ENSDF analysis and utility codes Exercises
BrIcc / BrIccMixing / Ruler/Gabs

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Installing & running the codes

- PATH (variable) PATH is an environment variable on **Unix**-like operating systems, DOS, **OS/2**, and Microsoft Windows, specifying a set of **directories** where executable programs are located.
- Copy executables into a single directory (<myDir>) and add this directory to the PATH:

  Linux & MacOS add to the .bashsrc or .profile files:

  export PATH=<myDir>:$PATH

  Windows: use Control Panel\Environment Variables to add manually
- Check if PATH is correctly set. To list ALL environment variables

  Linux & MacOS: printenv

  Windows: set
- BrIcc & BrIccMixing requires BrIccHome environment variable, the directory, where the ICC (BrIccFOV22.icc) data and index files (BrIccFOV22.idx) are
- Pass input/output file names on the command line

  bricc 99mTc.ens merge <cr>
- Default file names convenient, but files will be overwritten!
- Consult with terminal dialogue and calculation report files to identify problems!

Numerical and ascii values in ENSDF

- ENSDF: 80 character/line (record or card) ASCII (American Standard Code for Information Interchange) file (ENSD format manual)
- 17 record types: Identification, Normalization, Parent, Q-value, Level, Alpha, Beta, EC+beta+, Gamma, Reference, Cross reference, Delayed Particle, Product normalisation, Special record, History, Atomic Relaxation, End records
- Often values are given in continuation records: 174Tm2 G FL=123.45
- Fixed length fields.
- Value is given as ASCII string to preserve accuracy reported in the original paper
- Uncertainty: symmetric, asymmetric, limits, data came from systematics, etc
- Uncertainty propagation (see BrIcc manual)
- No ENSDF editor available yet for all platforms

```
174TM    174ER B- DECAY               1991BE04,1989CH05        99NDS    199908
174TM  H TYP=UPD$AUT=Tibor Kibedi$CUT=1-Sep-2015$
174TM  H TYP=FUL$AUT=E. BROWNE, HUO JUNDE$CIT=NDS 87, 15 (1999)$CUT=1-Nov-1998
174TM  c Activity produced by bombarding natural tungsten target with {+176}Yb
174TM2c  (E=1.5 GeV) projectiles (1989Ch05) and {+186}W target with {+136}Xe
174TM3c  (E=1.577 GeV) projectiles (1991Be04). Mass separated {+174}Er.
174TM4c  Measured |b{+-}, |g-ray energies and intensities, coincidences, Tm
174TM5c  K-x rays (1991Be04,1989Ch05).
174TM  c {+174}Er decay scheme is based on 1991Be04. Direct |b{+-} population
174TM2c  to levels at 767 and 773 from {+174}Er (J|p=0+) is inconsistent with
174TM3c  |g-ray decay from these levels to {+174}Tm (J|p=4-) g.s., which
174TM4c  suggests the existence of a a very low-energy level with J|<2
174TM5c  (1991Be04). But 2006Ch10 exclude this conclusion.
174TM  c Measured E|b|~1.3 MeV (1989Ch05).
174TM cG E,RI$From 1991Be04.
174TM cG M$From adopted gammas
174TM cL T$From adopted levels. Other: 3.3 M 2 (1989Ch05), 3.1 M 3 (1991Be04)
174TM CL J$ From adopted levels
174TM DG CC$FROM BrIcc v2.3b (16-Dec-2014) 2008Ki07, "Frozen Orbitals" appr.
174TM CG MR$IF NO VALUE GIVEN IT WAS ASSUMED MR=1.00 FOR E2/M1,
174TM2CG MR=1.00 FOR E3/M2 AND MR=0.10 FOR THE OTHER MULTIPOLARITIES
174ER  P 0.0         0+                3.2 M     2              1.92E3   30
174TM  N 0.114     7          1.0
174TM cN NR$Assuming no |b{+-} population to levels at 58.5 keV and below, and
174TM2cN using I|g(71.7|g + 100.4|g + 130.4|g + 708.6|g + 714.4 + 766.5|g
174TM3CN + 773.4|g)=100%.
174TM PN                                                                    3
174TM  L 0.0         4-                5.4 M     1
174TM  L 58.53    17 (2-)
174TM  G 58.5      2 45       LT (E2)                 25.6  6
174TMS G  LC=19.6 5$MC=4.81 11
174TMS G  NC=1.091 24$OC=0.124 3$PC=0.0001396 22
174TM cG $Observed only in a coincidence experiment (1989Ch05). Not observed
174TM2cG by 1991Be04 (I|g|<45, estimated from K| x ray intensities).
174TM  L 100.40   20 3-
174TM  G 100.4     2 100         M1                   3.07
174TMS G  KC=2.57 4$LC=0.389 6$MC=0.0867 14
174TMS G  NC=0.0203 3$OC=0.00291 5$PC=0.0001577 24
174TM cG $EKC=1.7 {I3} (1991Be04) suggests M1+E2 with MR=1.1 {I+7-4}, which
174TM2cG disagrees with 2005Ch67 and 2006Ch10
174TM CG $Other: E|g=100.4 {I2}, I|g=100 {I1} (1989Ch05)
```

Redit (Windows)
Sergey Lisin (PNPI)

BrIcc - interactive use

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ENSDF_codes — bricc — 118×24

~/ENSDF_codes — bricc

```
MacBook-Pro-2:ENSDF_codes tibor$ bricc
          BrIcc v2.3b (16-Dec-2014) calculates conversion coefficients
                 (for electron conversion and pair production)
                           and E0 electronic factors
                      using cubic spline interpolation
```

element

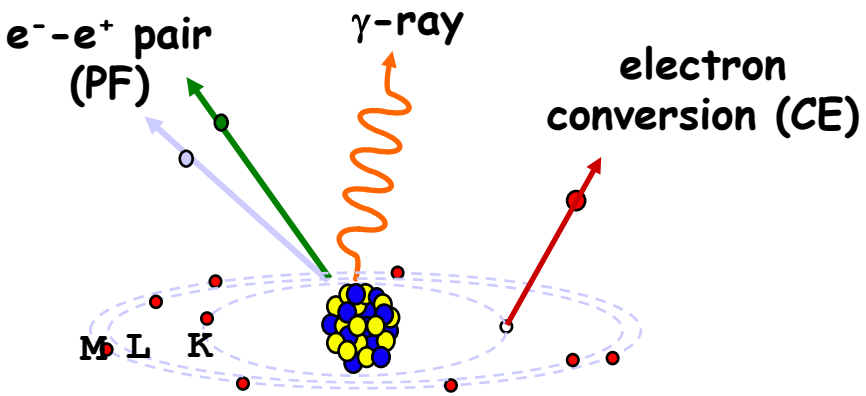
Version & data table

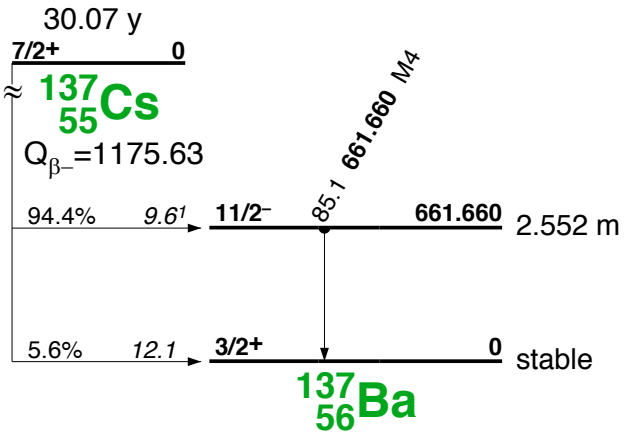
```
Z= 70  Ytterbium          Transition energy: 279.717 keV                    BrIcc v2.3b (16-Dec-2014)
                                                                            Data Table: BrIccFO
                                          Conversion Coefficient
Shell  E_e [keV]    E1          M1          E2          M2          E3          M3          E4          M4          E5          M5
-------------------------------------------------------------------------------------------------------------------------------------
Tot              2.367E-02 1.901E-01 9.151E-02 8.110E-01 4.258E-01 3.015E+00 2.267E+00 1.179E+01 1.251E+01 4.967E+01
K        218.38  1.989E-02 1.593E-01 6.401E-02 6.437E-01 1.910E-01 2.138E+00 5.694E-01 6.979E+00 1.741E+00 2.279E+01
L-tot            2.946E-03 2.393E-02 2.115E-02 1.292E-01 1.787E-01 6.694E-01 1.279E+00 3.622E+00 8.019E+00 1.995E+01
M-tot            6.561E-04 5.351E-03 5.038E-03 2.999E-02 4.463E-02 1.637E-01 3.323E-01 9.367E-01 2.182E+00 5.468E+00
N-tot            1.526E-04 1.257E-03 1.161E-03 7.067E-03 1.028E-02 3.862E-02 7.675E-02 2.212E-01 5.061E-01 1.294E+00
O-tot            2.109E-05 1.799E-04 1.447E-04 9.933E-04 1.223E-03 5.205E-03 8.903E-03 2.841E-02 5.697E-02 1.584E-01
P-tot            1.001E-06 9.639E-06 3.226E-06 4.933E-05 1.179E-05 2.169E-04 5.326E-05 9.480E-04 2.740E-04 4.167E-03
TranEner|ChemSymb|Z+Integer|SUBShell|DATAtable|? for help|EXIT [279.717] >
```

Input parameter can be:

- **Transition Energy [keV]:** 123; 123.0, 1.23E2
- **Chemical Symbol [max 2 char]:** *Os*
- **Z+integer [5-110]:** Z76 selects Os
- **SUBS:** toggles between to show/NOT to show sub shell ICCs
- **DATA table:** toggles between "Frozen Orbitals" (BrIccFO) and "No Hole" (BrIccNH) approximations
- **?:** *displays information on how to use BrIcc*

BrIcc - interactive use





Energetics

Gamma $E_\gamma = E_i - E_f + T_r$

CE $E_{CE,i} = E_i - E_f - E_{BE,i} + T_r$

PF $E^+ + E^- = E_i - E_f - 2m_oc^2 + T_r$

Transition probability

$$\lambda_T = \lambda_\gamma + \lambda_K + \lambda_L + \lambda_M \ldots\ldots + \lambda_{PF}$$

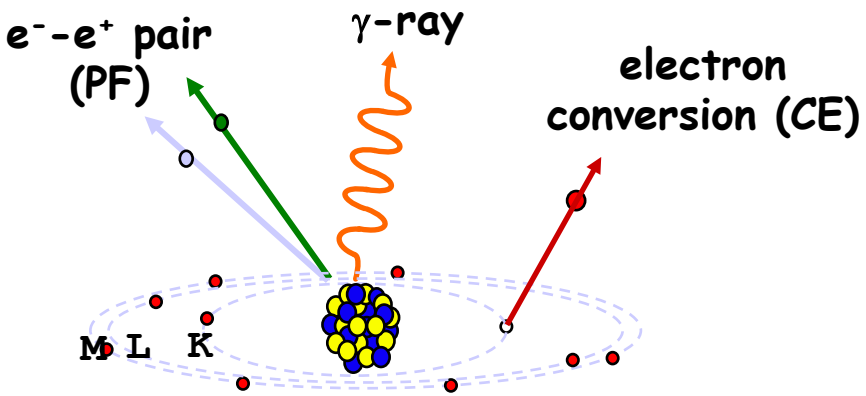
Conversion coefficient

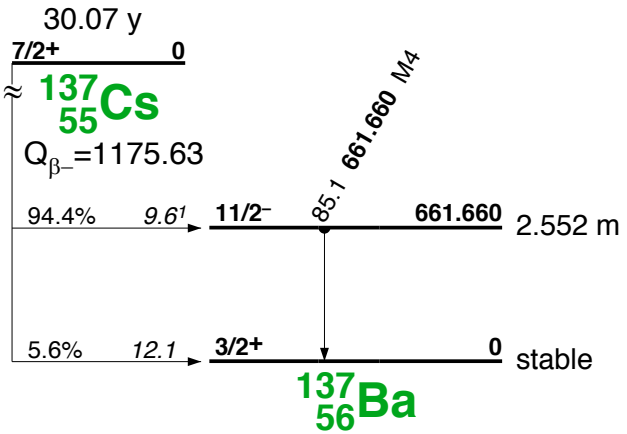
$$\alpha_{CE,PF} = \lambda_{CE,PF} / \lambda_\gamma$$

$$\lambda_{CE,PF} = \lambda_\gamma \times \alpha_{CE,PF}$$

Q: How many ^{137}Cs decays will proceed with the emission of K conversion electrons?

BrIcc – interactive use





Energetics

Gamma $E_\gamma = E_i - E_f + T_r$

CE $E_{CE,i} = E_i - E_f - E_{BE,i} + T_r$

PF $E^+ + E^- = E_i - E_f - 2m_oc^2 + T_r$

Transition probability

$\lambda_T = \lambda_\gamma + \lambda_K + \lambda_L + \lambda_M \ldots\ldots + \lambda_{PF}$

Conversion coefficient

$\alpha_{CE,PF} = \lambda_{CE,PF} / \lambda_\gamma$

$\lambda_{CE,PF} = \lambda_\gamma \times \alpha_{CE,PF}$

Q: How many ^{137}Cs decays will proceed with the emission of K conversion electrons?

A: α_K=9.148E-02

λ_K= 94.4%*λ_K/λ_T=94.4%*$\alpha_K/(1+\alpha_T)$

λ_K=7.76%

BrIcc - interactive use

Skip Navigation | ANU Home | Search ANU | RSPhysSE | Nucl. Phys. Home

Department of Nuclear Physics

Research School of Physics and Engineering

BrIcc
- BrIcc Home
- BrIcc Grapher
- Quick reference
- Data tables
- Program manual
- Obtaining BrIcc
- Version history
- Authors

Nuclear Structure Links
- ANU Nuclear Physics
- National Nuclear Data Center
- IAEA Nuclear Data Centre
- NSDD network
- DDEP network

BrIcc v2.3S

Conversion Coefficient Calculator

Z (atomic number or symbol): Ba

γ-energy (in keV): 661.6 Uncertainty:

Enter (optional) uncertainty in energy as **x** or **+x-y**

Multipolarity: M4 δ: Uncertainty:

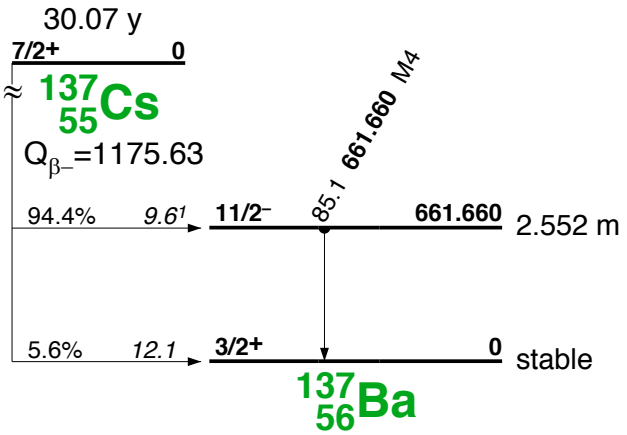
Enter (optional) uncertainty in δ as **x** or **+x-y**

Show Subshells ☐ **Data Set** BrIccFO

Calculate Reset

BrIccS v2.3 (9-Dec-2011)
Z=56 (Ba, Barium)
γ-energy: 661.6 keV
Data Sets: BrIccFO

Shell	E(ce)	M4
Tot		0.1124 (16)
K	624.16	0.0915 (13)
L-tot	655.72	0.01649 (23)
K/L		5.55 (11)
M-tot	660.35	0.00352 (5)
L/M		4.68 (10)
N-tot	661.36	0.000759 (11)
L/N		21.7 (5)
O-tot	661.57	0.0001134 (16)
L/O		145 (3)
P-tot	661.59	7.22E-6 (11)
L/P		2.28E3 (5)



Q: How many ^{137}Cs decays will proceed with the emission of K conversion electrons?

A: α_K=9.148E-02

λ_K= 94.4%*λ_K/λ_T=94.4%*$\alpha_K/(1+\alpha_T)$

λ_K=7.76%

BrIcc - use as evaluation tool
Step 1: calculations

```
MacBook-Pro-2:Excersises tibor$ bricc 1974Re07.ens
          BrIcc v2.3b (16-Dec-2014) calculates conversion coefficients
                (for electron conversion and pair production)
                          and E0 electronic factors
                       using cubic spline interpolation
            Theoretical Dirac-Fock conversion coefficients based on
                 the so-called "Frozen Orbital" approximation

  Input & Data Files:
    Input ENSDF file: 1974Re07.ens

  Output Files:
    Complete calculations report, (Def: BrIcc.lst):
    New G/SG records, (Def: Cards.new):
    G/SG (New/Old) comparison report, (Def: Compar.lst):

  Execution control:
    List conversion coefficients for all subshells (Def. N):
    Calculate conversion coefficients for all transitions (Def. N):
    Lowest CC value to be put on G-card (Def. 1.00E-04):
    Assumed value MR for E2/M1 transitions (Def. 1.00):

  Processing started. Please wait.
```

BrIcc - use as evaluation tool
Step 1: calculation report

bricc myEnsdf.ens<CR>

bricc.lst

```
Record name = "GAMMA"
NUCIDCARDE          DERI       DRM          MR       DMR    CC      DCTI          DTCCBQ
Format=, Color_Index=4, Align=block, Convert=no, Id=CARD

----+---1----+----2----+----3----+----4----+----5----+----6----+----7----+----8
172YB  G 90.605 25 0.40  3 M1+E2      -1.64  2      4.65
```

```
================================================================================================
BrIcc v2.3b (16-Dec-2014)  Z= 70 Egamma= 90.605 25 keV       Multipolarity= M1+E2      14:24:21 23-Aug-2016
                                                  M1+E2      Mixing ratio= -1.64 2
                                          M1+E2 Mixed
Shell     M1          E2                   Icc         dIcc         dIccDMRL    dIccDMRH
          ---------   ---------            ---------   ---------    ----------  ----------
K         3.745E+00   1.243E+00            1.921E+00   2.956E-02   -1.192E-02   1.220E-02

L-tot     5.745E-01   2.647E+00            2.085E+00   3.100E-02    9.871E-03  -1.010E-02
K/L       6.520E+00   4.695E-01            9.213E-01   1.971E-02

M-tot     1.287E-01   6.531E-01            5.109E-01   7.624E-03    2.498E-03  -2.557E-03
L/M       4.465E+00   4.053E+00            4.081E+00   8.596E-02

N-tot     3.021E-02   1.489E-01            1.167E-01   1.740E-03    5.654E-04  -5.788E-04
L/N       1.902E+01   1.777E+01            1.786E+01   3.760E-01

O-tot     4.316E-03   1.704E-02            1.359E-02   2.008E-04    6.060E-05  -6.203E-05
L/O       1.331E+02   1.554E+02            1.534E+02   3.216E+00

P-tot     2.295E-04   5.415E-05            1.017E-04   1.662E-06   -8.350E-07   8.548E-07
L/P       2.503E+03   4.888E+04            2.051E+04   4.532E+02

Tot       4.483E+00   4.709E+00            4.648E+00   6.524E-02    1.073E-03  -1.098E-03
```

Uncertainty on ICC

- ❑ Uncertainty DE
- ❑ Uncertainty on MR
- ❑ Flat 1.4% from theory

NOTE

- ❑ Uncertainty on MR may not be symmetric
- ❑ Total ICC will be inserted into CC field if α_T > 1.0E-4

See BrIcc Manual how uncertainties propagated

BrIcc – use as evaluation tool
Step 1: calculations

BrIcc verifies *G*, *G*-cont cards and generates error messages, if needed:

```
150GD  G 650.33    0 .3         (E2)
<E> Invalid uncertainty on transition energy.

181RE  G 148.4     2      0.8 3M1        0.13    LT    1.724  17
<E> Invalid mixing ratio.
```

Use FMTCHK before running BrIcc!

For some Elements and Atomic shells BrIcc energy range is limited:

```
<W> ICC could not be calculated for EG+DEGH above 398.000 keV
```

Extra user information

```
146SM  G 2644.43   5 0.108    3E1+(M2)
<I> Mixing ratio empty, assumed to be equal to 1.
246CM  G    42.9   2   2     AP  E2
<I> Uncertainties on ICC`s from transition energy uncertainty is greater than 1.0%.
```

Observe messages on terminal window!

BrIcc - use as evaluation tool
Step 1: new ENSDF records

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New ENSDF records: Cards.new

```
# Program: BrIcc v2.3b (16-Dec-2014)                    # # # DO NOT EDIT THIS LINE # # #
# Input ENSDF file: 1974Re07.ens
# Processed on: 14:48:21 23-Aug-2016
# Letters after record numbers indicate: R-replace, I-insert before, D-delete
#
# DsId: 172YB    172TM B- DECAY (63.6 H)       1974RE07,1967OT03,1968WI2295NDS    199509
172YB DG CC$FROM BrIcc v2.3b (16-Dec-2014) 2008Ki07, "Frozen Orbitals" appr.        51 I
172YB CG MR$IF NO VALUE GIVEN IT WAS ASSUMED MR=1.00 FOR E2/M1,                     51 I
172YB2CG MR=1.00 FOR E3/M2 AND MR=0.10 FOR THE OTHER MULTIPOLARITIES                51 I
172YB  G 78.750    7 109     8 E2                          8.25          C        71 R
172YBS G KC=1.48 3$LC=5.12 11$MC=1.26 3$NC+=0.321 6$                                72 D
172YBS G  KC=1.543 22$LC=5.12 8$MC=1.265 18                                         72 I
172YBS G  NC=0.288 4$OC=0.0328 5$PC=7.37E-5 11                                      72 I
172YBS G NC=0.288 6$OC=0.0328 7$                                                    73 D
172YB  G 181.520   9 45.9    24E2                          0.372          C        79 R
172YBS G KC=0.214 5$LC=0.1188 24$MC=0.0289 6$NC+=0.00742 14$                        80 D
172YBS G  KC=0.217 3$LC=0.1189 17$MC=0.0289 4                                       80 I
172YBS G  NC=0.00662 10$OC=0.000791 11$PC=9.92E-6 14                                80 I
172YBS G NC=0.00662 14$OC=0.00079 2$                                                81 D
```

Comments

New CC

New S_G cards

BrIcc - use as evaluation tool
Step 2: merge new and old cards

bricc myEnsdf.ens merge<CR>

```
MacBook-Pro-2:Excersises tibor$ bricc 1974Re07.ens merge
          BrIcc v2.3b (16-Dec-2014) calculates conversion coefficients
                 (for electron conversion and pair production)
                           and E0 electronic factors
                        using cubic spline interpolation
                    MERGE: inserting/replacing G_S record
   New G/SG cards, (Def: Cards.new):
   Output file of merged old and new cards, (Def: Cards.mrg):
 Merge operation completed!
```

```
Record name = "GAMMA"
NUCIDCARDE          DERI       DRM          MR       DMR    CC      DCTI          DTCCBQ
Format=, Color_Index=4, Align=block, Convert=no, Id=CARD

----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8
172YB   G 90.605    25 0.40    3 M1+E2     -1.64    2      4.65
172YBS  G  KC=1.92 3$LC=2.09 4$MC=0.511 8
172YBS  G  NC=0.1167 18$OC=0.01359 20$PC=0.0001017 17
```

BrIccMixing

	Δπ=+1		Δπ=-1	
πL	M1	M3	E1	E3
π'L'	E2	E4	M2	M4

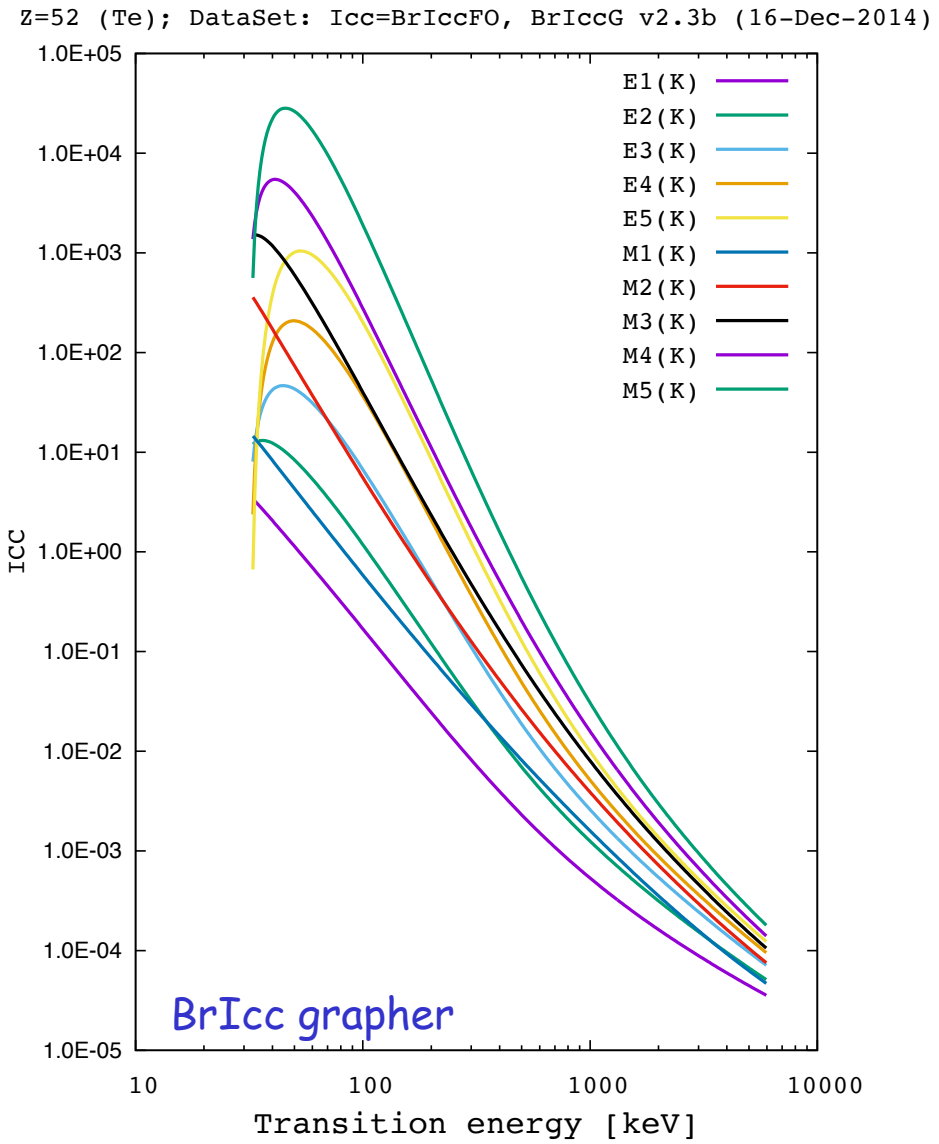
Mixing ratio (MR)

$$\delta(\pi' L'/\pi L) = \frac{\lambda_\gamma(\pi' L')}{\lambda_\gamma(\pi L)}$$

Mixing ratios can be determined from
- Gamma-ray angular distributions
- Gamma-gamma angular correlations
- Conversion coefficients

Conversion coefficient for CE and PF

$$\alpha(\pi' L'/\pi L) = \frac{\alpha(\pi L) + \delta^2 \alpha(\pi' L')}{1 + \delta^2}$$



BrIccMixing

Mixing ratio (MR)

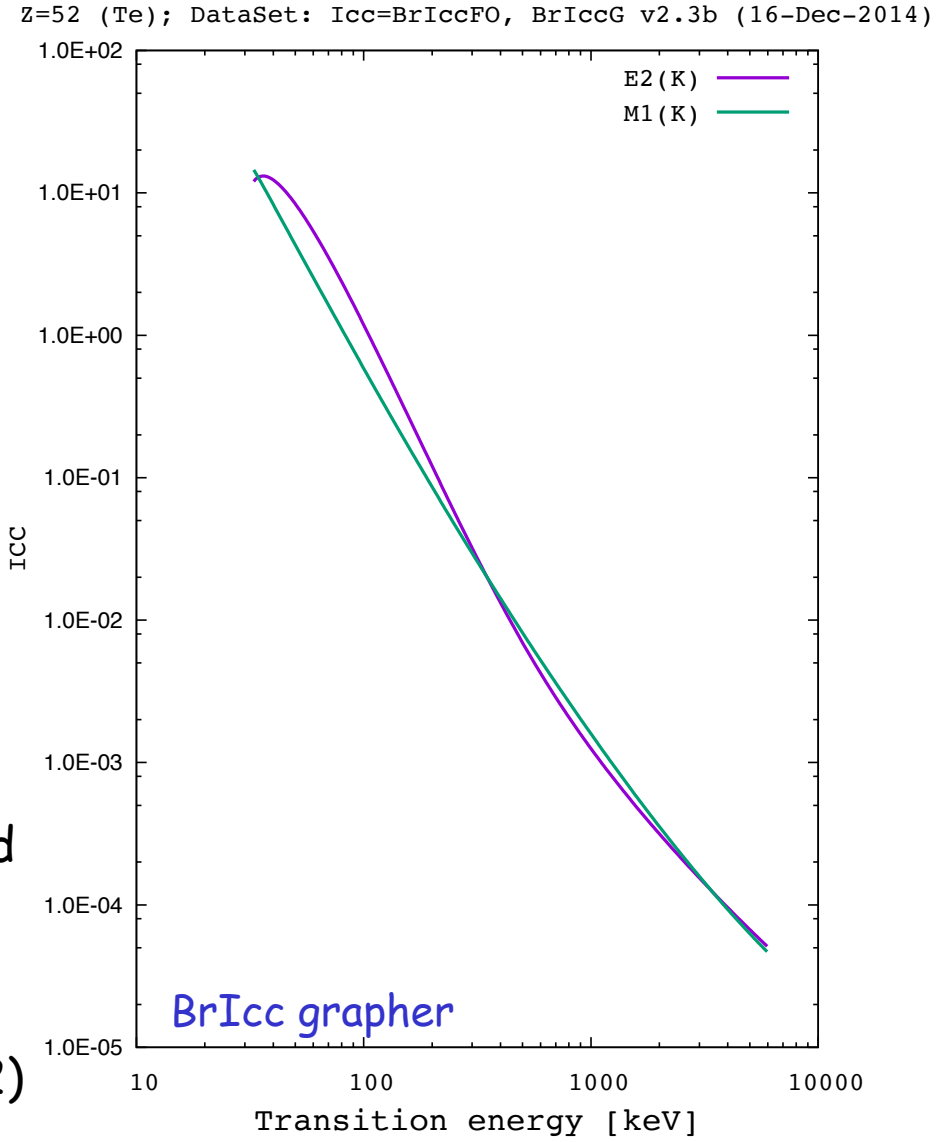
$$\delta(E2/M1) = \frac{\lambda_\gamma(E2)}{\lambda_\gamma(M1)}$$

Conversion coefficient for CE and PF

$$\alpha(exp) = \frac{\alpha(M1) + \delta^2\alpha(E2)}{1 + \delta^2}$$

a(exp) – experimental ICC, ratio of ICC`s or CE,π intensities
a(M1), a(E2) – theoretical M1, E2 ICC

- δ (MR): -∞ < δ < +∞
- α ~ δ²; sign of δ could not be determined from CE data!
- Sensitivity varies largely with energy, multipolarity and shell
- α(exp) must be between α(M1) and α(E2)



Running BrIccMixing

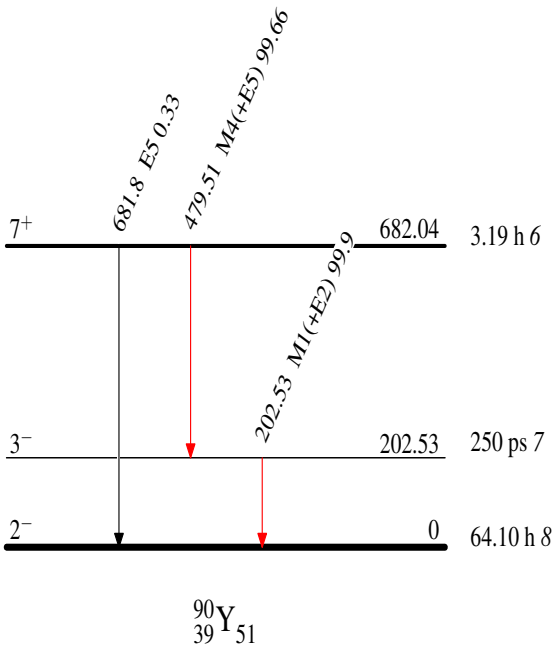
- BrIcc and Gnuplot need to be installed
- Prepare ASCII input file
- Shell: K,L1,L2,… for ICC values: L1/L2, K/L… ICC ratio; MR mixing rato
- Symmetric uncertainties only (no limits, no asymmetric UNC)
- Use "#" for comments

```
125TE  G 35.4925   5  6.68   13M1+E2     0.032   +3-2  13.68
125TE  35.4925   5
M1+E2 0.029  1.0
# NsrKey     Shell    IccVal     Unc    Type
1965Ge04     L1/L2    11.236     505    R
# 1965Ge04     L2/L3    3.708      351    R # more than 3 sigma away
1965Ge04     MR       0.035      20     A
# 1966Ma49     L1/L2    10.7               R no uncertainty given
# 1966Ma49     L2/L3    5                  R no uncertainty given
1969Ca01     L1/L2    9.39       180    R
1969Ca01     L2/L3    2.62       50     R
# 1969Ca01     K/L      12.3       25     R # nearly 2 sigma away + experimental value is highe
1982Ba16     L1/L2    10.482     224    R
1982Ba16     L2/L3    4.166      1928   R
# 1952Bo16     K/L      7.27       140    R
# 1952Bo16     L/M      5.5        15     R
1952Bo16     K        11.7       25     A
1952Bo16     L        1.6        5      A
1952Bo16     M        0.3        1      A
1969Ka08     K/L      7.27       140    R
```

Header

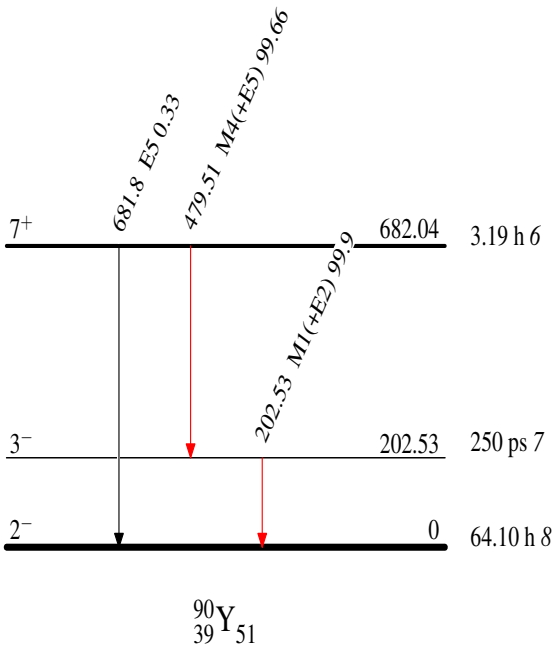
- <E> Error with explanation and line number will be given
- Data-Sets can be combined with the "*NEW" command

BrIcc / BrIccMixing - ^{90}Y IT



90Y	H	TYP=FMT$AUT=J. TULI$DAT=22-JUL-1999$COM=ADDED P RECORD$															
Y	H	TYP=FUL$AUT=E. BROWNE$CIT=NDS 82, 379 (1997)$CUT=1-May-1997$															
Y	P	682.04	6	7+				3.19 H	6								
90Y	c	From {+87}Rb(|a,n). Measured I|g. Ge(Li) detector (1978Ra05).															
90Y	c	From {+89}Y(n,|g), {+89}Y(d,p). Measured I|g, |g|g coin, |g|g(t),															
90Y	2c	|g|g(|q). Plastic scintillators, Ge(Li) and NaI detectors (1974Kl06).															
90Y	c	Measured E|g, I|g. Ge(Li) and Si detectors (1973Ha18).															
90Y	c	See also: 1989Mu15, 1990Mu11, 1990Ne08															
90Y	c	Others: 1961He09, 1961Ha17, 1970Si21															
90Y	cL	J,T		See adopted levels.													
90Y	cG	E		From 1973Ha18, except as noted.													
90Y	cG	E(A)		From 1974Kl06.													
90Y	N	0.9106	4					0.999979	2								
90Y	PN															3	
90Y	L	0		2-				64.10 H	8								
90Y	L	202.53	3	3-				250 PS	7								
90Y	2 L	G=-0.283 23															
90Y	cL	G		From IPAC (1974Kl06).													
90Y	cL	T		From 1974Kl06, delayed coin. Other: 1970Si21													
90Y	G	202.53	3	106.8	4	M1(+E2)		-0.04	4	0.0274	3						
90Y	S G	KC=0.02409 23$LC=0.00272 3															
90Y	cG	RI		Calculated by evaluators from intensity balance.													
90Y	cG	MR		From |a(K)exp=0.0243 {I14} and 479.5|g-202.5|g correlation													
90Y	2cG	with A{-2}=-0.178 {I5} and A{-4}=0.009 {I8} (1973Ha18).															
90Y	L	682.04	6	7+				3.19 H	6							M	
90Y	2 L	%IT=99.9982 2 $ %B-=0.0018 2															
90Y	cL	T		from adopted levels													
90Y	cL	%B-		See {+90}Y |b{+-} decay (3.19 h).													
90Y	G	479.51	5	99.65	3	M4(+E5)		0.1	LT	0.0983							
90Y	S G	KC= 0.0829 $LC=0.0116															
90Y	cG	RI		Photon branching ratio.													
90Y	cG	MR		From B(E5)(W.u.)<300.													
90Y	cG	CC		|a(exp)=0.101 {I4} from intensity balance, |a(202)=0.0274													
90Y	2cG	{I3}, and measured I|g(202|g)/I|g(479|g)=1.072 {I4} (1973Ha18).															
90Y	G	681.8	6	0.35	3	E5				0.023						A	
90Y	cG	E		From 1978Ra05.													
90Y	cG	RI		Photon branching ratio from I|g(682|g)/I|g(479|g)=0.0035 {I3}													
90Y	2cG	(1978Ra05). Other: 0.0040 {I8} (1974Kl06).															

BrIcc / BrIccMixing - ^{90}Y IT



Intensity balance at 202.53 keV level:

$$I_\gamma^{202}\times[1+\alpha_T^{202}] = I_\gamma^{479}\times[1+\alpha_T^{479}]$$

90Y		L	202.53	3	3-			250 PS	7						
90Y	2	L	G=-0.283 23												
90Y		cL	G		From IPAC (1974Kl06).										
90Y		cL	T		From 1974Kl06, delayed coin. Other: 1970Si21										
90Y		G	202.53	3	106.8	4	M1(+E2)	-0.04	4	0.0274	3				
90Y	S	G	KC=0.02409 23$LC=0.00272 3												
90Y		cG	RI		Calculated by evaluators from intensity balance.										
90Y		cG	MR		From |a(K)exp=0.0243 {I14} and 479.5|g-202.5|g correlation										
90Y	2	cG	with A{-2}=-0.178 {I5} and A{-4}=0.009 {I8} (1973Ha18).												
90Y		L	682.04	6	7+			3.19 H	6						M
90Y	2	L	%IT=99.9982 2 $ %B-=0.0018 2												
90Y		cL	T		from adopted levels										
90Y		cL	%B-		See {+90}Y |b{+-} decay (3.19 h).										
90Y		G	479.51	5	99.65	3	M4(+E5)	0.1	LT	0.0983					

With RI and CC from ENSDF

IN: 202.53(3) keV M1(+E2), MR=-0.04(4)

RI: 106.8+/-0.4

CC: 0.02740+/-0.00030

TI(202): 109.7+/-0.4

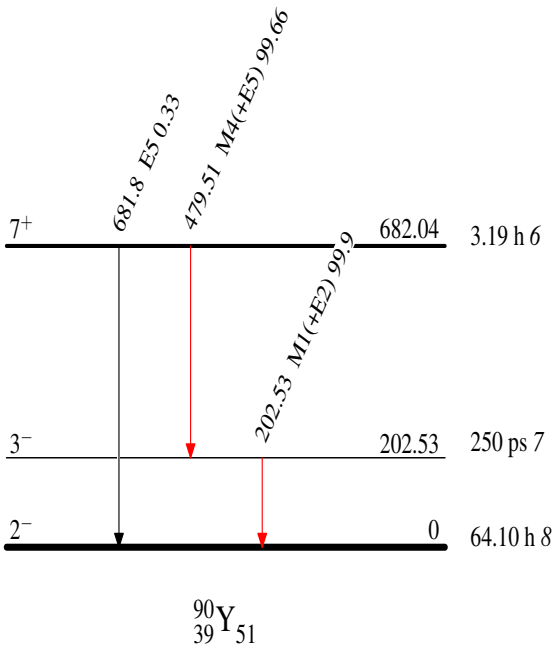
OUT: 479.51(5)(3) keV M4(+E5), MR=0.1 LT

RI: 99.650+/-0.030

CC: 0.0983 ← Recalculate with BrIcc!

TI(479): 109.446+/-0.033

BrIcc / BrIccMixing - ^{90}Y IT



Intensity balance at 202.53 keV level:

$$I_\gamma^{202} \times [1 + \alpha_T^{202}] = I_\gamma^{479} \times [1 + \alpha_T^{479}]$$

90Y		L	202.53	3	3-		250 PS	7					
90Y	2	L	G=-0.283 23										
90Y		cL	G		From IPAC (1974Kl06).								
90Y		cL	T		From 1974Kl06, delayed coin. Other: 1970Si21								
90Y		G	202.53	3	106.8	4	M1(+E2)	-0.04	4	0.0274	3		
90Y	S	G	KC=0.02409 23$LC=0.00272 3										
90Y		cG	RI		Calculated by evaluators from intensity balance.								
90Y		cG	MR		From |a(K)exp=0.0243 {I14} and 479.5|g-202.5|g correlation								
90Y	2	cG	with A{-2}=-0.178 {I5} and A{-4}=0.009 {I8} (1973Ha18).										
90Y		L	682.04	6	7+		3.19 H	6					M
90Y	2	L	%IT=99.9982 2 $ %B-=0.0018 2										
90Y		cL	T		from adopted levels								
90Y		cL	%B-		See {+90}Y |b{+-} decay (3.19 h).								
90Y		G	479.51	5	99.65	3	M4(+E5)	0.1	LT	0.0983			

With RI and CC from ENSDF

IN: 202.53(3) keV M1(+E2), MR=-0.04(4)

RI: 106.8+/-0.4

CC: 0.02740+/-0.00030

TI(202): 109.7+/-0.4

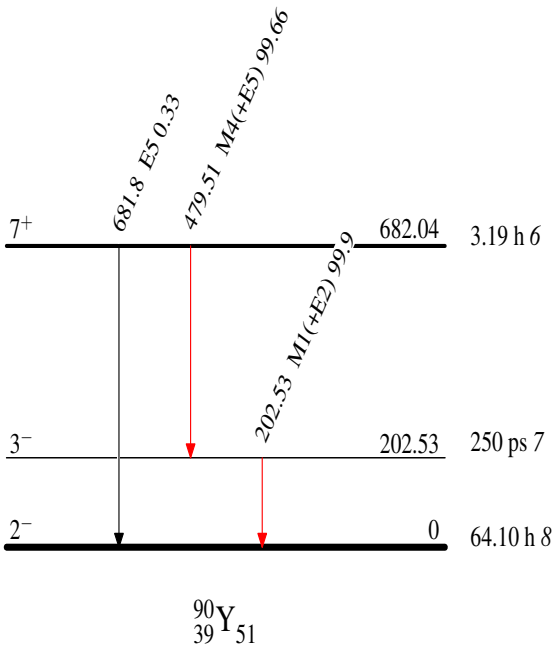
OUT: 479.51(5)(3) keV M4(+E5), MR=0.1 LT

RI: 99.650+/-0.030

CC: ~~0.0983~~ 0.0965(14) from BrIcc

TI(479): 109.26+/-0.14

BrIcc / BrIccMixing - ^{90}Y IT



Intensity balance at 202.53 keV level:

$$I_\gamma^{202}\times[1+\alpha_T^{202}] = I_\gamma^{479}\times[1+\alpha_T^{479}]$$

90Y		L	202.53	3	3-			250 PS	7						
90Y	2	L	G=-0.283 23												
90Y		cL	G		From IPAC (1974Kl06).										
90Y		cL	T		From 1974Kl06, delayed coin. Other: 1970Si21										
90Y		G	202.53	3	106.8	4	M1(+E2)	-0.04	4	0.0274	3				
90Y	S	G	KC=0.02409 23$LC=0.00272 3												
90Y		cG	RI		Calculated by evaluators from intensity balance.										
90Y		cG	MR		From |a(K)exp=0.0243 {I14} and 479.5|g-202.5|g correlation										
90Y	2	cG	with A{-2}=-0.178 {I5} and A{-4}=0.009 {I8} (1973Ha18).												
90Y		L	682.04	6	7+			3.19 H	6						M
90Y	2	L	%IT=99.9982 2 $ %B-=0.0018 2												
90Y		cL	T		from adopted levels										
90Y		cL	%B-		See {+90}Y |b{+-} decay (3.19 h).										
90Y		G	479.51	5	99.65	3	M4(+E5)	0.1	LT	0.0983					

With RI and CC from ENSDF

IN: 202.53(3) keV M1(+E2), MR=-0.04(4)

RI: 106.8+/-0.4

CC: 0.02740+/-0.00030

TI(202): 109.7+/-0.4

OUT: 479.51(5)(3) keV M4(+E5), MR=0.1 LT

RI: 99.650+/-0.030

CC: ~~0.0983~~ 0.0965(14) from BrIcc

TI(479): 109.26+/-0.14

CC(479) data

1961Ha17 0.10(2)

1961He09 0.11(2)

1973Ha18 0.1002(34)

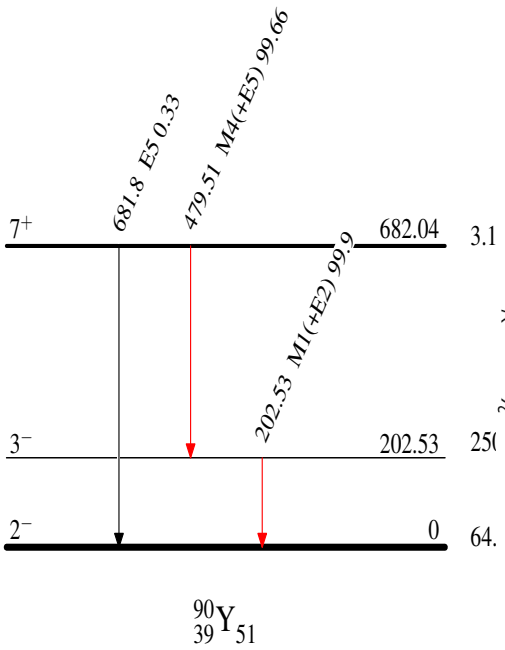
1990Mu11 0.0990(56)

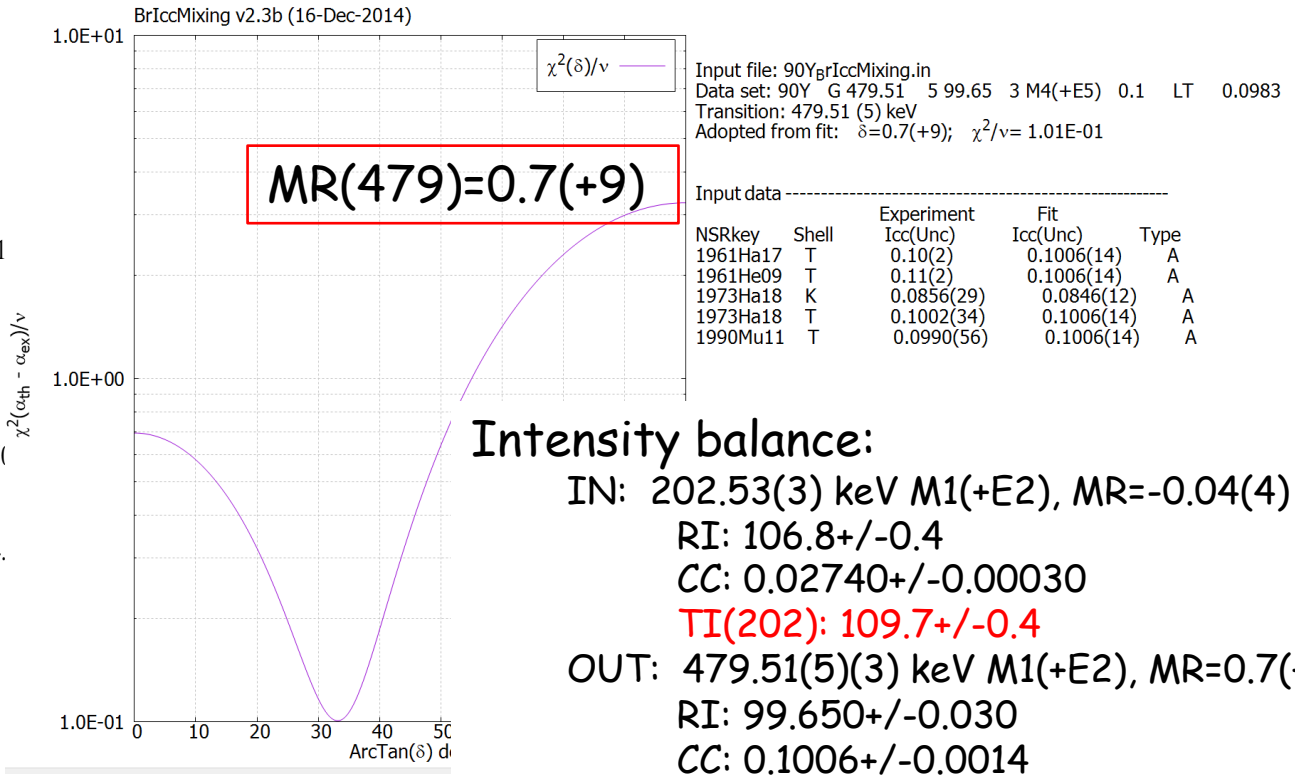
ADOPTED 0.0999(29)

KC(479) data

1973Ha18 0.0856(29)

BrIcc / BrIccMixing - ^{90}Y IT





Intensity balance:

IN: 202.53(3) keV M1(+E2), MR=-0.04(4)
RI: 106.8+/-0.4
CC: 0.02740+/-0.00030
TI(202): 109.7+/-0.4

OUT: 479.51(5)(3) keV M1(+E2), MR=0.7(+9)
RI: 99.650+/-0.030
CC: 0.1006+/-0.0014
TI(479): 109.67+/-0.14

ENSDF: MR==0.1 LT from
B(E5)(W.u.)<300.

1979En04: No definite RUL for E4

CC(479) data
1961Ha17 0.10(2)
1961He09 0.11(2)
1973Ha18 0.1002(34)
1990Mu11 0.0990(56)
ADOPTED 0.0999(29)

KC(479) data
1973Ha18 0.0856(29)

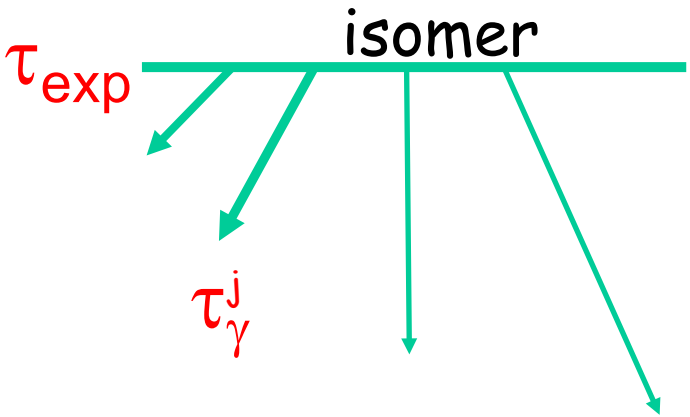
Ruler

Aim: calculate empirical photon transition rates and compare with recommended upper limits

Some useful formulas from Kondev et al., ADNDT 103-104 (2015) 50

$\Gamma \times \tau = \hbar = 0.6582 \times 10^{-15} eV\ s$

$T_{1/2} = \ln 2 \times \tau$



Partial γ-ray mean-life:

$$\tau_\gamma^j = \tau^{exp} \times \frac{\sum_{k=1}^{N} I_\gamma^k \times (1 + \alpha_T^k)}{I_\gamma^j}$$

Mixed transitions: $\delta^2(\sigma'\lambda'/\sigma\lambda) = I_\gamma(\sigma'\lambda')/I_\gamma(\sigma\lambda)$

$$\tau_\gamma(\sigma\lambda) = \tau_\gamma^j \times (1 + \delta^2) \qquad \Gamma_\gamma(\sigma\lambda) = \Gamma_\gamma^j \times \frac{1}{(1 + \delta^2)}$$

$$\tau_\gamma(\sigma'\lambda') = \tau_\gamma^j \times \frac{(1 + \delta^2)}{\delta^2} \qquad \Gamma_\gamma(\sigma'\lambda') = \Gamma_\gamma^j \times \frac{\delta^2}{(1 + \delta^2)}$$

Ruler

Reduced γ-ray transition probabilities

$$B_{sp}(\sigma\lambda)\downarrow[W.u.] = \frac{B_\gamma(\sigma\lambda)\downarrow}{B_{sp}(\sigma\lambda)\downarrow}$$

Electric

$$B_{sp}(E\lambda)\downarrow = \frac{1}{4\pi}\times\left(\frac{3}{3+\lambda}\right)^2\times\left(1.2\times A^{1/3}\right)^{2\lambda}$$

$[e^2\,fm^{2\lambda}]$

Magnetic

$$B_{sp}(M\lambda)\downarrow = \frac{10}{4\pi}\times\left(\frac{3}{3+\lambda}\right)^2\times\left(1.2\times A^{1/3}\right)^{2\lambda-2}$$

$[\mu^2_N\,fm^{2\lambda-2}]$

Recommended Upper Limits RUL

	Γ_γ/Γ_W (Upper Limit)		
Character*	A=6–44[a§]	A=45–150[b,c]	A>150[d]
E1 (IV)	0.3#	0.01	0.01
E2 (IS)[e]	100	300	1000
E3	100	100	100
E4	100	100†	
M1 (IV)	10	3	2
M2 (IV)	3	1	1
M3 (IV)	10	10	10
M4		30	10

* 'IV' and 'IS' stand for isovector and isoscalar
† Γ_γ/Γ_w(Upper Limit)=30 for A=90–150
# Γ_γ/Γ_w(Upper Limit)=0.1 for A=21–44
§ Γ_γ/Γ_w(Upper Limit)=0.003 for E1 (IS),
10 for E2 (IV), 0.03 for M1 (IS), 0.1 for M2 (IS)
[a] From 1979En05
[b] From 1979En04
[c] From 1981En06
[d] Deduced from **ENSDF** by M. J. Martin
[e] In super-deformed bands the E2 transitions can have Γ_γ/Γ_w>1000.

Ruler

Terminal dialogue

```
MacBook-Pro-2:ruler_example tibor$ ruler

 RULER Version 3.2d [20-Jan-2009]

     INPUT DATA FILE (DEF: ruler.inp):
     OUTPUT REPORT FILE (DEF: ruler.rpt):
     Mode of Operation
          (R-Compare to RULs,B-Calculate BELW,BMLW)? R
     Assumed DCC theory (Bricc-1.4%, Hsicc-3%, Other-?) -
 CURRENT DATA SET: 228TH     ADOPTED LEVELS, GAMMAS
 CURRENT DATA SET: 228TH     228AC B- DECAY
 CURRENT DATA SET: 228TH     228PA EC DECAY
 CURRENT DATA SET: 228TH     232U A DECAY
 CURRENT DATA SET: 228TH     226RA(A,2NG)
 CURRENT DATA SET: 228TH     230TH(P,T)
                       NO GAMMAS EXPECTED
 CURRENT DATA SET: 228TH     230TH(A,A'2NG)


 >>>>> *** possible problems encountered.
 >>>>> Problems summarized in:
 >>>>> Full details in: ruler.rpt


 Program completed successfully
```

Calculates reduced B(EL) and B(ML) and

R - Compare to RULs

B - Compare to RULs and creates new ENSDF file with B(EL) and B(ML) on new G records

Operating Mode

Ruler

Calculation report file

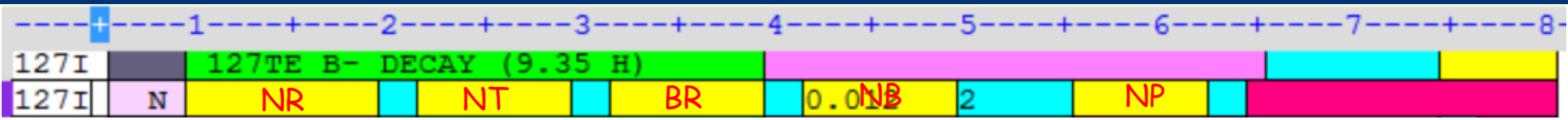
```
228TH  L    57.759 4    2+              0.405 NS 7                          A
228THX L XREF=ABCDEF
228TH cL J          E2 |g to 0+ g.s.
228TH cL T          from {+232}U |a decay
228TH  G    57.766 5  100          E2                    156                 L    DCC of 22 from theor
assumed
228TH cG M          also from {+232}U |a decay
228THB G BE2W=167 6
```

Experimental B(E2) → Output ENSDF file: ruler.out

```
EG=57.766 5                  BRANCHING RATIO (IN PERCENT)=100.0
 PARTIAL TRANSITION T1/2=4.05E-10 7 SEC
 TO OBTAIN PARTIAL GAMMA T1/2 MULTIPLY BY (1+CC)=157.0 22
         WEISSKOPF SINGLE-PARTICLE HALF-LIFES (SEC), INCLUDES UNCERTAINTY IN EG
         ORDER     ELECTRIC                  MAGNETIC
           1       9.403E-13       6         1.1429E-10      7
           2       1.063E-5        11        0.0012925       13
           3       183.2           24        2.228E4         3
           4       4.680E3         8         5.688E11        10
           5       1.673E17        4         2.033E19        4

        RECOMMENDED UPPER LIMITS COMPARISON
         ORDER       ELECTRIC                          MAGNETIC
                CALCULATED            RUL                  CALCULATED            RUL
           1  (IV)      1.48E-5  4     0.010          (IV)      0.00180  4      2.000
           2  (IS)          167  4  1000.000          (IV)       2.03E4  5      1.000 <===
           3           2.88E9  7   100.000 <===                3.50E11  8     10.000 <===
           4                                                   8.95E18 20     10.000 <===

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



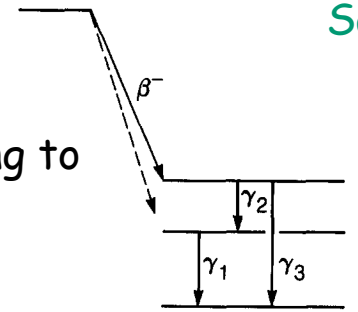
NR - multiplier to convert RI to # of photons/100 decays
NT - multiplier to convert TI to # of transitions/100 decays (if TI given)
BR - branching ratio multiplier for converting intensity/100 decays
NB - multiplier for converting relative b^- and EC intensities/100 decays
NP - multiplier for converting per hundred delayed-transition intensities to /100 decays of precursor

NR (γ-ray) Normalisation factor:

$$N_1 = \frac{100}{I_{\gamma 1}(1+\alpha_1) + I_{\gamma 3}(1+\alpha_3)}$$

Alternative normalisation factor, assuming no direct feeding to g.s. and 1st excited state:

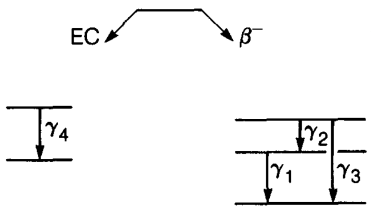
$$N_2 = \frac{100}{I_{\gamma 2}(1+\alpha_2) + I_{\gamma 3}(1+\alpha_3)}$$



Samples
127Te.in
176Lu.in

NR (γ-ray) and BR (decay branch) Normalisation factor:

$$B_{\beta^-} = \frac{I_{\gamma 1}(1+\alpha_1) + I_{\gamma 3}(1+\alpha_3)}{I_{\gamma 1}(1+\alpha_1) + I_{\gamma 3}(1+\alpha_3) + I_{\gamma 4}(1+\alpha_4)}$$



Sample
80Br.in

1986Br21 E. Browne, Nucl. Instr. Meth. **A249** (1986) 462

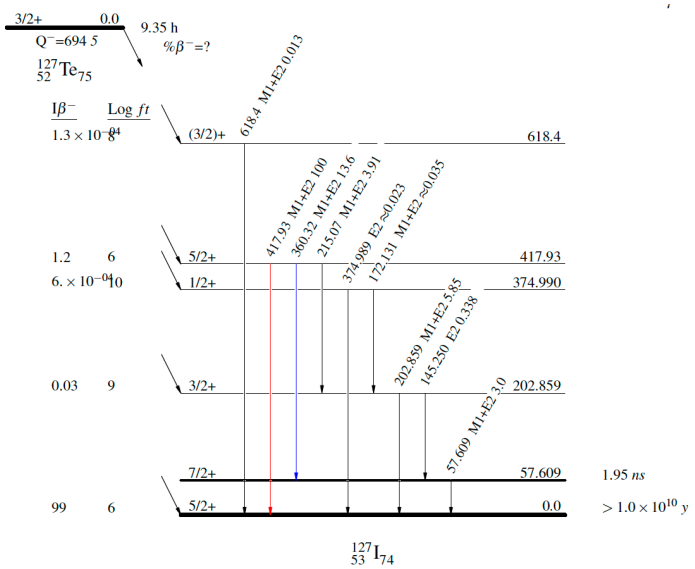
Prepare input ENSDF file by marking column 79 of transitions to the g.s.

X. If DRI blank, DRI=20% assumed

Y. Original DRI, including blank value is used

```
Record name = "NORMALIZATION"
NUCIDCARDNR          DNNT       DNBR       DBNB       DNB    NP       DNBLANK
Format=v.1, Color_Index=9, Align=no, Convert=upper, Id=NUCID
```

```
----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8-
127I      127TE B- DECAY (9.35 H)
127I  N                                0.012     2
127TE P   0.0      3/2+                9.35 H    7                694
127I  L   0.0      5/2+                1.0E+10 YGT
127I  B                99                     6
127I  L   57.609   117/2+               1.95 NS   1
127I  G   57.609   11       3.0  3M1+E2 0.084     6    3.72
127I  L   202.859  83/2+
127I  G   145.250  9        0.338 16E2                 0.471
127I  G   202.859  8        5.85 21M1+E2 0.52        5 0.1143 22
127I  B                0.03                   9
127I  L   374.990  91/2+
127I  G   172.131  8        0.035 APM1+E2 0.084      7 0.1649 24
127I  G   374.989  9        0.023 APE2                 0.0199
127I  B                6.E-04                 10
127I  L   417.93   65/2+
127I  G   215.07   6        3.91 17M1+E2 0.203       15 0.0911
127I  G   360.32   6        13.6  3M1+E2 0.194       15 0.0233
127I  G   417.93   6        100  10M1+E2 0.08        3  0.01599
127I  B                1.2                    6
127I  L   618.4    3(3/2)+
127I  G   618.4    3        0.013  2M1+E2
127I  B                1.3E-04                8
```



GABS

```
NUCIDCARDNR          DNNT       DNBR       DBNB       DNB    NP       DNBLANK
Format=v.1, Color_Index=9, Align=no, Convert=upper, Id=NUCID

----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8-
127I                 127TE B- DECAY (9.35 H)
127I      N                                  0.012     2
```

NR - multiplier to convert RI to # of photons/100 decays
NT - multiplier to convert TI to # of transitions/100 decays (if TI given)
BR - branching ratio multiplier for converting intensity/100 decays
NB - multiplier for converting relative β^- and EC intensities/100 decays
NP - multiplier for converting per hundred delayed-transition intensities to /100 decays of precursor

New ENSDF file

```
127I                 127TE B- DECAY (9.35 H)
127I      N          0.0098    19                1.00
```

NR

BR

$I_\gamma(abs)=NR * RI$

```
GABS Version 11 [15-Dec-2014] Report file  * * *
Current date: 12/15/2014
ENSDF input file: 127te.in
new ENSDF file:   127te.new

Data Set:  127TE B- DECAY (9.35 H)
NR=    0.0098  19     BR=    1.00

E= 57.609    11 %IG=0.029  6 per 100 dis. Compare with 0.029  7
E= 145.250   9  %IG=0.0033  7 per 100 dis.
E= 202.859   8  %IG=0.057 11 per 100 dis. Compare with 0.057 11
E= 172.131   8  %IG=0.00034 19 per 100 dis.
```

GABS

$\gamma(^{127}I)$

E_γ	I_γ[†]	E_i(level)	$J_i\pi$	E_f	$J_f\pi$	Mult.	δ	α	Comments
57.609 *11*	3.0 *3*	57.609	7/2+	0.0	5/2+	M1+E2	0.084 *6*	3.72	%Iγ=0.029 *6*, using the calculated normalization.
145.250 *9*	0.338 *16*	202.859	3/2+	57.609	7/2+	E2		0.471	%Iγ=0.0033 *7*, using the calculated normalization.
172.131 *8*	≈0.035	374.990	1/2+	202.859	3/2+	M1+E2	0.084 *7*	0.1649 *24*	%Iγ=0.00034 *19*, using the calculated normalization.
202.859 *8*	5.85 *21*	202.859	3/2+	0.0	5/2+	M1+E2	0.52 *5*	0.1143 *22*	%Iγ=0.057 *11*, using the calculated normalization.
215.07 *6*	3.91 *17*	417.93	5/2+	202.859	3/2+	M1+E2	0.203 *15*	0.0911	%Iγ=0.038 *8*, using the calculated normalization.
360.32 *6*	13.6 *3*	417.93	5/2+	57.609	7/2+	M1+E2	0.194 *15*	0.0233	%Iγ=0.13 *3*, using the calculated normalization.
374.989 *9*	≈0.023	374.990	1/2+	0.0	5/2+	E2		0.0199	%Iγ=0.00023 *12*, using the calculated normalization.
417.93 *6*	100 *10*	417.93	5/2+	0.0	5/2+	M1+E2	0.08 *3*	0.01599	%Iγ=0.98 *19*, using the calculated normalization.
618.4 *3*	0.013 *2*	618.4	(3/2)+	0.0	5/2+	M1+E2		0.0055 *7*	%Iγ=0.00013 *3*, using the calculated normalization.

I_γ(abs)=NR * RI

[†] For absolute intensity per 100 decays, multiply by 0.0098 *19*.