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ORNL/TM-7230

Report of the Task Group on Dose Calculations to ICRP Committee 2 March 17-21, 1980

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PREFACE

The Task Group on Dose Calculations is responsible for calculating the dosimetric data for the report of the International Commission on Radiological Protection (ICRP) Committee 2 entitled, *Limits for Intakes of Radionuclides by Workers*. Since the last meeting of the Committee (April, 1979), the task group has completed the computation of annual limit on intake (ALI) and derived air concentration (DAC) values for the 31 elements (257 radionuclides) planned for inclusion in the second volume of the report. Last year's report to the Committee, *Report of the Task Group on Dose Calculations at the Meeting of ICRP Committee 2, April 23-26, 1979, Harwell, England,* is documented in ORNL/TM-6988.

REPORT OF THE TASK GROUP ON DOSE CALCULATIONS TO ICRP COMMITTEE 2, MARCH 17-21, 1980

DOSIMETRIC DATA IN PART 1, PUBLICATION 30

The annual limit on intake (ALI) and derived air concentration (DAC) values for the 187 radionuclides (21 elements) reported at the last meeting of the Committee (April 23-26, 1979) were published during the year. They are presented in ICRP Publication 30, Part 1, *Annals of the ICRP*, Vol. 3/4, 1979, Pergamon Press.

Publication of the data supporting the ALI and DAC values is imminent. These data consist of computer printouts of decay chain drawings and tables of specific effective energy (SEE) values, nuclear transformations, committed dose equivalents, weighted committed dose equivalents, and the ALI and DAC for each of the radionuclides included in Part 1.

DOSIMETRIC DATA FOR PART 2, PUBLICATION 30

Since the meeting of the Committee last year at Harwell, the Task Group has completed the computations of dosimetric data for the 31 elements to be included in Part 2 of Publication 30. There are, on the average, 8 to 9 radioisotopes for each element that meet the requirement for inclusion in the report. That is, radionuclides are included that have a radioactive half-life of 10 min or more for which data are available in the Evaluated Nuclear Structure Data File (ENSDF) of the Nuclear Data Project at the Oak Ridge National Laboratory (ORNL). For the 31 elements, data have been generated for 257 radionuclides.

These data have been furnished to the Committee chairman in the form of a computer output suitable for publication. Following Committee review, the ALI and DAC values for Part 2 may be typeset, and the computer printouts of the supporting data photocopyed for the supplement to Part 2. Computer drawn decay chains have been furnished for each parent radionuclide.

Certain problems have arisen in generating the dosimetric data for Part 2 that have necessitated revisions and extensions of the computer codes used in Part 1. These situations involve:

1. Elements that concentrate in the walls of the gastrointestinal tract (GIT).

The metabolic models for technetium and rhenium show retention in the stomach wall, however, the specific absorbed fractions (SAF) of photons referenced in Part 1 are more representative of the GIT contents. Fortunately, SAF data for the GIT walls have been reported by Deus et al., *Health Phys.* Vol. 33, No. 3, 1977, and these data have been used.

2. Elements that concentrate in the brain.

Both copper and mercury concentrate to some extent in the brain. This is a source organ not encountered in Part 1 and for which SAF values were not available. During the past year, computations to provide these values for brain both as a source and a target organ have been made at ORNL according to the methodology used to estimate the SAF values in the Reference Man Report and/or in MIRD Pamphlet 5, Revised. These data will be reported at the 1980 annual meeting of the Health Physics Society in Seattle, Washington.

3. Elements that concentrate in bone marrow.

The indium model indicates retention within bone marrow. The first concern was whether total marrow or only the red marrow was involved. The Committee chairman indicated that indium retention was to be associated with the red marrow. A further question arose regarding absorption from deposition in red marrow. The decision was made to take absorbed fractions of photons from Snyder et al., MIRD Pamphlet No. 5, Revised, 1978. For beta particles, the absorbed fraction in red marrow is assumed to be 1, and the dose to bone surfaces adjacent to red marrow is taken to be the same as that in red marrow. Thus, the absorbed fraction from red marrow to bone surfaces is one half that in red marrow because red marrow is associated with trabecular bone which involves only one half the bone surfaces.

4. Elements that produce gases and/or vapors.
The metabolic model sheet for sulfur provides data for gases, and the mercury model includes data for vapors. This would seem to present quite a problem because the ICRP lung model is defined only for particulate matter. The problem is not insurmountable, however, because the metabolic models either essentially bypass the lungs in the case of sulfur or provide a simple retention function for the lungs in the case of mercury. The format of the dose tables used in Part 1 is inappropriate in this case because of the absence of ingestion values and lung clearance classes. A new format was established to meet this need.

ERRATA FOR PART 1

The ALI and DAC values for isotopes of tellurium with iodine daughters which appear in Part 1 must be revised due to a misinterpretation by the Task Group of the metabolic model. These revisions will appear in the errata to Part 1. The new values represent the best judgement of the Task Group and the Committee as to how the radioiodine daughters behave.

NUCLEAR DECAY DATA PUBLICATION

Progress is being made toward publication of the nuclear decay data used in the computations of dosimetric data for Publication 30. During the year, communication between the Task Group, the Committee chairman, and Pergamon Press has resulted in the following decisions to:

1. Publish the data in one volume for the whole of Publication 30.
2. Arrange the data in order of ascending atomic number of the elements and mass numbers of the isotopes.
3. Include in the compilation only decay scheme drawings and "output" data. Examples of these data for ^{60m}Co are shown in Fig. 1 and in Table 1. The "input" data shown in Table 2 are typical of data taken from the ENSDF file of the Nuclear Data Group that will not be published in the document.

4. Neglect transitions in the "output" data that contribute less that 0.1% to the total number of transformations.
5. Omit data for the last member (or members) of a decay chain that fail to contribute as much as 0.1% to the total weighted committed dose equivalent. Decay data will be included for a member failing to contribute 0.1% if later chain members contribute 0.1% or more.
6. Conform the format of the computer printout data to the scheme agreed to previously (i.e., as shown in the example).
7. Begin, as time permits, to provide data for Pergamon Press on an element by element basis.

L. T. Dillman has documented his computer code that produces the "output" data in the report entitled, *EDISTR — A Computer Program to Obtain a Nuclear Decay Data Base for Radiation Dosimetry*, ORNL/TM-6689.

USEFUL RELATED DATA AND REPORTS

The Task Group realizes that data too voluminous to include in the Committee reports will, nevertheless, be of considerable importance to the scientific community as well as perhaps in the future work of the Committee. The Task Group has arranged to retain all of the data used to generate the ALI and DAC values. The complete sets of SEE values for 20 source organs and 20 target organs generated during the course of the Part 1 computations and the complete tables of nuclear transformations and committed dose equivalents per unit intake will be documented in separate ORNL reports. Likewise, future ORNL reports will provide the data corresponding to Parts 2 and 3. In addition, computer tapes of the data will be available.

In last year's report to the Committee, mention was made of a manuscript in preparation for documenting the computer programs developed and used by the Task Group. The report has been completed for publication in a document entitled, *A User's Manual to the ICRP Code — A Series of Computer Programs to Perform Dosimetric Calculations for the IRCP Committee 2 Report* ORNL/TM-6980 by S. B. Watson and M. R. Ford.

DATA MANAGEMENT AND AVAILABILITY

The calculation of ALI and DAC values for every member of a decay chain requires many computer manipulations. When this is repeated for 750-1000 radionuclides, as the Task Group is currently doing, under the requirement that most of the data generated be stored in retrievable form, data management problem of immense proportions is encountered. The decay data alone average over 200 radiations per radionuclide totaling in excess of 150,000 records, and this is only the beginning. From there the number of records grow as SEE arrays, cumulated activity arrays, committed dose equivalent arrays, etc., are calculated.

To assist with the management of this vast amount of data, the Task Group is developing an information retrieval network with both on-line and off-line capabilities. Metabolic models for each element, formated according to the Publication 30 scheme, and ALI and DAC values for each isotope included in Publication 30 will be available for visual retrieval by the user through the on-line system. Off-line data including nuclear decay data, SEE values, and dose per unit intake, are referenced in the on-line system through the use of indices. The on-line user is able to access off-line data in printed form by using these indices.

DOSIMETRIC DATA FOR THE THIRD GROUP OF ELEMENTS

Considerable progress has been made toward providing dosimetric data for Part 3. The "input" decay data from the ENSDF file for most of the remaining elements have been edited and processed through the EDISTR decay data code to provide the "output" decay data needed in the computations. Efforts have begun toward drawing the decay chains for these radionuclides, and the metabolic models are under review.

CONCERNS FOR THE FUTURE

The pattern and sequence of data generation is more or less fixed now that the publication of data computed for Publication 30 has progressed beyond Part 1. Nevertheless, a large effort is still required on the part of the Task Group because nearly half of the elements must

be considered. In addition, the generation and processing of data for the nuclear decay data publication as well as preparation of the text are just now beginning. Also, questions remain on a few issues. These issues include:

1. The addition of isotopes of elements already published.
   Last year the Committee indicated that this is desirable. What is the Task Group's responsibility in this area?
2. The updating of material already published or computed.
   Will the Committee undertake to revise or update the data in preceding Parts of the report?
3. The time-frame for completion of Publication 30, the supplements, and the decay data publication.
   What is the anticipated time schedule?

ACKNOWLEDGEMENTS

The members of the Task Group on Dose Calculations acknowledge the assistance of many individuals in carrying out this work. The encouragement and support of the Committee members is a major source of inspiration. Particular thanks go to the Committee chairman, J. Vennart, who coordinates the Task Group effort with the Committee directives. Also, the Task Group appreciates greatly the advice and guidance of C. R. Richmond in establishing the data management and retrieval system.

Grateful appreciation is extended to the secretariat: to M. Thorne for providing the cumulated activities of the alkaline earth elements and to N. Adams for help in checking the ALI and DAC values.

The Task Group contracts the expert computational assistance of N. B. Gove and J. Bledsoe, both of the ORNL Computer Sciences Division, and data management support from C. S. Fore, ORNL Information Division. The Group is grateful to those at ORNL who have provided administrative support for the project. The administrative staff of the Health and Safety Research Division (HASRD) during this phase of the work has consisted of: K. F. Eckerman, leader of the Metabolism and Dosimetry Group; D. C. Parzyck, head of the Health Studies Section; S. V. Kaye, Director of HASRD; and C. R. Richmond, ORNL Associate Laboratory Director for Biomedical and Environmental Sciences.

COMPOSITION OF THE TASK GROUP

The task group membership during this period has remained the same as last year, namely, M. R. Ford, Chairman, and S. R. Bernard, HASRD, ORNL; S. B. Watson, Computer Sciences Division, ORNL; L. T. Dillman, consultant to HASRD, Ohio Wesleyan University; and J. W. Poston, Georgia Institute of Technology.

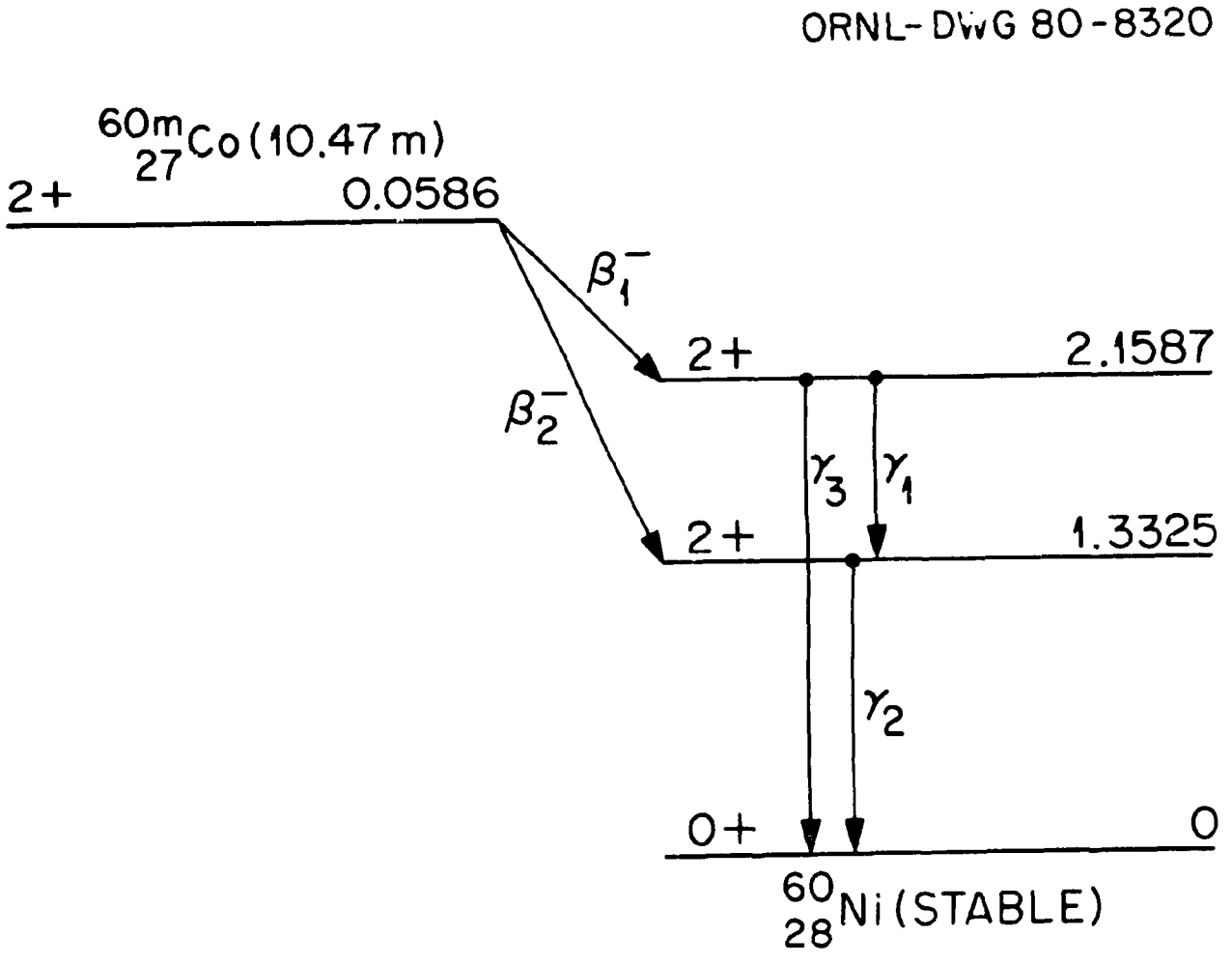

Figure 1. Decay scheme of ^{60m}Co.

Table 1.

OUTPUT DATA

60M-COBALT-27 HALFLIFE = 10.47 MINUTES 06-14-79

MODES OF DECAY: ISOMERIC LEVEL, BETA MINUS

TYPE OF RADIATION		MEAN NUMBER/ TRANSFOR-MATION	ENERGY (MEV)	MEV/ TRANSFOR-MATION
GAMMA-RAY	1	2.07E-02	5.860E-02	1.22E-03
K SHELL CONVERSION ELECTRON		8.46E-01	5.089E-02	4.31E-02
L1 SHELL CONVERSION ELECTRON		1.03E-01	5.768E-02	5.92E-03
L2 SHELL CONVERSION ELECTRON		1.61E-02	5.781E-02	9.32E-04
L3 SHELL CONVERSION ELECTRON		3.57E-02	5.782E-02	2.06E-03
K-ALPHA1 X-RAY		1.88E-01	6.930E-03	1.31E-03
K-ALPHA2 X-RAY		9.55E-02	6.915E-03	6.61E-04
K-BETA1 X-RAY		2.55E-02	7.649E-03	1.95E-04
K-BETA3 X-RAY		1.30E-02	7.649E-03	9.92E-05
KLL AUGER ELECTRON		4.11E-01	6.024E-03*	2.48E-03
KLX AUGER ELECTRON		1.03E-01	6.817E-03*	7.04E-04
KXY AUGER ELECTRON		9.38E-03	7.583E-03*	7.11E-05
LMM AUGER ELECTRON		1.28E 00	7.358E-04*	9.38E-04
LMX AUGER ELECTRON		8.63E-02	7.781E-04*	6.72E-05
MXY AUGER ELECTRON		2.80E 00	2.512E-05*	7.03E-05
BETA MINUS	2	2.42E-03	6.063E-01*	1.47E-03
GAMMA-RAY	1	7.80E-05	8.300E-01	6.47E-05
GAMMA-RAY	2	2.50E-03	1.330E 00	3.32E-03
GAMMA-RAY	3	8.00E-06	2.160E 00	1.73E-05

ALL LISTED X-RAYS, GAMMA-RAYS AND ANNIHILATION RADIATION	6.88E-03
ALL NEGLECTED X-RAYS, GAMMA-RAYS AND ANNIH. RADIATION**	2.31E-06
ALL LISTED BETAS, INTERNAL CONVERSION AND AUGER ELECTRONS	5.78E-02
ALL NEGLECTED BETAS, INT. CONVERSION AND AUGER ELECTRONS**	2.05E-05
ALL LISTED RADIATIONS	6.47E-02
ALL NEGLECTED RADIATIONS**	2.28E-05

* AVERAGE ENERGY (MEV)
** EACH NEGLECTED TRANSITION CONTRIBUTES LESS THAN 0.100%
TO THE TOTAL MEV/TRANSFORMATION FOR THIS CATEGORY.
DAUGHTER NUCLIDE, 60-COBALT GROUND STATE, IS STABLE.
DAUGHTER NUCLIDE, 60-NICKEL GROUND STATE, IS STABLE.
- - - - - - - - - -
INPUT DATA SOURCE: EVALUATED NUCLEAR STRUCTURE DATA FILE (ENSDF)
NUCLEAR DATA PROJECT, OAK RIDGE NATIONAL LABORATORY.
DATE INPUT DATA WERE ENTERED INTO ENSDF: 20-DEC-77

Table 2.

INPUT DATA

60M-COBALT-27 HALFLIFE = 10.47 MINUTES 06-14-79

MODES OF DECAY: ISOMERIC LEVEL, BETA MINUS

TYPE OF TRANSITION		MEAN NUMBER/ TRANSFOR-MATION	TRANSITION ENERGY (MEV)	OTHER NUCLEAR PARAMETERS
I.C.E. + GAMMA	1	1.02E 00	5.860E-02	M3+E4 MULTIPOLE MRS=0.00122 AK= 40.8 AL1=4.94 AL2=0.777 AL3=1.72
BETA MINUS	1	8.06E-05	7.236E-01*	ALLOWED
BETA MINUS	2	2.42E-03	1.550E 00*	ALLOWED
I.C.E. + GAMMA	1	7.80E-05	8.300E-01	M1 MULTIPOLE
I.C.E. + GAMMA	2	2.50E-03	1.330E 00	E2 MULTIPOLE
I.C.E. + GAMMA	3	8.00E-06	2.160E 00	E2 MULTIPOLE

* ENDPOINT ENERGY (MEV)

REFERENCE: EVALUATED NUCLEAR STRUCTURE DATA FILE (ENSDF)
NUCLEAR DATA PROJECT, OAK RIDGE NATIONAL LABORATORY.
DATE DATA WERE ENTERED INTO ENSDF: 20-DEC-77