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# ENDF Cross Sections are not Uniquely Defined

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# ENDF Cross Sections are not Uniquely Defined

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

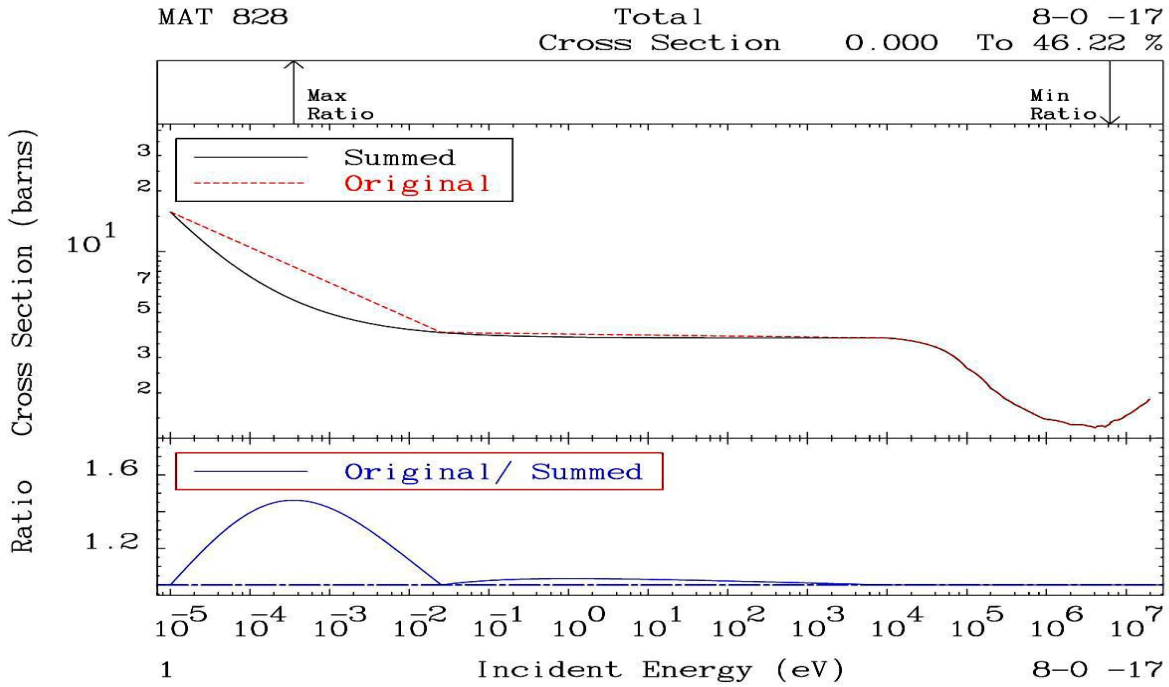
Here there will be a different exponential variation for each reaction, and there is no ENDF interpolation law for a sum of such variations. In other words, **when we have log cross section interpolation or a mix of interpolation schemes, we cannot accurately define the sum of reaction for use in ENDF.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

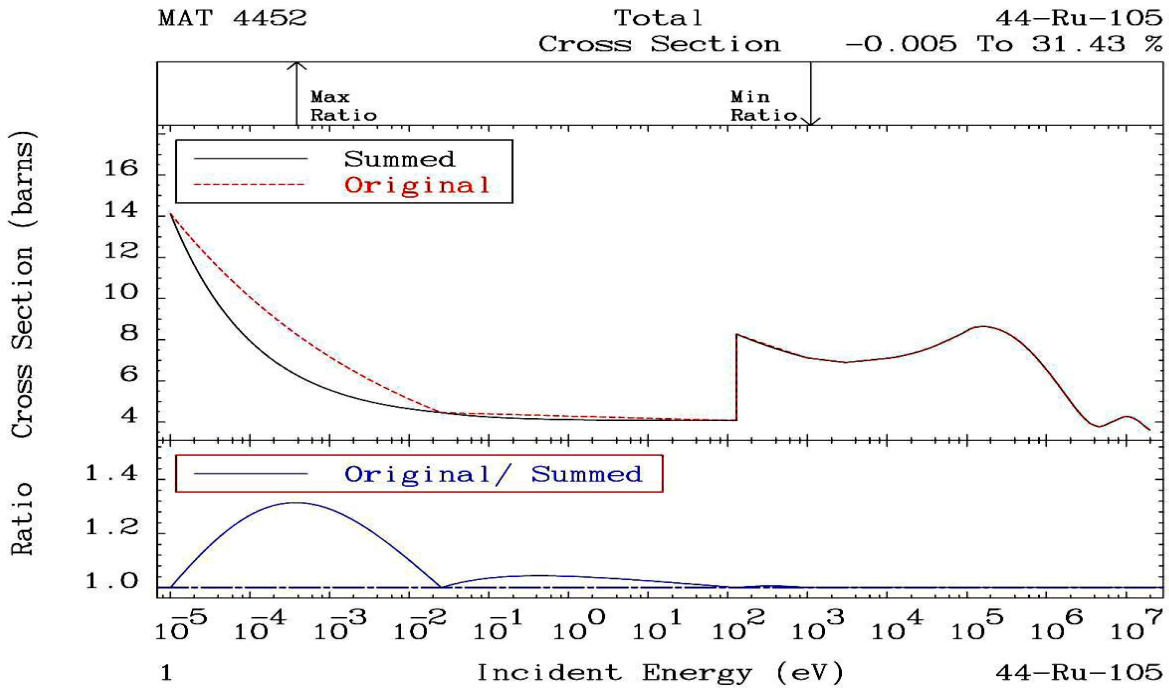
The bottom line is that **within the ENDF format we can only accurately define summed cross sections, such as the total, at ALL energies, if ALL contributing reactions are lin E – lin σ interpolable**. Again, let me state that the rules for defining ENDF summed cross sections are complicated and periodically 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**.

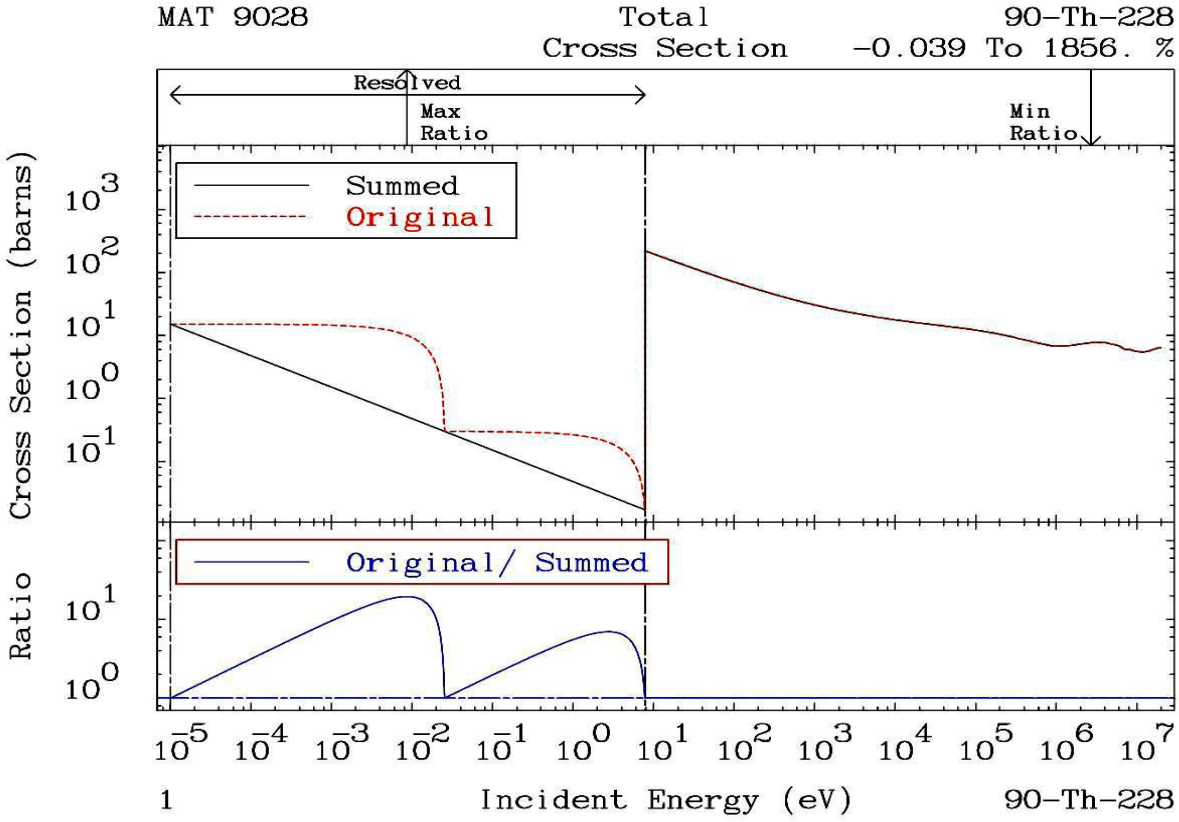
**But the evaluators had a problem when it came to making their evaluations available in the ENDF format**; here the rules are that each evaluation MUST include a total cross section, and the evaluators made the mistake in assuming that they could define the total at the same energies at which the elastic 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.

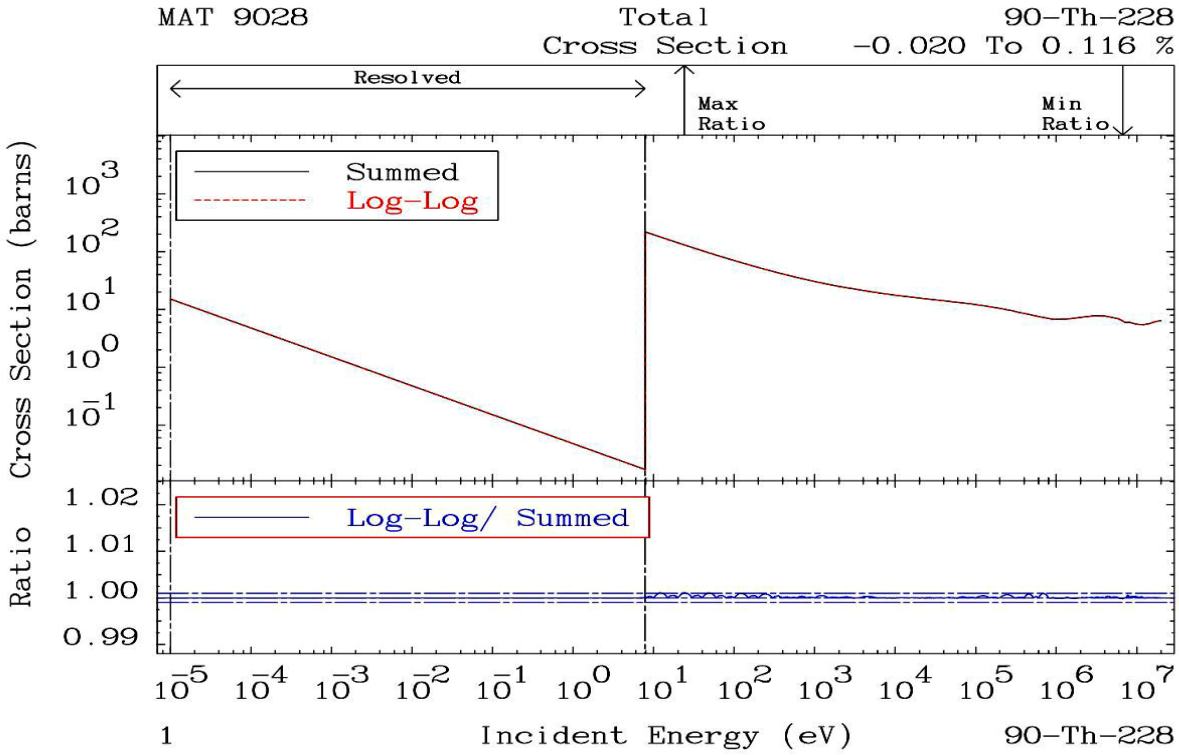


The case of 90-Th-228 clearly illustrates the problem of the evaluators trying to define the "best" interpolation law for their tabulated total cross sections. Based on the evaluator's choice of INT=2 (lin-lin) interpolation, we found an inconsistency of up to 1836%. This is such a shame, because if 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?

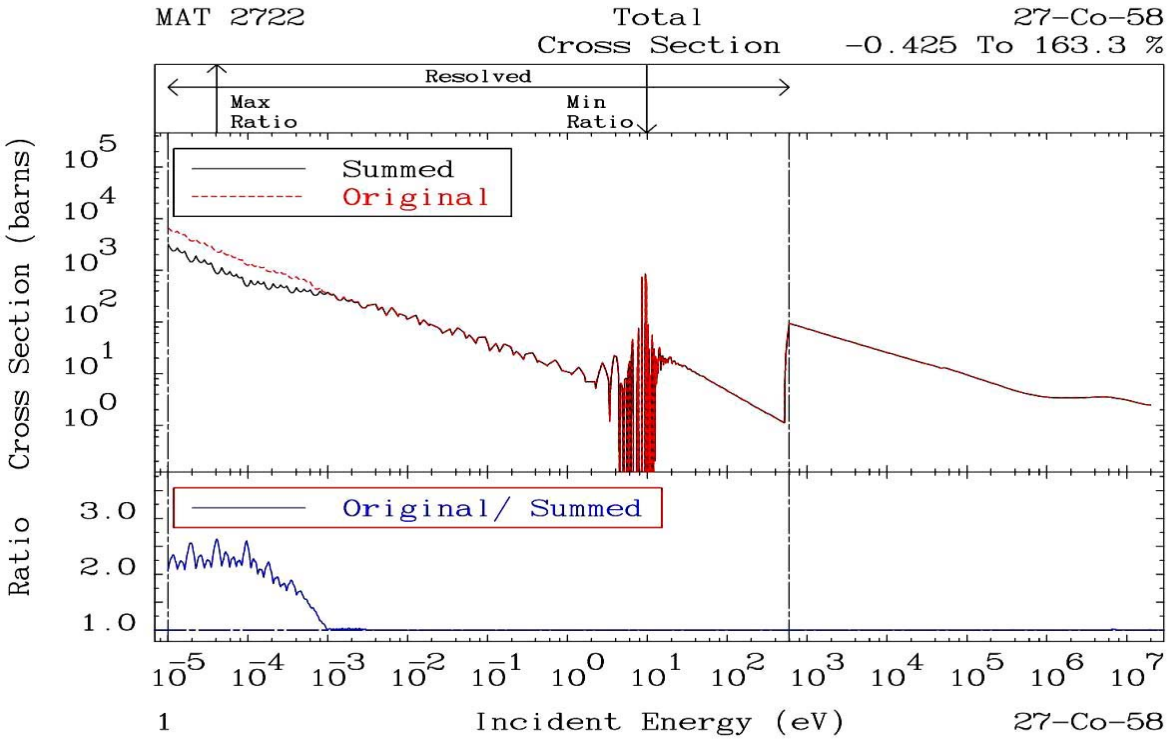
Generally we like to try and insure that we interpret evaluated data exactly as the evaluator intended. In the case of the ENDF format we attempt to do this by having strict coding rules; rules that both the evaluator MUST use to code their data and that data users MUST use to interpret data for use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

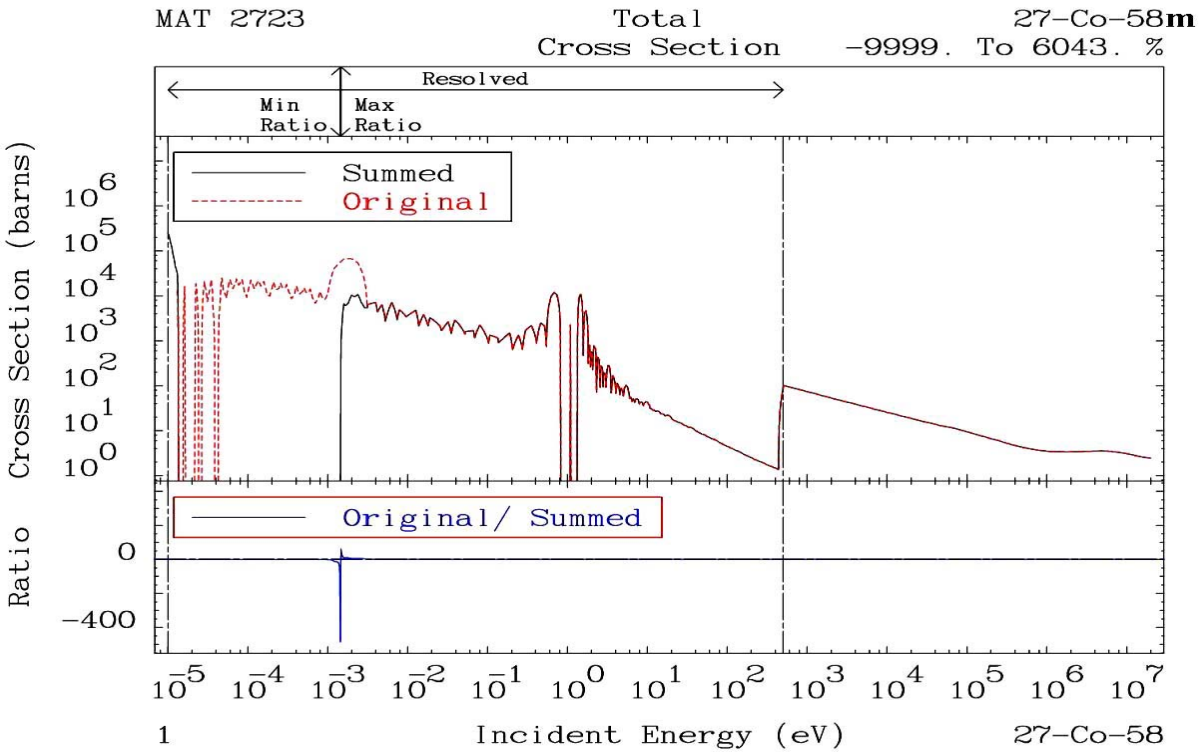
As much as we would like to interpret data as the evaluator intend, once the data is coded into the ENDF format the "best" we can do it to try and interpret the data exactly as the evaluator coded it, i.e., we cannot read the evaluator's mind to try and figure out what they intend; their intent MUST 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.

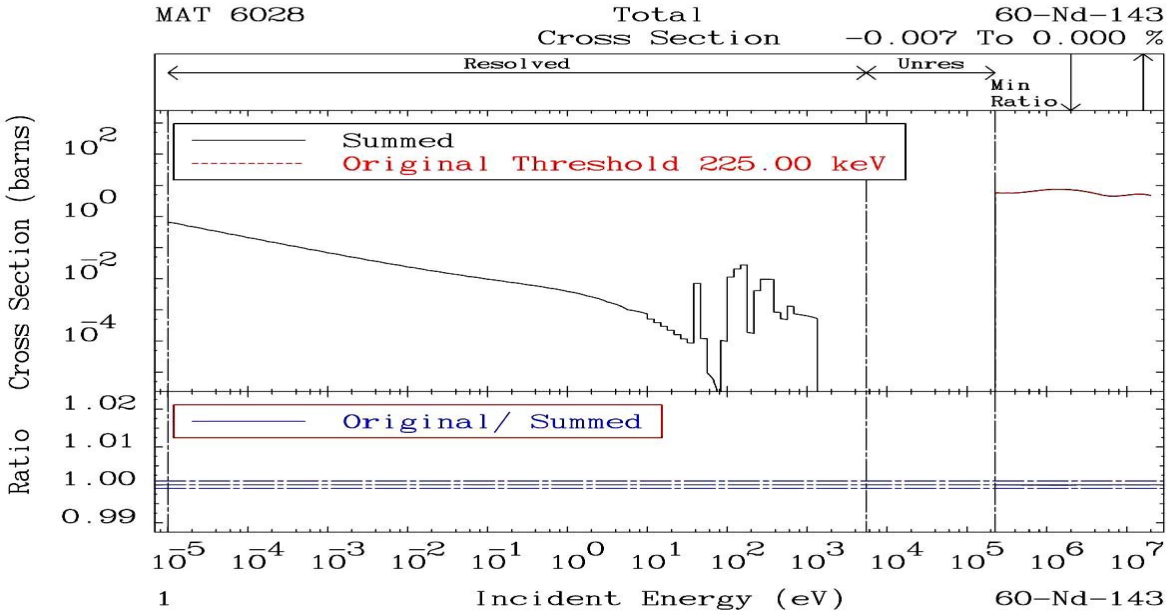
The first two plots below show results for 27-Co-58 and 27-Co-58m. In both cases it appears that the evaluators went to some effort to include detail in their tabulated total. Unfortunately, the details in the tabulated total do not exactly correspond to that tabulated with the parts (elastic and capture). 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.

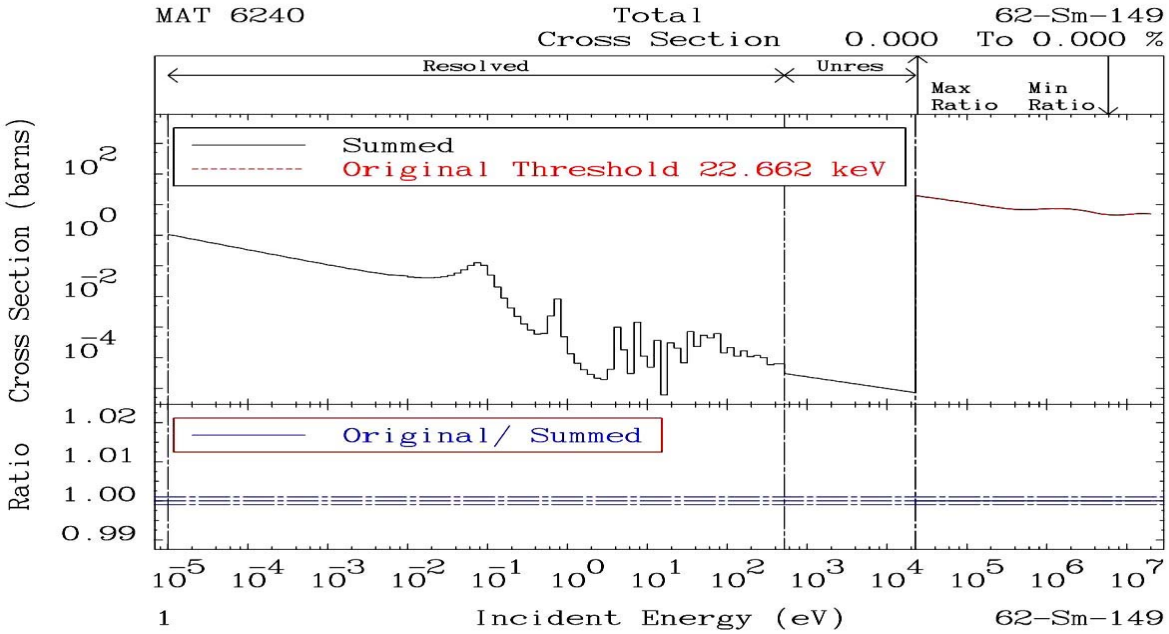
This seems crazy: why go to all of this effort and then have your efforts wasted? This is but one example where we ask evaluators to insure that their data are consistent. We also want to stress that if evaluators do not make their data consistent, we are forced to do the "best" to can to make their 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

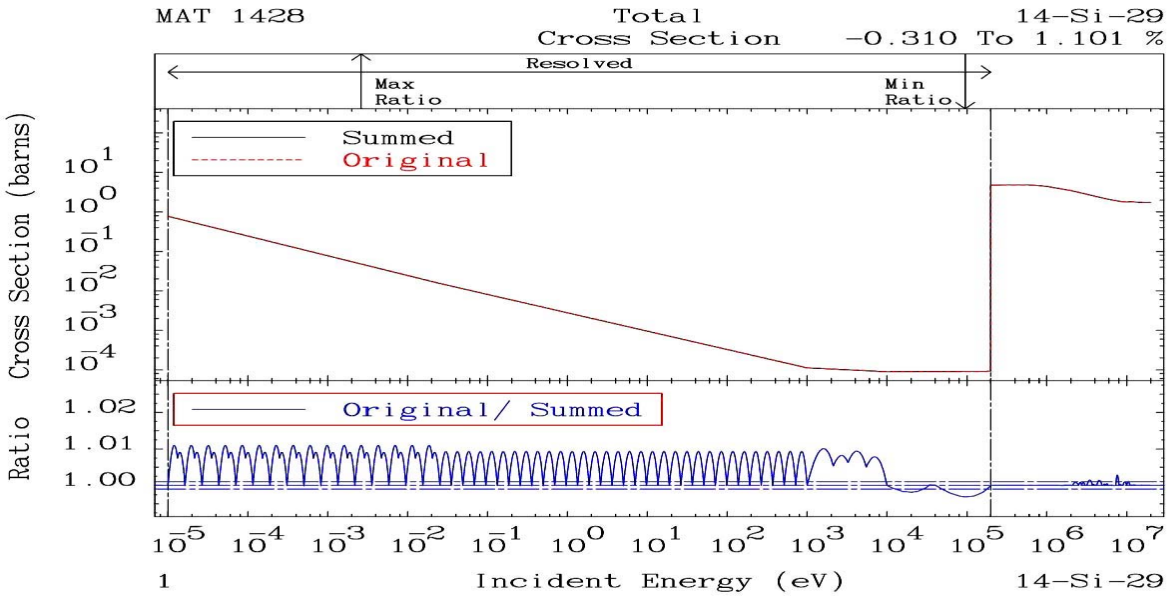
In the following two figures we illustrate cases where the evaluator included details in their parts (elastic and capture), but not in their tabulated total. In the case of 60-Nd-143 there is no tabulated total below 225 keV, but the parts include background corrections to the parts. The case of 62-Sm-149 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.

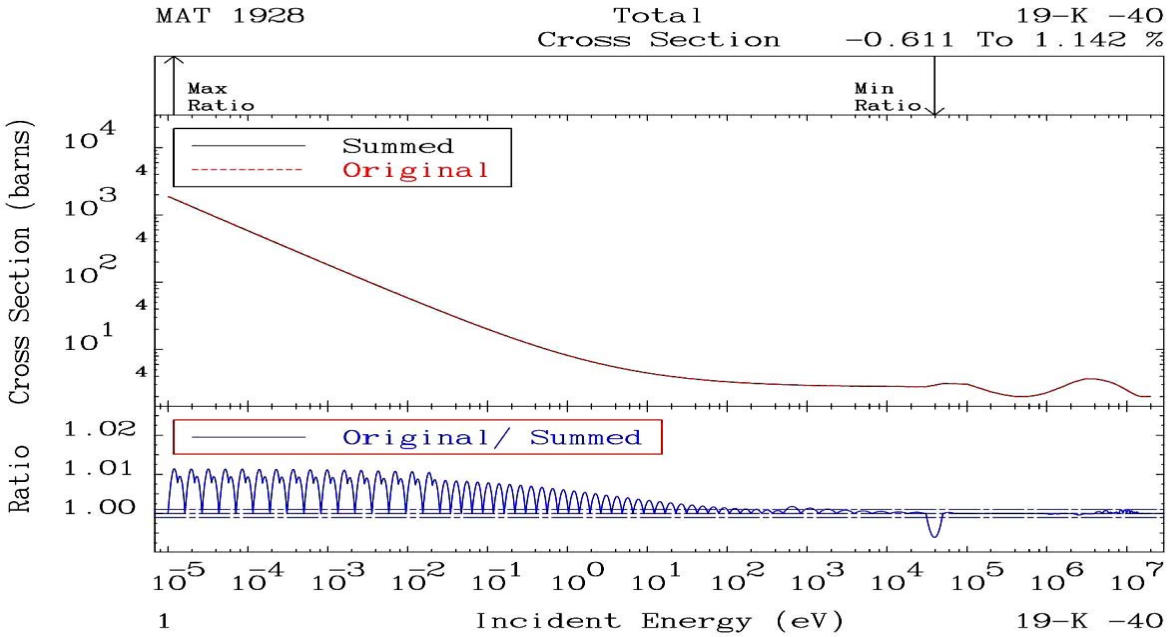


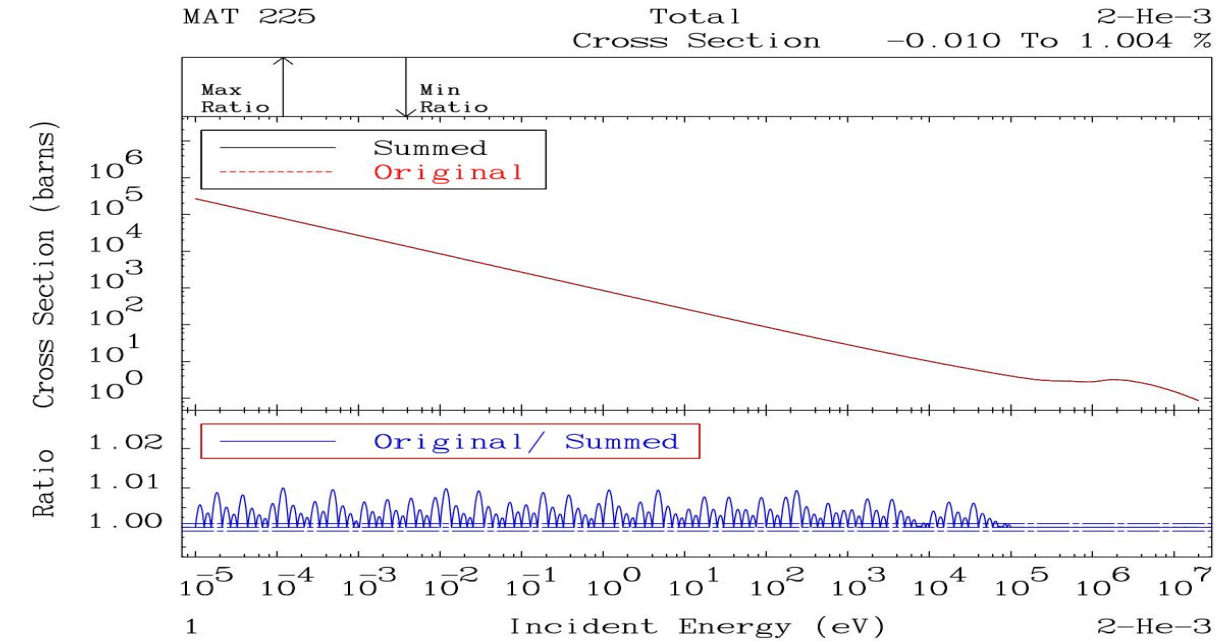
## Evaluators Often Do Try

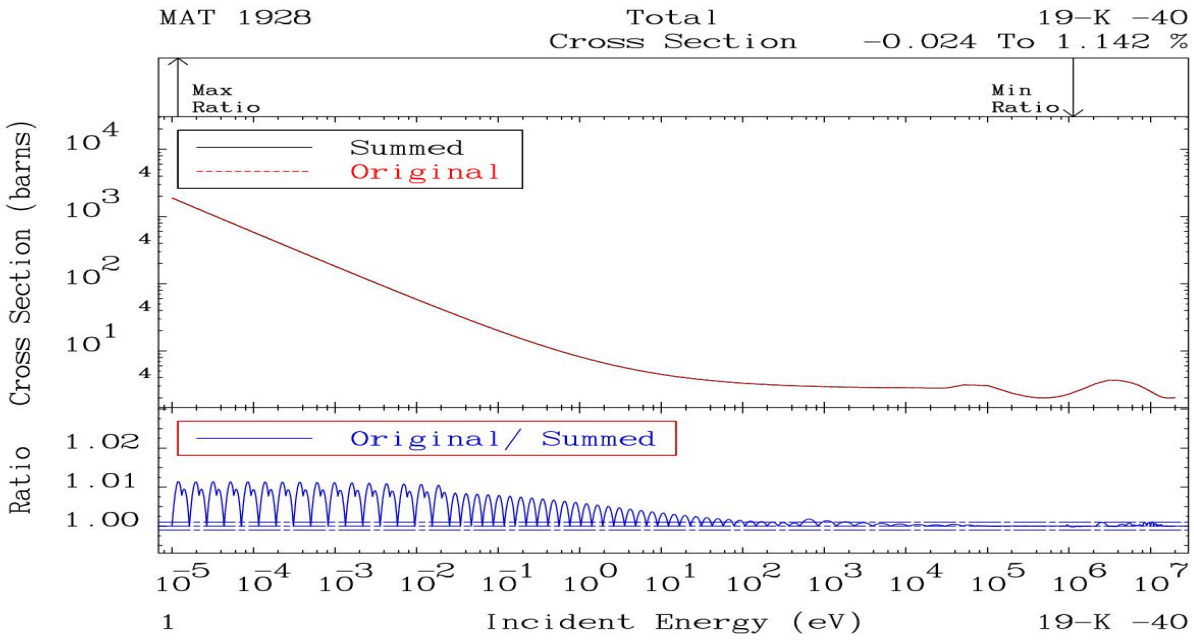
Below are two examples from JEFF-3.1, where the evaluators did try to include a sufficient number of data points to allow their tabulated total to "better" approximate the sum of its parts. The evaluators did a pretty good job and managed to reduce the difference to about 1%. **This illustrates that 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.**



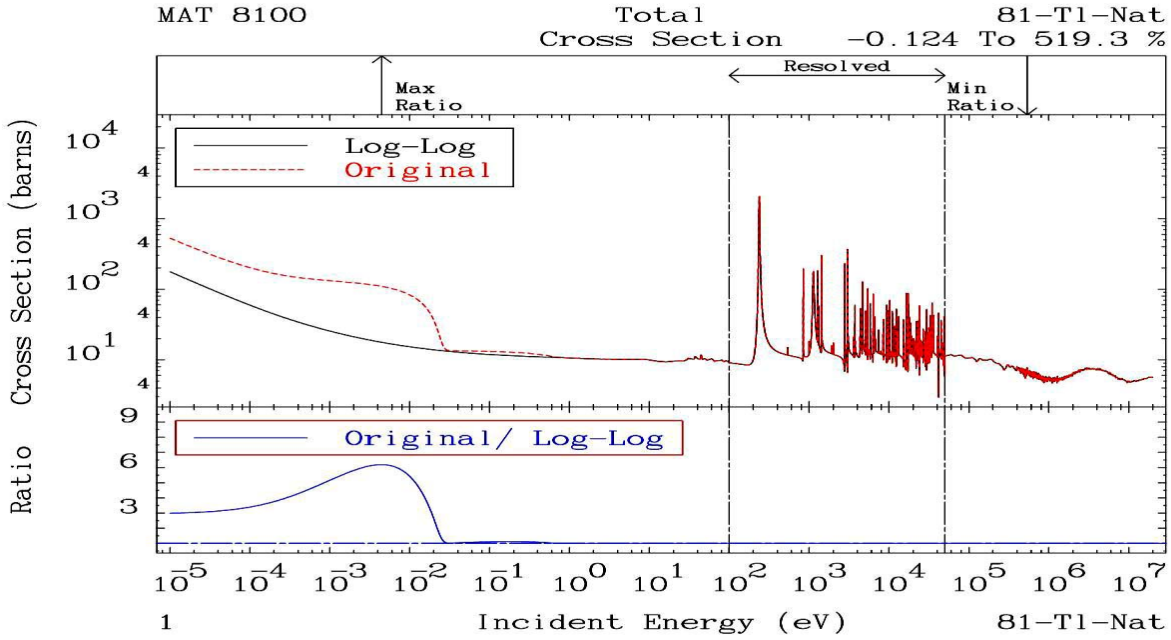
## Evaluator Error

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

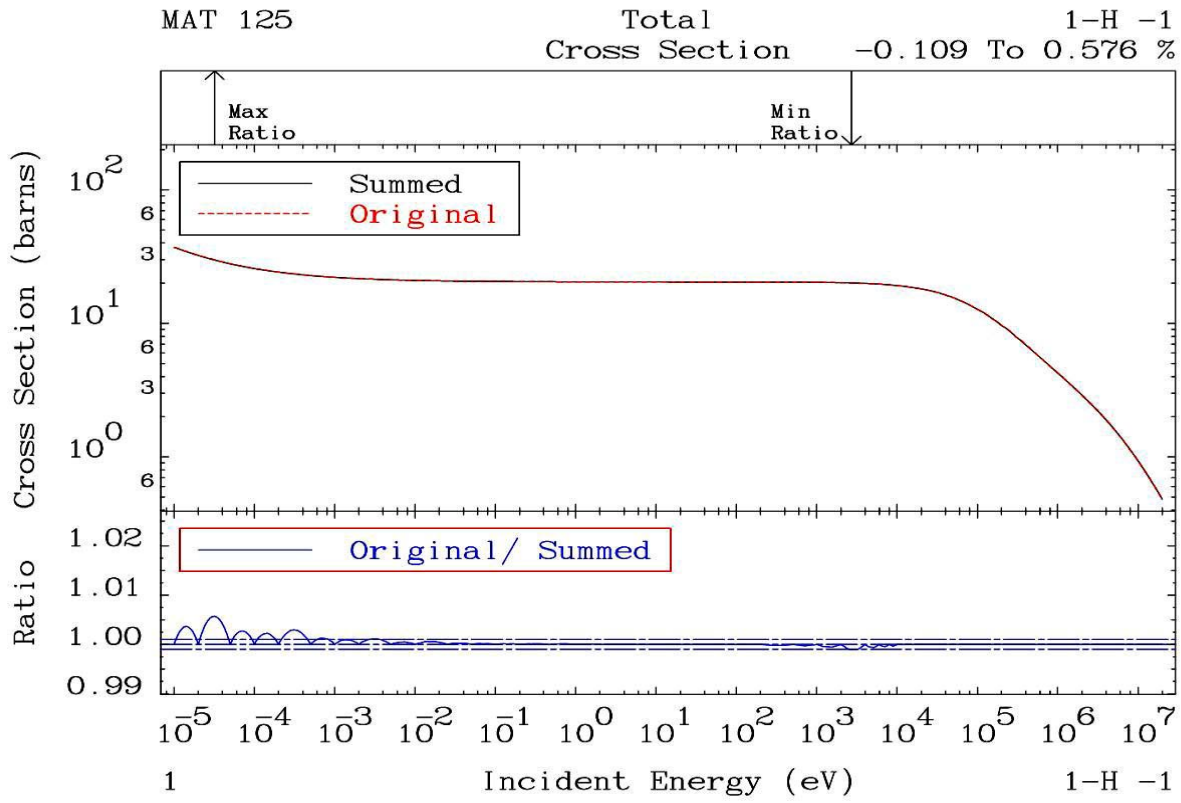
In the Appendices we summarize the differences that we found for all 393 materials in the ENDF/B-VII.0 library (Appendix C), 381 materials in the JEFF-3.1 library (Appendix D), 337 materials in the JENDL-3.3 library (Appendix E), and 240 material in the CENDL-3.library (Appendix F). We will mention that 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,

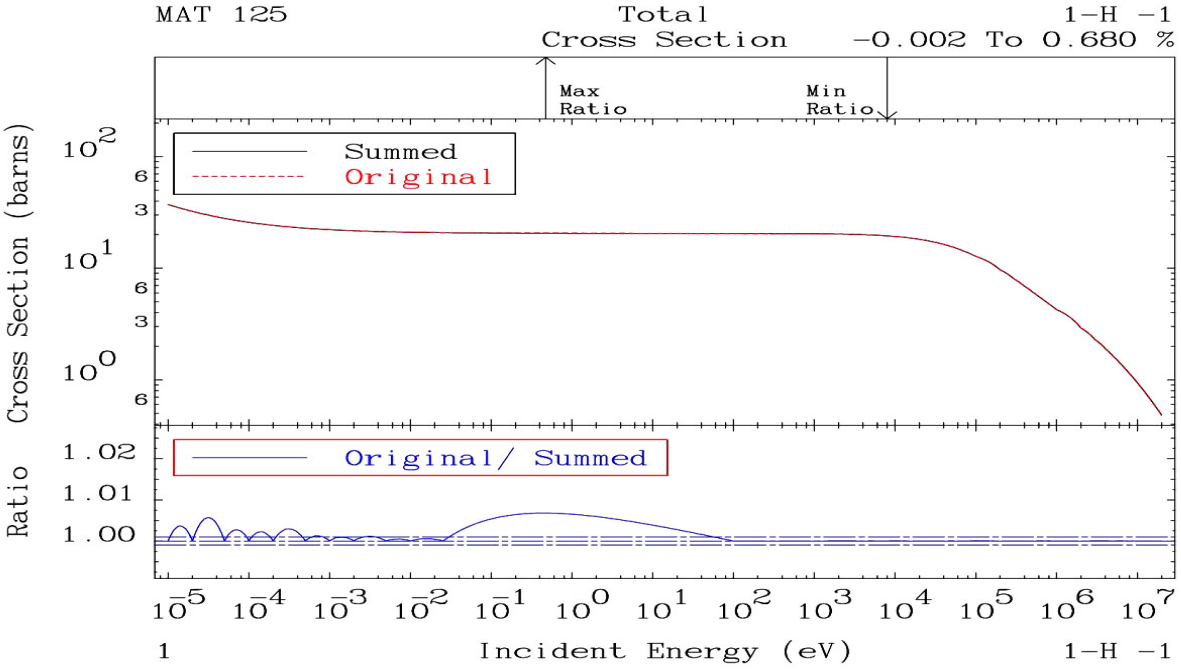
1) We used the PREPRO LINEAR code to linearize all cross sections.
2) We used the PREPRO FIXUP code to define cross sections by summation.
3) We used the PREPRO COMPLOT code to compare the results of steps 1) and 2). On all plots these are identified as 1) Original or 2) Summed.

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.

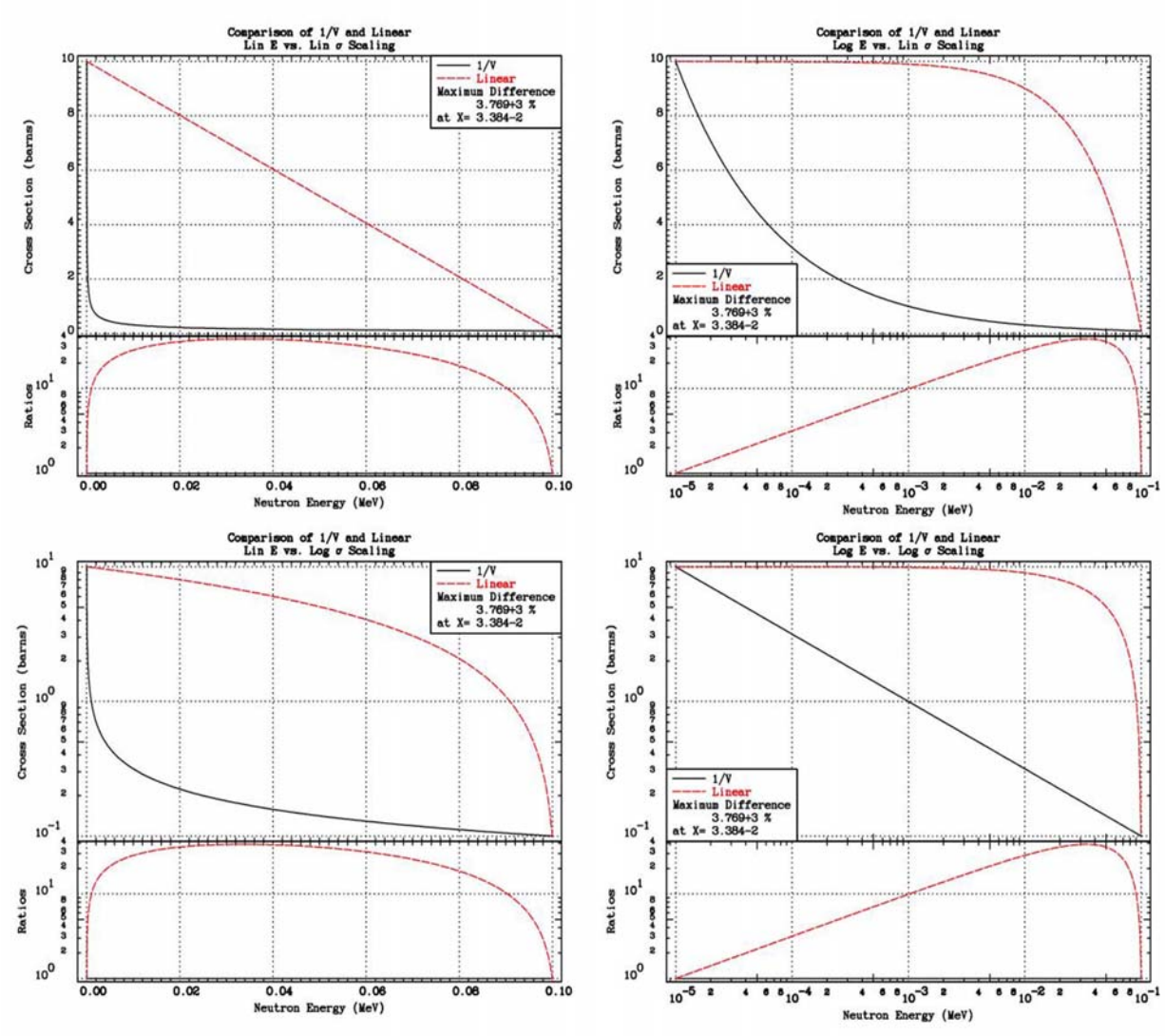
[6} "**POINT 2009:** A Temperature Dependent ENDF/B-VII.0 data Cross Section Library", by Dermott E. Cullen, June 2009, http://www-nds.iaea.org/point2009/pt2009.htm

## 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 $E',\Omega'$ before the interaction to $E,\Omega$ 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 $E',\Omega'$ before the interaction to $E,\Omega$ after the interaction. This is a normalized distribution which is equalm to unity when integrated over all final $E,\Omega$.

# 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 |
| 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 |
| 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 |