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THE EVALUATION AND TESTING OF ACTINIDE CROSS SECTION DATA

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ABSTRACT

The neutron cross section data below 10 keV for ^{242}Cm, ^{245}Cm, and ^{249}Bk have been evaluated and put into ENDF/B format. The new evaluations supersede the first release of ENDF/B-V and include both the average neutrons per fission, $\overline{\nu}$, and cross section data for neutron scattering, capture, and fission as functions of energy. The evaluated data are available through the National Nuclear Data Center, Brookhaven National Laboratory. The evaluated cross sections were successfully tested against a limited amount of integral and production data. In addition, the thermal region of the ENDF/B-V evaluation of ^{241}Am was tested against Savannah River Laboratory (SRL) integral data.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Differential and integral neutron cross section data for ^{242}Cm, ^{245}Cm, and ^{249}Bk were evaluated below 10 keV and put into the ENDF/B format. These evaluations supersede the initial version of ENDF/B-V. They are based upon substantially better differential cross section measurements in the thermal and resonance regions than were available for the ENDF/B-V evaluations. The evaluated data are available through the National Nuclear Data Center, Brookhaven National Laboratory.

The new evaluations were processed to the SRL 37- and 84-energy group formats, and tested against integral and a limited amount of transmutation data. Calculations that used the evaluations gave results within the uncertainties of available reactor production measurements.

The ENDF/B-V evaluation for ^{241}Am was processed to the SRL 84-group format and the thermal region was tested against SRL data that have been used for successful ^{241}Am burnup studies. The tests demonstrated that the thermal region of the ENDF/B-V evaluation is consistent with the SRL data within the uncertainties of burnup measurements.

INTRODUCTION

The results described in this report extend and update work(1) done with the Electric Power Research Institute (EPRI) and completed in 1975. The earlier work converted the Savannah River Laboratory (SRL) evaluated actinide library to the Evaluated Nuclear Data File (ENDF/B) format for inclusion in ENDF/B-V (release date 1/79). Both projects were also part of a program(2-5) begun some years ago at SRL to provide sound differential neutron cross section data on heavy actinides for reactor depletion calculations. The key attribute of the resulting data sets is that they have been tested in calculations of actinide transmutation against reactor benchmark measurements that represent a wide variety of thermal reactor neutron spectra.

EVALUATIONS

The cross section evaluations which follow are based upon more recent data than were available for use in ENDF/B-V. The ENDF/B-V evaluations below 10 keV are documented in Reference 1.

The new evaluation for ^{245}Cm utilizes 38 resolved resonances and a bound level to provide more realistic but substantially more complex thermal and resonance cross section structure. In contrast, the ENDF/B-V evaluation for ^{245}Cm included only three resolved resonances and a thermal cross section of 1/v shape.

The current evaluations for ^{242}Cm and ^{249}Bk utilize new experimental data to provide realistic cross section descriptions in the thermal and resonance regions. In contrast, the resonance regions for ^{242}Cm and ^{249}Bk for ENDF/B-V were artificially fabricated using the GENRPAR(6) code and average resonance parameters from nuclear systematics.

The descriptions which follow include the changes required in the ENDF/B-V, MOD 1 (release date 1/79) evaluations by File number. The ENDF/B-V format is described in Reference 7.

THE EVALUATION OF ^{242}Cm DATA

This evaluation of ^{242}Cm data supersedes the current ENDF/B-V evaluation (release date 1/79) and is based primarily upon the results of recent differential neutron total cross sections by Artamanov et al.(8). The major improvement is the use of resonance parameters derived from the Artamanov results to describe the resolved and unresolved resonance regions below 10 keV. Cross sections below 10 keV include total, elastic, capture, and fission. They are described entirely through single-level Breit-Wigner resonance parameters from 10^{-5} eV to 10 keV. The only significant changes to ENDF/B-V are in Files 1, 2, and 3.

The Average Number of Neutrons per Fission (ENDF/B - File 1)

The average number of neutrons per fission, $\bar{\nu}$, is described by

$$\bar{\nu}(E) = 3.44 + 0.172\ E$$

where energy, E, is in MeV.

Both the thermal value and the energy dependence are based on the work of Howerton(9).

Resonance Parameters (ENDF/B - File 2)

The region from 10^{-5} eV to 276 eV is described entirely by single-level Breit-Wigner resonance parameters with 12 resolved s-wave resonances and one bound level. The resolved resonances are from the work of Artamanov et al.(8). The bound level parameters were selected to give a reasonable match to the existing, but poorly defined, integral measurements(10,11). The resolved resonance and bound level parameters are listed in Table 1 with uncertainties from Reference 8. A potential (hard sphere) scattering cross section of 10.2 barns from optical model calculations at 10 keV is associated with these parameters.

Unresolved resonance parameters for s- and p-wave neutrons have been derived from average parameters in the resolved region combined with a p-wave strength function $S_1 = 1.9 \times 10^{-4}$ obtained through an extrapolation of the work of Lynn(12). The unresolved resonance parameters are summarized in Table 2.

The resolved and unresolved resonance data combined with the ENDF/B-V evaluation of Mann and Schenter(13) above 10 keV yield the thermal cross sections and resonance integrals listed in Table 3, in which the few integral values available in the literature(10,11,14) are listed also for comparison. A discussion of the resonance integral of ^{242}Cm by Holden(15) is included as Appendix A.

Smooth Cross Sections (ENDF/B - File 3)

There are no smooth cross sections in File 3 below 10 keV, because all required cross section information is provided by the resonance parameters.

Table 1

RESOLVED RESONANCE PARAMETERS FOR ^{242}Cm — 10^{-5} eV TO 276 eV

E_o (eV)	ΔE_o (eV)	Γ_n^a (meV)	$\Delta\Gamma_n$ (meV)
-2.98	-	0.951[b]	-
13.62	0.06	1.82	0.05
30.33	0.13	3.1	0.3
37.49	0.15	4.4	0.3
60.10	0.18	23.6	4.0
89.3	0.3	12.5	3.4
103.4	0.4	5.4	1.6
130.3	0.6	3.6	1.5
148.7	0.7	24.0	8.3
154.6	0.7	11.5	3.6
235.2	1.0	51.0	24.0
245.3	1.1	71.0	30.0
265.0	1.1	68.0	38.0

[a]A radiation width of Γ_γ = 37 meV is assumed.

[b]Γ_n^o is listed for this (bound) level, and a fission width of 6.95 meV was added to provide a thermal fission cross section consistent with the rather poor integral measurements.

Table 2

UNRESOLVED RESONANCE PARAMETERS FOR ^{242}Cm — 276 eV TO 10 keV

ℓ	J	$\overline{D}$ (eV)	S_ℓ ($\times10^4$)	$\overline{\Gamma_n^o}$ (meV)	$\overline{\Gamma_\gamma}$ (meV)	$\overline{\Gamma_f}$ (meV)
0	1/2	22	0.83	1.83	37	0
1	1/2	18.9	1.9	3.59	37	0
1	3/2	25.1	1.9	4.77	37	0

Table 3

THERMAL CROSS SECTIONS AND RESONANCE INTEGRALS FOR ^{242}Cm

	Thermal[a]		Resonance Integrals[a] (E > 0.625 eV)	
	$\sigma_{n\gamma}^{2200}$	σ_{nf}^{2200}	$I_{n\gamma}$	I_{nf}
Calculated (This Work)	16.8	3.0	111	4.7
Measured	20 ±10[b]	≤5[c]	150 ±40[d] 110 ±25[e]	-

[a]Measured in barns.

[b]Reference 10.

[c]Reference 11.

[d]Reference 14.

[e]Reference 15.

THE EVALUATION OF ^{245}Cm DATA

This evaluation of ^{245}Cm data supersedes the current ENDF/B-V evaluation (release date 1/79) below 10 keV. The major improvements are the inclusion of more recent results from the differential neutron fission measurements of Browne et al.(16) and Moore and Keyworth(17). Cross sections included below 10 eV are total, elastic, capture and fission, and they are described entirely through the single-level Breit-Wigner resonance parameters. The only significant changes from ENDF/B-V are in Files 1, 2, and 3.

The Average Number of Neutrons per Fission (ENDF/B - File 1)

The average number of neutrons per fission, $\bar{\nu}$, is described by

$$\bar{\nu}(E) = 3.83 + 0.190\ E$$

where energy, E, is in MeV.

The thermal value is from the compilation of Manero and Konshin(18), who renormalized the work of Jaffey et al.(19). The energy dependence is based upon the work of Howerton(9).

Resonance Parameters (ENDF/B - File 2)

The region from 10^{-5} eV to 60 eV is described entirely with resonance parameters for 38 resolved s-wave resonances and one bound level. The parameters are a blend of analyzed results from the LINAC measurements of Browne et al.(16) and the nuclear detonation measurements of Moore and Keyworth(17). Other, more limited, recent data(20-22) have been examined, but References 16 and 17 provide a consistent data base below 60 eV and sufficient resonance information to obtain reasonable unresolved resonance parameters from 60 eV to 10 keV. The only notable difference in the resolved range is a very small resonance at 3.207 eV reported in Reference 20. This resonance adds little to the strength and is implicitly accounted for in the resonance analysis of Reference 16. The resolved resonance parameters are listed in Table 4 with some uncertainties derived from Reference 16 and some uncertainties recommended by M. S. Moore(23). A potential (hard sphere) scattering cross section of 10.1 barns from optical model calculations at 10 keV is associated with these resonance parameters.

Unresolved resonance parameters for s- and p-wave neutrons have been determined from combining average parameters in the resolved region with a p-wave strength function $S_1 = 2.00 \times 10^{-4}$ obtained through extrapolation of Lynn's work(12). The unresolved resonance parameters are summarized in Table 5. Upon expansion with the single-level Breit-Wigner formalism, these unresolved parameters provide a reasonable match below 10 keV to the recent fission measurements of Nakagome and Block(24).

Table 4

RESOLVED RESONANCE PARAMETERS[a] FOR ^{245}Cm — 10^{-5} TO 61.5 eV

E_o (eV)	ΔE_o (eV)	$2g\Gamma_n$ (meV)	$\Delta 2g\Gamma_n$ (meV)	Γ_f (meV)	$\Delta\Gamma_f$ (meV)
-0.1	-	0.144[b]	0.004[b]	300	50
0.85	0.03	0.102	0.009	800	50
1.98	0.03	0.24	0.03	175	25
2.45	0.05	0.11	0.017	300	50
4.68	0.05	2.10	0.02	325	30
5.75	0.10	0.11	0.03	300	100
7.53	0.05	1.91	0.12	300	30
8.65	0.15	0.53	0.10	500	100
9.15	0.15	0.39	0.10	200	50
10.15	0.10	0.40	0.05	200	50
11.34	0.10	0.88	0.12	150	25
13.75	0.10	0.34	0.10	170	30
16.0	0.1	0.66	0.20	400	100
21.4	0.1	3.41	1.0	490	100
24.8	0.1	4.05	1.2	225	50
25.8	0.1	0.04	0.01	550	165
26.8	0.1	0.77	0.2	130	39
27.6	0.1	0.73	0.2	200	50
29.4	0.1	3.58	1.0	350	100
31.7	0.1	0.50	0.05	690	200
33.0	0.1	0.37	0.04	4	2
34.6	0.1	0.23	0.02	60	20
35.3	0.1	7.58	0.80	4195	1200
36.3	0.1	1.54	0.15	190	60
39.5	0.1	0.653	0.07	102	30
40.4	0.1	4.48	0.45	385	170
42.5	0.1	6.37	0.54	10	4
43.1	0.1	1.73	0.17	537	160
44.6	0.1	2.61	0.26	694	210
45.8	0.1	0.59	0.10	900	270
47.5	0.1	3.56	0.36	280	80
49.2	0.1	5.04	0.50	1399	420
50.5	0.1	1.79	0.18	751	225
51.6	0.1	0.625	0.08	207	60
53.6	0.1	12.35	1.24	896	270
54.6	0.1	0.33	0.05	1057	325
56.3	0.1	1.40	0.14	505	150
58.5	0.1	13.85	1.39	393	120
60.0	0.1	0.610	0.08	518	150

[a]A value of Γ_γ = 40 meV was used for all resonances except for the bound level at -0.1 eV where 50 eV was used. The uncertainty attributed to these values should be ∿±20%.

[b]For this (bound) level, $2g\Gamma_n^o$ is listed.

Table 5

UNRESOLVED RESONANCE PARAMETERS FOR ^{245}Cm — 61.5 eV TO 10 keV

ℓ	J	$\bar{D}$ (eV)	S_ℓ ($\times 10^4$)	$\overline{\Gamma_n^0}$ (meV)	$\overline{\Gamma_\gamma}$ (meV)	$\overline{\Gamma_f}$ (meV)
0	3	2.57	1.17	0.30	40	519
0	4	2.00	1.17	0.23	40	519
1	2	3.59	2.00	0.70	40	519
1	3	2.57	2.00	0.51	40	519
1	4	2.00	2.00	0.40	40	519
1	5	1.63	2.00	0.33	40	519

These resolved and unresolved resonance data combined with the ENDF/B-V evaluation of Howerton above 10 keV yield the thermal cross sections and infinitely dilute resonance integrals listed in Table 6, where they are compared with the best integral data(25,26). The evaluation represents the best current description of the ^{245}Cm cross sections below 10 keV.

Table 6

THERMAL CROSS SECTIONS AND RESONANCE INTEGRALS FOR ^{245}Cm

	Thermal[a]		Resonance Integrals[a] (E > 0.625 eV)	
	σ_{nf}^{2200}	$\sigma_{n\gamma}^{2200}$	I_{nf}	$I_{n\gamma}$
Calculated (This Work)	2210	341	821.4	107.5
Measured	2143 ±58[b]	345 ±20[c]	772 ±40[d]	101 ±8[c]

[a]Measured in barns.

[b]Reference 1.

[c]Reference 25.

[d]Reference 26.

Smooth Cross Sections (ENDF/B - File 3)

There are no smooth cross sections in File 3 below 10 keV, because all required cross section information is provided by the resonance parameters.

THE EVALUATION OF ^{249}Bk DATA

This evaluation of ^{249}Bk data supersedes the current ENDF/B-V evaluation (release date 1/79), and is based upon the results of recent differential neutron cross section measurements by Benjamin et al.(27). The major improvement in this evaluation is the use of a bound level and resonance parameters derived from Reference 27 to describe the neutron cross sections from 10^{-5} eV to 10 keV. Cross sections in this evaluation include the total, elastic, and capture cross sections; they are described entirely by single-level Breit-Wigner resonance parameters below 10 keV. The only significant changes from ENDF/B-V are in Files 1, 2, and 3.

The Average Number of Neutrons per Fission (ENDF/B - File 1)

The average number of neutrons per fission, $\bar{\nu}$, is described by

$$\bar{\nu}(E) = 3.41 + 0.214\ E$$

where energy, E, is in MeV.

Both the thermal value and the energy dependence are based upon the work of Howerton(9).

Resonance Parameters (ENDF/B - File 2)

The region from 10^{-5} eV to 63 eV is described entirely by Breit-Wigner single-level resonance parameters for 35 resolved resonances and 1 bound level from the work of Benjamin et al.(27). The bound level and resolved resonance parameters are listed with their uncertainties in Table 7. A potential (hard sphere) scattering cross section of 9.92 barns determined by optical model calculations at 10 keV is associated with these parameters.

Unresolved resonance parameters for s- and p-wave neutrons have been derived from averaged parameters in the resolved region combined with a p-wave strength function of 2.20×10^{-4} obtained by extrapolating the work of Lynn(12). The unresolved resonance parameters are summarized in Table 8.

Table 7

RESOLVED RESONANCE PARAMETERS FOR ^{249}Bk — 10^{-5} eV TO 63 eV

E_0 (eV)	ΔE_0 (eV)	Γ_γ (meV)	$\Delta\Gamma_\gamma$ (meV)	$2g\Gamma_n$ (meV)	$\Delta 2g\Gamma_n$[a] (meV)
-0.167	-	35.7	-	0.0679[b]	-
0.195	0.006	35.9	1.6	0.102	0.004
1.338	0.002	35.1	0.7	0.174	0.008
1.600	0.002	33.2	1.3	0.645	0.024
2.149	0.004	36.7	1.1	0.120	0.005
3.112	0.006	37.0	1.8	0.126	0.006
5.190	0.008	44.3	2.4	0.258	0.012
6.281	0.015	33.8	4.5	0.163	0.018
7.043	0.024	39.0	7.2	0.184	0.023
7.992	0.008	36.1	1.9	1.589	0.088
10.59	0.01	35.7[c]	2.0[c]	0.147	0.019
11.69	0.01	35.7	2.0	0.567	0.034
14.29	0.01	35.7	2.0	0.783	0.049
15.01	0.02	35.7	2.0	2.334	0.112
15.73	0.02	35.7	2.0	1.226	0.067
18.16	0.02	35.7	2.0	0.734	0.079
19.02	0.02	35.7	2.0	4.737	0.051
19.85	0.02	35.7	2.0	6.567	0.350
21.91	0.02	35.7	2.0	0.576	0.049
24.06	0.02	35.7	2.0	1.043	0.076
24.67	0.02	35.7	2.0	1.348	0.100
30.24	0.03	35.7	2.0	1.158	0.114
30.71	0.03	35.7	2.0	1.645	0.120
35.83	0.04	35.7	2.0	2.407	0.169
36.93	0.04	35.7	2.0	11.21	0.630
40.31	0.04	35.7	2.0	5.991	0.339
40.99	0.04	35.7	2.0	1.584	0.170
43.76	0.04	35.7	2.0	2.147	0.216
44.77	0.04	35.7	2.0	3.643	0.287
46.76	0.05	35.7	2.0	7.355	0.497
51.85	0.05	35.7	2.0	3.288	0.380
54.06	0.05	35.7	2.0	2.638	0.242
56.67	0.06	35.7	2.0	4.810	0.490
57.91	0.06	35.7	2.0	6.257	0.509
61.19	0.06	35.7	2.0	3.018	0.517
61.76	0.06	35.7	2.0	1.446	0.314

[a] Includes a target thickness uncertainty of 3%.

[b] For this bound level, $2g\Gamma_n^0$ is listed.

[c] Averaged parameters.

Table 8

UNRESOLVED RESONANCE PARAMETERS FOR ^{249}Bk — 63 eV TO 10 keV

ℓ	J	$\overline{D}$ (eV)	S_ℓ ($\times 10^4$)	$\overline{\Gamma_n^0}$ (meV)	$\overline{\Gamma_\gamma}$ (meV)	$\overline{\Gamma_f}$ (meV)
0	3	2.48	1.13	0.28	35.7	0
0	4	1.93	1.13	0.22	35.7	0
1	2	3.47	2.20	0.76	35.7	0
1	3	2.48	2.20	0.55	35.7	0
1	4	1.93	2.20	0.42	35.7	0
1	5	1.58	2.20	0.35	35.7	0

These data, combined with the ENDF/B-V evaluation of Howerton(28) above 10 keV, give the calculated thermal cross sections and resonance integrals listed in Table 9. The resonance capture integral agrees with the integral measurements of Gavrilov et al.(29). Thermal comparisons with integral data are more difficult; the large resonance at 0.195 eV gives a strong temperature and neutron energy spectrum dependence to the cross section. Comparison with Gavrilov et al.(29), BNL-325 (Third Edition(25), and early work by Harvey(30) are shown in Table 3. To compare directly the differential data with the integral data, it is necessary to assume a thermal spectrum and to calculate the 2200 m/s cross section as if the differential cross section shape were 1/v. The interaction of the low-lying resonance and the assumed thermal Maxwellian makes any comparison of calculated and integrally measured thermal cross section values questionable.

Smooth Cross Sections (ENDF/B - File 3)

There are no smooth cross sections in File 3 below 10 keV, because all required cross section information is provided by the resonance parameters.

Table 9

THERMAL CROSS SECTIONS AND RESONANCE INTEGRALS FOR ^{249}Bk

	Thermal Capture[a]		Resonance Integrals (E > 0.625 eV)	
	$\sigma_{n\gamma}^{2200}$	$\sigma_{n\gamma}^{2200}$ (1/v equiv.)	$I_{n\gamma}$	I_{nf}
Calculated (This Work)	746	1134	1087	3.1
Measured	710 ±40[b]	1800 ±100[c] 1300 ±300[d] 1100 ±300[e]	1100 ±100[c] 1300 ±300[c]	

[a]Measured in barns.

[b]Reference 22.

[c]Reference 29.

[d]Reference 25.

[e]Reference 30.

DATA TESTING

TESTING OF THE ENDF/B-V ^{241}Am EVALUATION IN THE THERMAL REGION

A new evaluation of ^{241}Am data in the thermal and resonance regions was done for ENDF/B-V by L. W. Weston. The thermal and resonance regions are described by recently measured resonance parameters(31,32) combined with a bound level and a 1/v "background" capture cross section. The 1/v component serves to normalize the data between 0.02 and 0.03 eV so that(31)

$$\int_{0.02\ \mathrm{eV}}^{0.03\ \mathrm{eV}} \sigma_{n\gamma} \sqrt{E}\, dE = 0.925$$

where:

$\sigma_{n\gamma}$ is expressed in barns

This is equivalent to a capture cross section of 582 barns at 0.0253 eV.

The ^{241}Am thermal data testing was intended to demonstrate that the new thermal evaluation was consistent with ^{241}Am thermal data from the SRL STANDARD data library. The SRL data for ^{241}Am thermal data are essentially equivalent to ENDF/B-III in the thermal region and have been used extensively in integral(33) and depletion studies. The tests involved processing the ENDF/B-V evaluation for ^{241}Am to obtain the SRL 84-group format, collapsing the thermal groups over typical thermal neutron spectra, and comparing the results with those obtained using the SRL data for ^{241}Am. The results demonstrated that the spectrum-averaged thermal capture cross section for ^{241}Am in ENDF/B-V is typically 2% higher than the SRL library value (ENDF/B-III). The extremely spectrum-dependent value of the 2200 m/s capture cross section has already been examined in Reference 33. The results are well within the experimental errors of depletion studies, and the ENDF/B-V evaluation for ^{241}Am can be expected to provide very good results in a variety of thermal neutron spectra.

PRODUCTION TESTING OF ^{245}Cm AND ^{249}Bk EVALUATIONS

^{245}Cm and ^{249}Bk evaluations were tested against production and transmutation measurements similar to, but less extensive than, those described in Reference 2. No satisfactory benchmarks are available for ^{242}Cm. Selective tests were done to demonstrate the adequacy of the ^{245}Cm and ^{249}Bk evaluations over a range of neutron spectra. The production tests used were:

- Cf-I Q-Foils — A four-adjacent rod assembly initially containing ^{243}Am and ^{244}Cm. The spectrum is highly thermal, i.e., $\phi_f/\phi_s \simeq 0.3$.
- BARELAT — A resonance spectrum assembly with $\phi_f/\phi_s \simeq 1.85$. It originally contained mostly ^{244}Cm.
- HARDLAT — A hard-spectrum ($\phi_f/\phi_s \simeq 10$) irradiation which initially had mostly ^{244}Cm.

The testing benchmarks above are described in Reference 2 in considerable detail, and their general properties are outlined in Table 10.

Test calculations were done with the SRL reactor codes GLASS and GOSPEL; calculational techniques have also been described in Reference 2. Calculated and measured results using the new ^{245}Cm and ^{249}Bk evaluations are compared in Tables 11-13 and are shown graphically in Figures 1 and 2. The final concentrations calculated with the new data remain consistent in quality with the depletion results obtained in the earlier study(2). Therefore, these new evaluations of ^{245}Cm and ^{249}Bk are suitable for use in depletion studies of thermal reactors.

Table 10

GENERAL PROPERTIES OF REACTOR EXPERIMENTS

Experiment	Unit Name	Exposure Time, days	Initial Major Isotope(s)	Integrated Flux, n/cm^2	Fast-to-Slow Flux Ratio Range	Brief Description
Q-Foils	K-37	280	^{243}Am, ^{244}Cm	8.12×10^{22}	0.278-0.312	Target rods of americium oxide, curium oxide, and aluminum
	K-40	260	^{243}Am, ^{244}Cm	7.62×10^{22}	0.278-0.312	
	K-41	255	^{243}Am, ^{244}Cm	7.47×10^{22}	0.278-0.312	
	K-42	250	^{243}Am, ^{244}Cm	7.11×10^{22}	0.278-0.312	
BARELAT		165	^{244}Cm	1.83×10^{21}	1.630-2.110	Deposits on aluminum foils in quartz ampoules
HARDLAT		165	^{244}Cm	2.47×10^{20}	7.438-12.451	Deposits on aluminum foils in quartz ampoules

Table 11

Cf-I Q-FOILS (CONCENTRATION IN GRAMS PER ASSEMBLY)

Assembly	Isotope	Initial Concentration Measured	Final Concentration Measured	Final Concentration Calculated
K-37	^{243}Am	118.9	0.17	0.162
	^{244}Cm	109.4	80.8	81.1
	^{245}Cm	0.863	0.548	0.616
	^{246}Cm	4.79	20.0	19.4
	^{247}Cm	0.0846	0.453	0.419
	^{248}Cm	0.0449	1.08	1.06
	^{249}Bk	0	6.23 E-3	5.78 E-3
	^{250}Cf	0	5.12 E-3	4.81 E-3
	^{251}Cf	0	1.10 E-3	1.19 E-3
	^{252}Cf	0	3.66 E-2	4.04 E-2
K-40	^{243}Am	124.5	0.061	0.20
	^{244}Cm	103.3	90.6	88.4
	^{245}Cm	0.816	0.601	0.657
	^{246}Cm	4.53	20.2	18.6
	^{247}Cm	0.0759	0.452	0.398
	^{248}Cm	0.0432	1.02	0.945
	^{249}Bk	0	5.28 E-3	5.13 E-3
	^{250}Cf	0	4.76 E-3	4.26 E-3
	^{251}Cf	0	1.01 E-3	1.06 E-3
	^{252}Cf	0	3.30 E-2	3.47 E-2
K-41	^{243}Am	125.9	0.122	0.221
	^{244}Cm	107.3	101.3	91.8
	^{245}Cm	0.851	0.675	0.685
	^{246}Cm	4.70	21.8	19.0
	^{247}Cm	0.0768	0.497	0.407
	^{248}Cm	0.0450	1.09	0.95
	^{249}Bk	0	5.82 E-3	5.17 E-3
	^{250}Cf	0	5.24 E-3	4.29 E-3
	^{251}Cf	0	1.10 E-3	1.06 E-3
	^{252}Cf	0	3.61 E-2	3.47 E-3
K-42	^{243}Am	129.3	0.279	0.277
	^{244}Cm	118.1	102.9	101.9
	^{245}Cm	0.939	0.689	0.759
	^{246}Cm	5.17	21.3	19.9
	^{247}Cm	0.0920	0.481	0.427
	^{248}Cm	0.0483	1.03	0.963
	^{249}Bk	0	5.31 E-3	5.22 E-3
	^{250}Cf	0	4.88 E-3	4.34 E-3
	^{251}Cf	0	1.03 E-3	1.07 E-3
	^{252}Cf	0	3.31 E-2	3.44 E-2

Table 12

BARELAT ($\phi_f/\phi_s \simeq$ 1.6 TO 2.1) — CONCENTRATIONS RELATIVE TO ^{244}Cm

Isotope	Initial Concentration Measured	Final Concentration Measured	Final Concentration Calculated
^{243}Cm	2.68 E-4	-	-
^{244}Cm	1.00	8.95 E-1	8.87 E-1
^{245}Cm	8.31 E-3	3.08 E-2	3.14 E-2
^{246}Cm	4.40 E-2	5.28 E-2	5.19 E-2
^{247}Cm	7.37 E-4	1.36 E-3	1.23 E-3
^{248}Cm	4.22 E-4	5.65 E-4	5.49 E-4
^{250}Cf	0	3.04 E-6	4.31 E-6
^{252}Cf	0	2.31 E-6	2.43 E-6

Table 13

HARDLAT ($\phi_f/\phi_s \simeq$ 7.4 TO 12.5) — CONCENTRATIONS RELATIVE TO ^{244}Cm

Isotope	Initial Concentration Measured	Final Concentration Measured	Final Concentration Calculated
^{243}Cm	2.68 E-4	-	-
^{244}Cm	1.00	9.22 E-1	9.23 E-1
^{245}Cm	8.31 E-3	5.54 E-2	5.49 E-1
^{246}Cm	4.40 E-2	4.49 E-2	4.47 E-2
^{247}Cm	7.37 E-4	1.21 E-3	1.13 E-3
^{248}Cm	4.22 E-4	4.6 E-4	4.51 E-4
^{250}Cf	0	1.87 E-6	2.11 E-6
^{252}Cf	0	1.91 E-7	8.04 E-8

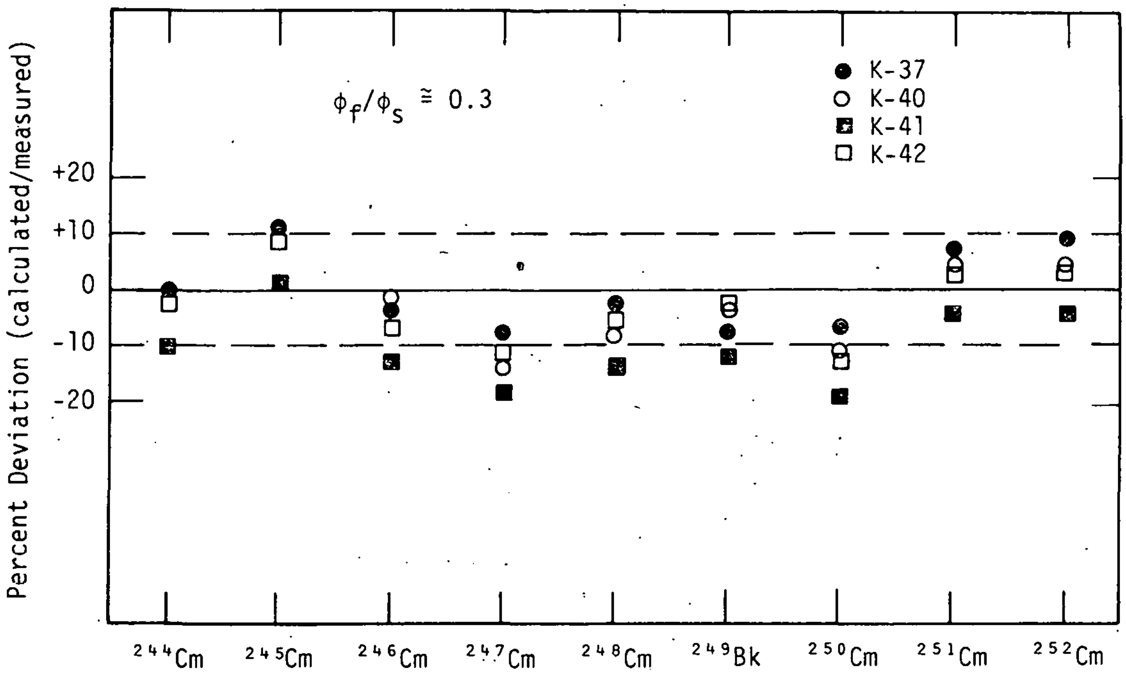

Figure 1. Deviation of Calculated Concentrations: Cf-I Q-Foils

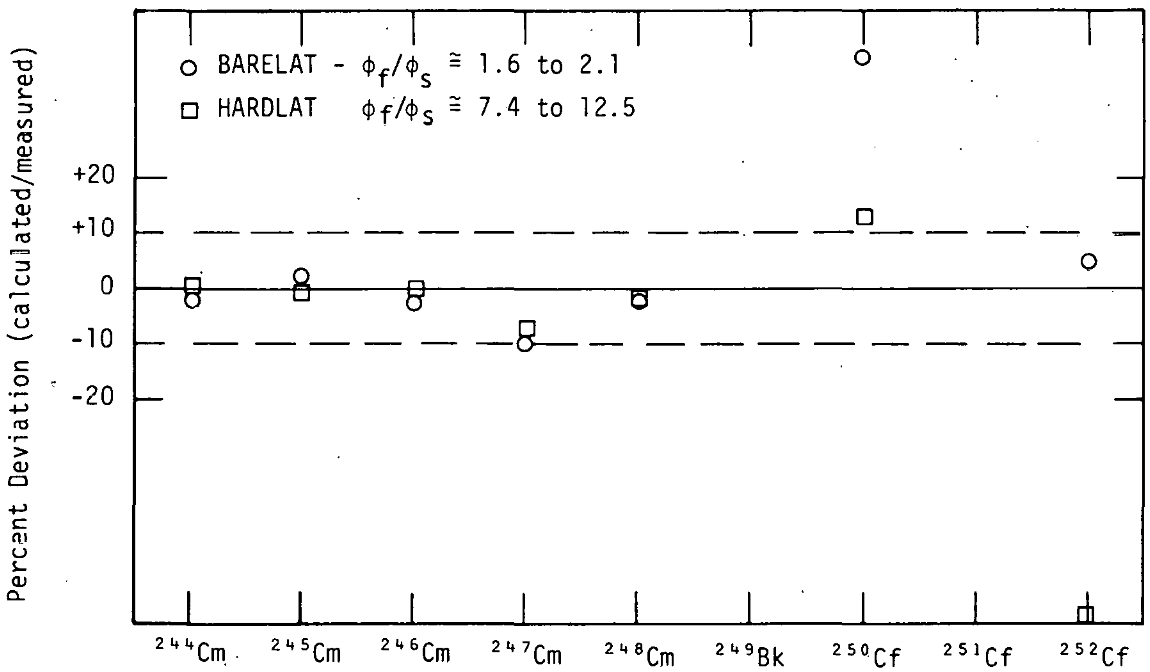

Figure 2. Deviation of Calculated Concentrations: Harder Spectrum Measurements

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BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

Memo N.E.H. 78-9

DATE: November 29, 1978

TO: Distribution

FROM: N.E. Holden N.E.H.

SUBJECT: ^{242}Cm Resonance Integral

In his recent ENDF/B-V evaluation of ^{242}Cm, Benjamin has pointed out a problem in the resonance integral as measured compared to the calculated value[1].

The only integral measurement is due to Schumann[2], who reported a value of 150±40 barns. Parameters have been calculated from the total cross section in the 1 to 265 eV range by Artamonov, et al.[3]

Using the parameters as measured by Artamonov, the resonance integral is 101 barns, with an additional 7 barns from the 1 component and 12 barns from the unresolved resonances above 265 eV using Dřesner[4]. This gives a resonance integral of 120±60 barns.

In the Schumann measurement, two samples of pure ^{241}Am were irradiated in high flux ETR core positions. Resonance integrals were assumed for ^{241}Am, ^{242m}Am, and ^{242}Cm and isotope ratios were calculated. Values giving the best fit were $^{241}Am \rightarrow {}^{242}Am$ (16 hr) 850±60 barns, and ^{242}Cm 150±40 barns.

My best estimate[5] of the resonance integral for $^{241}Am \rightarrow {}^{242}Am$ (16 hr) is 1224±110 barns. In the Idaho experiment the ^{242}Cm source material was that produced from the beta decay of the 16 hour ^{242}Am.

Assuming that Schumann estimated the ^{242}Am available by production of the ^{241}Am (n,γ) reaction, the starting material would be underestimated by the factor (850±60)/(1224±110) or 0.694±0.079. For the fixed amount of final product, the resonance integral must be reduced by the same factor. The resulting resonance integral from this experiment is 105±30 barns.

Weighting these two results would give a value of 110±25 barns, although I would recommend giving more weight to the resonance parameter estimate because of the rather indirect method of obtaining the resonance integral from the ETR irradiation and the uncertainty in the cutoff energy. Thus a value between 110 and 120 barns would be recommended.

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