Revised policy for inclusion of Resonance data in ENSDF

USNDP Nov 4-6, 2009
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- Subcommittee at USNDP-08 to reformulate consistent policies for inclusion of resonance data in ENSDF: John Cameron (McMaster), Caroline Nesaraja (ORNL), Chris Ouellet (BNL), B. Singh (McMaster).
- Michael Smith (ORNL) and Alan Chen (McMaster) were consulted about need of such data in nuclear astrophysics context.
- First draft sent out for comments early March 2009. Coral Baglin (LBNL) helped greatly with this draft. Charles Reich (Idaho), Filip Kondev (ANL), Rick Firestone (LBNL), Ninel Nica (Texas A&M) sent comments.
- Proposed revisions were presented at NSDD meeting in March 2009. Comments were to be received by June 30, 2009.
- John Kelley (TUNL) and Filip Kondev (ANL) sent comments in April 2009

John Kelley's comments (April 7, 2009)

- First: resonances
  Second: the thermal neutron capture state.

  1: has two parts, proton/charged_particle and neutron resonances.

- In general I am favorable to including resonance data into the ENSDF. Resonance states are states; and in general they hold the same "footing" as other bound states.

  On the issue of what should be presented in the level-E in the nuclide record, I believe that the numeric level energy should be given. There should be a global qualifier of the mass excesses used, and each level should also carry a qualifier of the projectile resonance energy with a well defined system (either lab or cm).

  I recall some discussion that the level E should be of the form Q+eres, because the level energy is not directly measured, but it is inferred. I disagree with this point of view mainly because the level energies are rarely(never) directly measured; they are always inferred, usually from a photon reaction product. Level energies are sometimes reconstructed from the addition of a sequence of gamma-ray transitions - rather than a single decay to the ground-state. In short I believe that deducing a level energy from a resonance is about on par with deducing a resonance energy from gamma-rays.

  1:a proton/charged-particle resonances: these are pretty straight forward and should be included.

John Kelley's comments (cont.)

- 1:b neutron resonances: These can be tricky. Well above En~0 I think that they should be included. At En~0 it is more complicated. These are charge zero particles interacting with a nucleus; there is no coulomb barrier and the issue of angular momentum barrier comes into play.

  10Li comprises an s-wave neutron and a 9Li nucleus; 10Li is unbound to neutron emission. What is that? Is it a nuclear artifact? a state? a ground state?

  In much heavier nuclei the En~0 neutrons can have a bzillion open resonance states open, but what are they really? I think the evaluator could include these as a compiled data set, but I wouldn't include all of them in the adopted levels. It should be the evaluator's discretion.

  I'd check with the ENDF/reactions people to make sure that this doesn't mess up their system.

  2: thermal neutron capture. I don't like this one. It is a state with no width (but a cross section), and no Jpi. It is a reaction that happens at an arbitrary energy, that happens to be well defined. What about global warming and it's impact on the definition of thermal energy?

  I don't think it should be included in the adopted levels. It isn't even a resonance state.

Filip Kondev's comments (April 10, 2009; March 9, 2009)

- Following discussion at the NSDD meeting regarding the resonance data – I'd stick to my initial suggestion (below) to include only the charged particle resonance data into the adopted data sets.
- On the neutron side, inclusion of the primary gammas following thermal neutron capture into the adopted levels, gamma is fine.
- The neutron resonance data should be dealt at the corresponding reaction data sets – I don't see much more such data coming in the literature in foreseen future.

March 9, 2009 comment:

- The draft reads fine. My only suggestion is to focus entirely on the charged particle data. There are many reasons for that with the main being that I doubt very much how the neutron resonances data would be helpful to nuclear astrophysics community? In addition, these data are covered by others (e.g. ENDF and 2006MuZX) and we should avoid duplication, if possible. My suggestion regarding the neutron resonances is to stick to the current policy, e.g. keeping them in the reaction data sets, but not into adopted. The charged particle resonance data should be included, as suggested in the document.

Current stated policy for ENSDF evaluations

Item #7, page ii) in general policies of NDS:

"Radiations from the decay of neutron and proton resonances are not presented. The energies and other level properties for bound levels deduced from resonance experiments are included. Primary as well as secondary γ's following thermal-neutron capture are generally included."

Note: no mention of excitation (or level) energies and other level properties such as widths, spins and parities, etc.

Current practice of item #7 for ENSDF datasets

Include only the resonance data which primarily relate to the population of bound states and the determination of their energies, spin-parities, etc.

The general presentation is a reaction dataset with SN (or SP)+E(n or p) for level energies, E(n or p) generally in the lab system. The resonance parameter and gamma-ray data are given at evaluator's discretion.

In the "adopted levels" dataset, the excitation energies, spins and widths are given for those resonances which populate the bound states. The gamma-ray data are generally not carried over into 'adopted levels' dataset.

The evaluators exercise own discretion in presenting or not presenting such data in 'reaction' and 'adopted' datasets, thus one finds inconsistency in the presentation of such data in ENSDF

Revised policy for inclusion of Resonance data in ENSDF

1. Charged-particle resonances

Reaction dataset: following quantities should be given in a charged-particle resonance reaction:

a) **Level excitation energies**: deduced from lab or c.m. energies of resonances, using the most recent mass evaluation, making certain that resonance energies in the lab system are converted to c.m. system.

(In some cases the level energies are from primary gamma-ray data)

Uncertainties on level energies: relative or absolute

The measured (lab) resonance energies must be given in comment or re-labeled records.

In all cases, the use of SN+…, SP+.. should be avoided

b) Level spins and parities, and L-values (when available).

c) **Total level widths** or $T_{1/2}$ and partial widths; the latter should be given as data continuation records (or in comment records if the ENSDF format does not permit to list some of these quantities)

1. Charged-particle resonances (cont.)

Reaction dataset (contd.)

d) Resonance strength in relabeled field or in comment record.

e) Cross sections and reaction Q values under comment records; the latter should specify assumptions made by the authors.

f) Gamma-ray energies (Often measured energies not given by authors, deduced from level-energy differences, with recoil correction removed)

g) Gamma-ray intensities, generally branching ratios (Often missing branches)

h) Gamma-ray multipolarities and mixing ratios.
Related information about angular distributions/correlations or linear polarizations should be given under data continuation records or comment records.

1. Charged-particle resonances (cont.)

"Adopted" dataset:

a) Level excitation energies. (uncertainties: absolute)

b) Spins and parities.

c) Total level widths or $T_{1/2}$

d) Partial level widths as data-continuation records (or comment records if not permitted by format)

e) Gamma-ray energies (say how obtained)

f) Gamma-ray branching ratios (indicate total missing branch if any)

g) Gamma-ray multipolarities and mixing ratios.

h) Reduced transition probabilities when applicable.

2. Neutron Resonances

Includes averaged-resonance capture (ARC) data

Note: The evaluated data for all nuclides are given in 2006MuZX (Atlas of Neutron Resonances by S. Mughabgab) and also (for A>17) in **ENDF/B-VII.0.**

Reaction dataset:

a) **Level excitation energies**, deduced from lab or c.m. resonance energies, if the resonances are well separated in energy, e.g. more than 1-2 keV; measured (lab) resonance energies should be listed in comment records or relabeled field; (uncertainties: relative/absolute)

Level excitation energies as **SN+E(n),** where E(n)=measured neutron resonance energy in lab system, if many resonances are grouped in a narrow energy region so that it is impractical to translate these into excitation energies.

Note: use of S(n)+….. in level record may be needed if resonances are grouped in a narrow energy range.

2. Neutron Resonances (cont.)

b) Spins and parities, and L-value (if available)

c) Total level width or $T_{1/2}$, and partial gamma- and neutron-widths;
the latter on data continuation records.

d) Resonance strengths in a relabeled data field or in comment records

e) Gamma-ray energies

f) Gamma-ray intensities, generally branching ratios

g) Gamma-ray multipolarities and mixing ratios.
Related information about angular distributions / correlations or linear polarizations should be given under data continuation or comment records

2. Neutron Resonances (cont.)

“Adopted” dataset

Inclusion of neutron-resonance data in adopted dataset is left to evaluator’s discretion.

Note: Thermal-neutron capture data:

Currently the primary gamma-ray data are generally given only in the “reaction” dataset. These data can be carried over to the ‘adopted levels’ at evaluator’s discretion.

In column #80 of the level record letter ‘S’ should be given for a capture state with a warning that it is not a discrete state.

These revisions do not require modification of any of the existing formatting or analysis codes for processing of ENSDF-formatted data files or production codes for generating NDS