PROGRAM GABSPC
(Version 9, May 2000)

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Adapted for IBM PC by

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I. Introduction

GABSPC calculates absolute γ-ray intensities and a decay-scheme-normalizing factor (NR) for converting relative intensities to absolute values per 100 decays of the parent nucleus. The program calculates the decay mode branching ratios (BR) for radionuclides that decay through several decay modes. It also calculates the uncertainties in all these quantities.

The nature of the physical problem and the mathematical formulas used here are described elsewhere.[1]

II. Technical Specifications

GABSPC consists of a main program (GABSPC), a subroutine GAMMAS, a few functions, and NSDFLIB, a package of character-string functions and subroutines maintained by the Brookhaven National Laboratory. The program, written in FORTRAN 77 for a VAX-11/8600 computer with the VMS operating system, was later adapted for IBM PC.

GABSPC prompts the user for a file name of an input data set, and writes the results of the calculation on a report file (default name: GABSPC.RPT). The program can also create output data sets (ENSDF format), which include the results of the calculation, and writes them to a file. The user may specify the name of each of these files.

III. Input Data

GABSPC reads up to three data sets (ENSDF format). A blank record should follow each data set, including the last one. The user must supply the following additional information:

1. N-RECORD. The fraction (G) of the decay intensity carried by the γ rays, in columns 42-49, and its corresponding uncertainty (DG), in columns 50-51, are used for normalizing the decay scheme. Both quantities should be given in ENSDF style; for example, 0.934 21 implies 0.934 ± 0.021. Default values assigned by the program are G=1.0 and DG=0.0. Input values for the branching ratio (BR), in columns 32-39, and its uncertainty (DBR), in columns 40-41, are used for single-data set calculations. Default values assigned by the program are BR=1.0 and DBR=0.0. Alphanumeric data are not acceptable in the uncertainty fields DG or DBR. A character "C" in column 80 tells the program that the γ rays belong to a cascade and that they carry the

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[1] E. Browne, *Calculated Uncertainties of Absolute γ-ray Intensities and Decay Branching Ratios Derived from Decay Schemes*, published in *Nucl. Instr. Meth.* **A249**, 462 (1986).

full transition intensity (i.e., there are no direct β^- or ε feedings to intermediate levels). For multiple-data set calculations (for which the program calculates the branching BR), the BR fields *must* be blank in all data sets.

2. G-RECORD. All γ-ray records of transitions used for calculating the normalizing factors must be identified with an "X" or a "Y" in column 79, as described below. The following character strings are acceptable in the uncertainty fields (DRI):

   A. CA (calculated) - translated to represent 50% uncertainty. Carefully estimated input uncertainties are of course far preferable to arbitrarily assigned 50% values.

   B. AP (approximate) - translated to represent 50% uncertainty.

   C. LT - (less than) - translated to RI/2 ± RI/2.

   The program assigns 20% uncertainty to relative γ-ray intensities (unless a "Y" instead of an "X" is used in column 79) if DRI values are missing from the input data. Transitions for which these guidelines are not appropriate, most often the "nominal" γ ray with RI set to 100 (without uncertainty), are those which one would designate "Y". Additionally, GABSPC assigns 3% uncertainty to conversion coefficients (CC) of pure-multipolarity γ rays. It also adds in quadrature 3% uncertainty to those of mixed-multipolarity γ rays, since the reported uncertainties in their CC values typically reflect uncertainties in the values of the mixing ratios alone. Since GABSPC does not use the total-intensity field (TI) in columns 65-74 in the calculation, one could make use of reported total transition intensities (photons + conversion electrons) by moving them to the relative-photon field (RI) in columns 22-29. Their uncertainties should be correspondingly moved and the conversion coefficients (CC) set to 0 (columns 56-62 blank). The output file should be edited at the end to restore the records to their original form.

   Since the program ignores all comment (CG) and continuation (2 G, 3 G) records, users should not include any input data needed by GABS in this type of record.

IV. Calculations

1. Single Data Set

GABSPC calculates the normalizing factor NR and its uncertainty DNR, as well as the uncertainties in the absolute γ ray intensities. The following example shows a calculation for a single data set.

```
                                INPUT ENSDF DATA SET
127I      127TE B- DECAY (9.35 H)
127I   N                                0.012   2
127TE  P        0.0  3/2+                9.35 H 7                    694 5
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       3.77                X
127I   L    202.859 83/2+
127I   G    145.250 9  0.338 16E2                       0.474
127I   G    202.859 8   5.85 21M1+E2         0.52 5      0.115               X
127I   B                0.03                   9
127I   L    374.990 91/2+
127I   G    172.131 8  0.035 APM1+E2        0.084 7      0.166
127I   G    374.989 9  0.023 APE2                       0.0200              X
127I   B              6.E-04                 10
127I   L     417.93 65/2+
127I   G     215.07 6   3.91 17M1+E2       0.203 15    0.0918
127I   G     360.32 6    13.6 3M1+E2       0.194 15     0.0234
127I   G     417.93 6    100 10M1+E2         0.08 3     0.0162              X
127I   B                1.2                    6
127I   L      618.4 3(3/2)+
127I   G      618.4 3   0.013 2M1+E2                    0.0055 7            X
127I   B             1.3E-04                   8
<---------------------------BLANK RECORD--------------------------------------->
                                OUTPUT ENSDF DATA SET
127I      127TE B- DECAY (9.35 H)
127I   N   0.0098  19              1.00
127TE  P        0.0  3/2+                9.35 H 7                    694 5
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       3.77
127I  CG           %IG=0.029  6, using the calculated normalization.
127I   L    202.859 83/2+
127I   G    145.250 9  0.338 16E2                       0.474
127I   G    202.859 8   5.85 21M1+E2         0.52 5      0.115
127I  CG           %IG=0.057 11, using the calculated normalization.
127I   B                0.03                   9
127I   L    374.990 91/2+
127I   G    172.131 8  0.035 APM1+E2        0.084 7      0.166
127I   G    374.989 9  0.023 APE2                       0.0200
127I  CG           %IG=0.00023 12, using the calculated normalization.
127I   B              6.E-04                 10
127I   L     417.93 65/2+
127I   G     215.07 6   3.91 17M1+E2       0.203 15    0.0918
127I   G     360.32 6    13.6 3M1+E2       0.194 15     0.0234
127I   G     417.93 6    100 10M1+E2         0.08 3     0.0162
127I  CG           %IG=0.98 19, using the calculated normalization.
127I   B                1.2                    6
127I   L      618.4 3(3/2)+
127I   G      618.4 3   0.013 2M1+E2                    0.0055 7
127I  CG           %IG=0.00013  3, using the calculated normalization.
127I   B             1.3E-04                   8
<---------------------------BLANK RECORD--------------------------------------->
```

2. Single Data Set with Cascade γ rays

GABSPC calculates the normalizing factor (NR) and its uncertainty (DNR), as well as the uncertainties in the absolute γ-ray intensities. The program normalizes the sum of the transition intensities of K cascade γ rays to "100 × K × BR × G". There are three (K=3) cascade γ rays in the example shown below, therefore GABSPC normalizes to 300 the sum of the transition intensities.

```
                                INPUT ENSDF DATA SET
176HF    176LU B- DECAY
176LU  P 0.0                 7-        4.00E10 Y 22             1192.8    9
176HF  N                       1.0       1.0                                  C
176HF PN                                                                    3
176HF  L        0.0  0+
176HF  L     88.36  4 2+
176HF  G      88.36 4    14.114 E2                      5.86                 X
176HF  L    290.19  6 4+
176HF  G     201.83 4    90.850 E2                      0.282                X
176HF  L    597.03  7 6+
176HF  G     306.84 4     100   E2                      0.0746               Y
176HF  L    998.13 22 8+
176HF  G      401.1 2    0.35 2 E2                      0.0347
<----------------------------BLANK RECORD--------------------------------------->
                                OUTPUT ENSDF DATA SET
176HF    176LU B- DECAY
176LU  P 0.0                 7-        4.00E10 Y 22             1192.8    9
176HF  N     0.94   4              1.00
176HF PN                                                                    3
176HF  L        0.0  0+
176HF  L     88.36  4 2+
176HF  G      88.36 4    14.114 E2                      5.86
176HF CG           %IG=13.2 10, using the calculated normalization.
176HF  L    290.19  6 4+
176HF  G     201.83 4    90.850 E2                      0.282
176HF CG           %IG=85  4, using the calculated normalization.
176HF  L    597.03  7 6+
176HF  G     306.84 4     100   E2                      0.0746
176HF CG           %IG=94  4, using the calculated normalization.
176HF  L    998.13 22 8+
176HF  G      401.1 2    0.35 2 E2                      0.0347
<----------------------------BLANK RECORD--------------------------------------->
```

3. Multiple Data Sets

GABSPC calculates for each data set the branching ratio BR and its uncertainty DBR, the γ– ray normalizing factor NR, and the uncertainties in the absolute γ-ray intensities. Notice that NR and BR *are not* independent quantities for a decay scheme with two or more decay modes. Therefore, the relevant uncertainty for the branching ratio is that of BR, and for the absolute γ-ray intensities, that of BR x NR. The following example illustrates a calculation for two data sets.

```
                              INPUT ENSDF DATA SETS
80SE     80BR EC DECAY (17.68 M)
80SE  N                                 0.145  12
80BR  P        0.0  1+                  17.68 M 2               1870.3 20
80SE  L        0.0  0+
80SE  E                2.17 22     4.9 5     4.7 1                     7
80SE  L    665.94 152+
80SE  G    665.94 15   16.1 14E2                      0.00121               X
80SE  E                            1.1        4.9 1                  1.1
80SE  L     1448.9 32+                                                     ?
80SE  G      783.0 3     0.1APE2+M1                                        ?
80SE  G     1448.9 3   0.24 LTE2                                          X
80SE  E                            0.02LE       6GT                   0.02LE
80SE  L     1477.4 50+
80SE  G      811.4 5     0.6 2(E2)
80SE  E                            0.05 2     5.3 3                    0.05 2
<----------------------------BLANK RECORD------------------------------------>
80KR     80BR B- DECAY (17.68 M)
80KR  N                                0.073   8
80BR  P        0.0  1+                  17.68 M 2                  2006 11
80KR  G     677.6 10    0.12 4                                             ?
80KR  G     688.0 10    0.18 5                                             ?
80KR  G     1339.1 8
80KR  L        0.0  0+
80KR  B      1997 10    85.0 7                6
80KR  L      616.9 32+
80KR  G      616.9 3    100 10E2                      0.00175               X
80KR  B      1380 20     6.2 6              6.0 1
80KR  L     1256.8 32+
80KR  G    639.93 18     3.8 3E2+M1           6 1    0.00157
80KR  G     1256.8 3   1.18 10                                            X
80KR  B                0.31 3              6.3 1
80KR  L     1321.2 30(+)
80KR  G    704.37 19     2.9 4(E2)                     0.00121
80KR  B                0.19 2              6.4 1
<----------------------------BLANK RECORD------------------------------------>
```

OUTPUT ENSDF DATA SETS

```
 80SE     80BR EC DECAY (17.68 M)
 80SE  N     0.89                 0.07514
 80BR  P        0.0  1+                   17.68 M 2               1870.3 20
 80SE  L        0.0  0+
 80SE  E               2.17 22     4.9 5     4.7 1                     7
 80SE  L    665.94 152+
 80SE  G    665.94 15   16.1 14E2                     0.00121
 80SE CG           %IG=1.07 19, using the calculated normalization.
 80SE  E                          1.1        4.9 1                   1.1
 80SE  L     1448.9 32+                                                    ?
 80SE  G      783.0 3     0.1APE2+M1                                       ?
 80SE  G     1448.9 3   0.24 LTE2
 80SE CG           %IG=0.008  8, using the calculated normalization.
 80SE  E                          0.02LE       6GT                  0.02LE
 80SE  L     1477.4 50+
 80SE  G      811.4 5     0.6 2(E2)
 80SE  E                          0.05 2     5.3 3                   0.05 2
<----------------------------BLANK RECORD------------------------------------>
 80KR     80BR B- DECAY (17.68 M)
 80KR  N    0.072                0.92514
 80BR  P        0.0  1+                   17.68 M 2                 2006 11
 80KR  G     677.6 10    0.12 4                                            ?
 80KR  G     688.0 10    0.18 5                                            ?
 80KR  G     1339.1 8
 80KR  L        0.0  0+
 80KR  B      1997 10    85.0 7                6
 80KR  L      616.9 32+
 80KR  G      616.9 3    100 10E2                     0.00175
 80KR CG           %IG=6.7 11, using the calculated normalization.
 80KR  B      1380 20     6.2 6               6.0 1
 80KR  L     1256.8 32+
 80KR  G    639.93 18     3.8 3E2+M1            6 1    0.00157
 80KR  G     1256.8 3   1.18 10
 80KR CG           %IG=0.079 14, using the calculated normalization.
 80KR  B                0.31 3               6.3 1
 80KR  L     1321.2 30(+)
 80KR  G    704.37 19     2.9 4(E2)                    0.00121
 80KR  B                0.19 2               6.4 1
<----------------------------BLANK RECORD------------------------------------>
```

4. Report File (Default: GABSPC.RPT)

The report files for the examples presented above are given below. The *absolute* γ-ray intensities and uncertainties given in parentheses are the values calculated assuming the *relative* γ-ray intensities and NR to be independent quantities. For weak γ rays these uncertainties are very close to those calculated without this assumption. Therefore, for these γ rays the user may remove from the output ENSDF data set their corresponding %IG comment records.

```
                          REPORT FILE
Current date: 05/16/2000
   127TE B- DECAY (9.35 H)
NR=    0.0098  19     BR=     1.00

FOR INTENSITY UNCERTAINTIES OF GAMMA RAYS NOT USED IN CALCULATING NR,
COMBINE THE UNCERTAINTY IN THE RELATIVE INTENSITY IN QUADRATURE
WITH THE UNCERTAINTY IN THE NORMALIZING FACTOR (NR x BR).
FOR THE FOLLOWING GAMMA RAYS:

E=    57.609 11 %IG=0.029  6 PER 100 DIS.(Compare with 0.029  7)
E=    202.859 8 %IG=0.057 11 PER 100 DIS.(Compare with 0.057 11)
E=    374.989 9 %IG=0.00023 12 PER 100 DIS.(Compare with 0.00023 12)
E=     417.93 6 %IG=0.98 19 PER 100 DIS.(Compare with 0.98 21)
E=      618.4 3 %IG=0.00013  3 PER 100 DIS.(Compare with 0.00013  3)

                          REPORT FILE
Current date: 05/16/2000
  80BR EC DECAY (17.68 M)
NR=      0.89         BR=    0.075  14

FOR INTENSITY UNCERTAINTIES OF GAMMA RAYS NOT USED IN CALCULATING NR,
COMBINE THE UNCERTAINTY IN THE RELATIVE INTENSITY IN QUADRATURE
WITH THE UNCERTAINTY IN THE NORMALIZING FACTOR (NR x BR).
FOR THE FOLLOWING GAMMA RAYS:

E=    665.94 15 %IG=1.07 19 PER 100 DIS.(Compare with 1.1  3)
E=     1448.9 3 %IG=0.008  8 PER 100 DIS.(Compare with 0.008  9)

  80BR B- DECAY (17.68 M)
NR=     0.072         BR=    0.925  14

FOR INTENSITY UNCERTAINTIES OF GAMMA RAYS NOT USED IN CALCULATING NR,
COMBINE THE UNCERTAINTY IN THE RELATIVE INTENSITY IN QUADRATURE
WITH THE UNCERTAINTY IN THE NORMALIZING FACTOR (NR x BR).
FOR THE FOLLOWING GAMMA RAYS:

E=      616.9 3 %IG=6.7 11 PER 100 DIS.(Compare with 6.7 13)
E=     1256.8 3 %IG=0.079 14 PER 100 DIS.(Compare with 0.079 14)

               REPORT FILE - CASCADE GAMMA RAYS
Current date: 05/16/2000
 176LU B- DECAY
NR=      0.94   4     BR=     1.00

FOR INTENSITY UNCERTAINTIES OF GAMMA RAYS NOT USED IN CALCULATING NR,
COMBINE THE UNCERTAINTY IN THE RELATIVE INTENSITY IN QUADRATURE
WITH THE UNCERTAINTY IN THE NORMALIZING FACTOR (NR x BR).
FOR THE FOLLOWING GAMMA RAYS:

E=      88.36 4 %IG=13.2 10 PER 100 DIS.(Compare with 13.2 14)
E=     201.83 4 %IG=85  4 PER 100 DIS.(Compare with 85  6)
E=     306.84 4 %IG=94  4 PER 100 DIS.(Compare with 94  4)
```