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ROOTS: A Program to Generate Radionuclide Decay Chains

D. E. Fields
D. E. Dunning, Jr.

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ORNL/TM-9452

Health and Safety Research Division

ROOTS: A PROGRAM TO GENERATE RADIONUCLIDE DECAY CHAINS

D. E. Fields, D. E. Dunning, Jr.*

*The MAXIMA Corporation, 107 Emory Valley Road, Oak Ridge, Tennessee 37830.

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ABSTRACT

A set of algorithms has been developed to support dosimetric and transport calculations. These subroutines read a radionuclide data file and prepare a decay chain showing branching fractions and radioactive half-lives of each member. One application of these subroutines has been their implementation as a set of FORTRAN subroutines for application in the PREREM code (Ryan and Fields, 1981). Recent use of these subroutines in stand-alone form required their expansion to print branching fractions. An expanded data set based on ICRP-38 radionuclide data (ICRP, 1983) was also prepared.

This subroutine package is called Radionuclide Origin and Ontogeny Tracing Subroutines (ROOTS). The package is intended for execution on a Digital Equipment Corporation PDP-10 Computer System, and may require modification to run on other machines.

1. INTRODUCTION

A set of algorithms has been developed to read a radionuclide data file and prepare a decay chain. This decay chain is printed, together with branching fractions and daughter half-lives. These branching (decay) fractions are the fractions of parent radionuclide decay that yield specific daughters; they sum to unity for each parent. Radioactive half-lives are also read and printed for each member of the decay chain.

The original package of subroutines was written for use in a data preprocessor program (Ryan and Fields, 1981) for the INREM II internal dosimetry code (Killough et al., 1978), and subsequent applications have also been in support of dosimetry and transport calculations.

This subroutine package is called Radionuclide Origin and Ontogeny Tracing Subroutines (ROOTS). These subroutines are intended for execution on a Digital Equipment Corporation PDP-10 Computer System, and may require modification to run on other machines. If modification is intended, the reader should obtain DEC documentation (Digital Equipment Corporation, 1977) for a detailed description of features of DEC FORTRAN, which uses a 36-bit word length.

An expanded radionuclide data set based on ICRP-38 nuclear data (ICRP, 1983) has been prepared for use with the ROOTS package of subroutines.

Appendix A consists of a listing of the ROOTS subroutines. The supporting data base for these subroutines is found in Appendix B. Appendix C consists of a simple interactive driver code for invoking the ROOTS subroutines and printing sample output. Appendix D contains sample output obtained using the code listed in Appendix C.

2. CODE STRUCTURE

The ROOTS subroutine structure is shown in Figure 1. The subroutines are shown being invoked by the interactive driver program WORM that is included in APPENDIX C of this report.

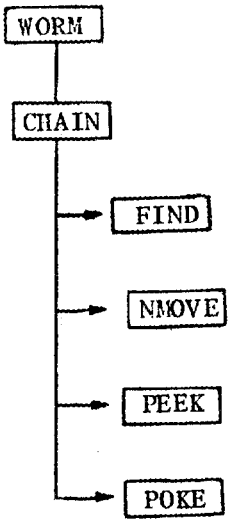

Figure 1. Subroutine structure of ROOTS. WORM is an interactive driving program listed in Appendix C.

3. SUBROUTINE FUNCTIONS

Subroutine CHAIN, called by the main driver program, invokes the nuclear decay chain algorithms. When given the name of a parent radionuclide, CHAIN repeatedly searches a nuclear data base (accessed as logical unit 8) for elements of the decay chain. The data base consists of card images, one for each isotope, containing isotope name, half-life, daughter radionuclides, and the branching fractions to each daughter. These data are returned to the main program.

Subroutine FIND, called by CHAIN, performs the search on the radionuclide data base for the parent radionuclide card image. When this record is located, FIND stores the data in arrays. If the record is not found in the data base, a message is printed at the user's terminal. The format of this message is "(parent name) IS NOT LISTED IN CURRENT DATABASE." This message will most likely result from an incorrect entry of the parent radionuclide name. As explained in Chapter 4, this name must be specified as the chemical symbol followed by the nuclide mass number, separated by a hyphen.

Subroutine NMOVE is called by CHAIN. Its purpose is to compute certain radionuclide indices used in the main program and to determine elements of array BRANCH, the branching fractions for transitions between nuclides.

Subroutine PEEK is called from CHAIN. PEEK takes the next nuclide name to be searched for from the last-in/first-out stack ISTK. This stack is written onto by POKE.

Subroutine POKE, called from CHAIN, writes values of nuclide names and branching fractions onto vectors ISTK and FSTK. These vectors are used as last-in/first-out stacks by subroutines PEEK and POKE.

Subroutines PEEK and POKE perform tests on values of array indices computed therein. Should future modifications to the radionuclide data set (logical unit 8) lead to decay chains of uncondensed length greater than the size of the stack vectors IDAU and FDAU, error messages will be printed. The "uncondensed length" of the chain may be greater than the number of daughter radionuclides because of the manner in which daughters are referenced by the code. Messages printed by PEEK and POKE are, respectively, "ATTEMPT TO PEEK OUTSIDE STACK BOUNDS" and "ATTEMPT TO POKE VALUE INTO FULL STACK." These messages indicate that the DIMENSION statement must be changed to enlarge the program arrays. We do not anticipate that this need for action by the user will occur.

4. DATA BASE STRUCTURE

The ROOTS data base consists of records for radionuclides ranked in order of increasing atomic charge number and mass numbers. The FORMAT of each record is (A9,3(A10,E10.4),E11.5), where the first alphameric variable is the radionuclide parent name abbreviation (chemical symbol) and atomic mass number, separated by dashes and including no blanks. If the radionuclide is considered metastable, the letter M follows the name and atomic mass number. If metastable and non-metastable daughter radionuclide names are listed in the daughter name field, the metastable name must be listed before the non-metastable name. The next (up to three) alphameric variables are daughter names and atomic mass numbers, and the branching fraction from the parent to that daughter isotope. The final variable represents the radiological half-life of the parent, expressed in seconds.

The data base listed in Appendix B is based on ICRP-38 data (ICRP, 1983).

REFERENCES

Digital Equipment Corporation, 1977. DecSystem 10 Fortran Programmer's Reference Manual, Order No. AA-0944E-TB.

Fields, D. E., M. T. Ryan, D. E. Dunning, Jr., and J. C., Pleasant, 1981. "Part II. Code Structure," in PREREM: An Interactive Data Preprocessing Code for INREM II, M. T. Ryan and D. E. Fields, Eds., Oak Ridge National Laboratory, NUREG/CR-1478, ORNL/NUREG/TM-422.

ICRP, 1983. "Radionuclide Transformations; Energy and Intensity of Emissions," in Ann. ICRP 11-13. International Commission on Radiation Protection, Publication 38.

Killough, G. G., D. E. Dunning, Jr., and J. C. Pleasant, 1978. INREM II: A Computer Implementation of Recent Models for Estimating the Dose Equivalent to Organs of Man from an Inhaled or Ingested Radionuclide, Oak Ridge National Laboratory, NUREG/CR-0114, ORNL/NUREG/TM-84.

Ryan, M. T., D. E. Fields, D. E. Dunning, Jr., J. C. Pleasant, 1981. "Part I. User's Manual," in PREREM: An Interactive Data Preprocessing Code for INREM II, M. T. Ryan and D. E. Fields, Eds., Oak Ridge National Laboratory, NUREG/CR-1478, ORNL/NUREG/TM-422.

Ryan, M. T., and D. E. Fields, Eds., 1981. PREREM: An Interactive Data Preprocessing Code for INREM II. Oak Ridge National Laboratory, NUREG/CR-1428, ORNL/NUREG/TM-422.

APPENDIX A: FORTRAN LISTING OF ROOTS SUBROUTINES

APPENDIX A: FORTRAN LISTING OF ROOTS SUBROUTINES

```
C
C
      SUBROUTINE CHAIN
C
C      CHAIN DETERMINES RADIOISOTOPE DECAY CHAIN AND
C      MAKES ENTITIES AND BRANCHING FRACTIONS AVAILABLE
C
C      INPUT ON DEVICE 8, TTY IS DEVICE 6
C
      DOUBLE PRECISION IPAR,FSTK,ISTK,ID(3),FD(3),IDAU,FDAU,IDSTK(40),
     1 NAMNUC
      COMMON /SUB/ ISTK(40),FSTK(40),IPTR,NXTPTR
      COMMON NAMNUC(25),NSPEC,TR(25),BRANCH(25,25),NDAUG(25)
      DATA BRANCH/625*0./,TR/25*0./, ISTK/40*'          '/,FSTK/40*0./
      IPTR = 0
      NXTPTR = 1
      NSPEC = 1
      LL = 1
      IPAR = NAMNUC(1)
      IDAU=IPAR
      FDAU=0.
      CALL POKE(IDAU,FDAU)
   10 CONTINUE
C AVOID MULTIPLE LOOKUPS
      DO 20 IC=1,NSPEC
        IF(IPAR.EQ.NAMNUC(IC).AND.TR(IC).GE.0.1E-30) GO TO 50
   20 CONTINUE
      CALL FIND(IPAR,ID,FD,NDAU,IDSTK)
      NDAUG(LL)=NDAU
      LL=LL+1
      IF (NDAU.EQ.0) GO TO 40
      DO 30 N=1,NDAU
        IDAU=ID(N)
        FDAU=FD(N)
        CALL POKE(IDAU,FDAU)
   30 CONTINUE
   40 CALL NMOVE(IDSTK,NDAU,FD,LL,ID)
   50 IF (NXTPTR.EQ.IPTR) GO TO 60
      CALL PEEK(IPAR)
      GO TO 10
   60 RETURN
      END
C
C
      SUBROUTINE FIND(IPAR,ID,FD,NDAU,IDSTK)
C
      COMMON /SUB/ ISTK(40),FSTK(40),IPTR,NXTPTR
      DOUBLE PRECISION IPAR,ID(3),FD(3),IP,IBLK,IDSTK(40), ISTK,FSTK
      DATA IBLK/'          '/
      REWIND 8
   10 READ(8,1000,END=40) IP,(ID(I),FD(I),I=1,3),IDSTK(NXTPTR)
      IF (IP.NE.IPAR) GO TO 10
      DO 20 I=1,3
```

```
        NDUM=I-1
        IF (ID(I).EQ.IBLK) GO TO 30
   20 CONTINUE
      NDUM=3
   30 NDAU=NDUM
      RETURN
   40 WRITE(6,2000) IPAR
      STOP
 1000 FORMAT(A9,3(A10,E10.4),E11.5)
 2000 FORMAT(/,2X,A10,' IS NOT LISTED IN CURRENT DATABASE!')
      END
C
C
      SUBROUTINE NMOVE(IDSTK,NDAU,FD,LL,ID)
C
      DOUBLE PRECISION NAMNUC,IDSTK(40),FD(3), ISTK,FSTK,ID(3)
      COMMON NAMNUC(25),NSPEC,TR(25),BRANCH(25,25)
      COMMON /SUB/ ISTK(40),FSTK(40),IPTR,NXTPTR
      DO 10 I=1,NSPEC
        IF(NAMNUC(I).NE.ISTK(NXTPTR)) GO TO 10
        IP=I
        TR(I)=IDSTK(NXTPTR)
        GO TO 20
   10 CONTINUE
   20 IF(NDAU.EQ.0)RETURN
      DO 50 J=1,NDAU
        DO 30 I=1,NSPEC
          IF (ID(J).EQ.NAMNUC(I)) GO TO 40
   30   CONTINUE
C DAUGHTER NAME NOT YET IN LIST
      NSPEC=NSPEC+1
      NAMNUC(NSPEC)=ID(J)
   40 CONTINUE
      IF (NDAU.EQ.0) RETURN
      BRANCH(NSPEC,IP)=FD(J)
   50 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE PEEK(IPAR)
C
      DOUBLE PRECISION IPAR,ISTK,FSTK
      COMMON /SUB/ ISTK(40),FSTK(40),IPTR,NXTPTR
      NXTPTR=NXTPTR+1
      IF (NXTPTR.LT.40) GO TO 10
      WRITE(6,2000)
      STOP
   10 IPAR=ISTK(NXTPTR)
      RETURN
 2000 FORMAT(/,2X,'ATTEMPT TO PEEK OUTSIDE OF STACK BOUNDS.')
      END
C
```

```
C
      SUBROUTINE POKE(IDAU,FDAU)
C
      DOUBLE PRECISION IDAU,FDAU,ISTK,FSTK
      COMMON /SUB/ ISTK(40),FSTK(40),IPTR,NXTPTR
      IPTR=IPTR+1
      IF (IPTR.LT.40) GO TO 10
      WRITE(6,2000)
      STOP
   10 ISTK(IPTR)=IDAU
      FSTK(IPTR)=FDAU
      RETURN
 2000 FORMAT(/,2X,'ATTEMPT TO POKE VALUE INTO FULL STACK')
      END
```

APPENDIX B: ROOTS DATA BASE*

*Spaces have been deleted to permit printing within allowed margins.

APPENDIX B: ROOTS DATA BASE

H-3			3.89736E 08
BE-7			4.60512E 06
BE-10			5.04922E 13
C-11			1.22280E 03
C-14			1.80825E 11
N-13			5.97900E 02
N-16			7.13000E 00
O-15			1.22240E 02
F-18			6.58620E 03
NE-19			1.72200E 01
NA-22			8.21128E 07
NA-24			5.40000E 04
MG-27			5.67480E 02
MG-28	AL-28	1.0000E 00	7.52759E 04
AL-26			2.25952E 13
AL-28			1.34400E 02
SI-31			9.43800E 03
SI-32	P-32	1.0000E 00	1.42009E 10
P-30			1.49940E 02
P-32			1.23466E 06
P-33			2.19456E 06
S-35			7.55481E 06
CL-36			9.49884E 12
CL-38			2.23260E 03
CL-39	AR-39	1.0000E 00	3.33600E 03
AR-37			3.02573E 06
AR-39			8.48899E 09
AR-41			6.57720E 03
K-38			4.58160E 02
K-40			4.03937E 16
K-42			4.44960E 04
K-43			8.13599E 04
K-44			1.32780E 03
K-45	CA-45	1.0000E 00	1.20000E 03
CA-41			4.41806E 12
CA-45			1.40832E 07
CA-47	SC-47	1.0000E 00	3.91392E 05
CA-49	SC-49	1.0000E 00	5.22960E 02
SC-43			1.40076E 04
SC-44			1.41372E 04
SC-44M	SC-44	9.8630E-01	2.10960E 05
SC-46			7.24291E 06
SC-46M	SC-46	1.0000E 00	1.87200E 01
SC-47			2.89526E 05
SC-48			1.57320E 05
SC-49			3.44400E 03
TI-44	SC-44	1.0000E 00	1.49267E 09

TI-45			1.10880E 04
TI-51			3.45120E 02
V-47			1.95600E 03
V-48			1.40296E 06
V-49			2.85120E 07
V-52			2.25000E 02
CR-48	V-48	1.0000E 00	8.26559E 04
CR-49	V-49	1.0000E 00	2.52540E 03
CR-51			2.39363E 06
MN-51	CR-51	1.0000E 00	2.77200E 03
MN-52			4.83062E 05
MN-52M	MN-52	1.7500E-02	1.26600E 03
MN-53			1.16763E 14
MN-54			2.70000E 07
MN-56			9.28260E 03
MN-57			8.82000E 01
FE-52	MN-52M	1.0000E 00	2.97900E 04
FE-55			8.52055E 07
FE-59			3.84730E 06
FE-60	CO-60M	1.0000E 00	3.15576E 12
CO-55	FE-55	1.0000E 00	6.31440E 04
CO-56			6.80486E 06
CO-57			2.34057E 07
CO-58			6.11712E 06
CO-58M	CO-58	1.0000E 00	3.29400E 04
CO-60			1.66340E 08
CO-60M	CO-60	9.9750E-01	6.28200E 02
CO-61			5.94000E 03
CO-62M			8.34600E 02
NI-56	CO-56	1.0000E 00	5.27040E 05
NI-57	CO-57	1.0000E 00	1.29888E 05
NI-59			2.36682E 12
NI-63			3.02953E 09
NI-65			9.07200E 03
NI-66	CU-66	1.0000E 00	1.96560E 05
CU-60			1.39200E 03
CU-61			1.22688E 04
CU-62			5.84400E 02
CU-64			4.57236E 04
CU-66			3.06000E 02
CU-67			2.22696E 05
ZN-62	CU-62	1.0000E 00	3.33360E 04
ZN-63			2.28600E 03
ZN-65			2.10729E 07
ZN-69			3.42000E 03
ZN-69M	ZN-69	9.9970E-01	4.95360E 04
ZN-71M			1.41120E 04
ZN-72	GA-72	1.0000E 00	1.67400E 05
GA-65	ZN-65	1.0000E 00	9.12000E 02
GA-66			3.38400E 04
GA-67			2.81736E 05
GA-68			4.08000E 03

GA-70				1.26900E 03
GA-72				5.07600E 04
GA-73				1.76760E 04
GE-66	GA-66	1.0000E 00		8.17200E 03
GE-67	GA-67	1.0000E 00		1.12200E 03
GE-68	GA-68	1.0000E 00		2.48832E 07
GE-69				1.40580E 05
GE-71				1.01952E 06
GE-75				4.96680E 03
GE-77	AS-77	1.0000E 00		4.06800E 04
GE-78	AS-78	1.0000E 00		5.22000E 03
AS-69	GE-69	1.0000E 00		9.12000E 02
AS-70				3.15600E 03
AS-71	GE-71	1.0000E 00		2.33280E 05
AS-72				9.36000E 04
AS-73				6.93792E 06
AS-74				1.53446E 06
AS-76				9.47519E 04
AS-77				1.39680E 05
AS-78				5.44200E 03
SE-70	AS-70	1.0000E 00		2.46000E 03
SE-73	AS-73	1.0000E 00		2.57400E 04
SE-73M	AS-73	2.7000E-01SE-73	7.3000E-01	2.34000E 03
SE-75				1.03507E 07
SE-77M				1.74500E 01
SE-79				2.05124E 12
SE-81				1.11000E 03
SE-81M	SE-81	1.0000E 00		3.43500E 03
SE-83	BR-83	1.0000E 00		1.35000E 03
BR-74				1.51800E 03
BR-74M				2.49000E 03
BR-75	SE-75	1.0000E 00		5.88000E 03
BR-76				5.83200E 04
BR-77				2.01600E 05
BR-80				1.04400E 03
BR-80M	BR-80	1.0000E 00		1.59120E 04
BR-82				1.27080E 05
BR-83	KR-83M	9.9980E-01		8.60400E 03
BR-84				1.90800E 03
BR-85	KR-85M	0.9984E 00KR-85	0.1630E-02	1.72000E 02
KR-74	BR-74	1.0000E 00		6.90000E 02
KR-76	BR-76	1.0000E 00		5.32800E 04
KR-77	BR-77	1.0000E 00		4.48200E 03
KR-79				1.26144E 05
KR-81				6.62710E 12
KR-81M	KR-81	1.0000E 00		1.30000E 01
KR-83M				6.58800E 03
KR-85				3.38297E 08
KR-85M	KR-85	2.1100E-01		1.61280E 04
KR-87	RB-87	1.0000E 00		4.57800E 03
KR-88	RB-88	1.0000E 00		1.02240E 04
KR-89	RB-89	1.0000E 00		1.89600E 02

KR-90	RB-90M	0.1190E 00RB-90	0.8810E 00	3.3200E 01
RB-79	KR-79	1.0000E 00		1.37400E 03
RB-80				3.40000E 01
RB-81	KR-81	1.0000E 00		1.64880E 04
RB-81M	RB-81	1.0000E 00		1.92000E 03
RB-82				7.80000E 01
RB-82M				2.23200E 04
RB-83	KR-83M	7.6199E-01		7.44768E 06
RB-84				2.83133E 06
RB-86				1.61222E 06
RB-87				1.48321E 18
RB-88				1.06800E 03
RB-89	SR-89	1.0000E 00		9.12000E 02
RB-90	SR-90	1.0000E 00		1.57000E 02
RB-90M	RB-90	0.2300E-01SR-90	0.9770E 00	2.58000E 02
SR-80	RB-80	1.0000E 00		6.00000E 03
SR-81	RB-81	1.0000E 00		1.53000E 03
SR-82	RB-82	1.0000E 00		2.16000E 06
SR-83	RB-83	1.0000E 00		1.16640E 05
SR-85				5.60218E 06
SR-85M	SR-85	8.7900E-01		4.17000E 03
SR-87M	RB-87	3.0000E-03		1.00980E 04
SR-89				4.36320E 06
SR-90	Y-90	1.0000E 00		9.18957E 08
SR-91	Y-91M	5.7800E-01Y-91	4.2200E-01	3.42000E 04
SR-92	Y-92	1.0000E 00		9.75600E 03
SR-93	Y-93	1.0000E 00		4.38000E 02
Y-86				5.30640E 04
Y-86M	Y-86	9.9310E-01		2.88000E 03
Y-87	SR-87M	9.9900E-01		2.89080E 05
Y-88				9.21370E 06
Y-90				2.30400E 05
Y-90M	Y-90	9.9200E-01		1.14840E 04
Y-91				5.05526E 06
Y-91M	Y-91	1.0000E 00		2.98260E 03
Y-92				1.27440E 04
Y-93	ZR-93	1.0000E 00		3.63600E 04
Y-94				1.14600E 03
Y-95	ZR-95	1.0000E 00		6.42000E 02
ZR-86	Y-86	1.0000E 00		5.94000E 04
ZR-88	Y-88	1.0000E 00		7.20576E 06
ZR-89				2.82348E 05
ZR-93	NB-93M	1.0000E 00		4.82831E 13
ZR-95	NB-95M	6.9800E-03NB-95	9.9300E-01	5.52787E 06
ZR-97	NB-97M	9.4700E-01NB-97	5.3000E-02	6.08400E 04
NB-88	ZR-88	1.0000E 00		8.58000E 02
NB-89	ZR-89	1.0000E 00		3.96000E 03
NB-89A	ZR-89	1.0000E 00		7.32000E 03
NB-90				5.25600E 04
NB-91				3.15360E 11
NB-91M	NB-91	0.9650E 00		5.27040E 06
NB-92				1.13530E 15

NB-92M				8.76960E 05
NB-93M				4.29183E 08
NB-94				6.40619E 11
NB-94M	NB-94	0.9953E 00		3.75600E 02
NB-95				3.03696E 06
NB-95M	NB-95	1.0000E 00		3.11760E 05
NB-96				8.40599E 04
NB-97				4.32600E 03
NB-97M	NB-97	1.0000E 00		6.00000E 01
NB-98				3.09000E 03
MO-90	NB-90	1.0000E 00		2.04120E 04
MO-91	NB-91	1.0000E 00		9.29400E 02
MO-93	NB-93M	1.0000E 00		1.10452E 11
MO-93M	MO-93	1.0000E 00		2.46600E 04
MO-99	TC-99M	8.7600E-01TC-99	1.2400E-01	2.37600E 05
MO-101	TC-101	1.0000E 00		8.77200E 02
TC-93	MO-93	1.0000E 00		9.90000E 03
TC-93M	TC-93	8.1800E-01MO-93	1.8200E-01	2.61000E 03
TC-94				1.75800E 04
TC-94M				3.12000E 03
TC-95				7.20000E 04
TC-95M	TC-95	4.0000E-02		5.27040E 06
TC-96				3.69792E 05
TC-96M	TC-96	9.8000E-01		3.09000E 03
TC-97				8.20497E 13
TC-97M	TC-97	1.0000E 00		7.51680E 06
TC-98				1.32542E 14
TC-99				6.72177E 12
TC-99M	TC-99	1.0000E 00		2.16720E 04
TC-101				8.52000E 02
TC-104				1.09200E 03
RU-94	TC-94M	1.0000E 00		3.10800E 03
RU-97	TC-97M	7.5500E-04TC-97	9.9920E-01	2.50560E 05
RU-103	RH-103M	9.9700E-01		3.39379E 06
RU-105	RH-105	1.0000E 00		1.59840E 04
RU-106	RH-106	1.0000E 00		3.18125E 07
RH-99				1.38240E 06
RH-99M				1.69200E 04
RH-100				7.48799E 04
RH-101				1.00984E 08
RH-101M	RH-101	7.2000E-02		3.74976E 05
RH-102				9.15170E 07
RH-102M	RH-102	5.0000E-02		1.78848E 07
RH-103M				3.36720E 03
RH-105				1.27296E 05
RH-105M	RH-105	1.0000E 00		4.50000E 01
RH-106				2.99000E 01
RH-106M				7.92000E 03
RH-107	PD-107	1.0000E 00		1.30200E 03
PD-100	RH-100	1.0000E 00		3.13632E 05
PD-101	RH-101M	9.9700E-01RH-101	3.0000E-03	2.97720E 04
PD-103	RH-103M	9.9974E-01		1.46534E 06
PD-107				2.05124E 14

PD-109				4.83372E 04
AG-102				7.74000E 02
AG-103	PD-103	1.0000E 00		3.94200E 03
AG-104				4.15200E 03
AG-104M	AG-104	3.3000E-01		2.01000E 03
AG-105				3.54240E 06
AG-106				1.43760E 03
AG-106M				7.26624E 05
AG-108				1.42200E 02
AG-108M	AG-108	8.9000E-02		4.00782E 09
AG-109M				3.96000E 01
AG-110				2.46000E 01
AG-110M	AG-110	1.3300E-02		2.15913E 07
AG-111				6.43680E 05
AG-112				1.12320E 04
AG-115	CO-115M	6.6000E-02	CO-115	9.3400E-01
CD-104	AG-104	1.0000E 00		1.20000E 03
CD-107				3.46200E 03
CD-109				2.33640E 04
CD-113				4.00896E 07
CD-113M				2.93486E 23
CD-115	IN-115M	1.0000E 00		4.29183E 08
CD-115M	IN-115	1.0000E 00		1.92456E 05
CD-117	IN-117M	9.2000E-01	IN-117	8.0000E-02
CD-117M	IN-117M	9.9800E-03	IN-117	9.9000E-01
IN-109	CO-109	1.0000E 00		1.20960E 04
IN-110				1.51200E 04
IN-110				1.76400E 04
IN-111				4.14600E 03
IN-112				2.44512E 05
IN-113M				8.64000E 02
IN-114				5.96880E 03
IN-114M	IN-114	9.5700E-01		7.19000E 01
IN-115				4.27766E 06
IN-115M	IN-115	9.5000E-01		1.60944E 23
IN-116M				1.61496E 04
IN-117	SN-117M	3.1700E-03		3.24900E 03
IN-117M	IN-117	4.7100E-01		2.62800E 03
IN-119	SN-119M	1.0900E-01		6.99000E 03
IN-119M	IN-119	2.5000E-02		1.44000E 02
SN-110	IN-110	1.0000E 00		1.08000E 03
SN-111	IN-111	1.0000E 00		1.44000E 04
SN-113	IN-113M	1.0000E 00		2.11800E 03
SN-117M				9.94464E 06
SN-119M				1.17590E 06
SN-121				2.53152E 07
SN-121M	SN-121	7.7600E-01		9.74159E 04
SN-123				1.73567E 09
SN-123M				1.11629E 07
SN-125	SB-125	1.0000E 00		2.40480E 03
SN-126	SB-126M	1.0000E 00		8.32896E 05
SN-127	SB-127	1.0000E 00		3.15576E 12
				7.56000E 03

SN-128	SB-128	1.0000E 00		3.54600E 03
SB-115				1.90800E 03
SB-116				9.48000E 02
SB-116M				3.61800E 03
SB-117				1.00800E 04
SB-118M				1.80000E 04
SB-119				1.37160E 05
SB-120				4.97664E 05
SB-120				9.53400E 02
SB-122				2.33280E 05
SB-124				5.20128E 06
SB-124M	SB-124M	1.0000E 00		1.21200E 03
SB-124M	SB-124	8.0000E-01		9.30000E 01
SB-125	TE-125M	2.2800E-01		8.74145E 07
SB-126				1.07136E 06
SB-126M	SB-126	1.4000E-01		1.14000E 03
SB-127	TE-127M	1.7600E-01TE-127	8.2400E-01	3.32640E 05
SB-128				3.24360E 04
SB-128				6.24000E 02
SB-129	TE-129M	2.2500E-01TE-129	7.7500E-01	1.55520E 04
SB-130				2.40000E 03
SB-131	TE-131M	9.9300E-02TE-131	9.0070E-01	1.38000E 03
TE-116	SB-116	1.0000E 00		8.96400E 03
TE-121				1.46880E 06
TE-121M	TE-121	8.8600E-01		1.33056E 07
TE-123				3.15576E 20
TE-123M	TE-123	1.0000E 00		1.03421E 07
TE-125M				5.01120E 06
TE-127				3.36600E 04
TE-127M	TE-127	9.7600E-01		9.41760E 06
TE-129	I-129	1.0000E 00		4.17600E 03
TE-129M	TE-129	6.5000E-01I-129	3.5000E-01	2.90304E 06
TE-131	I-131	1.0000E 00		1.50000E 03
TE-131M	TE-131	2.2200E-01I-131	7.7800E-01	1.08000E 05
TE-132	I-132	1.0000E 00		2.81520E 05
TE-133	I-133	1.0000E 00		7.47000E 02
TE-133M	TE-133	1.3000E-01I-133	8.7000E-01	3.32400E 03
TE-134	I-134	1.0000E 00		2.50800E 03
I-120				4.86000E 03
I-120M				3.18000E 03
I-121	TE-121	1.0000E 00		7.63200E 03
I-122				2.17200E 02
I-123	TE-123M	5.0000E-05TE-123	9.9990E-01	4.75200E 04
I-124				3.61152E 05
I-125				5.19610E 06
I-126				1.12493E 06
I-128				1.49940E 03
I-129				4.95454E 14
I-130				4.44960E 04
I-131	XE-131M	1.1100E-02		6.94656E 05
I-132				8.28000E 03
I-132M	I-132	8.6000E-01		5.01600E 03

I-133	XE-133M	2.9000E-02XE-133	9.7100E-01	7.48799E 04
I-134				3.15600E 03
I-135	XE-135M	1.5400E-01XE-135	8.4600E-01	2.37960E 04
XE-120	I-120	1.0000E 00		2.40000E 03
XE-121	I-121	1.0000E 00		2.40600E 03
XE-122	I-122	1.0000E 00		7.23599E 04
XE-123	I-123	1.0000E 00		7.48800E 03
XE-125	I-125	1.0000E 00		6.12000E 04
XE-127				3.14582E 06
XE-129M				6.91200E 05
XE-131M				1.02816E 06
XE-133				4.53168E 05
XE-133M	XE-133	1.0000E 00		1.89043E 05
XE-135	CS-135	1.0000E 00		3.27240E 04
XE-135M	XE-135	1.0000E 00CS-135	4.0000E-05	9.17400E 02
XE-137	CS-137	1.0000E 00		2.29800E 02
XE-138	CS-138	1.0000E 00		8.50200E 02
CS-125	XE-125	1.0000E 00		2.70000E 03
CS-126				9.84000E 01
CS-127	XE-127	1.0000E 00		2.25000E 04
CS-128				2.34000E 02
CS-129				1.15416E 05
CS-130				1.79400E 03
CS-131				8.37216E 05
CS-132				5.59440E 05
CS-134				6.50717E 07
CS-134M	CS-134	1.0000E 00		1.04400E 04
CS-135				7.25825E 13
CS-135M	CS-135	1.0000E 00		3.18000E 03
CS-136				1.13184E 06
CS-137	BA-137M	9.4600E-01		9.46728E 08
CS-138				1.93200E 03
CS-139	BA-139	1.0000E 00		5.64000E 02
BA-126	CS-126	1.0000E 00		5.79000E 03
BA-128	CS-128	1.0000E 00		2.09952E 05
BA-131	CS-131	1.0000E 00		1.01952E 06
BA-131M	BA-131	1.0000E 00		8.76000E 02
BA-133				3.38928E 08
BA-133M	BA-133	1.0000E 00		1.40040E 05
BA-135M				1.03320E 05
BA-137M				1.53120E 02
BA-139				4.96200E 03
BA-140	LA-140	1.0000E 00		1.10074E 06
BA-141	LA-141	1.0000E 00		1.09620E 03
BA-142	LA-142	1.0000E 00		6.36000E 02
LA-131	BA-131	1.0000E 00		3.54000E 03
LA-132				1.72800E 04
LA-134				4.00200E 02
LA-135				7.02000E 04
LA-137				1.89346E 12
LA-138				4.26027E 18
LA-140				1.44979E 05

LA-141	CE-141	1.0000E 00		1.41480E 04
LA-142				5.55000E 03
LA-143	CE-143	1.0000E 00		8.53800E 02
CE-134	LA-134	1.0000E 00		2.59200E 05
CE-135	LA-135	1.0000E 00		6.33600E 04
CE-137	LA-137	1.0000E 00		3.24000E 04
CE-137M	LA-137	5.9000E-03CE-137	9.9410E-01	1.23840E 05
CE-139				1.18938E 07
CE-141				2.80809E 06
CE-143	PR-143	1.0000E 00		1.18800E 05
CE-144	PR-144M	1.7800E-02PR-144	9.8220E-01	2.45635E 07
PR-136				7.86000E 02
PR-137	CE-137	1.0000E 00		4.59600E 03
PR-138				8.70000E 01
PR-138M				7.56000E 03
PR-139	CE-139	1.0000E 00		1.62360E 04
PR-142				6.88679E 04
PR-142M	PR-142	1.0000E 00		8.76000E 02
PR-143				1.17158E 06
PR-144				1.03680E 03
PR-144M	PR-144	9.9900E-01		4.32000E 02
PR-145				2.15280E 04
PR-147	ND-147	1.0000E 00		3.16000E 02
ND-136	PR-136	1.0000E 00		3.03900E 03
ND-138	PR-138	1.0000E 00		1.81440E 04
ND-139	PR-139	1.0000E 00		1.78200E 03
ND-139M	PR-139	8.8000E-01ND-139	1.2000E-01	1.98000E 04
ND-141				8.96400E 03
ND-141M	ND-141	9.9960E-01		6.24000E 01
ND-147	PM-147	1.0000E 00		9.48672E 05
ND-149	PM-149	1.0000E 00		6.22800E 03
ND-151	PM-151	1.0000E 00		7.46400E 02
PM-141	ND-141M	9.6800E-04ND-141	9.9900E-01	1.25400E 03
PM-142				4.05000E 01
PM-143				2.28960E 07
PM-144				3.13632E 07
PM-145				5.58569E 08
PM-146	SM-146	3.5900E-01		1.74528E 08
PM-147	SM-147	1.0000E 00		8.27882E 07
PM-148				4.63968E 05
PM-148M	PM-148	4.6000E-02		3.56832E 06
PM-149				1.91088E 05
PM-150				9.64800E 03
PM-151	SM-151	1.0000E 00		1.02240E 05
SM-141	PM-141	1.0000E 00		6.12000E 02
SM-141M	SM-141	3.1000E-03PM-141	9.9690E-01	1.35600E 03
SM-142	PM-142	1.0000E 00		4.34940E 03
SM-145	PM-145	1.0000E 00		2.93760E 07
SM-146				3.25043E 15
SM-147				3.34510E 18
SM-151				2.84018E 09
SM-153				1.68120E 05

SM-155	EU-155	1.0000E 00			1.32600E 03
SM-156	EU-156	1.0000E 00			3.38400E 04
EU-145	SM-145	1.0000E 00			5.13216E 05
EU-146	SM-146	1.0000E 00			3.98304E 05
EU-147	PM-143	2.2000E-05	SM-147	1.0000E 00	2.07360E 06
EU-148	PM-144	9.4000E-09			4.70880E 06
EU-149					8.04384E 06
EU-150					4.54320E 04
EU-150					1.07927E 09
EU-152	GD-152	2.7920E-01			4.20663E 08
EU-152M	GD-152	7.2000E-01			3.35520E 04
EU-154					2.77707E 08
EU-155					1.56526E 08
EU-156					1.31242E 06
EU-157					5.45400E 04
EU-158					2.75400E 03
GD-145	EU-145	1.0000E 00			1.37400E 03
GD-146	EU-146	1.0000E 00			4.17312E 06
GD-147	EU-147	1.0000E 00			1.37160E 05
GD-148					2.93486E 09
GD-149	EU-149	1.0000E 00			8.12160E 05
GD-151	SM-147	8.0000E-09			1.03680E 07
GD-152					3.40822E 21
GD-153					2.09088E 07
GD-159					6.68159E 04
GD-162	TB-162	1.0000E 00			5.82000E 02
TB-147	GD-147	1.0000E 00			5.94000E 03
TB-149	GD-149	8.0000E-01	EU-145	2.0000E-01	1.49400E 04
TB-150					1.17720E 04
TB-151	GD-151	1.0000E 00	EU-147	9.5000E-05	6.33600E 04
TB-153	GD-153	1.0000E 00			2.02176E 05
TB-154					7.70399E 04
TB-155					4.59648E 05
TB-156					4.61376E 05
TB-156M	TB-156	1.0000E 00			8.78399E 04
TB-156M	TB-156	1.0000E 00			1.80000E 04
TB-157					4.73364E 09
TB-158					4.73364E 09
TB-160					6.24672E 06
TB-161					5.97024E 05
TB-162					4.65600E 02
DY-155	TB-155	1.0000E 00			3.60000E 04
DY-157	TB-157	1.0000E 00			2.91600E 04
DY-159					1.24762E 07
DY-165					8.40240E 03
DY-166	HO-166	1.0000E 00			2.93760E 05
HO-155	DY-155	1.0000E 00			2.88000E 03
HO-157	DY-157	1.0000E 00			7.56000E 02
HO-159	DY-159	1.0000E 00			1.98000E 03
HO-161					9.00000E 03
HO-162					9.00000E 02
HO-162M	HO-162	6.1000E-01			4.08000E 03

HO-164				1.74000E 03
HO-164M	HO-164	1.0000E 00		2.25000E 03
HO-166				9.64799E 04
HO-166M				3.78691E 10
HO-167				1.11600E 04
ER-161	HO-161	1.0000E 00		1.16640E 04
ER-165				3.72960E 04
ER-169				8.03520E 05
ER-171	TM-171	1.0000E 00		2.70720E 04
ER-172	TM-172	1.0000E 00		1.77480E 05
TM-162				1.30200E 03
TM-166				2.77200E 04
TM-167				7.98336E 05
TM-170				1.11110E 07
TM-171				6.05906E 07
TM-172				2.28960E 05
TM-173				2.96640E 04
TM-175	YB-175	1.0000E 00		9.12000E 02
YB-162	TM-162	1.0000E 00		1.13400E 03
YB-166	TM-166	1.0000E 00		2.04120E 05
YB-167	TM-167	1.0000E 00		1.05000E 03
YB-169				2.76566E 06
YB-175				3.62016E 05
YB-177	LU-177	1.0000E 00		6.84000E 03
YB-178	LU-178	1.0000E 00		4.44000E 03
LU-169	YB-169	1.0000E 00		1.22616E 05
LU-170				1.72800E 05
LU-171				7.10208E 05
LU-172				5.78880E 05
LU-173				4.32339E 07
LU-174				1.04456E 08
LU-174M	LU-174	9.9300E-01		1.22688E 07
LU-176				1.13607E 18
LU-176M				1.32480E 04
LU-177				5.79744E 05
LU-177M	LU-177	2.1000E-01		1.39018E 07
LU-178				1.70400E 03
LU-178M				1.36200E 03
LU-179				1.65240E 04
HF-170	LU-170	1.0000E 00		5.76360E 04
HF-172	LU-172	1.0000E 00		5.90127E 07
HF-173	LU-173	1.0000E 00		8.64000E 04
HF-175				6.04800E 06
HF-177M				3.08400E 03
HF-178M				9.78286E 08
HF-179M				2.16864E 06
HF-180M				1.98000E 04
HF-181				3.66336E 06
HF-182	TA-182	1.0000E 00		2.84018E 14
HF-182M	HF-182	4.6000E-01	TA-182 5.4000E-01	3.69000E 03
HF-183	TA-183	1.0000E 00		3.84000E 03
HF-184	TA-184	1.0000E 00		1.48320E 04

TA-172	HF-172	1.0000E 00	2.20800E 03
TA-173	HF-173	1.0000E 00	1.31400E 04
TA-174	HF-174	1.0000E 00	4.32000E 03
TA-175	HF-175	1.0000E 00	3.78000E 04
TA-176			2.90880E 04
TA-177			2.03760E 05
TA-178			7.92000E 03
TA-178			5.58600E 02
TA-179			5.74473E 07
TA-180			3.15576E 20
TA-180M			2.91600E 04
TA-182			9.93600E 06
TA-182M	TA-182	1.0000E 00	9.50400E 02
TA-183			4.40640E 05
TA-184			3.13200E 04
TA-185	W-185	1.0000E 00	2.94000E 03
TA-186			6.30000E 02
W-176	TA-176	1.0000E 00	8.28000E 03
W-177	TA-177	1.0000E 00	8.10000E 03
W-178	TA-178	1.0000E 00	1.87488E 06
W-179	TA-179	1.0000E 00	2.25000E 03
W-181			1.04717E 07
W-185			6.48864E 06
W-187	RE-187	1.0000E 00	8.60399E 04
W-188	RE-188	1.0000E 00	5.99616E 06
RE-177	W-177	1.0000E 00	8.40000E 02
RE-178	W-178	1.0000E 00	7.92000E 02
RE-180			1.45800E 02
RE-181	W-181	1.0000E 00	7.20000E 04
RE-182M			2.30400E 05
RE-182			4.57200E 04
RE-183			6.04800E 06
RE-184			3.28320E 06
RE-184M	RE-184	7.4700E-01	1.42560E 07
RE-186			3.26304E 05
RE-186M	RE-186	1.0000E 00	6.31152E 12
RE-187			1.57788E 18
RE-188			6.11280E 04
RE-188M	RE-188	1.0000E 00	1.11600E 03
RE-189	OS-189M	2.4100E-01	8.74799E 04
OS-180	RE-180	1.0000E 00	1.32000E 03
OS-181	RE-181	1.0000E 00	6.30000E 03
OS-182	RE-182	1.0000E 00	7.92000E 04
OS-185			8.12160E 06
OS-186			6.30720E 22
OS-189M			2.16000E 04
OS-190M			5.94000E 02
OS-191			1.33056E 06
OS-191M	OS-191	1.0000E 00	4.69080E 04
OS-193			1.08000E 05
OS-194	IR-194	1.0000E 00	1.89346E 08
IR-182	OS-182	1.0000E 00	9.00000E 02

IR-184				1.08720E 04
IR-185	OS-185	1.0000E 00		5.04000E 04
IR-186				5.68800E 04
IR-186				6.30000E 03
IR-187				3.78000E 04
IR-188				1.49400E 05
IR-189	OS-189M	8.3000E-02		1.14912E 06
IR-190				1.04544E 06
IR-190M	IR-190	1.0000E 00		4.32000E 03
IR-190M1	IR-190M	5.0000E-02		1.11600E 04
IR-191M				4.94000E 00
IR-192				6.39533E 06
IR-192M	IR-192	1.0000E 00		7.60538E 09
IR-193M				1.02816E 06
IR-194				6.89399E 04
IR-194M				1.47744E 07
IR-195				9.00000E 03
IR-195M	IR-195	4.0000E-02		1.36800E 04
PT-186	OS-182	1.4000E-06	IR-186 1.0000E 00	7.20000E 03
PT-188	IR-188	1.0000E 00		8.81280E 05
PT-189	IR-189	1.0000E 00		3.91320E 04
PT-191				2.41920E 05
PT-193				1.57788E 09
PT-193M	PT-193	1.0000E 00		3.74112E 05
PT-195M				3.47328E 05
PT-197				6.58799E 04
PT-197M	PT-197	9.6700E-01		5.66400E 03
PT-199	AU-199	1.0000E 00		1.84800E 03
PT-200	AU-200	1.0000E 00		4.50000E 04
AU-193	PT-193	1.0000E 00		6.35400E 04
AU-194				1.42200E 05
AU-195				1.58112E 07
AU-195M	AU-195	1.0000E 00		3.05000E 01
AU-196				5.34211E 05
AU-198				2.32934E 05
AU-198M	AU-198	1.0000E 00		1.98720E 05
AU-199				2.71210E 05
AU-200				2.90400E 03
AU-200M	AU-200	1.8000E-01		6.73199E 04
AU-201				1.58400E 03
HG-193	AU-193	1.0000E 00		1.26000E 04
HG-193M	AU-193	9.2000E-01	HG-193 8.0000E-02	3.99600E 04
HG-194	AU-194	1.0000E 00		8.20497E 09
HG-195	AU-195	1.0000E 00		3.56400E 04
HG-195M	HG-195	5.4200E-01	AU-195 4.5800E-01	1.49760E 05
HG-197				2.30760E 05
HG-197M	HG-197	9.3000E-01		8.56799E 04
HG-199M				2.55600E 03
HG-203				4.02624E 06
TL-194	HG-194	1.0000E 00		1.98000E 03
TL-194M	HG-194	1.0000E 00		1.96800E 03
TL-195	HG-195	1.0000E 00		4.17600E 03

TL-197	HG-197	1.0000E 00		1.02240E 04
TL-198				1.90800E 04
TL-198M	TL-198	4.7000E-01		6.73200E 03
TL-199				2.67120E 04
TL-200				9.39599E 04
TL-201				2.63002E 05
TL-202				1.05667E 06
TL-204				1.19256E 08
TL-206				2.52000E 02
TL-207				2.86200E 02
TL-208				1.84200E 02
TL-209	PB-209	1.0000E 00		1.32000E 02
TL-210	PB-210	1.0000E 00		7.80000E 01
PB-195M	TL-195	1.0000E 00		9.48000E 02
PB-198	TL-198	1.0000E 00		8.64000E 03
PB-199	TL-199	1.0000E 00		5.40000E 03
PB-200	TL-200	1.0000E 00		7.74000E 04
PB-201	TL-201	1.0000E 00		3.38400E 04
PB-202	TL-202	1.0000E 00		9.46728E 12
PB-202M	PB-202	9.0500E-01TL-202	9.5000E-02	1.30320E 04
PB-203				1.87380E 05
PB-204M				4.01400E 03
PB-205				4.51274E 14
PB-209				1.17108E 04
PB-210	BI-210	1.0000E 00		7.03734E 08
PB-211	BI-211	1.0000E 00		2.16600E 03
PB-212	BI-212	1.0000E 00		3.83040E 04
PB-214	BI-214	1.0000E 00		1.60800E 03
BI-200	PB-200	1.0000E 00		2.18400E 03
BI-201	PB-201	1.0000E 00		6.48000E 03
BI-202	PB-202M	2.5000E-03PB-202	9.9750E-01	6.01200E 03
BI-203	PB-203	1.0000E 00		4.23360E 04
BI-205	PB-205	1.0000E 00		1.32278E 06
BI-206				5.39395E 05
BI-207				1.19919E 09
BI-208				1.16052E 13
BI-210	PO-210	1.0000E 00		4.33037E 05
BI-210M	TL-206	1.0000E 00		9.46728E 13
BI-211	TL-207	9.9720E-01PO-211	2.8000E-03	1.28400E 02
BI-212	PO-212	6.4070E-01TL-208	3.5930E-01	3.63300E 03
BI-213	PO-213	9.7840E-01TL-209	2.1600E-02	2.73900E 03
BI-214	PO-214	9.9980E-01		1.19400E 03
PO-203	BI-203	9.9890E-01		2.20200E 03
PO-205	PB-201	1.4000E-03BI-205	9.9900E-01	6.48000E 03
PO-207	BI-207	1.0000E 00		2.10000E 04
PO-209	PB-205	0.9974E 00		3.21667E 09
PO-210				1.19560E 07
PO-211				5.16000E-01
PO-212				3.05000E-07
PO-213	PB-209	1.0000E 00		4.20000E-06
PO-214	PB-210	1.0000E 00		1.64300E-04
PO-215	PB-211	1.0000E 00		1.78000E-03

PO-216	PB-212	1.0000E 00			1.50000E-01
PO-218	PB-214	9.9980E-01	AT-218	2.0000E-04	1.83000E 02
AT-207	PO-207	9.0000E-01	BI-203	1.0000E-01	6.48000E 03
AT-211	PO-211	5.8300E-01	BI-207	4.1700E-01	2.59704E 04
AT-215	BI-211	1.0000E 00			9.99999E-05
AT-216	BI-212	1.0000E 00			3.00000E-04
AT-217	BI-213	1.0000E 00			3.23000E-02
AT-218	BI-214	1.0000E 00			2.00000E 00
RN-218	PO-214	1.0000E 00			3.50000E-02
RN-219	PO-215	1.0000E 00			3.96000E 00
RN-220	PO-216	1.0000E 00			5.56000E 01
RN-222	PO-218	1.0000E 00			3.30350E 05
FR-219	AT-215	1.0000E 00			2.10000E-02
FR-220	AT-216	1.0000E 00			2.74000E 01
FR-221	AT-217	1.0000E 00			2.88000E 02
FR-222	RA-222	1.0000E 00			8.64000E 02
FR-223	RA-223	1.0000E 00			1.30800E 03
RA-222	RN-218	1.0000E 00			3.80000E 01
RA-223	RN-219	1.0000E 00			9.87897E 05
RA-224	RN-220	1.0000E 00			3.16224E 05
RA-225	AC-225	1.0000E 00			1.27872E 06
RA-226	RN-222	1.0000E 00			5.04922E 10
RA-227	AC-227	1.0000E 00			2.53200E 03
RA-228	AC-228	1.0000E 00			1.81456E 08
AC-223	FR-219	1.0000E 00			1.32000E 02
AC-224	FR-220	1.0000E-01	RA-224	9.0000E-01	1.04400E 04
AC-225	FR-221	1.0000E 00			8.64000E 05
AC-226	FR-222	6.0000E-05	TH-226	8.2800E-01	RA-226 1.7200E-01 1.04400E 05
AC-227	TH-227	9.8620E-01	FR-223	1.3800E-02	6.87103E 08
AC-228	TH-228	1.0000E 00			2.20680E 04
TH-226	RA-222	1.0000E 00			1.85400E 03
TH-227	RA-223	1.0000E 00			1.61723E 06
TH-228	RA-224	1.0000E 00			6.03728E 07
TH-229	RA-225	1.0000E 00			2.31633E 11
TH-230	RA-226	1.0000E 00			2.42993E 12
TH-231	PA-231	1.0000E 00			9.18719E 04
TH-232	RA-228	1.0000E 00			4.43384E 17
TH-233	PA-233	1.0000E 00			1.33800E 03
TH-234	PA-234M	9.9800E-01	PA-234	2.0000E-03	2.08224E 06
PA-227	TH-227	1.5000E-01	AC-223	8.5000E-01	2.29800E 03
PA-228	AC-224	2.0000E-02	TH-228	9.8000E-01	7.92000E 04
PA-230	AC-226	3.2000E-05	TH-230	9.0500E-01	U-230 9.5000E-02 1.50336E 06
PA-231	AC-227	1.0000E 00			1.03383E 12
PA-232	U-232	1.0000E 00			1.13184E 05
PA-233	U-233	1.0000E 00			2.33280E 06
PA-234	U-234	1.0000E 00			2.41200E 04
PA-234M	U-234	9.9870E-01	PA-234	1.3000E-03	7.01999E 01
U-230	TH-226	1.0000E 00			1.79712E 06
U-231	PA-231	1.0000E 00	TH-227	5.5000E-05	3.62880E 05
U-232	TH-228	1.0000E 00			2.27215E 09
U-233	TH-229	1.0000E 00			5.00188E 12
U-234	TH-230	1.0000E 00			7.71583E 12

U-235	TH-231	1.0000E 00		2.22102E 16
U-236	TH-232	1.0000E 00		7.38921E 14
U-237	NP-237	1.0000E 00		5.83200E 05
U-238	TH-234	1.0000E 00		1.40999E 17
U-239	NP-239	1.0000E 00		1.41240E 03
U-240	NP-240M	1.0000E 00		5.07600E 04
NP-232	U-232	1.0000E 00		8.82000E 02
NP-233	U-233	1.0000E 00		2.17200E 03
NP-234	U-234	1.0000E 00		3.80160E 05
NP-235	U-235	9.9990E-01PA-231	1.4000E-05	3.42230E 07
NP-236	PU-236	4.8000E-01U-236	5.2000E-01	8.10000E 04
NP-236A	U-236	9.1000E-01PU-236	8.9000E-02	3.62912E 12
NP-237	PA-233	1.0000E 00		6.75333E 13
NP-238	PU-238	1.0000E 00		1.82909E 05
NP-239	PU-239	1.0000E 00		2.03472E 05
NP-240	PU-240	1.0000E 00		3.90000E 03
NP-240M	PU-240	1.0000E 00		4.44000E 02
PU-234	U-230	6.0000E-02NP-234	9.4000E-01	3.16800E 04
PU-235	NP-235	1.0000E 00U-231	2.7000E-05	1.51800E 03
PU-236	U-232	1.0000E 00		8.99707E 07
PU-237	U-233	5.0000E-05NP-237	1.0000E 00	3.91392E 06
PU-238	U-234	1.0000E 00		2.76886E 09
PU-239	U-235	1.0000E 00		7.59434E 11
PU-240	U-236	1.0000E 00		2.06292E 11
PU-241	U-237	2.4500E-05AM-241	1.0000E 00	4.54429E 08
PU-242	U-238	1.0000E 00		1.18751E 13
PU-243	AM-243	1.0000E 00		1.78416E 04
PU-244	U-240	9.9880E-01		2.60666E 15
PU-245	AM-245	1.0000E 00		3.78000E 04
PU-246	AM-246M	1.0000E 00		9.37440E 05
AM-237	NP-233	2.5000E-04PU-237	9.9970E-01	4.38000E 03
AM-238	PU-238	1.0000E 00NP-234	1.0000E-06	5.88000E 03
AM-239	NP-235	1.0000E-04PU-239	9.9990E-01	4.28400E 04
AM-240	NP-236	1.9000E-06PU-240	1.0000E 00	1.82880E 05
AM-241	NP-237	1.0000E 00		1.36392E 10
AM-242	PU-242	1.7300E-01CM-242	8.2700E-01	5.76720E 04
AM-242M	NP-238	4.7600E-03AM-242	9.9500E-01	4.79675E 09
AM-243	NP-239	1.0000E 00		2.32895E 11
AM-244	CM-244	1.0000E 00		3.63600E 04
AM-244M	CM-244	1.0000E 00		1.56000E 03
AM-245	CM-245	1.0000E 00		7.38000E 03
AM-246	CM-246	1.0000E 00		2.34000E 03
AM-246M	CM-246	1.0000E 00		1.50000E 03
CM-238	AM-238	9.0000E-01PU-234	1.0000E-01	8.64000E 03
CM-240	PU-236	1.0000E 00		2.33280E 06
CM-241	PU-237	1.0000E-02AM-241	9.9000E-01	2.83392E 06
CM-242	PU-238	1.0000E 00		1.40659E 07
CM-243	PU-239	9.9800E-01AM-243	2.4000E-03	8.99391E 08
CM-244	PU-240	1.0000E 00		5.71507E 08
CM-245	PU-241	1.0000E 00		2.68240E 11
CM-246	PU-242	9.9970E-01		1.49267E 11
CM-247	PU-243	1.0000E 00		4.92299E 14

CM-248	PU-244	9.1740E-01		1.06980E 13
CM-249	BK-249	1.0000E 00		3.84900E 03
CM-250	PU-246	2.5000E-01BK-250	1.4000E-01	2.17747E 11
BK-245	AM-241	1.2000E-03CM-245	9.9900E-01	4.26816E 05
BK-246	CM-246	1.0000E 00		1.58112E 05
BK-247	AM-243	1.0000E 00		4.35495E 10
BK-249	CF-249	1.0000E 00AM-245	1.4500E-05	2.76480E 07
BK-250	CF-250	1.0000E 00		1.15992E 04
BK-251	CF-251	1.0000E 00		3.42000E 03
CF-244	CM-240	1.0000E 00		1.16400E 03
CF-246	CM-242	9.9970E-01		1.28520E 05
CF-248	CM-244	1.0000E 00		2.88144E 07
CF-249	CM-245	1.0000E 00		1.10641E 10
CF-250	CM-246	9.9920E-01		4.12773E 08
CF-251	CM-247	1.0000E 00		2.83387E 10
CF-252	CM-248	9.6910E-01		8.32489E 07
CF-253	ES-253	9.9690E-01CM-249	3.1000E-03	1.53878E 06
CF-254	CM-250	3.1000E-03		5.22720E 06
ES-250	CF-250	1.0000E 00		7.56000E 03
ES-251	CF-251	9.9500E-01BK-247	5.0000E-03	1.18800E 05
ES-253	BK-249	1.0000E 00		1.76861E 06
ES-254	BK-250	1.0000E 00		2.38205E 07
ES-254M	BK-250	3.2000E-03FM-254	9.8000E-01	1.41480E 05
ES-255	BK-251	0.8000E-01FM-255	0.9200E 00	3.43872E 06
FM-252	CF-248	1.0000E 00		8.17199E 04
FM-253	ES-253	8.8000E-01CF-249	1.2000E-01	2.59200E 05
FM-254	CF-250	1.0000E 00		1.16640E 04
FM-255	CF-251	1.0000E 00		7.22519E 04
FM-256	CF-252	0.8100E-01		9.45600E 03
FM-257	CF-253	1.0000E 00		8.68320E 06
MD-257	ES-253	1.0000E-01FM-257	9.0000E-01	1.87200E 04
MD-258	ES-254	1.0000E 00		4.75200E 06

APPENDIX C: INTERACTIVE DRIVER CODE FOR STAND-ALONE APPLICATION

APPENDIX C: INTERACTIVE DRIVER CODE FOR STAND-ALONE APPLICATION

```
C
C THIS PROGRAM CALLS SUBROUTINE "CHAIN" TO CONSTRUCT
C A RADIONUCLIDE DECAY CHAIN, HALF LIFE FILE, AND BRANCHING MATRIX
C FOR A SPECIFIED RADIONUCLIDE.
C
      DOUBLE PRECISION NAMNUC
      COMMON NAMNUC(25),NSPEC,TR(25),BRANCH(25,25),NDAU(25)
    1 WRITE(6,2000)
      READ(6,1000)NAMNUC(1)
      DO 10 ISPEC=1,25
        TR(ISPEC)=0.0
        NDAU(ISPEC)=0
        DO 10 JSPEC=1,25
          BRANCH(JSPEC,ISPEC)=0.0
   10   CONTINUE
C
C COMPUTE AND SET DECAY CHAIN PARAMETERS
C
      CALL CHAIN(NDAU)
C
C PRINT CONTENTS OF STACK
      LAST=5
      IF (NSPEC .LT. 5) LAST=NSPEC
      WRITE(6,2100) NAMNUC(1),(NAMNUC(I),I=1,LAST)
      WRITE(6,2200)
      DO 20 I=1,NSPEC
        WRITE(6,2300) I,NAMNUC(I),TR(I),(BRANCH(J,I),J=1,LAST)
   20 CONTINUE
      IF (LAST .EQ. NSPEC) GO TO 30
      WRITE(6,2400)(NAMNUC(I),I=6,NSPEC)
      DO 30 I=1,NSPEC
        WRITE(6,2500)NAMNUC(I),(BRANCH(J,I),J=6,NSPEC)
   30 CONTINUE
      GO TO 1
      STOP
 1000 FORMAT(A10)
 2000 FORMAT(//' INPUT PARENT RADIONUCLIDE (FORMAT XX-999 OR XX-999M)')
 2100 FORMAT(/' DECAY CHAIN FOR ',A10,':'/' ',27('-')//' ',30X,
     $  'BRANCHING FRACTIONS:'/' INDEX NUCLIDE  HALF-LIFE (S)',2X,5A10)
 2200 FORMAT(' ----- -------  -------------',2X,49('-'))
 2300 FORMAT(2X,I3,2X,A10,1PE11.5,2X,5(0PF7.5,3X))
 2400 FORMAT(/' BRANCHING MATRIX (CONTINUED)'/' FROM     TO'/10X,7A10)
 2500 FORMAT(' ',A8,7(F7.5,3X))
        END
```

APPENDIX D: SAMPLE OUTPUT OBTAINED USING CODE IN APPENDIX C

APPENDIX D: SAMPLE OUTPUT OBTAINED USING CODE IN APPENDIX C

```
.ASS TTY 6
TTY232 assigned
.ASS DSK 8
DSK assigned
.EX CHAIN.FOR
LINK:   Loading
[LNKXCT CHAIN execution]


INPUT PARENT RADIONUCLIDE (FORMAT XX-999 OR XX-999M)
SR-90

DECAY CHAIN FOR SR-90     :
---------------------------
```

INDEX	NUCLIDE	HALF-LIFE (S)	BRANCHING FRACTIONS: SR-90	Y-90
1	SR-90	9.18957E+08	.00000	1.00000
2	Y-90	2.30400E+05	.00000	.00000

```
INPUT PARENT RADIONUCLIDE (FORMAT XX-999 OR XX-999M)
MO-99

DECAY CHAIN FOR MO-99     :
---------------------------
```

INDEX	NUCLIDE	HALF-LIFE (S)	BRANCHING FRACTIONS: MO-99	TC-99M	TC-99
1	MO-99	2.37600E+05	.00000	.87600	.12400
2	TC-99M	2.16720E+04	.00000	.00000	1.00000
3	TC-99	6.72177E+12	.00000	.00000	.00000

```
INPUT PARENT RADIONUCLIDE (FORMAT XX-999 OR XX-999M)
RA-226

DECAY CHAIN FOR RA-226    :
---------------------------
```

INDEX	NUCLIDE	HALF-LIFE (S)	BRANCHING FRACTIONS: RA-226	RN-222	PO-218	PB-214	AT-218
1	RA-226	5.04922E+10	.00000	1.00000	.00000	.00000	.00000
2	RN-222	3.30350E+05	.00000	.00000	1.00000	.00000	.00000
3	PO-218	1.83000E+02	.00000	.00000	.00000	.99980	.00020
4	PB-214	1.60800E+03	.00000	.00000	.00000	.00000	.00000
5	AT-218	2.00000E+00	.00000	.00000	.00000	.00000	.00000
6	BI-214	1.19400E+03	.00000	.00000	.00000	.00000	.00000
7	PO-214	1.64300E-04	.00000	.00000	.00000	.00000	.00000
8	PB-210	7.03734E+08	.00000	.00000	.00000	.00000	.00000
9	BI-210	4.33037E+05	.00000	.00000	.00000	.00000	.00000
10	PO-210	1.19560E+07	.00000	.00000	.00000	.00000	.00000

BRANCHING MATRIX (CONTINUED)

FROM	TO BI-214	PO-214	PB-210	BI-210	PO-210
RA-226	.00000	.00000	.00000	.00000	.00000
RN-222	.00000	.00000	.00000	.00000	.00000
PO-218	.00000	.00000	.00000	.00000	.00000
PB-214	1.00000	.00000	.00000	.00000	.00000
AT-218	1.00000	.00000	.00000	.00000	.00000
BI-214	.00000	.99980	.00000	.00000	.00000
PO-214	.00000	.00000	1.00000	.00000	.00000
PB-210	.00000	.00000	.00000	1.00000	.00000
BI-210	.00000	.00000	.00000	.00000	1.00000
PO-210	.00000	.00000	.00000	.00000	.00000

INPUT PARENT RADIONUCLIDE (FORMAT XX-999 OR XX-999M)
XXX

XXX IS NOT LISTED IN CURRENT DATABASE!
STOP

END OF EXECUTION

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53. P. H. Hunter, Program Manager, Ford, Bacon & Davis, 375 Chipeta Way, P.O. Box 8009, Salt Lake City, UT 84108.
54. S. L. Iverson, Environmental Research Branch, Whiteshell Nuclear Research Establishment, Pinawa, Manitoba, Canada ROE 1LO.
55. D. Jacobs, Evaluation Research Corporation, 25 E. Tennessee Avenue, Oak Ridge, TN 37830.
56. J. R. Johnson, Biomedical Research Branch, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada K0J 1J0.
57. K. H. Kim, Engineering Science and Mechanics Department, 317A Perkins Hall, University of Tennessee, Knoxville, TN 37923.
58. C. King, Savannah River Laboratory, Aiken, SC 29808.
59. G. Levin, EG&G, 100 Midland Road, Oak Ridge, TN 37831.
60. H. Matsuzuru, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken, Japan.
61. J. G. McCray, Adjunct Associate Professor, Department of Nuclear Engineering, University of Arizona, Tucson, AZ 85721.
62. G. L. Meyer, LLW Standard Program, Criteria and Standards Division, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC 20460.
63. D. Mills, Office of Special Projects, Department of Natural Resources, and Environmental Protection, 4th Floor, Capital Plaza Tower, Frankfort, KY 40601.
64. W. A. Mills, Director, Criteria and Standards Division, Office of Radiation Programs, ANR-460, U.S. Environmental Protection Agency, Washington, DC 20460.
65. B. Napier, Battelle Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352.
66. R. Neider, Bundesanstalt fur Materialprufung (BAM), Fachgruppe 6.3, Unter den Eichen 87, D-1000 Berlin 45.
67. S. M. Neuder, MS-623-SS, U.S. Nuclear Regulatory Commission, Washington, DC 20555.
68. T. Papp, SKBF, Box 5864, S-102 48 Stockholm, Sweden.

69. J. Pensko, Institute of Nuclear Research, 05-400 Swierk-Otwock, Poland.
70. S. J. Phillips, Environmental Engineering Technology, Rockwell Hanford Operations, Energy Systems Group, P.O. Box 800, Richland, WA 99352.
71. W. L. Poe, E. I. DuPont de Nemours and Co., Petrochemicals Department, Atomic Energy Division, Savannah River Laboratory, Aiken, SC 29808.
72. R. W. Pollock, P.Eng., Whiteshell Environmental Authority, Whiteshell Nuclear Research Establishment, Pinawa, Manitoba, Canada R0E 1L0.
73. J. N. Rogers, Div. 8324, Sandia Laboratories, Livermore, CA 94550.
74. R. Root, E. I. DuPont de Nemours, Savannah River Laboratory, Bldg. 773-A, Aiken, SC 29801.
75. S. Rope, EG&G, 100 Midland Road, Oak Ridge, TN 37831.
76. V. L. Sailor, Nuclear Waste Research, Brookhaven National Laboratory, Upton, NY 11973.
77. G. Schwarz, Lutharstr 18, D-5100 Achen, BRD (West Germany).
78. J. Schwibach, Bundesgesundheitsamt, Ingolstadter Landstrasse 1, D-8042 Neuherberg, Federal Republic of Germany.
79. G. Shen, Science Secretary, Engineering Bldg., Room 136, McMaster University, Hamilton, Ontario, Canada L8S 4L7.
80. J. K. Soldat, CHP, Staff Environmental Scientist, Battelle Pacific Northwest Laboratories, P.O. Box 999, Richland, WA 99352.
81. A. M. Sourkes, Director, Radiation Protection Section, Manitoba Cancer Foundation, 100 Olivia Street, Winnipeg, Manitoba, Canada R3E 0V9.
82. J. A. Stoddard, Science Applications, Inc., P.O. Box 2351, 1200 Prospect St., La Jolla, CA 92038.
83. J. E. Till, Rt. 2, Box 122, Neeses, SC 29107.
84. F. Van Dorp, N.A.G.R.A., Parkstrasse 23, CH-5401, Baden, Switzerland.
85. B. R. Westerman, Director, Radiation Control, University of Arizona, 1827 E. Mabel A(B/210), Tucson, AZ 85724.
86. G. H. Whipple, 3301 Rutland Loop, Tallahassee, FL 32312.
87. K. Whitaker, Chem Nuclear Systems, Inc., P.O. Box 726, Barnwell, SC 29812.
88. E. Wirth, Bundesgesundheitsamt, Ingolstadter Landstrasse 1, D-8042 Neuherberg, Federal Republic of Germany.
89. Jing-Yea Yang, Bldg. 214, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439.
90. Office of Assistant Manager for Energy Research and Development, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37831.

91-92. Technical Information Center, P.O. Box Oak Ridge, TN 37831.