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Subject: CINDA-quantities RIA, RIG, RIF.

This is our contribution to the questions about resonance integrals and the related quantities in Cinda (see action 10 of the 11th 4C-Meeting). Part A gives a survey of the problems that have appeared in Cinda and recommendations how they should be handled. Part B contains detailed proposals for the definitions of the quantities in the Cinda-Manual.

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A. The Problems

The "infinite dilute" resonance integral is defined as

$$RI = \int_{E_{min}}^{\infty} \frac{\sigma(E)}{E} \, dE$$

where σ (E) may be the cross-section for

capture (= n,γ),

absorption (= sum cross-section), or

fission.

The corresponding resonance integrals in Cinda are coded

RIG
RIA
RIF.

A fourth Cinda quantity RIR for the activation resonance integral has been cancelled at the 1975 Four-Centers Meeting. NDS is converting existing RIR entries to the actual reaction meant, mostly RIA (see recommendations below).

Several questions still remain to be solved.

1.) The definitions of RIG and RIA

2.) The energy notation

3.) Resonance integrals for other cross-sections

4.) Resonance integrals other than "infinite dilute"

1.) The definitions of RIG and RIA

Since at least 1965 there was a rule restricting the use of RIG to fissionable nuclides only. For non-fissionable nuclides RIA was to be used, even when clearly the (n,γ) reaction and not the sum-reaction "absorption" was meant. Since the reason for this rule had never been explained in the Manual, it was not understood by the Cinda indexers. Consequently, entries for non-fissile nuclides had been coded under RIG or RIA depending on the personal preference of the Cinda indexer.

The idea behind this rule is apparently the following:

For most non-fissionable nuclides RIG equals RIA, since reactions other than (n,γ) contribute little to the resonance-integral, due to their high threshold-energy. Therefore, for non-fissionable nuclides only one of the two quantities should be used in Cinda. There are, however, some light nuclides, for which the absorption cross-section in the resonance range includes, besides (n,γ), important contributions from other reactions like (n,p) and (n,α). Since in all cases the interest in reactor physics is mainly in the "absorption resonance integral", RIA is the preferable Cinda quantity for non-fissile nuclides.

In fact, it is often very difficult for the Cinda indexer to estimate whether the quantity "absorption R.I." given in a paper includes, for a given nuclide, exclusively the (n,γ) reaction or also contributions from other reactions. The use of only one quantity for non-fissionable nuclides, namely RIA, avoids such ambiguities.

For fissionable nuclides however, the distinction between RIG, RIA and RIF is essential and entries should be made for all three quantities. The sum rule is:

RIA = RIG + RIF (plus perhaps negligible contributions from other reactions).

In Exfor, where exact quantity definitions must be coded, the quantities NG,RI and ABS,RI exist for all nuclides applying the general definitions for NG and ABS. The resulting difficulty is that the Cinda-Exfor correspondence of quantities depends on the nuclide:

Exfor		Cinda	
NG,RI	→	RIG	for fissionable nuclides
	→	RIA	for non-fissionable nuclides

This difficulty does not seem to present problems. Related computer programs (at least at NDCC and NDS) include list of nuclides with a flag attached to fissionable ones. Similarly, a Cinda input checking, rejecting RIG entries for non-fissionable nuclides (or better: converting them to RIA), can be done.

Recommendation: The existing definitions of RIG and RIA, as outlined above, should be kept. In the Cinda Manual the information given to the Cinda indexer should be improved. Input checking should be done such that no RIG entries for non-fissionable nuclides show up in the file.

2.) The energy notation

It had been the practice in Cinda to code resonance-integrals having, e.g., $E_{min} = 0.45$ eV and $E_{max} = \infty$ with the energy notation:

$$E_{min} = 4.5\text{-}1 \qquad E_{max} = \text{blank.}$$

This notation is easily understandable for the user of Cinda. It was therefore generally agreed, during past discussions among Cinda people, that this practice should continue. The difficulty is, that this energy notation is interpreted, for all other Cinda quantities, as "data given at 0.45 eV only".

In an energy retrieval program it seems however not too difficult to consider this special energy notation which exists for only the three quantities RIG,RIA,RIF.

If E_{min} of the resonance integral is not mentioned in the paper considered, the Cinda-indexer shall enter $E_{min} = 5.0\text{-}1$ (except when there is reason to assume that something quite different may be meant).

Infinite dilute resonance-integral data which were not directly measured but integrated from point data, are entered with the actual energy limits of the point data.

Recommendation:

The previous practice of coding energies for resonance-integrals, as outlined above, should be continued.

3.) Resonance-integrals for other cross-sections

Occasionally, one finds resonance-integral data for other reactions, such as scattering, (n,p),(n,α), and others. These are sometimes, but not always, activation resonance-integrals. Often such data are obtained by integrating point data. Activation resonance integrals may also occur for partial cross-sections, leading to a metastable state or to the emission of a specific gamma-line.

In general, such data are entered under the reaction involved with an energy entry "PILE" and with an appropriate note in the Comment-field. If the resonance-integral considered contributes significantly to the "absorption resonance-integral", e.g. in the case of Li-6 (n,tα), entry is also made under RIA.

Sometimes, the 1/v part of the cross-section has been subtracted and the resulting data may be given as "reduced resonance integrals". Since the resonance integrals for the "complete" cross-section can easily be obtained from these data, they should, in Cinda, be treated like proper resonance integrals with appropriate comments.

Recommendation:

Resonance-integral data for scattering, (n,p),(n,α) and other reactions should be entered in Cinda under the relevant reactions, e.g. SIN, SCT, NP, NA, etc., with appropriate energy coding and with the code "RES-INT" in the Comment-field. Additional entry should be made under RIA when the reaction considered contributes significantly to the absorption res.int.

4.) Resonance-integrals other than "infinite dilute"

The definition of the infinite dilute resonance-integral assumes

a $^1/E$ neutron spectrum

E_{min} = Cd cut-off, that is ca 0.4 to 0.5 eV, depending on the Cd thickness

$E_{max} = \infty$

Other resonance-integrals which occur more or less frequently, include

a. neutron spectra deviating more or less strongly from $^1/E$ behaviour

b. different values of E_{min} and E_{max}, such as 10 eV to 100 eV

Recommendation

A cross-section, e.g. an absorption cross-section, averaged over a non-$^1/E$ spectrum, should not be entered under RIA but rather under NG or ABS with the code "PILE" in the energy field, (as far as such data are at all of interest.) However, slightly deviating $^1/E$ spectra can be accepted under RIA. The borderline cannot be defined and must be left to the discretion of the Cinda-indexer.

B. The Proposals

Based on the preceding discussion of the problems, we propose that the following be added in the list of quantity definitions in the Cinda Manual:

RIA **Res Int Abs** $\int_{E_{min}}^{E_{max}} \frac{\sigma_{nA}(E)}{E} dE$

Definition: The infinite dilution resonance integral for absorption. Except for some lighter (A≤40) and the fissionable nuclides (A>226), the capture resonance integral is equal to the absorption resonance integral and entered under this quantity.

For fissionable isotopes, see also RIG.

Note 1: Sometimes, a resonance integral $\int_{E_{min}}^{E_{max}} \sigma(E)\Phi(E)dE$ is given, that is not normalized to the infinite dilution-condition, i.e. the neutron spectrum $\Phi(E)$ deviates considerably from 1/E. Such data should only be entered in Cinda when either the actual $\Phi(E)$ is given (so that the correction can be performed by the user), or when the data are considered as preliminary and a later correction by the authors can be expected.

Note 2: Infinite dilution resonance integrals which are not equal to
-absorption res. int. in the case of non-fissionable isotopes,
-absorption, capture or fission res. int. in the case of fissionable isotopes,
are entered under the corresponding neutron reaction (e.g.: $\int_{E_{min}}^{E_{max}} \frac{\sigma_{np}(E)}{E} dE$ for N-14 would be indexed under the quantity NP, energy PILE, comment: RES-INT GIVEN)

If an "activation resonance integral" is given, it must be checked which Cinda-quantity is actually meant.

Note 3: In the energy-field the minium and maximum energy of the integral are entered (E_{max}=blank, if upper limit =∞).

If no energy limits are given, E_{min}=0.5 eV (= Cd-cutoff-energy) and $E_{max}=\infty$ is assumed.

If a resonance integral was derived from point cross-sections, the energy limits are equal to the lowest and highest energy used.

RIG **Res Int Capt** $\int_{E_{min}}^{E_{max}} \frac{\sigma_{n,\gamma}(E)}{E} dE$

Definition: The infinite dilution resonance integral for radiative capture.
Use: For fissionable isotopes only! For others, see RIA.
Note: See note 1 and note 3 of RIA.

RIF **Res Int Fiss** $\int_{E_{min}}^{E_{max}} \frac{\sigma_{n,f}(E)}{E} dE$

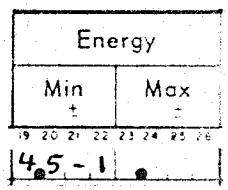
Definition: The infinite dilution resonance integral for fission.
Note: See note 1 and note 3 of RIA.

RIR Res Int Act: to be cancelled.

The following should be included in the "Energy" section of the Cinda Manual:

For Resonance Integrals the energy limits E_{min} = 0.45 eV and E_{max} = ∞ are coded with E_{max} = blank:

Note that for all other quantities this energy notation means: data given at 0.45 eV only.



If E_{min} of the resonance integral is not mentioned in the paper considered, the Cinda indexer shall enter the approximate value E_{min} = 0.5 eV (except when there is reason to assume that such a guess may be wrong; in this case NDG may be entered).

Infinite dilute resonance integral data which were integrated from point data, are entered with the actual energy limits of the point data.