The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2358-7

Joint ICTP-IAEA Workshop on Nuclear Structure Decay Data: Theory and Evaluation

6 - 17 August 2012

Adopted Data Sets

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ENSDF – Adopted Levels and Gammas

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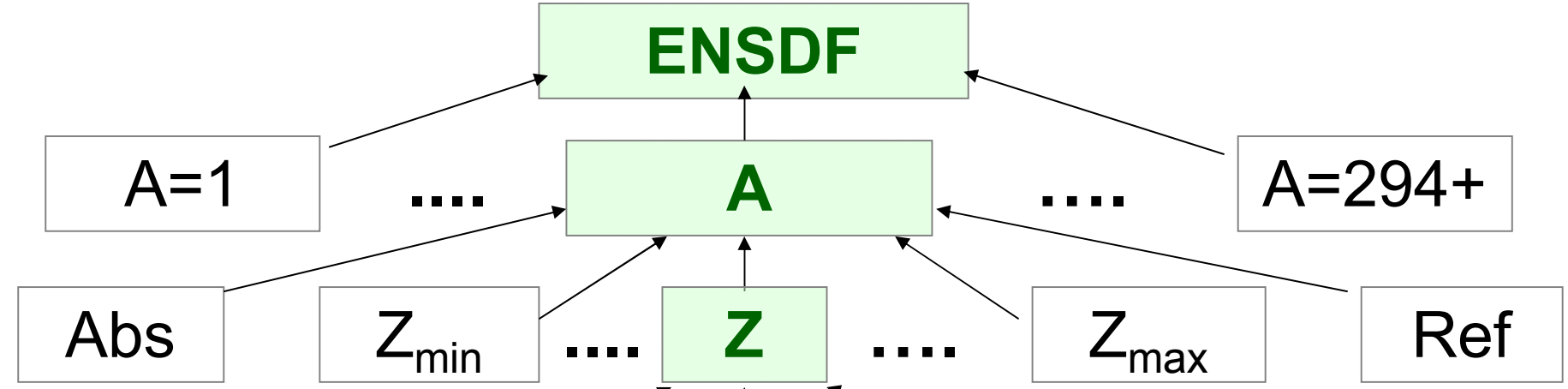
Workshop on *Nuclear Structure and Decay Data: Theory and Evaluation*
ICTP, Trieste, 6-17 August 2012

ENSDF Database Structure



Adopted
(best values)
Q values
Levels:
(E, Jπ, T1/2, μ, Q, config, excitn.)
Gammas:
(E, Br, Mult, δ)

1 dataset

Decays
β^-
$\varepsilon+\beta^+$
α
β^-n
etc.

0 to ~6 datasets

Reactions
(HI,xnγ), (HI,Xγ)
(p,p' γ)
(n, γ)
Coul. Exc.
(α,α')
(d,p)
etc.

0 to ~40 datasets

Adopted Levels, Gammas

This dataset is the heart of any nuclide evaluation !

- It is the condensation of all the information in all the other datasets and provides the **best values** known at the time of the evaluation.
- It provides the information that goes into the summary database NUDAT.
- It may be the **only** dataset that some readers will ever look at.
- The source of all data appearing here must be made transparent to the reader and easily traceable.

General Information

Q values:

• Usually rounded values from latest mass table (presently 2011AuZZ).

• Add new S(p), Q(α), *etc*., (with keynumber) if available; compare Q's with 2003Au03 values.

• Optional: Comment on uncertainties in 'SY' values; note newly-measured masses if very different from Audi's prediction.

General Comments:

e.g., Production/Identification, keynumber lists for major shell model calculations or isotope shift/hfs references (all optional).

Other Reactions:

Give reaction and keynumber if wanted for completeness, even though no data have been used and no reaction dataset has been created; *e.g*., a continuum gamma study (optional).

Define XREF Symbols:

Every DSID in nuclide must be listed here, even if it won't be associated with any specific level.

Example 1 →

```
167IR      ADOPTED LEVELS
167IR  C  Production: 92MO(78KR,p2n) E=357, 384 MEV (1997DA07).
167IR  C  Identification: 1981HO10 unambiguously assign a new |a group to 167IR
167IR2C  by relating it to known transitions through a multi-dimensional
167IR3C  analysis correlating parent energies, daughter energies, and the
167IR4C  timing of events. The production reactions involved 58NI on
167IR5C  molybdenum-tin targets and 107AG on vanadium-nickel targets
167IR  C  For calculation of proton decay widths for 167IR GS and isomer see
167IR2C  2000DA11.
167IR    Q            11944   SY-1070   6 6507     5    1995AU04,1997DA07
167IR  CQ          |DS(n)=300 (1995AU04).
167IR  CQ QA$from measured EA=6351 5 (1997DA07) for GS to GS transition; 1995AU04
167IR2CQ give QA=6495 50, reflecting lack of information concerning daughter
167IR3CQ state at that time.
167IR  CQ SP       From measured EP=1064 6 (1997DA07) for GS to GS transition;
167IR2CQ SP=-1110 10 in 1995AU04.
167IR     XA171AU A DECAY (1.02 MS)
167IR     XB78KR(92MO,2NPG)
167IR     L 0           (1/2+)          35.2 MS   20
167IR2   L %A=48 6 (1997DA07)$%P=32 4 (1997DA07)$%EC+%B+=?
167IRX   L XREF=B
167IR   CL J        comparison of calculated and measured partial lifetimes for
167IR 2CL p decay rule out d{-3/2} and h{-11/2} transitions, so 1997DA07 conclude
167IR 3CL that an L=0 p is emitted to the 0+ GS of 166OS.
167IR   CL %A,%P     From relative intensities of |a and p decay from level,
```

Level & Gamma Properties - General

• Assignments are definite (no parens.) if based on 'strong' arguments but indefinite (in parens.) if justification includes a 'weak' argument; see Nuclear Data Sheets (NDS) introductory material for specific rules.
• Every nuclide must have at least 1 level.
• Document sources of all data (**dataset name**, not just keynumber).
• Comment on serious discrepancies.
• Specify whether 'average' is weighted or unweighted (use larger of internal & external uncertainties for weighted averages).
• Remember to round off so uncertainty <26.
• Remember that 'level' and 'gamma' data appear in different tables in NDS; unhelpful to say "Jpi for levels with γ to 8+ isomer are based on …" (in level table) or "mult for γ's observed in low spin reactions is from …" (in γ table).
• Do not include:
    • continuation G records that give CC, KC, *etc*.;
    •coincidence 'C' from col. 78 of G records.
    • unplaced γ rays listed in source datasets.
•Optional:
    •neutron capture state(s) and primary γ rays from it.

Level Properties

Level Energy:

• Use GTOL to calculate from adopted $E\gamma$ (in most cases).

• Include all discrete levels and giant resonances; identify analog resonances.

• Adopt <u>minimum</u> number of levels consistent with source datasets.

T1/2 (or Γ):

• Specify source, *e.g.*, "from B(E2)↑ in Coulomb excitation", *etc*.

• Give bare-atom half-lives in comment (*e.g.*, "$T_{1/2}$(52Fe26+)= …").

• Remember $\Gamma=\Gamma\gamma+\Gamma p+\ldots$ for resonance, so note any <u>assumptions</u> made, such as ' $\Gamma=\Gamma\gamma_0+\Gamma\gamma_1$' or ' $\Gamma=\Gamma p$ '.

Band Flag: (if relevant)

Give rotational band parameters in comment (if meaningful) from:

$E_K(J)=E_0+A(J(J+1)-K^2)+B(J(J+1)-K^2)^2+(-)^{(J+K)}(J+K)!/(J-K)!(A_{2K}+B_{2K}(J(J+1)-K^2))$.

Isospin: very important for low A nuclides !

Level Decay Branches: for g.s. and isomeric levels, include all modes that might reasonably be expected, even if not yet observed.

```
 92RB  Q 8093      6  5098   10 11089   7 -6464  24    2011AUZZ
 92RB  L 0.0          0-                4.492 S   20
 92RB2 L %B-=100 $ %B-N=0.0107 5 (1993RU01)$
 92RBX L XREF=AB
--------------
192PO  Q -10990    60 11087  16 2120   13 7320    3    2011AUZZ
192PO CQ          FROM 2011AUZZ (cf. ^S(n)=11089 16, ^S(p)=..2003AU03)
192PO  L 0.0          0+                33.2 MS   14
192POX L XREF=AB
192PO2 L %A AP 100$ %EC+%B+=?$
192PO CL           %A: only A DECAY observed. %(EC+B+) AP 0.4 can be
192PO2CL estimated from gross B decay theory (partial T AP 8 S)
192PO3CL (1973TA30), or AP 0.54 from partial BETA T of 6.1 S
192PO4CL calculated by 1997MO25.
-------------
168RE  Q -5803     329030    SY995     365063    13    2011AUZZ
168RE CQ           |DS(n)=61 (2011AUZZ, from systematics).
168RE  L  0.0         (5+,6+,7+)       4.4 S     1
168RE2 L %EC+%B+=100$ %A AP 5E-3 (1992Me10)$
168REX L XREF=AB
168RE CL           %A: deduced from IA/RI(199.3G in 168W) and EC decay
168RE2CL scheme for 168RE (1992Me10).
```

Example 2: decay branches

XREF Flags:

• Use ‘N(*)’ if level from dataset N cannot be uniquely identified with level in question.

• Use ‘N(energy)’ to resolve any ambiguity due to poor energy match between adopted level and dataset X level.

Example 3: XREF’s

```
59NI    L 5821      10
59NIX   L XREF= BN(*5830)
59NI  CL          JPI=3/2+ FROM (POL P,D) AND L(P,D)=2 FOR 5821 AND/OR
59NI2CL 5844 LEVEL(S).
59NI    L 5844      10 (3/2+,5/2+)
59NIX   L XREF=BN(*5830)
59NI  CL  J       L(D,P)=(2). JPI=3/2+ FROM (POL P,D) AND L(P,D)=2 FOR 5821
59NI2CL AND/OR 5844 LEVEL(S).
```

• Watch out for systematic energy scale deviations between various reaction studies.

• Avoid associating a transfer reaction level with an adopted level whose configuration it would not excite.

Example 4

169Tm(d,p) Target g.s.: π 1/2[411]

n stripped from d

170Tm states populated must be π 1/2[411] $\otimes$ ν Ω[xxx]

Populated:

π 1/2[411] $\pm$ ν 1/2[521]
π 1/2[411] $\pm$ ν 5/2[512]
π 1/2[411] $\pm$ ν 7/2[633]
π 1/2[411] $\pm$ ν 3/2[521]

Not populated:

π 7/2[404] $\pm$ ν 7/2[633]
π 1/2[541] $\pm$ ν 5/2[512]
π 1/2[541] $\pm$ ν 7/2[633]

B(Lλ)$\uparrow$:

Include with level information **only** when value measured, but photon branching or $T_{1/2}$ is unknown (*e.g.*, E3 Coulomb excitation measured, but no E3 transition observed).

Moments (μ, Q): static, model-independent values.

- Summarized in 1989Ra17 (evaluation) and 2005St24, 2011StZZ (compilations); add any new measurements.
- Specify method used.
- Mention standards used, corrections applied (*e.g.*, Sternheimer).
- Signs matter.
- Convert g-factor data to μ.

Δ<r2> (DAVRSQ): include data in comment on g.s. (or isomer) if available.

Example 5: μ, Δ<r2>, *etc.*

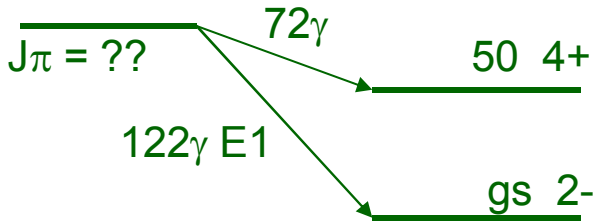
```
167LU   L      0.0+X   1/2(+)          1 M       GE                    CM
167LUX L XREF=B
167LU2 L %EC+%B+=?$%IT=?
167LU3 L MOMM1=-0.0999 13 (1998GE13)$
167LU CL          DAVRSQ(170LU,167LU)=-0.291 (1998GE13); 10%
167LU2CL systematic uncertainty.
167LU CL          J,MOMM1: from collinear fast beam laser spectroscopy
167LU2CL (1998GE13). PI based on proximity of MOMM1 to value expected for
167LU3CL 1/2[411] orbital (-0.05) cf. that for the only other nearby J=1/2
167LU4CL orbital (viz. 1/2[541], |m AP +0.7).
167LU CL T        estimated by 1998GE13; based on known rare-earth diffusion …
```

.

Spin and Parity:

- An argument must be provided for every Jπ that is given.
- Use fewest and best strong arguments for definite Jπ; the more arguments the better if J or π is uncertain. Try to convince reader; enable a quick check on the impact of any new data that may become available later.
- Use flagged comments for long, repetitive arguments (*e.g.*, "Jpi based on presence of primary γ from ½+ capture state in (n, γ) E=thermal and log$f^{1u}t$<8.5 from 1/2- in … EC decay").
- If J is directly measured (*e.g.*, atomic beam), state the method.
- Note that μ no longer provides a strong Jπ argument (it used to).
- Avoid using multiply-placed γ's in "γ to Jπ=…" type arguments.
- Note that "γ's to 3/2+ and 5/2-" (2 levels) differs from "γ's to 3/2+, 5/2-" (1 level) – avoid ambiguities.
- "γ to Jπ=…" is a weak argument.
- In "γ to …" arguments, the level Jπ is what matters, not E(level).
- Use "log*ft*=…from Jπ=1/2-" and L(d,p)=2 for 9/2+ target" type arguments; the parent/target Jπ is part of the argument.

Sample Jπ Arguments:



Argument(s)	So Jπ=
E2 737γ to 7/2+ g.s.; log*ft*<5.9 from 1/2+.	3/2+
Primary γ from 1/2+ in (n,γ) E=thermal; E1 438γ from 7/2- 832 level.	5/2+
From (pol d,p) and L(d,p)=2 for 0+ target.	5/2+
Log$f^{1u}t$<8.5, log*ft*=7.0 from 2-; M1 558γ from 4+ 1038 level.	3+
M1+E2 78γ to 1/2- 132 level.	3/2-
E1 122γ to 2- g.s.; 72γ to 4+ 50 level.	(2,3)+
Probable analog of 3/2- 358 level in ^{AA}ZZ.	(3/2-)
Unhindered (HF<4) α decay from (10-) parent.	(10-)
γ to 2- and γ to 4+.	(2+,3,4-)

Gamma-Ray Properties

Energy:

If $E\gamma$ came from level-energy difference, say so and recalculate after GTOL has been run (without that $E\gamma$ included, of course).

Relative Branching:

• Scale $I\gamma$ so strongest branch is 100;

Exceptions:

Strongest line is multiply placed (& in col. 77) (give as <(I+ΔI)).

Strongest line is given as a limit.

Transition is within a superdeformed band.

• Omit uncertainty if only 1 branch.

• Give TI for E0 or fully converted transitions (if known).

Multipolarity:

• [mult] means 'deduced solely from level scheme'; use [E2], *etc*., only if <u>needed</u> to calculate transition probability or CC for a transition with no measured multipolarity.

• Convert 'D' or 'Q' to '(E1)', '(E2)', *etc*., if desired or if needed for calculation or $J\pi$ argument; specify how $\Delta\pi$ was deduced.

• Remember that ‘M1,E2’ and ‘M1+E2’ are not equivalent.

Mixing Ratio:

• Include sign, if known. Absence of sign indicates modulus δ.

• If 2 solutions, give both in comment, none in MR field.

• Watch for cases where experiment gives higher limit than RUL allows; modify adopted δ if appropriate.

Total Conversion Coefficient (CC):

Give whenever significant.

E0 Transitions:

Quote ρ^2(E0) from 2005Ki02 or 1999Wo07 (or from authors of later papers who provide it).

Reduced Transition Probabilities:

• Give whenever calculable.

• If δ overlaps 0 or ∞, calculate for pure D or pure Q, respectively.

• Calc. for [E1], [E2], [ΔJ>2].

• Watch out for δ, $T_{1/2}$ or I_γ data given as a limit.

← Example 6

Reduced Transition Probability Calculations (Special Cases)

I: Data given as limit:

δ(M1,E2)<0.3:

$B(E2)_W$: give as upper limit.

$B(M1)_W$: give av. of $B(M1)_W(\delta=0)$ and $B(M1)_W(\delta=0.3)$.

TI<i for non-dominant branch:

Assign $1/2i \pm 1/2i$ to this transition to enable calculation of $B(L\lambda)_W$'s for other branches.

$T_{1/2}$<t:

Give resulting lower limits on $B(L\lambda)_W$'s.

$T_{1/2}$>t:

Typically, forget it !

However, $B(E2)_W<0.005$ or $B(E1)_W< 2\times10^{-10}$ might, *e.g.*, be worth mentioning.

II: When $T_{1/2}$ has been calculated directly from $B(L\lambda)$:

Calculate $B(L\lambda)_W\downarrow$ from measured $B(L\lambda)\uparrow$ and single-particle value (available from RULER) so uncertainty is not overestimated.

Checking Your Evaluation

- Make sure that all data sets satisfy current ENSDF policies/practice.
- Run FMTCHK and make the necessary corrections.
- Read through the ENSDAT or pre-review output; it is amazing what the eye can catch this way!
- Check band drawings – a typographical error in Jπ or an incorrect band flag may be extremely easy to see there.
- Run PANDORA.
    - Use PANDORA.ERR file to identify physics errors.
    - Use PANDORA.GLE file to check for:

(i) Inconsistencies in Jπ, MULT, δ between adopted and decay datasets.

(ii) Adopted photon branching that has not been renormalised so the strongest photon branch is 100.

(iii) Levels or transitions in decay or reaction datasets which were accidentally omitted from *Adopted Levels, Gammas* (or conversely).