ENDF-368

LLNL-TR-446331

ENDF Cross Sections are not Uniquely Defined

by
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DISCLAIMER

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Overview of the Problem

Most evaluated data that is coded into the ENDF format [1] does not uniquely define cross sections, because **the evaluator defined total is not equal to the sum of evaluator defined partial cross sections**, i.e., the total is not equal to elastic plus capture, etc. So we have always had the question: What is the correct total cross section? This is not a new problem; it has existed since the very beginning of ENDF over forty years ago. It is a problem that is periodically discussed and apparently handled, only to have it pop up again every ten years or so, as we have the next generation of ENDF format users who are not aware of the problem. See the Appendices for a summary of the differences that exist today for the ENDF/B-VII.0 (Appendix C), JEFF-3.1(Appendix D), JENDL-3.3 (Appendix E), and CENDL-3.1 (Appendix F) data libraries.

For use in our application we need consistent, unique data. To accomplish this for decades we [2, 3] have been ignoring the **evaluator defined total**, and re-defining it as equal to the **sum of its evaluator defined parts**. This has never been completely satisfactory to us, because we have been doing this without consulting evaluators, or obtaining their approval, so that **the data we actually use in our applications may or may not be what the evaluators intended**.

Many times the best known cross sections for a material is the total cross sections, because so many transmission measurements have been performed over the years. For this reason evaluators may try to represent the tabulated total cross sections in their evaluations as accurately as possible. Our problem is that unless the tabulated cross section is equal to the sum of its parts, the procedure that we use will ignore any efforts that evaluators put into the accuracy of their tabulated total. Let me stress this point by saying this again: for decades we [2, 3] have been ignoring the **evaluator defined total**, and re-defining it as equal to the **sum of its evaluator defined parts.** This may be completely counter to the intent of evaluators, but it is the BEST we can do to make evaluations

unique. We would really prefer if it were evaluators, not our processing codes, that make this decision. Here we both describe the problem and propose a solution that allows evaluators to be in control of how their evaluations are interpreted.

Several friends who read a preliminary version of this paper asked: what inconsistency is acceptable or important; could we make a short list of important materials that really need attention. After hearing this I realized that they had missed the whole point of this paper. **The bottom line is that for use in our applications NO inconsistency is acceptable = ZERO!!! What it comes down to is that either evaluators make their evaluations consistent the way they decide, or we will be forced to make their evaluations consistent, without evaluator approval; of these we would prefer that evaluators maintain control and make the decisions.**

In Praise of Evaluators

We should start by praising the excellent job that our nuclear and atomic data evaluators do. Compared to the accuracy and volume of data available in the early days of the ENDF system, today thanks to the excellent work of evaluators we have an enormous amount of very accurate data. So readers should not consider this paper to be a criticism of the ability of evaluators as far as the quality of their evaluation work.

What we are trying to point out here is that we think **it is asking too much of our evaluators to also be experts in the ENDF system**. The problems we discuss here are strictly due to having to represent their very accurate evaluated data in the ENDF format, and their having to deal with the constraints that the ENDF system puts on evaluators, as far as maintaining the accuracy and uniqueness of their evaluated data.

What we suggest here is that evaluators be allowed to concentrate on what they know best: namely, evaluation. In addition we suggest that they rely on us and our verified codes to deal with the problems of the ENDF format.

Our Suggested Solution

It would be much better if the evaluators would agree to insure consistency of their evaluated data. **Here we propose that rather than having us change the evaluations to make the data consistent, evaluators do this BEFORE distributing their evaluations**. This is the only way that we can insure that users can uniquely interpret their data.

The data can easily be made consistent by using existing computer codes [2, 3] to insure that the total tabulated in the evaluation is equal to the sum of its parts. **This summation can only be done for all energies if ALL cross sections are linearly interpolable**; non-linear interpolation does not allow accurate summations at ALL energies. By ALL energies, we mean not just those energies where cross sections are tabulated, but also the entire range of energies between tabulated energies, since it is ALL energies which are important to accurately define the integrals over energy that we are interested in our applications.

We recommend that evaluators,

1) Use the PREPRO LINEAR code to linearize all cross sections.
2) Use the PREPRO FIXUP code to define total, and other redundant cross sections, by summation.
3) Use the PREPRO DICTIN code to correct the section lines counts in MF/MT=1/451.

The result will be an evaluation whose cross sections are consistent and completely compatible for use in applications. Running these three codes takes seconds of computer time, and eventually can end up saving evaluators effort and time having to explain why your evaluations may be misinterpreted by users and give poor answers.

An Offer You Can't Refuse

We feel that this is so important that I will even offer to do this work for evaluators for FREE: think of me as **a FREE consultant**. If you e.mail me, RedCullen1@comcast.net , your evaluation in the ENDF format, I will run it through these three codes, and usually within 24 hours, return to you my results, including a consistent version of the evaluation and plots of any inconsistencies that I find. **We cannot make this any easier for you**.

Let me stress: In doing this I will merely be acting as a FREE consultant to you; I will not make any final decisions. After seeing any inconsistencies, the evaluators will still have complete freedom to use either the original form of their evaluation, or the consistent form I return to them, or anything else that they decide on; **the decision will remain strictly in the hands of the evaluators, where we feel it should be.**

Don't mess with my Evaluation

As stated above, evaluators do an excellent job in preparing their evaluated data, so it is only natural if they may be reluctant to let us mess with their evaluations, by running them through our codes (read, black boxes), to make evaluations "consistent". Let me suggest that if an evaluator does not want us to mess with their evaluations, that **they at least run our codes to check on the consistency of their data**; they can then decide what to do. If you want to check your data we suggest you use the PREPRO codes [3] as follows,

1) Use the PREPRO LINEAR code to linearize all cross sections.
2) Use the PREPRO FIXUP code to define total, and other redundant cross sections, by summation.

After running these codes you will have three versions of your evaluation,

1) The original data that you started with.
2) LINEAR output.
3) FIXUP output.

The only difference between the LINEAR and FIXUP output will be due to FIXUP making ALL cross sections consistent, by defining them as the sum of their parts; this applies to the Total, as well as total inelastic, total (n,2n), total charged particles, and others. We suggest that you use the PREPRO COMPLOT [3] code to compare the FIXUP and LINEAR outputs; any difference

between these two indicates inconsistencies in the evaluation. Based on what the evaluator "sees" they can decide what course of action to follow.

Naturally if evaluators prefer I can run these codes for them; see above for "An Offer You Can't Refuse". **Regardless of who runs these codes to check for inconsistencies, the final decision regarding the evaluation will remain with the evaluator, where we feel it should be.**

Backup Plan

We have been preaching about this problem to ENDF evaluators for decades, but human nature being what it is, very little has been accomplished; each version of ENDF that is distributed continues to include the same problem. Therefore as a backup **we propose that Nuclear Data Centers only distribute data after they have been made consistent**. If they think this is too much work, I will volunteer to do it for them. For example, the summaries of ENDF/B-VII.0 (Appendix C) , JEFF-3.1 (Appendix D), JENDL-3.3 (Appendix E) and CENDL-3.1 (Appendix F) were created by me processing ALL of the evaluations in each library to create consistent evaluations. In each case I processed an entire library on my own PC using a single batch run in less than a day. **Send me your WHOLE library and I will fix ALL OF IT for you, usually the same day.**

As our second backup plan, one purpose of this report is to inform data users of this problem and suggest that **data users be sure to make ALL data consistent before they use it**; they can use exactly the same codes we suggested evaluators use. See the section below on "PREPRO Documentation"; this documentation will allow you to check any evaluation to see whether or not it has been made consistent (just look for the PREPRO comment lines in any evaluation). I do not volunteer to do check evaluations for every data user, but I will mention that consistent ENDF/B-VII.0 data is now available on-line at, http://www-nds.iaea.org/point2009/pt2009.htm [6].

Uncertainty versus Errors

We would like to distinguish between the inherent **uncertainty** in nuclear data, and any **error** that our formats or data processing codes add to the uncertainty. Our objective in processing ENDF formatted data is to insure that the additional error that we add is always small compared to the inherent uncertainty in the data. Today there are few cross sections for any material at any energy and any target temperature that are known in absolute terms to better than roughly 1%; that is what we mean by the **inherent uncertainty** in the data. In an attempt to insure that we preserve the accuracy of data, today we attempt to process data to within an accuracy substantially less than 1%. Today the error we introduce in data processing cross sections we attempt to keep under 0.1% and in the thermal range even 0.01%. Please remember that here we are not talking about the inherent uncertainty in the data; we are only talking about the additional error that our data processing introduces. If we can accomplish this we can claim that our data processing has not introduced any significant additional error that changes the overall uncertain of the data we use in our applications.

With that as background, hopefully the reader can appreciate that we can control the extra error we introduce by our data processing, but **we cannot control any error due to non-uniqueness in the evaluated data which is given to us**. That's is why we are so concerned with any non-uniqueness in the total cross section defined by evaluators; if the non-uniqueness in the evaluation in the ENDF

format is comparable to the uncertainty in the data or even to the error we introduce by our data processing, much of our efforts to provide accurate data for use in applications will be wasted.

Only the Tip of the Iceberg

Here we only have time to discuss the inconsistency of the evaluator defined total cross section. But this is only the tip of the iceberg. **Trying to define consistent ENDF tabulated total cross sections and its constituents is complicated, and the rules keep changing as new reactions (MT numbers) are defined**. Also in order to define consistent cross sections more than the total are required. **The FIXUP code [3] calculated a variety of cross sections** including: the total inelastic (MT=4, as the sum of MT=50 through 91), total (n,2n) (MT=16), total charged particles (MT=103 through 107), first chance fission (MT=19), and others (see, the FIXUP output listing for details). Depending on the applications that an evaluation is applied to, these other sum cross sections may be more important than their individual constituents, e.g., the total (n,p) cross section may be more important for activation than the individual (n,p) levels. **Indeed for activation the individual (n,p) levels may be completely ignored, and only the total (n,p) used, so if this is not correct you will get the wrong answer.**

Details of the Problem

The introduction of a standard universally accepted computer format for nuclear and atomic data, namely the ENDF format [1], has led to a tremendous improvement in the quality and the availability of data for use in applications throughout the World. In principle this format allows us to uniquely interpret our data, so that we can easily compare different data sets, and use them in our applications to identify the importance of differences.

Although our efforts have generally been quite successful there remains one glaring problem, that has been recognized since the inception of ENDF, that we periodically address and think we have solved, only to find that eventually it manages to creep back into our data files as the problem is forgotten by each new generation of data evaluators and users as they start to use ENDF.

The problem that we address here is that in many ENDF formatted evaluations [1], **the evaluator defined total cross section is not equal to the sum of the evaluator defined parts; let us stress the point that BOTH the total and parts are DEFINED by the EVALUATOR,** and yet because of constraints of the ENDF format these are inconsistent, resulting in a non-unique total cross section. Below we show but a few examples. In each of these cases the evaluator defined the low energy elastic to be constant and the capture to be 1/v (varying inversely as the speed of the incident neutron); this was done correctly. The evaluator had to define the total cross section AND its continuous variation versus energy by using one of the ENDF interpolation laws. But there is no ENDF interpolation law that corresponds to the sum of a constant cross section plus a 1/v cross section. In each case the evaluator MUST decide the "best" choice for their evaluation; usually they define the total to be log-log (INT=5) or lin-lin (INT=2) interpolable. The below plots show the results: the total cross section defined by the evaluator in each evaluation grossly overestimates the "real" total defined by summing the constant elastic and 1/v capture. The differences are ENORMOUS: in the plots shown, up to 46%, 31% and 1856%; these are unacceptable for use in

our applications. **The real question: Here the total is obviously not unique, but which total is correct? What did the evaluator really intend?**

It is Integrals, not Energy Points that Matter

In this discussion it is important for the reader to understand that in our applications it is integrals over energy ranges, not values at specific energy points that matter. As such **we MUST define cross sections at ALL energies, not merely the energies at which they are tabulated**. To do this ENDF defines cross sections as a combination of tabulated cross sections at discrete energies, and an interpolation law that defines how to interpolate between tabulated values. In order to obtain accurate integrals it is IMPERATVE that we use both the tabulated values and the interpolation law. See Appendix A for an example of the effect of interpolation; hopefully from the plots in Appendix A the reader can appreciate the effect on integrals, i.e., the area under these curves. Virtually all of **the differences shown in the figures in this report are due solely to how we interpolate between tabulated values**.

Definition of ENDF Interpolation Laws

Tabulated cross sections in the ENDF format are defined at ALL energies. This is accomplished by defining a table of cross sections at discrete energies, and **an interpolation law to define the cross section at ALL energies between where it is tabulated**. The available ENDF evaluation laws [1] are very useful during evaluation, e.g., 1/v cross section can be exactly defined using log-log interpolation. The most popular interpolation laws are INT=1 through 5, corresponding to histogram interpolation as well as linear or log in energy and cross section.

For any two tabulated data points (E1,σ1) to (E2,σ2) our problem is to define the cross section for each reaction (MT) at ANY energy, E, between E1 and E2. In each case we can define the cross section as a weighted average of the cross sections at the two ends of the energy interval. In all of the following equations the weights are defined as: wt1 + wt2 = 1,

Int			
1, 2, 4	Lin E	wt1 = (E2 – E)/(E2 – E1)	; wt2 = (E – E1)/(E2 - E1)
3,5	Log E	wt1 = (ln E2 – ln E)/(ln E2 – ln E1)	; wt2 = (ln E – ln E1)/(ln E2 – ln E1)

Int		
1	Histogram	$\sigma(E) = \sigma 1$
2	Lin E – Lin σ	$\sigma(E) = wt1*\sigma 1 + wt2*\sigma 2$
3	Log E – Lin σ	$\sigma(E) = wt1*\sigma 1 + wt2*\sigma 2$
4	Lin E – Log σ	$\ln \sigma(E) = wt1*\ln \sigma 1 + wt2* \ln \sigma 2$
5	Log E – Log σ	$\ln \sigma(E) = wt1*\ln \sigma 1 + wt2* \ln \sigma 2$

To define sums we sum over contributions for a collection of reactions. For linear cross section interpolation (INT=1 through 3) for all reactions we can easily do this by defining the summed cross section at the same energies at which each reaction is tabulated. For example, we can define the Total summed cross sections σTot1 and σTot2 at the tabulated energies E1 and E2, as the **LINEAR sum**,

$\sigma Tot1 = \Sigma\, \sigma 1$; $\sigma Tot2 = \Sigma\, \sigma 2$; sum Σ over contributing reactions (MTs)

For the total at any other energy we can then use EXACTLY the same linear cross section relationship that we used for each individual reaction, to define the Total summed cross section at ANY other energy E, between E1 and E2,

Int
1 $\sigma Tot(E) = \sigma Tot1$
2 $\sigma Tot(E) = wt1*\sigma Tot1 + wt2*\sigma Tot2$
3 $\sigma Tot(E) = wt1*\sigma Tot1 + wt2*\sigma Tot2$

But no such linear relationship exists for the log cross section interpolation or for a mix of interpolation schemes for the reactions (i.e., different interpolation for each reaction). For log cross section interpolation the interpolated cross section for one reaction is,

Int
4 $\sigma(E) = Exp[wt1*\ln \sigma 1 + wt2*\ln \sigma 2]$
5 $\sigma(E) = Exp[wt1*\ln \sigma 1 + wt2*\ln \sigma 2]$

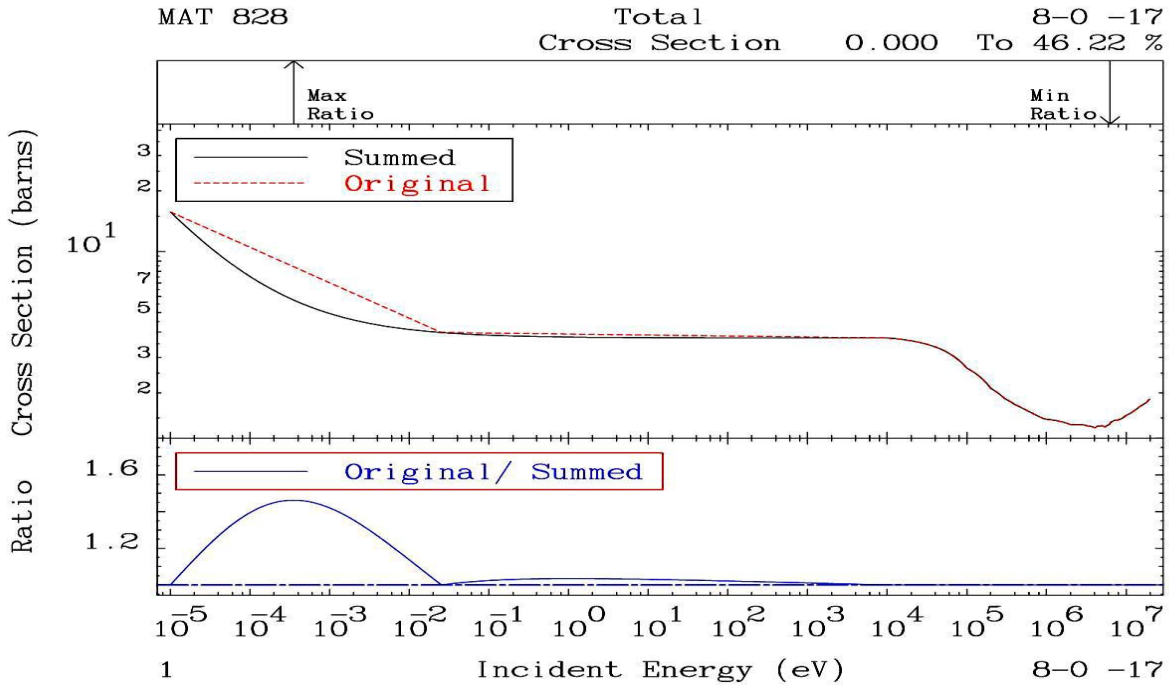
Here there will be a different exponential variation for each reaction, and there is no ENDF interpolation law for a sum of such variations. In other words, **when we have log cross section interpolation or a mix of interpolation schemes, we cannot accurately define the sum of reaction for use in ENDF. Let me stress this point: IT IS IMPOSSIBLE WITHOUT LINEAR INTRRPOLATION.**

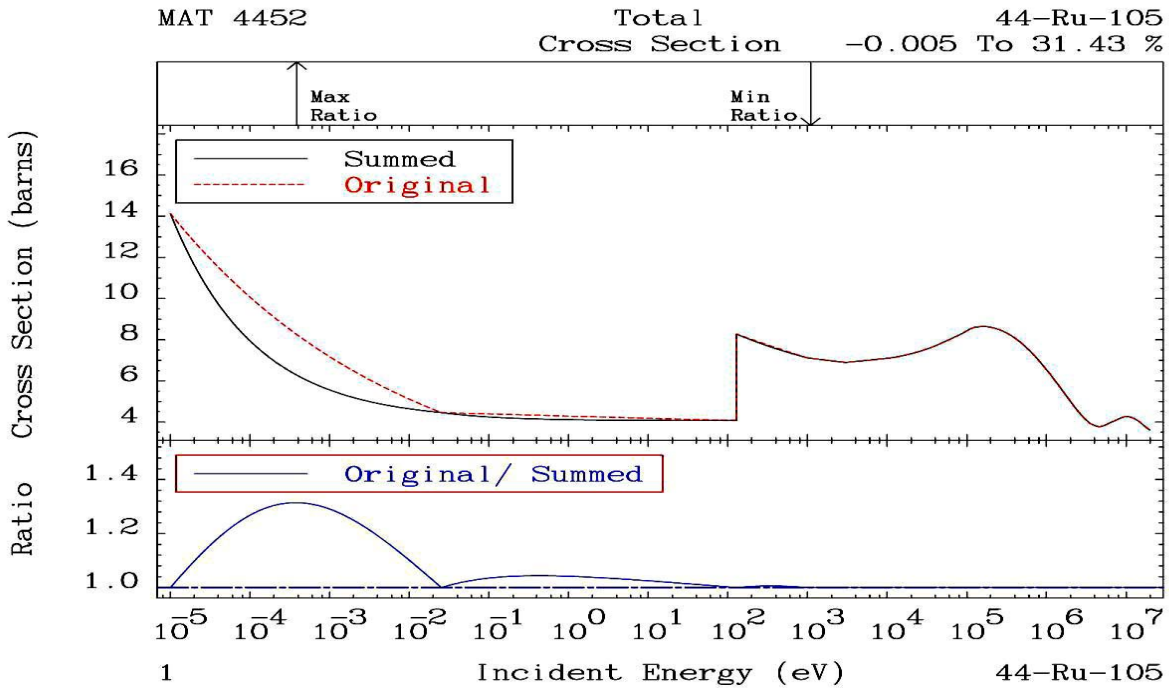
The bottom line is that **within the ENDF format we can only accurately define summed cross sections, such as the total, at ALL energies, if ALL contributing reactions are lin E – lin σ interpolable**. Again, let me state that the rules for defining ENDF summed cross sections are complicated and periodically change as new reactions (MTs) are defined; the purpose of the PREPRO [3] codes LINEAR and FIXUP is to do this for you, so that **we can accurately define summed cross sections, such as the total, for use in our applications**.

Introducing the ENDF Interpolation Problem

Most of the inconsistencies shown below are a direct result of the problem of trying to define the total cross section because of interpolations difficulties, as explained above. If you look closely at each of the below evaluations you can see that the evaluators tried to accurately define the thermal cross sections, by defining an energy point at 0.0253 eV. For capture they then used 1/v varying to define of energy point at 1.0d-5 eV and another energy point in the eV energy range. The ENDF interpolation laws allow this to be done very accurately and easily using only three tabulated energy points: 1.0d-5 eV, 0.0253 V, and one in the eV range, assuming linear variation for elastic (INT=2, lin-lin interpolation) and 1/v for capture (INT=5, log-log). **So that as far as elastic and capture we can find no fault with the evaluators; they did a good job on what they are familiar with, namely neutron data evaluation**.

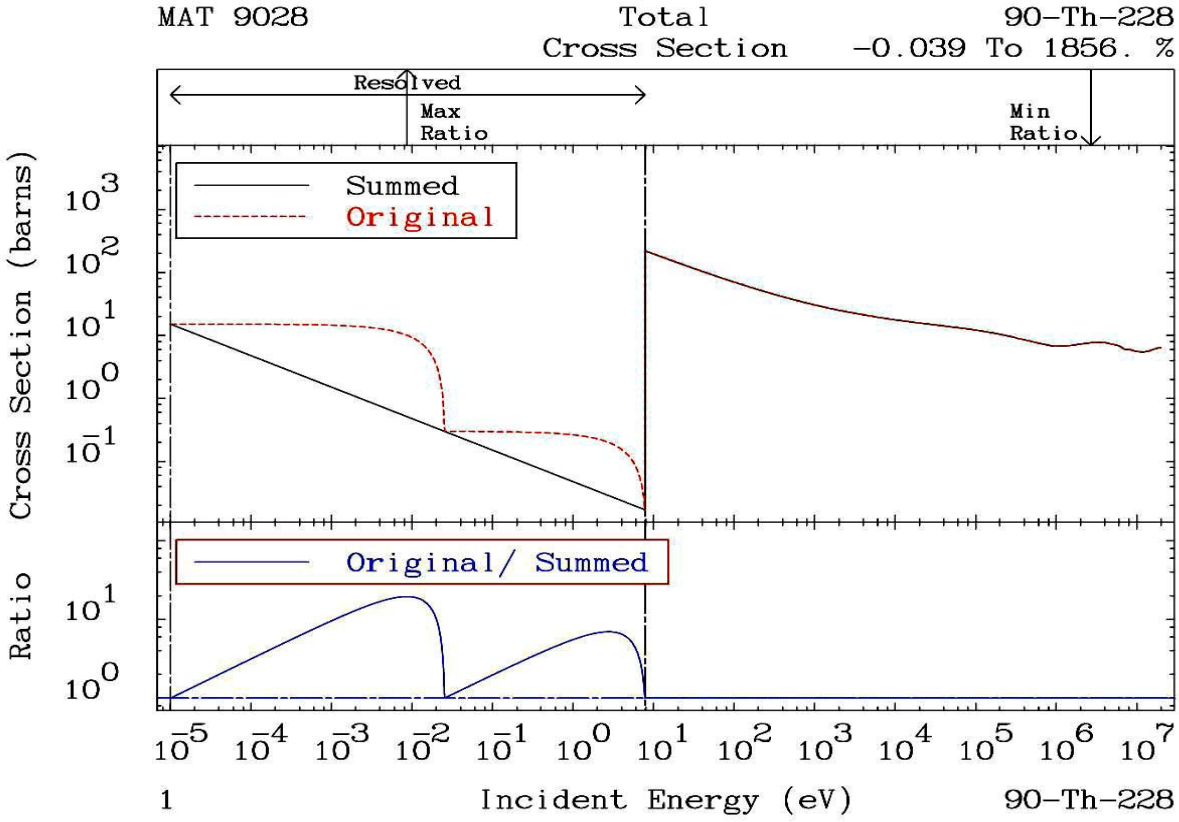
But the evaluators had a problem when it came to making their evaluations available in the ENDF format; here the rules are that each evaluation MUST include a total cross section, and the evaluators made the mistake in assuming that they could define the total at the same energies at which the elastic and capture are given, and assume log-log (INT=5) or lin-lin (INT=2) interpolation between these points. **This is the sole source of the non-uniqueness**. In these cases INT=5 (log-log) is the best evaluator choice; using INT=2 (lin-lin) give even worse results.

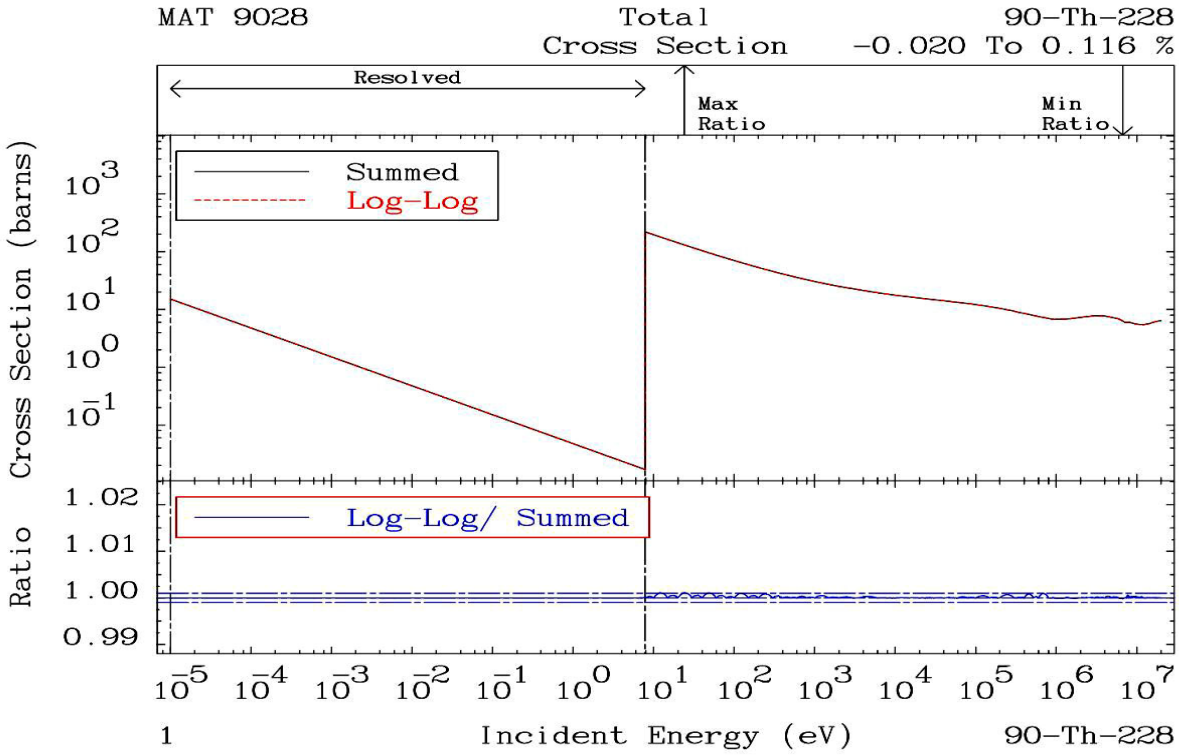




The case of 90-Th-228 clearly illustrates the problem of the evaluators trying to define the "best" interpolation law for their tabulated total cross sections. Based on the evaluator's choice of INT=2 (lin-lin) interpolation, we found an inconsistency of up to 1836%. This is such a shame, because if instead the evaluator had used INT=5 (log-log) there is NO SIGNIFICIANT INCONSTITENCY. Let us repeat this: For exactly the same evaluator defined tabulated total cross section, the evaluator's choice of INT=2 (lin-lin) results in an inconsistency of 1836%, whereas had the evaluator used INT=5 (log-log) there would be essentially no inconsistency. In other words, in this case the evaluator did have a good choice available, but mistakenly made the wrong choice. **This is an excellent example where the evaluator did a good job in evaluating the data, but apparently was not an expert in the ENDF format**. We contend that evaluators need not be ENDF experts; **we suggest evaluators be allowed to concentrate on evaluation, and leave the problems of the ENDF format to us.**

This is a case where the evaluators made a poor choice of INT=2 (lin-lin) for their total, but fortunately they made good choices to define elastic INT=2 (lin-lin) and capture INT=5 (log-log), so that our codes can correct this problem by defining the total by summation.


MAT 9028
Total
Cross Section
90-Th-228
-0.039 To 1856. %
Resolved
Max Ratio
Min Ratio
Summed
Original
Original/ Summed
Cross Section (barns)
Ratio
Incident Energy (eV)
1
90-Th-228


MAT 9028
Total
Cross Section
90-Th-228
-0.020 To 0.116 %
Resolved
Max Ratio
Min Ratio
Summed
Log-Log
Log-Log/ Summed
Cross Section (barns)
Ratio
Incident Energy (eV)
1
90-Th-228

What did the Evaluators Intend?

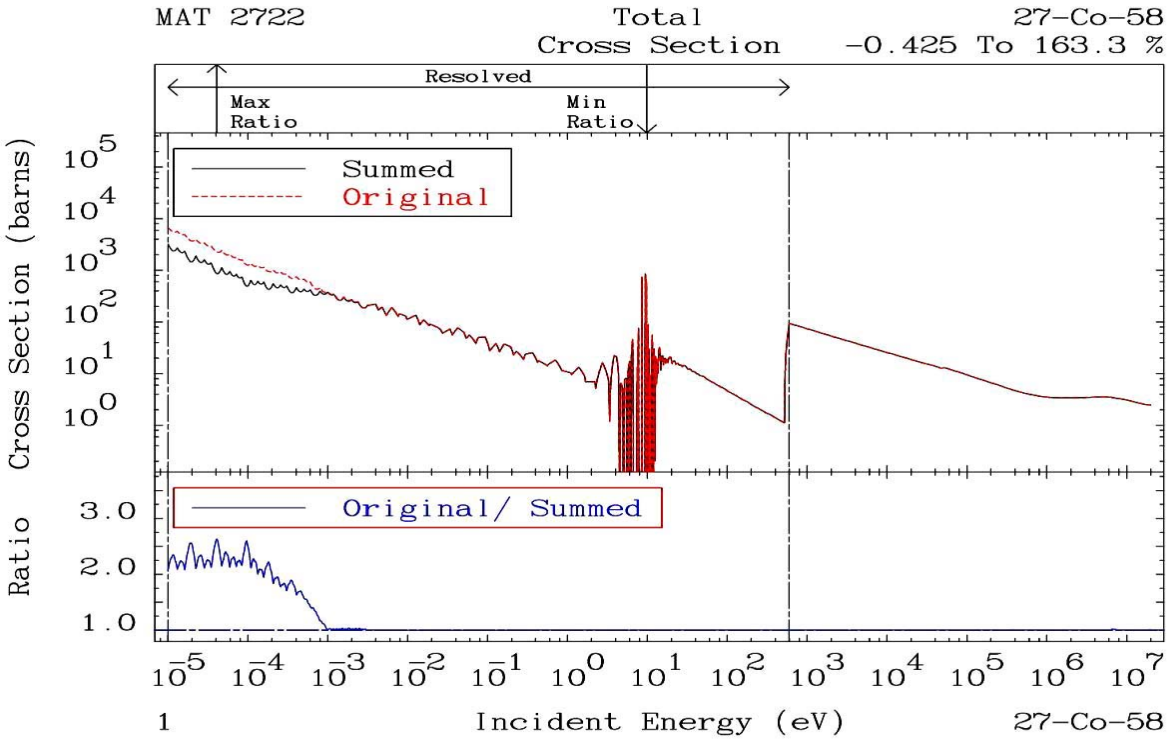
Generally we like to try and insure that we interpret evaluated data exactly as the evaluator intended. In the case of the ENDF format we attempt to do this by having strict coding rules; rules that both the evaluator MUST use to code their data and that data users MUST use to interpret data for use in their applications.

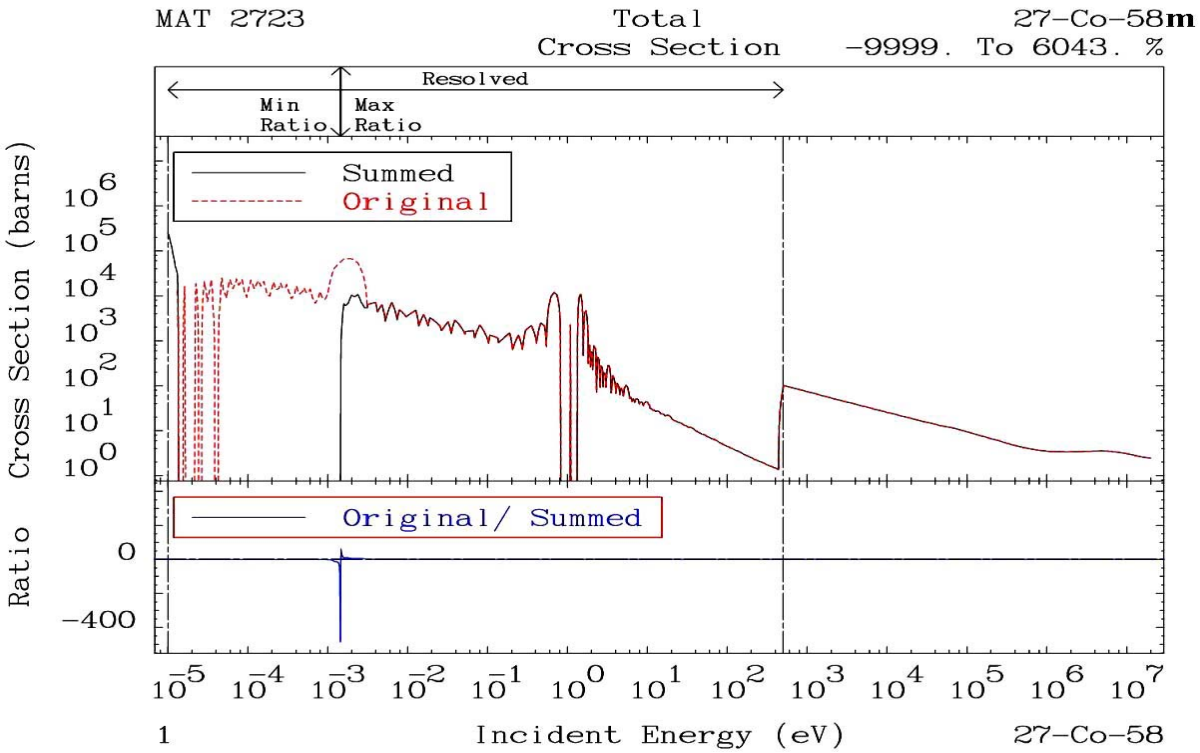
As much as we would like to interpret data as the evaluator intend, once the data is coded into the ENDF format the "best" we can do it to try and interpret the data exactly as the evaluator coded it, i.e., we cannot read the evaluator's mind to try and figure out what they intend; their intent MUST be clear from what they coded. Above we presented a few examples where the evaluators ran into interpolation law problems; in most of these cases we feel we can infer the intent of the evaluators by our defining a new total as the sum of its parts.

Below we present a few examples where it isn't at all clear to us what the evaluators intended; in these cases there are significant differences, and at least to us, no apparent correspondence between the evaluator defined totals and the sum of its parts. **In these cases the "best" we can do for use in applications is to continue to ignore the evaluator defined total and define a new total as the sum its parts**. We find this to be very unsatisfactory; we would much prefer that the evaluators make their total and sum of its parts consistent. Otherwise sorry to say they have to accept the fact that we may be misinterpreting their data.

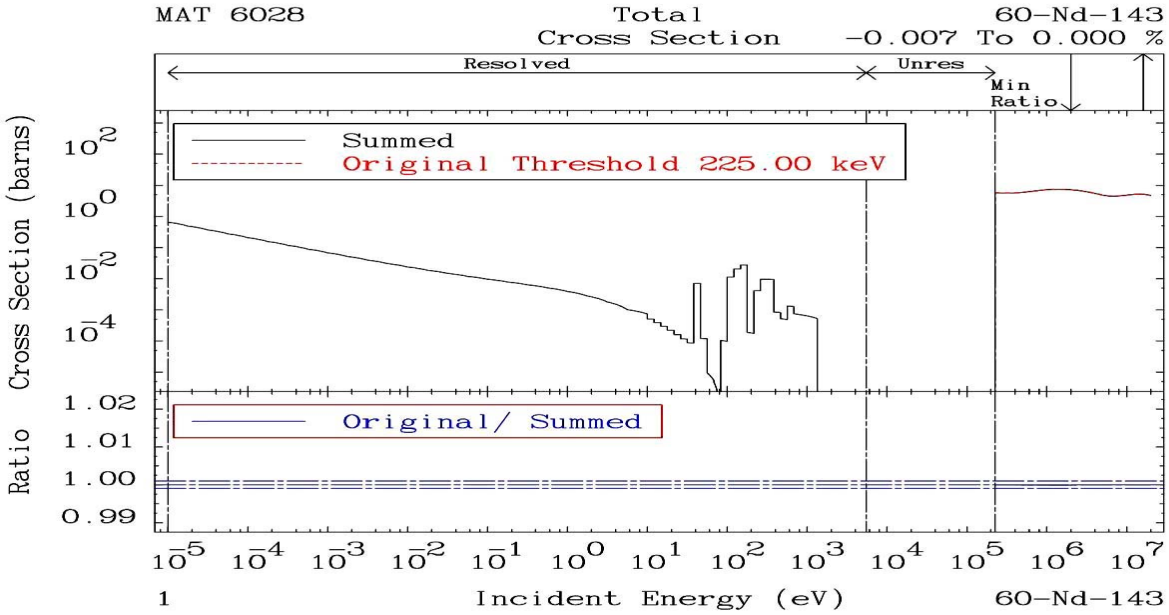
The first two plots below show results for 27-Co-58 and 27-Co-58m. In both cases it appears that the evaluators went to some effort to include detail in their tabulated total. Unfortunately, the details in the tabulated total do not exactly correspond to that tabulated with the parts (elastic and capture). In the case of 27-Co-58 there is a correspondence above about 1 milli-eV, but below this energy the tabulated total is significantly larger; up to 163% larger. In the case of 27-Co-58m there is a background correction to the total over the entire energy range, but none for the parts below about 1 keV. **We would like the evaluators to understand: the "best" interpretation we can give this data is to ignore their total and define a new total as the sum of its parts**; in doing this much of the evaluator's effort in creating their tabulated total is lost.

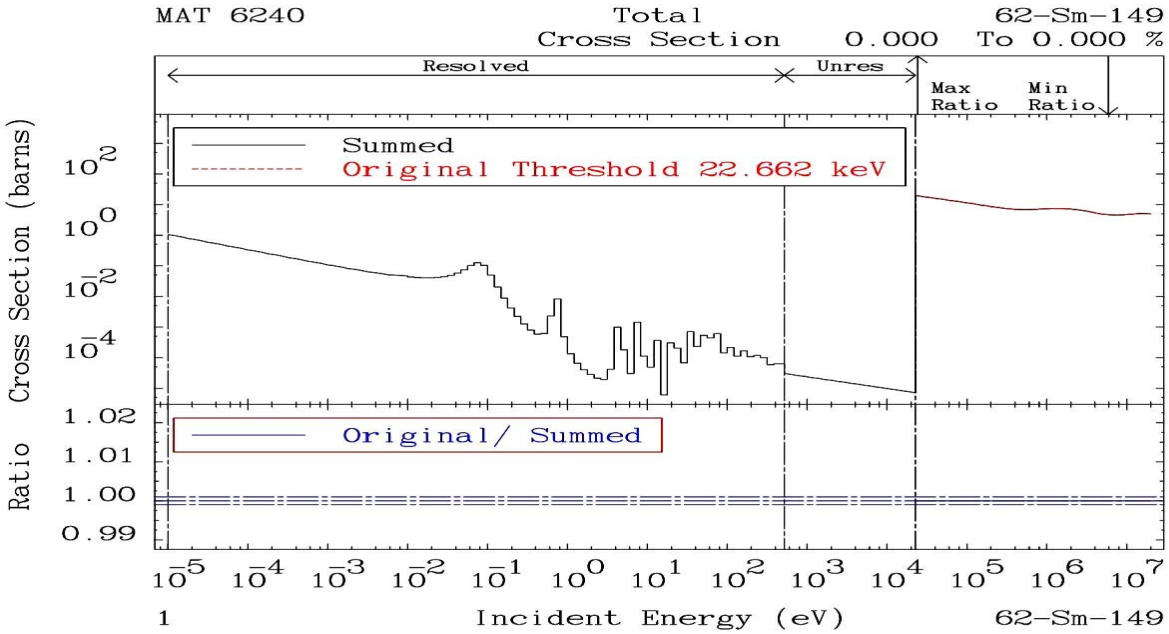
This seems crazy: why go to all of this effort and then have your efforts wasted? This is but one example where we ask evaluators to insure that their data are consistent. We also want to stress that if evaluators do not make their data consistent, we are forced to do the "best" to can to make their data consistent, and in doing this we may not interpret their data as they intend. **Just to be clear: We [2, 3] ALWAYS ignore the evaluator given tabulated total, and define a new total that is equal to the sum of its parts; this is what we use in our applications.**


MAT 2722
Total
Cross Section
27-Co-58
-0.425 To 163.3 %
Resolved
Max Ratio
Min Ratio
Summed
Original
Original/ Summed
Cross Section (barns)
Ratio
Incident Energy (eV)
1
27-Co-58


MAT 2723
Total
Cross Section
27-Co-58m
-9999. To 6043. %
Resolved
Min Ratio
Max Ratio
Summed
Original
Original/ Summed
Cross Section (barns)
Ratio
Incident Energy (eV)
1
27-Co-58

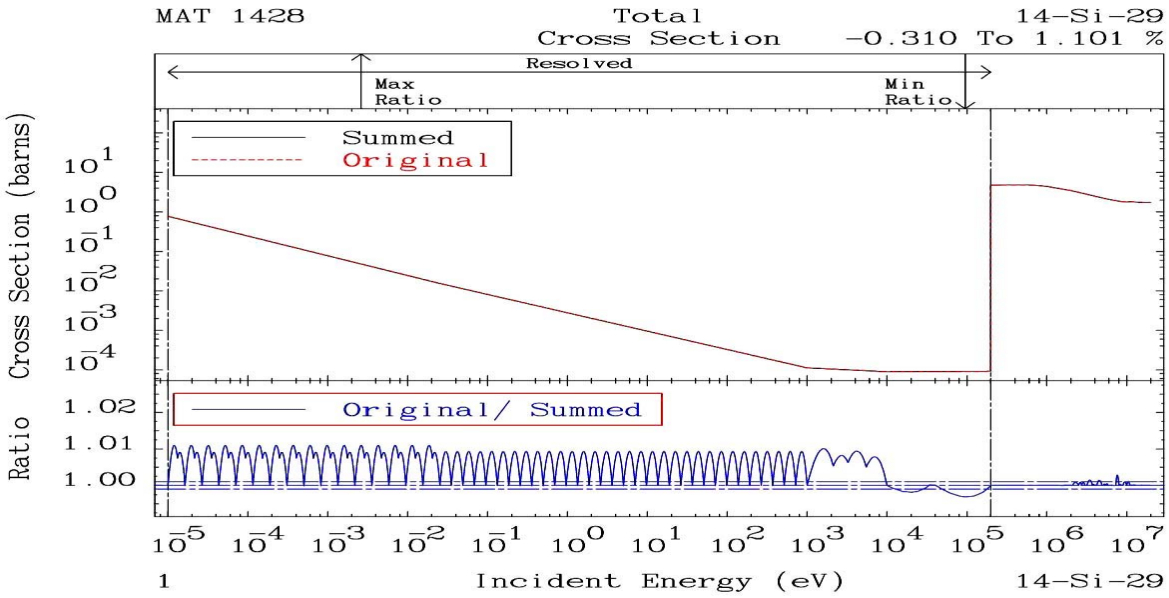
In the following two figures we illustrate cases where the evaluator included details in their parts (elastic and capture), but not in their tabulated total. In the case of 60-Nd-143 there is no tabulated total below 225 keV, but the parts include background corrections to the parts. The case of 62-Sm-149 is similar; here there is no tabulated total below 22.6 keV, but there are background corrections at lower energy. **Just to be clear: We [2, 3] ALWAYS ignore the evaluator given tabulated total, and define a new total that is equal to the sum of its parts; this is what we use in our applications.** So that in this these cases we will define a new total including the background corrections. Anyone who uses the original total will not include this background.

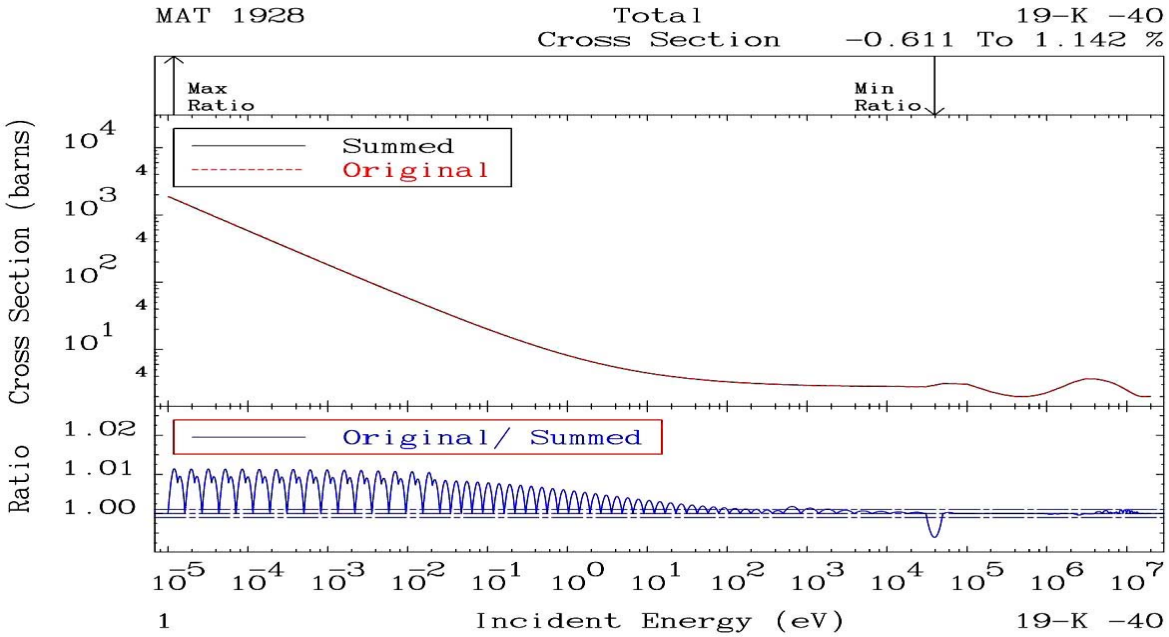




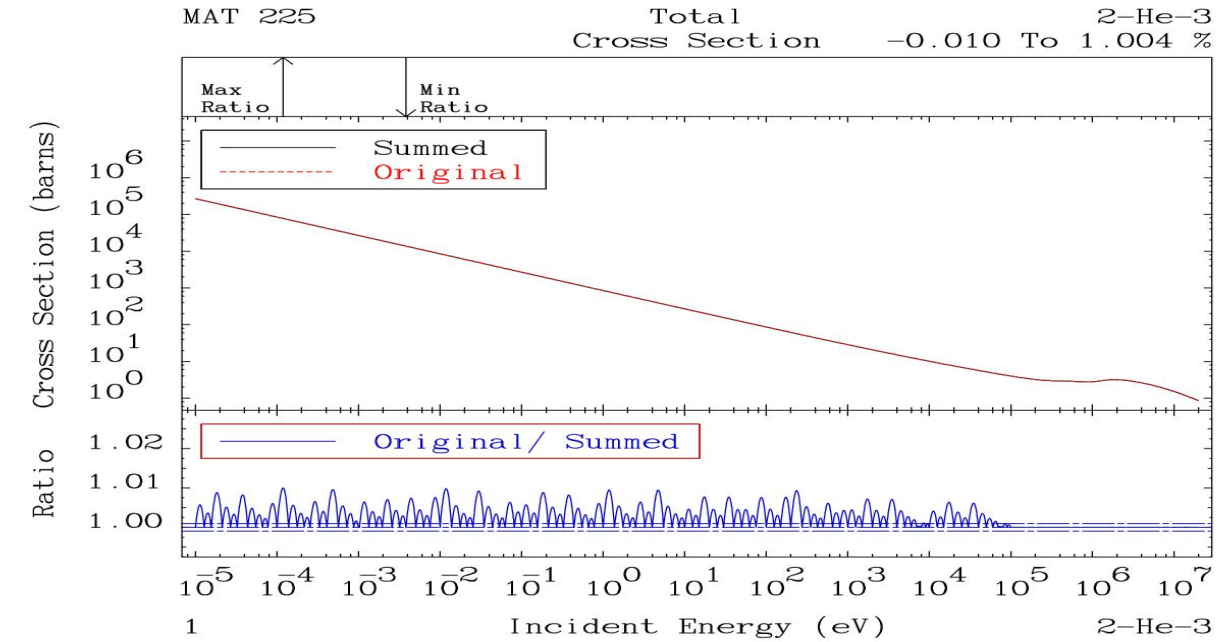
Evaluators Often Do Try

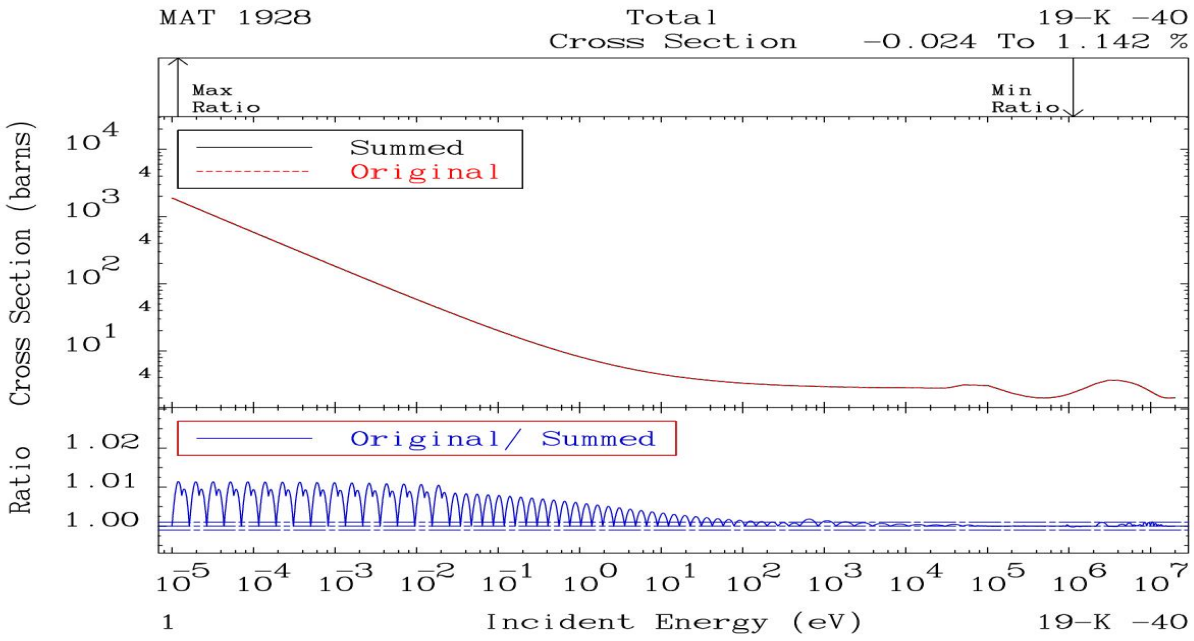
Below are two examples from JEFF-3.1, where the evaluators did try to include a sufficient number of data points to allow their tabulated total to "better" approximate the sum of its parts. The evaluators did a pretty good job and managed to reduce the difference to about 1%. **This illustrates that it is difficult to know where to add additional energy points**; and is something that evaluators really should not have to be concerned about. In these cases our codes can easily add additional energy points at energies where they are needed, and reduce the difference to say 0.01%; well below the accuracy to which we know any cross sections.





Below are two examples from JENDL-3.3 that are similar to the above two examples, where the evaluators did try to include a sufficient number of data points to allow their tabulated total to "better" approximate the sum of its parts. The evaluators did a pretty good job and managed to reduce the difference to about 1%. **Again, this illustrates that it is difficult to know where to add additional energy points.** It is important to understand that in the above and below figures the overall uncertainty of the data is not the 1% indicated on these figures. This is the additional ERROR added by constraints of the ENDF/B format and our code attempting to make the cross sections consistent. **It may be acceptable to have evaluated data with an inherent uncertainty of 1%, but we judge an additional 1% due to inconsistencies to be unacceptable.**





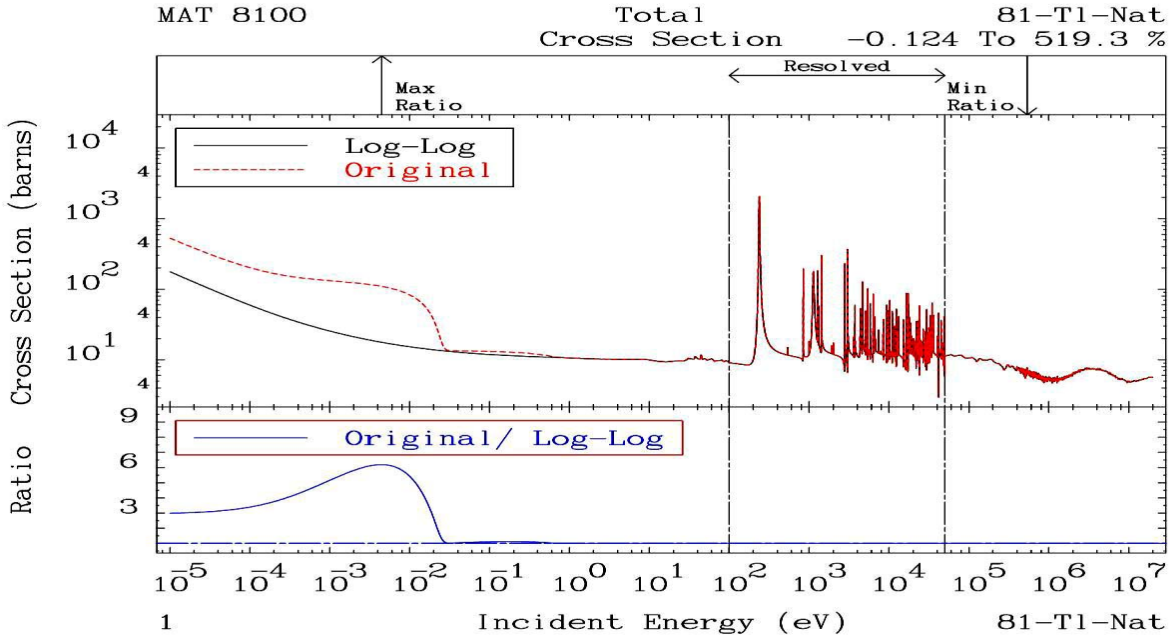
Evaluator Error

Nobody is perfect and the ENDF rules are complicated, so it should not come as surprise to us that evaluators occasionally make mistakes. In the above figures we saw a variety of cases where the evaluation had used INT=5 (log-log) interpolation for the low energy capture cross section and INT=2 (lin-lin) for the elastic. As a result the evaluators had trouble accurately defining the total, which is the sum of elastic and capture; again, there is no ENDF interpolation law that corresponds to the sum of 1/v and constant. Fortunately in these cases we could use our codes to correct the situation by defining a new total equal to the sum of its parts.

Here we see a case from JEFF-3.1 81-Tl-Nat where the evaluator apparently tried to avoid this problem by defining both elastic and capture using INT=2 (lin-lin); then they had no problem defining the total using INT=2 (lin-lin). **Unfortunately this has led to disastrous results**, because the evaluators did not accurately tabulate the capture cross section. The result is an enormous "Bubble" in the total cross section due to linearly interpolating the capture over a large energy range. This is disastrous because since the original evaluated data is all linearly interpolable, we cannot automatically correct this problem using our codes; as far as they are concerned the total is exactly as the evaluator defined it.

In order to illustrate the magnitude of the error we modified the JEFF-3.1 81-Tl-Nat to use INT=5 (log-log) interpolation for the capture, and below we compare this is how the evaluators Originally defined their data. We can see that over a large energy range below thermal the evaluators are overestimating the capture by up to 519% (over a factor of 5).

Unfortunately there is no way that our codes can automatically correct this, and even if you use our codes [2, 3] correctly what you will be using in your applications is the Original data shown below, with the obviously non-physical "bump" in the total. Only the evaluator can correct this problem.



Inconsistencies in Current Data Libraries

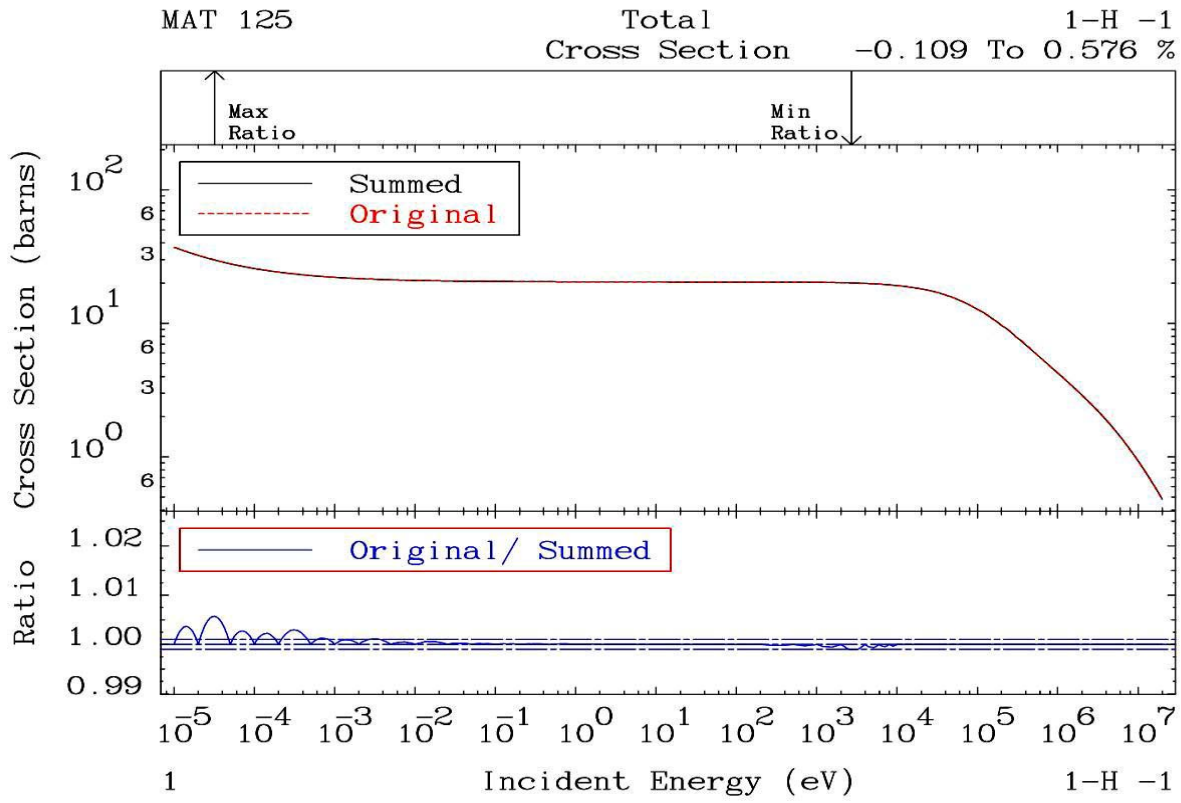
In the Appendices we summarize the differences that we found for all 393 materials in the ENDF/B-VII.0 library (Appendix C), 381 materials in the JEFF-3.1 library (Appendix D), 337 materials in the JENDL-3.3 library (Appendix E), and 240 material in the CENDL-3.library (Appendix F). We will mention that there is nothing special about these particular data libraries; we found similar differences when we looked at other data libraries. To define these differences we started from each original evaluation,

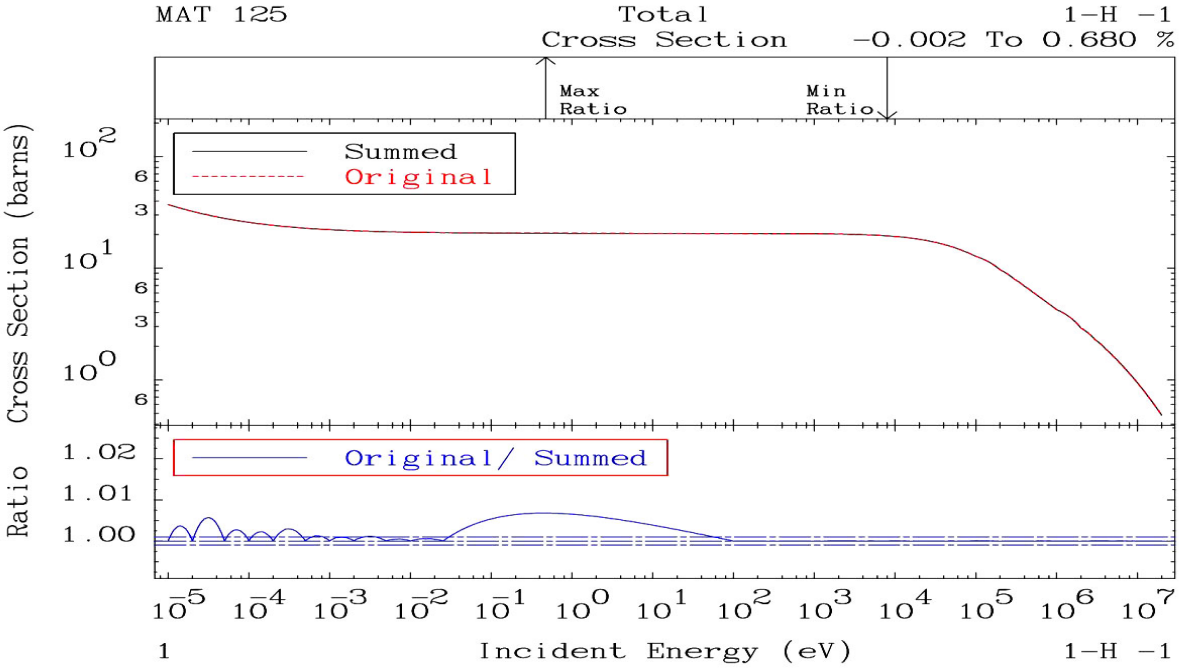
1) We used the PREPRO LINEAR code to linearize all cross sections.
2) We used the PREPRO FIXUP code to define cross sections by summation.
3) We used the PREPRO COMPLOT code to compare the results of steps 1) and 2). On all plots these are identified as 1) Original or 2) Summed.

The differences that we found illustrate the non-uniqueness of the data defined by the evaluator; **remember that both the tabulated total and tabulated reaction cross sections, used to define sums, are BOTH defined by the evaluato**r. There are many computer codes that use ENDF formatted data, and depends on how each defines and uses the cross sections, we could see differences like this between results from various computer codes, strictly because of this non-unique definition of the total cross sections.

The results in the Appendices show large differences for many materials, but we should mention that even seemingly small differences could potentially result in important differences in results. For example, below we illustrate the differences for ENDF/B-VII.0 1-H-1, which are up to over 0.5 %, which might seem small. But we are asked by data users to process evaluated data to high accuracy to insure that data processing introduces very little additional uncertainty, so that we can give them cross sections in the thermal energy range that are accurate to a small fraction of 1%. **That is pretty hard for us to do when we start from evaluated data that is already non-unique to over 0.5 %.**

This problem is seen not only in the ENDF/B-VII.0 library. The below figure of ENDF/B-VII.0 1-H-1, is followed by a figure showing CENDL-3.1 1-H-1, which at very low energy has differences similar to that seen for ENDF/B-VII.0. However, the CENDL-3.1 1-H-1 has in addition differences of almost 0.7% over a much widely energy range extending up to 100 eV.


MAT 125
Total
Cross Section
1-H -1
-0.109 To 0.576 %
Max Ratio
Min Ratio
Summed
Original
Original/ Summed
Cross Section (barns)
Ratio
Incident Energy (eV)
1
1-H -1


MAT 125
Total
Cross Section
1-H -1
-0.002 To 0.680 %
Max Ratio
Min Ratio
Summed
Original
Original/ Summed
Cross Section (barns)
Ratio
Incident Energy (eV)
1
1-H -1

We are not the ONLY users of this Data

Here we have tried to make sure that evaluators understand the importance of having unique data, and we also have tried to explain how we [2, 3] try to make ALL evaluated data consistent, so we can uniquely interpret it for use in our applications: **Again, let us state we ignore the tabulated total and define a new total equal to the sum of its parts**. But it is important for evaluators to realize that we [2, 3] are not the only users of your data. There are currently many computer codes that interpret and use data that has been coded in the ENDF format. **WARNING – we have no idea how other codes interpret your data, so if you want to be sure that your evaluated data is uniquely interpreted it is up to you, the evaluator, to uniquely define it; in particular, insure your tabulated total is equal to the sum of its parts. If you cannot easily do this, we volunteer to do it for you.**

Effect of Non-uniqueness

We use the nuclear and atomic data to solve the Boltzmann equation [4, 5] (see Appendix B for details of the Boltzmann equation), which can be summarized as,

Losses = Gains

$$\text{Losses} = \frac{1}{v}\frac{\partial}{\partial t} N(r,\Omega,E,t) + \vec{\Omega} * \vec{\nabla}\ N(r,\Omega,E,t) + \Sigma_t(r,E,t)\ N(r,\Omega,E,t)$$

$$\text{Gains} = \frac{1}{4\pi}\int_0^\infty dE' \int_{\Omega'} d\Omega' \Sigma(r,E'->E,\Omega'->\Omega) N(r,\Omega',E',t) + S(r,\Omega,E,t)$$

The total cross section $\Sigma_t(r,E,t)$ defines the **losses** due to interaction, and the cross sections for each reaction $\Sigma_k(r,E')$ defines the **gains** due to re-emission of neutrons, e.g., scatter, (n,2n), fission, etc. If we consider only neutron interactions any difference between the total, used to define losses, and the sum of the reactions, used to define gains, in deterministic codes (Sn) will be implicitly indistinguishable from either neutron **capture** (if the total exceeds the sum), or **multiplication** (if the total is less than the sum). In Monte Carlo any imbalance can lead to unpredictable results.

For the three examples shown above, at low neutron energy the evaluator defined total cross section greatly exceeds the sums of the parts (elastic and capture), so that if this total were used in actual Sn applications far too many neutrons would be lost from the system; here we assume the sum of the parts is what the evaluator actually intended.

PREPRO Documentation

When any PREPRO code processes ENDF formatted data and in any way changes the contents of the data, this is documented within the evaluation. At the end of the evaluation's documentation in section MF/MT=1/451, each PREPRO code adds its own documentation. Below is an example of the documentation added by PREPRO codes. From top to bottom the order of such comments define which version of each PREPRO code was used and the parameters used by these codes.

In the below example the codes run were,

1) **LINEAR** (Version 2010-1): This linearized ALL cross sections that are greater than 10^{-10} barns, to within 0.01% (0.0001 as a fraction). During this initial phase in linearizing all cross sections it is important to keep all original tabulated points (an input option), and only add additional energy points as needed to replace non-linear interpolation ranges.

2) **FIXUP** (Version 2010-1): This defines cross sections by summation. The important input options highlighted below, include: Allow cross section reconstruction (otherwise summation cross sections are not defined), and DO NOT make all cross sections non-negative – this is important if an evaluation includes any background cross sections for the resonance energy range; these may be negative, and you want to insure that they be allowed to stay negative.

3) **DICTIN** (Version 2010-1): There are no input options.

After running these three codes the resulting evaluation should include completely consistent cross sections and conform to ENDF formats and conventions [1] and be ready for further processing for use in applications. As a data user you can easily check any evaluation to see if these codes were used; if they haven't, we suggest you use them before you use the data in any application.

```
***************** Program LINEAR (VERSION 2010-1) *************** 125 1451   75
For All Data Greater than 1.0000E-10 barns in Absolute Value      125 1451   76
Data Linearized to Within an Accuracy of .010000000 per-cent      125 1451   77
***************** Program FIXUP (Version 2010-1) ***************** 125 1451   78
Corrected ZA/AWR in All Sections----------------------------Yes  125 1451   79
Corrected Thresholds----------------------------------------No   125 1451   80
Extended Cross Sections to 20 MeV---------------------------No   125 1451   81
Allow Cross Section Deletion--------------------------------No   125 1451   82
Allow Cross Section Reconstruction--------------------------Yes  125 1451   83
Make All Cross Sections Non-Negative------------------------No   125 1451   84
Delete Energies Not in Ascending Order----------------------Yes  125 1451   85
Deleted Duplicate Points------------------------------------Yes  125 1451   86
Check for Ascending MAT/MF/MT Order-------------------------Yes  125 1451   87
Check for Legal MF/MT Numbers-------------------------------Yes  125 1451   88
Allow Creation of Missing Sections--------------------------Yes  125 1451   89
Allow Insertion of Energy Points----------------------------No   125 1451   90
Create Uniform Energy Grid----------------------------------No   125 1451   91
Delete Section if Cross Section =0 at All Energies----------Yes  125 1451   92
***************** Program DICTIN (VERSION 2010-1) ***************** 125 1451   93
```

Conclusion: An Easily Avoidable Problem

This problem is so easily avoidable, requiring little additional effort by evaluators. We suggest that evaluators use some of our codes [2,3] that have existed for decades and been verified for accuracy. Specifically we recommend,

1) Use the PREPRO LINEAR code to linearize all cross sections.
2) Use the PREPRO FIXUP code to define total, and other redundant cross sections, by summation.
3) Use the PREPRO DICTIN code to correct the section lines counts in MF/MT=1/451.

The result will be an evaluation whose cross sections are consistent and compatible for use in applications. Running these three codes takes seconds of computer time, and eventually can end up saving evaluators much more effort and time trying to explain why your evaluations may be misinterpreted by users and give poor answers.

We feel that this is so important that I will even offer to do this work for evaluators. If you e.mail me, RedCullen1@comcast.net your evaluation in the ENDF format, I will run it through these three codes and return it to you, usually within 24 hours. **We cannot make this any easier for you**.

As an example of consistent data that is now available for FREE on line, see POINT 2009 [6], http://www-nds.iaea.org/point2009/pt2009.htm. This includes of the all evaluations in ENDF/B-VII.0 library, both the original data (with the inconsistencies described here), as well as data at many temperatures; the temperature dependent data has been made consistent using exactly the procedures recommended here.

Bottom line

Several friends who read a preliminary version of this paper asked: what inconsistency is acceptable or important; could we make a short list of important materials that really need attention. After hearing this I realized that they had missed the whole point of this paper. **The bottom line is that for use in our applications NO inconsistency is acceptable = ZERO!!! What it comes down to is that either evaluators make their evaluations consistent the way they decide, or we will be forced to make their evaluations consistent, without evaluator approval; of these we would prefer that evaluators maintain control and make the decisions.**

Acknowledgement

I thank **Mary Chin**, CERN, for reminding me of the problem of consistent cross sections. Discussions with her lead directly to this paper, as well as to improvements in my ENDF/B Pre-Processing Codes (PREPRO 2010), which will be available to users later in 2010.

I also thank my friends who reviewed a preliminary version of this paper; their comments and suggestions have been incorporated into this paper and I feel they have significantly contributed to improving this paper. The reviewers in alphabetical order include: **Roger Blomquist** (ANL), **S. Ganesan** (BARC), **M. Greene** (ORNL, retired), **Claes Nordborg** (OECD/NEA Data Bank), **Pavel Oblozinsky** (BNL, Retired), **Ernest Plechaty** (LLNL, retired), **Andrej Trkov** (IJS).

Last but certainly not least I thank **Robert MacFarlane**, LANL, my colleague and friend for many decades, who has contributed greatly to this paper. By rights Bob should be an author of this paper, but in his own modest way he declined my offer to be an author. Whether or not his name appears as an author he does deserve much credit for the ideas expressed in this paper. **THANKS BOB!!!**

References

[1] **ENDF format:** "ENDF-6 Formats Manual: Data Formats and Procedures for the Evaluated Nuclear Data File ENDF/B-VI and ENDF/B-VII", CSEWG Document ENDF-102, edited by Michael Herman and Andrej Trkov, (June 2009). Note, that the ENDF formats and conventions have had a number of updates, latest being the ENDF-6 formats.

[2] **NJOY:** "The NJOY Nuclear Data Processing System, Version 91," Los Alamos National Laboratory report LA-12740-M, by R. E. MacFarlane and D. W. Muir, (October 1994) is still the latest official manual.

[3] "**PREPRO 2007**: 2007 ENDF/B pre-processing Codes", IAEA-NDS-39, Rev. 13, March 17, 2007, by Dermott E. Cullen, Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria. These codes are available FREE on-line at http://www-nds.iaea.or.at/ndspub/endf/prepro/

[4] **MCNP** - A General Monte Carlo N-Particle Transport Code, Version 5, Volume I: Overview and Theory, X-5 Monte Carlo Team, Los Alamos National Laboratory report LA-UR-03-1987 (April 24, 2003). Portions of the MCNP manual are available on-line at http://www-xdiv.lanl.gov/x5/MCNP/themanual.html

[5] **TART 2005**: A Coupled Neutron-Photon 3-D, Time Dependent, Combinatorial Geometry Monte Carlo Transport Code, by Dermott E. Cullen, Lawrence Livermore National Laboratory, UCRL-SM-218009, November 22, 2005.

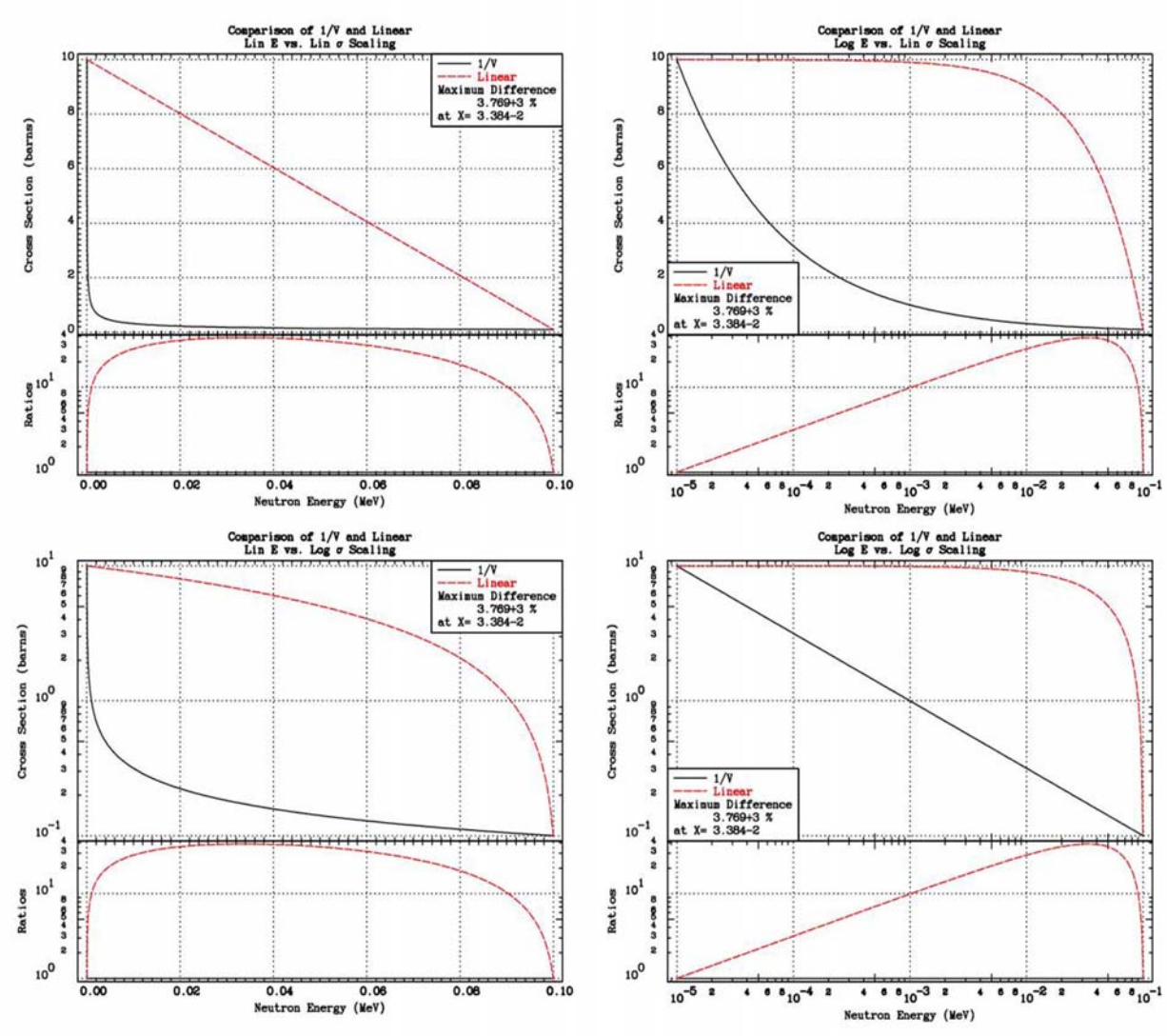
[6} "**POINT 2009:** A Temperature Dependent ENDF/B-VII.0 data Cross Section Library", by Dermott E. Cullen, June 2009, http://www-nds.iaea.org/point2009/pt2009.htm

Appendix A: The Effect of Scaling on What you see

When comparing data using non-linear scaling for a figure, you may be confused by what you see. Here we show exactly the same data: 1/v compared to Linear, using four different scales for the figures: all combination of linear and log scaling for energy and cross section (four results).

In the first figure (upper, left), with lin-lin scaling **we see the Linear data as a straight line**, compared to the 1/v that rapidly decreases; the result being a difference of over 3700% (over a factor of 37). This may be the most familiar view to you.

Now look at the other figures using exactly the same 1/v and Linear data, with the only difference being the x and y scaling of the figure (linear or log). By the last figure (lower, right), with log-log scaling, **we now see that it is the 1/v that appears as a straight lin**e, and the Linear appears as a curve, well above the 1/v. Regardless of how we display the data the ratio remains the same. **Be assured that this is not a mistake or an optical illusion; this is the effect of how the figures are scaled.**



Appendix B: Details of Boltzmann Equation

We can defined the time dependent Boltzmann equation as,

$$\frac{1}{v}\frac{\partial}{\partial t}N(r,\Omega,E,t) + \vec{\Omega}*\vec{\nabla}\,N(r,\Omega,E,t) + \Sigma_t(r,E,t)\,N(r,\Omega,E,t) =$$
$$\frac{1}{4\pi}\int_0^\infty dE'\int_{\Omega'} d\Omega'\Sigma(r,E'->E,\Omega'->\Omega)N(r,\Omega',E',t) + S(r,\Omega,E,t)$$

Where,

$N(r,\Omega,E,t)$ **Neutron flux** per unit volume, energy, and solid angle at time t.

v **Neutron speed** (not, velocity)

$\Sigma_t(r,E,t)$ **Total macroscopic cross section** at location r and time t for a particle of energy E. Generally the macroscopic cross sections will be spatially dependent since different materials will be used at different positions (e.g., core vs. shield) and time dependent because of burn-up.

$\Sigma(r,E'->E,\Omega'->\Omega)$ **Differential cross section**, describing the transfer of particles with initial coordinates E',Ω' before the interaction to E,Ω after the interaction. Written in this form it includes the effect of all possible processes, e.g., scatter, fission, (n,2n), etc.

$S(r,\Omega,E,t)$ **Flux independent neutron source**

The differential cross section can be written in terms of the contributions from the individual reactions in the form,

$$\Sigma(r,E'->E,\Omega'->\Omega) = \sum_k M_k(E')\Sigma_k(r,E')P_k(E'->E,\Omega'->\Omega)$$

Where the summation is over reactions k, e.g., k = elastic, fission, etc., and

$M_k(E')$ **Multiplicity** or average number of secondary neutrons, e.g., 1 for elastic, 2 for (n,2n), $\nu(E')$ for fission.

$\Sigma_k(r,E')$ **Reaction Cross Section** for process k

$P_k(E'->E,\Omega'->\Omega)$ **Probability Distribution** for process k, describing the transfer of particles with initial coordinates E',Ω' before the interaction to E,Ω after the interaction. This is a normalized distribution which is equalm to unity when integrated over all final E,Ω.

Appendix C: Summary of ENDF/B-VII.0 Non-uniqueness

Material	MAT	Differences (%) Negative	Positive
1-H -1	125	-0.109	0.576
1-H -2	128	0.000	0.205
1-H -3	131	-0.006	0.029
2-He-3	225	-0.008	0.367
2-He-4	228	0.000	0.000
3-Li-6	325	-0.009	0.443
3-Li-7	328	-0.004	1.714
4-Be-7	419	No Total	
4-Be-9	425	0.000	0.025
5-B -10	525	-0.007	0.492
5-B -11	528	-0.022	0.027
6-C -Nat	600	0.000	2.197
7-N -14	725	-0.005	2.230
7-N -15	728	0.000	0.011
8-O -16	825	-2.452	7.785
8-O -17	828	0.000	46.215
9-F -19	925	-0.054	0.242
11-Na-22	1122	-0.138	36.002
11-Na-23	1125	-0.305	13.707
12-Mg-24	1225	-0.066	0.051
12-Mg-25	1228	-0.003	0.189
12-Mg-26	1231	-0.026	0.175
13-Al-27	1325	-0.023	0.015
14-Si-28	1425	0.000	0.000
14-Si-29	1428	0.000	0.000
14-Si-30	1431	0.000	0.016
15-P -31	1525	-0.002	4.149
16-S -32	1625	-0.024	0.102
16-S -33	1628	-0.014	0.096
16-S -34	1631	-0.010	0.095
16-S -36	1637	-0.007	0.404
17-Cl-35	1725	-0.380	0.491
17-Cl-37	1731	0.000	0.000
18-Ar-36	1825	-6.303	59.219
18-Ar-38	1831	-49.144	7.936
18-Ar-40	1837	-0.006	0.212
19-K -39	1925	-0.012	0.223
19-K -40	1928	-0.611	1.142
19-K -41	1931	-0.261	0.089
20-Ca-40	2025	-0.029	9999.000
20-Ca-42	2031	-0.005	0.030
20-Ca-43	2034	-23.714	7502.908
20-Ca-44	2037	-0.004	0.004
20-Ca-46	2043	-0.046	1.122
20-Ca-48	2049	-0.005	0.005
21-Sc-45	2125	-0.017	0.018
22-Ti-46	2225	-0.087	0.194
22-Ti-47	2228	-0.235	0.034
22-Ti-48	2231	-0.006	0.088
22-Ti-49	2234	-0.015	0.093
22-Ti-50	2237	-0.019	0.167
23-V -Nat	2300	-0.546	0.653
24-Cr-50	2425	0.000	0.000
24-Cr-52	2431	-0.002	0.002
24-Cr-53	2434	-0.001	0.001
24-Cr-54	2437	-0.001	0.000
25-Mn-55	2525	0.000	0.002
26-Fe-54	2625	0.000	0.000
26-Fe-56	2631	-0.006	0.006
26-Fe-57	2634	0.000	0.000
26-Fe-58	2637	0.000	0.000
27-Co-58	2722	-0.425	163.264
27-Co-58m	2723	-9999.000	6043.455
27-Co-59	2725	0.000	0.000
28-Ni-58	2825	-0.002	0.001
28-Ni-59	2828	-22.443	0.399
28-Ni-60	2831	0.000	0.000
28-Ni-61	2834	0.000	0.000
28-Ni-62	2837	0.000	0.000
28-Ni-64	2843	0.000	0.000
29-Cu-63	2925	0.000	0.027
29-Cu-65	2931	0.000	0.000
30-Zn-Nat	3000	0.000	0.000
31-Ga-69	3125	-0.097	0.110
31-Ga-71	3131	0.000	0.000
32-Ge-70	3225	-100.000	0.000
32-Ge-72	3231	0.000	0.000
32-Ge-73	3234	-2.407	0.000
32-Ge-74	3237	0.000	0.000
32-Ge-76	3243	0.000	0.000
33-As-74	3322	-4.007	7.999
33-As-75	3325	-3.923	8.007
34-Se-74	3425	-0.008	0.387
34-Se-76	3431	-0.003	0.185
34-Se-77	3434	-0.007	0.240
34-Se-78	3437	-0.003	0.134
34-Se-79	3440	-1.542	0.818
34-Se-80	3443	-0.003	0.147
34-Se-82	3449	-0.002	0.149
35-Br-79	3525	-0.002	0.159
35-Br-81	3531	-0.003	0.204
36-Kr-78	3625	-0.004	0.238
36-Kr-80	3631	-0.011	0.166
36-Kr-82	3637	-0.003	0.186
36-Kr-83	3640	-0.001	0.077
36-Kr-84	3643	-0.005	0.229
36-Kr-85	3646	0.000	0.000
36-Kr-86	3649	-0.020	0.200
37-Rb-85	3725	-0.002	0.181
37-Rb-86	3728	0.000	2.361

Material	MAT	Differences (%)	
		Negative	Positive
37-Rb-87	3731	-0.003	0.142
38-Sr-84	3825	0.000	2.986
38-Sr-86	3831	-0.005	0.250
38-Sr-87	3834	-0.004	0.371
38-Sr-88	3837	-0.001	0.001
38-Sr-89	3840	-0.003	0.852
38-Sr-90	3843	-0.030	0.845
39-Y -89	3925	0.000	0.000
39-Y -90	3928	-35.385	0.000
39-Y -91	3931	-0.006	0.753
40-Zr-90	4025	0.000	0.000
40-Zr-91	4028	0.000	0.006
40-Zr-92	4031	0.000	0.017
40-Zr-93	4034	-0.003	0.215
40-Zr-94	4037	0.000	0.008
40-Zr-95	4040	-0.018	0.750
40-Zr-96	4043	0.000	0.014
41-Nb-93	4125	0.000	0.000
41-Nb-94	4128	-0.983	0.124
41-Nb-95	4131	-0.009	0.755
42-Mo-92	4225	-0.028	0.076
42-Mo-94	4231	-0.003	0.114
42-Mo-95	4234	0.000	0.000
42-Mo-96	4237	-0.005	0.128
42-Mo-97	4240	-0.006	0.120
42-Mo-98	4243	-0.087	0.147
42-Mo-99	4246	-0.486	0.694
42-Mo-100	4249	-0.003	0.002
43-Tc-99	4325	-3.989	0.000
44-Ru-96	4425	-0.008	0.955
44-Ru-98	4431	-0.009	0.908
44-Ru-99	4434	-0.409	0.283
44-Ru-100	4437	-0.003	0.397
44-Ru-101	4440	0.000	0.000
44-Ru-102	4443	-0.026	0.022
44-Ru-103	4446	-0.002	0.002
44-Ru-104	4449	-0.086	0.065
44-Ru-105	4452	-0.005	31.432
44-Ru-106	4455	-0.006	0.769
45-Rh-103	4525	0.000	0.000
45-Rh-105	4531	-0.054	0.001
46-Pd-102	4625	-0.081	0.000
46-Pd-104	4631	-0.044	0.000
46-Pd-105	4634	0.000	0.000
46-Pd-106	4637	-0.044	0.000
46-Pd-107	4640	-0.003	0.359
46-Pd-108	4643	-0.041	0.000
46-Pd-110	4649	-0.025	0.012
47-Ag-107	4725	0.000	0.000
47-Ag-109	4731	0.000	0.000

Material	MAT	Differences (%)	
		Negative	Positive
47-Ag-110m	4735	-0.995	0.191
47-Ag-111	4737	0.000	2.054
48-Cd-106	4825	-0.004	0.315
48-Cd-108	4831	-0.021	0.014
48-Cd-110	4837	0.000	0.126
48-Cd-111	4840	-0.012	0.072
48-Cd-112	4843	-0.024	0.018
48-Cd-113	4846	-0.025	0.002
48-Cd-114	4849	0.000	0.000
48-Cd-115m	4853	0.000	2.625
48-Cd-116	4855	-0.013	0.017
49-In-113	4925	-0.005	0.387
49-In-115	4931	-0.005	0.283
50-Sn-112	5025	-0.003	0.442
50-Sn-113	5028	0.000	0.004
50-Sn-114	5031	-0.003	0.326
50-Sn-115	5034	-0.003	0.273
50-Sn-116	5037	-0.004	0.246
50-Sn-117	5040	-0.018	0.284
50-Sn-118	5043	-0.004	0.747
50-Sn-119	5046	-3.628	0.369
50-Sn-120	5049	-0.005	0.194
50-Sn-122	5055	-0.002	0.255
50-Sn-123	5058	-0.948	0.757
50-Sn-124	5061	-0.004	0.177
50-Sn-125	5064	0.000	1.325
50-Sn-126	5067	-0.008	1.156
51-Sb-121	5125	-0.002	0.002
51-Sb-123	5131	-0.002	0.002
51-Sb-124	5134	-1.185	0.984
51-Sb-125	5137	-0.010	1.000
51-Sb-126	5140	0.000	0.000
52-Te-120	5225	-0.011	0.751
52-Te-122	5231	-0.009	0.687
52-Te-123	5234	-0.013	0.043
52-Te-124	5237	-0.008	0.459
52-Te-125	5240	-0.694	0.217
52-Te-126	5243	-0.013	0.426
52-Te-127m	5247	-0.022	0.292
52-Te-128	5249	-0.010	0.567
52-Te-129m	5253	-0.946	0.576
52-Te-130	5255	-0.001	0.001
52-Te-132	5261	0.000	0.000
53-I -127	5325	-100.000	0.869
53-I -129	5331	-4.534	0.287
53-I -130	5334	0.000	13.677
53-I -131	5337	-0.019	0.869
53-I -135	5349	-0.010	0.201
54-Xe-123	5422	-0.008	0.038
54-Xe-124	5425	0.000	0.000

Material	MAT	Differences (%)	
		Negative	Positive
54-Xe-126	5431	-0.026	0.405
54-Xe-128	5437	-0.025	0.348
54-Xe-129	5440	-2.662	0.261
54-Xe-130	5443	-0.002	0.127
54-Xe-131	5446	0.000	0.000
54-Xe-132	5449	0.000	0.000
54-Xe-133	5452	-0.025	0.952
54-Xe-134	5455	0.000	0.000
54-Xe-135	5458	-0.029	0.600
54-Xe-136	5461	0.000	0.000
55-Cs-133	5525	0.000	0.000
55-Cs-134	5528	-1.018	0.169
55-Cs-135	5531	-0.015	0.253
55-Cs-136	5534	-1.783	0.734
55-Cs-137	5537	-0.037	0.843
56-Ba-130	5625	-0.021	0.620
56-Ba-132	5631	-0.024	0.607
56-Ba-133	5634	0.000	0.000
56-Ba-134	5637	-0.015	0.496
56-Ba-135	5640	-0.018	0.570
56-Ba-136	5643	-0.023	0.546
56-Ba-137	5646	-0.018	0.616
56-Ba-138	5649	-0.002	0.002
56-Ba-140	5655	0.000	0.000
57-La-138	5725	-0.570	0.442
57-La-139	5728	-0.001	0.001
57-La-140	5731	0.000	0.000
58-Ce-136	5825	0.000	2.606
58-Ce-138	5831	0.000	2.348
58-Ce-139	5834	0.000	3.201
58-Ce-140	5837	-0.003	0.241
58-Ce-141	5840	-0.260	0.001
58-Ce-142	5843	-0.004	0.036
58-Ce-143	5846	0.000	1.361
58-Ce-144	5849	-0.036	0.991
59-Pr-141	5925	0.000	0.000
59-Pr-142	5928	0.000	8.727
59-Pr-143	5931	-0.306	0.361
60-Nd-142	6025	0.000	0.000
60-Nd-143	6028	-0.007	0.000
60-Nd-144	6031	0.000	0.000
60-Nd-145	6034	0.000	0.000
60-Nd-146	6037	0.000	0.000
60-Nd-147	6040	0.000	0.000
60-Nd-148	6043	0.000	0.000
60-Nd-150	6049	0.000	0.000
61-Pm-147	6149	-0.349	0.042
61-Pm-148	6152	-1.202	0.193
61-Pm-148m	6153	-0.003	0.003
61-Pm-149	6155	-0.038	0.564
61-Pm-151	6161	0.000	0.000
62-Sm-144	6225	0.000	0.000
62-Sm-147	6234	-0.004	0.004
62-Sm-148	6237	0.000	0.000
62-Sm-149	6240	0.000	0.000
62-Sm-150	6243	0.000	0.000
62-Sm-151	6246	0.000	0.000
62-Sm-152	6249	0.000	0.000
62-Sm-153	6252	0.000	0.000
62-Sm-154	6255	0.000	0.000
63-Eu-151	6325	-81.793	0.259
63-Eu-152	6328	-0.950	0.239
63-Eu-153	6331	-9999.000	9999.000
63-Eu-154	6334	-0.040	0.041
63-Eu-155	6337	-0.076	0.056
63-Eu-156	6340	-1.200	0.920
63-Eu-157	6343	-0.084	0.000
64-Gd-152	6425	0.000	0.000
64-Gd-153	6428	-0.221	0.000
64-Gd-154	6431	-0.004	0.006
64-Gd-155	6434	-0.317	0.000
64-Gd-156	6437	0.000	0.000
64-Gd-157	6440	-0.427	0.000
64-Gd-158	6443	-0.253	0.000
64-Gd-160	6449	-1.032	0.007
65-Tb-159	6525	-0.390	0.058
65-Tb-160	6528	-0.299	0.104
66-Dy-156	6625	0.000	0.000
66-Dy-158	6631	0.000	0.000
66-Dy-160	6637	0.000	0.000
66-Dy-161	6640	0.000	0.000
66-Dy-162	6643	0.000	0.000
66-Dy-163	6646	0.000	0.000
66-Dy-164	6649	0.000	0.000
67-Ho-165	6725	-0.007	0.112
67-Ho-166m	6729	0.000	0.000
68-Er-162	6825	0.000	0.000
68-Er-164	6831	0.000	0.000
68-Er-166	6837	0.000	0.000
68-Er-167	6840	0.000	0.000
68-Er-168	6843	0.000	0.000
68-Er-170	6849	0.000	0.000
71-Lu-175	7125	-0.001	0.019
71-Lu-176	7128	0.000	0.044
72-Hf-174	7225	0.000	0.050
72-Hf-176	7231	-0.001	0.030
72-Hf-177	7234	0.000	0.086
72-Hf-178	7237	0.000	0.010
72-Hf-179	7240	0.000	0.082
72-Hf-180	7243	0.000	0.011

Material	MAT	Differences (%)	
		Negative	Positive
73-Ta-181	7328	0.000	0.000
73-Ta-182	7331	-0.008	0.159
74-W -182	7431	-0.093	0.000
74-W -183	7434	-0.001	0.004
74-W -184	7437	0.000	0.000
74-W -186	7443	0.000	0.000
75-Re-185	7525	-0.054	0.187
75-Re-187	7531	-0.086	0.148
77-Ir-191	7725	-0.735	0.039
77-Ir-193	7731	-0.004	0.367
79-Au-197	7925	0.000	0.044
80-Hg-196	8025	-0.076	0.402
80-Hg-198	8031	-0.082	0.631
80-Hg-199	8034	-0.097	0.185
80-Hg-200	8037	-0.103	0.277
80-Hg-201	8040	-0.078	0.479
80-Hg-202	8043	-0.075	0.428
80-Hg-204	8049	-0.055	0.301
82-Pb-204	8225	-0.007	25.725
82-Pb-206	8231	-902.730	8793.605
82-Pb-207	8234	-0.065	8787.364
82-Pb-208	8237	0.000	0.000
83-Bi-209	8325	0.000	0.000
88-Ra-223	8825	-0.023	0.954
88-Ra-224	8828	-0.038	0.976
88-Ra-225	8831	-0.023	0.976
88-Ra-226	8834	-0.037	0.741
89-Ac-225	8925	-0.011	0.979
89-Ac-226	8928	-0.010	0.976
89-Ac-227	8931	-0.384	0.979
90-Th-227	9025	-0.010	0.979
90-Th-228	9028	-0.020	1855.674
90-Th-229	9031	-0.008	0.848
90-Th-230	9034	-0.085	0.094
90-Th-232	9040	-0.374	0.562
90-Th-233	9043	-0.151	0.588
90-Th-234	9046	-0.020	0.748
91-Pa-231	9131	-0.210	0.352
91-Pa-232	9134	-0.028	0.906
91-Pa-233	9137	-0.002	0.501
92-U -232	9219	0.000	0.000
92-U -233	9222	0.000	0.000
92-U -234	9225	0.000	0.003
92-U -235	9228	0.000	0.000
92-U -236	9231	0.000	0.000
92-U -237	9234	-4.936	0.009
92-U -238	9237	0.000	0.000
92-U -239	9240	0.000	0.000
92-U -240	9243	0.000	0.000
92-U -241	9246	0.000	1559.455

Material	MAT	Differences (%)	
		Negative	Positive
93-Np-235	9340	-0.009	0.425
93-Np-236	9343	-0.013	0.894
93-Np-237	9346	0.000	0.000
93-Np-238	9349	-0.011	1.098
93-Np-239	9352	-0.097	1.187
94-Pu-236	9428	-0.009	0.090
94-Pu-237	9431	0.000	0.000
94-Pu-238	9434	-0.002	0.005
94-Pu-239	9437	0.000	0.000
94-Pu-240	9440	0.000	0.000
94-Pu-241	9443	-0.040	0.050
94-Pu-242	9446	-0.004	0.072
94-Pu-243	9449	-0.004	0.003
94-Pu-244	9452	-0.022	0.028
94-Pu-246	9458	-0.008	0.988
95-Am-241	9543	-0.001	0.042
95-Am-242	9546	0.000	0.000
95-Am-242m	9547	0.000	0.005
95-Am-243	9549	0.000	0.013
95-Am-244	9552	-0.007	0.161
95-Am-244m	9553	-0.007	0.234
96-Cm-241	9628	-0.006	1.082
96-Cm-242	9631	-0.086	0.007
96-Cm-243	9634	-0.019	0.002
96-Cm-244	9637	-0.016	0.157
96-Cm-245	9640	-0.014	0.093
96-Cm-246	9643	0.000	0.013
96-Cm-247	9646	-0.014	0.202
96-Cm-248	9649	-0.007	0.000
96-Cm-249	9652	-0.009	0.128
96-Cm-250	9655	-0.005	0.639
97-Bk-249	9752	0.000	0.000
97-Bk-250	9755	-0.005	0.183
98-Cf-249	9852	-0.008	0.152
98-Cf-250	9855	-0.017	0.343
98-Cf-251	9858	-0.010	0.020
98-Cf-252	9861	-0.003	0.002
98-Cf-253	9864	0.000	0.000
98-Cf-254	9867	-0.008	0.769
99-Es-253	9913	-0.647	11.272
99-Es-254	9914	-0.008	0.990
99-Es-255	9915	-0.009	1.092
100-Fm-255	9936	-0.011	1.013

Appendix D: Summary of JEFF-3.1 Non-uniqueness

Material	MAT	Differences (%) Negative	Positive
1-H -1	125	-0.010	0.036
1-H -2	128	0.000	0.205
1-H -3	131	-0.086	0.036
2-He-3	225	-0.008	0.367
2-He-4	228	0.000	0.000
3-Li-6	325	-0.039	0.416
3-Li-7	328	-0.807	0.816
4-Be-9	425	-6.559	1.321
5-B -10	525	-0.087	0.516
5-B -11	528	-0.022	0.027
6-C -Nat	600	0.000	2.197
7-N -14	725	-0.005	2.230
7-N -15	728	0.000	0.011
8-O -16	825	0.000	0.000
8-O -17	828	0.000	46.215
9-F -19	925	-22.917	0.431
11-Na-22	1122	-0.138	36.002
11-Na-23	1125	0.000	0.000
12-Mg-24	1225	-0.066	0.051
12-Mg-25	1228	-0.003	0.189
12-Mg-26	1231	-0.026	0.175
13-Al-27	1325	-0.023	0.015
14-Si-28	1425	-0.006	0.005
14-Si-29	1428	-0.310	1.101
14-Si-30	1431	-0.006	0.749
15-P -31	1525	-0.029	0.190
16-S -32	1625	-0.024	0.102
16-S -33	1628	-0.014	0.096
16-S -34	1631	-0.010	0.095
16-S -36	1637	-0.007	0.404
17-Cl-35	1725	-13.031	18.072
17-Cl-37	1731	0.000	0.000
18-Ar-36	1825	-6.303	59.219
18-Ar-38	1831	-49.144	7.936
18-Ar-40	1837	-0.006	0.212
19-K -39	1925	-0.012	0.223
19-K -40	1928	-0.611	1.142
19-K -41	1931	-0.261	0.089
20-Ca-40	2025	-0.029	9999.000
20-Ca-42	2031	-0.005	0.030
20-Ca-43	2034	-23.714	7502.908
20-Ca-44	2037	-0.004	0.004
20-Ca-46	2043	-0.004	0.005
20-Ca-48	2049	-0.005	0.005
21-Sc-45	2125	-0.055	9830.962
22-Ti-46	2225	-0.107	0.099
22-Ti-47	2228	-0.107	0.099
22-Ti-48	2231	-0.559	1.153
22-Ti-49	2234	-0.107	0.099
22-Ti-50	2237	-0.107	0.099
23-V -Nat	2300	-0.056	0.002
24-Cr-50	2425	0.000	0.000
24-Cr-52	2431	-0.258	0.098
24-Cr-53	2434	-0.001	0.001
24-Cr-54	2437	-0.001	0.000
25-Mn-55	2525	0.000	0.004
26-Fe-54	2625	-0.076	7.050
26-Fe-56	2631	-0.420	0.004
26-Fe-57	2634	-1.101	656.231
26-Fe-58	2637	-0.073	0.060
27-Co-58	2722	-0.425	163.264
27-Co-58m	2723	-9999.000	6043.455
27-Co-59	2725	0.000	0.000
28-Ni-58	2825	0.000	0.000
28-Ni-59	2828	-22.443	0.399
28-Ni-60	2831	0.000	0.000
28-Ni-61	2834	0.000	0.000
28-Ni-62	2837	0.000	0.000
28-Ni-64	2843	0.000	0.000
29-Cu-63	2925	0.000	0.027
29-Cu-65	2931	0.000	0.000
30-Zn-Nat	3000	0.000	0.000
31-Ga-Nat	3100	-0.092	0.076
32-Ge-70	3225	-0.004	8373.622
32-Ge-72	3231	-0.005	0.018
32-Ge-73	3234	-24.038	2441.305
32-Ge-74	3237	-0.004	0.063
32-Ge-76	3243	-0.013	0.004
33-As-75	3325	-0.010	0.965
34-Se-74	3425	-0.009	0.966
34-Se-76	3431	-0.010	0.514
34-Se-77	3434	-0.009	0.409
34-Se-78	3437	-0.010	1.111
34-Se-79	3440	-1.542	0.818
34-Se-80	3443	-0.010	0.807
34-Se-82	3449	-0.009	0.675
35-Br-79	3525	-0.010	0.701
35-Br-81	3531	-0.012	0.706
36-Kr-78	3625	0.000	0.121
36-Kr-80	3631	0.000	0.406
36-Kr-82	3637	0.000	0.415
36-Kr-83	3640	0.000	0.360
36-Kr-84	3643	0.000	0.372
36-Kr-85	3646	-0.085	0.969
36-Kr-86	3649	0.000	0.516
37-Rb-85	3725	-0.009	0.311
37-Rb-86	3728	-0.033	0.725
37-Rb-87	3731	-0.008	0.645
38-Sr-84	3825	-0.002	0.000
38-Sr-86	3831	-0.031	0.726

Material	MAT	Differences (%) Negative	Positive
38-Sr-87	3834	-0.007	0.472
38-Sr-88	3837	-0.024	1.007
38-Sr-89	3840	-0.262	0.615
38-Sr-90	3843	-0.189	0.735
39-Y -89	3925	0.000	0.002
39-Y -90	3928	-0.027	0.838
39-Y -91	3931	-0.007	0.819
40-Zr-90	4025	0.000	0.096
40-Zr-91	4028	0.000	0.006
40-Zr-92	4031	0.000	0.017
40-Zr-93	4034	0.000	0.000
40-Zr-94	4037	0.000	0.008
40-Zr-95	4040	-0.004	0.003
40-Zr-96	4043	0.000	0.014
41-Nb-93	4125	0.000	0.000
41-Nb-94	4128	-0.983	0.124
41-Nb-95	4131	-0.009	0.755
42-Mo-92	4225	-0.028	0.076
42-Mo-94	4231	-0.003	0.114
42-Mo-95	4234	0.000	0.388
42-Mo-96	4237	-0.005	0.128
42-Mo-97	4240	-0.006	0.120
42-Mo-98	4243	-0.087	0.147
42-Mo-99	4246	-0.486	0.694
42-Mo-100	4249	-0.050	0.145
43-Tc-99	4331	-36.714	9999.000
44-Ru-96	4425	-0.004	0.839
44-Ru-98	4431	-0.009	0.662
44-Ru-99	4434	-0.008	0.425
44-Ru-100	4437	-0.014	0.690
44-Ru-101	4440	-0.028	0.905
44-Ru-102	4443	-0.009	0.517
44-Ru-103	4446	0.000	0.000
44-Ru-104	4449	-100.000	0.211
44-Ru-105	4452	-0.017	0.850
44-Ru-106	4455	-0.009	1.030
45-Rh-103	4525	0.000	1.204
45-Rh-105	4531	-0.236	4.069
46-Pd-102	4625	0.000	0.000
46-Pd-104	4631	-0.001	0.000
46-Pd-105	4634	0.000	0.000
46-Pd-106	4637	0.000	0.143
46-Pd-107	4640	-0.003	0.000
46-Pd-108	4643	-0.006	0.000
46-Pd-110	4649	0.000	0.208
47-Ag-107	4725	0.000	0.130
47-Ag-109	4731	0.000	0.000
47-Ag-110	4735	-0.995	0.191
47-Ag-111	4737	-0.009	0.691
48-Cd-106	4825	0.000	0.000
48-Cd-108	4831	-0.021	0.014
48-Cd-110	4837	0.000	0.126
48-Cd-111	4840	-0.001	0.000
48-Cd-112	4843	-0.024	0.018
48-Cd-113	4846	-0.013	0.020
48-Cd-114	4849	0.000	0.000
48-Cd-115	4853	-0.095	0.591
48-Cd-116	4855	-0.013	0.017
49-In-113	4925	-0.005	0.387
49-In-115	4931	-0.005	0.283
50-Sn-112	5025	-0.003	0.442
50-Sn-114	5031	-0.003	0.326
50-Sn-115	5034	-0.003	0.273
50-Sn-116	5037	-0.004	0.246
50-Sn-117	5040	-0.018	0.284
50-Sn-118	5043	-0.004	0.747
50-Sn-119	5046	-0.593	0.369
50-Sn-120	5049	-0.005	0.194
50-Sn-122	5055	-0.002	0.255
50-Sn-123	5058	-0.008	0.829
50-Sn-124	5061	-0.004	0.177
50-Sn-125	5064	-0.021	0.627
50-Sn-126	5067	-0.115	0.976
51-Sb-121	5125	-1.220	0.141
51-Sb-123	5131	-0.012	0.149
51-Sb-124	5134	-0.056	0.967
51-Sb-125	5137	-0.009	0.654
51-Sb-126	5140	-0.096	0.558
52-Te-120	5225	-0.009	0.863
52-Te-122	5231	-0.008	1.002
52-Te-123	5234	-0.012	0.899
52-Te-124	5237	-0.007	0.473
52-Te-125	5240	-0.004	0.942
52-Te-126	5243	-0.008	0.895
52-Te-127	5247	-0.065	0.857
52-Te-128	5249	-55.912	0.997
52-Te-129	5253	-0.120	0.831
52-Te-130	5255	-0.008	0.875
52-Te-132	5261	-0.202	0.849
53-I -127	5325	0.000	1.185
53-I -129	5331	0.000	1.513
53-I -130	5334	-0.009	0.537
53-I -131	5337	-0.008	0.812
53-I -135	5349	-0.052	7.610
54-Xe-124	5425	-0.001	0.825
54-Xe-126	5431	-0.004	0.475
54-Xe-128	5437	-0.011	0.156
54-Xe-129	5440	0.000	0.344
54-Xe-130	5443	-0.002	0.127
54-Xe-131	5446	-0.001	0.265

Material	MAT	Differences (%)	
		Negative	Positive
54-Xe-132	5449	-0.001	0.082
54-Xe-133	5452	-0.066	0.599
54-Xe-134	5455	0.000	0.046
54-Xe-135	5458	-0.013	0.070
54-Xe-136	5461	-0.018	0.777
55-Cs-133	5525	-0.001	0.032
55-Cs-134	5528	-0.008	0.559
55-Cs-135	5531	0.000	0.000
55-Cs-136	5534	-0.007	0.812
55-Cs-137	5537	0.000	0.000
56-Ba-130	5625	-0.021	0.620
56-Ba-132	5631	-0.024	0.770
56-Ba-134	5637	-0.015	0.496
56-Ba-135	5640	-0.018	0.570
56-Ba-136	5643	-0.023	0.546
56-Ba-137	5646	-0.018	0.616
56-Ba-138	5649	-0.005	0.425
56-Ba-140	5655	0.000	0.000
57-La-138	5725	-0.570	0.442
57-La-139	5728	0.000	0.000
57-La-140	5731	-0.008	0.686
58-Ce-140	5837	-0.012	0.214
58-Ce-141	5840	0.000	0.000
58-Ce-142	5843	-0.008	0.010
58-Ce-143	5846	-0.048	0.633
58-Ce-144	5849	-0.003	0.003
59-Pr-141	5925	0.000	0.000
59-Pr-142	5928	-0.058	0.535
59-Pr-143	5931	-0.030	0.540
60-Nd-142	6025	-100.000	0.275
60-Nd-143	6028	0.000	0.000
60-Nd-144	6031	0.000	0.000
60-Nd-145	6034	0.000	0.000
60-Nd-146	6037	-0.061	3.897
60-Nd-147	6040	-0.633	0.425
60-Nd-148	6043	-0.010	0.988
60-Nd-150	6049	-100.000	0.188
61-Pm-147	6149	0.000	0.030
61-Pm-148	6152	-0.065	7.256
61-Pm-148m	6153	-0.065	2.657
61-Pm-149	6155	-0.010	0.349
61-Pm-151	6161	-0.055	0.559
62-Sm-144	6225	-0.009	0.902
62-Sm-147	6234	0.000	0.000
62-Sm-148	6237	-0.008	0.887
62-Sm-149	6240	-0.002	0.000
62-Sm-150	6243	-100.000	0.211
62-Sm-151	6246	0.000	0.000
62-Sm-152	6249	0.000	0.000
62-Sm-153	6252	-0.058	0.483
62-Sm-154	6255	-0.375	0.221
63-Eu-151	6325	-0.003	0.419
63-Eu-152	6328	-0.950	0.239
63-Eu-153	6331	-7.223	5.899
63-Eu-154	6334	-0.005	1.658
63-Eu-155	6337	-91.830	0.384
63-Eu-156	6340	-0.102	0.776
63-Eu-157	6343	-0.169	38.673
64-Gd-152	6425	-0.010	0.284
64-Gd-154	6431	-0.005	0.577
64-Gd-155	6434	-1.008	0.185
64-Gd-156	6437	0.000	0.000
64-Gd-157	6440	-0.008	3.811
64-Gd-158	6443	-0.020	0.561
64-Gd-160	6449	-0.010	0.765
65-Tb-159	6525	-3.829	2.101
65-Tb-160	6528	-0.244	72.369
66-Dy-160	6637	-0.107	4.042
66-Dy-161	6640	-0.197	0.139
66-Dy-162	6643	-0.191	0.164
66-Dy-163	6646	-0.207	0.127
66-Dy-164	6649	0.000	0.017
67-Ho-165	6725	-0.007	65.047
68-Er-162	6825	0.000	0.000
68-Er-164	6831	0.000	0.000
68-Er-166	6837	0.000	0.000
68-Er-167	6840	0.000	0.000
68-Er-168	6843	0.000	0.000
68-Er-170	6849	0.000	0.000
71-Lu-175	7125	-0.001	0.019
71-Lu-176	7128	0.000	0.044
72-Hf-174	7225	-0.003	0.225
72-Hf-176	7231	-0.004	0.201
72-Hf-177	7234	-0.008	0.272
72-Hf-178	7237	-0.006	0.260
72-Hf-179	7240	-0.007	0.277
72-Hf-180	7243	-0.004	0.130
73-Ta-181	7328	-0.069	0.150
73-Ta-182	7331	-0.008	0.212
74-W -182	7431	-0.006	0.179
74-W -183	7434	-0.012	0.277
74-W -184	7437	-0.011	0.152
74-W -186	7443	-0.011	0.167
75-Re-185	7525	-0.054	0.187
75-Re-187	7531	-0.086	0.148
76-Os-Nat	7600	0.000	0.000
77-Ir-191	7725	0.000	0.000
77-Ir-193	7731	0.000	0.000
78-Pt-Nat	7800	0.000	0.000
79-Au-197	7925	0.000	0.000

Material	MAT	Differences (%)	
		Negative	Positive
80-Hg-196	8025	-0.142	0.544
80-Hg-198	8031	-0.071	0.337
80-Hg-199	8034	-0.104	0.351
80-Hg-200	8037	-0.104	0.277
80-Hg-201	8040	-0.078	0.173
80-Hg-202	8043	-0.293	0.428
80-Hg-204	8049	-0.231	0.301
81-Tl-Nat	8100	-100.000	0.004
82-Pb-204	8225	-0.007	25.725
82-Pb-206	8231	-902.730	8793.605
82-Pb-207	8234	-0.065	8787.364
82-Pb-208	8237	-0.003	9999.000
83-Bi-209	8325	-0.106	9999.000
88-Ra-223	8825	-0.734	0.977
88-Ra-224	8828	-0.038	0.976
88-Ra-225	8831	-0.625	0.976
88-Ra-226	8834	-0.037	0.741
89-Ac-225	8925	-0.020	0.979
89-Ac-226	8928	-0.010	0.998
89-Ac-227	8931	-0.384	0.979
90-Th-227	9025	-0.010	0.979
90-Th-228	9028	-0.023	0.979
90-Th-229	9031	-0.008	0.966
90-Th-230	9034	0.000	0.000
90-Th-232	9040	-33.636	0.027
90-Th-233	9043	-0.151	0.588
90-Th-234	9046	-0.043	0.748
91-Pa-231	9131	-0.024	0.004
91-Pa-232	9134	-0.028	0.906
91-Pa-233	9137	-0.012	0.010
92-U -232	9219	-0.016	0.003
92-U -233	9222	-0.008	0.001
92-U -234	9225	0.000	0.007
92-U -235	9228	0.000	0.005
92-U -236	9231	0.000	0.000
92-U -237	9234	0.000	0.000
92-U -238	9237	0.000	0.000
93-Np-235	9340	-0.009	0.425
93-Np-236	9343	-0.043	0.700
93-Np-237	9346	-0.003	0.040
93-Np-238	9349	-0.096	0.084
93-Np-239	9352	-0.097	1.187
94-Pu-236	9428	-0.009	0.090
94-Pu-237	9431	-0.008	0.947
94-Pu-238	9434	-9.564	0.293
94-Pu-239	9437	0.000	0.000
94-Pu-240	9440	-0.723	0.000
94-Pu-241	9443	-0.006	0.030
94-Pu-242	9446	-0.166	0.117
94-Pu-243	9449	-0.004	0.003
94-Pu-244	9452	0.000	0.002
94-Pu-246	9458	-0.196	0.988
95-Am-241	9543	-0.013	0.187
95-Am-242	9546	-0.015	0.123
95-Am-242m	9547	-0.009	0.159
95-Am-243	9549	-0.013	0.228
95-Am-244	9552	-0.007	0.161
95-Am-244m	9553	-0.007	0.234
96-Cm-240	9625	-0.004	0.450
96-Cm-241	9628	-0.006	0.898
96-Cm-242	9631	-0.101	0.300
96-Cm-243	9634	-0.144	0.257
96-Cm-244	9637	0.000	0.000
96-Cm-245	9640	-0.014	0.093
96-Cm-246	9643	0.000	0.013
96-Cm-247	9646	-0.006	0.204
96-Cm-248	9649	-0.037	0.270
96-Cm-249	9652	-0.009	0.133
96-Cm-250	9655	-0.005	0.639
97-Bk-247	9746	-0.102	0.581
97-Bk-249	9752	-0.717	0.395
97-Bk-250	9755	-0.005	0.183
98-Cf-249	9852	-0.003	0.107
98-Cf-250	9855	-0.012	0.304
98-Cf-251	9858	-0.010	0.020
98-Cf-252	9861	-0.003	0.002
98-Cf-254	9867	-0.014	0.769
99-Es-253	9913	-0.647	11.272
99-Es-254	9914	-0.026	0.990
99-Es-255	9916	-0.009	1.272
100-Fm-255	9936	-0.021	1.016

Appendix E: Summary of JENDL-3.3 Non-uniqueness

Material	MAT	Differences (%) Negative	Positive
1-H -1	125	-0.010	0.575
1-H -2	128	-0.002	0.032
2-He-3	225	-0.010	1.004
2-He-4	228	0.000	0.000
3-Li-6	325	-0.008	0.985
3-Li-7	328	-0.005	0.546
4-Be-9	425	0.000	0.039
5-B -10	525	-0.010	0.979
5-B -11	528	0.000	0.000
6-C -Nat	600	-0.002	0.024
7-N -14	725	-0.010	0.855
7-N -15	728	0.000	0.039
8-O -16	825	-0.011	0.054
9-F -19	925	-0.044	0.058
11-Na-23	1125	0.000	0.000
12-Mg-24	1225	-0.066	0.051
12-Mg-25	1228	-0.003	0.414
12-Mg-26	1231	-0.026	0.175
13-Al-27	1325	-0.003	0.159
14-Si-28	1425	-0.002	0.091
14-Si-29	1428	-0.310	1.101
14-Si-30	1431	-0.006	0.749
15-P -31	1525	-0.029	0.190
16-S -32	1625	-0.024	0.102
16-S -33	1628	-0.004	0.096
16-S -34	1631	-0.010	0.341
16-S -36	1637	-0.007	0.404
17-Cl-35	1725	-0.007	0.290
17-Cl-37	1731	-0.014	0.202
18-Ar-40	1837	-0.006	0.212
19-K -39	1925	-0.012	0.223
19-K -40	1928	-0.024	1.142
19-K -41	1931	-0.261	0.131
20-Ca-40	2025	-0.003	0.085
20-Ca-42	2031	-0.010	0.069
20-Ca-43	2034	-0.015	0.096
20-Ca-44	2037	-0.059	0.104
20-Ca-46	2043	-0.018	1.095
20-Ca-48	2049	-0.003	0.101
21-Sc-45	2125	-0.039	0.281
22-Ti-46	2225	-0.087	0.383
22-Ti-47	2228	-0.235	0.034
22-Ti-48	2231	-0.006	0.088
22-Ti-49	2234	-0.015	0.093
22-Ti-50	2237	-0.019	0.167
23-V -Nat	2300	-0.320	1.812
24-Cr-50	2425	-0.091	0.143
24-Cr-52	2431	-0.010	0.039
24-Cr-53	2434	-0.048	0.314
24-Cr-54	2437	-0.065	0.305
25-Mn-55	2525	0.000	0.004
26-Fe-54	2625	-100.000	0.125
26-Fe-56	2631	-0.003	0.111
26-Fe-57	2634	-0.054	1.003
26-Fe-58	2637	-0.030	0.094
27-Co-59	2725	-0.165	0.113
28-Ni-58	2825	0.000	0.836
28-Ni-60	2831	-0.001	0.196
28-Ni-61	2834	-0.003	0.279
28-Ni-62	2837	-0.002	0.005
28-Ni-64	2843	-0.002	0.005
29-Cu-63	2925	-0.010	0.104
29-Cu-65	2931	-0.020	0.080
31-Ga-69	3125	-0.097	0.110
31-Ga-71	3131	-0.075	0.216
32-Ge-70	3225	-0.007	0.235
32-Ge-72	3231	-0.003	0.310
32-Ge-73	3234	-0.009	0.384
32-Ge-74	3237	-0.005	0.136
32-Ge-76	3243	-0.004	0.203
33-As-75	3325	-0.018	0.131
34-Se-74	3425	-0.008	0.387
34-Se-76	3431	-0.003	0.552
34-Se-77	3434	-0.007	0.322
34-Se-78	3437	-0.003	0.177
34-Se-79	3440	-0.010	0.818
34-Se-80	3443	-0.003	0.175
34-Se-82	3449	-0.002	0.733
35-Br-79	3525	-0.002	0.234
35-Br-81	3531	-0.003	0.822
36-Kr-78	3625	-0.004	0.544
36-Kr-80	3631	-0.011	0.166
36-Kr-82	3637	-0.003	0.237
36-Kr-83	3640	-0.615	0.407
36-Kr-84	3643	-0.005	0.229
36-Kr-85	3646	-0.010	0.782
36-Kr-86	3649	-0.012	0.404
37-Rb-85	3725	-0.002	0.181
37-Rb-87	3731	-0.003	0.167
38-Sr-86	3831	-0.005	0.395
38-Sr-87	3834	-0.004	1.244
38-Sr-88	3837	-0.033	0.450
38-Sr-89	3840	-0.017	0.852
38-Sr-90	3843	-0.015	0.845
39-Y -89	3925	-0.008	0.377
39-Y -91	3931	-0.006	0.753
40-Zr-90	4025	0.000	0.096
40-Zr-91	4028	0.000	0.006
40-Zr-92	4031	0.000	0.017
40-Zr-93	4034	-0.003	1.079

Material	MAT	Differences (%)	
		Negative	Positive
40-Zr-94	4037	0.000	0.008
40-Zr-95	4040	-0.010	0.846
40-Zr-96	4043	0.000	0.014
41-Nb-93	4125	-100.000	0.017
41-Nb-94	4128	-0.983	4.346
41-Nb-95	4131	-0.009	1.024
42-Mo-92	4225	-0.028	0.076
42-Mo-94	4231	-0.003	0.114
42-Mo-95	4234	-0.007	0.108
42-Mo-96	4237	-0.005	0.128
42-Mo-97	4240	-0.006	0.120
42-Mo-98	4243	-0.087	0.147
42-Mo-99	4246	-0.009	0.694
42-Mo-100	4249	-0.050	0.145
43-Tc-99	4331	-0.024	0.256
44-Ru-96	4425	-0.007	0.955
44-Ru-98	4431	-0.009	0.908
44-Ru-99	4434	-0.004	0.283
44-Ru-100	4437	-0.003	0.411
44-Ru-101	4440	-0.004	0.273
44-Ru-102	4443	-0.003	0.379
44-Ru-103	4446	-0.987	3.642
44-Ru-104	4449	-0.002	0.490
44-Ru-106	4455	-0.006	0.769
45-Rh-103	4525	-0.872	0.415
45-Rh-105	4531	-0.006	0.400
46-Pd-102	4625	-0.003	0.383
46-Pd-104	4631	-0.005	0.675
46-Pd-105	4634	-0.006	0.302
46-Pd-106	4637	-0.004	0.430
46-Pd-107	4640	-0.002	0.359
46-Pd-108	4643	-0.004	0.451
46-Pd-110	4649	-0.003	0.364
47-Ag-107	4725	0.000	0.000
47-Ag-109	4731	0.000	0.000
47-Ag-110m	4735	-0.995	0.675
48-Cd-106	4825	-0.004	0.315
48-Cd-108	4831	-0.011	0.454
48-Cd-110	4837	-0.003	0.823
48-Cd-111	4840	-0.012	0.072
48-Cd-112	4843	-0.005	0.805
48-Cd-113	4846	-0.011	0.159
48-Cd-114	4849	-0.005	0.169
48-Cd-116	4855	-0.005	0.274
49-In-113	4925	-0.005	0.387
49-In-115	4931	-0.005	0.283
50-Sn-112	5025	-0.002	0.569
50-Sn-114	5031	-0.003	0.677
50-Sn-115	5034	-0.003	0.840
50-Sn-116	5037	-0.004	0.361
50-Sn-117	5040	-0.018	0.284
50-Sn-118	5043	-0.004	1.147
50-Sn-119	5046	-0.593	0.369
50-Sn-120	5049	-0.005	0.194
50-Sn-122	5055	-0.002	0.352
50-Sn-123	5058	-0.948	0.757
50-Sn-124	5061	-0.004	0.177
50-Sn-126	5067	-0.236	1.156
51-Sb-121	5125	-1.220	0.141
51-Sb-123	5131	-0.012	0.149
51-Sb-124	5134	-0.907	17.034
51-Sb-125	5137	-0.009	1.000
52-Te-120	5225	-0.011	0.751
52-Te-122	5231	-0.009	0.687
52-Te-123	5234	-0.013	0.146
52-Te-124	5237	-0.008	1.009
52-Te-125	5240	-0.672	0.217
52-Te-126	5243	-0.013	0.426
52-Te-127m	5247	-16.269	9.732
52-Te-128	5249	-0.010	1.080
52-Te-129m	5253	-0.946	9.341
52-Te-130	5255	-0.011	0.992
53-I -127	5325	-0.738	0.267
53-I -129	5331	-0.714	0.287
53-I -131	5337	-0.019	0.869
54-Xe-124	5425	-0.021	0.431
54-Xe-126	5431	-0.026	0.405
54-Xe-128	5437	-0.025	0.348
54-Xe-129	5440	-0.921	0.261
54-Xe-130	5443	-0.012	0.388
54-Xe-131	5446	-0.014	0.184
54-Xe-132	5449	-0.014	0.304
54-Xe-133	5452	-0.025	0.952
54-Xe-134	5455	-0.011	0.673
54-Xe-135	5458	-0.029	1.178
54-Xe-136	5461	-0.016	0.518
55-Cs-133	5525	-0.010	0.331
55-Cs-134	5528	-0.317	1.237
55-Cs-135	5531	-0.015	0.253
55-Cs-136	5534	-0.495	24.870
55-Cs-137	5537	-0.037	1.329
56-Ba-130	5625	-0.021	0.620
56-Ba-132	5631	-0.024	0.958
56-Ba-134	5637	-0.015	0.496
56-Ba-135	5640	-0.018	0.570
56-Ba-136	5643	-0.023	0.715
56-Ba-137	5646	-0.018	0.652
56-Ba-138	5649	-0.005	0.634
56-Ba-140	5655	-0.015	0.937
57-La-138	5725	-0.570	0.442

Material	MAT	Differences (%)	
		Negative	Positive
57-La-139	5728	-0.023	0.385
58-Ce-140	5837	-0.003	0.341
58-Ce-141	5840	-0.008	0.923
58-Ce-142	5843	-0.004	0.107
58-Ce-144	5849	-0.036	0.991
59-Pr-141	5925	-0.037	0.182
59-Pr-143	5931	-0.306	16.765
60-Nd-142	6025	-0.016	0.899
60-Nd-143	6028	-0.004	0.060
60-Nd-144	6031	-0.008	0.138
60-Nd-145	6034	-0.785	2.988
60-Nd-146	6037	-0.007	0.152
60-Nd-147	6040	-0.061	0.256
60-Nd-148	6043	-0.006	1.012
60-Nd-150	6049	-0.015	0.069
61-Pm-147	6149	-0.014	0.042
61-Pm-148	6152	-0.371	1.211
61-Pm-148m	6153	-0.961	6.358
61-Pm-149	6155	-0.018	0.564
62-Sm-144	6225	-0.008	0.142
62-Sm-147	6234	-0.015	0.195
62-Sm-148	6237	-0.007	0.502
62-Sm-149	6240	-0.405	3.758
62-Sm-150	6243	-0.007	1.315
62-Sm-151	6246	-0.715	0.768
62-Sm-152	6249	-0.007	0.338
62-Sm-153	6252	-0.334	1.449
62-Sm-154	6255	-1.281	0.109
63-Eu-151	6325	-58.268	65.177
63-Eu-152	6328	-0.950	3.431
63-Eu-153	6331	-7.224	8.160
63-Eu-154	6334	-0.317	0.216
63-Eu-155	6337	-0.877	0.187
63-Eu-156	6340	-0.484	3.598
64-Gd-152	6425	-0.010	0.370
64-Gd-154	6431	-0.015	0.228
64-Gd-155	6434	-0.104	13.194
64-Gd-156	6437	-0.010	0.232
64-Gd-157	6440	-0.443	8.335
64-Gd-158	6443	-0.015	0.190
64-Gd-160	6449	-0.908	0.247
65-Tb-159	6525	-0.390	0.058
68-Er-162	6825	0.000	0.000
68-Er-164	6831	0.000	0.000
68-Er-166	6837	0.000	0.000
68-Er-167	6840	0.000	0.000
68-Er-168	6843	0.000	0.000
68-Er-170	6849	0.000	0.000
72-Hf-174	7225	-0.003	0.225
72-Hf-176	7231	-0.004	0.201
72-Hf-177	7234	-0.008	0.670
72-Hf-178	7237	-0.006	0.260
72-Hf-179	7240	-0.007	0.349
72-Hf-180	7243	-0.003	0.130
73-Ta-181	7328	-0.069	0.150
74-W -182	7431	-0.006	0.707
74-W -183	7434	-0.012	0.277
74-W -184	7437	-0.011	0.570
74-W -186	7443	-0.011	0.432
80-Hg-196	8025	-0.117	0.544
80-Hg-198	8031	-0.071	0.337
80-Hg-199	8034	-0.079	0.351
80-Hg-200	8037	-0.055	0.277
80-Hg-201	8040	-0.078	0.173
80-Hg-202	8043	-0.045	0.428
80-Hg-204	8049	-0.189	0.301
82-Pb-204	8225	-0.977	0.987
82-Pb-206	8231	-0.063	0.200
82-Pb-207	8234	-0.025	0.187
82-Pb-208	8237	-0.005	0.147
83-Bi-209	8325	0.000	0.010
88-Ra-223	8825	-0.734	0.977
88-Ra-224	8828	-0.038	0.976
88-Ra-225	8831	-0.625	0.976
88-Ra-226	8834	-0.037	0.741
89-Ac-225	8925	-0.020	0.979
89-Ac-226	8928	-0.010	1.082
89-Ac-227	8931	-0.384	0.979
90-Th-227	9025	-0.010	0.979
90-Th-228	9028	-0.020	0.979
90-Th-229	9031	-0.135	1.011
90-Th-230	9034	-0.009	0.137
90-Th-232	9040	-0.018	0.153
90-Th-233	9043	-0.151	0.588
90-Th-234	9046	-0.043	0.748
91-Pa-231	9131	-0.032	1.181
91-Pa-232	9134	-0.076	1.045
91-Pa-233	9137	-0.034	0.372
92-U -232	9219	-0.005	1.013
92-U -233	9222	-0.008	0.002
92-U -234	9225	-0.013	3.410
92-U -235	9228	-0.795	5.058
92-U -236	9231	-0.025	0.050
92-U -237	9234	-0.486	0.129
92-U -238	9237	-0.018	0.019
93-Np-235	9340	-0.009	0.425
93-Np-236	9343	-0.043	0.700
93-Np-237	9346	-0.003	0.040
93-Np-238	9349	-0.078	1.098
93-Np-239	9352	-0.145	0.998

Material	MAT	Differences (%)	
		Negative	Positive
94-Pu-236	9428	-0.009	0.090
94-Pu-237	9431	-0.006	0.834
94-Pu-238	9434	-0.011	0.070
94-Pu-239	9437	-0.549	0.028
94-Pu-240	9440	-0.002	0.018
94-Pu-241	9443	-0.013	0.025
94-Pu-242	9446	-0.001	0.006
94-Pu-244	9452	-0.100	0.341
94-Pu-246	9458	-0.196	0.988
95-Am-241	9543	-0.013	0.187
95-Am-242	9546	-0.015	0.123
95-Am-242m	9547	-0.009	0.159
95-Am-243	9549	-0.013	0.228
95-Am-244	9552	-0.007	0.161
95-Am-244m	9553	-0.007	0.234
96-Cm-240	9625	-0.004	0.450
96-Cm-241	9628	-0.003	0.292
96-Cm-242	9631	-0.012	0.310
96-Cm-243	9634	-0.009	0.096
96-Cm-244	9637	-0.016	0.157
96-Cm-245	9640	-0.014	0.093
96-Cm-246	9643	-0.008	0.487
96-Cm-247	9646	-0.012	0.188
96-Cm-248	9649	-0.026	0.183
96-Cm-249	9652	-0.009	0.133
96-Cm-250	9655	-0.005	0.639
97-Bk-247	9746	-0.102	0.581
97-Bk-249	9752	-0.717	0.395
97-Bk-250	9755	-0.005	0.183
98-Cf-249	9852	-0.003	0.147
98-Cf-250	9855	-0.012	0.304
98-Cf-251	9858	-0.005	3.910
98-Cf-252	9861	-0.005	0.097
98-Cf-254	9867	-0.014	0.769
99-Es-254	9914	-0.026	0.990
99-Es-255	9915	-0.009	1.272
100-Fm-255	9936	-0.021	1.016

Appendix F: Summary of CENDL-3.1 Non-uniqueness

Material	MAT	Differences (%) Negative	Positive
1-H -1	125	-0.002	0.680
1-H -2	128	-0.071	0.074
1-H -3	131	-0.086	0.036
2-He-3	225	-0.085	1.004
2-He-4	228	0.000	0.000
3-Li-6	325	-0.035	0.449
3-Li-7	328	-0.001	0.000
4-Be-9	425	0.000	0.025
5-B -10	525	-0.031	0.492
5-B -11	528	-0.086	0.099
6-C -12	625	0.000	0.032
7-N -14	725	-0.007	0.873
8-O -16	825	0.000	0.002
9-F -19	925	-0.002	0.020
11-Na-23	1125	-100.000	0.009
12-Mg-24	1225	-0.005	0.014
12-Mg-25	1228	-0.096	0.003
12-Mg-26	1231	-0.008	0.003
13-Al-27	1325	-0.003	0.159
14-Si-28	1425	0.000	0.000
14-Si-29	1428	0.000	0.000
14-Si-30	1431	0.000	0.000
15-P -31	1525	-0.010	0.008
16-S -Nat	1600	-0.030	0.044
17-Cl-Nat	1700	0.000	0.000
19-K -Nat	1900	-0.042	0.043
20-Ca-Nat	2000	-0.018	0.004
22-Ti-46	2225	0.000	0.000
22-Ti-47	2228	0.000	0.000
22-Ti-48	2231	0.000	0.000
22-Ti-49	2234	0.000	0.000
22-Ti-50	2237	0.000	0.000
23-V -Nat	2300	-0.002	0.001
24-Cr-50	2425	-0.092	0.144
24-Cr-52	2431	-0.009	0.034
24-Cr-53	2434	-0.048	0.313
24-Cr-54	2437	-0.065	0.305
25-Mn-55	2525	0.000	0.004
26-Fe-54	2625	-0.010	0.081
26-Fe-56	2631	-0.405	0.106
26-Fe-57	2634	-4.430	1.204
26-Fe-58	2637	-0.012	0.487
27-Co-59	2725	-0.099	0.061
28-Ni-58	2825	0.000	0.000
28-Ni-60	2831	0.000	0.000
28-Ni-61	2834	0.000	0.000
28-Ni-62	2837	0.000	0.000
28-Ni-64	2843	0.000	0.000
29-Cu-Nat	2900	0.000	0.000
29-Cu-63	2925	0.000	0.000
29-Cu-65	2931	0.000	0.000
30-Zn-Nat	3000	-0.001	0.001
31-Ga-69	3125	-0.010	0.639
31-Ga-71	3131	-0.003	0.003
32-Ge-Nat	3200	-0.097	0.042
32-Ge-70	3225	-0.095	0.040
32-Ge-71	3228	-0.095	0.715
32-Ge-72	3231	-0.097	0.040
32-Ge-73	3234	-0.097	0.044
32-Ge-74	3237	-0.098	0.044
32-Ge-75	3240	-0.096	0.059
32-Ge-76	3243	-0.095	0.042
32-Ge-77	3246	-0.099	0.051
32-Ge-78	3249	-0.096	0.042
33-As-75	3325	-0.002	0.078
33-As-77	3331	-0.021	0.097
33-As-79	3337	-0.001	0.066
36-Kr-83	3640	-0.001	0.077
36-Kr-84	3643	-0.001	0.001
36-Kr-85	3646	-0.097	0.782
36-Kr-86	3649	-0.045	0.002
37-Rb-85	3725	0.000	0.000
37-Rb-87	3731	0.000	0.000
38-Sr-88	3837	-0.001	0.001
38-Sr-89	3840	-0.003	0.852
38-Sr-90	3843	-0.023	0.827
39-Y -89	3925	-0.002	0.268
39-Y -91	3931	-0.008	32.681
40-Zr-90	4025	0.000	0.000
40-Zr-91	4028	0.000	0.000
40-Zr-92	4031	0.000	0.000
40-Zr-93	4034	-0.003	0.026
40-Zr-94	4037	0.000	0.000
40-Zr-95	4040	-0.065	0.003
40-Zr-96	4043	0.000	0.000
41-Nb-93	4125	-0.002	0.002
41-Nb-95	4131	-0.003	0.002
42-Mo-92	4225	0.000	0.000
42-Mo-94	4231	0.000	0.000
42-Mo-95	4234	0.000	0.000
42-Mo-96	4237	0.000	0.000
42-Mo-97	4240	0.000	0.000
42-Mo-98	4243	0.000	0.000
42-Mo-100	4249	0.000	0.000
43-Tc-99	4325	-0.064	0.182
44-Ru-99	4434	-0.008	0.001
44-Ru-100	4437	-0.001	0.001
44-Ru-101	4440	-0.002	0.002
44-Ru-102	4443	-0.026	0.022
44-Ru-103	4446	-0.003	0.003

Material	MAT	Differences (%)	
		Negative	Positive
44-Ru-104	4449	-0.086	0.065
44-Ru-105	4452	-0.005	31.432
45-Rh-103	4525	-0.002	0.061
45-Rh-105	4531	-0.054	0.001
46-Pd-105	4634	-0.001	0.001
46-Pd-108	4643	0.000	0.000
47-Ag-Nat	4700	0.000	0.000
47-Ag-107	4725	0.000	0.000
47-Ag-109	4731	0.000	0.000
48-Cd-Nat	4800	-0.045	0.074
48-Cd-113	4846	-0.025	0.002
49-In-113	4925	-0.001	0.045
49-In-115	4931	-0.002	0.002
50-Sn-Nat	5000	-0.028	0.012
50-Sn-112	5025	-0.001	0.001
50-Sn-114	5031	-0.001	0.001
50-Sn-115	5034	-0.001	0.001
50-Sn-116	5037	-0.001	0.002
50-Sn-117	5040	-0.001	0.001
50-Sn-118	5043	-0.001	0.001
50-Sn-119	5046	-0.001	0.051
50-Sn-120	5049	-0.001	0.001
50-Sn-122	5055	-0.001	0.001
50-Sn-124	5061	-0.001	0.001
51-Sb-121	5125	-0.002	0.002
51-Sb-123	5131	-0.002	0.002
51-Sb-125	5137	-0.099	0.673
52-Te-130	5255	-0.001	0.001
53-I -127	5325	-0.003	0.003
53-I -129	5331	-0.003	0.003
53-I -135	5349	-0.010	0.201
54-Xe-123	5422	-0.008	0.038
54-Xe-124	5425	0.000	0.000
54-Xe-129	5440	-100.000	10.431
54-Xe-131	5446	-0.002	0.001
54-Xe-132	5449	0.000	0.000
54-Xe-134	5455	0.000	0.000
54-Xe-135	5458	0.000	0.000
54-Xe-136	5461	0.000	0.000
55-Cs-133	5525	-0.002	0.001
55-Cs-134	5528	-0.012	0.002
55-Cs-135	5531	-0.002	0.003
55-Cs-137	5537	-0.001	0.000
56-Ba-130	5625	0.000	0.000
56-Ba-132	5631	-0.006	0.737
56-Ba-134	5637	-0.002	0.002
56-Ba-135	5640	-0.002	0.003
56-Ba-136	5643	-0.002	0.002
56-Ba-137	5646	-0.002	0.023
56-Ba-138	5649	-0.002	0.002

Material	MAT	Differences (%)	
		Negative	Positive
57-La-139	5728	-0.001	0.001
58-Ce-136	5825	0.000	0.000
58-Ce-138	5831	-0.007	0.125
58-Ce-140	5837	-0.002	0.002
58-Ce-141	5840	-0.002	0.001
58-Ce-142	5843	-0.003	0.003
58-Ce-144	5849	-0.002	44.159
59-Pr-141	5925	-0.010	0.161
60-Nd-142	6025	-0.001	0.044
60-Nd-143	6028	-0.002	0.002
60-Nd-144	6031	-0.002	0.024
60-Nd-145	6034	-0.785	2.988
60-Nd-146	6037	-0.002	0.008
60-Nd-147	6040	0.000	0.000
60-Nd-148	6043	0.000	0.000
60-Nd-150	6049	0.000	0.000
61-Pm-147	6149	-0.002	0.002
61-Pm-148	6152	-0.002	0.002
61-Pm-148m	6153	-0.003	0.003
61-Pm-149	6155	-0.040	0.002
62-Sm-144	6225	-0.003	0.078
62-Sm-147	6234	-0.002	0.071
62-Sm-148	6237	-0.077	0.056
62-Sm-149	6240	-0.066	0.002
62-Sm-150	6243	-0.099	0.097
62-Sm-151	6246	-0.003	0.002
62-Sm-152	6249	-0.089	0.089
62-Sm-154	6255	-0.077	0.097
63-Eu-151	6325	-81.793	0.259
63-Eu-153	6331	-6.945	8.160
63-Eu-154	6334	-0.040	0.041
63-Eu-155	6337	-0.076	0.056
64-Gd-152	6425	-0.001	0.002
64-Gd-154	6431	-0.001	0.002
64-Gd-155	6434	-0.006	0.001
64-Gd-156	6437	-0.002	0.002
64-Gd-157	6440	-0.443	8.335
64-Gd-158	6443	-0.002	0.002
64-Gd-160	6449	-0.002	0.084
66-Dy-164	6649	-0.020	0.000
72-Hf-174	7225	-0.002	0.002
72-Hf-176	7231	-0.002	0.003
72-Hf-177	7234	-0.002	0.003
72-Hf-178	7237	-0.005	0.002
72-Hf-179	7240	-0.002	0.002
72-Hf-180	7243	-0.003	0.002
73-Ta-181	7328	-0.012	0.074
74-W -Nat	7400	-0.015	0.014
79-Au-197	7925	-0.003	0.005
80-Hg-Nat	8000	-0.017	0.004

Material	MAT	Differences (%)	
		Negative	Positive
81-Tl-Nat	8100	-100.000	0.004
82-Pb-204	8225	-0.006	0.739
82-Pb-206	8231	0.000	0.000
82-Pb-207	8234	-0.003	0.005
82-Pb-208	8237	0.000	0.000
83-Bi-209	8325	-0.012	0.052
90-Th-232	9040	-0.126	0.013
92-U -232	9219	0.000	0.000
92-U -233	9222	0.000	0.000
92-U -234	9225	0.000	0.000
92-U -235	9228	0.000	0.000
92-U -236	9231	0.000	0.000
92-U -237	9234	0.000	0.000
92-U -238	9237	-0.005	0.971
92-U -239	9240	0.000	0.000
92-U -240	9243	0.000	35.967
92-U -241	9246	0.000	21.576
93-Np-236	9343	0.000	0.000
93-Np-237	9346	0.000	0.000
93-Np-238	9349	0.000	0.000
93-Np-239	9352	-0.009	0.973
94-Pu-236	9428	0.000	0.000
94-Pu-237	9431	-0.009	0.992
94-Pu-238	9434	0.000	0.000
94-Pu-239	9437	-0.003	0.000
94-Pu-240	9440	-1.217	1.249
94-Pu-241	9443	0.000	0.000
94-Pu-242	9446	0.000	0.000
94-Pu-243	9449	0.000	0.000
94-Pu-244	9452	0.000	0.086
94-Pu-245	9455	0.000	33.853
94-Pu-246	9458	-0.003	51.040
95-Am-240	9540	-0.141	0.922
95-Am-241	9543	0.000	0.000
95-Am-242	9546	0.000	0.000
95-Am-242m	9547	0.000	0.000
95-Am-243	9549	0.000	0.000
95-Am-244	9552	0.000	30.963
97-Bk-249	9752	0.000	0.000
98-Cf-249	9852	-0.008	0.152