ENDF6 format: nuclear and atomic masses

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> Ian Thompson with B. Beck, C. Mattoon, D. Brown



Lawrence Livermore National Laboratory

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ENDF6: nuclear and atomic masses

From the ENDF6 manual:

- § 0.5.1.1 on masses:
 - Mass quantities for materials (AWR for all Z) and "heavy" reaction products (AWP for Z > 2) should be expressed in <u>atomic units</u>, i.e., the mass of the electrons should be <u>included</u>.
 - Mass quantities for incident particles (AWI) and "light" reaction products (AWP for Z ≤ 2) should be expressed in <u>nuclear mass</u> units. (See Table 2, Appendix H)

• § 3.1.1 on Q-values:

- In general, the masses used in the calculation of QM and QI should correspond the rest masses of the target and residual nuclei.
- If the target or residual is in the ground state, the rest mass is just the <u>nuclear mass</u>.

Present Issues:

- 1. Example: ⁴He as projectile is 4.0015, as target is 4.0026 amu Example: in reaction n + 7Li $\rightarrow \alpha + \alpha$, the electrons are 0 + 3 \rightarrow 0 + 0 !!
- 2. Hard to measure all nuclear masses! (Total ionizations rare for Z>20!)
- 3. Many Q-values cannot be consistently checked from masses in ENDF file!



Overview of Masses in ENDF/B-VIII

- Caleb & I checked all masses in current release.
 - Using tolerance of $m_e/2 \approx 0.25$ MeV.
- Statistics of mass errors (counting each error in each file)
 - Target masses too small, as <u>missing</u> Z*m_e : 92
 - Light nuclei (Z≤2) given atomic mass+electrons : 659
 - Precision given to 3 places (~ 1 MeV accuracy) : 1782
 - Other errors (incl. 1144 over 2^*m_e , 68 over 10^*m_e) : <u>12785</u>
 - Total : 15318

(lists of specific errors available on request, along with recommended replacement AWR and AWP values).



Desired Features of ENDF Solution

- 1. Masses be given accurately and consistently.
- 2. We might still live with rule 0.5.1.1
 - Even though ⁴He as projectile is 4.0015, as target is 4.0026 amu
- 3. Q-values be checkable for consistency
 - (to avoid big mistakes!)
- 4. These consistency checks be coded within ADVANCE
 - All evaluation submissions should be checked.
 - A 'reasonable evaluation' should pass all checks.



Recommendations for ENDF

- 1. Keep rule §0.5.1.1 on atomic and nuclear masses
 - Check for these in ADVANCE
 - Suggested tolerance: 0.1 MeV/c² (≈10⁻⁴ amu)
- 2. Change §3.1.1 rule for Q-values to use <u>atomic</u> rather than <u>nuclear</u> masses.
 - Only atomic masses are known for all nuclei.
 - Results should be very similar to those from nuclear masses
 - No disappearing electrons in reactions: included on both sides.
- Checking in ADVANCE should add in electron masses and binding energies to Z≤2 nuclear masses before checking Qvalues.
 - Caleb has written Fudge code for checking, but it not used yet
 - Note that this is only for Q-values, not for listed masses!
 - Suggested tolerance: 0.1 MeV. Or stricter?



Extra note: Recommendations for GND

- 1. Masses be given accurately and consistently.
- 2. Use <u>atomic masses</u> everywhere, <u>not</u> nuclear.
 - In GND, do <u>not</u> use any rule 0.5.1.1
 - So ⁴He as projectile and target is never 4.0015, but always 4.0026 amu
- 3. Check Q-values with <u>atomic</u> masses
 - (to avoid big mistakes!)
- 4. These consistency checks be coded within fudge
 - All evaluations should be checked.
 - A 'reasonable evaluation' should pass checks.





