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

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Analysis Codes

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ENSDF Analysis and Utility Codes BrICC, Mixing, and Ruler

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NNDC

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BrICC
Need for Internal Conversion Coefficients

- Internal conversion of an electron or gamma?
    - Total intensity depopulating a level must take into account usually unmeasured internally converted electrons
    - $I_{total} = I_\gamma * (1 + \alpha_{total})$
- Multipolarity
    - Measured ICC can help with multipolarity decisions

BrICC

- $\alpha(EL) = \text{const} * \text{const}(L) * (Z/n)^3 * (L/(L+1)) / E^{L+5/2}$

- $\alpha(ML) = \text{const} * \text{const}(L) * (Z/n)^3 / E^{L+3/2}$

(nonrelatistic)

BrICC
Relation to transition strengths

- B(E2) (in Weiskopf units)

$$B(E2)(W.u.) = \frac{9.527 \times 10^6 \ BR}{(E_\gamma)^5 \ A^{4/3} \ T_{1/2} \ (1 + \alpha)}$$

- Mixed transitions (example, E2/M1)
    - L, and L + 1
        - Multiply the L+1 rate by $\delta^2/(1 + \delta^2)$
        - Multiply the L rate by $1/(1 + \delta^2)$

BrICC
Installation and Running

- Maintained by T. Kibedi (ANU)

- On Windows, installs as usual Windows installation program, and by default goes to the "Program Files" directory and is added to the path (go ahead and add if not there). Creates BrICC program group.

  - To upgrade: uninstall first

- On Linux, grab the tarball, extract and add to your path

- BrIccHome enviroment variable needs to be set on Linux (part of installation for Windows)

BrICC
Running and installation continued

- Run on a "Console" or "Command" window by typing:

  - Prompt> bricc [ensdf-file-name]

  - Answer questions as prompted:

    - Report file in BrICC.lst (default)

    - New "cards" (Cards.new is the default)

    - Comparison report (Compar.lst)

    - All subshells? (defaults to N, can change to "Y")

    - All transitions? (defaults to N)

BrICC
Running and installation (continued)

- Lowest CC value (version 2.3 -- default is 1.00E-4)

- Assumed MR value for E2/M1 (version 2.3 -- default is 1.00)

Creates a new Cards.new file to be merged in another step.

Records flagged to what's going on….

BrICC
Step 2. Folding into the ENSDF dataset

- To merge the results into your dataset
    - Prompt> bricc someset.ens merge

Asks for the results of prior run, defaulted to Cards.new

The new file (by default) Cards.mrg

Bricc Merged Example

```
87NB    ADOPTED LEVELS, GAMMAS                                    02NDS    200205
87NB  H TYP=FUL$AUT=T.D. Johnson, W. D. Kulp$CIT= $CUT=31-Mar-2011$
87NB DG CC$ FROM BrIcc v2.3 (3-Oct-2011) 2008Ki07, "Frozen Orbitals" appr.
87NB  c  With the exception of the 400-keV level, these data are
```

```
87NB3CQ $Q(|ecp)=-2.19E+3 6 (syst.)
87NB CG MR$ IF NO VALUE GIVEN IT WAS ASSUMED MR=0.10 FOR E2/M1,
87NB2CG MR=1.00 FOR E3/M2 AND  MR=0.20 FOR THE OTHER MULTIPOLARITIES
87NB PN                                                                        6
```

```
87NB  L 266.7       11 (7/2)+                                     M
87NB2 L XREF=A
87NB  G 263.9            100.0  M1                       0.01690
87NBS G NC=4.39E-5 7$OC=2.53E-6 4
87NBS G KC=0.01485 21$LC=0.001700 24$MC=0.000300 5$NC+=4.64E-5 7
87NB  L 333.0        9 (5/2-)            28 NS    2               F
```

BrICC Mixing

```
mixit.ens
189AU
189AU 1164.3  5
M1+E2 0.10    .01
1969Wo04 K 0.005 1  A
#1969Wo04 L12/K 0.26 9 A
#1969Wo04 L3/K 0.01 1 A
#1969Wo04 M/K 0.054 14 A
#1969Wo04 N/K 0.016 5 A
# A for Absolutely measured ICC intensity or intensity ratio
# N for unnormalized intensity
# *NEW to start a new datablock
```

BrICC Mixing Result
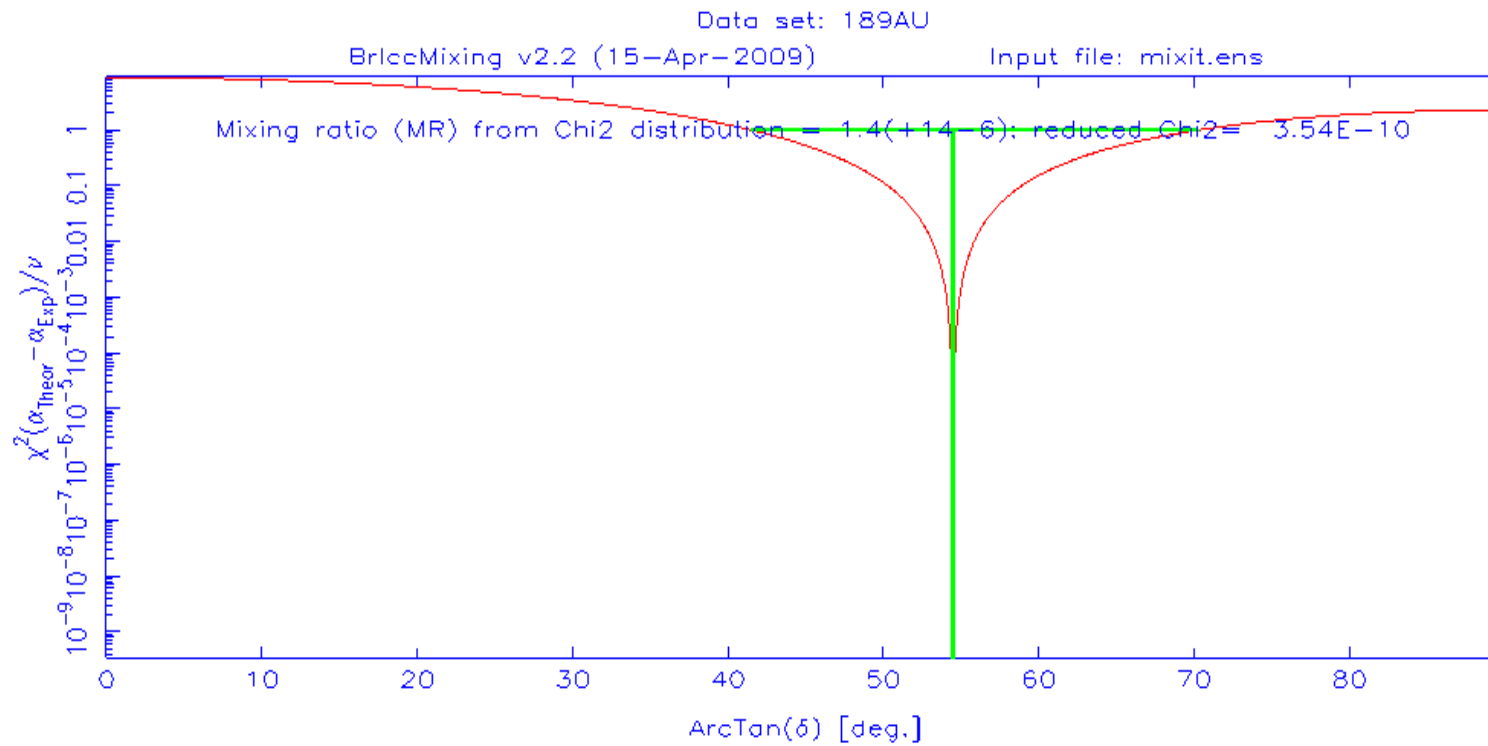
Ruler

- ## From Krane:

  - $\lambda(\sigma L)$ = const * $2(L+1)/[L(2L + 1)!!]2\ (\omega/c)^{2L+1}[m_{fi}(\sigma L)]^2$

  - For a few simple transitions in single-particle estimates:

    - $\lambda(E2)$ = const * $A^{4/3}\ E^5$

    - $\lambda(M1)$ = const * E^3

    Noting probability per unit time is inverse of lifetime, and switching to half-life

Ruler
Typical Equations Used

- B(E2) (W.u.) = const. BR/[$E^5 A^{4/3} T_{1/2} (1+\alpha)$]
- B(M1) (W.u.) = const. BR/[$E^3 T_{1/2}(1+\alpha)$]

See the Procedures Manual for more information

Ruler and Selection Rules

- Triangle Rule
    - $|li - lf| \leq L \leq li + lf$
- Parity rules

$\Delta\pi = +$ (no change): even E, odd M

$\Delta\pi = -$ (changes): odd E, even M

Run in report mode and check ruler.rpt for your transition

When asked for "Mode of Operation", choose "R" to compare to RULS (Recommended Upper Limits)

Ruler
Portion of a sample report file

```
EG=136.0 10                   BRANCHING RATIO (IN PERCENT)=42 11
 PARTIAL TRANSITION T1/2=1.4E-10 4 SEC
TO OBTAIN PARTIAL GAMMA T1/2 MULTIPLY BY (1+CC)=1.0969 14
              WEISSKOPF SINGLE-PARTICLE HALF-LIFES (SEC), INCLUDES UNCERTAINTY IN EG
              ORDER     ELECTRIC               MAGNETIC
                1      1.37E-13        7      8.8E-12         5
                2      5.3E-7          5      3.4E-5          3
                3      3.1             4      201             23
                4      2.7E7           4      1.76E9          25
                5      3.4E14          6      2.2E16          4


              RECOMMENDED UPPER LIMITS COMPARISON
              ORDER       ELECTRIC                             MAGNETIC
                    CALCULATED           RUL                CALCULATED           RUL
                1  (IV)      0.0009  3       0.010       (IV)      0.057 16      3.000
                2  (IS)        3.5E3 10    300.000 <===  (IV)      2.2E5   7     1.000 <===
                3            2.1E10  6     100.000 <===            1.3E12  4    10.000 <===
                4            1.8E17  6     100.000 <===            1.1E19  4    30.000 <===


              <===CALCULATED STRENGTH EXCEEDS RECOMMENDED UPPER LIMIT
```

Ruler
(run in regular mode—option B)

```
87NB  L 782.8     11 (13/2)+        1.8 PS    3                    L
87NB CL $T from 1991Ju05
87NB  G 779.9        100    10 (E2)
87NB2 G DCO=0.97 1
87NB CG $Other: R(DCO)=1.09 {I2} from 1997We04
87NBS G CC=0.001311 19$KC=0.001153 17$LC=0.0001314 19$MC=2.31E-5 4$NC+=3.56E-6
87NBS G NC=3.37E-6 5$OC=1.90E-7 3
87NBB G BE2W=48 8
```