Project Report

Evaluation of Nuclear Structure Data for Mass Chain A=225

Submitted by

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Acknowledgement

I owe my deep gratitude to my guide Prof. A. K. Jain, for his valuable guidance, active interest and constant encouragement for this work. During this project he arranged several seminars of the people working in the corresponding field all over the world in the Department of Physics, IIT Roorkee to familiarize us with the recent works going on.

I am also thankful to National Nuclear Data Center at Brookhaven National Laboratory, New York for giving me a chance to work in the frontier field of nuclear physics.

I am thankful to my colleague Mr. Dipayan Sen for his active support and cooperation.

I am grateful to all of teachers of Department of Physics, IIT Roorkee for their valuable suggestions during my presentations on the topic.

I am also grateful to Research Scholars of the department specially Sukhjeet Singh and all of our friends.

Last but not the least I am indebted to the internet for my most of the materials and for the latest information.

I hereby certify that this report has been submitted for the partial fulfillment of the degree of Master of Science of Indian Institute of Technology Roorkee, and no part of it has been published or sent for publication anywhere else.

Needless to say, I take sole responsibility for any mistakes here.

Nuruzzaman.
(Nuruzzaman)

Certificate

This is to certify that the dissertation entitled **"Evaluation of Nuclear Structure Data for Mass Chain A=225"**, submitted for the partial fulfillment of the degree of Master of Science with advanced courses in Nuclear Physics of Indian Institute of Technology Roorkee, is the work of Nuruzzaman under the guidance of Prof. Ashok Kumar Jain of Department of Physics, IIT Roorkee.

(Prof. A. K. Jain) 27-4-2007

Abstract

In the present project, I trace the history and origin of the nuclear data evaluation work, the process of data evaluation, the technical details of writing ENSDF records, usage of analysis and utility codes, significance of the different physical quantities involved, and a qualitative description of evaluation of nuclear structure data for mass chain **A=225**. I have tried to present here different features of the nuclear data evaluation in a very simple manner especially for the students and the beginners who want to work in this field.

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Part-I

Introduction:

The first American Nobel Laureate, Albert A. Michelson, in an 1894 speech at University of Chicago lamented that

"The most important fundamental laws and facts of physical science have all been discovered. These are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote. Our future discoveries must be looked for in the sixth place of decimals."

Within three years of this speech, x-rays, the electron, and the radioactivity were discovered!!

And that was the beginning!

In 1941 an Editor of Table of Isotopes observed:

"The rate at which radioactivities are discovered may be reduced very considerably and the table would itself become stable."

That clearly did not happen!

Within a few years the rapidly expanding field of Nuclear Physics demanded a systematic tabulation of reliable experimental data for convenient usage. Recognizing the situation a group of farsighted scientists which included M. Curie, H. Geiger, O. Hahn, E. Rutherford, J. Chadwick, K.W.F. Kohlrausch pioneered the work of Nuclear Data Evaluation.

So we are just standing on the shoulders of giants!

Nuclear data and its sources:

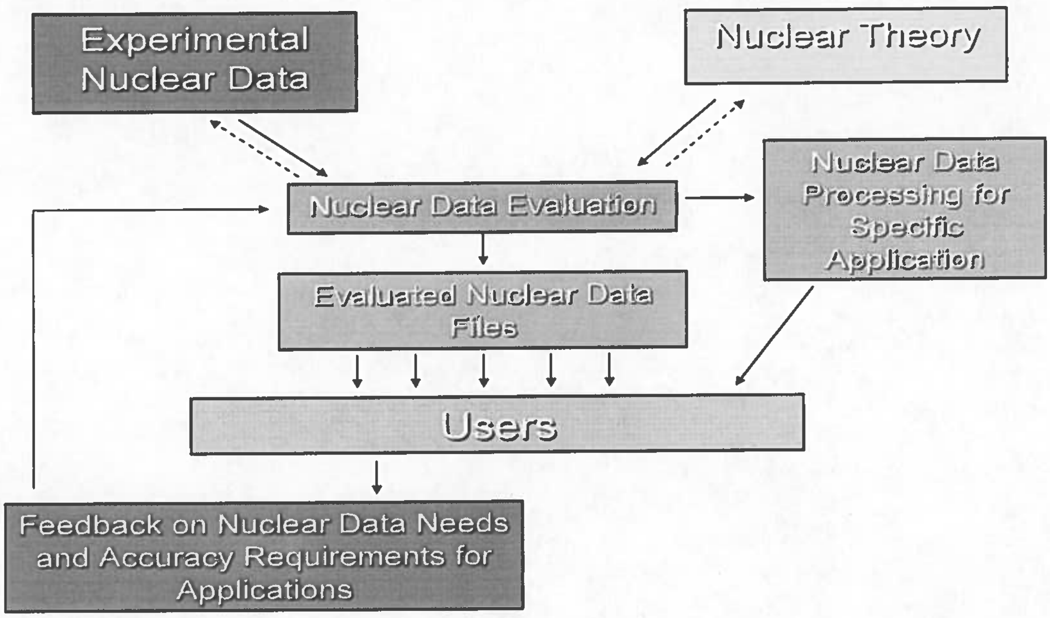
We are concerned about the nuclear data....now what exactly is it? Let us see....

Nuclear Data includes:

- Nuclear level Properties
- Nuclear Radiation types and their Properties
- Nuclear Decay Types and their Probabilities

And they come from various sources, like

- ✓ Experimental measurements
- ✓ Nuclear physics model calculations
- ✓ Data Evaluations



The process of nuclear and atomic data generation is cyclic in nature and includes feedback from users on the basis of which the necessary corrections, improvements and additions to the data files are made. A schematic diagram showing the process of generation of Nuclear Data Files is shown in the above figure. The feedback information from users on the nuclear data needs worldwide is compiled and published as the World Request List for Nuclear Data Measurements (WRENDA) by the IAEA (International Atomic Energy Agency). The last edition of this document, WRENDA 93/94, contains 720 of such requests, including 468 requests, which were newly added. In many Member States WRENDA serves as a basis for justification of funding for further nuclear data research.

Compilation and Evaluation of Nuclear Data:

"To compile" means "To collect" or "To put together in a new form out of material already existing" (Webster's Dictionary definition) or "To put in compact form so that it should serve as a convenient source of detailed information" (Scientific definition) "Evaluate" means, "make judgment or assessment" or "to appraise; to determine value" (Webster's Dictionary definition)

"GOOD COMPILATION ALWAYS INVOLVES EVALUATION"

Why data evaluation work started?

The process of measuring atomic and nuclear data requires the use of modern research reactors, neutron generators, charged particle accelerators, spectrometers and other unique scientific devices. Such measurements are very costly. Billions of dollars have been spent on the construction and operation of these devices and on data measurements in the Member States. But still not all the required data can be measured. For example theoretical calculations and evaluations must obtain data for short-lived isotopes. Nuclear model calculations and evaluations make use of considerable computer resources and the theoretical results obtained require experimental testing and verification. Nuclear data are generated in many Member States in a wide variety of research institutions. No single Member State whether developing or developed has enough resources to perform the immense task of providing nuclear and atomic data for applications alone. Recognizing this situation the IAEA initiated a continuing program to collect, analyze, recommend and disseminate such data particularly to developing countries and established the Nuclear Data Section in 1964.

History of data evaluation work:

The history of nuclear data evaluation work dates back to as early as 1930s. In a report of the International Radium-Standards Commission titled "The Radioactive Constants as of 1930" by a group of renowned scientists including M. Curie, H. Geiger, O. Hahn, E. Rutherford, J. Chadwick, K.W.F. Kohlrausch, published a set of evaluated nuclear structure data in the Reviews of Modern Physics.

Katherine Way first started systematic nuclear data collection at Clinton Lab (later renamed ORNL (Oak Ridge National Laboratory)). In 1948, Way headed the Nuclear Data Project at US National Bureau of Standards (later renamed US National Institute of Standards and Technology (NIST))

First "Nuclear Data" report was published in 1950. In 1953 nuclear data were published in the form of loose-leaf pages called Nuclear Data Sheets. Decentralization of Data Evaluation activity at international level was undertaken by IAEA in 1975. Evaluation responsibility was divided amongst various data centers within and outside the US. The NNDC (National Nuclear Data Centre) at BNL (Brookhaven National Laboratory) coordinated the national and the international effort for the USDOE (United States Department of Energy). But the lead role in editing and processing of evaluation continued at the ORNL. However, NNDC has now become the nodal center for all data work.

Objective of Nuclear Data Evaluation Work:

The goal of the evaluation is to obtain a set of recommended values following a careful compilation and analysis of all available experimental results dealing with nuclear properties such as:

- ✓ Nuclear levels: energy, half-life, spin and parity, decay modes, static moments, bands and configurations.
- ✓ Nuclear radiation types: gamma, electron, positron, neutron, proton, alpha.
- ✓ Nuclear radiation properties: energy, intensity and other radiation-specific properties such as multipolarities, mixing ratios and internal conversion coefficients (gamma rays), log ft values (beta decay) and hindrance factors (alpha decay).

- ✓ Nuclear decay types and their probabilities: positron emission, electron capture, electron emission, double beta decay, isomeric transition; neutron, proton, alpha, and cluster emission; fission.

International Network of Nuclear Structure and Decay Data Evaluators:

Nuclear Data Center Network consists of four main service centers:

- ➢ National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY, USA
- ➢ OECD Nuclear Energy Agency, Paris, France
- ➢ International Atomic Energy Agency, Vienna, Austria
- ➢ Institute of Physics and Power Engineering, Obninsk, Russia and Kurchatov Institute, Moscow, Russia

which provide full customer services in their respective geographical area, and include:

- ✓ Seven Nuclear Reaction Data Centers in 4 countries
- ✓ 17 Nuclear Structure and Decay Data groups in 11 countries
- ✓ 15 Atomic and Molecular Data groups in 9 countries

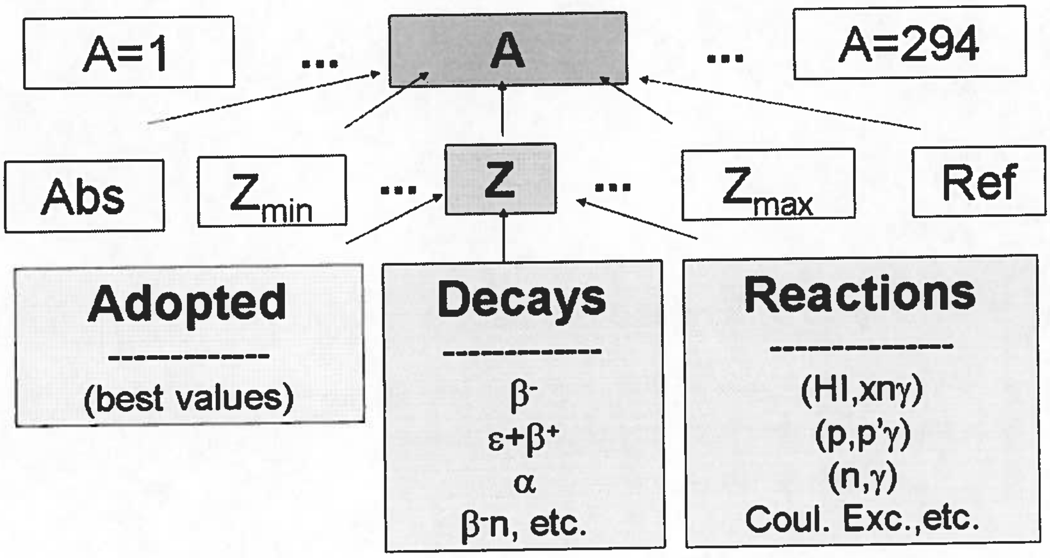
The following table gives complete list of Nuclear Structure and Decay data centers:

US National Nuclear Data Center, Brookhaven, USA (maintenance of master ENSDF database) *http://www.nndc.bnl.gov/* Contact: J. K. Tuli (network coordinator) e-mail: Tuli@bnl.gov
Nuclear Data Project, Oak Ridge National Laboratory, USA *http://www.phy.ornl.gov/ndp/* Contact: S. M. Smith e-mail: MSmith@ORNL.gov
Isotope Project, Lawrence Berkeley National Laboratory, Berkeley, USA *http://ie.lbl.gov/* Contact: C. M. Baglin e-mail: baglin@lbl.gov

Triangle University Nuclear Laboratory, Duke University, USA *http://www.tunl.duke.edu/NuclData/* Contact: J. H. Kelley e-mail: kelley@tunl.duke.edu
Argonne National Laboratory 9700 South Cass Ave. Argonne, IL 60439-4815, U.S.A Contact: F.G. Kondev Email: kondev@ANL.Gov
Nuclear Data Centre, Petersburg Nuclear Physics Institute, Russian Federation Contact: I. A. Mitropolsky e-mail: mart@hep486.pnpi.spb.ru
Institute of Atomic Energy, Beijing, PR China Contact: Ge Zhigang e-mail: gezg@iris.ciae.ac.cn
Jilin University, Physics Department, Changchun, PR China Contact: Huo Junde e-mail: jdhuo@mail.jlu.edu.cn
Centre d'Études Nucléaires, Grenoble, France Contact: J. Blachot e-mail: jblacho@cea.fr
JAERI Nuclear Data Centre, Tokai-Mura, Japan *http://wwwndc.tokai.jaeri.go.jp/* Contact: J. Katakura e-mail: Katakura @cracker.tokai.jaeri.go.jp
Nuclear Data Centre, Physics Department, Kuwait University, Kuwait Contact: A. Farhan e-mail: Ameenah@kuc01.kuniv.edu.kw
Laboratorium voor Kernfysica, Gent, Belgium *http://hage.rug.ac.be/ns_homepage/* Contact: D. De Frenne e-mail: denis.defrenne@rug.ac.be
Department of Physics and Astronomy, McMaster University, Hamilton, Canada *http://physwww.physics.mcmaster.ca/~balraj/* Contact: J. C. Waddington e-mail: JCW@physun.physics.mcmaster.ca
Nuclear Data Center **Indian Institute of Technology, Roorkee (Uttranchal)- INDIA** **Contact: Prof. A.K. Jain** **Email: ajainfph@iitr.ernet.in**
Austrialian National University Dept. of Nuclear Physics Contact: T. kibedi email: Tibor.Kibedi@anu.edu.

Evaluated Nuclear Structure Data File:

The ENSDF (Evaluated Nuclear Structure Data File) database contains evaluated nuclear structure and decay information for over 2900 nuclides. The file is updated on a continuous basis. New evaluations are published in the Nuclear Data Sheets.

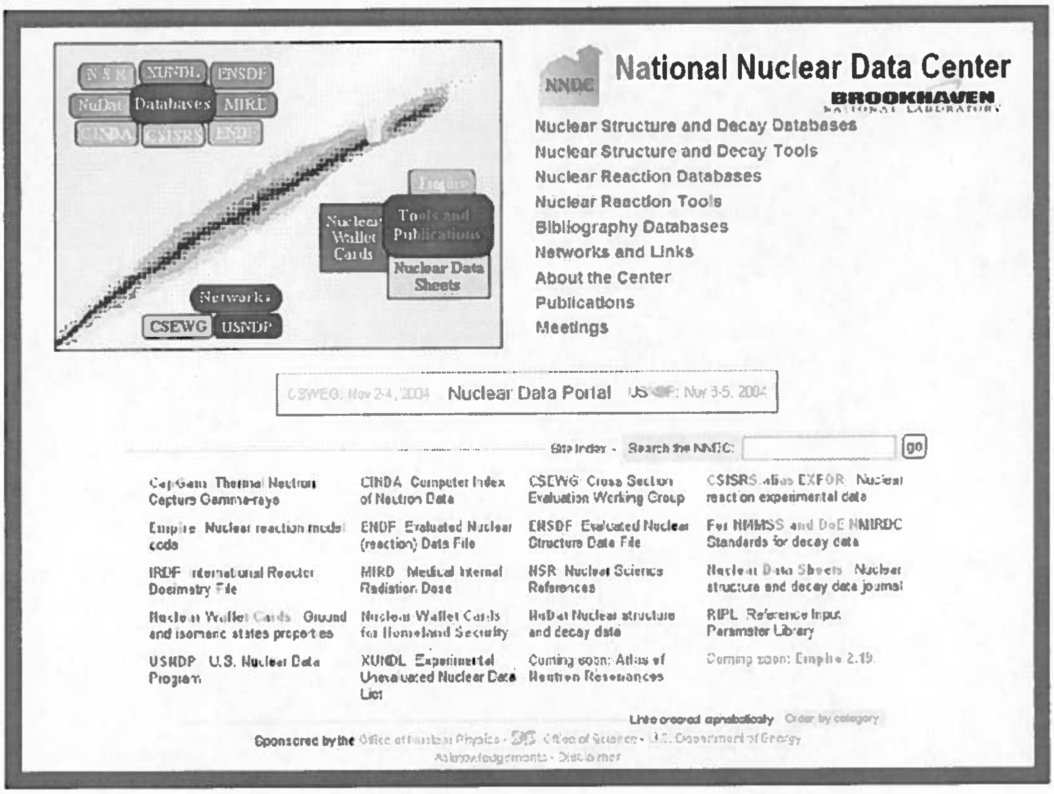


The layout of ENSDF database (accessible at www.nndc.bnl.gov) is schematically shown above. The database contains mass chains starting from A=1 to A=294 serially. In each mass chain the elements are arranged serially in order of atomic no.; where the mass chain itself begins with abstract dataset and finishes with reference dataset.

In each element of the mass chain the experimental data are arranged in form of datasets, which again may be divided into three types categorically namely adopted dataset, decay dataset and reaction dataset.

Bibliographic Databases in Support of NSDD Evaluations:

Nuclear Science References (NSR) is the primary bibliographic resource for NSDD (Nuclear Structure and Decay Data) evaluators. Originally known as Nuclear Structure References, the name was changed in 1995 to reflect the extended coverage. The NSR database is accessible at www.nndc.bnl.gov. (the web page shown below). Other databases used are XUNDL (eXperimental Unevaluated Nuclear Data List) and existing ENSDFs.



The first step in starting an evaluation of a nuclide is described below. One should check NSR to define the nuclide; also the ENSDF cut-off date for the nuclide should be defined.

NSR Indexed Search

NSR Home Indexed Search Text Search Keynumber Search Help

Initialization Parameters

Publication year range: 1910 to 2005
Primary only: ☐ Require measured quantity: ☐
Output year order: Descending
Output format: Normal
○ Search all entries ◉ Search entries added since 6 / 16 / 1995 (month/day/year)

Search parameters

Search Reset

Nuclide 48cr browse...
AND
(none) browse...
AND
(none) browse...

Search Reset

As a result one would obtain the list of publications a part of which is shown below:

NSR Query Results

Publication year range: 1910 to 2005
Primary and secondary references.
Search entries added since 6/16/1995.

Output year order: Descending
Format: Normal

NSR database version of Feb 25, 2005.

Indexed quantity search: Nuclide=48cr

Found 122 matches. Showing 1 to 100. [Next]

Back to query form

2004AL23

Chinese Physics 13, 1230 (2004)

F.H.Al-Khudair, G.-L.Long

Isospin and F-spin symmetry structure in low-lying levels of ^{48,50}Cr isotopes

NUCLEAR STRUCTURE ^{48,50}Cr, calculated levels, J, π, δ, B(E2), B(M1); deduced mixed symmetry states. Interacting boson model with isospin, comparison with data.

2004AN25

Yad.Fiz. 67, 1861 (2004); Phys.Atomic Nuclei 67, 1834 (2004)

F.Andreozzi, N.Lo Iudice, A.Porrino

An Importance Sampling Algorithm for Diagonalizing the Nuclear Shell-Model Hamiltonian

ENSDF Records and their format:

A data set is composed of 80-character records. A data set has at least two records, as described below:

A data set must begin with an IDENTIFICATION record and must end with an END record (a blank record). Between these two records, there can be as many additional records as are needed to describe fully the experimental or the evaluated information.

Immediately following the IDENTIFICATION record is a group of records which contain information about the entire dataset.

The History (H), general COMMENT (C), NORMALIZATION (N), Q-VALUE (Q), PARENT (P), and CROSS-REFERENCE (X) records are of this type.

Not all of these records are included in every data set. For example, Q-VALUE (Q) and CROSS-REFERENCE (X) records normally appear only in adopted datasets while the PARENT (P) record is given only in radioactive decay data sets.

The LEVEL records, and the corresponding radiation records, are placed in the data set in the order of increasing energy.

If a GAMMA, ALPHA, EC, BETA record properly belongs in a data set but cannot be associated with any particular level, then the record should be placed in the data set before any LEVEL records.

The format of different records is shown below:

The Identification Record

(Required for all data sets. Must precede all other records)

Field (Col.)	Name
1-5	NUCID
10-39	DSID
40-65	DSREF
66-74	PUB
75-80	DATE (year/month)

The History Record

Field (Col.)	Name
1-5	NUCID
6	Blank
7	Blank
8	H
9	Blank
10-80	History

The Q-value Record

Field (Col.)		Name	
1-5		NUCID	
8	Q	Letter 'Q' is required	
10-19	Q-	20-21	DQ-
22-29	SN	30-31	DSN
32-39	SP	40-41	DSP
42-49	QA	50-55	DQA
56-80	QREF		

The Comment Record

Field (Col.)	Name
1-5	NUCID
7	Letter 'C', 'D', or 'T' is required
8	RTYPE Blank or record type
9	PSYM Blank, or symbol
10-80	CTEXT Text of the comment

The Beta Record

Field	Name		
1-5	NUCID		
8	B (required)		
10-19	E Energy	20-21 DE	
22-29	IB Intensity	30-31 DIB	
42-49	Logft	50-55 DFT	
77	Flag		
78-79	Forbiddenness	80 Q	

The EC Record

Field	Name		
1-5	NUCID		
8	E (required)		
10-19	E Energy	20-21 DE	
22-29	IB Intensity	30-31 DIB	
32-39	IE Intensity	40-41 DIE	
42-49	Logft	50-55 DFT	
65-74	TI	75-76 DTI	77 Flag
78-79	Forbiddenness	80 Q	

The Alpha Record

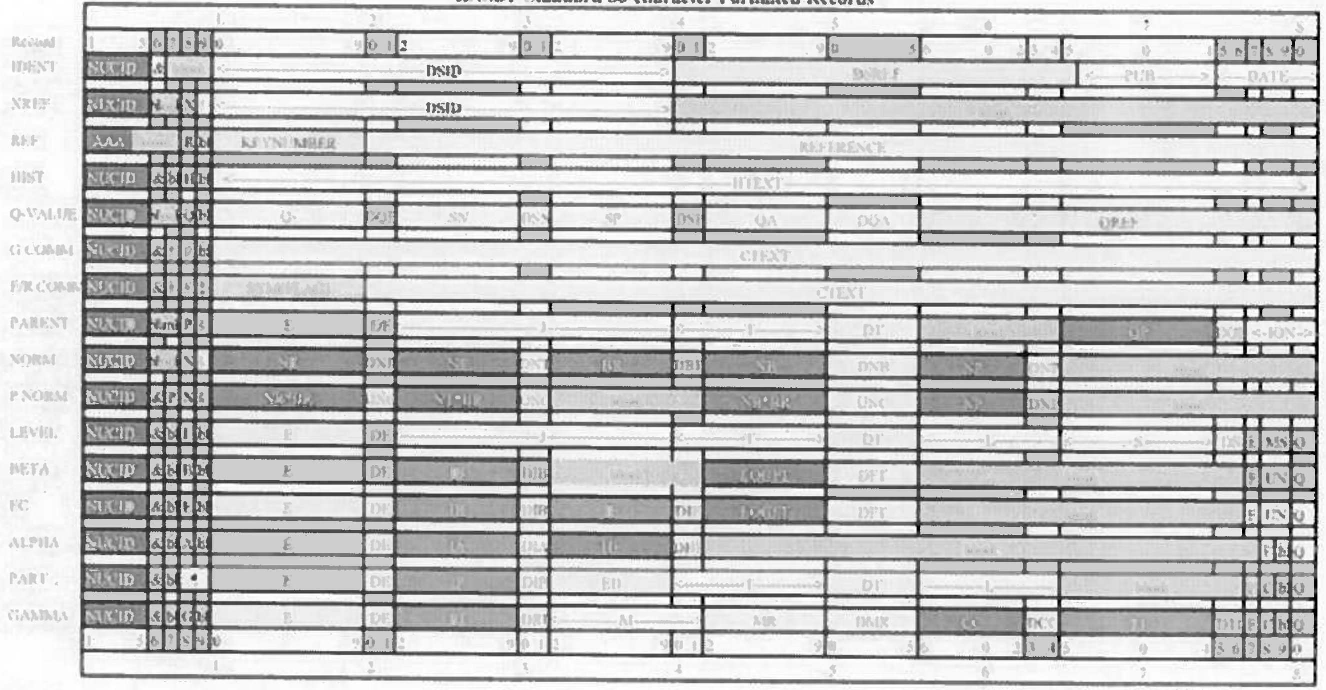
Field	Name		
1-5	NUCID		
8	A (required)		
10-19	E Energy	20-21 DE	
22-29	IA Intensity	30-31 DIA	
32-39	HF	40-41 DHF	
77	Flag		
80	Q		

The Gamma Record

Field	Name	
8	G (required)	
10-19	E Energy	20-21 DE
22-29	RI rel Intensity	30-31 DRI
32-41	M multipolarity	
42-49	MR mix ratio	50-55 DMR
56-62	CC total CC	63-64 DCC
65-74	TI	75-76 DTI
77	Flag	78 COIN
80	Q	

The format of all records is summarized in the next table.

ENSDF Standard 80-character Formatted Records



Notes:

blank These fields must be blank.

& Primary record must have a blank or "1" in this field. Continuation records should have any printable ASCII character except for blank or "1" (one).

Unique alphanumeric character identifying the source data set.

Allowed characters for this field are C, c, D, d, T, and t.

Character identifying the record being commented on. Allowed characters for this field are N, P, Q, L, G, B, E, A, D, and blank.

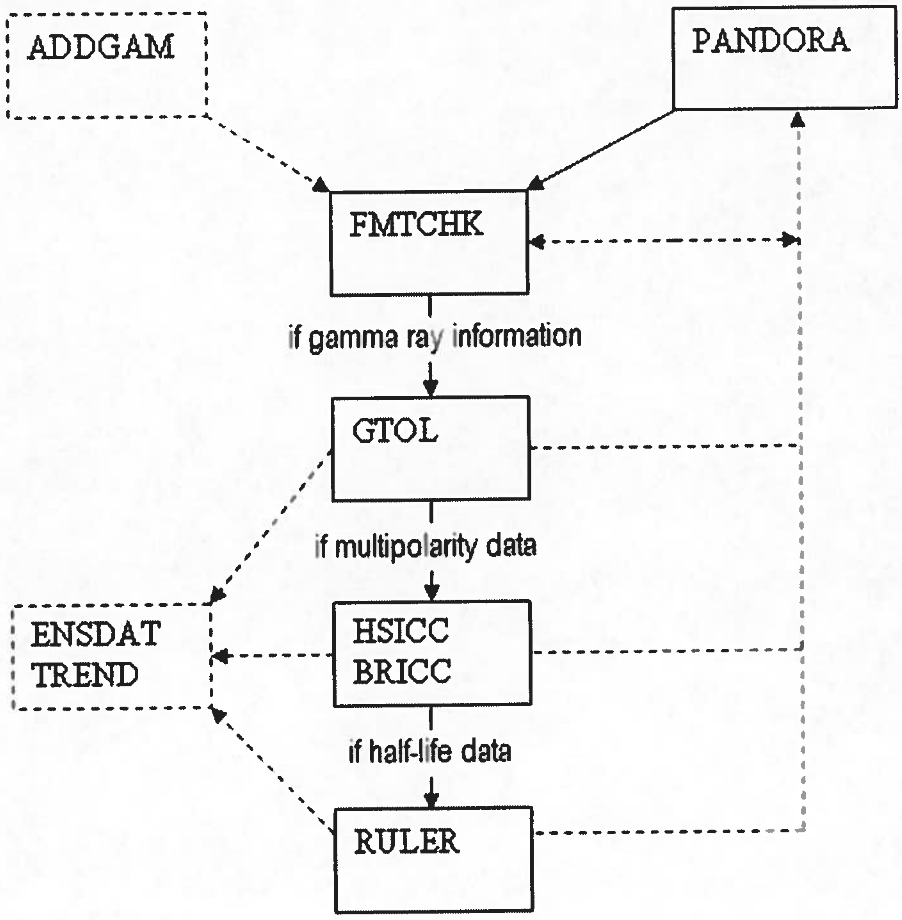
Must be blank except for: 1) Particle code for a (delayed)-particle record. 2) Sequence number for normalization and parent records.

Must be blank except when there are multiple parent records then this field should contain an integer relating the parent record to the related normalization record.

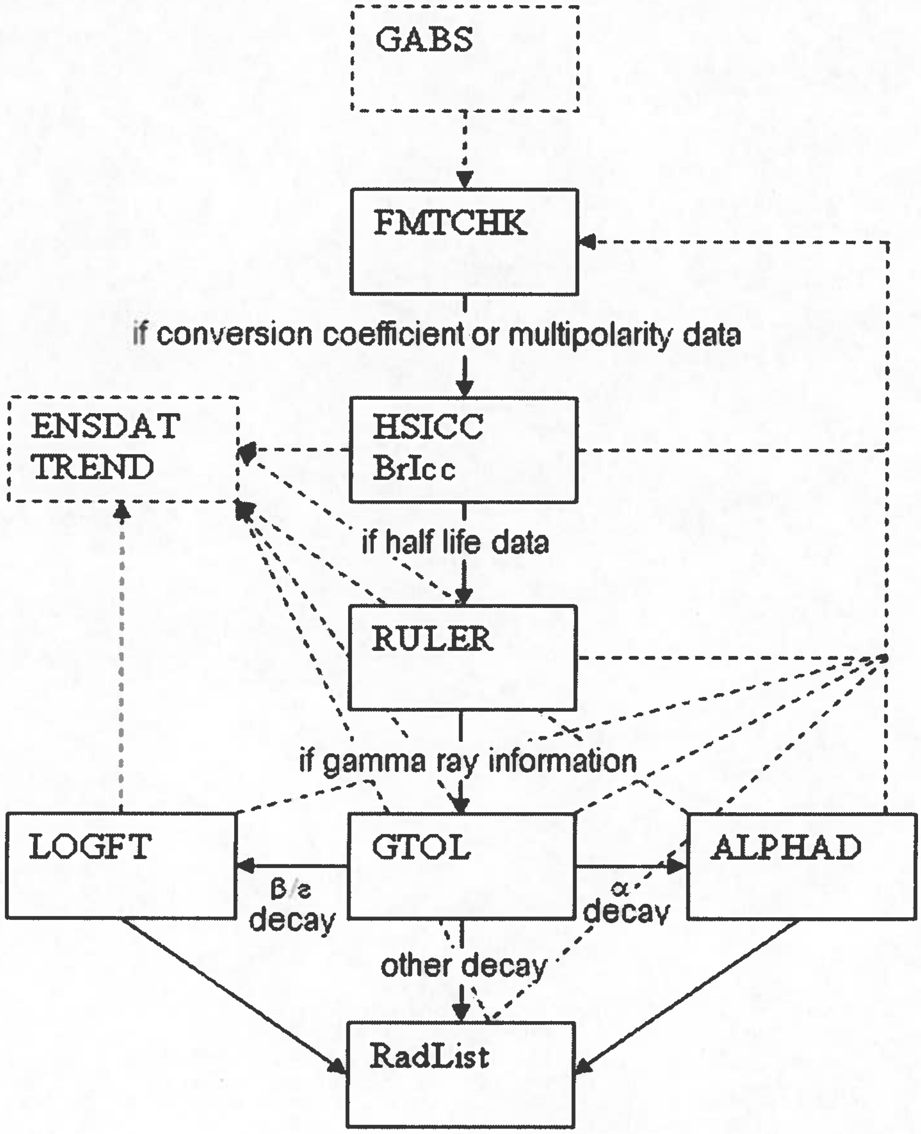
Byte 8 must either be blank for a prompt particle radiation or D for a delayed particle radiation. Byte 9 identifies the particle (N, P, D, or T).

ENSDF Analysis and Utility Codes:

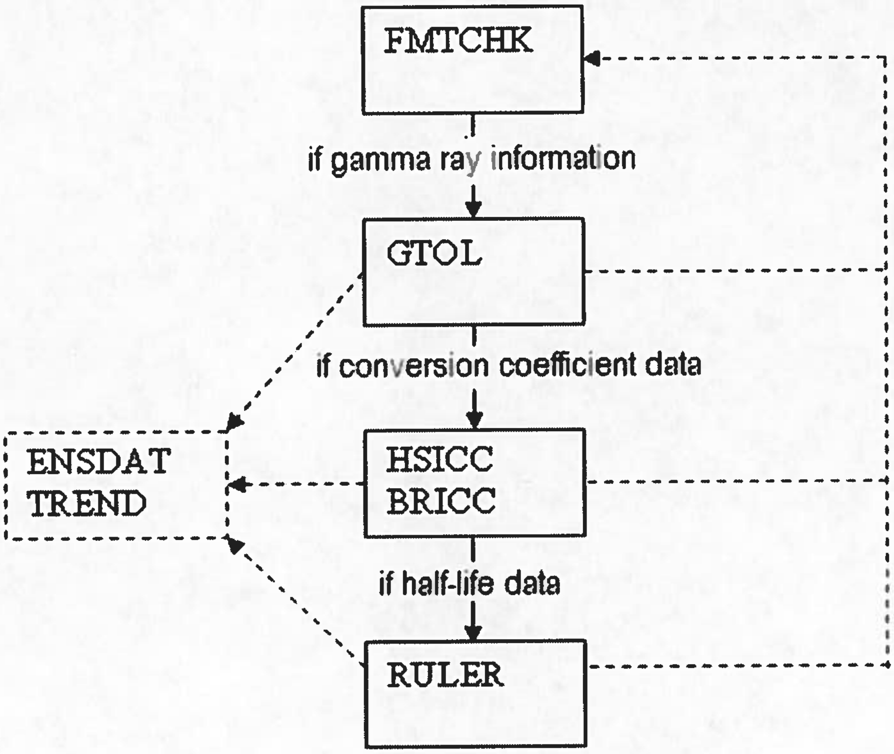
- **GTOL (Gamma to level)** - Performs a least-squares fit to the gamma-energies and calculates the net feedings to levels
- **ALPHAD** - Calculates the alpha hindrance factors and theoretical half-lives
- **ADDGAM** - Add gammas to adopted level data set, if gammas are from only one data set.
- **ENSDAT (Evaluated Nuclear Structure Drawings and Tables)**- Production program for the Nuclear Data Sheets .
- **HSICC (Hager-Seltzer Internal Conversion Coefficients)/BrIcc (Band-Raman Internal Conversion Coefficients)** - Interpolates conversion coefficients
- **FMTCHK (Format and Syntax Checking)** - Checks format for individual files
- **PANDORA (Physics Analysis of Nuclear Data to Outline Required Adjustments)** - Physics checking tool
- **COMTRANS (Comment Translation)** -Translates comments in ENSDF file
- **GABS** - Calculates absolute gamma ray frequencies
- **LOGFT** - Calculates logft for beta decay
- **RULER** - Calculates reduced em transition strengths
- **DELTA** - analyses angular corelation and conversion coefficient data
- **TREND** -(Tabular Representation of ENSDF)– Generates ENSDF data tables report



Flowcharts of programs for Adopted Levels ,Gammas and datasets



Flowchart for programs for decay datasets



Flowchart of programs for reaction datasets

Working of some of the most used codes is illustrated below. They were executed on standard sample file; sometimes an error is deliberately included to show how the respective code reacts.

§ FMTCHK

Note that this file has had errors deliberately introduced for illustrative purposes.

Sample Terminal Dialog:

```
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>c:\ensdf\fmtchk

 INPUT file to be checked:          fmtchk-example.ens
 OUTPUT file for report:            fmtchk.rpt
 Errors only or full report (E, F):
 Check continuation cards (Y, N):
 Report only fatal errors (N, Y):
 Suppress warning messages (N, Y):
 Suppress XREF/DSID check (N, Y):
  48SC    ADOPTED LEVELS, GAMMAS
    2 fatal errors reported
    3 error(s) reported
   19 warning(s) reported
  48SC    48CA B- DECAY: ?
  48SC    46CA(3HE,P)
  48SC    46CA(A,D)
  48SC    48CA(P,N)                 1968MC10,1967MC08,1967MC07        200408
  48SC    48CA(P,N),(POL P,N)       1986AN23,1985AN06,1980AN19        200408
  48SC    48CA(P,NG)                1975AS07,1971RO27,1971CA36        200408
   19 warning(s) reported
  48SC    48CA(3HE,T)               1980GA04,1972RI07,1970OH01        200408
  48SC    48CA(6LI,6HE)             1990KAZH,1973GA21                 200408
  48SC    48TI(T,3HE)               1985AJ03                          200408
  48SC    48TI(7LI,7BE): IV GIANT RES  1987NA16                       200408
  48SC    49TI(D,3HE),(T,A)         1970OH04,1967SC03                 200408
  48SC    50TI(P,3HE) IAS           1978KO27                          200408
  48SC    50TI(D,A),(POL D,A)       1984HA22,1972WAZG                 200408
  48SC    TI(MU-,G)                 1973EV02                          200408
    1 error(s) reported

 ***** Mismatches in X Records and ID Records found
```

FMTCHK will summarize the fatal errors, errors, and warnings for each data set in the terminal output.

If an adopted dataset is found and one or more source datasets for the same nuclide are present, FMTCHK will compare the DSID on the X Records of the adopted dataset with the DSID on the source datasets ID record and summarize the results in the terminal output

Report File:

1. INVALID NUCID – FMTCHK was unable to recognize the chemical symbol. If this had occurred on the ID Record, HSICC and LOGFT could not perform calculations.
2. NUCID DOESN'T MATCH DSID – There is a mismatch between the NUCID on the ID record and on this record. This may cause a program to think that a new dataset has started.

```
                                                                                    PAGE    1
  1.  48SC    ADOPTED LEVELS, GAMMAS                                 200408
  7.  48Sc cG M(B),MR(D)$From |g(|q) and linear polarization in (p,n|g)
     *****                                                                  <F> INVALID NUCID
     *****                                                                  <F> NUCID DOESN'T MATCH DSID
118.  48SC  G 130.94    4 100              0.054   LE    0.0083 2
                                 **********                                 <E> MISSING MULT
130.  48SCX G FL=130.
               ****                                                         <E> MATCHING LEVEL NOT FOUND
139.  48SCX G FL=130.94
               ******                                                       <E> NOT CONS. WITH EL-EG=252.35 10
148.  48SC  G 519.9     2 100       M1+E2
                                         ********                           <W> MISSING MR
155.  48SC  G 259.1     2 4.2      11D+Q
                                         ********                           <W> MISSING MR
```

1. The level energy for FL= must be exactly the same as on the Level Record. If not, unknown problems may occur.
2. The final level has been found but there is a severe mismatch in with the calculated level energy. In this instance, the results from GTOL will be wrong and the γ arrow drawn in the level scheme will go to the wrong level.

1. If a mixing ratio is given, then a multipolarity is required even if only D(+Q).
2. Authors sometimes do not give the mixing ratio or there may be several possible mixing ratios (include these on a comment). Therefore, this is only a warning for the evaluator to check. HSICC and BrIcc will assume a 50%/50% admixture if the ratio is missing.

```
  1.  48SC    46CA(A,D)                      1972RI06              200408
 10.  48SC CL S$LABEL=(DS/DW(EXPT))/(DS/DW(THEORY)
           ********                                                 <I> "LABEL=". FLD CHCKD AS <W> NOT <E>
```

As noted in Coral Baglin's presentations, a field on a formatted record may be redefined. In such cases, FMTCHK will issue a warning instead of an error message if there are problems with this field in the current dataset and provide an informational message that this is being done.

```
---------+---------+-+-------+-+-------+-+-------+------+------+-+---------+-++-+
   1.  48SC    TI(MU-,G)                     1973EV02                         200408
                                                                                     <E> END CARD NOT IN ANY DATASET
.
.
.
.
.
X RECORD TO ID RECORD COMPARISON

 X Record                                   ID Record
  48SC  XA48CA B- DECAY                     ***** NO MATCH *****
 ***** NO MATCH *****                        48SC    48CA B- DECAY: ?
```

An extraneous END (blank) record has been found after this dataset. There should be one and only one END (blank) record after each dataset. If no END record is found, this is flagged as a fatal error since a program may include the following dataset in the processing of this dataset.

If an adopted dataset and source datasets for the same nuclide are found, FMTCHK will compare the DSID on the adopted dataset X records with the DSID on the ID records of the source datasets. Any mismatches will be reported. The DSID's must be identical and, if the source dataset has level records, there must be an X record in the adopted dataset

Explanation of Messages: The various types of messages (<F> - Fatal error, <E> - Error, <W> - Warning, and <I> - Informational) are explained in readfmtc.me or readfmtc.html. These are included in the FMTCHK distribution.

§ GTOL

Sample Terminal Dialog:

```
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>c:/ensdf/gtol

  GTOL Version 6.4b [ 3-Dec-2003]
   (single precision,localized)
  Max. number of levels=        1000
  Max. number of gammas=        4000
  Max. number of fixed levels=        1000

 Enter INPUT-DATASET file name:  gtol-example.ens
 Enter REPORT-FILE name:(def-GTOL.RPT)
  Do you wish to create a new file
  with level energies replaced by GTOL results(N/Y)?  y
 Enter OUTPUT-DATASET file name:  out.ens
 Do you wish to suppress gamma energy comparison(N/Y)?
 Do you wish to suppress intensity comparison(N/Y)?

  GTOL started, wait patiently!

 CURRENT DATA SET: 152GD    152TB EC DECAY (17.5 H)
END OF FILE
```

Default is not to create a new file. After checking GTOL results, rerun the program and enter "Y" or "y" to create a new file.

Report File:

```
*********************
*     GTOL 6.4b     *
*********************

DATE:   09-Apr-2005
TIME:   12:45:55


 INPUT-FILE name: gtol-example.ens
 OUTPUT-FILE name: out.ens
1PROGRAM   G T O L   VERSION 6.4b AS OF 3-Dec-2003

         152GD    152TB EC DECAY (17.5 H)        1971ZO05,1970AD05,1990TA1996NDS    199701
         152GD  N 0.065     4  0.065  4 1.0        1.0
         152GD PN                                                                     3
         152GD  G 472.0      7 0.2     1                                             D
+                                                                                          UNPLACED GAMMA IGNORED
.
.
.
         152GD  L 615.40        0+
         152GD  E               0.87  12   5.0  7   9.65   6             5.9      8  1U
         152GD  G 271.08    10 132     9   E2              0.0831
         152GDS G KC= 0.0623$  LC=0.0161$  MC=0.00365$  NC+=0.00101
         152GDX G FL=344.28
+                                                                                     FINAL LEVEL FOUND
 ***** No differences introduced due to continuation record
         152GD  G 615.6                E0                     19.8      8 A
+                                                                                     +-  1.00 keV unc. assigned to energy
         152GD3 G FLAG=E
         152GDS G K/T=0.88$  L/T=0.12
         152GD  L 755.40        4+                                       J
.
```

All unplaced gamma records (*i.e.*, those coming before the first level record) are ignored and this is reported.

GTOL will check for "FL=" on gamma continuation records, note that these have been found, and update the matrices if necessary.

GTOL will assign an uncertainty in certain cases such as "DE" if none is given. Either a default or user-defined value is used. See readgtol.me for options on changing defaults.

```
.
.
152GD  L 1434.0        3+                                                          J
        152GD  E               0.082 11  0.69  9   8.66   6            0.77      10
        152GD  G 325.3     6   1.0   LT [M1+E2]                  0.063  16           & ?
+                                                                                      UNCERTAIN GAMMA IS IGNORED
        152GDS G KC=0.052 15$  LC=0.0089 5$  MC=0.00196 7$  NC+=0.00055 3
        152GD  G 503.5     7   0.9   4   (E2)                    0.0139
        152GDS G KC=0.0112$  LC=0.00200
.
.
.
        152GD  L 1941.2        2+                                                   J
        152GD  E               0.11  1    4.4  4   7.65   4            4.5       4
        152GD  G 248.5     2   1.7   4   [M1+E2]                 0.14   3
        152GDS G KC=0.11 3$  LC=0.0210 15$  MC=0.0046 5$  NC+=0.00130 11
        152GD  G 335.5     5   1.0   LT  [M1+E2]                 0.058  15
+                                                                                      RI=DRI=RI/2 assumed
        152GDS G KC=0.047 14$  LC=0.0080 6$  MC=0.00177 9$  NC+=0.00049 3
        152GD
        152GD
.
.
.
```

Uncertainly placed gammas ("?" in field 80 of the record) are ignored in the calculations.

If an upper limit on intensity is found, GTOL will assume that the intensity is ½ of the value given and assign an uncertainty equal to ½ of the intensity. This is done for the calculation of the intensity imbalances for the levels.

Summary of options. Apply recoil correction; calculate for all datasets; and assume $\Delta E\gamma$=1 keV if not given.

```
 MASS NUMBER= 152

 OPTIONS: RECOIL= T   ALL= T
         DEG=1 keV
1          152GD     152TB EC DECAY (17.5 H)       1971ZO05,1970AD05,1990TA1996NDS    199701

 BOTTOM  (OUT)        0.0       344.30  7     615.35  9     755.43  9     930.59  8    1047.83 10    1109.21  8    1123.17  8    1282.32 15
 LEVEL=   (IN)        0.0       344.28        615.40        755.40        930.55       1047.85       1109.17       1123.19       1282.26

   TOP
  LEVEL

0    344.30  7     344.30  7   ---                                                  ---          ---          ---          ---
                   344.28 10
```

Top value is $E\gamma$ based on the adjusted level energies. Bottom value is the input $E\gamma$.

```
0   1314.68 10    1314.67 10    970.37 10    699.33 11    559.25 11    384.09 11    266.85 12    205.47 11    191.50 11     32.36 16
                  1314.70 20    970.40 20     699.0  5

0   1318.37  8    1318.36  8    974.06  7    703.02  8    562
                   1318.2  3    974.10 20    703.34 15     56
                                         ****2*****
0   1434.11 13    1434.10 13   1089.80 11    818.76 13    678

.
.
.
1NR=0.6500E-01+-0.40E-02
 NT=0.6500E-01+-0.40E-02
 BR=0.1000E+01+-0.00E+00
 NB=0.1000E+01+-0.00E+00

                   RI           RI           RI           TI           TI            TI           NET FEEDING
    LEVEL        (OUT)         (IN)         (NET)        (OUT)        (IN)          (NET)        (CALC)          (INPUT)

      0.0        0.000         1141  5     -1141  5     0.000         1201  5      -1201  5       22  5   22         5
    344.30  7     1000          823 17       177 17    1039.9 12       840 18        200 18      13.0 14  13.0        14
    615.35  9      132  9        64  3        68 10       163 10        72  3         90 11       5.9  8   5.9        8
    755.43  9       63  4      46.1 17        17  5        65  4      46.8 17         18  5       1.1  3   1.0          3
.
.
.
.
NET FEEDING TO G.S. IS 21.93+-4.81
1                  Replacing Levels for:  152GD     152TB EC DECAY (17.5 H)

          OLD CARD:  152GD  L 0.0          0+                                                   KEPT

          OLD CARD:  152GD  L 344.28         2+            0.3 NS      LE
          NEW CARD:  152GD  L 344.30      7  2+            0.3 NS      LE

          OLD CARD:  152GD  L 615.40         0+
          NEW CARD:  152GD  L 615.35      9  0+

          OLD CARD:  152GDX G FL=344.28
          NEW CARD:  152GDX G FL=344.30
+
```

GTOL will flag transitions where the input Eγ and calculated Eγ are discrepant. 1 – 1 to 2 σ deviation; 2 – 2 to 3 σ; 3 – 3 to 4 σ; 4 – 4 to 5 σ; 5 – ≥ 5 σ.

Normalization factors from the N and PN records.

Absolute feeding from TI(NET) and normalization record. Ground state net feeding is calculated as 100+TI(NET).

Relative ΣIγ(out), ΣIγ(in), and ΣIγ(out)- ΣIγ(in).

Relative ΣIγ+ce(out), ΣIγ+ce(in), and ΣIγ+ce(out)- ΣIγ+ce(in).

From the B, E, or A record.

May be useful in obtaining the normalization.

GTOL will also update the final level flags.

Replacing "FL" value

§ HSICC and BrIcc

HSICC

Sample Terminal Dialogs:

```
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>c:/ensdf/hsicc
 HSICC Version 11.13d [ 20-Mar-2001]
INPUT FILES -
   DATA DECK (DEF: data.tst):
hsicc-example.ens
   ICC INDEX (DEF: iccndx.dat): c:\ensdf\iccndx.dat
   ICC TABLE (DEF: icctbl.dat): c:\ensdf\icctbl.dat
OUTPUT FILES -
   COMPLETE H.S. CALCULATIONS REPORT (DEF: hscalc.lst):

   NEW G/SG CARD DECK (DEF: cards.new):

  G/2G (NEW/OLD) COMPARISON REPORT (DEF: compar.lst):

 CALC CONV. COEFS. ONLY IF MULTIPOL. KNOWN (Y OR CR):

   END OF REQUEST LIST
```

If index and data table are not in the current directory, the full path must be given.

If any character other than "Y" or "y" is entered, conversion coefficients will be calculated for all gamma records.

```
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>c:/ensdf/hsmrg
0INPUT FILES -
   DATA DECK (DEF: data.tst):
hsicc-example.ens
   NEW G/2G CARD DECK (DEF: cards.new):

0OUTPUT FILES -
   MERGED DATA DECK (DEF: cards.mrg):

0PROGRAM   H S M R G   VERSION 7.1 AS OF 9-Feb-01.
```

The input file (data deck) must be unchanged from that used to generate the new G/2G records.

Report File:

```
1PROGRAM  H S I C C  VERSION 11.13d  AS OF 20-Mar-2001

    1:  48SC    ADOPTED LEVELS, GAMMAS                                     200408
.
.
   ICC (HAGER-SELTZER), Z =  21 ( 48SC); EG= 121.
                   M1            E2            MIXED ICC     DICC(+DMR)    DICC(-DMR)
                                                 MR=-0.04    9

                 -----------   -----------   -----------   -----------   -----------

         K       8.821E-03     1.318E-01     9.017E-03     1.103E-04     1.848E-03

         L1      7.744E-04     1.108E-02     7.909E-04     9.241E-06     1.549E-04
         L2      1.551E-05     4.412E-04     1.619E-05     3.815E-07     6.394E-06
         L3      7.965E-06     6.637E-04     9.013E-06     5.877E-07     9.850E-06

   TOTAL-L       7.979E-04     1.219E-02     8.161E-04     1.021E-05     1.711E-04
       K/L       11.06         10.81         11.05
   K+1.33L       9.882E-03     1.480E-01     1.010E-02     1.238E-04     2.075E-03

         M1        Z IS OUTSIDE TABLE RANGE FOR THIS SHELL                     Z IS OUTSIDE TABLE RANGE FOR THIS SHELL
         M2        Z IS OUTSIDE TABLE RANGE FOR THIS SHELL                     Z IS OUTSIDE TABLE RANGE FOR THIS SHELL
         M3        Z IS OUTSIDE TABLE RANGE FOR THIS SHELL                     Z IS OUTSIDE TABLE RANGE FOR THIS SHELL
         M4        Z IS OUTSIDE TABLE RANGE FOR THIS SHELL                                                           LL
         M5        Z IS OUTSIDE TABLE RANGE FOR THIS SHELL                                                           LL

  N+O+ FROM
  DRAGOUN          Z IS OUTSIDE TABLE RANGE FOR THIS SHELL                                                           LL

  L=3, 4 CC's multiplied by 0.975 10, 0.975 5, respectively (Cf. 90Ne01).
                   COMPARE OLD/NEW CARDS
    125:  48SC  G 121.41    4 100      (M1(+E2)) -0.04   9     0.0101 21
 +                                                                                 OLD CARD
    125:  48SC  G 121.41    4 100      (M1(+E2)) -0.04   9      0.010121
```

The larger of the absolute value of these two numbers is placed on the new records

L=3 and L=4 conversion coefficients are adjusted and, when appropriate, HSICC will insert a comment record noting this in CARDS.NEW.

The comparisons are summarized in COMPARE.LST.

```
 125:  48SCS G KC=0.0090 19$LC=0.00082 18
 125:  48SCS G KC=0.0090 19 $LC=0.00082 18
+                                                                OLD CARD
.
.
.
                   COMPARE OLD/NEW CARDS
 118:  48SC  G 130.94    4 100       M1(+E2)   0.054   LE     0.0083 2
+
Changing 0.00829 15 to 0.0083  2 due to 3% uncer in theory
 118:  48SC  G 130.94    4 100       M1(+E2)   0.054   LE
Changing 0.00740 14 to 0.0074  1 due to 3% uncer in theory
UNCERTAINTY IS BEING INCREASED FOR ROUNDOFF. ORIGINAL VALUES: X=  0.669E-03 DX=  0.122E-04
UNCERTAINTY IS BEING INCREASED FOR ROUNDOFF. ORIGINAL VALUES: X=  0.669E-03 DX=  0.235E-04
 118:  48SCS G CC=0.0083 2$KC=0.0074 1$LC=0.00067 1
 118:  48SCS G KC=0.00740 13$LC=0.000669 13
+                                                                OLD CARD
```

Total conversion coefficients less than 0.01 are now placed on the "S G" record.

The number of significant digits shown may be adjusted when compared to the 3% uncertainty in theory.

Sample Terminal Dialogues:

```
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>bricc
BrIcc v1.3 (05-Jan-2005) calculates conversion coefficients
 (for electron conversion and pair production)
           and E0 electronic factors
        using cubic spline interpolation
Index file: C:\Program Files\BrIcc\BrIcc.idx
ICC file: C:\Program Files\BrIcc\BrIcc.icc
-----------------------------------------------------------
Z= 70 Ytterbium              BrIcc v1.3 (05-Jan-2005)
Transition energy: 279.717 keV
Shell  E_e                                             I C C
      [ keV]       E1       M1       E2       M2       E3       M3       E4       M4       E5       M5
---------------------------------------------------------------------------------------------------------
Tot                2.36E-02 1.90E-01 9.08E-02 8.04E-01 4.22E-01 2.98E+00 2.25E+00 1.16E+01 1.24E+01 4.90E+01
K        218.38    1.98E-02 1.59E-01 6.34E-02 6.37E-01 1.88E-01 2.10E+00 5.59E-01 6.83E+00 1.70E+00 2.22E+01
L-tot              2.95E-03 2.39E-02 2.11E-02 1.29E-01 1.78E-01 6.67E-01 1.27E+00 3.60E+00 7.97E+00 1.98E+01
M-tot              6.56E-04 5.35E-03 5.04E-03 3.00E-02 4.46E-02 1.63E-01 3.32E-01 9.35E-01 2.18E+00 5.45E+00
N-tot              1.53E-04 1.26E-03 1.16E-03 7.06E-03 1.03E-02 3.86E-02 7.67E-02 2.21E-01 5.06E-01 1.29E+00
O-tot              2.11E-05 1.80E-04 1.45E-04 9.93E-04 1.22E-03 5.20E-03 8.90E-03 2.84E-02 5.69E-02 1.58E-01
P-tot              1.00E-06 9.64E-06 3.23E-06 4.93E-05 1.18E-05 2.17E-04 5.32E-05 9.48E-04 2.74E-04 4.17E-03
TranEner / ChemSymb(2 char) / SUBShell/ EXIT [ 279.717] >
```

For interactive use simply enter bricc. Under Windows, this mode may also be invoked with the BrIcc desktop icon.

Paths for the index and ICC files and the program are obtained from the environment. The environment is automatically set up with the Windows installation. For Linux/UNIX, see the manual.

Enter transition energy in keV, chemical symbol (or Z followed by atomic number. Note: for Z>109, the atomic number must be used), toggle between showing and not showing the subshells (SUB), or EXIT the program. All input is case insensitive.

```
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>bricc hsicc-example.ens
BrIcc v1.3 (05-Jan-2005) calculates conversion coefficients
 (for electron conversion and pair production)
          and E0 electronic factors
       using cubic spline interpolation
Index file: C:\Program Files\BrIcc\BrIcc.idx
ICC file: C:\Program Files\BrIcc\BrIcc.icc
Input ENSDF file: hsicc-example.ens
Output Files
  Complete calculations report, (Def: BrIcc.lst):
  List conversion coefficients for all subshells (Def. N):
  Calculate conversion coefficients for all transitions (Def. N):
  New G/SG records, (Def: Cards.new):
  G/SG (New/Old) comparison report, (Def: Compar.lst):
      Processing a new data set
       1 :  48SC    ADOPTED LEVELS, GAMMAS
     118 :  48SC  G 130.94    4 100       M1(+E2)    0.054   LE    0.0083 2
<I> Uncertainties on ICC`s from transition energy uncertainty is greater than 2%.
     125 :  48SC  G 121.41    4 100       (M1(+E2)) -0.04    9     0.0101 21
     135 :  48SC  G 370.29    5 100       D(+Q)     -0.02    2
<W> Valid but NON-unique multipolarity. Calculation could not be performed.
     146 :  48SC  G 519.9     2 100       M1+E2
<I> Mixing ratio empty, assumed to be equal to 1.
     153 :  48SC  G 259.1     2 4.2     11D+Q
<W> Valid but NON-unique multipolarity. Calculation could not be performed.
     155 :  48SC  G 779.0     2 100.0   11E1+M2    -0.04    1
     162 :  48SC  G 489.3     3 72.5    20M1+E2
<I> Mixing ratio empty, assumed to be equal to 1.
     166 :  48SC  G 748.3     4 13.7    20D+Q
<W> Valid but NON-unique multipolarity. Calculation could not be performed.
     168 :  48SC  G 1268.3    6 11.8    20
     169 :  48SC  G 1638.8    3 100.0   20E1+M2    +0.05    3
     178 :  48SC  G 1811.8    6 31.6    14
     179 :  48SC  G 2063.9    6 100.0   14D(+Q)    -0.02    3
.
.
.
BrIcc finished processing hsicc-example.ens
 Processed:
 #DataSets      :       1
 #AllRecords    :     522
 #GammaRecords  :      56
 #Errors        :       0
 #Warnings      :      25
```

As an ENSDF evaluation tool, enter bricc followed by the ENSDF file name.

BrIcc terminal dialog and defaults are very similar to those of HSICC. An additional question on listing or not listing the subshell conversion coefficients has been added.

BrIcc will list all gamma records processed in the terminal output along with any messages noted during the processing (<I> - Informational, <W> - Warning, <E> - Error, and <F> - Internal programming error).

Summary of results.

```
 Skipped:
 #DataSets     :       0
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>bricc hsicc-example.ens merge
BrIcc v1.3 (05-Jan-2005) calculates conversion coefficients
 (for electron conversion and pair production)
          and E0 electronic factors
       using cubic spline interpolation
Index file: C:\Program Files\BrIcc\BrIcc.idx
ICC file: C:\Program Files\BrIcc\BrIcc.icc
  New G/SG cards, (Def: Cards.new):
  Output file of merged old and new cards, (Def: Cards.mrg):
```

As an ENSDF utility to merge new records into the original dataset, enter bricc followed by the ENSDF file name and "merge".

Report File:

Only the ID record and gamma-related records of the input are included in the report.

```
        Program BrIcc v1.3 (05-Jan-2005)

Input ENSDF file: hsicc-example.ens

      1 :  48SC    ADOPTED LEVELS, GAMMAS                                      200408
      4 :  48SC CG            ALL INFORMATION IS FROM (P,NG), EXCEPT AS NOTED
      5 :  48SC cG M,MR       From |g(|q) in (p,n|g), except as noted
      6 :  48SC cG E(A)       From Ti(|m(+-),|g)
      7 :  48SC cG M(B),MR(D)$From |g(|q) and linear polarization in (p,n|g)
    118 :  48SC  G 130.94     4 100       M1(+E2)   0.054   LE    0.0083 2
    119 :  48SCS G KC=0.00740 13$LC=0.000669 13
    120 :  48SC cG M,MR       from |a(exp) in (p,n|g)
.
.
.
=========================================================================
 BrIcc Z= 21 Egamma= 130.94 4 keV          Multipolarity= M1(+E2)
                                           M1(+E2)    Mixing ratio = 0.054 LE
 <I> Uncertainties on ICC`s from transition energy uncertainty is greater than 2%.
                                         M1+E2 Mixed Icc
 Shell    M1         E2                  Icc       dIcc       dIccDMRL   dIccDMRH   dIccDEL    dIccDEH
         ---------- ----------         ---------- ---------- ---------- ---------- ---------- ----------
 K        7.193E-03 9.680E-02           7.323E-03 2.277E-04  1.303E-04  1.303E-04  1.158E-04  1.157E-04

 L-tot    6.465E-04 8.860E-03           6.585E-04 2.077E-05  1.194E-05  1.194E-05  1.075E-05  1.073E-05
 K/L      1.113E+01 1.093E+01           1.112E+01 4.926E-01

 M-tot    8.004E-05 1.088E-03           8.151E-05 2.557E-06  1.466E-06  1.466E-06  1.317E-06  1.315E-06
```

BrIcc checks for instances where the uncertainty associated with ΔIγ may contribute to the Δα and includes this in the results.

```
L/M      8.077E+00 8.142E+00           8.079E+00 3.594E-01

N-tot    4.420E-06 5.700E-05           4.496E-06 1.360E-07  7.644E-08  7.644E-08  6.755E-08  6.753E-08
L/N      1.463E+02 1.554E+02           1.465E+02 6.401E+00

Tot      7.924E-03 1.068E-01           8.067E-03 2.511E-04  1.437E-04  1.437E-04  1.279E-04  1.278E-04

 Compare OLD/NEW cards
    118 :  48SC  G 130.94     4 100      M1(+E2)   0.054   LE    0.0083 2                 <Old Card>
    118 :  48SCS G KC=0.00740 13$LC=0.000669 13                                           <Old Card>
    118 :  48SC  G 130.94     4 100      M1(+E2)   0.054   LE    0.0081 3                 <New Card>
    118 :  48SCS G KC=0.00732 23$LC=0.00066 2$                                            <New Card>
```

Comparisons of old and new records are summarized in Compare.lst.

```
.
.
.
=============================================================================================================
BrIcc Z= 21 Egamma= 1638.8 3 keV           Multipolarity= E1+M2                          10-APR-05
                                           E1+M2      Mixing ratio = +0.05 3
                                        E1+M2 Mixed Icc
Shell     E1         M2                 Icc       dIcc       dIccDMRL   dIccDMRH
         --------- ---------           --------- ---------  ---------- ----------
K        1.783E-05 5.191E-05           1.791E-05 3.817E-07 -7.138E-08  1.318E-07

L-tot    1.555E-06 4.550E-06           1.562E-06 3.333E-08 -6.272E-09  1.158E-08
K/L      1.147E+01 1.141E+01           1.146E+01 3.457E-01

M-tot    1.927E-07 5.643E-07           1.936E-07 4.130E-09 -7.781E-10  1.436E-09
L/M      8.070E+00 8.063E+00           8.070E+00 2.435E-01

N-tot    1.084E-08 3.176E-08           1.089E-08 2.323E-10 -4.380E-11  8.086E-11
L/N      1.435E+02 1.433E+02           1.435E+02 4.329E+00

IPF      3.731E-04 4.692E-05           3.723E-04 7.555E-06  6.829E-07 -1.261E-06

Tot      3.927E-04 1.040E-04           3.919E-04 7.921E-06  6.045E-07 -1.116E-06

 Compare OLD/NEW cards
    169 :  48SC  G 1638.8     3 100.0   20E1+M2     +0.05    3                            <Old Card>
    169 :  48SC  G 1638.8     3 100.0   20E1+M2     +0.05    3      0.000391              <New Card>
    169 :  48SCS G NC+=0.00037 1$                                                         <New Card>
    169 :  48SCS G IPC=0.00037 1$                                                         <New Card>
```

BrIcc will also calculate the internal electron-positron pair formation coefficient.

To maintain downward compatibility, K, L, M, and NC+ are placed on one "S G" record. The components of NC+ are enumerated on a subsequent "S G" record.

§ LOGFT

Sample Terminal Dialog:

```
C:\Documents and Settings\Burrows\My Documents\Trieste2005\Model Exercises>c:\ensdf\logft
 LOGFT Version 7.2a [ 20-Mar-01]
 INPUT DATA SET FILE (data.tst):    gtol-example.ens
 OUTPUT REPORT FILE (logft.rpt):
 DATA TABLE (logft.dat): c:\ensdf\logft.dat
 OUTPUT DATA SET FILE (logft.new):
 Processing=====>152GD    152TB EC DECAY (17.5 H)
```

Report file:

```
1PROGRAM  L O G F T  VERSION 7.2a AS OF 20-Mar-2001.

                                                                                          10-Apr-2005
 152GD    152TB EC DECAY (17.5 H)        1971ZO05,1970AD05,1990TA1996NDS    199701
 152TB  P 0.0          2-                17.5 H    1              3850      15
 152GD  N 0.065      4  0.065   4 1.0      1.0
 152GD PN                                                                    3
 152GD  L 0.0          0+

                                      NO
0          TRANSITION(KEV)=    3850 15,                                          22   5, PARTIAL T1/2(SEC)=        2.9E5   7
                           LOG PARTIAL T1/2 =     5.46     10
                                             FIRST-FORBIDDEN-UNIQUE
                           LOG(F1/F0)  FOR ELECTRON CAPTURE =  1.744
                           LOG(F1/F0)  =   1.306 FOR BETAS, + OR -
                           APTURE TO POSITRON RATIO = 2.517E+00+- 5.15E-02        LOG(E/B+)=  0.401          K/B+= 2.107E+00
                           OSITRON INTENSITY = 6.26E+00+-  1.4E+00 ,         ELECTRON CAPTURE INTENSITY = 1.57E+01+-  3.6E+00 ,
```

LOGFT currently assumes 1.0 if NB is not given. NB **should** be given if known.

Branching and partial $T_{1/2}$ determined from P and N records and IB on B record or TI on E record.

"1U" in fields 78-9 of E record signals LOGFT to do this.

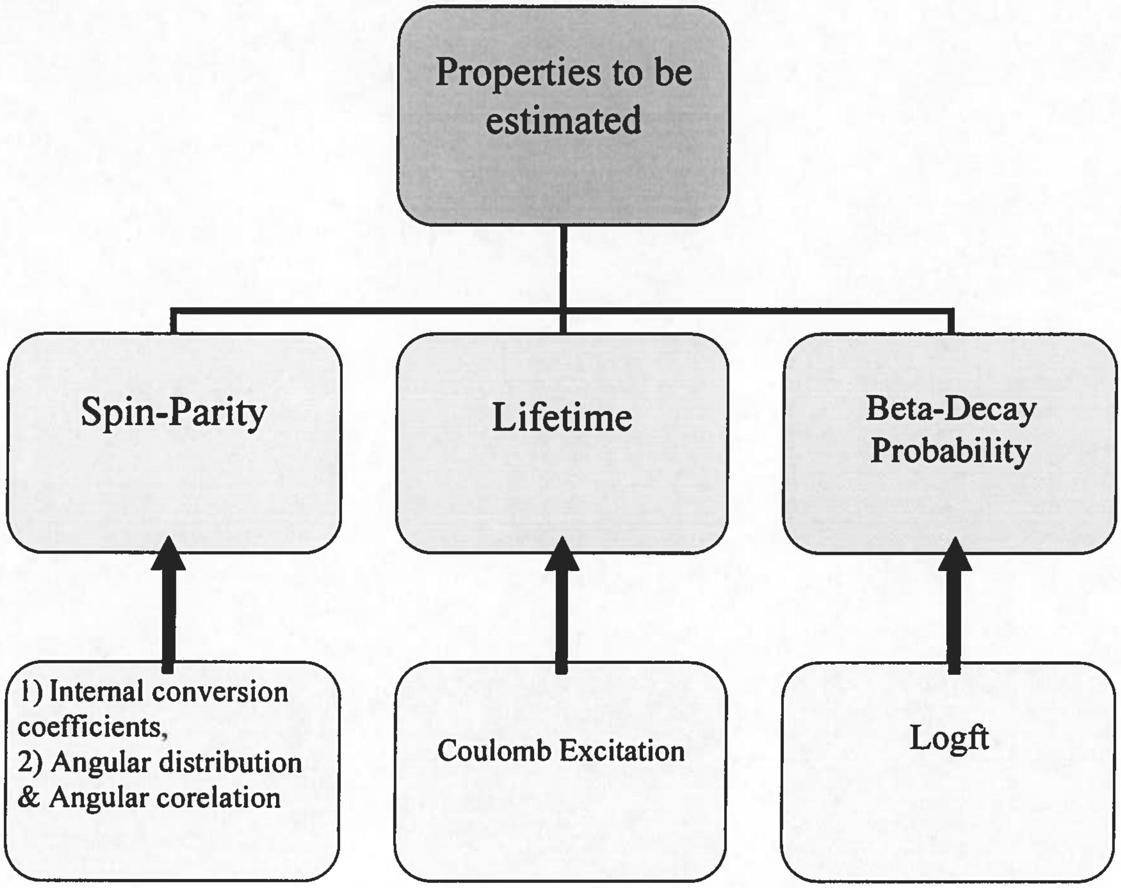
```
                    K/(EC+B+)=5.9917E-01+- 3.01E-03     L/(EC+B+)=9.0302E-02+- 4.70E-04     MNO/(EC+B+)=2.6206E-02+- 1.37E-04
                    E= 3850.00      LOG F1= 4.003+- 0.009
 LOG F1T =  9.460+- 0.099      F1T= 0.28827E+10
+                                        AVERAGE BETA(+-) ENERGY= 1275.06+-  6.667    EBAR/E =  0.4509

0152GD  E               6.2  18   16   4   9.46  10             22       5 A1U      OLD CARD
 152GD  E               6.3  14   16   4   9.46  10             22       5 A1U           NEW CARD
 152GDS E EAV=1275.1 67$CK=0.599 3$CL=0.0903 5$CM+=0.02621 14                            NEW CARD
 152GDS E EAV=1275 7 $CK=0.599 3 $CL=0.0903 5 $CM+=0.02621 14
+                                                                                                    CHECK OLD SECOND CARD
.
.
.
152GD  L 3573          (

0        TRANSITION(KEV                                                                 , PARTIAL T1/2(SEC)=       2.9E8 10
                    LOG
                    K/(EC+B+)=7.9158E-01+- 3.76E-03     L/(EC+B+)=1.6004E-01+- 2.78E-03     MNO/(EC+B+)=4.8371E-02+- 9.77E-04
                    E=  277.00      LOG F0=-0.309+- 0.057
 LOG F0T =  8.148+- 0.150      F0T= 0.14055E+09
0152GD  E                        0.022 7   8.15  15             0.022    7          OLD CARD
 152GD  E                        0.022 7   8.15  15             0.022    7               NEW CARD
```

Identifies transition as first-forbidden unique.

In this instance, TI could be safely removed and LOGFT would assume IE to be TI. Do not do this if there is a positron component.

Physics beyond ENSDF:

Up to this point what we have discussed is mainly a matrix of codes and arrays of numbers. Experimentally we can get as far as measuring the gamma ray intensities and energies only. But to infer the spin and parity of the concerning levels and even to draw the energy level diagram and to estimate the transition type we have to get to the basics of nuclear physics. In ENSDF the basic data come from experimental measurement and we verify the theoretical models with those. So during the evaluation of data as far as possible we extract physics from the experimental data as well as theoretical values to match them. Here I will explain some of the facts with an example.



TECHNIQUES

§ Internal Conversion Coefficients:

A nucleus can de-excite by emission of gamma ray photons. But there is an alternate process by which it transfers energy directly to an atomic electron and ejecting it. This process is called Internal Conversion.

Internal conversion coefficient α is defined as the ratio of no. of internal conversion electron and emitted gamma ray photons as;

$$\alpha = \frac{N_e}{N_\gamma}$$

Total conversion coefficient corresponding to emission of conversion electrons from K, L, M etc shells can be written as: $\alpha = \alpha_K + \alpha_L + \alpha_M + \ldots\ldots$

Measurement of α Gives Important Information About Multipolarity Of The EM Transition:

for EL transition:

$$\alpha_K(EL) = z^3 \left(\frac{e^2}{4\pi\varepsilon_0 \hbar c} \right)^4 \left(\frac{2m_e c^2}{\hbar\omega} \right)^{L+\frac{5}{2}}$$

for ML transition:

$$\alpha_K(ML) = z^3 \left(\frac{e^2}{4\pi\varepsilon_0 \hbar c} \right)^4 \left(\frac{2m_e c^2}{\hbar\omega} \right)^{L+\frac{3}{2}}$$

So we see internal conversion coefficient can be used to predict the transition type hence the spin parity of the corresponding nuclear state.

§ Angular Distribution & Angular Correlation:

Another technique to investigate the spin-parity of a nuclear state is by the method of angular distribution and angular corelation.

A classical electromagnetic field produced by oscillating charges and currents carries not only energy but angular momentum also. When we go to quantum limit, each emitted photon carries a definite angular momentum. The multipole operator of order L includes the factor $Y_{LM}(\theta,\phi)$ which is associated with angular momentum L. So a multipole of order L transfers an angular momentum $L\hbar$ per photon. Let us consider a γ transition from an initial angular momentum state $\mathbf{I_i}$ and parity π_i to a final state $\mathbf{I_f}$ and π_f where $\mathbf{I_i} \neq \mathbf{I_f}$. From conservation of angular momentum we can write: $\mathbf{I_i} = \mathbf{L} + \mathbf{I_f}$, where L ranges from $|I_i - I_f| \rightarrow |I_i + I_f|$ this gives the angular momentum selection rules. The parity selection rules are if $\Delta\pi = 0$, the transition will be either even parity electric transition or odd parity magnetic transition and if $\Delta\pi \neq 0$ the transition will be either odd parity electric transition or even parity magnetic transition .

Let us consider a dipole transition from $I_i = 1$ to $I_f = 0$. As shown below the initial state has three sublevels with $m_i = +1, 0, -1$ whereas the final state has only one sublevel $m_f = 0$.The angular distribution depends on the values of m_i and m_f . For $m_i = 0 \rightarrow m_f = 0$ transition the emission probability varies with $\sin^2\theta$ whereas for $m_i = \pm 1 \rightarrow m_f = 0$ transition the angular distribution varies as $\frac{1}{2}\left(1+\cos^2\theta\right)$. If $W(\theta)$ represents observed angular distribution then we have :

$$W(\theta) = \sum_{m_i} p(m_i) W_{m_i \rightarrow m_f}(\theta)$$

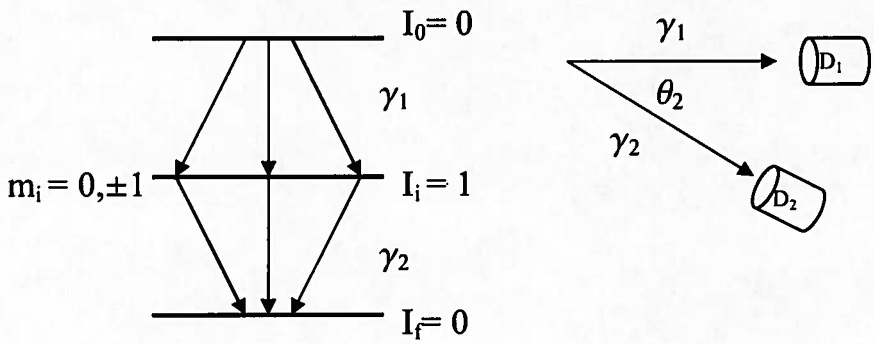
where $p\left(m_i\right)$ is the population of the initial state. Under normal circumstances all the states are equally probable i.e. $p(+1) = p(0) = p(-1)$

so that : $$W(\theta) \propto \frac{1}{3}\left[\frac{1}{2}\left(1+\cos^2\theta\right)\right] + \frac{1}{3}\left(\sin^2\theta\right) + \frac{1}{3}\left[\frac{1}{2}\left(1+\cos^2\theta\right)\right] = \text{constant}$$

As a result the angular distribution becomes spherically symmetric. There are two ways to create unequal populations $p\left(m_i\right)$ resulting in a useful $W(\theta)$.

(1) In the 1st method, we place the nuclei in a strong magnetic field, but at the same time we cool them to very low temperature, so low that the population are made unequal by the Boltzmann Distribution, $p(m_i) \propto e^{-m_i(\Delta E/kT)}$ .To have unequal populations the exponential must be different from one, resulting T~0.01 K. One thing must be noted that in this process we still cannot distinguish one component of the transition from the other, but we merely create a situation in which the various components contribute to the mixture with unequal weight.

(2) The second method consists of creating an unequal mixture of population $p(m_i)$ by observing a previous radiation. Let us assume for simplicity that the level $I_i = 1$ is populated from a level $I_0 = 0$, so that there is a cascade $0 \rightarrow 1 \rightarrow 0$ of two radiations γ_1 and γ_2.



Now if we observe the 1st radiation along a fixed axis say z axis then the 2nd radiation is observed at an angle θ_2 to the axis. With respect to the z axis the 1st radiation has the same angular distribution, i.e. for $m_o = 0$ to $m_i = 0$ the distribution is proportional to $\sin^2\theta_1$ and for $m_o = 0$ to $m_i = \pm 1$ to $\frac{1}{2}(1+\cos^2\theta_1)$. Since we define the z-axis by the direction of γ_1, then $\theta_1 = 0$ and so the $0 \rightarrow 0$ transition cannot be emitted in that direction. So the angular distribution of γ_2 with respect to γ_1 is:

$$W(\theta) \propto \frac{1}{2}\left[\frac{1}{2}\left(1+\cos^2\theta\right)\right] + 0\left(\sin^2\theta\right) + \frac{1}{2}\left[\frac{1}{2}\left(1+\cos^2\theta\right)\right]$$

$$\propto 1+\cos^2\theta$$

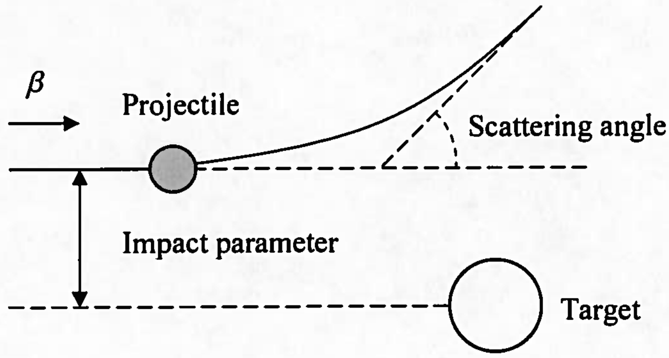
This type of experiment is called angular correlation.

In general angular distribution for multipole radiation is of the form of a polynomial in even powers of $\cos\theta$:

$$W(\theta)=1+\sum_{k=1}^{L} a_{2k}\cos^{2k}\theta$$

Experimentally we determine W and calculate the constant a's which when matched against standard values, the multipolarity and mixing ratio of the electromagnetic transition can be found out.

§ Coulomb Excitation:



Coulomb excitation is nothing but inelastic Coulomb scattering in which after the encounter the nucleus is left in an excited state from which it decays by emitting gamma rays. If we calculate the cross-section for EL transition, it comes out to be:

$$\sigma(EL)=\left(\frac{Ze}{4\pi\varepsilon_0\hbar v}\right)a^{-2L+2}B_{if}(EL)f(E,Z,\Delta E)$$

where E is the energy of the incident particle, and $\Delta E=E_\gamma$ is the excitation energy of the level. $f(E,Z,\Delta E)$ is a function which has been evaluated and are available in tabular forms. $B_{if}(EL)$ is the reduced transition probability. The magnetic transition probability is inhibited by a factor $\left(v/c\right)^2$ for the same multipole order L.

So we can calculate the life time of the nuclear state from the Coulomb excitation data.

§ Logft:

From the Fermi theory of β decay, we can arrive at the following expression of the decay probability:

$$\lambda=\frac{g^2c^4m_e^5}{2\pi^2h^7}\left|M_{if}^2\right|\int_0^{\eta_m}\left\{\sqrt{1+\eta_m^2}+\sqrt{1+\eta^2}\right\}\eta^2 d\eta \quad [\text{assuming coulomb correction term } F(Z,\eta)=\ 1]$$

$$\Rightarrow\lambda=\frac{g^2c^4m_e^5}{2\pi^2h^7}\left|M_{if}^2\right|f(\eta_m) \quad \textit{where } f(\eta_m)=\int_0^{\eta_m}\left\{\sqrt{1+\eta_m^2}+\sqrt{1+\eta^2}\right\}\eta^2 d\eta$$

assuming $\left|M_{if}^2\right|$ to be constant and putting $\lambda=\frac{\ln 2}{\tau}$, we get:

$$\frac{g^2c^4m_e^5}{2\pi^2h^7}\left|M_{if}^2\right|f(\eta_m)=\frac{\ln 2}{\tau}\Rightarrow f(\eta_m)\tau=\frac{2\pi^2h^7\ln 2}{g^2c^4m_e^5\left|M_{if}^2\right|}=\text{constant}$$

The product $f(\eta_m)\tau$ is called the comparative half-life of β decay. This term is of great importance. Small value of $f(\eta_m)\tau$ indicates large value of β decay probability and vice versa.

If the values of $\log_{10} f\tau$ is calculated for different β emitters, using the experimental values of P_m and τ then their values are found to be grouped in certain regions. For $\log_{10} f\tau$ 3 to 4, the β transitions are most probable, and they are called super allowed. For $\log_{10} f\tau$ 4.5 to 5, the β transitions are simply allowed. For $\log_{10} f\tau$ 7 to 9, the β transitions are 1^{st} forbidden. Higher $\log_{10} f\tau$ values give higher forbidden transitions.

By the LOGFT code described in this report which uses the radial wavefunctions, $\log_{10} f\tau$ can be calculated, making the prediction of β decay transition type and probability possible.

Applications of Data Evaluation Work:

(A) Nuclear Based Technologies:

We know that in these days nuclear-based technologies are used in many industrial applications both in developing and developed countries. Both, the development and maintenance of nuclear technologies rely on the availability of atomic, molecular and nuclear data to provide accurate numerical representations of the underlying physical processes. Essential data include energy-dependent reaction probabilities (cross sections), the energy and angular distributions of reaction products for many combinations of target and projectile, and the atomic and nuclear properties of excited states, and their radioactive decay data. Thus nuclear and atomic data are required to implement these technologies.

The Nuclear Data Section of the Division of Physical & Chemical Sciences (NAPC) within the IAEA Department of Nuclear Sciences & Applications (NA) is responsible for undertaking Agency activities in the related areas of the development and dissemination of atomic and nuclear data for applications.

Modern nuclear installations and nuclear instrumentation have reached a high degree of sophistication; their design and safe operation is only possible on the basis of accurate calculations using up-to-date nuclear constants, called nuclear and atomic data, as input. The amount of data needed for such calculations can be enormous. For example, for the calculation of the physical behaviour of the core of a research reactor and its safe operation, a collection of data for 130 nuclides with more than 10000 numbers in it must be used. Another set of data of about the same size is used to calculate the radioactive inventory build up in the reactor and to develop an optimal waste management strategy for the spent fuel of such a reactor.

Even more detailed data are required to design a modern nuclear reactor for electricity production and to make decisions on the fuel cycle for today and for the near future. This design must conform to the strict safety regulations and still remain cost effective. The requirements for the quality and accuracy of data for this purpose are very high.

Within the field of fission reactor technology, one can identify the following specializations that rely on the availability of accurate atomic and nuclear data:

- Fission reactor design
- Nuclear fuel cycles
- Nuclear safety
- Nuclear safeguards
- Reactor monitoring and fluence determination
- Waste disposal and transmutation

There are also many nuclear applications outside the field of fission reactor technology that require substantial data input:

- Accelerator shield design
- Fusion device design and plasma processing technologies
- Personnel dosimetry and radiation safety
- Production of radioisotopes for medical and industrial applications
- Cancer radiotherapy
- Radiation damage studies
- Environmental monitoring and clean-up
- Chemical analysis by activation methods

(B). Radiation Therapy:

Another common example of the application of nuclear techniques is radiation therapy of cancer patients. Only in the European Community countries there are more than 1 million new cases of cancer per year. About 18% of the patients are cured by radiotherapy. Different types of nuclear radiations, e.g. photons, electrons, neutrons and charged particles are used for this purpose. Accurate determinations of the dose delivered to a tumor and to the surrounding healthy tissue are crucial, and require extensive calibration calculations based on detailed and accurate atomic and nuclear data for the elements that comprise human tissue. The protection of medical personnel also requires the careful design of associated collimators and shields. According to an estimate, to minimize the damage to surrounding normal tissues, an accuracy of the dose delivery at the specified location should be better than 5%. Dose delivery with such precision requires comprehensive atomic, molecular and nuclear data.

(C). Standardization of Measurement Techniques:

Another important aspect is standardization of measurement techniques. The Nuclear Data Section maintains and updates several international standard data libraries. For example, in order to perform accurate measurements it is necessary to calibrate instruments. A specialist measuring environmental samples, performing activation analysis or other analytical measurements can immediately check the latest updates of standard data such as half-lives, energies of gamma rays etc., by logging on to the IAEA online database of X and gamma ray standards or by requesting the last version of data to be sent on diskette. This service is essential in supporting the high level of accuracy and consistency of measurements worldwide.

These are only a few of the many examples of the use of nuclear and atomic data.

(D) Application In Handling Radioactive Nuclides:

The knowledge of nuclear properties of the different atomic nuclei is of importance to the scientific and engineering community. The use and handling of radioactive nuclei requires very precise knowledge of nuclear properties of those nuclei. Some of the relevant nuclear properties are their energy levels, their decay mode and life times, the intensities of the emitted radiation, etc.

In places where those radioactive nuclei are used, like laboratories, hospitals, industries, it is of great importance to access to information that is up-to-date and relevant. The National Nuclear Data Center (NNDC) at BNL has such program to evaluate the experimental data of elements systematically in mass chains and publish them to be used by the community.

Conclusions

The goal of nuclear data evaluation work is:

- To build a set of critically evaluated properties of nuclides based on best known experimental information to date.
- To present best data available for each type of experiment
- To present best information for each nuclide
- To supply concise, consistent, and well-documented nuclear data to every potential user ranging from common user to medical professionals.

References

1) Evaluated Nuclear Structure Data File - A Manual for Preparation of Data Sets, Jagdish K. Tuli
2) Introductory Nuclear Physics – Kenneth S. Krane
3) The AME2003 Atomic Mass Evaluation (II) Tables, Graphs and References – G. Audi, A.H. Wapstra and C. Thibault
4) Experimental Nuclear Structure Part I – Filip G. Kondev, Lecture notes.
5) www.nndc.bnl.gov
6) Bibliographic Databases, Presentation for the ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Theory and Evaluation - T.W. Burrows
7) ENSDF Analysis and Utility Codes, Presentation for the ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Theory and Evaluation - T.W. Burrows
8) Nuclear Physics – S.N. Ghoshal
9) ENSDF Codes – Annotated Model Exercises for Distribution at the ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Theory and Evaluation - T.W. Burrows
10) www.sciencedirect.com
11) Perhaps the 75th Anniversary of Nuclear Data Evaluation - B. Singh and J. Roediger
12) Nuclear Structure and Decay Data: Introduction To Relevant Web Pages - T. W. Burrows, P. K. McLaughlin and A. L. Nichols
13) Citation Guidelines for Nuclear Data Retrieved from Databases Resident at the Nuclear Data Centers Network - Victoria McLane
14) Nuclear Physics: Principles and Applications – John Lilley

Part II

Adopted Levels

Q(β^-)=2680 *SY*; S(n)=4020 *SY*.
Δ(Q(β^-))=300, Δ(S(n))=420 (syst,2003Au03).
Assignment: Th(600-MeV p) mass separation 1997Bu03, 1987BoZP,1969Ha03 Fr K x rays following β^- decay (1987BoZP).
1991Cw01: Calculated excitation energy,equilibrium deformations.

^{225}Rn Levels

E(level)	Jπ	$T_{1/2}$	Comments
0.0	7/2-	4.66 min *4*	%β^-=100. μ=-0.696 *8*; Q=0.84. Jπ: spin measured (1988NeZZ). 7/2[743] orbital assignment from measured μ. See 1972El21 for calculated μ values. $T_{1/2}$: measurement of 1997Bu03;others 1969Ha03.

Comments Dataset for ^{225} *

Abstract: Nuclear structure data pertaining to ^{225}Fr have been evaluated, and incorporated into the ENSDF data file. This evaluation includes literature available by 13 May 2005 and supersedes the previous publication for ^{225}Fr (Y. A. Akovali, *Nuclear Data Sheets 60*, 617 (1990), literature cutoff date 1 June 1989). Data have been incorporated from the following references: 1987Co19, 1997Bu03 and 2003Au03. Extensive structure information on ^{225}Fr is now available from the detailed study of ^{225}Rn β^- decay by 1997Bu03.

Cutoff Date: Data received by 13 May 2005 have been evaluated.

General Policies and Organization of Material: See the introductory pages.

Acknowledgments: The evaluator thanks the reviewer of this nuclide for constructive comments.

* This work was supported by the Director, Office of Science, Office of Nuclear Physics of the U.S. Department of Energy under contract DE-AC03-76SF00098.

Adopted Levels, Gammas

Q(β⁻)=1820 *30*; S(n)=5914 *58*; S(p)=5915 *SY*; Q(α)=4576 *SY* 2003Au03.
Uncertainties in S(p) and Q(α) are 300 and 200, respectively (2003Au03).
Assignment: Th(600-MeV p) mass separation (1969Ha03,1975We23).
For discussions of the nuclear structure of ^{225}Fr see, for example, 1987Sh24, 1988Le13, 1991Cw01 and 2000Sh32.

^{225}Fr Levels

Cross Reference (XREF) Flags

A ^{225}Rn β⁻ Decay
B ^{226}Ra(t,α)

E(level)†	Jπ	XREF	$T_{1/2}$	Comments
0.0‡	3/2-	AB	3.95 min *14*	%β⁻=100. μ=1.07 *2*; Q=1.32 *5*. Δ<r²>(^{212}Fr,^{225}Fr)=1.34862 *22* (1987Co19); the uncertainty indicated is statistical only; a systematic uncertainty of the order of a few percent is expected (1987Co19). μ, Q: from atomic beam LASER spectroscopy (1985Co24,1989Ra17). Sternheimer correction applied for Q. See 1987Co19 for further discussion and anlysis. See 1988Le13 for calculated μ and Q values. Jπ: spin measured (atomic beam; 1985Co24). Nilsson orbital from cross section fingerprint in (t,α) for 0, 29, 83, 128 levels, supported by measured μ value. See 1986Ek02, 1997Bu03, and 1988Le13 for discussions. $T_{1/2}$: weighted average of 3.9 min *2* (1969Ha03), 4.0 min *2* (1983Ny01).
28.53‡ *3*	5/2-	AB		Jπ: from cross section fingerprint in (t,α) for 0, 29, 83, 128 levels; supported by M1+E2 29γ to 3/2- g.s.
82.50‡ *3*	7/2-	AB		Jπ: from cross section fingerprint in (t,α) for 0, 29, 83, 128 levels; supported by E2 83γ to 3/2- g.s., M1+E2 54γ to 5/2- 29 level.
128.06‡ *4*	9/2-	AB		Jπ: from cross section fingerprint in (t,α) for 0, 29, 83, 128 levels; supported by E2 99γ to 5/2- 29 level.
142.60§ *5*	(3/2)+	AB		Jπ: E1 143γ to 3/2-; E1 114γ to 5/2- 29 level.
151.61§ *3*	5/2+	A		E1 152γ to 3/2-; E1 69γ to 7/2- 83 level.
181 *3*	(1/2+)	B		Jπ: tentative value based on comparison of experimental σ(t,α) with DWBA calculation assuming this is the 1/2[400] bandhead. Assignment supported by comparison with (t,α) population of levels in neighboring odd-A Fr isotopes.
181.64§ *4*	(9/2)+	A		Jπ: E1 99γ to 7/2- 83 level; 99γ to 9/2- 128 level; band assignment.
198.22§ *4*	(7/2)+	A		Jπ: E1 169.7γ to 5/2- 29 level; E1 115.8γ to 7/2- 83 level; band assignment.
203.37# *4*	(9/2)-	Ab		XREF: b(205). Jπ: M1+E2 121γ to 7/2- 83 level; E2 175γ to 5/2- 29 level; band assignment.
205@ *3*	(3/2+)	B		XREF: B(205).
207.19# *3*	(5/2)-	Ab		XREF: b(205). Jπ: M1+E2 179γ to 5/2-29 level; M1+E2 207γ to 3/2- g.s.; band assignment.
228.34 *5*	(7/2,9/2)-	A		Jπ: M1+E2 146γ to 7/2- 83 level; (E1) 47γ to (9/2)+ 182 level.
241.36@a *4*	(5/2)+	AB		XREF: B(244). Jπ: M1 90γ to 5/2+ 152 level; (E1) 241γ to 3/2- g.s.; band assignment.
293.24@ *5*	(7/2)+	AB		Jπ: M1 95γ to (7/2)+ 198 level; E1 265γ to 5/2- 29 level; 165γ to 9/2- 128.
303.23 *6*	7/2+,9/2+,11/2+	A		Jπ: E1 175γ to 9/2- 128 level.
330.16 *4*	(5/2,7/2)-	AB		Jπ: E1 131γ to (7/2)+ 198 level; 330γ to 3/2- g.s.
346.05@ *4*	(9/2)+	A		Jπ: M1+E2 164γ to 9/2+ 182 level; 264γ to 7/2- 83 level; band assignment.
401 *3*		B		
409.03 *4*	(5/2)+	A		Jπ: M1(+E2) 210γ to (7/2)+ 198; M1+E2 257γ to 5/2+ 152; 409γ to 3/2- g.s.
424.96 *9*	(5/2-,7/2-)	A		Jπ: gammas to 3/2- g.s. and 9/2- 128 level.
≈448		B		
480.07 *4*	(5/2,7/2,9/2)+	A		Jπ: M1+E2 187γ to (7/2)+ 293 level.

Continued on next page (footnotes at end of table)

From NNDC(BNL)
program ENSDAT

Adopted Levels, Gammas (continued)

^{225}Fr Levels (continued)

E(level)†	Jπ	XREF	Comments
502.93ª 6	(5/2)-	AB	XREF: B(500). Jπ: M1 296γ to (5/2)- 207 level; 360γ to (3/2)+ 143 level; 305γ to (7/2)+ 198 level.
559.69# 4	7/2-	A	Jπ: M1 531γ to 5/2- 29 level; M1 431γ to 9/2- 28 level.
571.48ª 6	(7/2)-	AB	XREF: B(570). Jπ: M1 364γ to (5/2)- 207 level; 390γ to (9/2)+ 182 level.
591 3		B	
619.00 7	(5/2,7/2,9/2)+	A	Jπ: M1 420γ to (7/2)+ 198 level.
≈630		B	
635.67 7	(3/2,5/2,7/2)+	A	Jπ: M1 484γ to 5/2+ 152 level; possible 636γ to 3/2- g.s.
655 3		B	
665.11 5	(7/2)+	A	Jπ: M1 484γ to (9/2)+ 182 level; M1 423γ to (5/2)+ 241.
676 3		B	
721.05& 6	(5/2)-	A	Jπ: M1 721γ to 3/2- g.s.; M1 693γ to 5/2- 29; weak, doubly-placed M1 639γ to 7/2- 82 level disfavors J=3/2.
744.25ª 6	(5/2,7/2)+	AB	XREF: B(741). Jπ: M1 335γ to (5/2)+ 409 level; M1 546γ to (7/2)+ 198 level.
754.23 9		A	Jπ: 602γ to 5/2+ 152 level; possible 573γ to (9/2)+ 182 level; possible 551γ to (9/2)- 203 level.
778.63& 4	7/2-	A	Jπ: M1 750γ to 5/2- 29; M1 696γ to 7/2- 83 level; doubly-placed M1 651γ to 9/2- 128 level.
799 3		B	
832.09 8	(5/2+,7/2,9/2+)	A	Jπ: 681γ to 5/2+ 152 level; 651γ to (9/2)+ 182.
839.04 9	(5/2,7/2,9/2)+	A	Jπ: M1 536γ to 7/2+,9/2+,11/2+ 303 level.
845 3		B	
865.66 5	(7/2)-	A	Jπ: M1 658γ to (5/2)- 207 level; M1 738γ 9/2- 128 level.
885.94ª 5	(3/2,5/2)+	AB	XREF: B(882). Jπ: M1(+E2) 743γ to (3/2)+ 143 level; 858γ to 5/2- 29.
935.91 15	(5/2-,7/2,9/2+)	A	Jπ: 808γ to 9/2- 128 level; 784γ to 5/2+ 152 level.
974 3		B	
979.67 7	(3/2-,5/2)	A	Jπ: 980γ to 3/2- g.s.; 837γ to (3/2)+ 143; 408γ to (7/2)- 572.
1028 3		B	
1047.32 6		AB	Jπ: 1047γ to 3/2- g.s.; 896γ to 5/2+ 152 level.
1063.02 7		A	Jπ: 881γ to (9/2)+ 182.
1101.83 9	(7/2,9/2,11/2)+	A	Jπ: M1 920γ to (9/2)+ 182 level.
1127 3		B	
1185.15 6	(5/2-,7/2)	A	Jπ: 1034γ to 5/2+ 152; 982γ to (9/2)- 203; 978γ to (5/2)- 207.
1225.94ª 8		AB	XREF: B(1229). Jπ: 1144γ to 7/2- 83; 1045γ to (9/2)+ 182.
≈1247		B	
1321 3		B	
1351 3		B	
1392.13 8	(5/2,7/2-)	A	Jπ: 1392γ to 3/2- g.s.; 1194γ to (7/2)+ 198; 821γ to (7/2)- 572.
1398 3		B	
1479.55ª 5	(7/2)	AB	XREF: B(1477). Jπ: 1451γ to 5/2- 29; 1351γ to 9/2- 128; 1298γ to (9/2)+ 182; 1070γ to (5/2)+ 409.
1519.60ª 11		AB	XREF: B(1516). Jπ: 1337γ to (9/2)+ 182; 960γ to 7/2- 560 level.
1526.03 12		A	Jπ: 1498γ to 5/2- 29.
≈1535		B	
1577.92 7	(5/2+,7/2)	A	Jπ: 1232γ to (9/2)+ 346 level; 1549γ to 5/2- 29 level; 1169γ to (5/2)+ 409 level.
1614.21 8	(5/2,7/2+)	A	Jπ: 1471γ to (3/2)+ 143; 1416γ to (7/2)+ 198; 1385γ to (7/2,9/2)- 228 level.
1655.32 6	(5/2,7/2+)	A	Jπ: 1513γ to (3/2)+ 143; 1457γ to (7/2)+ 198; 1095γ to 7/2- 560 level.
1749.73 6	(5/2,7/2+)	A	Jπ: 1667γ to 7/2- 83; 1607γ to (3/2)+ 143; 1551γ to (7/2)+ 198 level.

† From (t,α) for levels observed in (t,α) only; uncertainties vary between 1 and 3 keV, but evaluator has assigned 3 keV for all energies adopted from (t,α). All other level energies are from least-squares adjustment of Eγ, omitting 136.0γ, 668.05γ and 1421.0γ, each of which fits its placement very poorly (at least 5σ from least-squares adjusted value), and all unresolved or multiply-placed lines.

‡ (A): π 3/2[532] band (1997Bu03). Coriolis mixed with 1/2[541] band (1997Bu03). Assignment based on (t,α) reaction cross section fingerprint.

§ (B): π 3/2[651] band (1997Bu03). Coriolis mixed with 1/2[660] band. K=3/2 assignment based on relative E1 branching from J=5/2, 7/2, 9/2 band members to levels in g.s. band (Alaga rule).

(C): possible π 1/2[541] mixed band (1997Bu03). Supported by γ decay patterns assuming a 3/2[532] band admixture.

Footnotes continued on next page

Adopted Levels, Gammas (continued)

^{225}Fr Levels (continued)

@ (D): possible π 3/2[402] band (1997Bu03). Coriolis mixed with J>1/2 members of 1/2[660] and 1/2[400] bands. Assignment supported by (t,α) cross section fingerprint.

& (E): Kπ=5/2− band (1997Bu03). possible configuration: π 5/2[523]. K=5/2 assignment based on comparison between Alaga rules and observed branching ratios for strong M1 transitions from J=5/2 and 7/2 band members to g.s. band levels. Supported by strong β^- branch from 7/2[743] ^{225}Rn parent to J=7/2 band member.

a It is questionable whether the (t,α) reaction excites this level or a separate level with comparable energy.

γ(^{225}Fr)

E(level)	Eγ†	Iγ†	Mult.†	δ†	α	Comments
28.53	28.51 5	100	M1+E2	0.45 15	750 270	δ: values measured in β^- decay are 0.32 2 and 0.44 2, but intensity balance at the 28 level in β^- decay implies δ≥0.6.
82.50	53.93 5	100 6	M1+E2	0.18 3	22.8	
	82.55§ 5	38§ 10	E2		22.1	
128.06	45.5 1	21 3	[M1]		29.6	
	99.4§ 1	100§ 33	E2		9.2	
142.60	114.03 5	28.7 15	E1		0.349	
	142.60@ 5	100@ 5	E1		0.202	
151.61	69.12 5	13.6 7	E1		0.291	
	123.06 5	45.3 23	E1		0.290	
	151.65 5	100.0	E1		0.174	
181.64	30.0#	0.0089#	[E2]		2990	
	53.6§ 1	2.0§ 7	[E1]		0.576	
	99.15 5	100 13	E1		0.111	
198.22	46.6@ 1	0.64@ 21	[M1]		27.6	
	70.15 5	5.8 3	[E1]		0.280	
	115.75 5	12.4 7	E1		0.337	
	169.73 5	100 6	E1		0.132	
203.37	21.72 10	8.8 19	[E1]		6.37	
	120.83 5	100 5	M1+E2		6.4 24	
	174.90§ 10	72§ 22	E2		0.92	
207.19	64.6 1	2.7 5	[E1]		0.349	
	178.66 5	100 5	M1+E2	1.47 +18−14	1.50 12	
	207.21 5	36.0 19	M1+E2	1.4 +4−3	0.98 17	
228.34	46.6@ 1	25.0@ 17	(E1)		0.84	
	145.80 5	100 5	M1+E2		3.5 17	
241.36	89.7§ 1	26§ 3	M1		4.08	
	212.85 5	52 3	(E1)		0.0766	
	241.34 5	100 5	(E1)		0.0569	
293.24	94.9§ 1	4.8§ 10	M1		3.47	
	141.65@ 10	2.4@ 10	[M1]		5.61	
	165.20 5	87 4	[E1]		0.141	
	264.67 5	100 5	E1		0.0459	
303.23	175.17 5	100	E1		0.122	
330.16	126.80 10	35.4 19	[M1,E2]		5.5 22	
	131.84§ 10	100§ 5	E1		0.245	
	247.60 5	89 4	[M1,E2]		0.7 5	
	301.5 2	11.9 19	[M1,E2]		0.4 3	
	330.10 10	40.5 20	[M1,E2]		0.32 21	
346.05	104.72 10	10.5 20	[E2]		7.52	
	142.60@ 10	26@ 3	[E1]		0.202	
	147.96 10	22 4	M1,E2		3.4 16	
	164.41 5	52 3	M1+E2		2.4 13	
	263.56 5	100 5				
409.03	202.02 5	78 4	[E1]		0.087	Measured multipolarity (β^- decay) is M1, inconsistent with this placement.
	210.70§ 10	24§ 3	M1(+E2)		1.1 7	
	257.38 5	100 5	M1+E2		0.6 4	
	326.47& 10	<84&				
	409.1 2	28 4				
424.96	296.80 10	100 5	[M1+E2]		0.4 3	
	424.9 2	12.0 23				

Continued on next page (footnotes at end of table)

From NNDC(BNL) program ENSDAT

Adopted Levels, Gammas (continued)

$\gamma(^{225}Fr)$ (continued)

E(level)	Eγ†	Iγ†	Mult.†	α
480.07	71.16 10	21.2 24	[M1]	8.01
	186.6§ 3	21§ 4	M1+E2	1.6 10
	251.65 10	12.6 13		
	298.35 10	100 5	[M1]	0.696
502.93	295.55 10	100 8	M1	0.714
	299.6 2	17 3	[E2]	0.148
	304.7 2	19.2 23		
	351.3§ 2	38§ 9		
	360.45 10	57 6		
	503.00& 10	<52&		
559.69	229.45 5	16.8 8	M1	1.44
	318.32 10	20.7 10		
	352.30 10	100 5	M1	0.442
	356.30 10	52.4 26	M1	0.429
	361.55 10	11.1 7		
	378.05 10	20.7 10		
	408.10@ 10	22.7@ 16		
	431.63 10	12.6 13	M1	0.255
	476.9& 2	<6.7&		
	531.10 10	58 3	M1	0.147
571.48	364.10 10	91 5	M1	0.404
	368.2 2	30 3	[M1]	0.392
	373.40 10	78 4		
	389.90 10	44 3		
	419.8§ 2	100§ 11		
	543.05 10	47 4		
619.00	273.07 10	46 4	[M1,E2]	0.5 4
	288.80 10	100 6		
	420.15§ 20	75§ 18	M1	0.274
635.67	394.50 10	41 4		
	483.80@ 10	100@ 14	M1	0.188
	635.60& 10	<72&		
665.11	105.29 10	34 4	[E1]	0.425
	256.20 10	20.9 21		
	423.65 10	59 3	M1	0.268
	461.55 10	26.0 23		
	466.90 10	62 4	M1	0.207
	483.80@ 10	100@ 7	M1	0.188
	537.15& 10	<61&		
721.05	240.6§ 3	1.3§ 4	[E1]	0.0573
	514.2 2	10.5 17	M1	0.160
	517.8 2	2.0 5		
	638.50& 10	<6.7&	M1	0.090
	692.60 10	42.5 21	M1	0.0728
	721.10 10	100 5	M1	0.0655
744.25	335.45 10	52.0 26	M1	0.505
	398.5 2	23 5		
	414.1& 2	<22&		
	451.00 10	44 3		
	503.00& 10	<54&		
	537.15& 10	<85&		
	545.85@ 10	100@ 4	M1	0.137
	562.50 10	20 6		
	600.9 2	33 4		
754.23	136.06 5	100 5		
	551.10& 10	47& 4		
	572.70& 10	97& 11		
	602.2 2	25 4		
778.63	218.60 10	0.86 6	[M1,E2]	1.0 7
	275.65 10	0.54 6	[M1]	0.87
	369.65 10	1.58 9		
	432.54 10	2.56 19		
	448.65 10	2.56 14		

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

γ(^{225}Fr) (continued)

E(level)	Eγ[†]	Iγ[†]	Mult.[†]	α
778.63	537.15[&] *10*	<1.98[&]		
	571.40 *10*	12.7 *6*	M1	0.121
	627.10 *10*	4.37 *23*		
	650.65[@] *10*	12.1[@] *7*	M1	0.086
	696.20 *10*	70 *3*	M1	0.0718
	750.15 *10*	100 *5*	M1	0.0591
	778.70 *10*	5.9 *3*		
832.09	486.1 *2*	93 *27*		
	590.6 *2*	38 *7*		
	634.0 *2*	41 *6*		
	650.65[@] *10*	100[@] *17*		
	680.9 *2*	54 *6*		
839.04	203.4[§] *3*	14[§] *4*	[M1,E2]	1.3 *8*
	414.1[&] *2*	<15.1[&]		
	535.80 *10*	100 *6*	M1	0.144
	545.85[@] *10*	28[@] *3*	M1	0.137
	635.60[&] *10*	<37[&]		
	640.8 *2*	21 *7*		
	711.0 *2*	23.5 *24*		
	756.70[&] *10*	<36[&]		
	839.2[&] *2*	<55[&]		
865.66	362.75 *10*	5.2 *4*	[M1]	0.408
	562.50 *10*	3.9 *8*		
	572.70[&] *10*	<13.2[&]		
	624.3 *2*	3.5 *4*		
	658.30 *10*	18.4 *10*	M1	0.0832
	662.30 *10*	20.7 *13*		
	668.05[‡] *10*	8.2 *4*		
	683.9 *2*	4.4 *5*		
	714.00 *10*	7.7 *4*		
	723.00 *10*	22.0 *10*		
	737.70 *10*	25.4 *13*	M1	0.0617
	783.40 *10*	18.7 *10*	M1	0.0527
	837.00[@] *10*	100[@] *6*	M1	0.0444
	866.0[&] *2*	<3.4[&]		
885.94	141.65[@] *10*	8[@] *6*	[M1,E2]	3.9 *18*
	326.47[&] *10*	<51[&]		
	405.6 *2*	44 *5*		
	476.9[&] *2*	<20.2[&]		
	644.40 *10*	27.8 *23*		
	679.1[&] *2*	<13.1[&]		
	734.40 *10*	55 *3*		
	743.35 *10*	100 *5*	M1(+E2)	0.038 *23*
	857.5 *2*	23 *3*		
	885.85 *10*	58 *3*		
935.91	605.6 *2*	100 *14*		
	784.0[§] *2*	[§]		
	808.0 *2*	79 *11*		
979.67	408.10[@] *10*	34[@] *7*		
	828.05 *10*	27 *3*		
	837.00[@] *10*	100[@] *25*		
	951.00 *10*	55 *3*		
	979.6 *2*	14.1 *20*		
1047.32	292.80 *10*	13.0 *19*		
	326.47[&] *10*	<97[&]		
	638.50[&] *10*	<59[&]		
	806.2 *2*	40 *3*		
	866.0[&] *2*	<24[&]		
	895.7 *2*	100 *15*		
	1047.32 *10*	77 *5*		
1063.02	127.31[&] *10*	<52[&]		
	308.8 *2*	27 *3*		
	397.6 *2*	39 *7*		

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

γ(^{225}Fr) (continued)

E(level)	Eγ†	Iγ†	Mult.†	α
1063.02	427.65 *10*	100 *6*		
	759.6 *2*	58 *6*		
	834.6 *2*	47 *8*		
	855.5& *2*	<35&		
	859.2 *2*	35 *5*		
	864.5 *2*	86 *6*		
	881.40 *10*	95 *6*		
1101.83	808.0 *2*			
	899.0 *2*	15.7 *17*		
	903.2 *2*	18 *5*		
	920.30 *10*	100 *5*	M1	0.0347
1185.15	319.61 *10*	37.5 *19*		
	566.3 *2*	23 *3*		
	705.10 *10*	81 *4*		
	839.2& *2*	<50&		
	855.5& *2*	14& *3*		
	891.7 *2*	29.1 *25*		
	978.1 *2*	16.0 *25*		
	981.5 *2*	29 *3*		
	1033.5 *2*	100 *5*		
	1102.55 *10*	41 *3*		
1225.94	472.1& *2*	<27&		
	801.0 *2*	39 *4*		
	1027.4 *2*	39 *8*		
	1044.7 *2*	24 *5*		
	1143.65 *10*	100 *6*		
1392.13	412.30 *10*	65 *6*		
	727.4 *2*	44 *6*		
	756.70& *10*	<79&		
	821.1 *2*	41 *7*		
	1194.1 *2*	100 *9*		
	1363.3 *2*	70 *6*		
	1392.0 *2*	35 *7*		
1479.55	758.5 *2*	16.7 *23*		
	814.1 *2*	20.9 *25*		
	999.5 *2*	22.9 *22*		
	1070.48 *10*	39 *3*		
	1176.2 *2*	16.0 *24*		
	1281.3 *2*	17.1 *23*		
	1298.03 *10*	83 *4*		
	1328.1@ *2*	84@ *11*		
	1337.40@ *10*	34@ *11*		
	1351.40 *10*	63 *4*		
	1397.00 *10*	28.7 *24*		
	1451.16 *10*	100 *6*		
1519.60	127.31& *10*	<40&		
	472.1& *2*	<26&		
	798.7& *2*	<40&		
	959.8 *2*	22 *4*		
	1173.3 *2*	48 *6*		
	1226.7 *2*	25 *5*		
	1321.4 *2*	49 *4*		
	1337.40@ *10*	100@ *20*		
1526.03	1195.7 *2*	83 *17*		
	1328.1@ *2*	100@ *33*		
	1374.6& *2*	<55&		
	1443.2 *2*	49 *7*		
	1498.0 *2*	69 *7*		
1577.92	798.7& *2*	<28&		
	942.8 *2*	14.6 *25*		
	1017.6 *2*	23 *4*		
	1169.2 *2*	36 *3*		
	1232.2 *2*	20 *3*		

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 $^{225}_{87}\mathrm{Fr}_{138}$-7

Adopted Levels, Gammas (continued)

γ(^{225}Fr) (continued)

E(level)	Eγ[†]	Iγ[†]
1577.92	1374.6[&] *2*	<22.9[&]
	1495.30 *10*	100 *6*
	1549.3 *2*	22 *3*
1614.21	388.50 *10*	100 *5*
	551.10[&] *10*	<72[&]
	679.1[&] *2*	<38[&]
	948.9 *2*	62 *6*
	1111.2 *2*	32 *12*
	1385.3 *2*	55 *6*
	1416.3 *2*	50 *4*
	1471.2 *2*	45 *8*
1655.32	470.2 *2*	27 *6*
	823.40 *10*	84 *5*
	876.7 *2*	43 *6*
	901.8 *2*	38 *10*
	990.0 *2*	35 *4*
	1019.40 *10*	100 *8*
1655.32	1095.1 *2*	41 *8*
	1229.9 *2*	32 *6*
	1457.10 *10*	62 *8*
	1504.4 *2*	59 *5*
	1512.8 *2*	63 *6*
	1626.8 *2*	26 *4*
1749.73	702.40 *10*	26 *3*
	917.4 *2*	11.4 *22*
	1028.8 *2*	26 *5*
	1084.2 *2*	22 *3*
	1130.9 *2*	17 *6*
	1421.0[‡] *2*	18.6 *18*
	1508.6 *2*	27.0 *24*
	1551.4 *2*	29.2 *24*
	1568.10 *10*	100 *6*
	1607.3 *3*	12.2 *13*
	1667.4 *2*	29.8 *22*

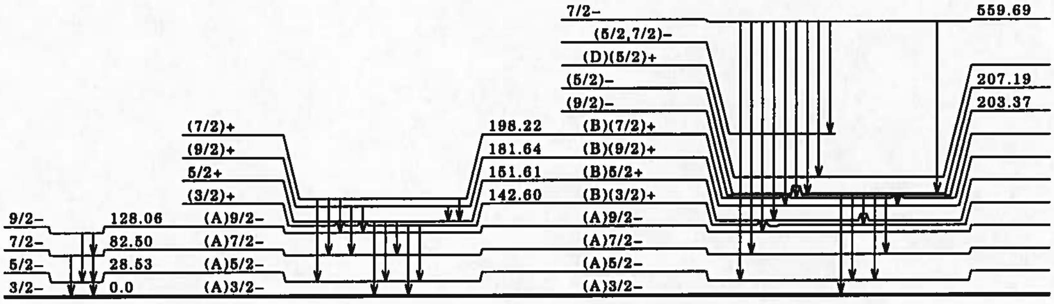
† From ^{225}Rn β^- decay.
‡ Eγ values for 136.0γ, 668.05γ and 1421.0γ are at least 5σ from expected least-squares adjusted value for placements indicated.
§ Peak obscured or unresolved in singles spectrum; most of information was obtained from coincidence experiments.
\# Transition not observed, but its existence and total intensity was deduced from coincidences between lines feeding the 182 level and those depopulating the 152 and 182 levels in β^- decay.
@ Multiply placed; intensity suitably divided.
& Multiply placed; undivided intensity given.

Adopted Levels, Gammas (continued)

(A) π 3/2[532] band (1997Bu03).

(B) π 3/2[651] band (1997Bu03).

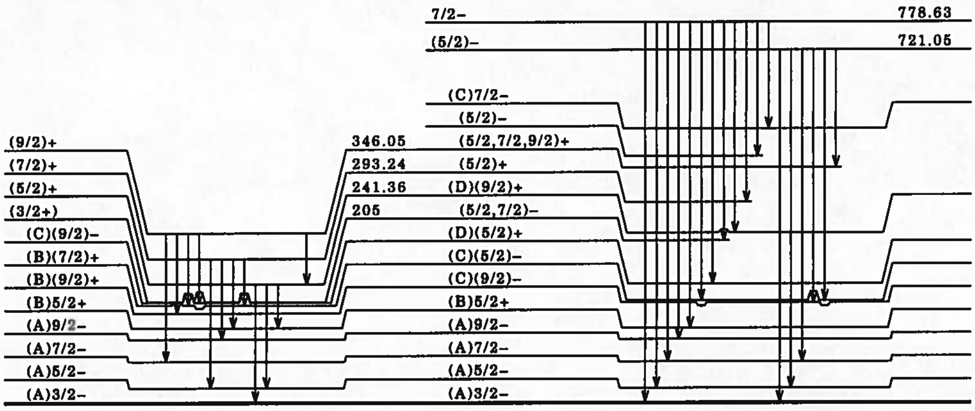
(C) possible π 1/2[541] mixed band (1997Bu03).



$^{225}_{87}Fr_{138}$

(D) possible π 3/2[402] band (1997Bu03).

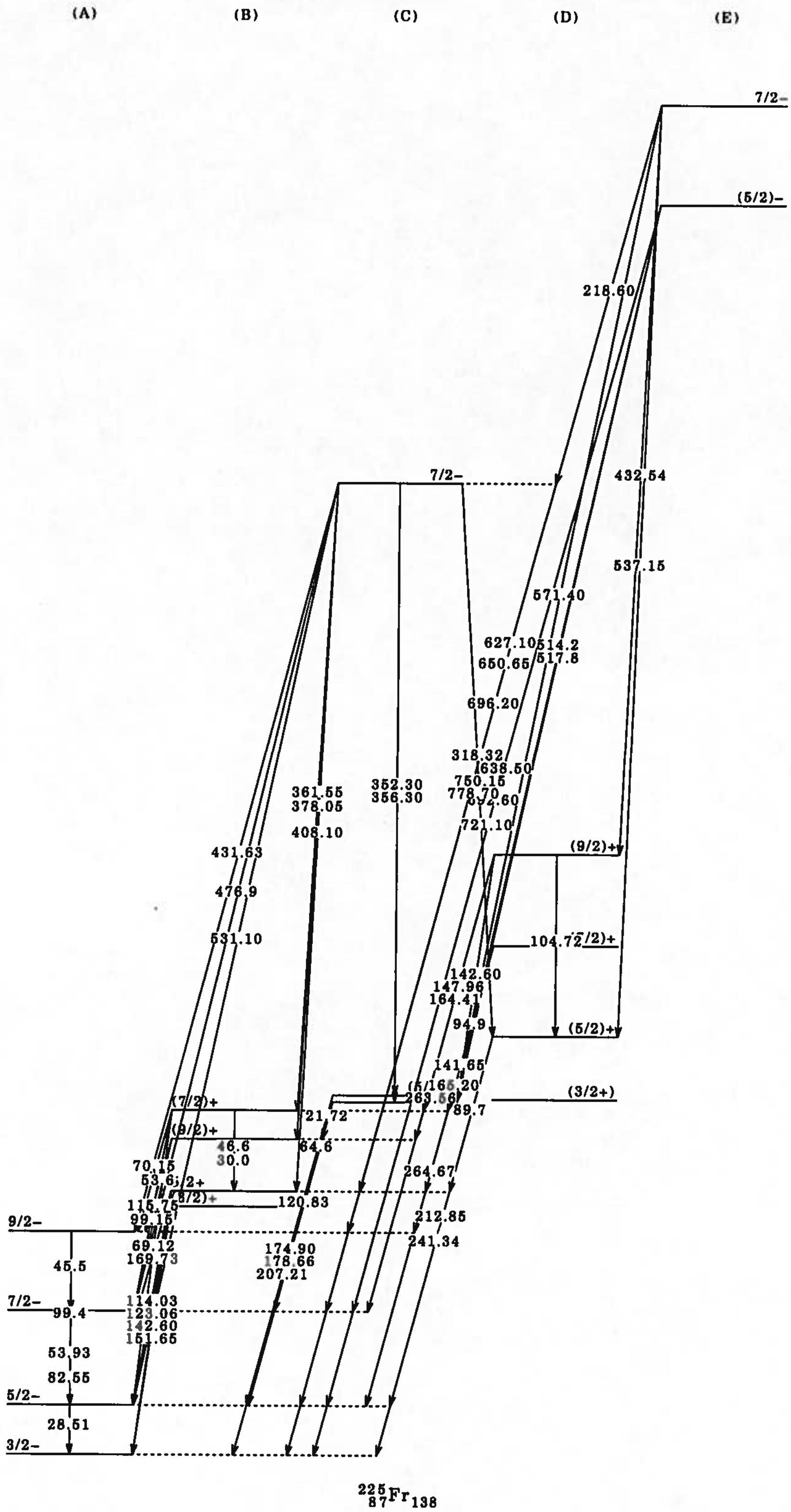
(E) Kπ=5/2− band (1997Bu03).



$^{225}_{87}Fr_{138}$

Adopted Levels, Gammas (continued)

Bands for ^{225}Fr

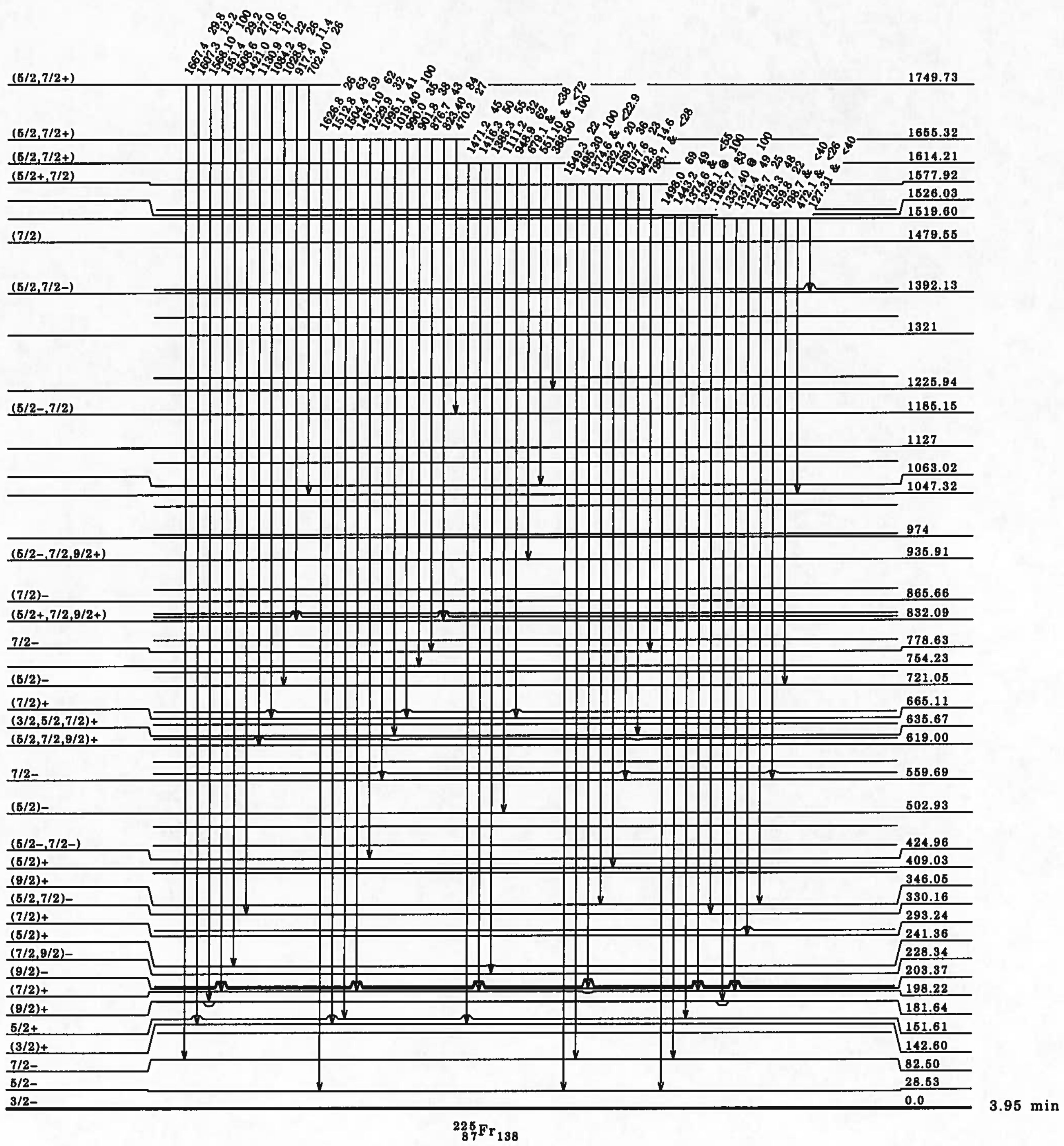


From NNDC(BNL) program ENSDAT

Adopted Levels, Gammas (continued)

Level Scheme

Intensities: relative photon branching from each level
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

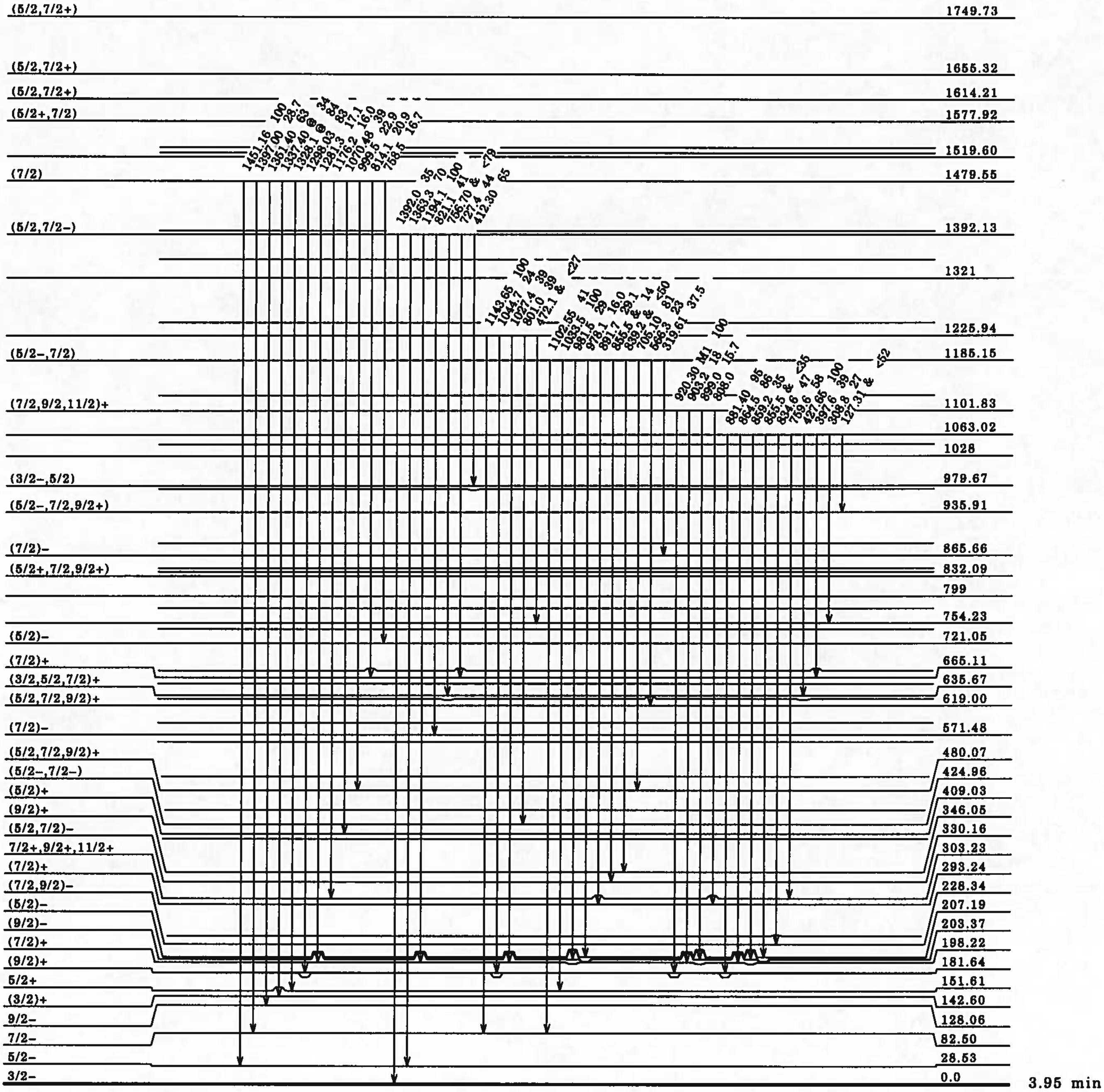


From NNDC(BNL)
program ENSDAT

Adopted Levels, Gammas (continued)

Level Scheme (continued)

Intensities: relative photon branching from each level
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given



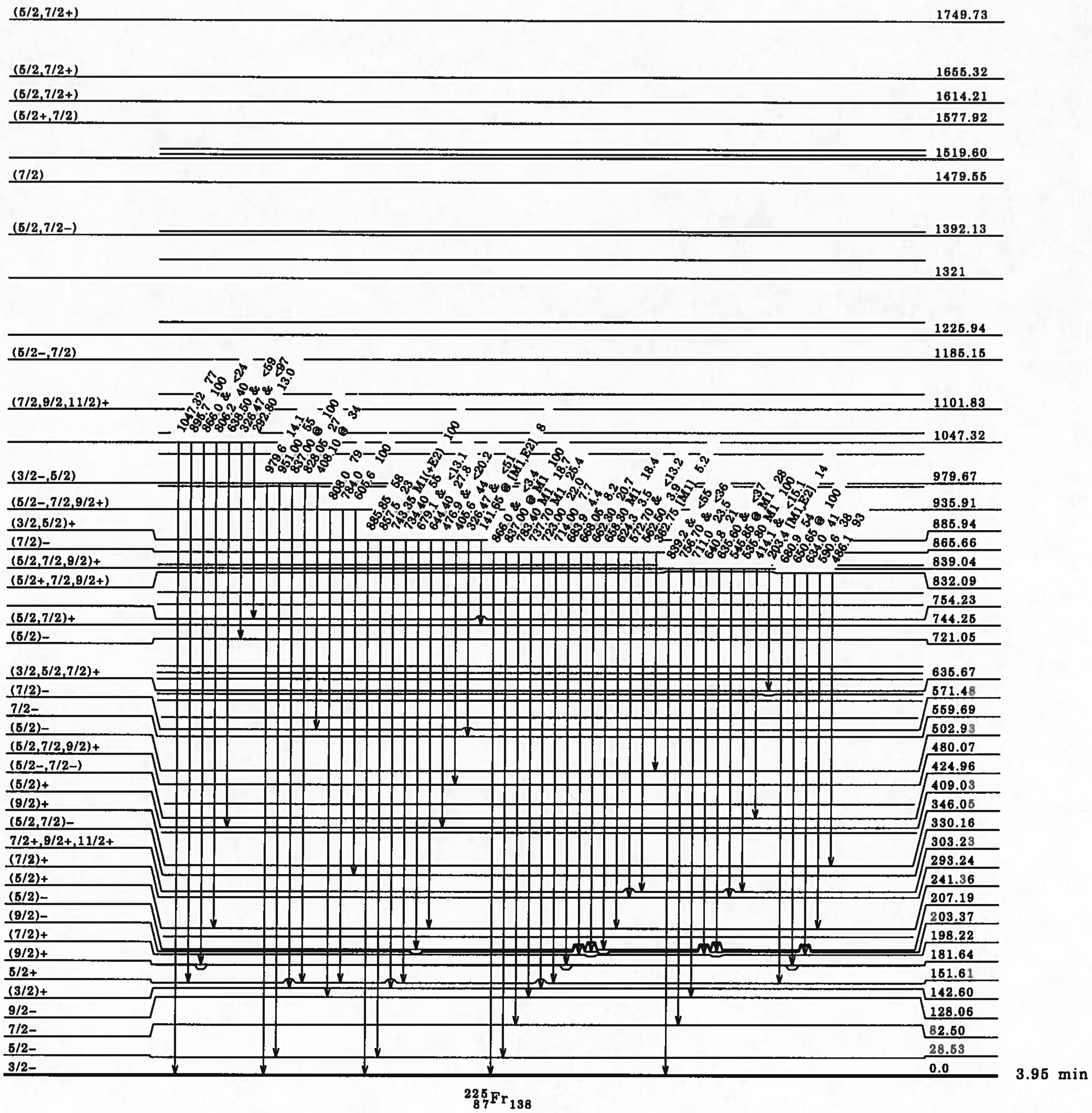
$^{225}_{87}Fr_{138}$

From NNDC(BNL)
program ENSDAT

Adopted Levels, Gammas (continued)

Level Scheme (continued)

Intensities: relative photon branching from each level
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

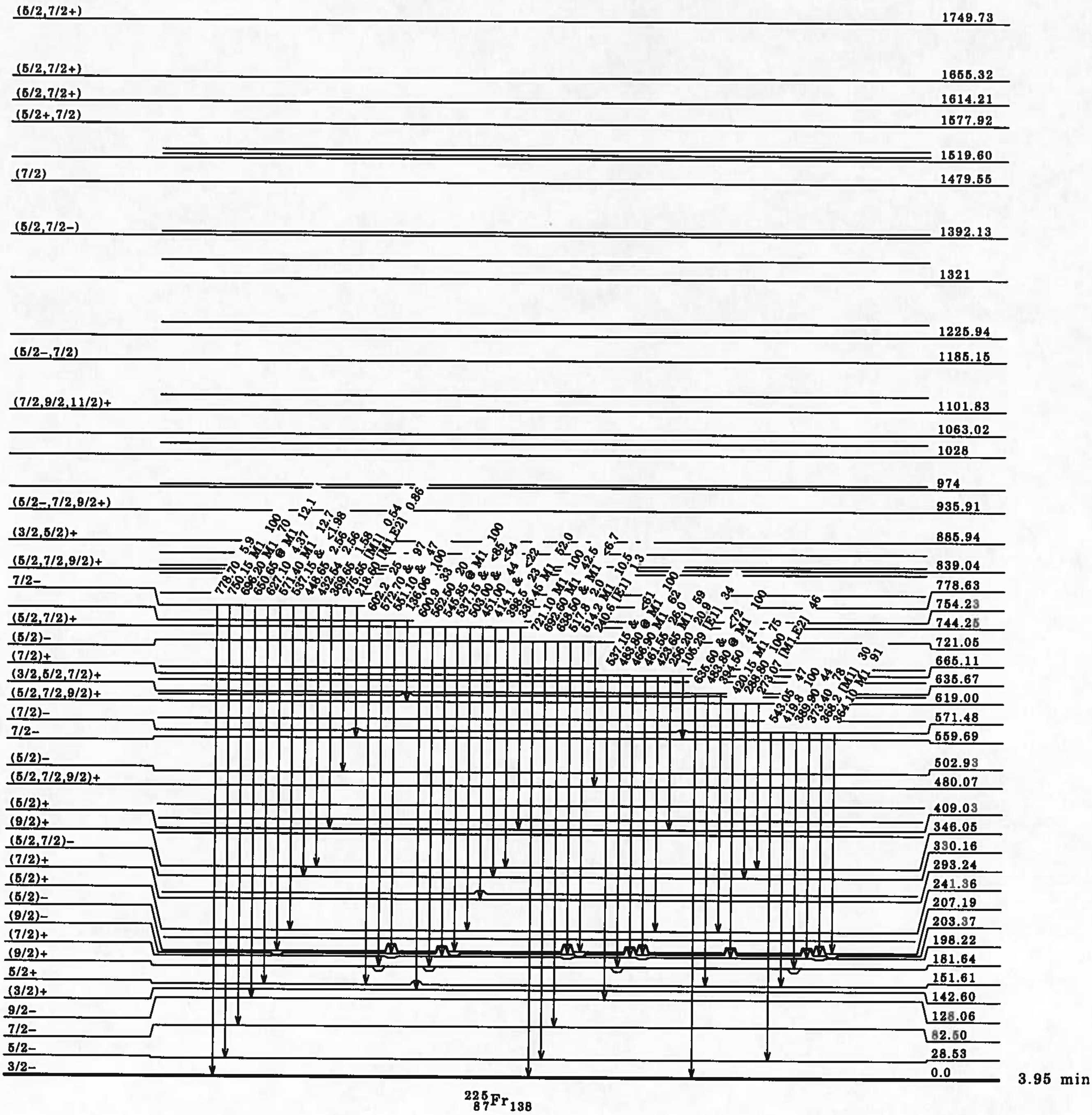


From NNDC(BNL)
program ENSDAT

Adopted Levels, Gammas (continued)

Level Scheme (continued)

Intensities: relative photon branching from each level
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

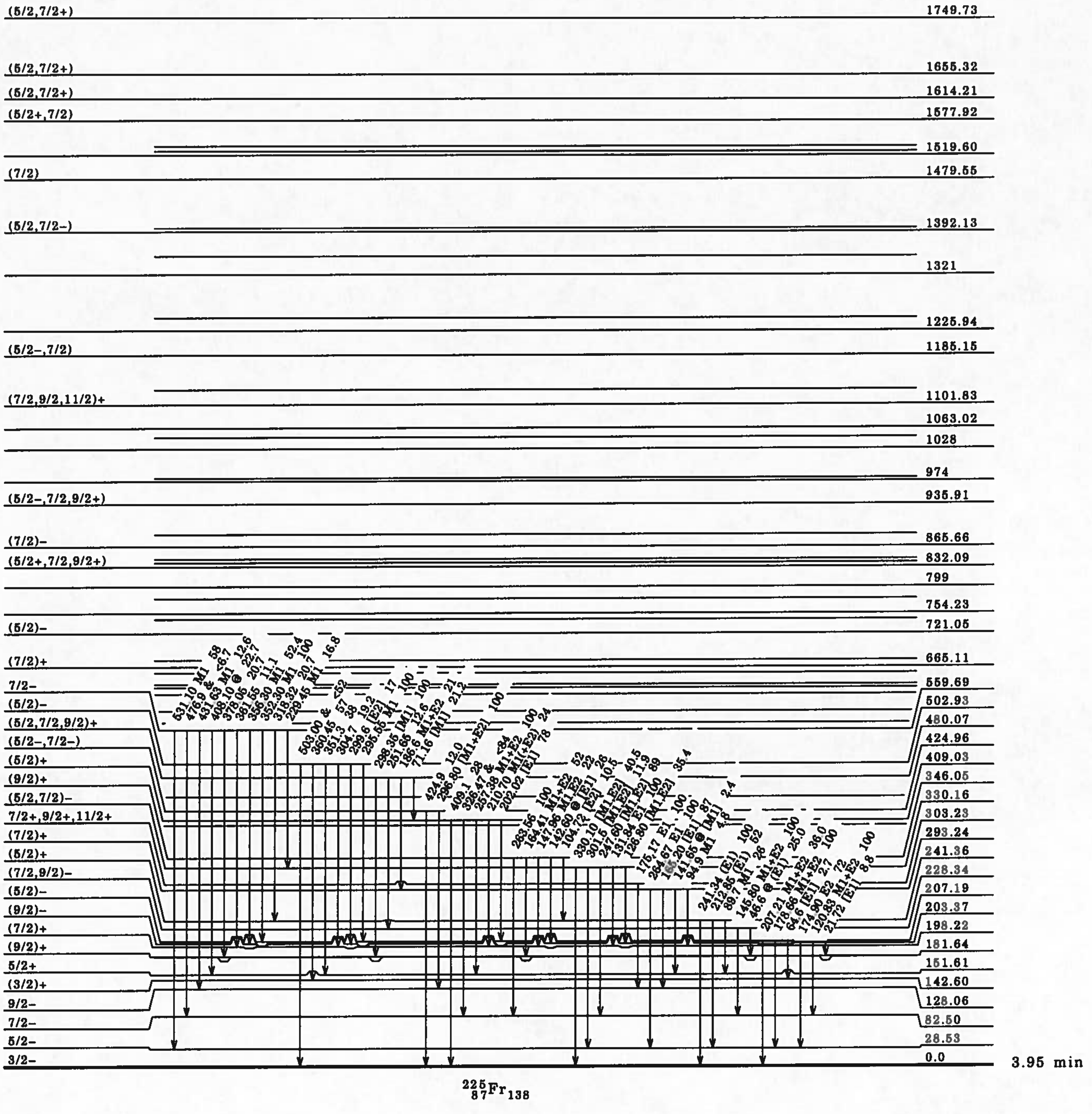


From NNDC(BNL)
program ENSDAT

Adopted Levels, Gammas (continued)

Level Scheme (continued)

Intensities: relative photon branching from each level
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

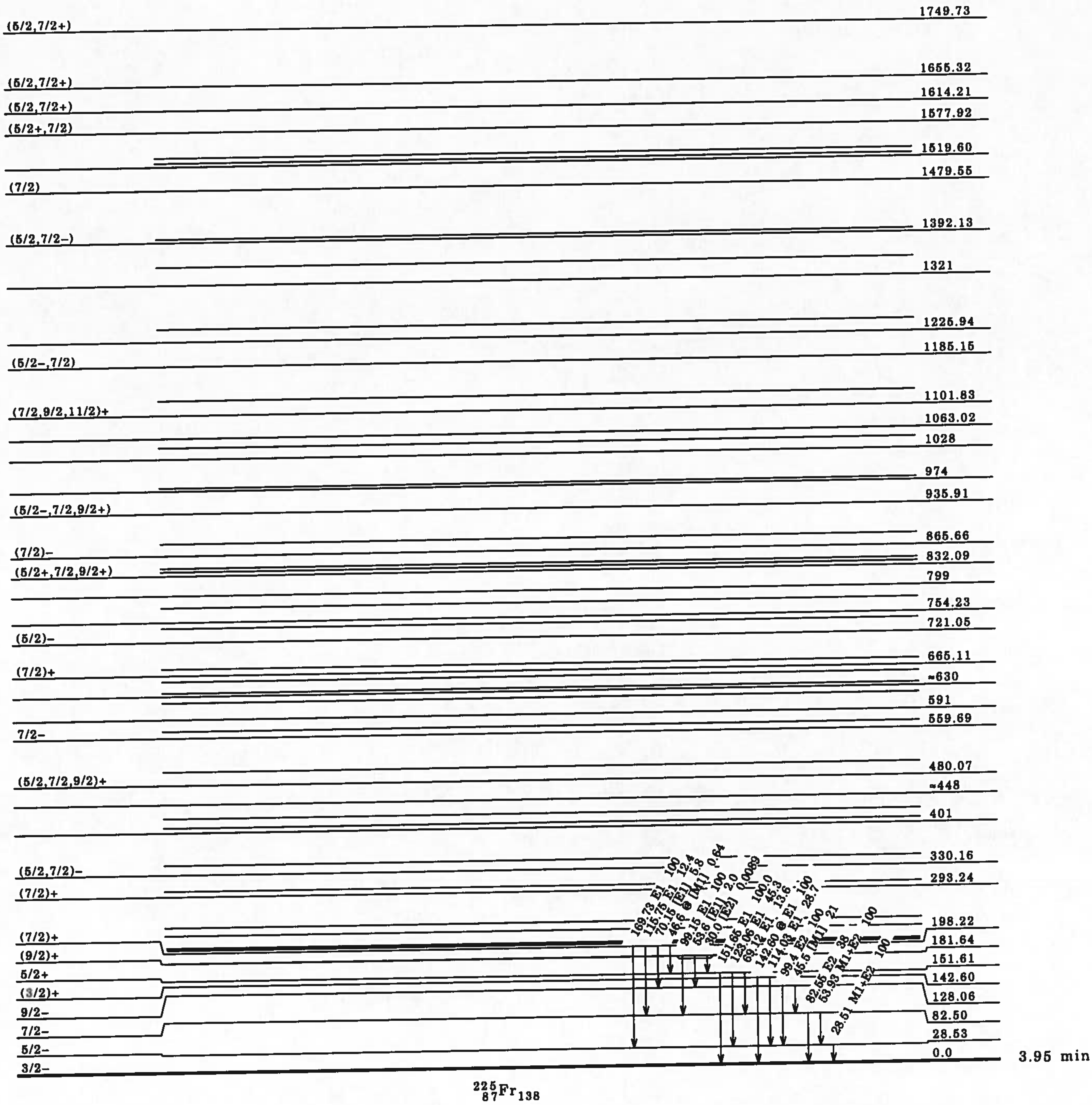


From NNDC(BNL) program ENSDAT

Adopted Levels, Gammas (continued)

Level Scheme (continued)

Intensities: relative photon branching from each level
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given



From NNDC(BNL)
program ENSDAT

^{225}Rn β^- Decay 1997Bu03

Parent ^{225}Rn: E=0.0; Jπ=7/2−; $T_{1/2}$=4.66 min *4*; Q(g.s.)=2680 syst; %β^- decay=100.

1997Bu03: ^{225}Fr sources from Isolde mass separator following spallation of UC_2 target by 600 MeV protons; two HPGe detectors (FWHM=1.8 keV at 1333); one HPGe x-ray detector (FWHM=0.70 keV at 122 keV); mini-Orange electron spectrometer; measured Eγ, Iγ, E(ce), I(ce), γγ coin, γ-ce coin, parent $T_{1/2}$. Supersedes 1987BoZP.

The decay scheme is taken from 1997Bu03. Note, however, that negative β^- feeding of the 28 level is implied unless δ(28γ)0.6, significantly larger than measured values (0.32 *2* and 0.44 *2*). Also, the measured multipolarity of the 202γ is inconsistent with its placement.

^{225}Fr Levels

E(level)†	Jπ‡	Comments
0.0	3/2−	
28.53 *3*	5/2−	Apparent %β^- feeding to level of −22 *21* may indicate that δ(29γ) is somewhat larger than α(M)exp and α(N)exp imply.
82.50 *3*	7/2−	
128.06 *4*	9/2−	
142.60 *5*	(3/2)+	
151.61 *3*	5/2+	
181.64 *4*	(9/2)+	
198.22 *4*	(7/2)+	
203.37 *4*	(9/2)−	
207.19 *3*	(5/2)−	
228.34 *5*	(7/2,9/2)−	
241.36 *4*	(5/2)+	
293.24 *5*	(7/2)+	
303.23 *6*	7/2+,9/2+,11/2+	
330.16 *4*	(5/2,7/2)−	
346.05 *4*	(9/2)+	
409.03 *4*	(5/2)+	
424.96 *9*	(5/2−,7/2−)	
480.07 *6*	(5/2,7/2,9/2)+	
502.93 *6*	(5/2)−	
559.69 *4*	7/2−	
571.48 *6*	(7/2)−	
619.00 *7*	(5/2,7/2,9/2)+	
635.67 *7*	(3/2,5/2,7/2)+	
665.11 *5*	(7/2)+	
721.05 *6*	(5/2)−	
744.25 *6*	(5/2,7/2)+	
754.23 *9*		
778.63 *4*	7/2−	
832.09 *8*	(5/2+,7/2,9/2+)	
839.04 *9*	(5/2,7/2,9/2)+	
865.66 *5*	(7/2)−	
885.94 *5*	(3/2,5/2)+	
935.91 *15*	(5/2−,7/2,9/2+)	
979.67 *7*	(3/2−,5/2)	
1047.32 *6*		
1063.02 *7*		
1101.83 *9*	(7/2,9/2,11/2)+	
1185.15 *6*	(5/2−,7/2)	
1225.94 *8*		
1392.13 *8*	(5/2,7/2−)	
1479.55 *5*	(7/2)	
1519.60 *11*		
1526.03 *12*		
1577.92 *8*	(5/2+,7/2)	
1614.21 *8*	(5/2,7/2+)	
1655.32 *6*	(5/2,7/2+)	
1749.73 *6*	(5/2,7/2+)	

† From least-squares adjustment of Eγ, omitting the 136.0γ, 668.05γ and 1421.0γ each of which fits its placement very poorly (at least 5σ from least-squares adjusted value), and all unresolved or multiply-placed lines.

‡ From adopted levels.

^{225}Rn β^- Decay 1997Bu03 (continued)

β^- radiations

$E\beta^-$	E(level)	$I\beta^-$ †§	Log *ft* ‡	Comments
(930.3)	1749.73	1.53 *9*	6.4 *6*	av Eβ=3.0E2 12.
(1025)	1655.32	1.32 *8*	6.6 *6*	av Eβ=3.3E2 12.
(1066)	1614.21	0.75 *9*	6.9 *5*	av Eβ=3.5E2 12.
(1102)	1577.92	0.95 *9*	6.8 *5*	av Eβ=3.6E2 12.
(1154)	1526.03	0.54 *8*	7.2 *5*	av Eβ=3.8E2 12.
(1160)	1519.60	0.80 *11*	7.0 *5*	av Eβ=3.9E2 12.
(1200)	1479.55	2.58 *15*	6.5 *5*	av Eβ=4.0E2 12.
(1288)	1392.13	0.65 *9*	7.2 *5*	av Eβ=4.4E2 12.
(1454)	1225.94	0.41 *5*	7.6 *4*	av Eβ=5.0E2 12.
(1495)	1185.15	1.62 *13*	7.1 *4*	av Eβ=5.2E2 13.
(1578)	1101.83	0.58 *5*	7.6 *4*	av Eβ=5.5E2 13.
(1617)	1063.02	1.04 *11*	7.4 *4*	av Eβ=5.7E2 13.
(1633)	1047.32	0.78 *18*	7.5 *4*	av Eβ=5.7E2 13.
(1700)	979.67	1.15 *16*	7.4 *4*	av Eβ=6.0E2 13.
(1744#)	935.91	0.09 *6*	8.6 *5*	av Eβ=6.2E2 13.
(1794)	885.94	2.2 *3*	7.2 *3*	av Eβ=6.4E2 13.
(1814)	865.66	5.3 *4*	6.9 *3*	av Eβ=6.5E2 13.
(1841)	839.04	1.12 *16*	7.6 *3*	av Eβ=6.6E2 13.
(1848)	832.09	0.30 *6*	8.2 *3*	av Eβ=6.6E2 13.
(1901)	778.63	27.1 *15*	6.2 *3*	av Eβ=6.8E2 13.
(1926#)	754.23	0.32 *15*	8.2 *4*	av Eβ=6.9E2 13.
(1936#)	744.25	0.86 *23*	7.8 *3*	av Eβ=7.0E2 13.
(1959)	721.05	4.1 *3*	7.1 *3*	av Eβ=7.1E2 13.
(2015)	665.11	1.01 *14*	7.8 *3*	av Eβ=7.3E2 13.
(2109)	571.48	1.12 *8*	7.8 *3*	av Eβ=7.7E2 13.
(2120)	559.69	6.4 *4*	7.1 *3*	av Eβ=7.7E2 13.
(2177)	502.93	0.63 *10*	8.1 *3*	av Eβ=8.0E2 13.
(2200)	480.07	1.49 *20*	7.75 *25*	av Eβ=8.1E2 13.
(2255#)	424.96	0.67 *19*	8.1 *3*	av Eβ=8.3E2 13.
(2334)	346.05	3.2 *7*	7.51 *25*	av Eβ=8.6E2 13.
(2350#)	330.16	0.8 *4*	8.1 *4*	av Eβ=8.7E2 13.
(2387)	293.24	3.0 *3*	7.58 *23*	av Eβ=8.8E2 13.
(2452)	228.34	2.9 *11*	7.6 *3*	av Eβ=9.1E2 13.
(2477#)	203.37	3.5 *20*	7.6 *4*	av Eβ=9.2E2 13.
(2482)	198.22	3.3 *7*	7.60 *24*	av Eβ=9.2E2 13.
(2498#)	181.64	5.2 *14*	7.41 *25*	av Eβ=9.3E2 13.
(2528)	151.61	2.3 *5*	7.79 *23*	av Eβ=9.4E2 13.
(2537)	142.60	2.4 *3*	9.0[1u] *4*	av Eβ=9.1E2 13.
(2552#)	128.06	7 *3*	7.3 *3*	av Eβ=9.5E2 13.

† From intensity balance at level, assigning (1/2)Iγ±(1/2)Iγ at each placement for doubly-placed transitions whose intensity division has not been determined.
‡ Calculated assuming an uncertainty of 300 keV in Q value.
§ Absolute intensity per 100 decays.
\# Existence of this branch is questionable.

$\gamma(^{225}$Fr)

Iγ normalization: From [Σ(I(γ+ce) to g.s. and 29 level) omitting I(γ+ce)(29)]=100; this assumes negligible β^- feeding from the 7/2[743] parent to the 3/2[532] g.s. (ΔK=ΔN=ΔJ=2, Δπ=no) and the 5/2 3/2[532] 28 level. Note that Iγ normalization becomes 0.0071 *19* if δ(28γ)=0.45 *15* (assuming Σ(I(γ+ce) to g.s.)=100), but this δ(28γ) implies negative β^- feeding to the 29 level.

Eγ	E(level)	Iγ&	Mult.†	δ	α	I(γ+ce)&	Comments
21.72 *10*	203.37	12.2 *26*	[E1]		6.37		α(L)=4.75; α(M)=1.22

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^{225}Rn β^- Decay 1997Bu03 (continued)

$\gamma(^{225}Fr)$ (continued)

Eγ	E(level)	Iγ[&]	Mult.[†]	δ	α	I(γ+ce)[&]	Comments
28.51 *5*	28.53	12.2 *22*	M1+E2	0.45 *15*	750 *270*		α(L)=553 *265*; α(M)=145 *71*. Mult.: α(M)exp=89 *6*, α(N)exp=35.7 *26*. δ: 0.32 *2* from α(M)exp; 0.44 *2* from α(N)exp, assuming no contribution from higher shells and α(N)(M1)=5.31, α(N)(E2)=195 from 2002Ba85. However, intensity balance at the 29 level implies a lower limit for α(exp) of 1.1×10^3 *2* and this corresponds to δ=0.6, so the evaluator adopts δ=0.45 *15*.
30.0[@]	181.64	@	[E2]		2990	400	α(L)=2.21E3; α(M)=589.
45.5[#] *1*	128.06	32 *5*	[M1]		29.6		α(L)=22.5; α(M)=5.37. Mult.: (α(L1)exp+α(L2)exp)≤37.
46.6[a] *1*	198.22	6[a] *2*	[M1]		27.6		α(L)=21.0; α(M)=5.00. Mult.: (α(L1)exp+α(L2)exp)≤196, α(M)exp≤10.0 for doubly-placed γ.
	228.34	29[a] *2*	(E1)		0.84		α(L)=0.634; α(M)=0.154. Mult.: (α(L1)exp+α(L2)exp)≤40.5, α(M)exp≤2.1 for doubly-placed γ dominated by this transition; not M1 from level scheme.
53.6[$] *1*	181.64	30[$] *10*	[E1]		0.576		α(L)=0.435; α(M)=0.105; α(N+..)=0.0350.
53.93[#] *5*	82.50	210 *12*	M1+E2	0.18 *3*	22.8		α(L)=17.1 *12*; α(M)=4.2 *3*; α(N+..)=1.48 *12*. Mult.: (α(L1)exp+α(L2)exp)=13.4 *10*, α(L3)exp=3.5 *3*, α(M)exp=4.3 *3*, α(N)exp<1.8. δ: from δ=0.17 *3* from α(L)exp=16.9 *10* and 0.19 *3* from α(M)exp. Note that δ<0.13 from α(L12)exp and δ=0.250 *12* from α(L3)exp. 1997Bu03 adopted δ=0.31 *4* from these data, however. %Iγ=1.16 *7* assuming adopted normalization.
[x]58.0 *1*		13.6 *17*					
[x]62.48 *5*		30.3 *15*					
64.6 *1*	207.19	10.0 *19*	[E1]		0.349		α(L)=0.264; α(M)=0.0637; α(N+..)=0.0212.
69.12[#] *5*	151.61	136 *7*	E1		0.291		α(L)=0.220; α(M)=0.0531; α(N+..)=0.0177. Mult.: (α(L1)exp+α(L2)exp)≤1.8.
70.15[#] *5*	198.22	54 *3*	[E1]		0.280		α(L)=0.212; α(M)=0.0510; α(N+..)=0.0170.
71.16 *10*	480.07	20.1 *23*	[M1]		8.01		α(L)=6.06; α(M)=1.44; α(N+..)=0.51.

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^{225}Rn β^- Decay 1997Bu03 (continued)

$\gamma(^{225}$Fr) (continued)

Eγ	E(level)	Iγ[&]	Mult.[†]	δ	α	Comments
82.55[§] *5*	82.50	80[§] *20*	E2		22.1	α(L)=16.2; α(M)=4.36; α(N+..)=1.54. Mult.: (α(L1)exp+α(L2)exp)=8 *3*, α(L3)exp=6.1 *23*, α(M)exp=5.4 *20*. %Iγ=0.44 *10* assuming adopted normalization.
89.7[§] *1*	241.36	26[§] *3*	M1		4.08	α(L)=3.09; α(M)=0.737; α(N+..)=0.260. Mult.: (α(L1)exp+α(L2)exp)=2.0 *3*.
94.9[§] *1*	293.24	14[§] *3*	M1		3.47	α(L)=2.62; α(M)=0.625; α(N+..)=0.221. Mult.: (α(L1)exp+α(L2)exp)=1.8 *5*.
99.16 *5*	181.64	1500 *200*	E1		0.111	α(L)=0.084; α(M)=0.0201; α(N+..)=0.00684. Mult.: (α(L1)exp+α(L2)exp)≤0.62, α(L3)exp≤0.31, α(M)exp≤0.21.
99.4[§] *1*	128.06	150[§] *50*	E2		9.2	α(L)=6.74; α(M)=1.82; α(N+..)=0.646. Mult.: (α(L1)exp+α(L2)exp)=4.8 *16*, α(L3)exp≤3.1, α(M)exp≤2.1.
104.72 *10*	346.05	16 *3*	[E2]		7.52	α(K)=0.307 *10*; α(L)=5.28 *16*; α(M)=1.43 *5*; α(N+..)=0.507 *16*.
105.29 *10*	665.11	24 *3*	[E1]		0.425	α(K)=0.330; α(L)=0.0716; α(M)=0.0172; α(N+..)=0.00584.
114.03[#] *5*	142.60	157 *8*	E1		0.349	α(K)=0.272; α(L)=0.0580; α(M)=0.0139; α(N+..)=0.00473. Mult.: (α(L1)exp+α(L2)exp)≤0.2, α(M)exp≤0.29.
115.75[#] *5*	198.22	116 *6*	E1		0.337	α(K)=0.263; α(L)=0.0558; α(M)=0.0133; α(N+..)=0.00455. Mult.: (α(L1)exp+α(L2)exp)≤0.54.
120.83[#] *5*	203.37	139 *7*	M1+E2		6.4 *24*	α(K)=4 *4*; α(L)=3.E1 3; α(M)=9 *9*; α(N+..)=3 *4*. Mult.: α(K)exp=6 *2*, (α(L1)exp+α(L2)exp)=1.6 *1*.
123.06[#] *5*	151.61	453 *23*	E1		0.290	α(K)=0.228; α(L)=0.0475; α(M)=0.0113; α(N+..)=0.00387. Mult.: (α(L1)exp+α(L2)exp)≤0.34, α(L3)exp≤0.10, α(M)exp≤0.25.
126.80 *10*	330.16	26.2 *14*	[M1,E2]		5.5 *22*	α(K)=3 *3*; α(L)=1.7 *6*; α(M)=0.43 *16*; α(N+..)=0.15 *6*.
127.31[b] *10*	1063.02	17[b] *3*				
	1519.60	17[b] *3*				
131.84[§#] *10*	330.16	74[§] *4*	E1		0.245	α(K)=0.193; α(L)=0.0396; α(M)=0.0095; α(N+..)=0.00323. Mult.: (α(L1)exp+α(L2)exp)≤0.07.
136.06[‡#] *5*	754.23	47.5 *24*				
141.65[a] *10*	293.24	7[a] *3*	[M1]		5.61	α(K)=4.51; α(L)=0.828; α(M)=0.198; α(N+..)=0.0697.
	885.94	8[a] *6*	[M1,E2]		3.9 *18*	α(K)=2.4 *21*; α(L)=1.1 *3*; α(M)=0.28 *8*; α(N+..)=0.10 *3*.
142.60[#a] *5*	142.60	547[a] *28*	E1		0.202	α(K)=0.160; α(L)=0.0323; α(M)=0.00770; α(N+..)=0.00263. Mult.: α(K)exp≤0.11, (α(L1)exp+α(L2)exp)≤0.04, α(M)exp≤0.07.
142.60[a] *10*	346.05	40[a] *5*	[E1]		0.202	α(K)=0.160; α(L)=0.0323; α(M)=0.00770; α(N+..)=0.00263.
145.80[#] *5*	228.34	116 *6*	M1+E2		3.5 *17*	α(K)=2.2 *20*; α(L)=0.96 *20*; α(M)=0.25 *7*; α(N+..)=0.088 *24*. Mult.: α(K)exp≤2.0, (α(L1)exp+α(L2)exp)=1.0 *5*.
147.96 *10*	346.05	33 *6*	M1,E2		3.4 *16*	α(K)=2.1 *19*; α(L)=0.91 *18*; α(M)=0.23 *6*; α(N+..)=0.083 *22*. Mult.: (α(L1)exp+α(L2)exp)=1.3 *4*.

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^{225}Rn β^- Decay 1997Bu03 (continued)

$\gamma(^{225}Fr)$ (continued)

Eγ	E(level)	Iγ[&]	Mult.[†]	δ	α	Comments
151.65[#] *5*	151.61	1000	E1		0.174	α(K)=0.138; α(L)=0.0275; α(M)=0.00656; α(N+..)=0.00224. Mult.: α(K)exp≤1.1, (α(L1)exp+α(L2)exp)=≤0.05, α(L3)exp≤0.01, α(M)exp≤0.10. %Iγ=5.5 *11* assuming adopted normalization.
164.41[#] *5*	346.05	79 *4*	M1+E2		2.4 *13*	α(K)=1.6 *14*; α(L)=0.61 *7*; α(M)=0.16 *3*; α(N+..)=0.055 *10*. Mult.: α(K)exp=2.2 *5*, (α(L1)exp+α(L2)exp)≤1.3.
165.20[#] *5*	293.24	255 *13*	[E1]		0.141	α(K)=0.112; α(L)=0.0221; α(M)=0.00525; α(N+..)=0.00179. Mult.: α(K)exp≤4.5, (α(L1)exp+α(L2)exp)≤0.41, α(M)exp≤0.47.
169.73 *5*	198.22	932 *56*	E1		0.132	α(K)=0.105; α(L)=0.0206; α(M)=0.00490; α(N+..)=0.00167. Mult.: α(K)exp≤0.66, (α(L1)exp+α(L2)exp)≤0.02, α(M)exp≤0.04.
174.90[§] *10*	203.37	100[§] *30*	E2		0.92	α(K)=0.214 *7*; α(L)=0.520 *16*; α(M)=0.140 *5*; α(N+..)=0.0493 *15*. Mult.: α(K)exp=0.33 *13*.
175.17[#] *5*	303.23	136 *32*	E1		0.122	α(K)=0.097; α(L)=0.0190; α(M)=0.00452; α(N+..)=0.00154. Mult.: α(K)exp≤0.92, (α(L1)exp+α(L2)exp)≤0.60, α(M)exp≤0.03.
178.66[#] *5*	207.19	367 *18*	M1+E2	1.47 *+18−14*	1.50 *12*	α(K)=0.88 *11*; α(L)=0.459 *3*; α(M)=0.119 *2*; α(N+..)=0.0420 *5*. Mult.: α(K)exp=0.88 *10*, (α(L1)exp+α(L2)exp)=0.27 *5*, α(M)exp≤0.12. δ: from α(K)exp.
186.6[§] *3*	480.07	20[§] *4*	M1+E2		1.6 *10*	α(K)=1.1 *10*; α(L)=0.385 *8*; α(M)=0.098 *8*; α(N+..)=0.034 *3*. Mult.: α(K)exp=0.54 *15*.
202.02[#] *5*	409.03	48.2 *24*	[E1]		0.087	α(K)=0.0694 *21*; α(L)=0.0132 *4*; α(M)=0.00314 *10*; α(N+..)=0.00107 *4*. Mult.: α(K)exp=2.4 *9*, (α(L1)exp+α(L2)exp)≤0.37. Note that mult=M1 from α(K)exp is inconsistent with placement from this level unless, perhaps, the 202γ feeds the (3/2+) level at E=205 *3* seen in (t,α); this would not, however, explain observed γγ coin data or absence of strong enough transition(s) to deexcite that (3/2+) level.
203.4[§] *3*	839.04	10[§] *3*	[M1,E2]		1.3 *8*	α(K)=0.9 *8*; α(L)=0.284 *13*; α(M)=0.0718 *10*; α(N+..)=0.0252 *4*.
207.21[#] *5*	207.19	132 *7*	M1+E2	1.4 *+4−3*	0.98 *17*	α(K)=0.62 *16*; α(L)=0.261 *5*; α(M)=0.0672; α(N+..)=0.0236. Mult.: α(K)exp=0.62 *15*, (α(L1)exp+α(L2)exp)≤0.43, α(M)exp≤0.08. δ: from α(K)exp.
210.70[§] *10*	409.03	15[§] *2*	M1(+E2)		1.1 *7*	α(K)=0.8 *7*; α(L)=0.251 *18*; α(M)=0.0634 *8*; α(N+..)=0.0222 *2*. Mult.: α(K)exp=1.4 *3*.

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From NNDC(BNL) program ENSDAT

$^{225}_{87}Fr_{138}$–21

^{225}Rn β^- Decay 1997Bu03 (continued)

γ(^{225}Fr) (continued)

Eγ	E(level)	Iγ&	Mult.†	α	Comments
212.85# 5	241.36	51.2 26	(E1)	0.0766	α(K)=0.0613; α(L)=0.0116; α(M)=0.00276; α(N+..)=0.00094. Mult.: α(K)exp≤0.18 consistent with E1 or E2; Δπ=yes from level scheme.
218.60 10	778.63	18.4 13	[M1,E2]	1.0 7	α(K)=0.7 6; α(L)=0.222 21; α(M)=0.056 2; α(N+..)=0.0195 7.
229.45# 5	559.69	51.8 26	M1	1.44	α(K)=1.16; α(L)=0.212; α(M)=0.0504; α(N+..)=0.0176. Mult.: α(K)exp=1.0 3 or 1.8 7.
240.6§ 3	721.05	6§ 2	[E1]	0.0573	α(K)=0.0460; α(L)=0.0085; α(M)=0.00203; α(N+..)=0.00069.
241.34# 5	241.36	99 5	(E1)	0.0569	α(K)=0.0457 14; α(L)=0.0085 3; α(M)=0.00202 6; α(N+..)=0.00069 2. Mult.: α(K)exp≤0.37, (α(L1)exp+α(L2)exp)≤0.11 consistent with E1 or E2. Δπ=yes from level scheme.
247.60# 5	330.16	66 3	[M1,E2]	0.7 5	α(K)=0.5 5; α(L)=0.15 3; α(M)=0.036 5; α(N+..)=0.0127 15. Mult.: α(K)exp≤1.6, (α(L1)exp+α(L2)exp)≤0.19.
251.65 10	480.07	12.0 12			
256.20 10	665.11	14.6 15	[M1,E2]	0.6 4	α(K)=0.5 4; α(L)=0.13 3; α(M)=0.032 5; α(N+..)=0.0114 16.
257.38# 5	409.03	62 3	M1+E2	0.6 4	α(K)=0.5 4; α(L)=0.13 3; α(M)=0.032 5; α(N+..)=0.0112 16. Mult.: α(K)exp=0.65 10, (α(L1)exp+α(L2)exp)≤0.19.
263.56# 5	346.05	152 7			Mult.: α(K)exp≤0.23, (α(L1)exp+α(L2)exp)≤0.05; consistent with E1 or E2.
264.67# 5	293.24	292 14	E1	0.0459	α(K)=0.0370; α(L)=0.00677; α(M)=0.00161; α(N+..)=0.00055. Mult.: α(K)exp≤0.12, (α(L1)exp+α(L2)exp)≤0.03.
273.07 10	619.00	12.8 11	[M1,E2]	0.5 4	α(K)=0.4 4; α(L)=0.106 25; α(M)=0.026 5; α(N+..)=0.0092 17.
275.65 10	778.63	11.6 12	[M1]	0.87	α(K)=0.697 21; α(L)=0.127 4; α(M)=0.0302 9; α(N+..)=0.0106 4.
288.80# 10	619.00	27.9 16	[E1]	0.0376	α(K)=0.0304 10; α(L)=0.00549 17; α(M)=0.00130 4; α(N+..)=0.00045 1.
292.80 10	1047.32	7.0 10			
295.55# 10	502.93	53 4	M1	0.714	α(K)=0.576; α(L)=0.105; α(M)=0.0249; α(N+..)=0.0087. Mult.: α(K)exp=0.48 13, (α(L1)exp+α(L2)exp)≤0.27.
296.80# 10	424.96	104 5	[M1+E2]	0.4 3	α(K)=0.32 25; α(L)=0.081 23; α(M)=0.020 5; α(N+..)=0.0070 16. Mult.: α(K)exp≤0.35, (α(L1)exp+α(L2)exp)≤0.13.
298.35# 10	480.07	95 5	[M1]	0.696	α(K)=0.561 17; α(L)=0.102 3; α(M)=0.0242 8; α(N+..)=0.0085 3. Mult.: α(K)exp=0.51 13 and 0.60 6, (α(L1)exp+α(L2)exp)=0.12 2.
299.6 2	502.93	8.9 14	[E2]	0.148	α(K)=0.0708 22; α(L)=0.0567 17; α(M)=0.0149 5; α(N+..)=0.00527 16.
301.5 2	330.16	8.8 14	[M1,E2]	0.4 3	α(K)=0.31 24; α(L)=0.077 22; α(M)=0.019 5; α(N+..)=0.0067 16.
304.7 2	502.93	10.2 12			
308.8 2	1063.02	10.5 12			
318.32# 10	559.69	64 3			Mult.: α(K)exp≤0.22, (α(L1)exp+α(L2)exp)≤0.08.
319.61# 10	1185.15	29.6 15			
326.47#b 10	409.03	49.5b 25			
	885.94	49.5b 25			
	1047.32	49.5b 25			
330.10# 10	330.16	30.0 15		0.32 21	α(K)=0.24 19; α(L)=0.058 19; α(M)=0.014 4; α(N+..)=0.0050 14.
335.45# 10	744.25	26.0 13	M1	0.505	α(K)=0.408; α(L)=0.0738; α(M)=0.0175; α(N+..)=0.00613. Mult.: α(K)exp=0.37 4.
351.3§ 2	502.93	20§ 5			
352.30# 10	559.69	309 15	M1	0.442	α(K)=0.357; α(L)=0.0645; α(M)=0.0153; α(N+..)=0.00536. Mult.: α(K)exp=0.33 2 and 0.34 5, (α(L1)exp+α(L2)exp)=0.070 3.

Continued on next page (footnotes at end of table)

^{225}Rn β⁻ Decay 1997Bu03 (continued)

γ(^{225}Fr) (continued)

Eγ	E(level)	Iγ[&]	Mult.[†]	α	Comments
356.30[#] 10	559.69	162 8	M1	0.429	α(K)=0.346; α(L)=0.0626; α(M)=0.0149; α(N+..)=0.00520. Mult.: α(K)exp=0.36 2, (α(L1)exp+α(L2)exp)=0.09 1.
360.45 10	502.93	30 3			Mult.: α(K)exp≤0.06; consistent with E1 or E2.
361.55 10	559.69	34.4 21			
362.75 10	865.66	20.0 16	[M1]	0.408	α(K)=0.330 10; α(L)=0.0596 18; α(M)=0.0142 5; α(N+..)=0.00495 15.
364.10[#] 10	571.48	52.1 26	M1	0.404	α(K)=0.326; α(L)=0.0590; α(M)=0.0140; α(N+..)=0.00490. Mult.: α(K)exp=0.50 4, (α(L1)exp+α(L2)exp)≤0.14.
[x]366.92[#] 10		57 3	M1	0.396	α(K)=0.319; α(L)=0.0577; α(M)=0.0137; α(N+..)=0.00480. Mult.: α(K)exp=0.54 4.
368.2 2	571.48	17.0 17	[M1]	0.392	α(K)=0.316 10; α(L)=0.0572 18; α(M)=0.0136 4; α(N+..)=0.00475 15.
369.65[#] 10	778.63	34.0 19			
373.40[#] 10	571.48	44.6 22			Mult.: α(K)exp≤0.32, (α(L1)exp+α(L2)exp)≤0.09.
378.05[#] 10	559.69	64 3			Mult.: α(K)exp≤0.22, (α(L1)exp+α(L2)exp)≤0.06.
388.50 10	1614.21	34.3 17			
389.90[#] 10	571.48	24.9 16			
394.50 10	635.67	14.8 15	[M1,E2]	0.20 13	α(K)=0.15 12; α(L)=0.034 14; α(M)=0.008 3; α(N+..)=0.0029 11.
397.6 2	1063.02	14.8 25			
398.5 2	744.25	11.5 26			
405.6[#] 2	885.94	45 5			
408.10[a] 10	559.69	70[a] 5			Mult.: α(K)exp≤0.16.
	979.67	34[a] 7			Mult.: α(K)exp≤0.34.
409.1 2	409.03	17.2 23			
412.30 10	1392.13	20.7 18			
414.1[b] 2	744.25	9.3[b] 14			
	839.04	9.3[b] 14			
419.8[§#] 2	571.48	57[§] 6			Mult.: α(K)exp≤0.16.
420.15[§] 20	619.00	21[§] 5	M1	0.274	α(K)=0.222; α(L)=0.0399; α(M)=0.0095; α(N+..)=0.00332. Mult.: α(K)exp=0.4 13.
423.65[#] 10	665.11	41.3 21	M1	0.268	α(K)=0.217; α(L)=0.0390; α(M)=0.0093; α(N+..)=0.00325. Mult.: α(K)exp=0.33 7.
424.9 2	424.96	12.5 24			
427.65[#] 10	1063.02	38.3 22			
431.63[#] 10	559.69	39 4	M1	0.255	α(K)=0.206; α(L)=0.0371; α(M)=0.0088; α(N+..)=0.00309. Mult.: α(K)exp=0.40 5.
432.54[#] 10	778.63	55 4			Mult.: α(K)exp≤0.29.
448.65[#] 10	778.63	55 3			Mult.: α(K)exp≤0.10.
451.00 10	744.25	22.0 16			
461.55 10	665.11	18.2 16			
466.90 10	665.11	43.3 22	M1	0.207	α(K)=0.167; α(L)=0.0301; α(M)=0.00714; α(N+..)=0.00250. Mult.: α(K)exp=0.19 3.
470.2 2	1655.32	10.4 22			
472.1[b] 2	1225.94	11.0[b] 22			
	1519.60	11.0[b] 22			
476.9[b] 2	559.69	18.7[b] 19			
	885.94	18.7[b] 19			
[x]482.1 2		15 5			
483.80[a] 10	635.67	36[a] 5	M1	0.188	α(K)=0.152; α(L)=0.0273; α(M)=0.00649; α(N+..)=0.00227. Mult.: α(K)exp=0.52 if entire I(ce) for doublet is assigned to this placement. α(K)exp=0.18 for doublet.
	665.11	70[a] 5	M1	0.188	α(K)=0.152; α(L)=0.0273; α(M)=0.00649; α(N+..)=0.00227. Mult.: α(K)exp=0.27 if entire I(ce) for doublet is assigned to this placement. α(K)exp=0.18 for doublet.
[x]484.7 2		22 5			
486.1 2	832.09	28 8			
503.00[b] 10	502.93	25.2[b] 20			
	744.25	25.2[b] 20			
514.2 2	721.05	50 8	M1	0.160	Mult.: α(K)exp=0.26 6. α(K)=0.129; α(L)=0.0232.

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^{225}Rn β^- Decay 1997Bu03 (continued)

$\gamma(^{225}Fr)$ (continued)

Eγ	E(level)	Iγ[&]	Mult.[†]	α	Comments
517.8 2	721.05	9.6 23			
x521.0 2		15.7 19			
531.10[#] 10	559.69	180 9	M1	0.147	α(K)=0.119; α(L)=0.0213. Mult.: α(K)exp=0.13 1, (α(L1)exp+α(L2)exp)=0.02 1.
x534.25 10		25.0 18			
535.80[#] 10	839.04	71 4	M1	0.144	α(K)=0.116; α(L)=0.0208. Mult.: α(K)exp=0.15 2.
537.15[b] 10	665.11	40.5[b] 21			Mult.: α(K)exp≤0.05.
	744.25	40.5[b] 21			
	778.63	40.5[b] 21			
543.05[#] 10	571.48	26.8 20			
545.85[#a] 10	744.25	50.0[a] 20	M1	0.137	α(K)=0.110; α(L)=0.0198. Mult.: α(K)exp=0.19, α(L12)exp=0.04 if entire I(ce) for doublet is assigned to this placement. α(K)exp=0.14 for doublet.
	839.04	20.0[a] 20	M1	0.137	α(K)=0.110; α(L)=0.0198. Mult.: α(K)exp=0.47 if entire I(ce) for doublet is assigned to this placement. α(K)exp=0.14 for doublet.
551.10[b] 10	754.23	22.5[b] 21			
	1614.21	22.5[b] 21			
x561.3 2		12 3			
562.50 10	744.25	10 3			
	865.66	15 3			
566.3 2	1185.15	17.9 22			
571.40[#] 10	778.63	272 13	M1	0.121	α(K)=0.098; α(L)=0.0175. Mult.: α(K)exp=0.10 1 and 0.11 3, (α(L1)exp+α(L2)exp)=0.021 2.
572.70[b] 10	754.23	46[b] 5			
	865.66	46[b] 5			
x587.7 2		11.4 20			
590.6 2	832.09	11.5 20			
600.9 2	744.25	16.6 19			
602.2 2	754.23	12.0 19			
605.6 2	935.91	17.0 23			
x614.8 2		15.3 21			
624.3 2	865.66	13.4 17			
627.10[#] 10	778.63	94 5			Mult.: α(K)exp≤0.023.
634.0 2	832.09	12.3 19			
635.60[b] 10	635.67	23.9[b] 20			
	839.04	23.9[b] 20			
638.50[#b] 10	721.05	29.6[b] 22	M1	0.090	α(K)=0.0729; α(L)=0.0130. Mult.: α(K)exp=0.10 3.
	1047.32	29.6[b] 22			
640.8 2	839.04	15 5			
644.40[#] 10	885.94	28.4 23			
650.65[#a] 10	778.63	260[a] 14	M1	0.086	α(K)=0.0694; α(L)=0.0124. Mult.: α(K)exp=0.071 6, (α(L1)exp+α(L2)exp)≤0.012.
	832.09	30[a] 5			Mult.: α(K)exp≤0.69.
658.30[#] 10	865.66	71 4	M1	0.0832	α(K)=0.0673; α(L)=0.0120. Mult.: α(K)exp=0.10 1. C.
662.30[#] 10	865.66	80 5			
668.05[‡] 10	865.66	31.7 16			
679.1[b] 2	885.94	11.1[b] 22			
	1614.21	11.1[b] 22			
680.9 2	832.09	16.1 18			
683.9 2	865.66	16.8 19			
692.60[#] 10	721.05	202 10	M1	0.0728	α(K)=0.0589; α(L)=0.0105. Mult.: α(K)exp=0.077 9.
696.20[#] 10	778.63	1510 70	M1	0.0718	α(K)=0.0581; α(L)=0.0104. Mult.: α(K)exp=0.052 2, (α(L1)exp+α(L2)exp)≤0.009.
702.40 10	1749.73	22.3 24			
705.10[#] 10	1185.15	64 3			

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^{225}Rn β^- Decay 1997Bu03 (continued)

$\gamma(^{225}\mathrm{Fr})$ (continued)

Eγ	E(level)	Iγ[&]	Mult.[†]	α	Comments
711.0[#] 2	839.04	16.7 17			
714.00 10	865.66	29.7 17			
[x]718.0 2		19.9 20			
721.10[#] 10	721.05	475 23	M1	0.0655	α(K)=0.0530; α(L)=0.0094. Mult.: α(K)exp=0.046 7, (α(L1)exp+α(L2)exp)=0.008 1. %Iγ=2.62 17 assuming adopted normalization.
723.00[#] 10	865.66	85 4			Mult.: α(K)exp≤0.08. Transition omitted from level scheme in fig. 6 of 1997Bu03.
727.4 2	1392.13	14.1 20			
[x]729.9 2		12.5 20			
734.40[#] 10	885.94	56 3			
737.70[#] 10	865.66	98 5	M1	0.0617	α(K)=0.0499; α(L)=0.0089. Mult.: α(K)exp=0.041 9.
743.35[#] 10	885.94	102 5	M1(+E2)	0.038 23	α(K)=0.030 19; α(L)=0.006 3. Mult.: α(K)exp=0.04 1.
750.15[#] 10	778.63	2150 110	M1	0.0591	α(K)=0.0478; α(L)=0.0085. Mult.: α(K)exp=0.040 2, (α(L1)exp+α(L2)exp)=0.007, α(M)exp≤0.002.
756.70[b] 10	839.04	22.9[b] 23			
	1392.13	22.9[b] 23			
758.5 2	1479.55	14.9 20			
759.6 2	1063.02	22.4 22			
[x]768.60[#] 10		71 5			
778.70[#] 10	778.63	127 6			Mult.: α(K)exp=0.004 3.
783.40[#] 10	865.66	72 4	M1	0.0527	α(K)=0.0427; α(L)=0.00758. Mult.: α(K)exp=0.052 9.
784.0[§] 2	935.91	[§]			
[x]788.8 2		17.3 24			
[x]790.70 10		30 3			
[x]795.3 2		19.7 20			
798.7[b] 2	1519.60	18.4[b] 17			
	1577.92	18.4[b] 17			
801.0 2	1225.94	19.7 22			
[x]804.6 2		24.0 18			
806.2 2	1047.32	21.7 17			
808.0 2	935.91	13.5 18			
	1101.83				
[x]812.6 2		14.5 16			
814.1 2	1479.55	18.6 22			
[x]815.5 2		16.2 26			
[x]817.70 10		38.0 24			
821.1 2	1392.13	13.0 23			
823.40 10	1655.32	32.8 21			
[x]826.25 10		31.5 21			
828.05 10	979.67	27 3			
834.6 2	1063.02	18 3			
837.00[#a] 10	865.66	386[a] 25	M1	0.0444	α(K)=0.0359; α(L)=0.00637. Mult.: α(K)exp=0.045 4.
	979.67	100[a] 25			Mult.: α(K)exp≤0.17.
839.2[b] 2	839.04	32[b] 7			
	1185.15	32[b] 7			
[x]844.90 10		32.5 24			
855.5[b] 2	1063.02	10.8[b] 26			
	1185.15	10.8[b] 26			
857.5 2	885.94	23 3			
859.2 2	1063.02	13.5 21			
864.5 2	1063.02	33.1 22			
866.0[b] 2	865.66	10.4[b] 25			
	1047.32	10.4[b] 25			
876.7 2	1655.32	16.9 22			
881.40 10	1063.02	36.4 22			
885.85[#] 10	885.94	59 3			

Continued on next page (footnotes at end of table)

^{225}Rn β^- Decay 1997Bu03 (continued)

γ(^{225}Fr) (continued)

Eγ	E(level)	Iγ[&]	Mult.[†]	α	Comments
891.7 2	1185.15	23.3 20			
895.7 2	1047.32	54 8			
899.0 2	1101.83	11.9 13			
901.8 2	1655.32	15 4			
903.2 2	1101.83	14 4			
x915.70 10		30.8 19			
917.4 2	1749.73	9.9 19			
920.30 10	1101.83	76 4	M1	0.0347	α(K)=0.0281; α(L)=0.00497. Mult.: α(K)exp=0.06 3.
x937.4 2		17.0 17			
x941.0 2		11.6 16			
942.8 2	1577.92	10.5 18			
948.9 2	1614.21	21.3 21			
951.00 10	979.67	54.8 27			
x956.1 2		12.9 20			
959.8 2	1519.60	11.0 20			
x974.6 2		28.1 22			
978.1 2	1185.15	12.6 20			
979.6 2	979.67	14.1 20			
981.5 2	1185.15	23.2 23			
990.0 2	1655.32	13.8 15			
x997.20 10		33.7 25			
999.5 2	1479.55	20.4 20			
x1002.5 2		24.4 24			
x1011.1 2		13.0 23			
x1015.45 10		48 3			
1017.6 2	1577.92	16.5 26			
1019.40 10	1655.32	39 3			
1027.4 2	1225.94	20 4			
1028.8 2	1749.73	23 4			
1033.5 2	1185.15	79 4			
1044.7 2	1225.94	12.3 25			
1047.32 10	1047.32	41.8 26			
x1067.52 10		29.0 18			
1070.48 10	1479.55	34.9 24			
1084.2 2	1749.73	18.9 24			
x1093.3 2		13 3			
1095.1 2	1655.32	16 3			
x1099.2 2		14.1 21			
1102.55 10	1185.15	32.3 26			
x1104.2 2		16.0 26			
1111.2 2	1614.21	11 4			
x1115.8 2		18.5 18			
x1126.6 2		11.7 26			
x1129.6 2		26 5			
1130.9 2	1749.73	15 5			
x1141.23 10		35.4 25			
1143.65 10	1225.94	51 3			
1169.2 2	1577.92	25.9 24			
1173.3 2	1519.60	24 3			
1176.2 2	1479.55	14.2 21			
1194.1 2	1392.13	32 3			
1195.7 2	1526.03	25 5			
x1215.2 2		34 3			
x1219.8 2		21.7 26			
1226.7 2	1519.60	12.4 25			
1229.9 2	1655.32	12.3 22			
1232.2 2	1577.92	14.3 22			
x1257.8 2		17.8 21			
x1261.5 2		12.7 17			
x1273.00 10		43 5			
1281.3 2	1479.55	15.2 20			
x1291.8 2		31 3			

Continued on next page (footnotes at end of table)

^{225}Rn β^- Decay 1997Bu03 (continued)

$\gamma(^{225}Fr)$ (continued)

Eγ	E(level)	Iγ[&]
1298.03 *10*	1479.55	74 *4*
[x]1301.6 *2*		13.7 *18*
[x]1308.42 *10*		33.7 *26*
[x]1314.88 *10*		76 *4*
[x]1317.3 *2*		23.2 *19*
1321.4 *2*	1519.60	24.6 *19*
1328.1[a] *2*	1479.55	75[a] *10*
	1526.03	30[a] *10*
1337.40[a] *10*	1479.55	30[a] *10*
	1519.60	50[a] *10*
1351.40 *10*	1479.55	56 *4*
[x]1361.0 *2*		14.3 *19*
1363.3 *2*	1392.13	22.4 *18*
[x]1371.6 *2*		24.1 *19*
1374.6[b] *2*	1526.03	14.7[b] *18*
	1577.92	14.7[b] *18*
1385.3 *2*	1614.21	18.9 *19*
[x]1389.3 *2*		17.1 *20*
1392.0 *2*	1392.13	11.3 *22*
1397.00 *10*	1479.55	25.5 *21*
1416.3 *2*	1614.21	17.0 *15*
1421.0[‡] *2*	1749.73	16.2 *16*
[x]1423.2 *2*		18.4 *16*
1443.2 *2*	1526.03	14.6 *22*
1451.16 *10*	1479.55	89 *5*
1457.10 *10*	1655.32	24 *3*
[x]1466.5 *2*		28 *3*
1471.2 *2*	1614.21	15.5 *26*
[x]1478.2 *2*		19.1 *22*
[x]1483.16 *10*		39.0 *22*
[x]1487.24 *10*		23.8 *20*
1495.30 *10*	1577.92	72 *4*
1498.0 *2*	1526.03	20.6 *21*
[x]1502.1 *2*		20.2 *21*
1504.4 *2*	1655.32	23.1 *21*
1508.6 *2*	1749.73	23.5 *21*
1512.8 *2*	1655.32	24.7 *22*
[x]1522.83 *10*		47 *3*
[x]1525.3 *2*		12.7 *15*
1549.3 *2*	1577.92	15.7 *21*
1551.4 *2*	1749.73	25.4 *21*
[x]1553.9 *2*		23 *4*
[x]1555.6 *2*		17 *4*
[x]1563.7 *2*		10.0 *20*
1568.10 *10*	1749.73	87 *5*
[x]1582.90 *10*		37 *4*
[x]1601.8 *2*		15.9 *16*
1607.3 *3*	1749.73	10.6 *11*
[x]1609.8 *2*		25.3 *20*
[x]1623.5 *2*		7.2 *19*
1626.8 *2*	1655.32	10.3 *16*
[x]1635.2 *2*		15.7 *16*
[x]1642.4 *2*		27.2 *20*
[x]1646.5 *2*		17.5 *16*
[x]1654.3 *2*		8.4 *15*
[x]1663.5 *5*		6.0 *13*
1667.4 *2*	1749.73	25.9 *19*
[x]1672.5 *2*		14.9 *15*
[x]1682.5 *5*		10.9 *14*
[x]1692.0 *2*		8.1 *19*
[x]1694.5 *2*		27.0 *20*
[x]1698.2 *5*		9.1 *19*
[x]1700.2 *5*		11.8 *19*
[x]1703.5 *5*		12.2 *18*
[x]1734.1 *5*		8.9 *19*
[x]1794.0 *5*		7.1 *14*
[x]1796.1 *5*		6.3 *12*
[x]1809.7 *5*		7.6 *15*
[x]1814.7 *5*		5.0 *10*
[x]1818.3 *5*		7.5 *15*
[x]1828.6 *5*		7.8 *17*
[x]1831.2 *5*		10.2 *18*
[x]1842.9 *5*		9.0 *19*
[x]1849.3 *5*		9.0 *19*
[x]1859.7 *5*		6.0 *12*
[x]1883.1 *5*		9.2 *19*
[x]1894.3 *5*		6.0 *12*
[x]1926.0 *5*		6.0 *12*

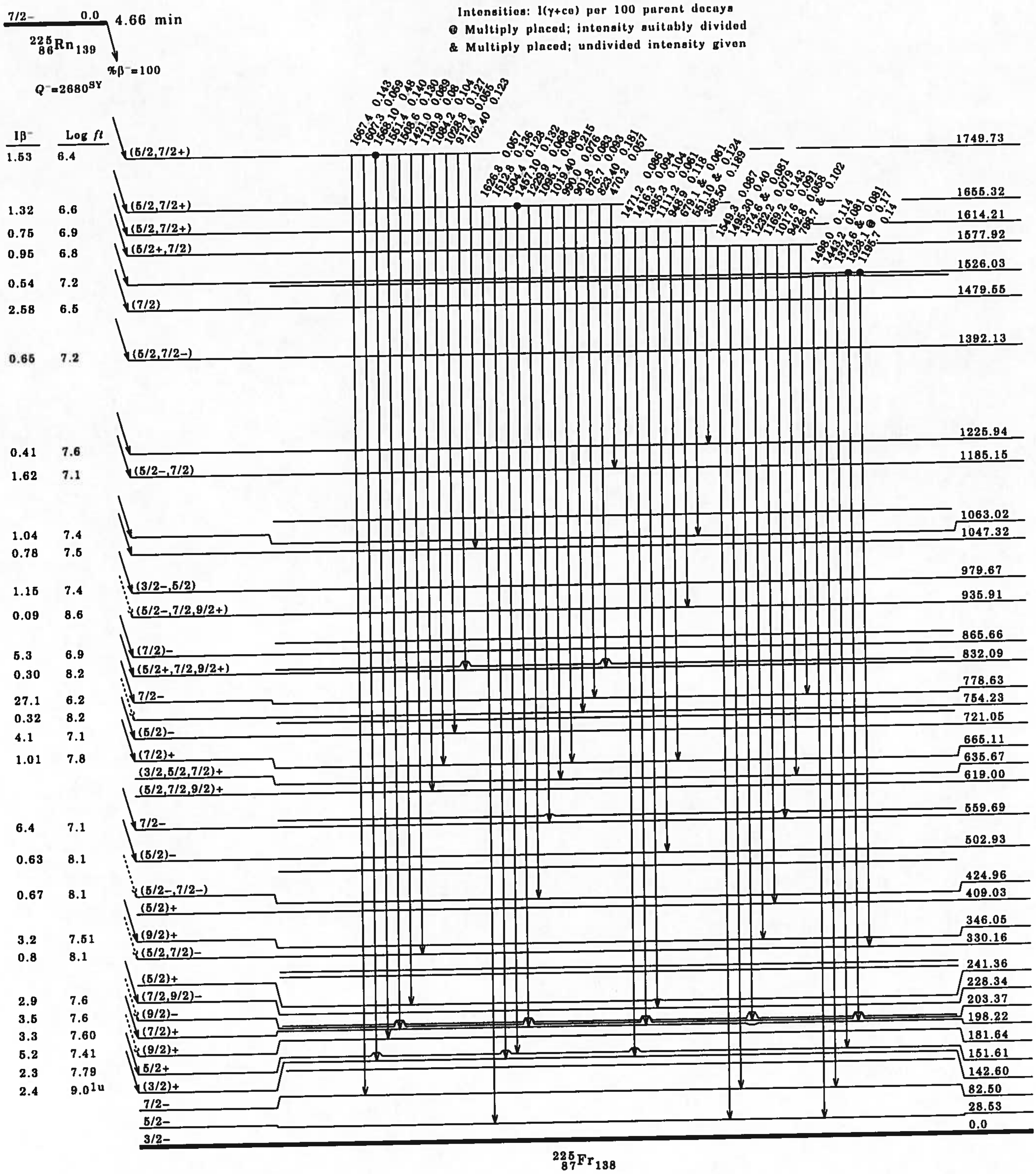
† From Iγ and I(ce) data measured using systems with known absolute efficiency calibrations.
‡ Eγ values for 136.0γ, 668.05γ and 1421.0γ are at least 5σ from expected least-squares adjusted value for placements indicated.
§ Peak obscured or unresolved in singles spectrum; most of information was obtained from coincidence experiments.
\# A multiscaling experiment indicates that this line has the correct half-life for ^{225}Rn decay.
@ Transition not observed, but its existence and total intensity was deduced from coincidences between lines feeding the 182 level and those depopulating the 152 and 182 levels.
& For absolute intensity per 100 decays, multiply by 0.00552 *25*.
a Multiply placed; intensity suitably divided.
b Multiply placed; undivided intensity given.
x γ ray not placed in level scheme.

$^{225}_{87}Fr_{138}$–27

^{225}Rn β^- Decay 1997Bu03 (continued)

Decay Scheme

Intensities: I(γ+ce) per 100 parent decays
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given



From NNDC(BNL)
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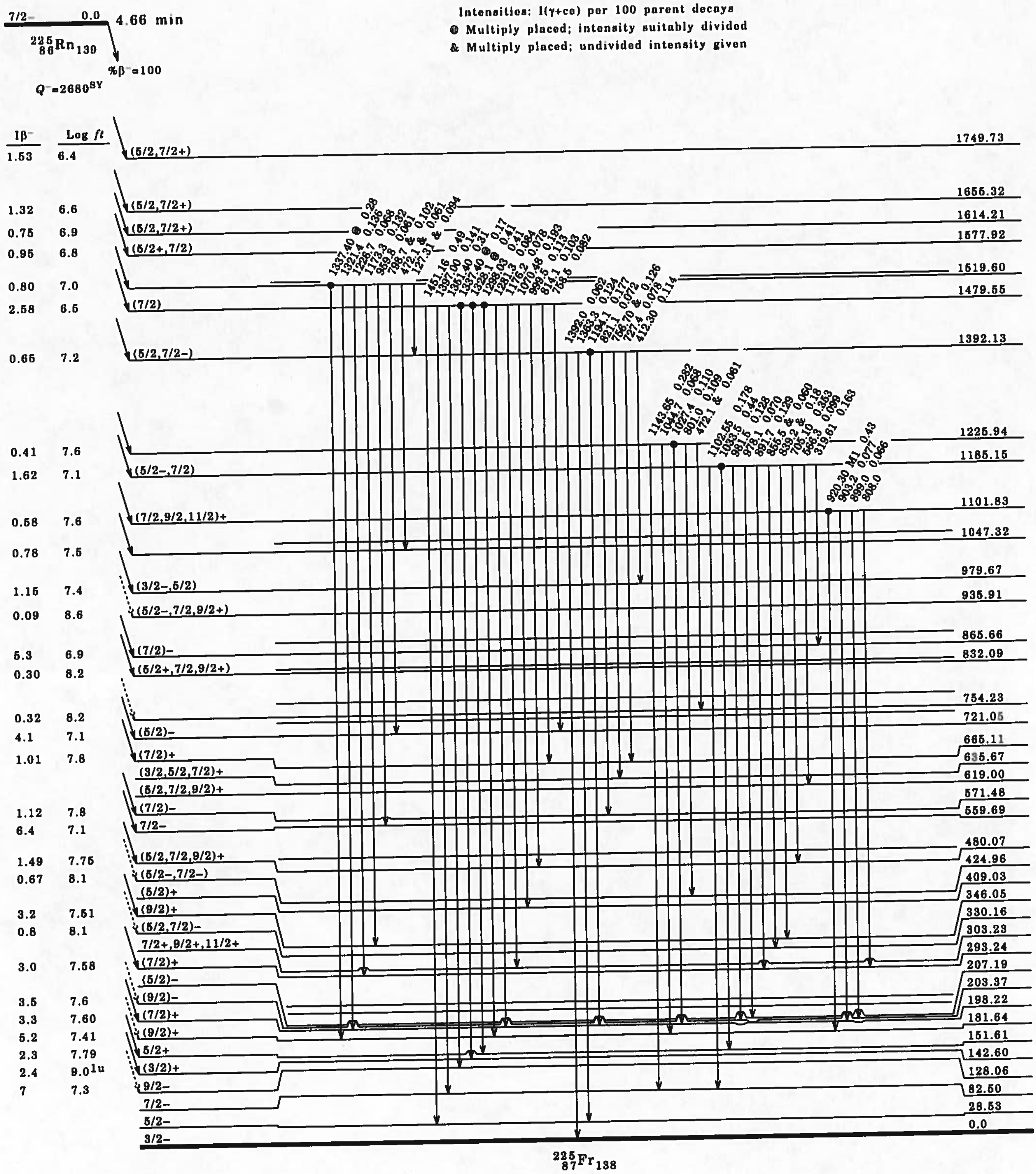
^{225}Rn β^- Decay 1997Bu03 (continued)

Decay Scheme (continued)

Intensities: I(γ+ce) per 100 parent decays
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

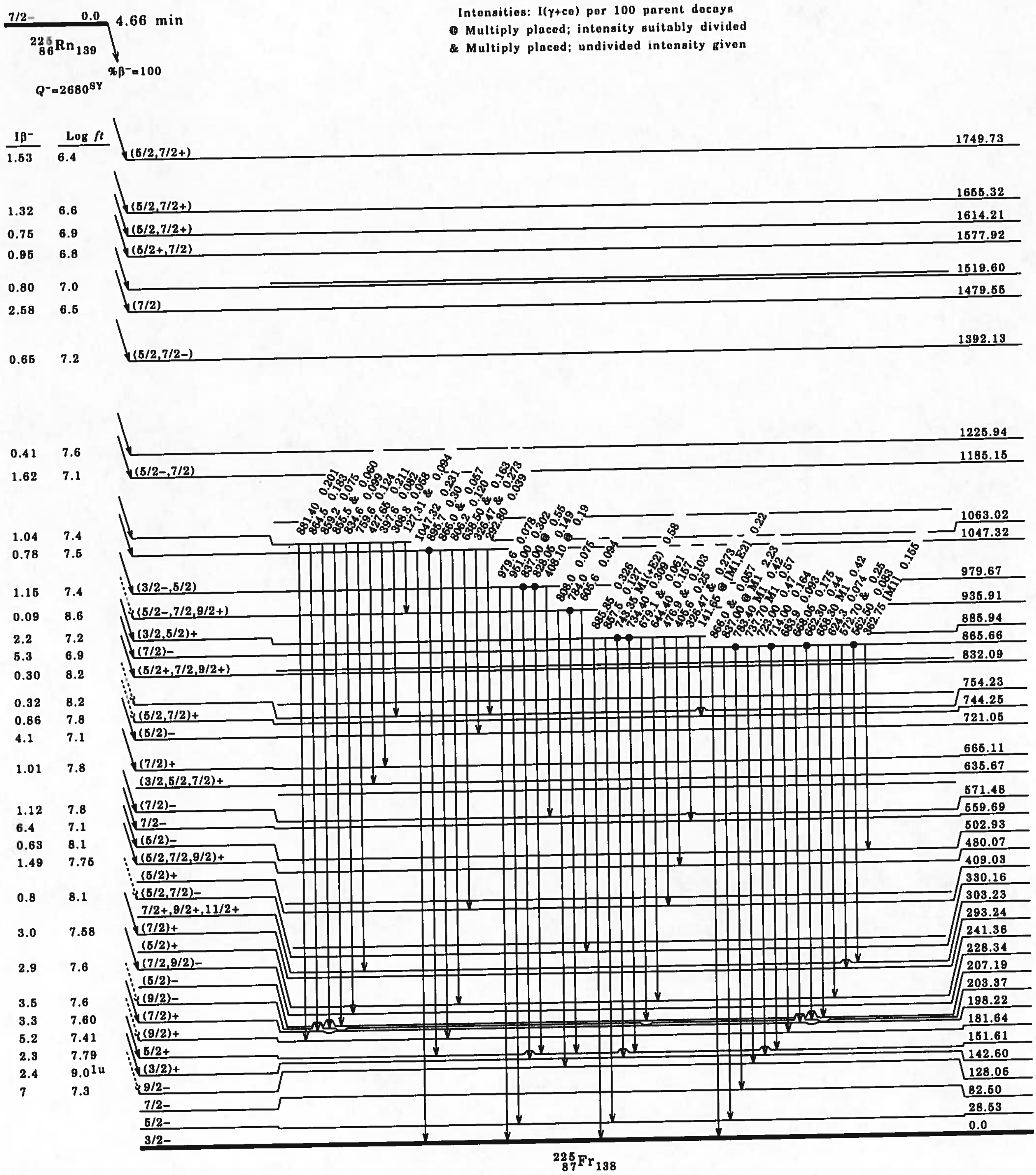


From NNDC(BNL)
program ENSDAT

^{225}Rn β^- Decay 1997Bu03 (continued)

Decay Scheme (continued)

Intensities: I(γ+ce) per 100 parent decays
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

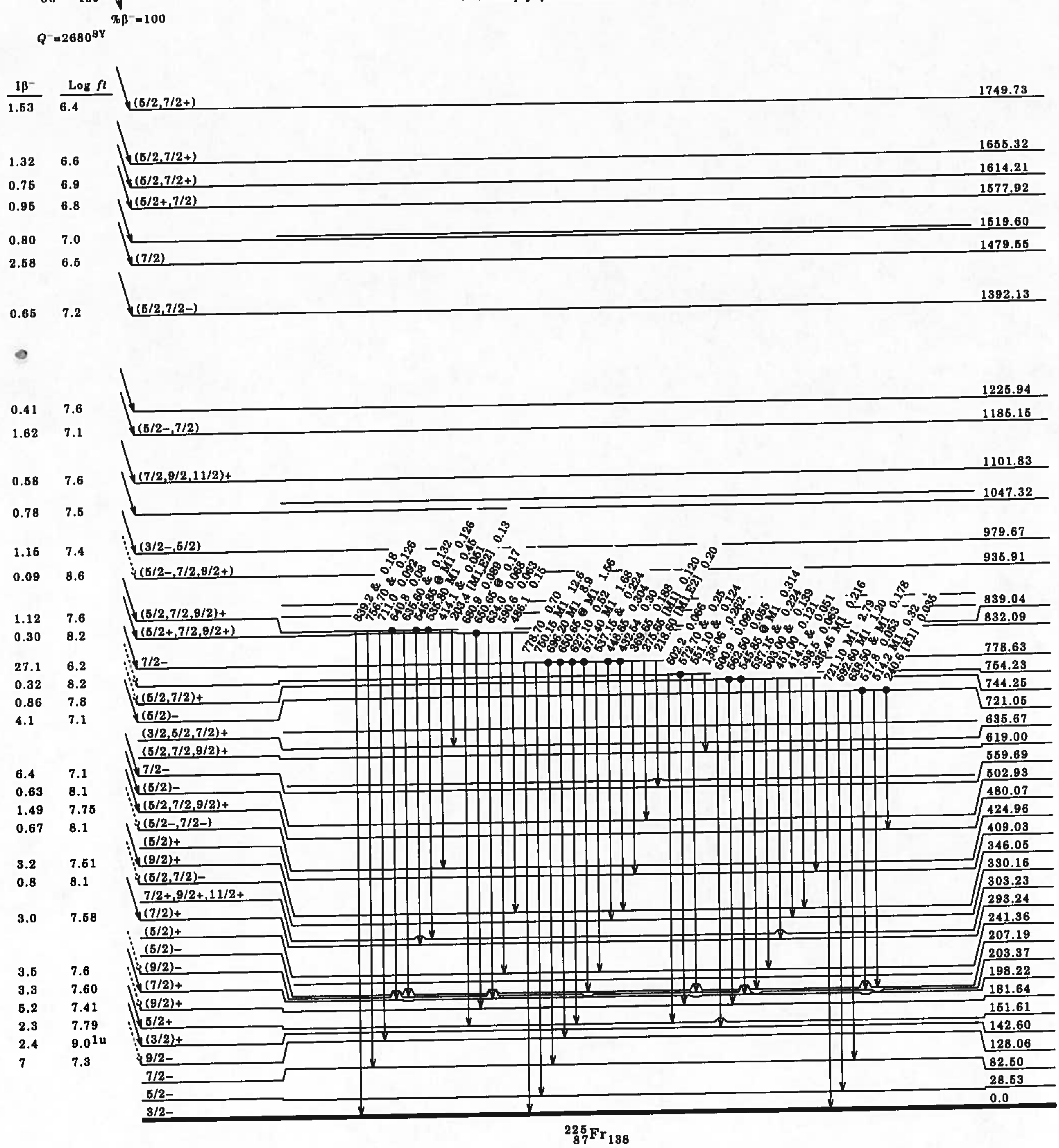


From NNDC(BNL)
program ENSDAT

^{225}Rn β^- Decay 1997Bu03 (continued)

Decay Scheme (continued)

Intensities: I(γ+ce) per 100 parent decays
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

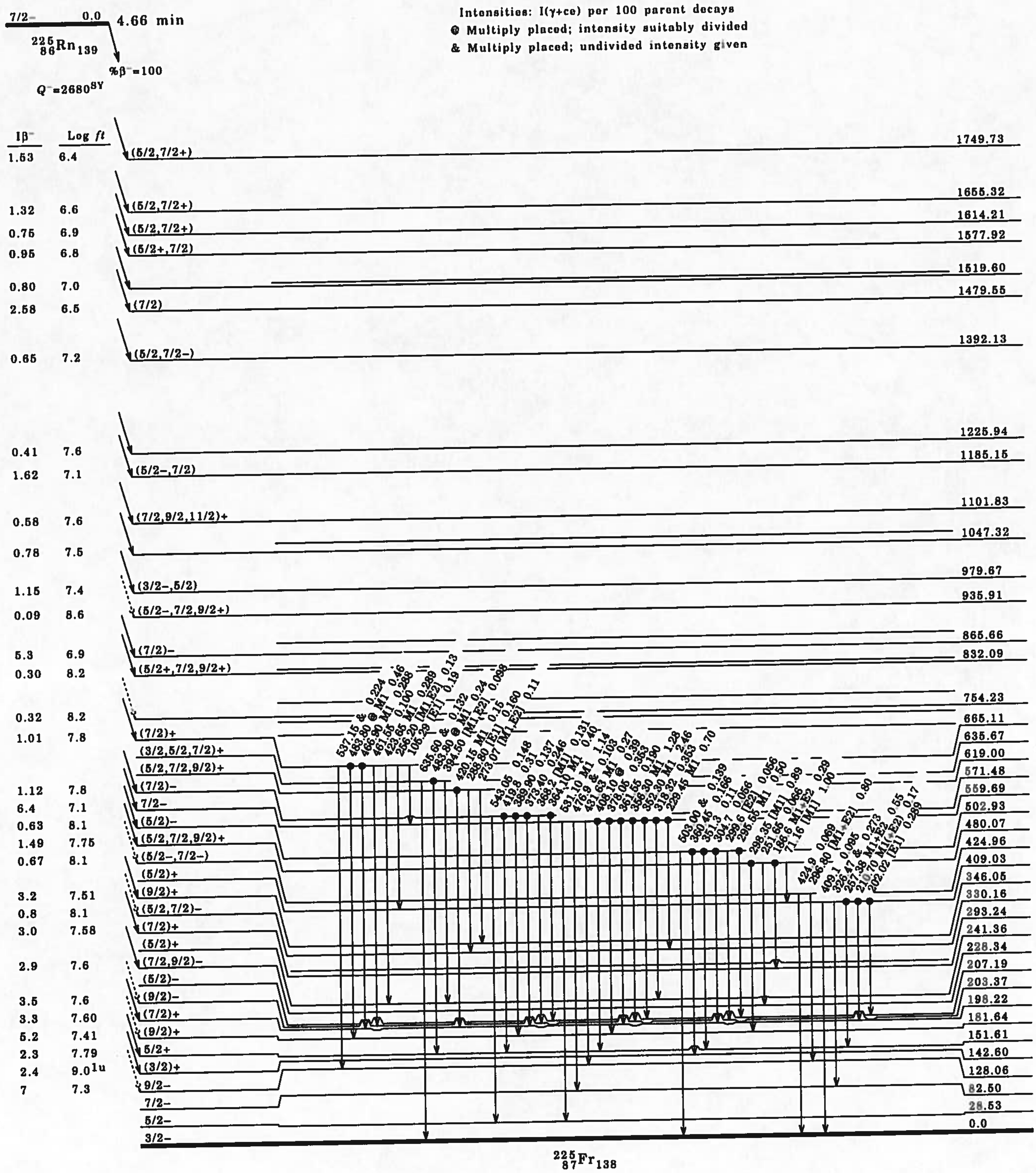


From NNDC(BNL)
program ENSDAT

^{225}Rn β^- Decay 1997Bu03 (continued)

Decay Scheme (continued)

Intensities: I(γ+ce) per 100 parent decays
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given

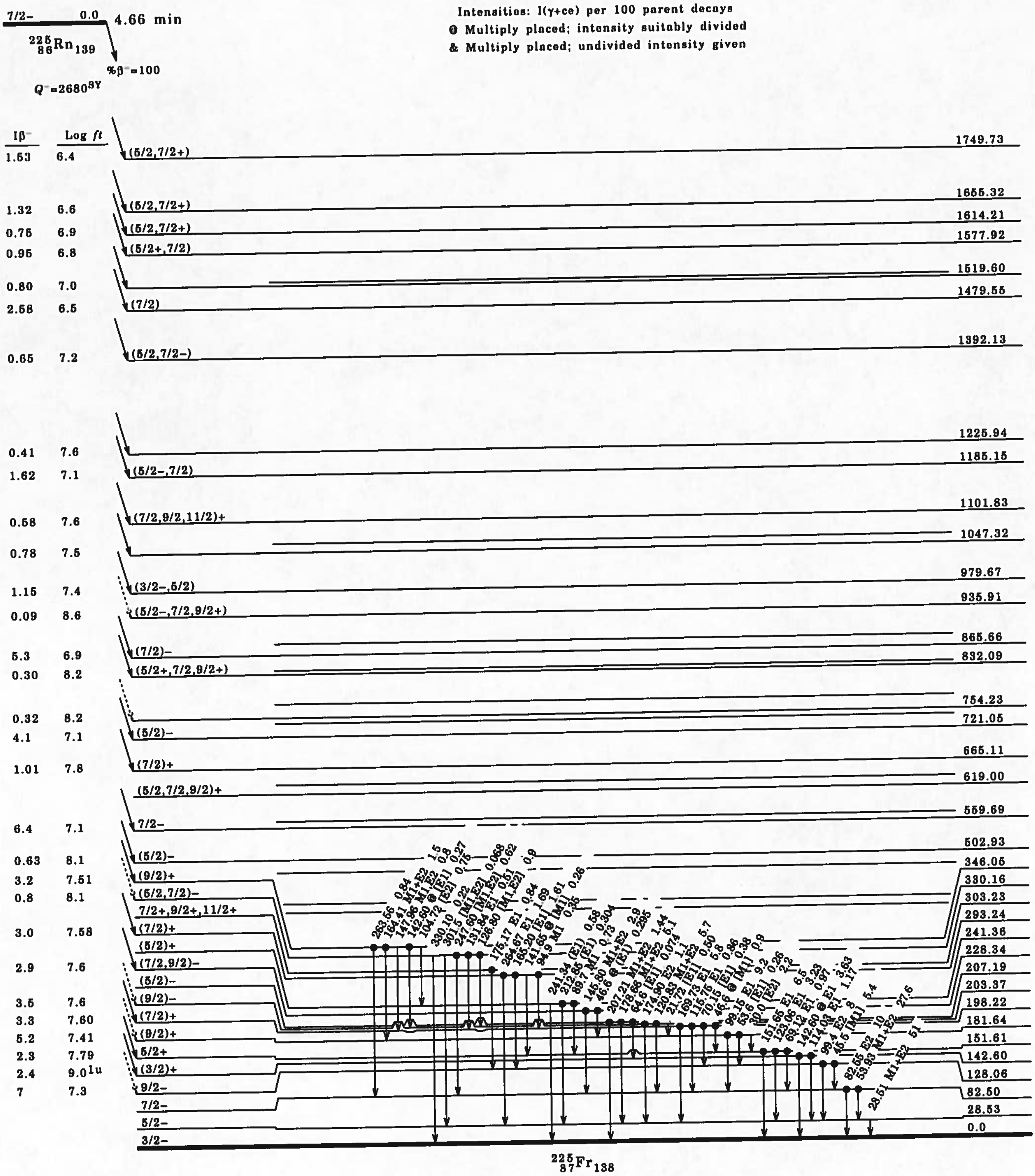


From NNDC(BNL)
program ENSDAT

^{225}Rn β^- Decay 1997Bu03 (continued)

Decay Scheme (continued)

Intensities: I(γ+ce) per 100 parent decays
@ Multiply placed; intensity suitably divided
& Multiply placed; undivided intensity given



From NNDC(BNL)
program ENSDAT

$^{226}Ra(t,\alpha)$ 1997Bu03

1997Bu03: E(t)=18 MeV; Enge split-pole spectrograph with photographic emulsions; FWHM=18 keV; θ(lab)=40°, 50°, 60°; ≈40 μgm/cm² carbon-backed ^{226}Ra ($T_{1/2}$=1600y) target; measured Eα, dσ/dΩ. Supersedes 1987BuZV.

^{225}Fr Levels

Calculated dσ/dΩ(60°) (μb/sr) (1997Bu03) for selected orbitals:

Spin	1/2[400]	1/2[530]	1/2[541]	3/2[402]	3/2[651]	3/2[532]
1/2	121	0.8	1.6			
3/2	23	14	1.5	103	0.0	0.7
5/2	7.6	0.2	13	4.6	0.03	6.2
7/2	0.4	39	2.0	1.2	0.0	3.3
9/2	0.05	0.4	33	0.05	2.0	26
11/2		0.8	0.1		0.01	0.3
13/2					12	

E(level)†	Jπ‡	dσ/dΩ(60°) μb/sr	Comments
0.0§	3/2-	≈1.5	
28§	5/2-	14	
82§	7/2-	20	
≈130§	9/2-	≈45	
≈142#		≈23	Jπ: observed dσ/dΩ is far too large for 3/2 3/2[651] level but this may be attributable to ΔN=2 mixing with 3/2[402] band (1997Bu03).
181&	(1/2+)	120	Possibly the 1/2[400] bandhead, based on very strong excitation; assignment supported by comparison with (t,α) systematics in neighboring odd-A Fr isotopes.
205@	(3/2+)	103	May include small contributions from (9/2)- and (7/2)- levels adopted at 203 and 207 keV, respectively.
244@&	(5/2+)	32	
≈294@	(7/2+)	≈3.1	
≈329		≈3.8	
401		80	
≈448		≈2.4	
500&		9	
≈570&		≈6	
591		75	
≈630		≈8	
655		29	
676		≈13	
≈741&		2.6	
799		4.4	
845		6.7	
882&		2.9	
974		8.8	
1028		3.4	
1049		5.6	
1127		70	
≈1229&		≈23	
≈1247		≈23	
1321		13	
1351		13	
1398		13	
1477&		18	
≈1516&		≈23	
≈1535		≈31	

† Average value from spectra at three angles. Uncertainties range from ≈1 keV for well-resolved, low-energy peaks to ≈3 keV for the highest-energy levels.

‡ Assignment based on comparison of experimental (t,α) cross sections with $[2Nc^2V^2\sigma(DWBA)$, where N=23, single-particle coefficients c are taken from the Nilsson model and V^2 is the probability that orbital has a pair of particles in the target nucleus. See 1997Bu03 for further discussion.

§ (A): π 3/2[532] band. Coriolis mixed with 1/2[541] band.

(B): π 3/2[651] band. Coriolis mixed 1/2[660] band.

@ (C): possible π 3/2[402] band. Coriolis mixed with J>1/2 members of 1/2[660] and 1/2[400] bands.

& It is questionable whether this peak includes the level observed at approximately this energy in β^- decay (1997Bu03).

Adopted Levels

Q(β⁻)=-2030 *70*; S(n)=7600 *70*; S(p)=2940 *70*; Q(α)=7390 *50* 2003Au03.
Assignment: parent of ^{221}Ac, ^{217}Fr, ^{213}At (1951Ke53); daughter of ^{229}Np (1968Ha14); excitation functions, cross bombardments (1970Bo13); ^{232}Th(α,xnyp) mass separation (1978IbZZ). 1991Cw01: Calculated excitation energy,equilibrium deformations.

^{225}Pa Levels

E(level)	$T_{1/2}$	Comments
0.0	1.7 s *2*	%α=100. $T_{1/2}$: measured values: 1.8 s *3* (1970Bo13), 1.7 s *1* (1978IbZZ). Other measurements: ≈2 s (1951Ke53), 0.8 s *3* (1958To25). %α: only α decay was observed. From gross β decay theory of 1973Ta30, %ε<0.03.

^{229}Np α Decay

Parent ^{229}Np: E=0.0; Jπ=(5/2+); $T_{1/2}$=4.0 min *2*; Q(g.s.)=7010 *50*; %α decay>50.0.
%α>50 (1968Ha14). Requirement of HF≤4.0 for the 6890α yields %α>15.

^{225}Pa Levels

E(level)
0+x

α radiations

Eα	E(level)	Iα†	HF	Comments
6890 *20*	0+x	100	<1.2	Eα: measurement of 1968Ha14. Systematics of α decay energies (see 1985Wa02) suggests that this α group feeds either the g.s. or a low-energy (<70 keV) level in ^{225}Pa. Iα: only one α group was observed by 1968Ha14. HF: r_0(^{225}Pa)=1.525 is used in calculation.

† For α intensity per 100 decays, multiply by >0.50.

CITATION:
Nuclear Data Sheets (1990)

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Adopted Levels

Q(β⁻)=-4210 *70*; S(n)=6408 *28*; S(p)=3782 *19*; Q(α)=8014 *7* 2003Au03.
Assignment: ^{208}Pb(^{22}Ne,5n), exit: E(^{22}Ne)=100-120 MeV (1988AnZS); ^{180}Hf(^{48}Ca,X), E(^{48}Ca)=204 MeV, daughter of ^{221}Th (1989He13).

^{225}U Levels

E(level)	Jπ	$T_{1/2}$	Comments
0.0	5/2+	61 ms *4*	%α=100. Jπ: Spin assignments are from sys.(2003Au03). Only α decay was observed. From gross β decay theory of 1973Ta30, %ε<0.005. $T_{1/2}$: from 2003AU03; other measurements: 30 *+20-10* ms (1988AnZS); 80 *+40-20* ms (1989He13).

Adopted Levels

S(p)=1410 *80*; Q(α)=8790 *50* 2003Au04.
^{236}U(22Ne,xn),E=124 MeV; measured E alpha, I alpha (1994YE08).

^{225}Np Levels

E(level)	Jπ	$T_{1/2}$	Comments
0.0	(9/2−)	3 ms	Jπ,$T_{1/2}$: From systematics (2003AU03). $T_{1/2}$: 2001Mo07 predicted half-life of exotic alpha decay as 1.2 ms. %α=100.

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KEYNUMBERS

1951Ke53
1958To25
1968Ha14
1969Ha03
1970Bo13
1972El21
1973Ta30
1975We23
1978IbZZ
1983Ny01
1985Co24
1985Wa02
1986Ek02
1987BoZP
1987BuZV
1987Co19
1987Sh24
1988AnZS
1988Le13
1988NeZZ
1989He13
1989Ra17
1991Cw01
1994Ye08
1997Bu03
2000Sh32
2001Mo07
2002Ba85
2003Au03
2003Au04