide-reflected cylinders of highly enriched uranium		Bottom	Top		Bottom	Top
					Be reflector	
	^{235}U	$4.5798*10^{-2}$	$4.5754*10^{-2}$	Beryllium	$1.2149*10^{-1}$	$1.2049*10^{-1}$
	^{238}U	$1.3387*10^{-3}$	$1.3374*10^{-3}$	Oxygen	$1.0492*10^{-3}$	$1.0406*10^{-3}$
	^{234}U	$5.6819*10^{-4}$	$5.6764*10^{-4}$		BeO reflector	
	^{12}C	$1.0276*10^{-4}$	$1.0266*10^{-4}$	Beryllium	$6.8675*10^{-2}$	$6.9459*10^{-2}$
	Fe	$5.0229*10^{-5}$	$5.0180*10^{-5}$	Oxygen	$6.8675*10^{-2}$	$6.9459*10^{-2}$
	W	$1.2206*10^{-6}$	$1.2194*10^{-6}$			
6. ^{235}U（94％）spheres surrounded By beryllium	^{234}U	$4.8554*10^{-4}$		Beryllium	$1.2295*10^{-1}$	
	^{235}U	$4.4508*10^{-2}$				
	^{238}U	$2.3775*10^{-3}$				

Cont. Table 1

Assembles	Core			Reflector	
	Isotope		Composition		Isotope
	Plutonium Atom Densities			Be reflector	BeO reflector
7a,7b. Spheres of plutonium surrounded by highly enriched uranium and reflected by beryllium or beryllium oxide	^{239}Pu	$3.4304*10^{-2}$	Be	$1.1994*10^{-1}$	$6.7508*10^{-2}$
	^{240}Pu	$3.4950*10^{-3}$	O	$8.1470*10^{-5}$	$6.7508*10^{-2}$
	^{241}Pu	$3.9076*10^{-4}$	C	$9.9480*10^{-5}$	
	Ga	$2.1289*10^{-3}$	Fe		
	C	$3.0536*10^{-4}$			
	Fe	$3.2837*10^{-4}$			
	W	$7.4811*10^{-5}$			
	Ni	$8.6774*10^{-4}$			
	HEU Atom Densities				
	^{235}U	$4.1030*10^{-2}$			
	^{238}U	$4.1009*10^{-3}$			
	^{234}U	$5.2286*10^{-4}$			
	^{236}U	$8.7989*10^{-5}$			
	C	$3.9571*10^{-4}$			
	Fe	$1.3507*10^{-4}$			
	W	$1.2436*10^{-5}$			
	Cu	$7.2150*10^{-4}$			
	Ni	$3.3480*10^{-4}$			
	Duralumin Atom Densities				
	Al	5.8077E-2			
	Mg	1.0332E-3			
	Mn	1.8284E-4			
	Cu	1.1329E-3			
8. Critical experiments performed using spherical composite cores reflected by beryllium	^{239}Pu	$4.5536*10^{-2}$	Be	$1.2295*10^{-1}$	
	^{240}Pu	$2.7719*10^{-3}$			
	^{241}Pu	$1.7313*10^{-4}$			
	^{235}U	$4.4401*10^{-2}$			
	^{238}U	$3.2137*10^{-3}$			

Table 2 The benchmark assemblies reflected by beryllium or beryllium oxide

Assemblies	*w* % (Beryllium)	Reflector Density / g/cm^3	Reflector Thickness / cm
1	98.0	1.83	3.6881
2	98.51	1.8169	5.65
3a	98.49	1.83846	9.995
3b	98.49	2.8675	9.995
4a	98.0	1.83	4.1961
4b	98.0	1.83	2.0447
5a	98.49	1.83	9.995
5b	98.49	2.86	9.995
6	99.058	1.84	4.699
7a	98.49	1.83	9.15
7b	98.49	1.93	9.15
8	100	1.84	16.2

Table 3 The k_{eff} values for assemblies

Assembles	Exp	CENDL3	ENDFB6	ENDFB5	JENDLl3.2	CENDL2.1
1	1.0000	0.99953	0.99946	0.99932	1.0054	1.00082
2	0.9992	0.99995	1.00185	1.00055	1.00713	1.0022
3a	1.0000	1.00413	1.00457	1.00466	1.01000	1.00540
3b	1.0000	0.99691	0.99759	0.99647	1.00166	0.99897
4a	1.0000	0.99527	0.99589	0.99474	0.99930	0.99732
4b	1.0000	0.99722	0.99822	0.99549	1.00322	0.99732
5a	0.9996	0.99752	0.99690	0.99626	1.00179	0.99666
5b	0.9996	1.00221	1.00267	1.00193	1.00568	1.00131
6	1.0000	1.00028	1.00040	0.99987	1.00482	1.00050
7a	0.9993	0.99697	0.99842	0.99734	1.00009	0.99753
7b	0.9993	0.99740	0.99860	0.99942	0.99962	0.99785
8	1.0000	1.00797	1.00783	1.00622	1.01647	1.01150

Table 4 The k_{eff} differences relative to the experimental results (Δk)*

Assembles	Exp	CENDL3	ENDFB6	ENDFB5	JENDL3.2	CENDL2.1
1	1.0000	-47	-54	-68	540	82
2	0.9992	75	265	135	793	300
3a	1.0000	413	457	466	1000	540
3b	1.0000	-309	-241	-353	166	-103
4a	1.0000	-473	-411	-526	-70	-268
4b	1.0000	-278	-178	-451	322	-268
5a	0.9996	-208	-270	-334	219	-294
5b	0.9996	261	307	233	608	171
6	1.0000	28	40	-13	482	50
7a	0.9993	-233	-88	-196	49	-177
7b	0.9993	-177	-70	12	32	-145
8	1.0000	797	783	622	1647	1150

*: Δk in units of 1.E-5. Note: All materials are from ENDF/B-5 except Beryllium, which is from different evaluated data file.

References

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