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A Simple Computer Program for Activity Calendar of Standard Sources

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A computer program in FORTRAN IV is presented for the activity calender of standard (calibrated) sources. This calendar lists the activities of the relevant γ-rays day after day with the self-attenuation and branching ratio corrections. Uncertainty of the evaluated activities is also given.

標準線源用放射能壊変カレンダー
(計算機プログラム)

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放射能計測器の較正に用いる標準線源の放射能壊変を計算しカレンダーを作るプログラムを作成した。カレンダーには，対応するエネルギーについて自己吸収ならびに分岐比を補正したのちの放射能の値が日付を追って記録される。また計算された放射能の誤差も同時に記録されている。

なお，プログラムはFACŌM 230－60用Fortranで書かれている。

目　次　な　し

1. Introduction

In measurements of radioactivity, especially in γ-ray spectrometry, several long-lived nuclides are frequently used as standard sources. Many types of standard (or calibrated) sources are distributed by the IAEA and other institutions and companies. Although the standard sources are usually given with the certified values of the activities at a given reference date, each user has to make corrections for the decay, self-absorption, and other nuclear characteristics whenever the sources are used.

A simple and useful computer program in FORTRAN IV, which is feasible to make an activity calendar of a given standard source set, was written for user's convenience. This paper describes details of the program exemplifying the calendar of the IAEA gamma calibrated set. Revising the program for the other types of sources will be easy with primary programmer.

2. Description of the program

This program consists of three parts. The first part is INPUT routine where name of the set (NSET), reference year (IYO) and month (IMO), number of days to be evaluated (ITMAX), starting year of the calendar printing (IYP), the relevant nuclear data, and the certified values of activities are read in and the echo is written down. In the present program the nuclear data for the IAEA calibrated sources are already stored in the DATA section.

The second part converts the certified values to the actual radiation values through corrections for the branching ratios and the self-absorptions on the relevant γ-ray energies. The third executes a correction for the decay of each nuclide and writes down the actual radiating activities in disintegrations per second day after day as activity calendar. For user's convenience the decay factors in hour unit are also printed in the heading line of the calendar.

This program includes the correction for leap year and for the difference of the standard times between the source-calibrating and the source-using areas.

Evaluation of the errors involved in the activities is carried out by following the principle of propagation of errors:

$$\Delta A = A\sqrt{\left(\frac{\Delta A_0}{A_0}\right)^2 + (\lambda t)^2\left(\frac{\Delta\lambda}{\lambda}\right)^2 + \left(\frac{\Delta B}{B}\right)^2} \quad ,$$

where A = the evaluated γ-activity at time t, ΔA = uncertainty in A, λ = decay constant of the nuclide, $\Delta\lambda$ = uncertainty in λ, B = branching ratio of the γ-ray, ΔB = uncertainty in B. Uncertainty in t and the interaction among the variables are ignored. In the program the $\Delta\lambda/\lambda$ ratio is substituted by that of the half-life, $\Delta t_{1/2}/t_{1/2}$.

Because of the limit of the printing space the calendar lists the evaluated uncertainty for each γ-ray activity only for the 1st day of the coming month in the heading line.

The information for INPUT is indicated in Table 1, a generalized flow chart in Fig. 1, and an example of the OUTPUT in Figs. 2 and 3. A sample problem using 13 standard energies requires about 10 sec per one year calendar on the electronic computer FACOM 230-60. The program uses about 10,000 words of storage.

The complete program is presented in the Appendix. The FACOM 230-60 permits to print 136 columns instead of 132 columns. Therefore, one who cannot use the printer of 136-columns type has to slightly change the FORMAT of the calendar.

Table 1 Card data and Format

Card Type	Column(s)	Format and Card Content
CONTROL CARD		FORMAT (8I6)
	1-6	Set No. of the sources (numeric)
	9-12	Certified year
	17-18	Certified month
	19-24	Total days to be evaluated
	27-30	Starting year of the calendar
	35-36	Difference between GMT and the standard time of the area in hours In this program BLANK in this column is recognized as 9 hours (JST)
	42	0 for IAEA sources set
		1 for the other set
	48	0 for next set
		1 for last set
TITLE CARD		Supply card only if 1 appears in column 42 of CONTROL CARD FORMAT (I5, 3A4)
	4-5	Number of the standard γ-rays (=13)
	6-17	Name of the set (alphabetic and/or numeric)
NUCLIDE CARD SET		Supply this set, one card for each γ-ray energy, if 1 appears in column 42 of CONTROL CARD FORMAT (2A4, F8.3, F6.3, I2, F9.3, F8.5, 2F6.4)
	1-8	Nuclide identification - alphabetic and/or numeric information such as Cs-137, Am-241, etc.
	9-16	Half-life in days or years
	17-22	Uncertainty of the half-life in %
	24	0 for day unit of half-life
		1 for year unit of half-life
	25-33	Energy of the γ-ray in keV
	34-41	Branching ratio of the γ-ray

Card Type	Column(s)	Format and Card Content
	42-47	Uncertainty of the branching ratio in %
	48-53	Self-attenuation of the γ-ray through the source
ACTIVITY CARD SET		FORMAT (8F10.4)
	1-10	Certified activity of each source at a given date in μCi
	11-20	Uncertainty of the activity in %
		Continue to column 80 in same manner, 4 γ-ray sources per card in order of increasing γ-ray energy

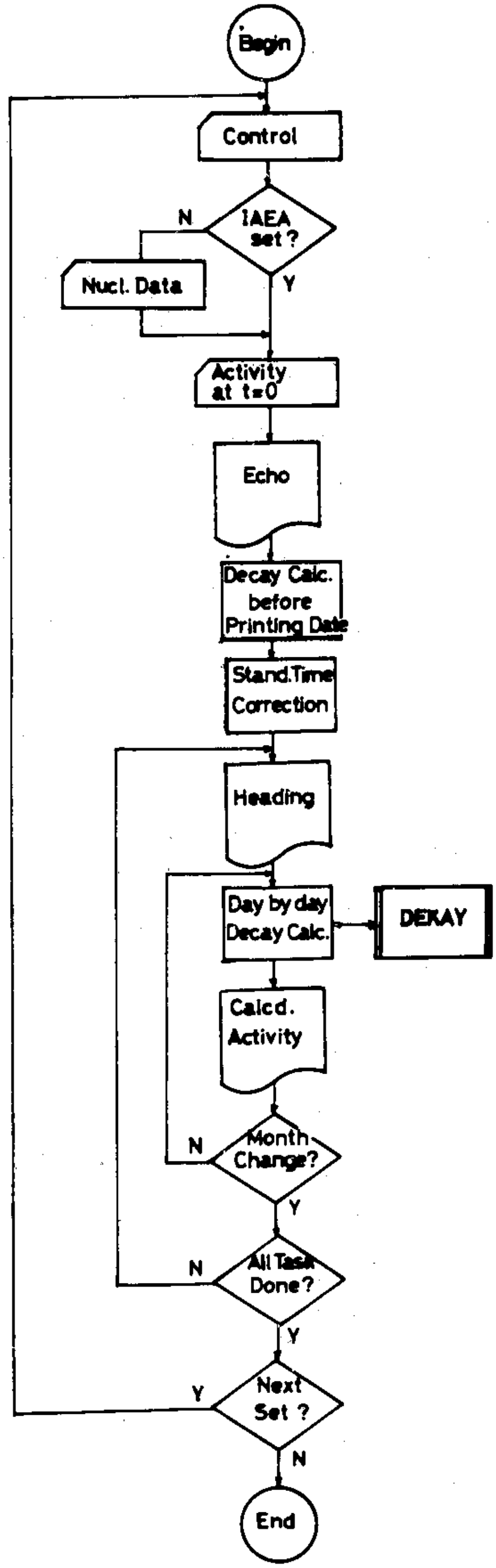

Fig. 1 A generalized flow chart

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***** ECHO OF INPUT *****

NUMBER OF STANDARD GAMMA RAYS =   13
IAEA SET NO.     24
DATED DECEMBER 1, 1970
TO BE CALCULATED FOR  1858 DAYS
PRINT FROM DECEMBER 1, 1971
```

NUCLIDE	MICROCI	PCT.ERR.	T1/2	ERROR		KEV	BR.RATIO	ERROR	ATEN
AM-241	10.62	0.700	432.900	0.800	Y	59.543	0.3590	0.0060	0.0380
CO- 57	10.59	1.000	271.600	0.500	D	121.970	0.8500	0.0170	0.0230
CO- 57	10.59	1.000	271.600	0.500	D	136.330	0.1140	0.0130	0.0220
HG-203	4857.22	0.900	46.800	0.200	D	279.191	0.8155	0.0015	0.0170
SN-113	74.58	1.500	115.200	0.800	D	391.700	1.0000	0.0	0.0150
NA- 22	10.39	0.900	2.602	0.005	Y	511.006	1.8110	0.0020	0.0130
CS-137	10.38	1.300	29.900	0.050	Y	661.635	0.8510	0.0040	0.0120
MN- 54	10.37	1.000	312.600	0.300	D	834.810	1.0000	0.0	0.0110
Y- 88	10.21	1.300	107.400	0.800	D	898.040	0.9140	0.0070	0.0100
CO- 60	10.57	0.600	5.275	0.005	Y	1173.230	0.9987	0.0005	0.0090
NA- 22	10.39	0.900	2.602	0.005	Y	1274.550	0.9995	0.0002	0.0087
CO- 60	10.57	0.600	5.275	0.005	Y	1332.490	1.0000	0.0	0.0085
Y- 88	10.21	1.300	107.400	0.800	D	1836.130	0.9940	0.0010	0.0070

Fig. 2 The first sheet of OUTPUT, Echo of INPUT

IN 1974 GAMMA ACTIVITY OF STANDARD SOURCES IAEA SET NO. 24 (IN GAMMA DISINTEGRATIONS/SEC)

NCLD	AM-241	CO- 57	CO- 57	HG-203	SN-113	NA- 22	CS-137	MN- 54	Y- 88	CO- 60	NA- 22	CO- 60	Y- 88
ENRG	59.543	121.970	136.330	279.191	391.700	511.006	661.635	834.810	898.040	1173.230	1274.550	1332.490	1836.130
HDCY	1.000E 00	9.999E-01	9.999E-01	9.994E-01	9.997E-01	1.000E 00	1.000E 00	9.999E-01	9.997E-01	1.000E 00	1.000E 00	1.000E 00	9.997E-01
ERR.	2.447E 03	3.902E 02	2.609E 02	3.808E-01	1.300E 02	2.678E 03	4.148E 03	3.000E 02	1.122E 01	1.537E 03	1.474E 03	1.534E 03	1.213E 01

FEBRUARY

1	1.350E 05	1.696E 04	2.277E 03	5.157E 00	2.566E 03	2.954E 05	3.000E 05	2.913E 04	1.946E 02	2.552E 05	1.637E 05	2.557E 05	2.123E 02
2	1.350E 05	1.691E 04	2.271E 03	5.081E 00	2.551E 03	2.952E 05	3.000E 05	2.907E 04	1.933E 02	2.551E 05	1.636E 05	2.556E 05	2.109E 02
3	1.350E 05	1.687E 04	2.265E 03	5.007E 00	2.535E 03	2.949E 05	3.000E 05	2.900E 04	1.921E 02	2.550E 05	1.635E 05	2.555E 05	2.095E 02
4	1.350E 05	1.683E 04	2.259E 03	4.933E 00	2.520E 03	2.947E 05	3.000E 05	2.894E 04	1.909E 02	2.549E 05	1.634E 05	2.554E 05	2.082E 02
5	1.350E 05	1.678E 04	2.253E 03	4.861E 00	2.505E 03	2.945E 05	3.000E 05	2.888E 04	1.896E 02	2.549E 05	1.633E 05	2.553E 05	2.069E 02
6	1.350E 05	1.674E 04	2.248E 03	4.789E 00	2.490E 03	2.943E 05	2.999E 05	2.881E 04	1.884E 02	2.548E 05	1.631E 05	2.552E 05	2.055E 02
7	1.350E 05	1.670E 04	2.242E 03	4.719E 00	2.475E 03	2.941E 05	2.999E 05	2.875E 04	1.872E 02	2.547E 05	1.630E 05	2.551E 05	2.042E 02
8	1.350E 05	1.666E 04	2.236E 03	4.649E 00	2.460E 03	2.939E 05	2.999E 05	2.869E 04	1.860E 02	2.546E 05	1.629E 05	2.550E 05	2.029E 02
9	1.350E 05	1.661E 04	2.231E 03	4.581E 00	2.445E 03	2.937E 05	2.999E 05	2.862E 04	1.848E 02	2.545E 05	1.628E 05	2.549E 05	2.016E 02
10	1.350E 05	1.657E 04	2.225E 03	4.514E 00	2.431E 03	2.934E 05	2.999E 05	2.856E 04	1.836E 02	2.544E 05	1.627E 05	2.549E 05	2.003E 02
11	1.350E 05	1.653E 04	2.219E 03	4.447E 00	2.416E 03	2.932E 05	2.998E 05	2.849E 04	1.824E 02	2.543E 05	1.625E 05	2.548E 05	1.990E 02
12	1.350E 05	1.649E 04	2.214E 03	4.382E 00	2.402E 03	2.930E 05	2.998E 05	2.843E 04	1.813E 02	2.542E 05	1.624E 05	2.547E 05	1.977E 02
13	1.350E 05	1.645E 04	2.208E 03	4.317E 00	2.387E 03	2.928E 05	2.998E 05	2.837E 04	1.801E 02	2.541E 05	1.623E 05	2.546E 05	1.964E 02
14	1.350E 05	1.640E 04	2.202E 03	4.254E 00	2.373E 03	2.926E 05	2.998E 05	2.831E 04	1.789E 02	2.540E 05	1.622E 05	2.545E 05	1.952E 02
15	1.350E 05	1.636E 04	2.197E 03	4.191E 00	2.359E 03	2.924E 05	2.998E 05	2.824E 04	1.778E 02	2.539E 05	1.621E 05	2.544E 05	1.939E 02
16	1.350E 05	1.632E 04	2.191E 03	4.130E 00	2.345E 03	2.922E 05	2.998E 05	2.818E 04	1.766E 02	2.538E 05	1.619E 05	2.543E 05	1.927E 02
17	1.350E 05	1.628E 04	2.185E 03	4.069E 00	2.331E 03	2.919E 05	2.997E 05	2.812E 04	1.755E 02	2.538E 05	1.618E 05	2.542E 05	1.914E 02
18	1.350E 05	1.624E 04	2.180E 03	4.009E 00	2.317E 03	2.917E 05	2.997E 05	2.806E 04	1.744E 02	2.537E 05	1.617E 05	2.541E 05	1.902E 02
19	1.350E 05	1.620E 04	2.174E 03	3.950E 00	2.303E 03	2.915E 05	2.997E 05	2.799E 04	1.732E 02	2.536E 05	1.616E 05	2.540E 05	1.890E 02
20	1.350E 05	1.615E 04	2.169E 03	3.892E 00	2.289E 03	2.913E 05	2.997E 05	2.793E 04	1.721E 02	2.535E 05	1.615E 05	2.539E 05	1.878E 02
21	1.350E 05	1.611E 04	2.163E 03	3.835E 00	2.275E 03	2.911E 05	2.997E 05	2.787E 04	1.710E 02	2.534E 05	1.614E 05	2.538E 05	1.866E 02
22	1.350E 05	1.607E 04	2.158E 03	3.779E 00	2.261E 03	2.909E 05	2.996E 05	2.781E 04	1.699E 02	2.533E 05	1.612E 05	2.538E 05	1.854E 02
23	1.350E 05	1.603E 04	2.152E 03	3.723E 00	2.248E 03	2.907E 05	2.996E 05	2.775E 04	1.688E 02	2.532E 05	1.611E 05	2.537E 05	1.842E 02
24	1.350E 05	1.599E 04	2.147E 03	3.668E 00	2.234E 03	2.905E 05	2.996E 05	2.769E 04	1.677E 02	2.531E 05	1.610E 05	2.536E 05	1.830E 02
25	1.350E 05	1.595E 04	2.141E 03	3.614E 00	2.221E 03	2.902E 05	2.996E 05	2.762E 04	1.667E 02	2.530E 05	1.609E 05	2.535E 05	1.818E 02
26	1.350E 05	1.591E 04	2.136E 03	3.561E 00	2.208E 03	2.900E 05	2.996E 05	2.756E 04	1.656E 02	2.529E 05	1.608E 05	2.534E 05	1.806E 02
27	1.350E 05	1.587E 04	2.130E 03	3.509E 00	2.194E 03	2.898E 05	2.995E 05	2.750E 04	1.645E 02	2.528E 05	1.607E 05	2.533E 05	1.795E 02
28	1.350E 05	1.583E 04	2.125E 03	3.457E 00	2.181E 03	2.896E 05	2.995E 05	2.744E 04	1.635E 02	2.528E 05	1.605E 05	2.532E 05	1.783E 02

Fig. 3 An example of monthly activity calendar

APPENDIX List of the program

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C
C     THIS PROGRAM EVALUATES GAMMA DISINTEGRATIONS/SEC OF STANDARD SOURCES
C     AT A GIVEN DATE AND MAKES AN ACTIVITY CALENDER.
C     ACTIVITY IS EVALUATED AT 0.00 AM OF THE GIVEN STANDARD TIME.
C
      LEAP(IY) = (IY/4)*4/IY-(IY/100)*100/IY+(IY/400)*400/IY-(IY/4000)
     1 *4000/IY
      DIMENSION ATCM(15),ANO(15),AO(15),EAO(15),TH(15),ETH(15),IH(15),
     1 E(15),BR(15),EBR(15),ATN(15),C(15),AT(15),ET(15),EL(15),EA(15),
     2 AM(12),AMM(12),IX(12),UH(15),H(15),SET(3)
      DOUBLE PRECISION EL,EA,TD
      DATA(AM(I),AMM(I),I=1,12)/4HJANU,4HARY ,4HFEBR,4HUARY,4HMARC,4HH
     1 ,4HAPRI,4HL    ,4HMAY ,4H    ,4HJUNE,4H    ,4HJULY,4H    ,4HAUGU,
     24HST  ,4HSEPT,4HEMBR,4HOCTO,4HBER ,4HNOVE,4HMBER,4HDECE,4HMBER/
     3,(IX(I),I=1,12)/31,28,31,30,31,30,31,31,30,31,30,31 /
     4,D,Y/2H D,2H Y/,(SET(I),I=1,3)/4HIAEA,4H SET,4H NO. /
C
      DATA(ATOM(I),ANO(I),TH(I),ETH(I),IH(I),E(I),BR(I),EBR(I),ATN(I),
     X I=1,13)/
     14H AM-, 4H241 , 432.9   , 0.8   , 1,   59.543, 0.359, 0.006, 0.038 ,
     24H CO-, 4H 57 , 271.6   , 0.5   , 0,  121.97 , 0.850, 0.017, 0.023 ,
     34H CO-, 4H 57 , 271.6   , 0.5   , 0,  136.33 , 0.114, 0.013, 0.022 ,
     44H HG-, 4H203 ,  46.8   , 0.2   , 0,  279.191, 0.8155,0.0015,0.017 ,
     54H SN-, 4H113 , 115.2   , 0.8   , 0,  391.7  , 1.000 , 0.0 , 0.015 ,
     64H NA-, 4H 22 ,   2.602, 0.005, 1,  511.006, 1.811 ,0.002, 0.013 ,
     74H CS-, 4H137 ,  29.9   , 0.05  , 1,  661.635, 0.851 ,0.004, 0.012 ,
     84H MN-, 4H 54 , 312.6   , 0.3   , 0,  834.81 , 1.000 , 0. ,  0.011 ,
     94H  Y-, 4H 88 , 107.4   , 0.8   , 0,  898.04 , 0.914 ,0.007, 0.010 ,
     04H CO-, 4H 60 ,   5.275, 0.005, 1, 1173.230, 0.9987,0.0005,0.009 ,
     A4H NA-, 4H 22 ,   2.602, 0.005, 1, 1274.55 , 0.9995,0.0002,0.0087,
     B4H CO-, 4H 60 ,   5.275, 0.005, 1, 1332.490, 0.99999,0.  , 0.0085,
     C4H  Y-, 4H 88 , 107.4   , 0.8   , 0, 1836.13 , 0.994 ,0.001, 0.007
     Z /
C
    1 READ  510,  NSET,IYO,IMO,ITMAX,IYP,IDT,IAEA,ITER
      IN = 13
      IF(IAEA.EQ.0) GO TO 2
      READ 530,   N,(SET(I),I=1,3),(ATCM(I),ANO(I),TH(I),ETH(I),IH(I),
     1 E(I),BR(I),EBR(I),ATN(I),I=1,N)
    2 READ 520,    (AO(I),EAO(I),I=1,N)
C
C     ECHO
C
    3 DO 5 I=1,N
      UH(I) = D
      IF(IH(I).EQ.1) UH(I)=Y
    5 CONTINUE
      PRINT 540,    N,SET,NSET,AM(IMO),AMM(IMO),IYO,ITMAX,AM(IMO),
     1 AMM(IMO),IYP
      PRINT 550,    (ATCM(I),ANO(I),AO(I),EAO(I),TH(I),ETH(I),UH(I),E(I),
     1 BR(I),EBR(I),ATN(I),I=1,N)
C
      IYD = 0
      IF(IYO.EQ.IYP) GO TO 20
      DO 10 J=IYO,IYP-1
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      IYD = IYD+365+(J/4)*4/J
      IF(MOD(J,100).EQ.0) IYD=IYD-1
      IF(MOD(J,400).EQ.0) IYD=IYD+1
      IF(MOD(J,4000).EQ.0) IYD=IYD-1
   10 CONTINUE
   20 DO 40 I=1,N
      IF(TH(I).EQ.0) GO TO 30
      TH(I) = 365.24225*TH(I)
   30 C(I) = 3.7E04*A0(I)*BR(I)*(1.-ATN(I))
      H(I) = DEKAY(4.1667E-02,TH(I))
      EA(I) = DBLE(EA0(I)/100.)**2+(DBLE(EBR(I))/DBLE(BR(I)))**2
      EL(I) = (DLOG(2.D0)*DBLE(ETH(I)))**2/(DBLE(TH(I)))**4
   40 CONTINUE
C
      IY = IYP
      ID = 0
      IM = IMO
      IX(2) = 28+LEAP(IY)
      IF(IDT.EQ.0) IDT=9                                        FOR JST
      T = FLOAT(IYD)-FLOAT(IDT)/24.
      TD = T
      DO 50 I=1,N
   50 ET(I) = DSQRT(EA(I)+EL(I)*TD**2)*C(I)*DEKAY(T,TH(I))
      PRINT 560,   IY,SET,NSET,(ATOM(I),ANO(I),I=1,N),(E(I),I=1,N),(H(I)
     1,I=1,N),(ET(I),I=1,N),AM(IM),AMM(IM)
      DO 120 I=1,ITMAX
      T = SNGL(TD)+FLOAT(I-1)
      DO 60 J=1,N
   60 AT(J) = C(J)*DEKAY(T,TH(J))
      ID = ID+1
      IF(ID-IX(IM)) 110,110,70
   70 ID = 1
      IM = IM+1
      IF(IM-13) 80,100,100
   80 TT = T
      DO 90 J=1,N
   90 ET(J) = AT(J)*DSQRT(EA(J)+EL(J)*TT**2)
      PRINT 560,   IY,SET,NSET,(ATOM(J),ANO(J),J=1,N),(E(J),J=1,N),(H(J)
     1 ,J=1,N),(ET(J),J=1,N),AM(IM),AMM(IM)
      GO TO 110
  100 IY = IY+1
      IM = 1
      IX(2) = 28+LEAP(IY)
      ID = 1
      GO TO 80
  110 PRINT 570,   ID,(AT(J),J=1,N)
  120 CONTINUE
      DO 130 I=1,N
      IF(TH(I).EQ.0) GO TO 130
      TH(I) = TH(I)/365.24225
  130 CONTINUE
      IF(ITER.EQ.0) GO TO 1
C
  510 FORMAT(10I6)
  520 FORMAT(8F10.4)
```

```
  530 FORMAT(I5,3A4/(2A4,F8.3,F6.3,I2,F9.3,F8.5,2F6.4))
  540 FORMAT(1H1///30X,25H***** ECHO OF INPUT ***** //10X,32HNUMBER OF S
     1TANDARD GAMMA RAYS = ,I4/10X,3A4,I6/10X,6HDATED ,2A4,3H 1.,I5/10X,
     220HTC BE CALCULATED FOR ,I6,5H DAYS /10X,11HPRINT FROM ,2A4,3H 1.,
     3 I5/)
  550 FORMAT(//12X,7HNUCLIDE,3X,7HMICROCI,2X,8HPCT.ERR.,2X,4HT1/2,4X,
     15HERROR,8X,3HKEV,4X,8HBR.RATIO,4X,5HERROR,4X,4HATEN //(12X,2A4,
     2F9.2,1X,F8.3,1X,F8.3,1X,F6.3,1X,A2,2X,F9.3,2X,F7.4,3X,F7.4,2X,F7.4
     3 ))
  560 FORMAT(1H1,8/3X,2HIN,I5,17X,40HGAMMA ACTIVITY OF STANDARD SOURCES
     1      ,3A4,I4,12X,30H(IN GAMMA DISINTEGRATIONS/SEC) ///1X,4HNCLD,
     213(2X,2A4)/1X,4HENRG,13(F9.3,1X)/1X,4HHDCY,13(1PE10.3)/1X,4HERR.,
     313(1PE10.3)//62X,2A4//)
  570 FORMAT(1X,I3,1X,13(1PE10.3))
      CALL EXIT
      END


      FUNCTION DEKAY(T1,T2)
C
      T = T1/T2
      IF(T-50.) 10,10,20
   10 D = EXP(-ALOG(2.)*T)
      GO TO 30
   20 D = 0.
   30 DEKAY = D
      RETURN
      END
```