USER GUIDE TO MIRD CD AND RADTABS SOFTWARE

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1. Basic information about the CD and software package

The MIRD monograph entitled "Radionuclide Data and Decay Schemes" includes a CD that provides electronic files of the unabridged nuclear decay data for 333 radionuclides of 87 elements. The CD contains the following:

- README.TXT: a file containing post-publication information
- CONTENT.PDF: a file listing contents of the CD
- SETUP.EXE: executable file to install the RADTABS software and associated data files
- USER GUIDE.PDF: user guide to MIRD CD and RADTABS software – this document
- MIRD-07 data files:
    - MIRD-07.NDX
    - MIRD-07.RAD
    - MIRD-07.BET
    - MIRD-07.NSF
    - MIRD-07.ACK
- ARCHIVE Folders:
    - SOURCE folder : RADTABS source code
    - INPUT folder: EDISTR04 input files for nuclides of the MIRD collection
    - OUTPUT folder: EDISTR04 output files for nuclides of the MIRD collection
    - TABLES folder: EDISTR04 ASCII files of the tables in the monograph
    - FIGURES folder: decay scheme figures
    - AUGER folder: ASCII file of unabridged Auger-CK emission
    - X-RAY folder: ASCII file of unabridged x-ray emission

The software RADTABS provides access to the nuclear decay data for a user-specified radionuclide and extracts the energies and yields of the emitted radiations into ASCII files for use in subsequent calculations. RADTABS enables the user to view the decay data in tabular and graphical form. RADTABS is intended for use on a personal computer (PC) with Windows operating system (Win 98/2000/XP/Vista).

The CD contains a file, AUTORUN.INF, which invokes SETUP.EXE to install RADTABS when the CD is placed in the CD drive. If this function has been disabled then, from Explorer, click on SETUP.EXE to install RADTABS. AUTORUN can be bypassed by holding down the shift key when the CD is placed in the drive.

SETUP.EXE is a Windows installation procedure[1] that installs RADTABS and its data files. The procedure creates a folder with the default name MIRD07 on the hard drive, installs the software in this folder, and places the RADTABS icon on the desktop. Three additional folders, below the main folder, are created. The data files are contained in the folder DATA, this user guide and other documents of interest are in the folder REPORT, and all output files created by RADTABS are written to the folder OUTPUT. Consult the README.TXT file, opened by the install procedure, for some configuration options.

RADTABS is a console application developed using PowerBASIC™ Console Compiler[2] with Console Tools™ and Graphics Tools™ providing additional functionality[3]. Plots of the radiation emissions are created using DPlot Jr[4]. Documents in the REPORT folder and some generated files can be viewed during a RADTABS session. The capability to view these files depends on the user having associated the file extensions *PDF* and *TXT* with Acrobat Reader[5] and an ASCII editor (such as Microsoft's Notepad), respectively.

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[1] The install package was created using Inno Setup compiler available from http://www.innosetup.com.
[2] PowerBASIC, Inc.; 1978 Tamiami Trail S. #200; Venice, FL 34293. See http://www.powerbasic.com/.
[3] Perfect Sync, Inc. 6511 Franklin Woods Dr., Traverse City, MI. See http://perfectsync.com/.
[4] HydeSoft Computing, Inc., 110 Roseland Drive, Vicksburg, MS 39180. See http://www.dplot.com/index.htm.
[5] Adobe Acrobat Reader of Adobe Inc. is available from http://www.pdf-2007.com/index.asp.

2. Information on the nuclear decay data files

The nuclear decay data are embodied in five formatted (hence readable with an ASCII editor) direct-access files, each with the root name MIRD-07. The file MIRD-07.RAD contains the data on the absolute intensities and mean[6] or discrete energies of the radiations emitted by the nuclides addressed in the MIRD monograph. This file contains data for all emitted radiations rather than the abbreviated data tabulated in the monograph; i.e., the cutoff on the number of radiations used in the monograph has not been applied to the data of the electronic files. ASCII files of the abbreviated data, the data of the tables in the monograph, can be found in the archive folder TABLE of the CD.

The file MIRD-07.BET, contains the beta spectra for all beta emitters in the collection. EDISTR04 (1), the software used to derive the energies and intensities of the emitted radiations, computes the spectrum for each beta transition to determine the mean beta energy of the transitions and tabulates the composite spectrum for all beta transitions of the radionuclide. The composite spectra in this file were not presented in the monograph. Spectra were synthesis for delayed beta emissions following spontaneous fission by assuming first forbidden-unique transitions in nuclei of atomic numbers 39 (yttrium) and 58 (cerium).

The file MIRD-07.ACK contains the Auger and Coster-Kronig, hereafter denoted as Auger-CK, electron spectra for selected radionuclides. In the RAD file these discrete emissions were collected in no more that 15 groups for each decay mode of the radionuclide. Only the collective data, over all decay modes, were reported in the monograph.

The spectrum of neutrons accompanying spontaneous fission is contained in the file MIRD-07.NSF. In the MIRD-07 collection, only Pu-238 and Cf-252 undergo spontaneous fission. These spectral data were not presented in the monograph.

To facilitate access to the data of the MIRD-07.RAD, MIRD-07.BET, MIRD-07.ACK, and MIRD-07.NSF files, an additional file, MIRD-07.NDX, was constructed. A brief description of each of these five files is presented below. For convenience, the files are referred to by their extensions, i.e., NDX, RAD, BET, ACK, and NSF.

Index File: MIRD-07.NDX

The NDX file serves as the entrance into the larger radiation (RAD) and spectral (BET, ACK, and NSF) data files. The NDX file contains one record for each nuclide of the collection. The nuclide record contains fields specifying the location of (or pointer to) the nuclide's record in the RAD, BET, ACK, and NSF files. In addition to these pointers, the record contains fields giving the nuclide's physical half-life, decay mode (e.g., alpha or beta), identity of radioactive decay products (daughters), fraction of the nuclear transformations forming each daughter (so-called branching fraction), the total energies emitted by alpha, electron, and photon emission (including electrons and photons accompanying spontaneous fission), and other supportive data. A full description of the NDX records is given in Table 1. A file (MIRD-07 LIST.TXT) listing the 333 radionuclides of the MIRD-07 collection is in the REPORT folder.

The records of the index file have been sorted by the nuclide field, making it possible to use a binary search algorithm to quickly locate the record of the radionuclide of interest. While the purpose of the NDX file is to provide entrance into the other data files, it is of considerable utility in its own right. For example, RADTABS constructs the decay chain headed by a radionuclide using only information in the NDX file.

Radiation File: MIRD-07.RAD

The records of the RAD file contain the data on the energy and yield of each radiation emitted in nuclear transformations of the radionuclide. No cutoff is applied to the number of radiations in this file. The fields of the RAD records are described in Table 2. The first record (header record) for the nuclide contains the name of the nuclide, its half-life, and the number of radiation records that follow. The radiation record (data record) of each emitted radiation have the following fields: (1) an integer code (ICODE) that identifies the radiation type; (2) the

[6] Mean values are reported for beta particles, Auger and Coster-Kronig electron groups, and the radiations emitted during spontaneous fission – fission fragments, neutrons, and delayed beta emission.

absolute yield of the radiation (i.e., number per nuclear transformation); (3) the unique or average energy of the radiation (MeV); and (4) a two-character mnemonic denoting the radiation type. The ICODE code and the mnemonic are defined in Table 3.

The radiation records are ordered by radiation type and by increasing energy. The radiations are listed in the following seven groups;

- photons: discrete energies and yields of γ-ray - including prompt and delayed photons accompanying spontaneous fission (ICODE 1), characteristic x-rays (ICODE 2), and annihilation photons (ICODE 3)
- beta particles: mean energies and yields of positron transitions (ICODE 4) and negatron transitions (ICODE 5)
- monoenergetic electrons: internal conversion electrons (ICODE 6) and Auger-CK electrons (ICODE 7)
- alpha particles: discrete energy and yield of alpha particles (ICODE 8)
- alpha recoil nuclei: discrete energy and yield of recoil nuclei (ICODE 9)
- fission fragments: mean energy and yield of fragments (ICODE 10)
- neutrons: mean energy and yield of neutrons (ICODE 11)

The records of the first five groups are sorted by increasing energy. This sorting facilitates interpolation of energy-dependent functions, e.g., the energy-dependent specific absorbed fraction data for the radiation type. The mnemonic can be used to identify a particular radiation type within its group (for example, annihilation photon, delayed gamma rays, etc.). The maximum number of records in the RAD file for a nuclide is 2497 for Tb-149. The maximum number of the photon is 441 (Tb-149), beta transitions 67 (Bi-214), discrete electrons 2028 (Tb-149), and alpha transitions 45 (Th-227).

Beta Spectra File: MIRD-07.BET

The BET file contains the beta spectrum for each beta emitter in the MIRD-07 collection. The spectral data are tabulated on a fixed logarithmic-type energy grid. For each nuclide, the header record gives the name of the nuclide and the number of data records that follow. The fields of the data record contain the electron energy E (MeV) and the number of electrons emitted per nuclear transformation with energy between E and $E + dE$. The maximum number of records in the BET file for a radionuclide is 134 (Cu-67). The structure of the records of the BET file is given in Table 4.

Auger-CK Electron Spectra File: MIRD-07.ACK

For 126 selected nuclides, the Auger-CK electron spectra are contained in the ACK file. These emissions were collapsed into no more than 15 groups for each decay mode in the RAD file. The maximum number of records in the ACK file is 3015 (for Hg-195m and Hg-197m). The fields of the header record contain the name of the nuclide and the number of data records that follow. The data records contain the electron energy E (eV), the yield (number of electrons of that energy per nuclear transformation), and an identification of the atomic transition. The format of the records is given in Table 5. A file listing the 126 selected nuclides is contained in the REPORT folder (AUGER LIST.TXT).

Neutron Spectra File: MIRD-07.NSF

The NSF file contains the spectrum of neutrons accompanying spontaneous fission. In the MIRD-07 collection, only Pu-238 and Cf-252 decay by spontaneous fission. For each nuclide, the header record gives the name of the nuclide, the branching fraction for spontaneous fission, and the number of data records that follow. The data records (52 records) define the neutron energy bin (or energy group) and the number of neutrons per nuclear transformation in that bin. The format of the records of the NSF file is given in Table 6.

3. Air kerma for ideal point source

The quantity air kerma is a measure of the strength of a radiation field. Kerma, an acronym for the kinetic energy released per unit mass, is the kinetic energy of charged particles liberated by photon and neutron interactions per unit mass. The NDX file includes the quantity as a measure of the radiation field in the vicinity of a point source of the radionuclides.

3.1. Air Kerma-Rate Constant

The nuclide records in the NDX file include a field containing the air kerma-rate constant. This constant, a characteristic of a radionuclide, is defined in terms of an ideal point source. The International Commission on Radiation Units and Measurements (ICRU) (2) defined the constant as $\Gamma_\delta = l^2 \dot{K}_\delta / A$ where $\dot{K}_\delta$ is the air kerma rate due to photons of energy greater than δ at a distance *l* in vacuum from a point source of the radionuclide of activity *A*. The constant is the SI equivalent to the earlier quantity referred to as the specific gamma constant. The photons addressed in the ICRU definition include gamma rays, characteristic x rays, and inner bremsstrahlung; the latter is not addressed in the MIRD-07 collection. Annihilation radiation associated with positron emitters and photons accompanying spontaneous fission, addressed in the collection, are not included in the definition. In a source of finite size, attenuation and scattering of the emitted photons occurs, and external bremsstrahlung will be produced as emitted electrons slow down within the source. In addition, any medium between the source and the point of measurement will give rise to absorption and scattering, external bremsstrahlung, and annihilation radiation. In many cases, these processes can substantially influence the observed kerma rate. The constant, as defined by ICRU, can be computed for a radionuclide as

$$\Gamma_\delta = \frac{1}{4\pi} \sum_i (\mu_k / \rho)_i \, Y_i \, E_i \tag{1}$$

where $(\mu_k/\rho)_i$ is the mass energy-transfer coefficient in air for photons of energy E_i emitted by the nuclide with yield Y_i. The summation is over all photons of energy greater than δ. The value of δ used here is 10 keV. The mass energy-transfer coefficients are from Shultis and Faw (3).

3.2. Point Source Air-Kerma Coefficient

As noted above, the air kerma-rate constant does not consider the annihilation radiation associated with positron emission and the neutron and photon radiations accompanying spontaneous fission. To address these radiations, the air-kerma coefficient $K_{\text{air},\delta}$ for a hypothetical point source is defined here as

$$K_{air,\delta} = \frac{1}{4\pi} \left[\sum_i (\mu_k / \rho)_i \, Y_i \, E_i + \sum_i Y(E_i, E_{i+1}) \, \bar{k}(E_i, E_{I+1}) \right] \tag{2}$$

and is included in the nuclide record of the NDX file. The summation in the first term of Eqn 2 extends over all photon of energy greater than δ, including annihilation radiation arising from position emission and the delay and prompt gamma radiations accompanying spontaneous fission. The second term of Eqn 2 is the contribution to air kerma of neutron accompanying spontaneous fission with yield $Y(E_i, E_{i+1})$ per nuclear transformation and $\bar{k}(E_i, E_{i+1})$ denotes the average value of the neutron air kerma coefficient (4) over energy E_i and E_{i+1}. Only neutrons of energy greater than δ (10 keV) are considered. The constant and the coefficient are numerically equal except in the cases of positron or spontaneous fission decay. The cautionary statements above regarding the air kerma-rate constant and the observed kerma rate for a real source in air are applicable to the coefficient as well.

4. Basic operation and features of the RADTABS software

RADTABS can be invoked by clicking on its desktop icon. To access the records for a radionuclide of interest the user clicks on the chemical symbol of the element in the periodic table. As seen in Fig. 1, displayed in the lower right corner of the screen is the name of the element and its symbol over which the mouse cursor is located. The mouse cursor is not evident in the figure but was over the Tc cell of the periodic table. If the MIRD-07 collection contains no radioisotopes of the element (e.g., for He, Li, B, etc.) then the phrase "No Data" appears in the lower right corner in place of the chemical symbol. To view the data for a radionuclide, left click the mouse over the element and select the isotopes of interest (see Fig. 2). If only a single radioisotope of the element is included in the collection (e.g., H-3 is the only radioisotope of hydrogen), then clicking on these elements result in the display of the summary report for the available isotope. If multiple radioisotopes of the element are include in the collection then a menu of the available isotopes is displayed as in Fig. 2. Following selection of the isotope of interest, a summary report is displayed giving the physical half-life, decay mode, specific activity, and radioactive progeny of the radionuclide followed by a tabulation of its emissions as shown in Fig. 3 for Tc-99m.

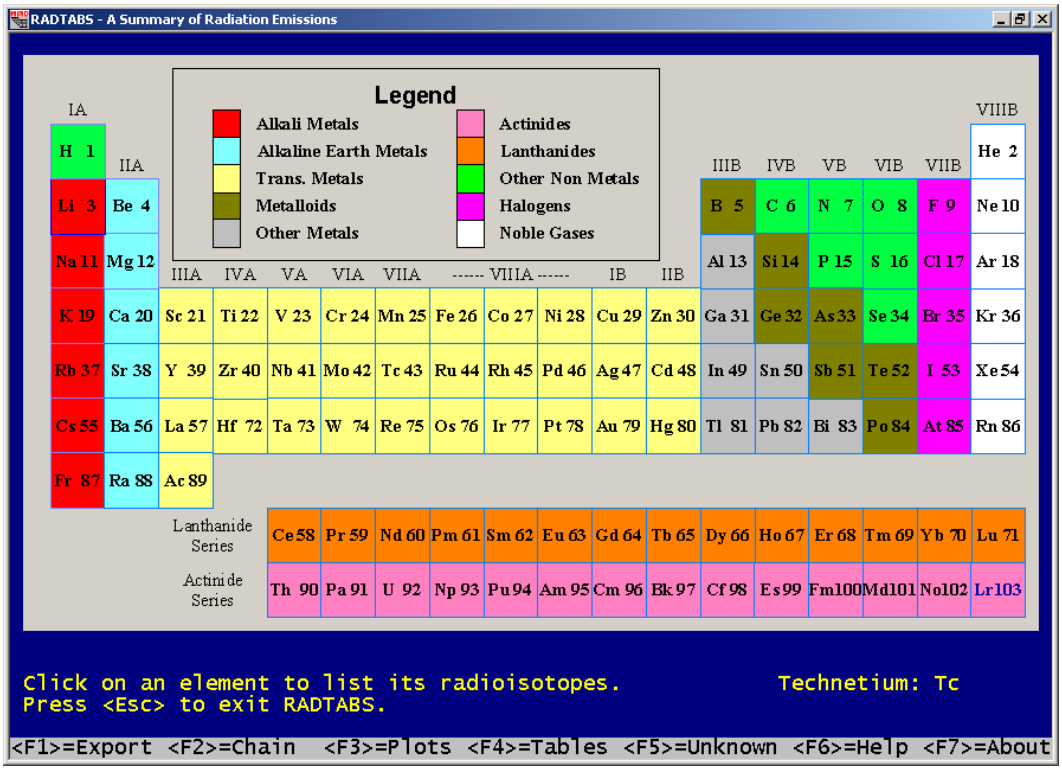


Fig. 1. RADTABS's interface for selecting radioisotopes of the elements in MIRD-07.

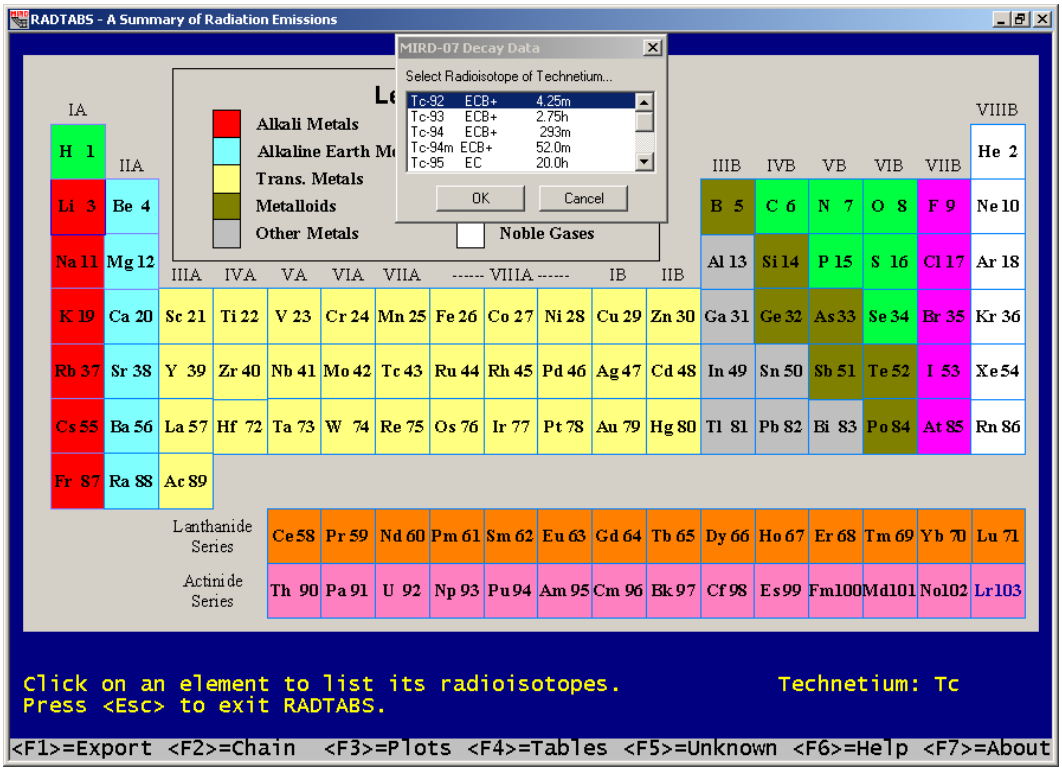


Fig. 2. Menu to select an isotope of technetium.

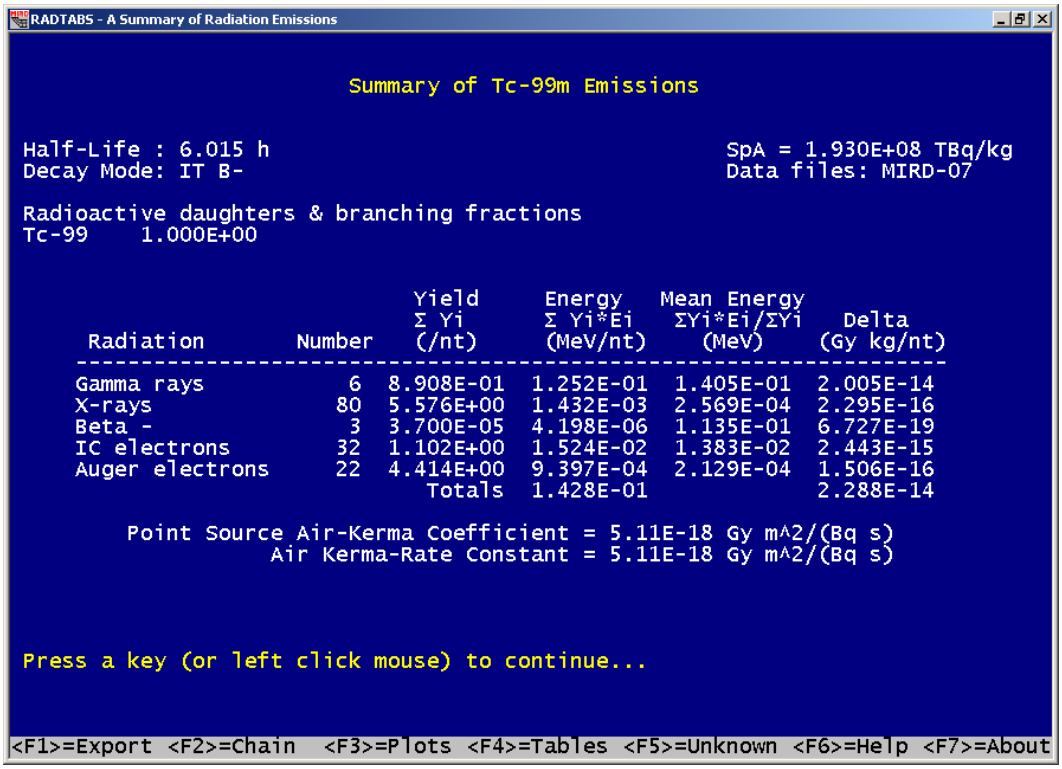


Fig. 3. Summary report of Tc-99m emissions.

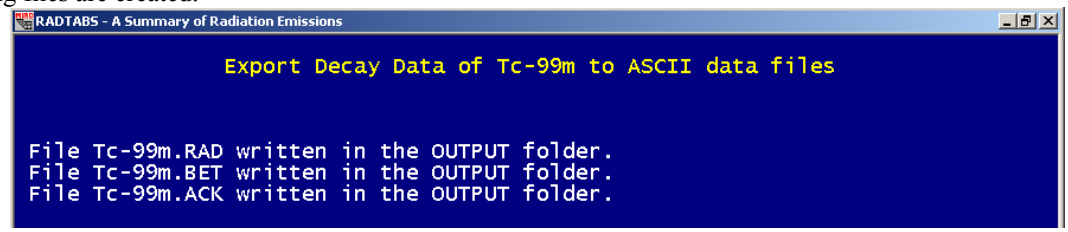
The summary report lists for each emitted radiation type, the number of records in the RAD file, their yield (per nuclear transformation), total emitted energy (MeV per nuclear transformation), mean emitted energy (MeV), and the equilibrium absorbed dose quantity Δ (Gy kg nt^{-1}). Nuclear transformation (Bq s) is abbreviated as *nt* in the display. The 13 radiations groups of the summary report are denoted as: Gamma rays, X-rays, Annh photons, Beta+, Beta-, IC electrons, Auger electrons, Alpha particles, Fission fragments, Neutrons, Prompt gamma, Delayed gamma, and Delayed beta. In the event photons of energy greater than 10 keV are emitted, the air kerma-rate constant and air-kerma coefficient are displayed.

The last line of the display delineates actions assigned to the function keys F1 through F7. These keys can be pressed at any time. The first three keys act on the displayed nuclide while the action of the other keys is not specific to a nuclide. The key assignments are summarized below and described in more detail in the paragraphs that follow.

Function Key	Action
F1	Export to ASCII files the nuclear decay data for the displayed nuclide
F2	Show the decay chain headed by the displayed nuclide and tabulate the cumulative energy associated with the chain members
F3	Graphically display the beta and neutron spectra (continuous in energy) and line spectra for the discrete energies of photons, IC electrons, alpha, and Auger-CK electrons
F4	List the radionuclides of the collection sorted by various characteristics and other attributes of the MIRD-07 collection – see details below
F5	Given an alpha or photon emission of known energy, a search of the RAD file is undertaken to associated the radiation with a radionuclide of the MIRD-07 collection
F6	Display documents in the REPORT folder
F7	Display the usual software credit screen

F1 key: Export nuclide data

If the F1 key is pressed while the summary report on the emissions of a radionuclide is displayed, then the unabridged (no restriction on number of radiations) data on the emitted radiations of the nuclide is extracted from the data files and written to ASCII files in the OUTPUT folder. In the case addressed in Fig. 3 (Tc-99m), the following files are created:



The name of the output files is constructed from the nuclide name with the extension being the extension of the file from which the data were extracted. The second line in each output file is the header record of the nuclide in the data file from which the data are extracted. A partial listing of the Tc-99m.RAD file follows.

```
Output File Tc-99m.RAD for Tc-99m
Tc-99m       6.015h       143
T1/2 = 6.015h Decay Mode: ITB-
Radiations of each type listed in increasing energy
Number of photon radiations:  86
Number of beta radiations:  3
Number of monoenergetic electron radiations:  54
ICODE  Y (/nt) E(MeV) Mnemonic
START RADIATION RECORDS
 2 5.49690E+00 7.87678E-06  X
 : : : : : : : : : : : : : :
 1 6.65489E-11 2.17260E-03  G
 2 1.69925E-06 2.23236E-03  X
 : : : : : : : : : : : : : :
 1 9.69400E-07 3.22400E-01  G
 5 1.07767E-06 3.01202E-02 B-
 : : : : : : : : : : : : : :
 6 5.99387E-11 3.22400E-01 IE
END RADIATION RECORDS
```

This file begins with a few brief comment lines and lists, for each radiation type, the number of records in the file. The decay data are bracketed between a start and end delimiter ("START RADIATION RECORDS" and "END RADIATION RECORDS", respectively). The radiation records are in the format of the MIRD-07.RAD file which is detailed below. See Table 2 for the definitions of ICODE and the mnemonic.

The Tc-99m.BET file begins with a few comment lines and the spectral records, extracted from the MIRD-07.BET file, bracketed by start and end delimiters. A few lines from the Tc-99m.BET file are listed below.

```
Output File Tc-99m.BET for Tc-99m
Tc-99m        100
Beta Spectrum for Tc-99m
Number of energy points: 100
E(MeV)  P(E) dE
START RADIATION RECORDS
0.00000 2.319E-04
0.00010 2.318E-04
   ::      ::
0.40000 1.990E-06
0.43618 0.000E+00
END RADIATION RECORDS
```

For selected radionuclides, Tc-99m being one, detailed spectra of the Auger-CK electron emissions are contained in the ACK file. While this level of detail is not necessary in calculations of mean absorbed dose, it is of interest in microdosimetric calculations, e.g., the dose to the cell nucleus from an emitter incorporated within the nucleus. Below is an excerpt from the Tc-99m.ACK file.

```
Output File Tc-99m.ACK for Tc-99m
Tc-99m                       968
Auger/Coster-Kronig Spectra for Tc-99m
Number of electrons: 968
START RADIATION RECORDS
  Y(/nt)       E(eV)   transition
6.57103E-05 3.34000E+00 M1 M4 M5
```

```
1.66012E-04 7.28000E+00 M1 M5 M5
  ::  ::      ::  ::      ::
1.26734E-11 2.20300E+04  K N3 O1
END RADIATION RECORDS
```

In the case of Tc-99m, the file includes data on the emission of 968 discrete Auger-CK electrons. The unit of the electron energy in this file is eV. For Tc-99m, the energy of the Auger-CK electrons ranges over four decades.

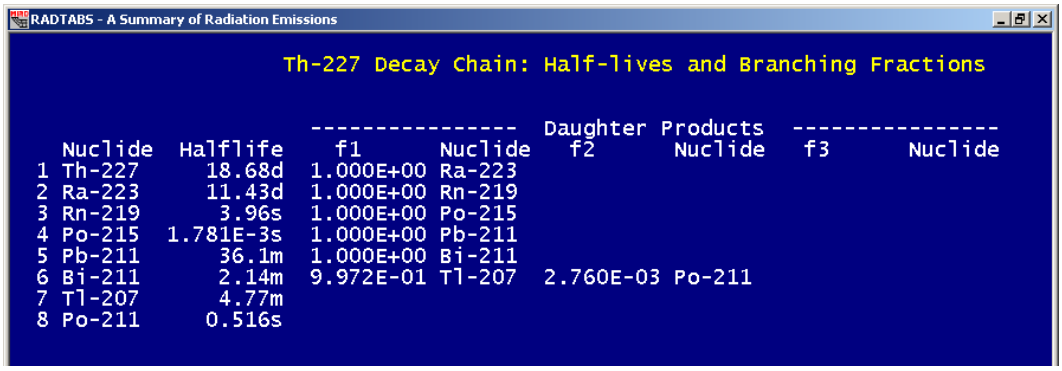
If data for Pu-238 or Cf-252 are requested, a file of the neutron spectra associated with the spontaneous fission process is created. Below is an excerpt from the Cf-252.NSF file.

```
Output File Cf-252.NSF for Cf-252
Cf-252  3.092E-02          52
Neutron Spectra for Cf-252
Number of energy bins: 52
E1 (MeV) E2 (MeV) Yield (/nt)
START RADIATION RECORDS
4.14E-07 1.00E-06 1.85105E-11
1.00E-06 1.00E-05 1.15581E-09
1.00E-05 5.00E-05 1.27176E-08
5.00E-05 1.00E-04 2.56849E-08
  ::   ::   ::  ::  ::  ::
1.20E+01 1.30E+01 3.82221E-05
1.30E+01 1.40E+01 1.82774E-05
1.40E+01 1.50E+01 8.66434E-06
END RADIATION RECORDS
```

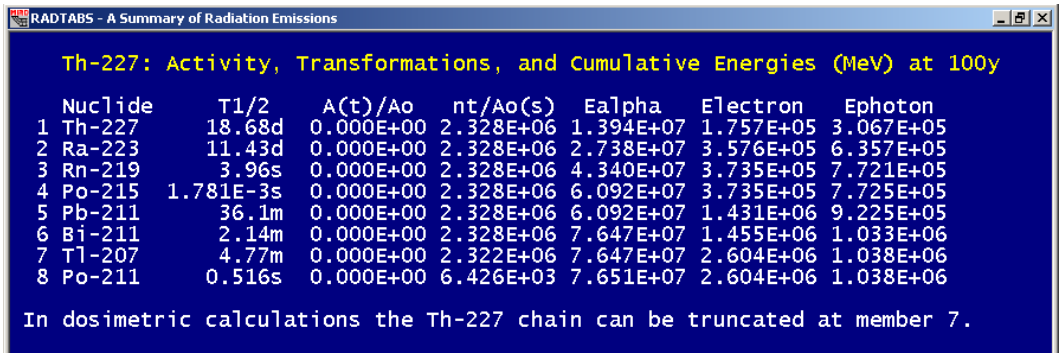
F2 key: Show the decay chain

The decay of some radionuclides results in formation of radioactive nuclei (daughters) and potentially a serial decay chain. The MIRD-07 collection includes only those daughter products judged to be of dosimetric significance. For example, the alpha decay of Am-241 ($T_{1/2}$ = 432.2 y) forms Np-237 ($T_{1/2}$ = 2.14 x 10^6 y). Because of the long half-life of Np-237 the formation of this daughter and all subsequent daughters are of no dosimetric importance and thus not included in the MIRD-07 collection. In some cases daughters were not included if formed by a low fraction of the parent's nuclear transformations. For example, 2.2 x 10^{-5} nuclear transformations of Eu-147 ($T_{1/2}$ = 24.1 d) forms Pm-143 ($T_{1/2}$ = 265 d). Because of this low yield, Pm-143 is not included in the collection. For information on the complete serial decay chains see Table 4.1 of Ref. 1 which is in the REPORT folder as JAERI1347.PDF.

The F2 key is used to view the decay chain of the displayed radionuclide as illustrated below for Th-227. After clicking on Th in the periodic table, the summary report for Th-227 is displayed and its decay chain, shown below, is displayed by pressing the F2 key. The values under the columns headed by *f1*, *f2*, and *f3* denote the fractions of the nuclear transformations of the nuclide in the second column that form the daughter nuclei shown immediately to the right of those fractions. For example, 0.9972 (99.72%) of Bi-211 nuclear transformations form Tl-207 and 0.00276 (0.276%) transformations form Po-211. Note that this chain diverges at Bi-211 however, both Tl-207 and Po-211 decay to the stable isotope Pb-207.



The decay chain information is presented in two screens when the length of the chain is greater than seven members, as in the Th-227 case. Upon continuing the display, the additional information provides an evaluation of the potential dosimetric importance of each chain member.



Briefly, RADTABS constructs and displays a table of activities, nuclear transformations, and cumulative energies of the chain members after 100 y, assuming a unit activity of the pure parent (e.g., 1 Bq of Th-227) present at time zero. The cumulative energy of alpha, electron (including beta), and photon emissions for the chain is shown in the right three columns. The length of the chain that accounts for 99% of the total emitted energy over the 100 y period is calculated for each energy type. For Th-227, the suggestion is made that, for dosimetric purposes, the chain could be truncated after the seventh member (Tl-207) as the contribution of Po-211 to the total energy of each radiation type is not significant. This suggestion reflects the small fraction of Bi-211 decays (2.76×10^{-3}) forming Po-211. Although the guidance is derived over a time period pick of an arbitrary length, it has proven to be useful when dealing with decay chains headed by or including long-lived radionuclides. In any event, the user must make the decision regarding truncation of the chain in his specific application.

F3 key: Plot of radiation emissions

This function key generates a series of plots of the yield of the emitted radiations of the displayed radionuclide as a function of energy. In the case of beta (negatron and positron) and neutron emissions (spontaneous fission) the plots are a continuous function of energy. For radiations of discrete energy (alpha, photon, etc.) line plots are generated.

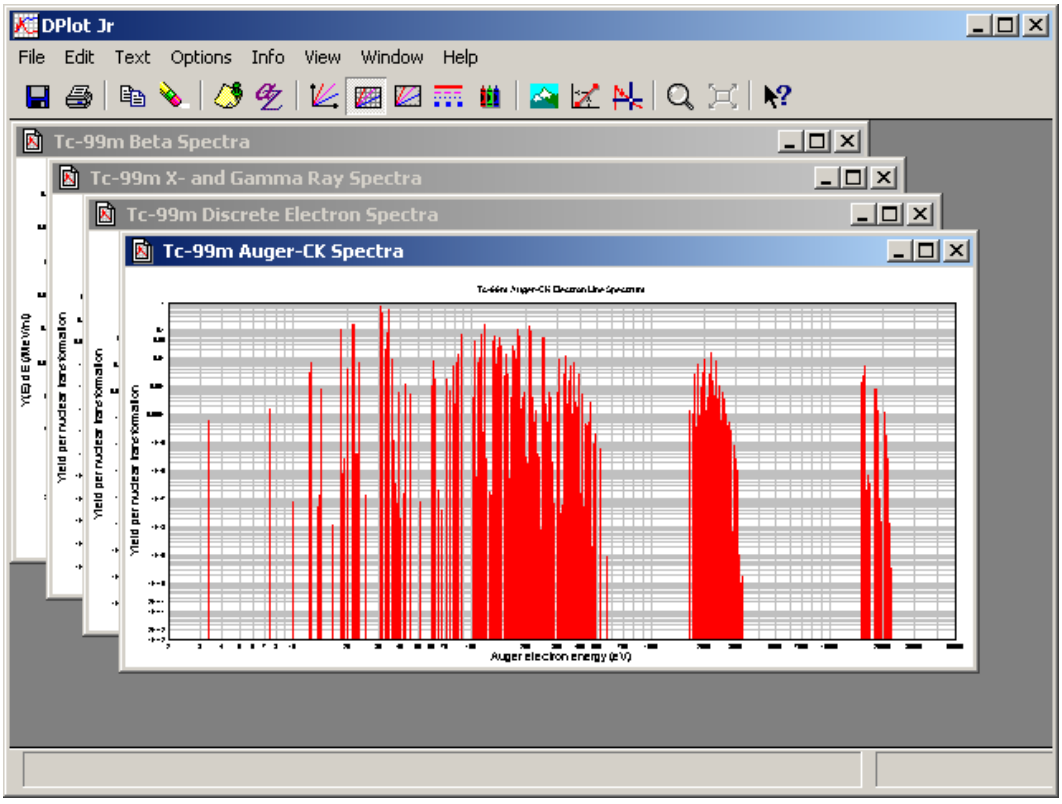


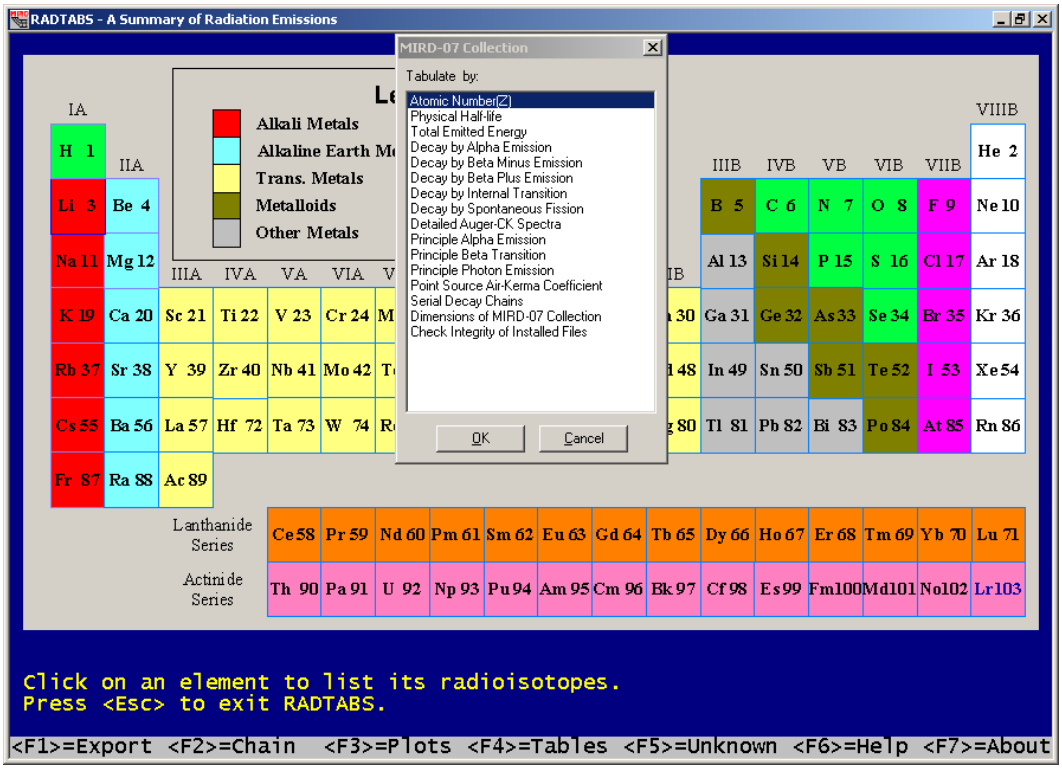
Fig. 2. Plots of the Tc-99m emissions, the detailed Auger-CK electron spectra is visible.

The type of axis and their numerical extent can be modified by selecting the 'Options' menu on DPlotJr's tool bar. Additional information is available via the DPlotJr's 'Help' menu. The plots can be maximized within DPlotJr's window or deleted by clicking the appropriate button in the upper right corner of the plot. Clicking the maximized button will result in all plots being maximized. The 'Window' menu on the toolbar is then used to select a specific plot for viewing. If the nuclide emits a single radiation type, the plot is maximized upon its creation, e.g., the beta spectrum for H-3. RADTABS can be directed to maximize all plots upon creation by adding a file (it can an empty) named DPlotJr.INI to the DATA folder.

F4 key: Nuclide lists

The function key F4 results in RADTABS creating a number of tables that characterize the radionuclides of the MIRD-07 collection and the collection itself. These tables are written to files named NucList-X.TXT, where X corresponds to the index of requested item in the menu of available tasks. After generating the file, RADTABS opens it using the ASCII editor registered to open files with the extension TXT. The user is cautioned to be patient, as creation of the information and the display of the file, in some instances, can take a bit of time. The menu items are tabulated below.

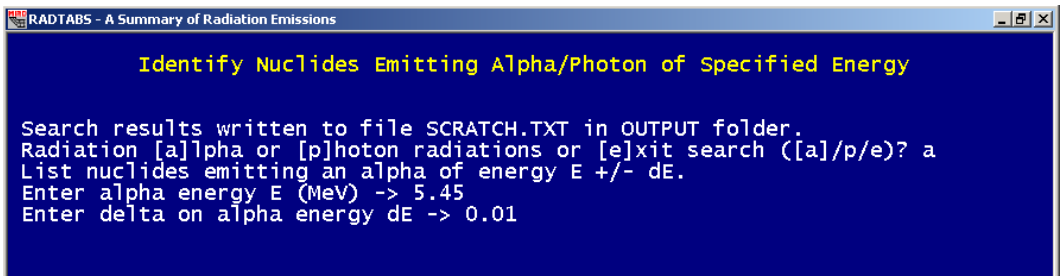
Menu entries for characterizing the radionuclides in MIRD-07	
Menu Item	Description
1. Atomic Number (Z)	List nuclides in order of atomic number
2. Physical Half-life	List nuclides by increasing physical half-life
3. Total Emitted Energy	List nuclides by increasing emitted energy
4. Decay by Alpha Emission	List nuclides that undergo alpha decay
5. Decay by Beta Minus Emission	List nuclides that undergo β^- (negatron) decay
6. Decay by Beta Plus Emission	List nuclides that undergo β^+ (positron) decay
7. Decay by Internal Transition	List nuclides that undergo internal transition decay
8. Decay by Spontaneous Fission	List nuclides that undergo spontaneous fission
9. Detailed Auger-CK Spectra	List nuclides in the ACK file
10. Principle Alpha Emission	List nuclides by increasing energy of principle alpha emission
11. Principle Beta Transition	List nuclides by increasing energy of principle beta emission
12. Principle Photon Emission	List nuclides by increasing energy of principle photon emission
13. Point Source Air-Kerma Coefficient	List nuclides by increasing air-kerma coefficient
14. Serial Decay Chain	List the decay chain for the nuclides
15. Dimension of MIRD-07 Data	Tabulate the dimensions of the data collection
16. Check Integrity of Installed Files	Perform check sum verification of data files



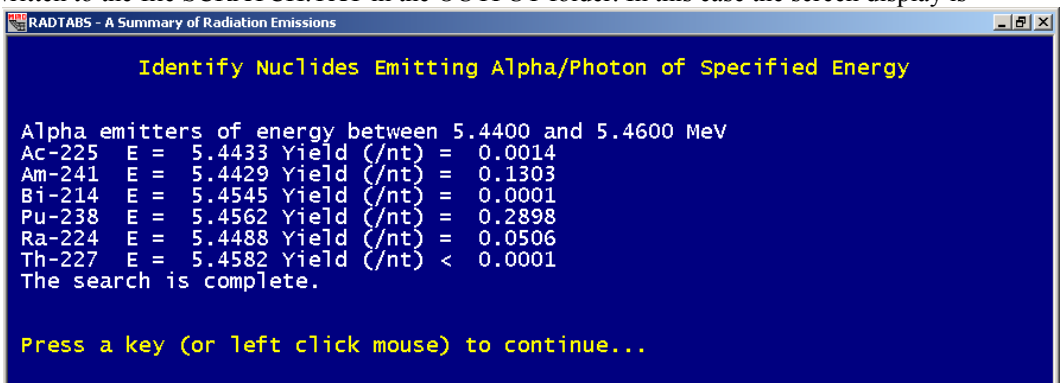
The last two items serve to characterize the MIRD-07 collection from a computational standpoint. The penultimate item interrogates the data files to determine the maximum number (dimension) of various quantities (radiations, length of decay chain, etc.). The last item conducts a check (so-called checksum) on the integrity of the data files to establish that the files have not been corrupted.

F5 key: Identify unknown radionuclide

This function key provides a means to associate an observed alpha or photon emission with a radionuclide of the MIRD-07 collection. For example, assume the emission of an alpha particle of energy 5.45 MeV has been observed. Pressing the F5 key opens a screen within which the user defines the search by entering the observed energy. In addition to the point-value for the alpha energy, a tolerance (or delta) in energy, in the example 0.01 MeV, is provided.



A search of the RAD file is performed, as guided by information in the NDX file. The results appear on the screen and are written to the file SCRATCH.TXT in the OUTPUT folder. In this case the screen display is



The information on the yield of radiations within the energy tolerance may be helpful in eliminating some candidate nuclides. The efficacy of the search is limited to some extent by the number of nuclides in the MIRD-07 collection. The search can lead to a substantial number of candidates, particularly for photons, and thus the SCRATCH.TXT file may need to be consulted. RADTABS opens this file using the application associated with files with the extension TXT, e.g., Microsoft Notepad or an ASCII editor.

F6 key: View files in the REPORT folder

The REPORT folder contains this document, reports produced by the authors during the course of the work leading to the MIRD monograph, two files created via the F4 key discussed above, a file detailing the contents of the CD, and other reports that provide additional information. The user can maintain a set of notes on the operation of RADTABS by adding notes to the file MyNotes.TXT in the folder. Additional documents of interest (with extension TXT or PDF) can be placed in the folder with the limitation that the selection menu is limited to 20 items.

F7 key: About

Provides the usual *About* screen associated with software.

5. Programmer's notes

The MIRD-07 data files are formatted direct-access files. Each record of these files is of fixed length with a carriage return and line feed so that the files are readable when opened with an ASCII editor. The length of the records, less the carriage return and line feed, and number of records for each file are:

Length of Records in the Direct-Access Files		
File	Record Length*	Number of Records
MIRD-07.NDX	201	334
MIRD-07.RAD	29	78,407
MIRD-07.BET	17	23,874
MIRD-07.ACK	32	131,571
MIRD-07.NSF	29	106
*Value does not include the carriage return and line feed.		

The number of radiation records in the RAD file for a given nuclide, *N*, is contained in the header record of the nuclide in the RAD file but it can be computed from the nuclide's record in the NDX file as

$$N = \begin{cases} \sum_{1}^{5} \text{Number}_i + \text{Number}_5 \ , & \text{Decay Mode} \neq \text{SF} \\ \sum_{1}^{5} \text{Number}_i + \text{Number}_5 + 2 \ , & \text{Decay Mode} = \text{SF} \end{cases}$$

where *Number* refers to the fields denoted as Number-1, Number-2… Number-5 in Table 1. The number of alpha transitions, $Number_5$, enters into the above equation twice since records are included in the RAD file for the kinetic energy of the recoiling nuclei formed in alpha decay as well as the alpha particles themselves. The two additional records for nuclides undergoing spontaneous fission are those of the mean energy of the fission fragments and neutrons.

The source code for RADTABS is included in the folder SOURCE of the ARCHIVE folder on the CD as an aid to those developing software for calculations of radiation dose. The functions and subroutines of the code can be readily translated to other programming languages. Information on the dimension of the MIRD-07 collection and potential dimensions of arrays can be generated by the penultimate menu item under the F4 key.

References

1. Endo A, Yamaguchi Y, and Eckerman KF. *Nuclear Decay Data for Dosimetry Calculation: Revised Data of ICRP Publication 38*. Japan Atomic Energy Research Institute, JAERI 1347, 2005.

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4. Chadwick MB, Barschall HH, Caswell RS, DeLuca PM, Hale GM, Jones DTL, MacFariane RE, Meulder JP, Schuhmacher H, Schrewe UJ, Wambersie A, and Young PG. A consistent set of neutron kerma coefficients from thermal to 150 MeV for biological important materials. *Med. Phys. 26(6)*:974-991, 1999.

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Table 1. Structure of Records in MIRD-07.NDX File

Field	Format*	Description
Record #1 (2I4)		
First	I4	Record number of first data record
Last	I4	Record number of last data record
Data Records (First, ..., Last) [§]		
Nuclide	A7	Name of nuclide (parent); e.g., Am-241, Tc-99m
Half-life	A8	Half-life of nuclide
Units	A2	Half-life units: us - microsecond, ms - millisecond, s – second, m – minute, d - day, and y – year
Decay Mode	A8	A denotes alpha, B- beta minus, B+ beta plus, EC electron capture, IT internal transition, and SF spontaneous fission
Pointer-1	I7	Location of nuclide in MIRD-07.RAD file
Pointer -2	I7	Location of nuclide in MIRD-07.BET file
Pointer -3	I7	Location of nuclide in MIRD-07.ACK file
Pointer -4	I6	Location of nuclide in MIRD-07.NSF file
The next three fields are repeated as a block for radioactive daughter *i*, *i* = 1 to 3.		
Daughter-*i*	A7	Name of daughter nuclide *i*
Pointer-*i*	I5	Location of daughter *i* in MIRD-07.NDX file
Branch-*i*	E11.0	Branching fraction to daughter *i*
E-alpha	E7.0	Energy of alpha emissions (MeV/nt)
E-electron	E8.0	Energy of electrons, including beta (MeV/nt)
E-photon	E8.0	Energy of photon emission (MeV/nt)
Number-1	I4	Number of photon of energy less than 10 keV
Number-2	I4	Number of photons of energy greater than 10 keV
Number-3	I4	Number of beta transitions
Number-4	I5	Number of monoenergetic electrons
Number-5	I4	Number of alpha transitions
AMU	E10.0	Atomic mass of radionuclide, see Ref. 5
Γ_{10}	E10.0	Air kerma-rate constant (Gy-m^2 (Bq s)$^{-1}$)
K_{air}	E10.0	Point source air kerma coefficient (Gy-m^2 (Bq s)$^{-1}$)

*The format is expressed in FORTRAN notation, e.g., A8 denotes an alphanumic field of length 8, I5 an integer field of length 5, and E11.0 a real numeric field of length 11.
[§]Format (A7,A8,A2,A8,3I7,I6,3(1X,A7,I5,E12.0),E7.0,2E8.0,3I4,I5,I4,E11.0, E10.0,E9.0)

Table 2. Structure of Records in MIRD-07.RAD File

Field	Format	Description
Nuclide Record (A7,1X,E10.0,A2,I9)		
Nuclide	A7	Nuclide name; e.g., Tc-99m
$T_{1/2}$	E10.0	Physical half-life of nuclide
Time unit	A2	Units of $T_{1/2}$, see Table 1
N	I9	Number of data records
Data Record (1, …, N) (I2, 2E12.0,1X,A2)		
ICODE	A2	Radiation type (see Table 3)
Yield	E12.0	Yield of the radiation (/nt)
Energy	E12.0	Energy of the radiation (MeV)
JCODE	A2	Mnemonic (see Table 3)

Table 3. Description of ICODE Variable

ICODE	Mnemonic For ICODE	Description
1	G	Gamma rays
	PG	Prompt gamma rays*
	DG	Delayed gamma rays*
2	X	x-rays
3	AQ	Annihilation quanta
4	B+	Beta + particles
5	B-	Beta – particles
	BD	Delayed beta particles*
6	IE	IC electrons
7	AE	Auger electrons
8	A	Alpha particles
9	AR	Alpha recoil nuclei
10	FF	Fission fragments
11	N	Neutrons

*Prompt and delayed radiations of spontaneous fission.

Table 4. Structure of Records in MIRD-07.BET File

Field	Format	Description
Nuclide Record (A7, 6X, I4)		
Nuclide	A7	Nuclide name; e.g., Tc-99m
N	I4	Number of data records
Data Record (1, …, N) (F8.0, E9.0)		
Energy	F8.0	Energy grid point (MeV)
Number	E9.0	Number of beta particles per MeV per nuclear transformation at this energy

Table 5. Structure of Records in MIRD-07.ACK File

Field	Format	Description
Nuclide Record (A7, 2X, E10.0,A2,7x, I4)		
Nuclide	A7	Nuclide name; e.g., I-123
$T_{1/2}$	E10.0	Half-life of nuclide
Time unit	A2	Units of $T_{1/2}$, see Table 1
N	I4	Number of discrete electron lines
Data Record (1, …, N) (E11.0, E12.0, 1X,A8)		
Energy	E11.0	Electron energy (eV)
Yield	E12.0	Number of electrons per *nt* at this energy
Transition	A8	Identification of atomic transition; e.g., L1 M2 M3

Table 6. Structure of Records in MIRD-07.NSF File

Field	Format	Description
Nuclide Record (A7, E10.0, 8X, I4)		
Nuclide	A7	Nuclide name; e.g., Cf-252
BF	E10.0	SF branching fraction
N	I4	Number of energy bins
Data Record (1, …, N) (E8.0,E9.0,E12.0)		
Energy-1	E8.0	Lower Energy (MeV)
Energy-2	E9.0	Upper Energy (MeV)
Yield	E12.0	Number of neutrons per nt in bin