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Asilomar Conference Grounds, Pacific Grove, CA,
October 27-30, 1981

PROCEEDINGS OF THE FIRST CONFERENCE ON NUCLEAR STRUCTURE DATA EVALUATION

April 1982

NUCLEAR SCIENCE DIVISION

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DISCLAIMER

Proceedings of the 1st Conference on Nuclear Structure Data Evaluation

held in conjunction with the
APS/Division of Nuclear Physics Fall Meeting
Asilomar Conference Grounds
Pacific Grove, CA
October 27-30, 1981

Isotopes Project
Lawrence Berkeley Laboratory
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Berkeley, CA 94720

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FOREWORD

The 1st Conference on Nuclear Structure Data Evaluation was organized by the Isotopes Project of the Lawrence Berkeley Laboratory in order to encourage the open discussion of the scientific aspects of ENSDF production and usage. Summaries of the roundtable discussion sessions, abstracts of the presented papers, and additional contributed papers are contained in these Proceedings.

Representatives and interested scientists from ten international centers involved in data evaluation and data usage convened in the hospitable environment of Asilomar, California. Amidst the inspiring atmosphere of the APS/DNP Fall meeting, a series of stimulating roundtable discussions of ENSDF evaluation took place. Additional lively debate accompanied the evaluation papers that were presented during the regular DNP sessions. Evaluators unable to attend the conference participated through their suggestions and contributed papers.

The organizing committee extends its appreciation to Charles W. Reich (Idaho Falls), Stanley L. Whetstone (DOE), and Richard B. Firestone (LBL) for chairing the roundtable discussions. We also extend our thanks to Lee Schroeder (APS/DNP Asilomar meeting organizing committee), Peggy Little (Technical Information Department), and Wanda Smith-Burnett and Jeanne Hassenzahl (Nuclear Science Division) for their assistance in obtaining meeting rooms, scheduling sessions, and producing this report. We feel that this conference was a very successful beginning to a dialogue in scientific nuclear structure data evaluation. We further feel that this dialogue should be continued and look forward to a second conference in the near future.

Richard B. Firestone
Janis M. Dairiki
Organizing Committee
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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ON NUCLEAR STRUCTURE DATA EVALUATION

1st Conference on Nuclear Structure Data Evaluation

Asilomar, CA

October 27-30, 1981

PROGRAM

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Informal discussion, cheese and wine provided.

Session I - Tuesday, October 27, 7:30 p.m.

Discussion leader: Charles Reich, Idaho Falls
Topic: Evaluation as a Science - scientific policies for the production of Nuclear Data Sheets; mechanisms for policy adoption and enforcement; the role of theory in evaluation.

Session II - Wednesday, October 28, 7:30 p.m.

Discussion leader: Stanley Whetstone, DOE
Topic: Evaluation and the Scientific Community - effectiveness of ENSDF in serving the needs of the scientific community; responsibility for critical evaluation of the literature; prospects for horizontal evaluations from ENSDF.

Session III - Thursday, October 29, 10:00 a.m.

Discussion leader: Richard B. Firestone, LBL
Topic: Continued Discussions.

Submitted APS papers:

AD14 - Compilation, Evaluation and Extrapolation of Nuclidic Masses, A. H. Wapstra and T. H. Delft, NIKHEF-K Amsterdam.
AD15 - Systematics of spin-parity of odd-odd actinide nuclides, L. K. Peker and J. K. Tuli, Brookhaven National Laboratory.
BD1 - Radioactivity Handbook, J. M. Dairiki, Lawrence Berkeley Laboratory.
CD1 - Nuclear Structure Database and Related Services, J. K. Tuli, Brookhaven National Laboratory.
DD14 - Are Logft Values Reliable Guides for Spin and Parity Assignments? R. B. Firestone, Lawrence Berkeley Laboratory.
DD15 - Systematic Survey of γ-ray Transition Probabilities, E. Browne, Lawrence Berkeley Laboratory.
EE31 - Data Evaluation in the U.K. and Use of the ENSDF Database, N. J. Ward, The University of Liverpool.

Summary of the Discussion Sessions at the 1st Conference on Nuclear Structure Data Evaluation

Introduction

This summary of the discussion sessions was prepared from tape recordings of the sessions supplemented by our handwritten notes. The many long and interesting discussions have been reduced here to a bare minimum, highlighting only the general discussion topics. Where possible, the contributions of the various participants have been identified by initials. We have tried to present a complete and accurate recounting of the proceedings and respectfully apologize for any inadvertent omissions or inaccuracies.

Discussion Participants

Roger L. Bunting	(RLB)	Idaho Falls
Thomas W. Burrows	(TWB)	Brookhaven
Janis M. Dairiki	(JMD)	Berkeley
Richard B. Firestone	(RBF)	Berkeley
C. Michael Lederer	(CML)	Berkeley
Jacquette Lyttkens	(JL)	Lund
John A. Keuhner	(JAK)	McMaster
Murray J. Martin	(MJM)	Oak Ridge
Charles W. Reich	(CWR)	Idaho Falls
Virginia S. Shirley	(VSS)	Berkeley
Raymond H. Spear	(RHS)	Canberra
Judit A. Szücs	(JAS)	McMaster
Aaldert H. Wapstra	(AHW)	NIKHEF
Naomi J. Ward	(NJW)	Liverpool
Stanley L. Whetstone	(SLW)	DOE

Abbreviations

ENSDF	Evaluated Nuclear Structure Data File
IAEA	International Atomic Energy Agency
NDN	Nuclear Data Network
NDP	Nuclear Data Project (Oak Ridge)
NDS	Nuclear Data Sheets
NSR	Nuclear Structure References

Session I: 7:30 P.M., Tuesday, October 27, 1981

Discussion Leader: Charles Reich, Idaho Falls

Topic: Evaluation as a Science

The following questions concerning the production of ENSDF/NDS were addressed:

1) What are the adopted evaluation policies and how were they derived?

2) What are the roles of systematics and theory with respect to the data files?

3) How are the ENSDF/NDS policies enforced?

CWR opened the discussion with a typical evaluation problem relevant to the first question. In the decay of ^{233}Pa, experimental intensity measurements for the highest energy β^- decay branch (to the ^{233}U ground state) range from 5 to 12%. Analysis of the absolute γ-ray transition intensities, however, suggests that there is no ground-state feeding by β^--decay. CWR suggested that this discrepancy is resolved if the theoretical ICC values vary by a few percent from those determined by experiment. A discussion ensued in which it was pointed out that large anomalies in the ICC values do exist and that there is strong evidence for systematic ICC variances of a similar magnitude in heavy elements. MJM suggested that evaluators should be aware of such problems and not proceed blindly. No solutions to this problem vis-a-vis ENSDF/NDS were reached.

VSS presented an evaluation problem from A = 193 pertaining to the second question. The EC decay data of ^{193}Pb suggested that this parent was a high-spin state, and the alpha decay of ^{197}Po to ^{193}Pb was observed but could not be directly utilized to obtain further information. The evaluator of A = 197 used systematics to determine that the observed EC decaying state was a 13/2+ isomer lying about 200 keV above an unobserved 3/2- ground state. Thus, two different data sets on ^{197}Po α-decay existed. Possible second-order difficulties, such as the effect of the conclusions on the mass adjustment, were pointed out.

MJM supported the use of trends, similar transitions, etc. to arrive at better numbers and conclusions while preparing mass chains for ENSDF. Other participants questioned the extent to which theoretical or systematic information should be included in the mass-chain file. A consensus was reached that nonexperimental numbers should at least be clearly flagged, indicating their origins for users of ENSDF. CWR emphasized that evaluators have a responsibility to ensure that numbers with qualifiers (SY, AP, etc.) do not lose the qualifiers in later computer searches.

NJW presented a summary of the activities and policies of the Liverpool evaluation group. The computer program DELTA, written by L.P. Ekström to analyze γ-γ angular correlation data, was offered to the evaluators. It was reported to be more versatile than the present ANGCOR program and to be capable of handling unobserved transitions and calculating uncertainties. MJM expressed concern that the use of different programs might lead to differing mixing ratios and confuse ENSDF users. RBF inquired about the possibility of distributing programs such as DELTA through Brookhaven.

NJW went on to describe the evaluation procedures in effect at Liverpool, which the group there would like the international network to adopt. In particular, discussion ensued over the handling of numbers whose uncertanties overlapped zero. For example, if an intensity balance yields a ground-state feeding of -2(5)% one normally quotes 0% with an asymmetric error. Alternate choices of <3%, or 0% (with a comment instead of an uncertainty) were proposed. As a result of comments by AHW and others who pointed out problems with all these possible forms, no satisfactory solution was found.

Other Liverpool policies included quoting only the lowest multipolarity when $\delta = 0$, reporting A_2 and A_4 values for decay only, writing the target J^π on all reaction data sets, and including both L and J^π for all observed levels. MJM preferred that only J^π be recorded since L is redundant. NJW further recommended that, outside the HSICC limit ($Z < 30$), ICC values should only be given, in adopted data sets, where the multipolarity and δ are known. Additionally, the Liverpool group includes transition probabilities (in Weisskopf units) whenever lifetimes, intensities, and δ are known. Finally, it was proposed that adopted gamma and level properties not be fed back into the original data sets unless necessary for completeness. Due to the late hour at this point, relatively little discussion of the Liverpool procedures ensued, and CWR adjourned the session.

Session II: 7:30 P.M., Wednesday, October 28, 1981

Discussion Leader: Stanley Whetstone, DOE

Topic: Evaluation and the Scientific Community

The following questions concerning the importance of ENSDF/NDS were addressed:

1) How effectively does ENSDF/NDS serve the needs of the scientific community?

2) What responsibility do evaluators have for critical evaluation of the literature?

3) What are the prospects for horizontal evaluations from ENSDF?

SLW began the discussion by reaffirming the support and commitment of DOE to the evaluation of nuclear data. The policy of providing for data evaluation by highly trained personnel at several centers while centralizing the production at Brookhaven is satisfactory. The current production rate, however, falls far short of the planned four-year cycle and is of considerable concern to DOE.

In regard to the first question, SLW referred to the importance of the NDN connection with IAEA. Education of the public to the availability of ENSDF as a searchable database has been limited. MJM pointed out that attempts to do so through an APS invited talk have so far been turned down. He added that brochures and questonnaires sent out by the Nuclear Data Project have led to minimal use of the files, indicating that the public is generally unaware of the NDP services. A suggestion of commercial handling of the searches from ENSDF was not favored by most of the participants.

RBF responded to the second question, stating that highly qualified evaluators would be valuable referees of journal articles. Also, evaluators can often assess experimental results better than individual authors and would make positive contributions to the literature by publishing their conclusions. CML suggested that the role of the Nuclear Data Sheets is to publish correct results and interpretations, but RBF argued that more is required. RBF would prefer that evaluators publish journal articles, piecing together various sources of data, to provide new, errorless conclusions. This is especially important since many authors fail to publish errata when major errors are discovered.

Only limited discussion of the third question followed. MJM stated that, despite many requests for information from ENSDF, few horizontal compilations directly resulted. CWR inquired if any attempt is made to coordinate ENSDF requests on the same subject. MJM said this is difficult in light of author competition, etc. and is thus not done. MJM reaffirmed his opinion that ENSDF is the best starting point available for many horizontal compilation efforts. RLB asked if horizontal evaluations are an approved function of network members. MJM replied that the approval of the data center director and the relevance of the evaluation to other evaluators must be considered to answer this question.

The subject of whether or not ENSDF is an acceptable basis for theoretical calculations and horizontal evaluations was discussed. CWR emphasized that ENSDF is a source of evaluated, not experimental, data and is hence tainted by evaluator judgement. Also, ENSDF is incomplete, especially in an historical sense, with many missing references. RBF added that complete coverage of the older references is available at LBL and could be incorporated into NSR and ENSDF were funding available.

CML discussed major retrieval problems with ENSDF due to numerous reasons, including multiple field designations (i.e., the S field on L-cards) and lost data on comment cards. CML added that the expertise needed to evaluate specialized horizontal compilations is not always available when ENSDF is prepared. Thus, retrieved data may not be consistently suitable to scientists in specialized fields.

SLW asked MJM to comment on his role as editor. MJM stressed the need for uniformity in evaluating mass chains for ENSDF and Nuclear Data Sheets. For example, B(E2) values appear the same on the printed data sheets whether entered on 2 L cards or as comments, but they are not retrievable from comment cards. The need for a new, expanded evaluators' manual was discussed. It was emphasized that the uniformity problem would be reduced if evaluators knew exacty how to handle data entries. RBF requested that a write-up of the networks' editorial and review policies also be prepared.

SLW requested that TWB comment on the production phase of the data sheets. TWB reported that the July 1 changeover from Oak Ridge to Brookhaven went smoothly, that some mass chains are in process, that the current publication rate suggests a seven-year cycle, and that many production improvements are underway to reduce required handwork. TWB added that checking programs are being improved and expanded and will be provided to the data centers as soon as possible.

Prior to adjourning the session, SLW reaffirmed the concern he senses about the frequent quoting of unpublished data in the data sheets. The session was then adjourned.

Session III: 10:00 A.M., Thursday, October 29, 1981

Discussion Leader: Richard Firestone, LBL

The discussion was open to all topics of interest.

CWR opened the discussion with the example of a dilemma encountered while evaluating A = 158. It became apparent that some of the authors' proposed octupole rotational bands and their associated spin assignments were incorrect. The evaluator's role in such situations was questioned. CWR chose to include the authors' proposals in the data sheets and state his disagreements in further comments. MJM suggested that, in such cases, the evaluator ignore the authors' text and reach his own conclusions. CML stressed the importance of extreme care in such instances. A consensus was reached that evaluators should not necessarily propagate authors' opinions, yet they should be aware of and deal with them.

MJM suggested that the evaluator use his judgement in the theoretical analysis or interpretation of data, but only minimal discussion should be included in the data sheets. RBF disagreed, stressing the importance of theory and suggesting that complete evaluations be stored in ENSDF. The published data sheets could be somewhat abbreviated. MJM added that existing mass chain evaluations vary widely in completeness. Also, theory is more useful for regional mass-chain comparisons. JMD emphasized the need for standard policies as to what and how much should be included in ENSDF. MJM agreed that minimum standards should exist, with evaluators free to do more if they wish. CWR added that it is useful for evaluators to do more, but "then A-chains don't get done."

A discussion followed on the need to document obvious author errors, including typographical ones. It was agreed that this documentation is useful to prevent NDS readers from erroneously assuming that changed numbers might be evaluator errors.

RBF suggested that evaluators publish papers in the literature highlighting interesting points in their mass chains. MJM felt this was research and not a network effort, although it would reflect favorably on the network. CWR added that journals might not be receptive to evaluation papers, but that an extended comments section could be added to the data sheets. MJM suggested that the data sheet abstracts could be expanded, although this could create layout problems. RLB offered the proposal that comments pertinent to a given isotope be included with the adopted levels set.

RBF asked how deficiencies and errors in ENSDF are corrected. MJM answered that errata data sets are entered in ENSDF and published in the data sheets. He added that revised values are added to ENSDF. MJM cited an example in which a decay energy was revised, and the resulting changes in logft values, etc. were published as errata and corrected in ENSDF. JMD stressed that these problems required careful followthrough and would not arise if calculated numbers (logft, ICC, etc.) were not in ENSDF. MJM disagreed, arguing that evaluators modify these calculated numbers in important ways. CML reaffirmed the argument of JMD.

JMD asked about the status of physics checking programs. TWB responded that the programs compare the levels of all data sets and parents, check γ-ray fits, compare transition intensities exciting and deexciting each level, and analyze the logic of spin assignments and logft magnitudes. JMD and RBF questioned the effectiveness of the latter two checks in light of many unreasonable values published recently in the data sheets. JMD asked if the data centers could have access to the checking programs. TWB responded that they are not yet suitable for distribution but may be so later. He added that coincidence checks are being added to the program. RBF described his SPIN program, which the Berkeley Isotopes Project finds effective for physics checking. The group concluded that Brookhaven should facilitate the distribution of programs to the data centers and provide revised versions as necessary.

MJM brought up the subject of inertial parameters and how they should be quoted. He mentioned that evaluators do not uniformly handle these parameters. Numerous unresolved problems were brought out, including choosing the number of levels to fit and number of parameters to use, putting uncertainties on the parameters, the importance of these parameters (and their uncertainties), and the necessity for evaluator judgement. RBF suggested that guidelines should be provided to aid evaluators in handling the parameters in a consistent manner.

Additional discussion points were tabled for future meetings as time ran out. RBF thanked all those in attendance for their contributions to a successful conference and put out the call for another data center to convene a second conference at some later date. RBF then adjourned the session and the conference.

ABSTRACTS OF EVALUATION PAPERS

PRESENTED AT THE ASILOMAR APS/DNP MEETING

AD 15 Systematics of spin-parity of odd-odd actinide nuclides.* L. K. PEKER and J. K. TULI, Brookhaven National Lab. Decay schemes of odd-odd actinide nuclides were analyzed. The spins and parities of beta decaying ground and isomeric states were deduced mostly from beta decay data (log ft) to the levels of g.s. bands or the 2-particle levels of e-e nuclei. We propose to take into account the data for beta transitions (log ft) to the measured particle-hole component of the octupole vibrational states I=1-, K=0, etc. In many cases this leads to substantial changes in the earlier accepted configurations, and therefore, the spins and parities of odd-odd actinide nuclides.

*Research carried out under the auspices of the United States Department of Energy under Contract No. EY-76-C-02-0016.

BD 1 Radioactivity Handbook. J. M. DAIRIKI, Lawrence Berkeley Laboratory.* On behalf of the U.S. Nuclear Data Network (NDN), the Isotopes Project at LBL will produce a handbook for applied users of nuclear data. The purpose of the Radioactivity Handbook is to provide a compilation of recommended decay data that is detailed enough for use in sophisticated applications but that is organized clearly for straightforward use in routine applications. The Handbook, as currently defined, will be produced at 4-year intervals beginning in 1983. Data will be taken primarily from the international Evaluated Nuclear Structure Data File (ENSDF). The proposed format and contents will be discussed.

*This work was supported by the Director, Office of Energy Research, Division of Nuclear Sciences of the Basic Energy Sciences Program of the U.S. Department of Energy under Contract W-7405-ENG-48.

CD 1 Nuclear Structure Data Base and Related Services.* J. K. TULI, Brookhaven National Lab. Data base for evaluated nuclear structure information will be discussed. Various kinds of retrievals and other nuclear structure related data services provided by National Nuclear Data Center will be described.

*Research carried out under the auspices of the United States Department of Energy under Contract No. EY-76-C-02-0016.

DD 14 Are Logft Values Reliable Guides for Spin and Parity Assignments? R. B. FIRESTONE, Lawrence Berkeley Lab.* Spin and parity assignments in Nuclear Data Sheets are often adopted partially on the basis of associated logft values. From the study of ^{145}Gd decay[1] and elsewhere it is apparent that in some decay schemes missing weak γ rays can cumulately negate the usefulness of existing logft spin/parity assignment rules. Such uncertainties generally require that experimental logft values be considered as lower limits. An upper limit for the logft must be reliably determined before spin/parity assignments can be inferred. Preliminary results of a new review of the logft systematics and proposed new spin/parity assignment rules for using logft values will be discussed.

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*This work was supported by the Director, Office of Energy Research, Division of Nuclear Sciences of the Basic Energy Sciences Program of the U.S. Department of Energy under Contract W-7405-ENG-48.

[1]R. B. Firestone, R. C. Pardo, R. A. Warner, W. C. McHarris, and W. H. Kelly, LBL-12424 and submitted to Physical Review C.

DD 15 Systematic Survey of γ-ray Transition Multipolarities. R. B. FIRESTONE and E. BROWNE, Lawrence Berkeley Lab.* The multipolarities of γ rays evaluated in Nuclear Data Sheets are inferred partially on the basis of their transition probabilities calculated in Weisskopf units. We are reevaluating the systematics of these transition probabilities using the γ rays of known half-life and multipolarity that were compiled in the Table of Isotopes.[1] Only transitions with directly measured multipolarities are being utilized. A progress report on the systematics of the higher multipolarity γ-ray transitions will be presented.

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*This work was supported by the Director, Office of Energy Research, Division of Nuclear Sciences of the Basic Energy Sciences Program of the U.S. Department of Energy under Contract W-7405-ENG-48.

[1]Table of Isotopes, 7th Edition: C. M. Lederer and V. S. Shirley, editors, John Wiley and Sons, Inc., New York (1978).

EE 31 Data Evaluation in the U.K. and Use of the ENSDF Database. N. J. WARD, University of Liverpool. Since the inauguration of the international network for NSDE, the evaluation of nuclear structure data has become progressively more rigorous with the procedures and physics policies followed by evaluators becoming much more extensive and uniform. However, there is still some dissimilarity of presentation in mass-chain compilations and it is not always clear whether inconsistencies are merely those of style or the result of considered opinion. It is desirable from the point of view of present and future users of ENSDF that unnecessary variations be eliminated. In order to achieve further agreement and improvement, we would like to draw attention to some of these differences. A summary of current procedures followed by the U.K. group at Liverpool, in the light of experience gained in evaluating the mass region A = 65 - 76, will be presented.

CONTRIBUTED PAPERS ON

NUCLEAR STRUCTURE DATA EVALUATION

Systematic Survey of γ-Ray Multipolarities

E. Browne and R. B. Firestone
Lawrence Berkeley Laboratory
University of California
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1. Introduction

Among the several methods known for determining γ-ray multipolarities, the comparison of experimental transition rates with those predicted by nuclear models[1] (e.g., the shell model) has been one of limited use for two reasons. First, although the electromagnetic operators for γ-ray transitions are well known, the nuclear wave functions are not. This precludes the determination of γ-ray multipolarities by the direct comparison of theoretical and experimental transition rates. Second, only very general rules for assigning multipolarities on the basis of systematic trends in transition rates exist. These rules have been expressed by Endt[2,3] in terms of "Recommended Upper Limits" (RUL)[4] in Weisskopf units for the deviation between experimental and theoretical values for transitions with a given multipolarity. In this preliminary report we shall describe a new systematic survey of γ-ray transition rates and suggest additional criteria for assigning multipolarities.

2. Experimental Data Survey

Data from the seventh edition of the Table of Isotopes[5], stored as a computer database[6], were utilized. All γ rays with measured half-lives and multipolarities, which have been observed in radioactive decay, have been considered. Additional data from Endt[2,3] et al. for A = 6 to 90 have been utilized since the multipolarity information contained in our file is not complete for the γ rays observed in nuclear reactions. We have limited this survey to the Weisskopf hindrance factors (Fw) for M2, M3, M4, E3, E4, and E5 isomeric transitions.

3. Interpretation of Data and Recommended Criteria for Assigning Multipolarities

The Weisskopf hindrance factors for M4 transitions are displayed as a function of N and Z in Figure 1. Because of the spherical symmetry of the shell-model potential used in the hindrance factor calculations, one expects the theory to reproduce the experimental rates for single-particle transitions best in spherical nuclei, i.e., at or near closed shells. Single-particle transitions in nuclei far from closed shells (deformed nuclei) should have larger Weisskopf hindrance factors. The smooth systematics of Fw values for different regions of N and Z can then determine the lower permissible limits of the hindrance factors used when assigning γ-ray multipolarities. This is seen in Figure 1, where the lowest values of Fw correspond to nuclei with Z = 50 and N = 50 or 82. These criteria provide a more fruitful method for using experimental transition rates to determine γ-ray multipolarities.

A specific example of the utility of systematic Fw values is shown in Figure 2, for the Weisskopf hindrance factors of $p_{1/2} \rightarrow g_{9/2}$ transitions in odd-proton nuclei. The lowest values are again observed for transitions

Fig.1. M4 WEISSKOPF HINDRANCES. CLOSED SHELLS ARE INDICATED BY ***.

N \ Z	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
39	1.1	.72																
40																		
41																		
42																		
43																		
44																		
45																		
46																		
47									.11	.08								
48											.37							
49								.09		.09		.09		.11				
50	*	*	*	*	*	*	*	*	*	*	.26	*	.06	*	.04	*	*	*
51											.65							
52											.62		.08		.06		.04	
53																		
54													.12		.08			
55																		
56													.19		.11		.46	
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81																		
82																	*	*

N \ Z	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
39				*														
40				*														
41				*														
42				*														
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61	24			*														
62			.11	*														
63	55			*														
64			.12	*														
65				*														
66			.12	*														
67				.21														
68			.07	*														
69				.17		.30												
70			.10	*														
71				*		.28												
72			.10	*														
73				*		.30												
74				*														
75				*		.28		.58										
76				*														
77				*		.24		.37		.62								
78				*														
79				*		.24		.32	.48	.41		.45		.45		.43		
80				*					60									
81				*		.21		.31		.37		.44						.54
82	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

N \ Z	73	74	75	76	77	78	79	80	81	82	83	84
107				1.4						*		
108										*		
109	5.0		8.4							*		
110										*		
111										*		
112										*		
113					.69			.63		*		
114										*		
115						.91		.65	.30	.34		
116					.49		.27			*		
117						.75	.23	.51	.57	.34		.45
118							>.3			*	>200	
119						.67	.34	.49		.33		.52
120										*		
121										.3,A		
122										*		
123										.29		
124										*		
125										.32		
126	*	*	*	*	*	*	*	*	*	*	*	*

OTHER VALUES A-.8

Figure 1.

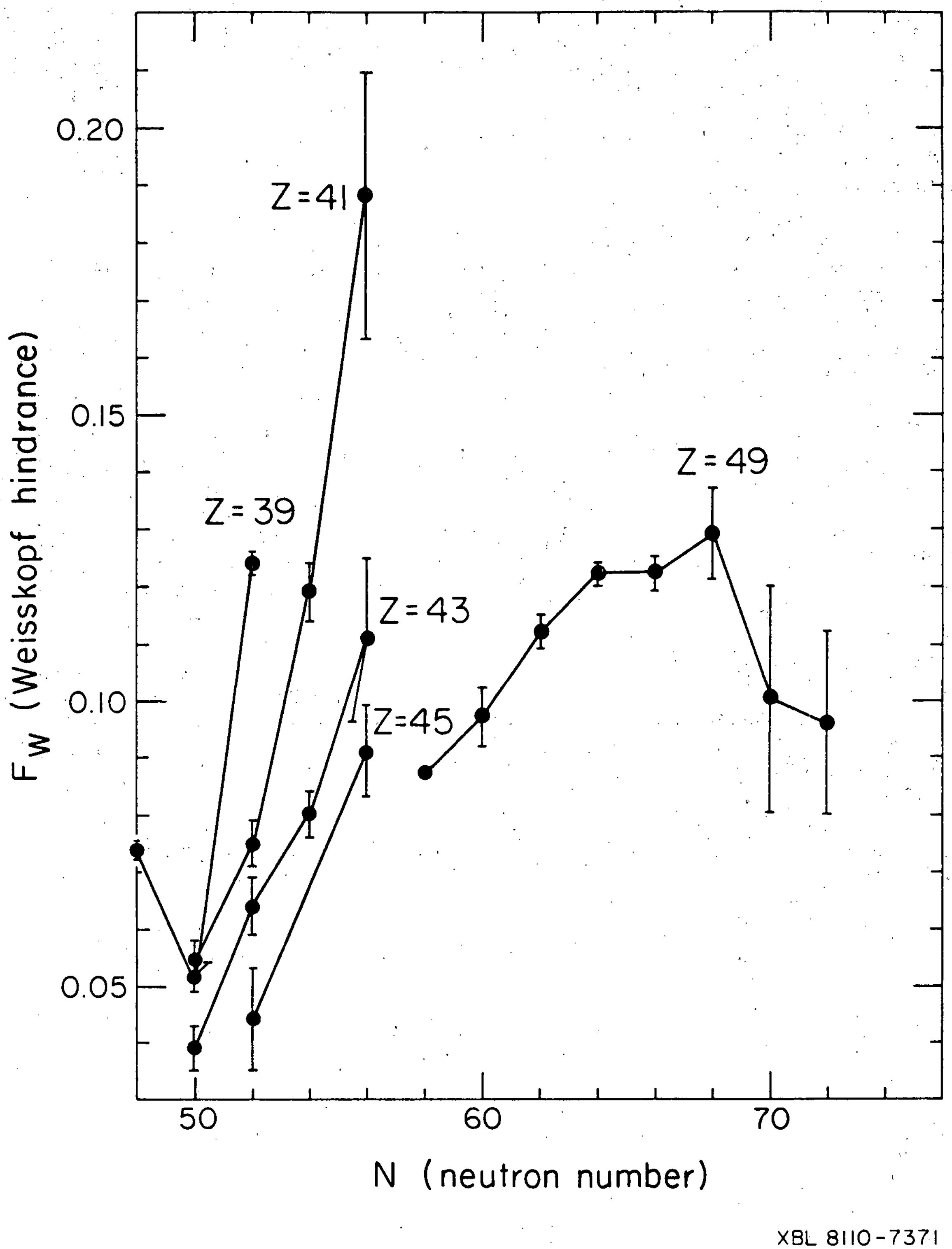

Figure 2. $g_{9/2} \rightarrow p_{1/2}$ M4 Weisskopf hindrances.

at or near the closed shell N = 50. The systematic trend is so smooth that transitions with values deviating from these systematics should be considered suspect. An example of this is the 315-keV M4 transition in ^{117}In (Figure 3), where a hindrance factor of 0.079 ± 0.005 was determined using an adopted isomeric branching of 43% from Baedecker et al.[7], which was apparently based on their relative γ-ray intensities. Other measurements of the isomeric branching were 47.1 ± 1.5% by Tang et al.[8] and 28 ± 3% by Wolfe and Hummel[9], but calculations leading to these values could not be verified because the relevant γ-ray intensities were not reported.

To determine the IT branching ratio from ^{117m}In, it is necessary to measure the relative intensities of the 158.6-, 315.3-, and 552.9-keV γ rays. The intensity of the 158.6- keV γ ray should be corrected for the contribution from ^{117}In decay (Figure 3). If the measurement is performed with a source containing ^{117}In and ^{117m}In in transient equilibrium, that correction should include a 64% reduction in the 158.6- keV γ-ray intensity due to the difference in the ^{117m}In and ^{117}In half-lives. Also, at transient equilibrium the intensity ratio $\gamma_{553}/\gamma_{315}$ should be 3.9. This ratio was reported to be 1.2 in reference 7, indicating that the measurement was not performed at equilibrium.

The earlier value of the IT branching ratio given by Wolfe and Hummel[9], although in disagreement with the most recent values of Baedecker et al.[7] and Tang et al.[8], yields a value of 0.12 ± 0.01 for the hindrance factor, which is consistent with the systematics (Figure 2).

A set of γ-ray intensities measured by Heath[10] provided us with the necessary tools to solve the dilemma. There the intensity ratio $\gamma_{553}/\gamma_{315}$ is 4.1 ± 0.2, indicating that the measurement was performed at transient equilibrium. Our analysis of Heath's γ-ray data resulted in an isomeric branching ratio of 26.5 ± 1.5% which yields a hindrance factor of 0.129 ± 0.008. These new values for the IT branching ratio and the corresponding hindrance factor confirm the results of Wolfe and Hummel[9] and the utility of systematics for the critical evaluation of nuclear data.

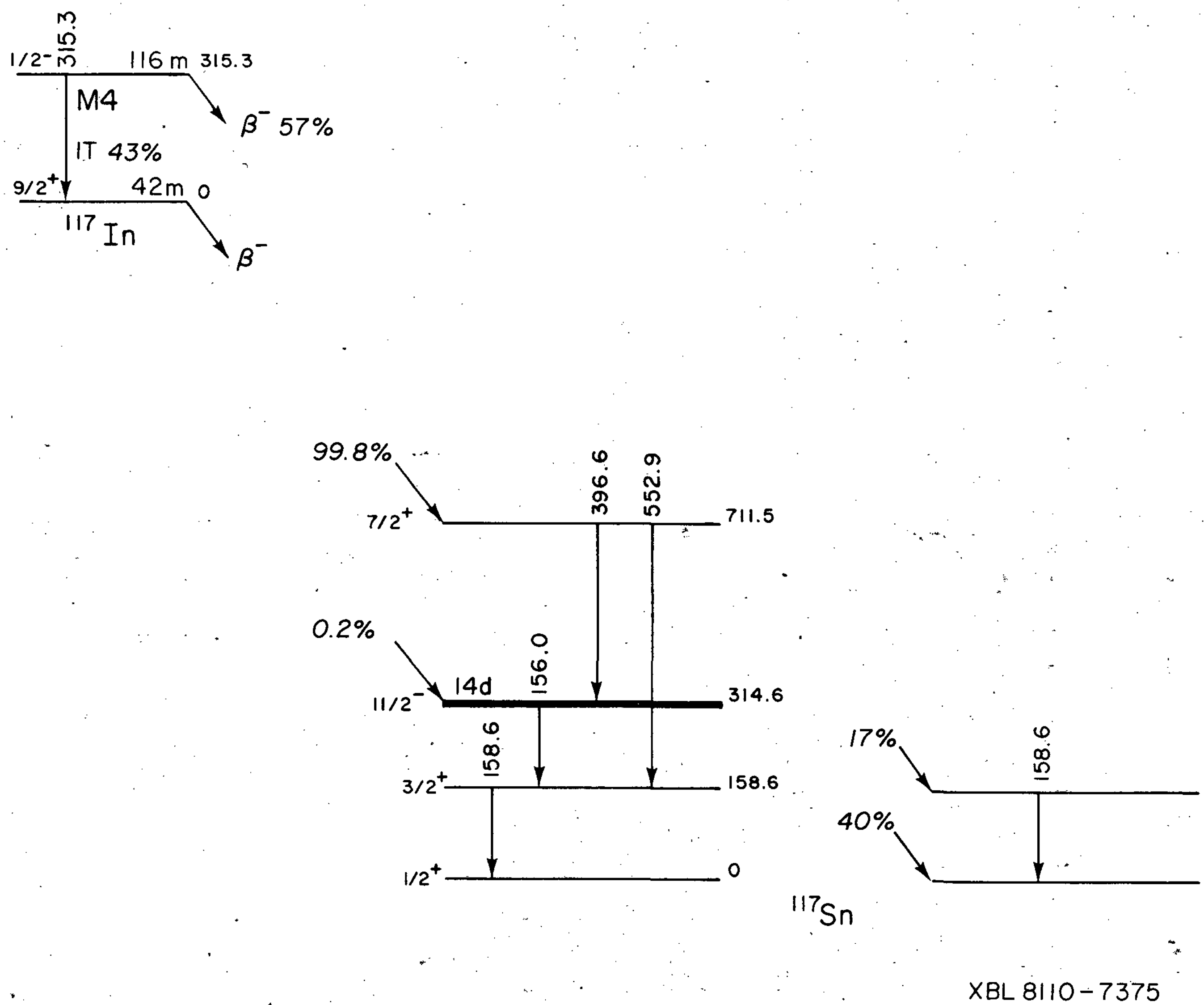

Figure 3. Decay schemes for ^{117}In and ^{117m}In.

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Radioactivity Handbook

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A *Radioactivity Handbook* for applied users is one of the planned publications of the U.S. Nuclear Data Network. On behalf of the NDN, the Isotopes Project at LBL will produce the *Handbook* with specifications agreeable to members of the international network of nuclear structure and decay data centers. We are requesting comments and suggestions from our colleagues on the contents and format proposed below.

The purpose of the *Handbook* is to provide a compilation of recommended decay data, based on the ENSDF file, that is detailed enough for use in sophisticated applications, but that is organized clearly so as to be usable in routine applications. The *Handbook* is not intended as a nuclear structure reference, but it should be useful to someone studying decay schemes. Its contents are based largely on responses to recent surveys of applied users.[1]

The *Handbook* will be produced at four year intervals, beginning in 1983. Data will be taken from the current version of ENSDF, with no further updating. Additional calculations and evaluation will be done to provide recommended data on atomic radiations and conversion electrons, and to provide "best" values for γ-ray properties, independent of the decay parent, in cases where ENSDF does not. Each mass chain will be referenced to the most recent evaluation in the *Nuclear Data Sheets*, as the source for further details and references to the original papers.

The *Handbook* will be ordered by mass number (A) and subordered by atomic number (Z). Each mass chain will consist of:

a) A "skeleton" mass-chain diagram showing the ground states and long-lived isomers with their half-lives, energies (for isomers), spin-parity assignments, decay modes, Q-values, and the decay relationships between the isotopes. Alpha parents and particle-decay daughters pertinent to the A-chain will also be shown.

b) Tabulated data for each isotope or isomer:

natural isotopic abundance
mass excess
thermal neutron cross sections (σ_c, σ_f); $\sigma(n,\alpha)$, $\sigma(n,p)$, and σ_{abs} will be given in a few cases.
half-life
decay mode, genetic branching (the fraction of the decay populating each of several isomers in daughter nuclei)
means of production
energies and intensities of all radiations
- α particles
- β^- and β^+ particles
- γ rays
- conversion electrons
- x-rays
- Auger electrons
- $\gamma^{\pm}$

protons
"delayed" p, n, α, fission
average e^- (β^-+ce+Auger), e^+ (β^++pair), photon (γ+x-ray)

c) A decay scheme for each parent isotope, giving the adopted daughter level energies and spin-parity assignments, β and α feeding intensities (and log ft, HF(α) factors), and γ-ray energies and intensities.

A proposed format is shown in figure 1. Figure 2 shows a fragment of another mass chain to illustrate the format for reporting genetic branching.

The main table will be supplemented by an energy-ordered γ-ray table, with the format illustrated in figure 3, and by appendices containing physical constants, spectroscopy standards, atomic binding energies, K x-ray energies and relative intensities, and radiation absorption curves.

Further characteristics, details, and conventions are described in the following comments:

1. Size: The size of the book, as defined here, will be about 1500 pages of size 21.6 by 27.9 cm. Several major components account for most of the bulk. Rough estimates for their contribution to the size of the book, based on 1977 data, are:

skeleton schemes	100 pages
α- and β-group listings	100 pages
photon and electron listings	500 pages
detailed schemes	500 pages
energy-ordered γ-ray table	100 pages*

The addition of adopted levels (E, Jπ, $t_{1/2}$ in the form of a ladder diagram) would require an extra 400 pages.

2. Uncertainties: Uncertainties will be given in the tables whenever they are available in ENSDF or another source used (see below). Q-values on the skeleton scheme will be given with uncertainty. Other data on the skeleton and detailed schemes will be given without uncertainty, rounded so that the uncertainty in the last place is ≦5 units.

3. Isotopes: All ground states, as well as isomers with a half-life ≳1 s, plus a few "historic" isomers of shorter half-life (e.g., ^{24m}Na) will be included. Unstable nuclides identified in nuclear reactions, for which no decay properties have been measured, will be omitted.

4. γ-ray intensities: Absolute photon intensities will be quoted, both in the tabular listings and on the decay schemes. When the uncertainty in the normalization is significant compared to the uncertainties in the relative intensities (the usual case), the stated uncertainties will include only the relative error; the uncertainty in the normalization will be noted separately (see figure 1). When the normalization is unknown, relative intensities will be listed with a comment.

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* This number is very approximate; it depends on what kind of intensity cutoff (if any) is applied.

5. Atomic radiations and conversion electrons: Figure 1 illustrates how these will be presented. Conversion-electron intensities will be calculated from the γ-ray intensities and the assigned multipolarities (or multipolarities deducible from the spin assignments), with the use of theoretical internal conversion coefficients. X-ray and Auger intensities will be calculated from the atomic shell vacancies produced by internal conversion and electron capture. Annihilation radiation will be calculated from the β^+ and internal pair conversion intensities.

   Some guidelines to limit the inclusion of weak transitions are being formulated, using those developed by M.J. Martin[2] as a starting point.

6. Other data sources: The following data will be derived from sources other than ENSDF:

mass excesses, Q-values	A.H. Wapstra and K. Bos, Atomic Data and Nucl. Data Tables 19 175(1977), or a more recent update.
abundances, neutron cross sections	Compilations by N.E. Holden
means of production	7th ed. of the *Table of Isotopes*, or more recent source, if available. (It would be desirable to list E_{max} and $\sigma(E_{max})$ for charged particle reactions if a suitable compilation were available.)

References

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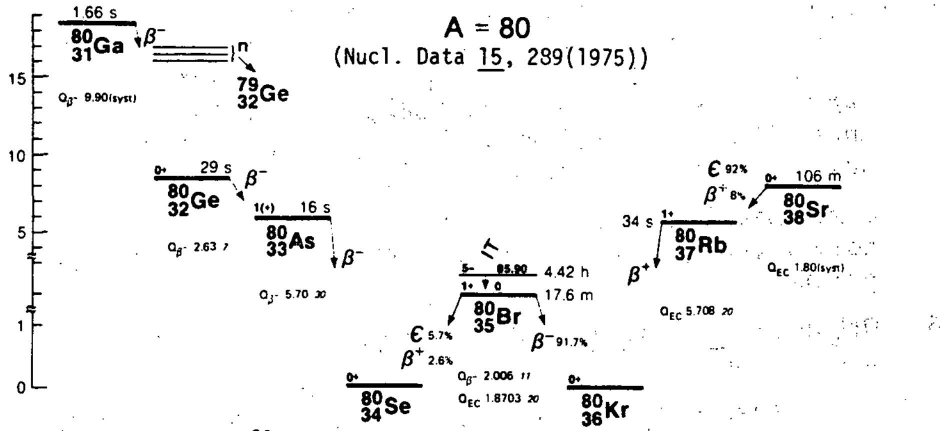
2) *Nuclear Decay Data for Selected Radionuclides*, M.J. Martin, ed., ORNL-5114 (1976); *Nuclear Decay Data for Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities*, D.C. Kocher, ORNL/NUREG/TM-102(1977).

Figure I

A = 80

(Nucl. Data 15, 289(1975))



$^{80}_{31}$Ga

$t_{1/2}$: 1.66 2 s
Decay: β⁻, β⁻n
Δ: -59.53(syst)
Prod: fission

$^{80}_{32}$Ge

$t_{1/2}$: 29 s
Decay: β⁻
Δ: -69.43 31
Prod: fission

γ:

Energy (keV)	Intensity[a] (%)
110.4 4	6.0 3
265.6 4	25
782.3 4?	≈0.8
937.2 4	4.0 4
1014.0 4	2.5 5
1116.0 4	2.6 4
1256.1 4	3.1 4
1564.3 4	4.5 4

a) Quoted uncertainties refer to relative intensities; 40% additional uncertainty applicable to absolute intensities.

Average energies:
$\langle E_{\gamma+x} \rangle$: 280 116

$^{80}_{33}$As

$t_{1/2}$: 16 s
Decay: β⁻
Δ: -72.06 30
Prod: ^{80}Se(n,p), fission

β⁻:

Energy (keV)	Intensity (%)
1970 300	0.1
2090 300	0.2
2680 300	1.0
2860 300	0.2
2930 300	0.3
3180 300	1.2
3390 300	7.1
3740 300	1.3
3830 300	4.2
4220 300	0.5
4250 300	0.9
5030 300	27
5700 300	56

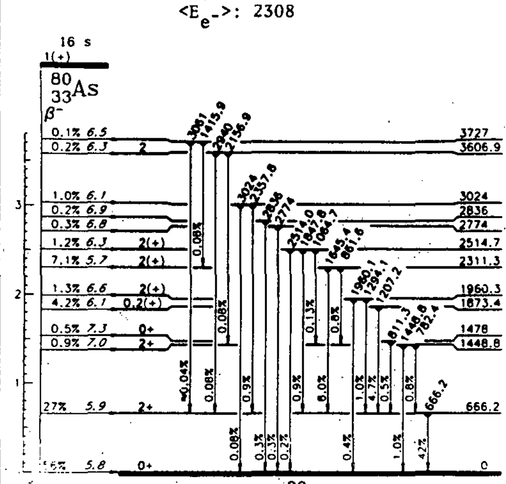
γ:

Energy (keV)	Intensity[a] (%)
321.2 5?	5.5 1[b]
666.2 2	42
782.4 5	0.80 17
908.7 5?	0.71 13[b]
811.3 5	0.46 17
861.6 4	0.76 8
1064.7 5	0.13 4
1207.2 2	4.7 4
1294.1 4	1.0 1
1415.9 5	0.08 4
1422.7 5?	0.04 4[b]
1448.8 5	1.0 1
1633.3 5?	1.2 2[b]
1645.4 2	8.0 4
1847.8 5	0.9 2
1960.1 5	0.38 8
1968.8 5?	0.13 8[b]
2156.9 5	0.08 4
2357.8 5	0.9 2
2461.3 5?	0.2 1[b]
2514.0 5	0.17 8
2598.1 5?	0.13 8[b]
2774.2 10	0.3 1
2836.2 10	0.25 8
2940.3 10	0.08 4
3024 2	0.08 4
3060.8 20	0.04 4

$^{80}_{33}$As (Continued)

a) Quoted uncertainties refer to relative intensities.
b) If isotopic assignment is correct; γ ray could alternatively be assigned to ^{82}As.

Average energies:
$\langle E_{\gamma+x} \rangle$: 643
$\langle E_{e^-} \rangle$: 2308



$^{80}_{34}$Se

%: 49.8
Δ: -77.7613 35
σ: 0.61 6 b (to ^{81}Se)
0.07 2 b (to ^{81m}Se)

Figure I (continued)

$^{80}_{35}Br$

$t_{1/2}$: 17.6 m
Decay: β^- 91.7%, ε 5.7 *3*%, β^+ 2.6 *2*%
Δ: -75.8910 *36*
Prod: $^{79}Br(n,\gamma)$, daughter ^{80m}Br, $^{79}Br(d,p)$

β^-:

Energy (keV)	Intensity (%)
686 *11*	0.19 *2*
750 *11*	0.31 *3*
1390 *11*	6.2 *6*
2006 *11*	84.9 *7*

β^+:

Energy (keV)	Intensity (%)
848.3 *20*	2.6 *2*

γ:

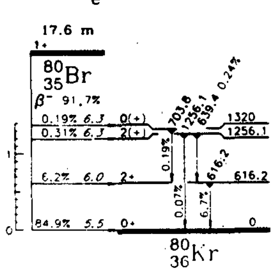
Energy (keV)	Intensity[a] (%)	Decay mode
616.2 *5*	6.7	β^-
639.4 *2*	0.24 *2*	β^-
666.2 *2*	1.1 *2*	$\varepsilon+\beta^+$
677.0 *10*?	0.008 *2*	
687.4 *10*?	0.012 *3*	
703.8 *2*	0.19 *3*	β^-
782.4 *5*?	≤0.013	$\varepsilon+\beta^+$
811.3 *5*	0.033 *7*	$\varepsilon+\beta^+$
1256.1 *4*	0.067 *7*	β^-
1338.5 *8*	0.020 *7*	β^-
1448.8 *5*?	≤0.016	$\varepsilon+\beta^+$

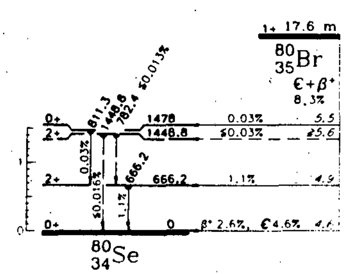
a) Quoted uncertainties refer to relative intensities; 9% additional uncertainty applicable to absolute intensities.

Other radiations:

Radiation	Energy (keV)	Intensity (%)
Se Auger-L	1.32	7.0 *7*
Se Auger-K	9.67	2.2 *2*
Se LX	1.38	∿0.1
Se $K_{\alpha_2}X$	11.18140 *2*	0.9 *1*
Se $K_{\alpha_1}X$	11.22240 *2*	1.8 *3*
Se $K_\beta X$	12.5	0.4 *1*
$\gamma^\pm$		5.2 *4*

Average energies:
$\langle E_{\gamma+x}\rangle$: 80 *25*
$\langle E_{e^-}\rangle$: 718 *7*
$\langle E_{e^+}\rangle$: 368 *28*





$^{80m}_{35}Br$

$t_{1/2}$: 4.42 *1* h
Decay: IT
Δ: -75.8051 *36*
Prod: $^{79}Br(n,\gamma)$

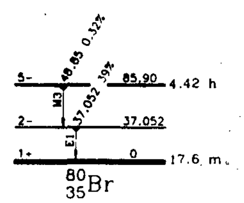
γ:

Energy (keV)	Intensity (%)
37.052 *2*	39.1 *8*
48.85 *3*	0.324 *6*

Other radiations:

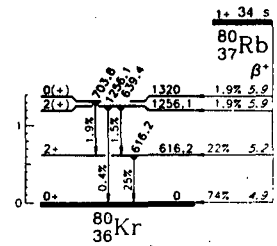
Radiation	Energy (keV)	Intensity (%)
Br Auger-L	1.4	176 *35*
Br Auger-K	10.2	48 *5*
K-37	23.578	54.0 *15*
L-37	35.270	6.1 *2*
K-49	35.38	72.6 *26*
M-37	36.795	0.95 *3*
L-49	47.07	22.4 *8*
M-49	48.59	3.8 *2*
Br LX	1.48	1.6 *4*
Br $K_{\alpha_2}X$	11.87760 *2*	23.0 *20*
Br $K_{\alpha_1}X$	11.92420 *2*	45 *4*
Br $K_\beta X$	13.3	11.0 *14*

Average energies:
$\langle E_{\gamma+x}\rangle$: 24 *1*
$\langle E_{e^-}\rangle$: 62 *1*



$^{80}_{36}Kr$

%: 2.27 (atmospheric sources; variations reported for meteoritic sources.)
Δ: -77.897 *11*
σ: 11.5 *6* b (to ^{81}Kr)
4.6 *7* b (to ^{81m}Kr)



$^{80}_{37}Rb$

$t_{1/2}$: 34 *4* s
Decay: β^+
Δ: -72.190 *23*
Prod: daughter ^{80}Sr, $^{71}Ga(^{12}C,3n)$

β^+:

Energy (keV)	Intensity (%)
3366 *20*	1.9 *3*
3430 *20*	1.9 *3*
4070 *20*	22 *3*
4686 *20*	74 *3*

γ:

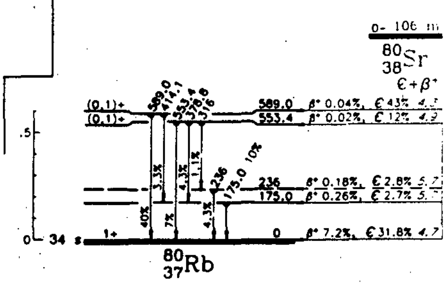
Energy (keV)	Intensity[a] (%)
616.2 *5*	25
639.4 *2*	1.5 *2*
703.8 *2*	1.9 *2*
1256.1 *4*	0.42 *6*

a) Quoted uncertainties refer to relative intensities; 12% additional uncertainty applicable to absolute intensities.

Other radiations:

Radiation	Energy (keV)	Intensity (%)
$\gamma^\pm$		200

Average energies:
$\langle E_{\gamma+x}\rangle$: 1204 *188*
$\langle E_{e^+}\rangle$: 2072 *14*



$^{80}_{38}Sr$

$t_{1/2}$: 106.3 *15* m
Decay: ε 92%, β^+ 8%
Δ: -70.39(syst)
Prod: ^{14}N on Ga, $^{65}Cu(^{20}Ne,5n)^{80}Y(\varepsilon+\beta^+)$

(Continued)

Figure I (continued)

$^{80}_{38}$Sr (Continued)

β^+:

Energy[a] (keV)	Intensity (%)
189	0.04
225	0.02
542	0.18
603	0.26
778	7.2

a) Based on systematic decay energy.

γ:

Energy (keV)	Intensity[a] (%)
175.0 *5*	10.4 *10*
235.9 *8*	4.3 *4*
316.0 *15*	1.1 *1*
378.8 *5*	4.3 *4*
414.1 *5*	3.3 *3*
553.4 *5*	7.0 *7*
589.0 *5*	40

a) Quoted uncertainties refer to relative intensities; 20% additional uncertainty applicable to absolute intensities.

Other radiations:

Radiation	Energy (keV)	Intensity (%)
Rb Auger-L	1.68	100 *3*
Rb Auger-K	11.4	27 *1*
Rb LX	1.69	1.0 *3*
Rb K_{α_2}X	13.33580 *2*	15.7 *6*
Rb K_{α_1}X	13.39530 *2*	30.4 *10*
Rb K_βX	15	7.9 *5*
$\gamma^\pm$		16

Average energies:
$\langle E_{\gamma+x} \rangle$: 425 *94*
$\langle E_{e^+} \rangle$: 198

Figure 2

Illustration of proposed handling of genetic decay branchings

$^{133}_{53}$I

$t_{1/2}$: 20.9 *1* h
$\star$: β^- (97.12% to ^{133}Xe; 2.88 *2*% to ^{133m}Xe)
Δ: -85.902 *31*
Prod: fission

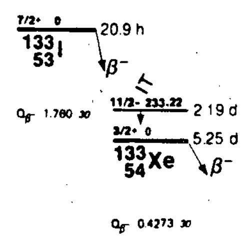


Figure 3

E_γ(keV)	I(%)	Isotope	$t_{1/2}$	
230.37 *5*	27	^{226}Ac[L]	29 h	
	0.12	^{230}U	20.8 d	
609.3 *1*	0.12	^{218}Rn(^{230}U)	20.8 d	
616.4 *5*	7	^{80}Br	17.6 m	n
	25	^{80}Rb(^{80}Sr)	106 m	
661.661 *3*	85	^{137m}Ba(^{137}Cs)	30.17 y	fn

Sample format for the energy-ordered gamma-ray table. (The gamma rays illustrated in the sample were chosen only to illustrate features of the layout.) Several listings under the same energy refer to the same transition (i.e., in the same daughter nucleus) excited by different radioactive parents. An isotope in parentheses following another is a longer-lived parent or ancestor with which the listed gamma ray is more commonly observed; the half-life given is that of the parent. A footnote "L" on the isotope indicates that a longer-lived ancestor exists, but is not the more common source of the gamma ray. An "n" following the half-life column denotes a nucleus produced by neutron capture on natural substances; an "f" denotes a fission product.

Results of the Radioactivity Handbook Survey

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A Radioactivity Handbook for applied users is one of the planned publications of the U.S. Nuclear Data Network. On behalf of the NDN, the Isotopes Project at LBL will produce the Handbook with specifications agreeable to members of the international network of nuclear structure and decay data centers. The purpose of the Handbook is to provide a compilation of recommended decay data, based on the Evaluated Nuclear Structure Data File (ENSDF), that is detailed enough for use in sophisticated applications, but that is organized clearly so as to be readily usable in routine applications.

Samples illustrating the proposed contents and format of the Radioactivity Handbook have been distributed, along with a survey requesting specific comments and feedback, to members of several professional societies. Approximately 5000 surveys were distributed; 806 completed surveys have been returned from:

American Physical Society (APS): Division of Nuclear Physics	303	(38%)
American Chemical Society (ACS): Division of Nuclear Chemistry and Technology	120	(15%)
Recipients of the National Nuclear Data Center (NNDC) Newsletter	116	(14%)
American Nuclear Society (ANS):		
Radiation and Protection Shielding Division (RPSD)	127	(16%)
Isotopes and Radiation Division (IRD)	92	(11%)
International Committee for Radionuclide Metrology (ICRM)	20	(2.5%)
ASTM/E-10 Committee	9	(1.1%)
American Association of Physicists in Medicine (AAPM)	3	(0.4%)
Health Physics Society (HPS)	1	(0.1%)
Others	15	(1.9%)

There is some cross-linking of membership that is not included in the above numbers. Many scientists belong to more than one professional society; in particular, most of the recipients of the NNDC newsletter are also members of at least one other society.

Figure 1 shows the actual survey, as well as the responses (in % of total replies) to each question. Question I provides some general data on the respondent's type of work and his/her need for nuclear data. Question II defines the specific data that he/she uses. Question III is an attempt to determine if there is a consensus about the optimum size of such a handbook. The responses of each society to these survey questions are given in Table I.

A very broad range of occupations and applications of data was evidenced in the replies. A strong cross-linkage between different applications and professions was also evident. As another way of viewing the responses, we have attempted a rough quantitative breakdown of the results into the following fields of application:

Basic:	basic nuclear physics research, nuclear theory, teaching	345	(43%)
Chem:	activation analysis, isotope production, tracer studies, chemical applications	158	(20%)
React:	reactor design, reactor safety, fuel rod and shielding design, radioactive waste problems, nuclear engineering	131	(16%)
Med:	medical diagnostics, radiotherapy, radiopharmaceutical production	59	(7%)
HP:	health physics, radiation dosimetry, radiation protection	37	(5%)
Envir:	environmental studies and monitoring	35	(4%)
Other:	weapons design, safeguards programs, geoscience applications, astrophysics, atmospheric physics, cosmology	41	(5%)

Table II summarizes the responses of each group to most of the questions on the survey.

Final conclusions have not yet been drawn from these results. However, there are some interesting observations. There is a clear mandate to include decay schemes in the Handbook. There were a few comments expressing great satisfaction that absolute photon intensities will be given. Clearly (question II. d) only basic researchers consider spins and parities to be important. However, the inclusion of these quantities on the level schemes will require no additional space and will be useful to a large body of researchers. On the other hand, let us consider isotope production methods which were considered important by slightly more than half of those surveyed. The medical professions, in particular, were very enthusiastic in their response. What they want, however, is a complete entry with reactions, production cross sections, yields, and original references. There is a need for collecting all this data in one place in a usable fashion since no such compilation currently exists. Certainly none of this data is contained in ENSDF. It would, therefore, require major compilation effort and is probably outside the scope of the Handbook production schedule. Perhaps isotope production would be an appropriate subject for an independent horizontal compilation.

Other types of data requested include charged particle cross sections (9 responses), fission yields (15), shielding factors (6), nuclear moments (13), neutron energies (14), spontaneous fission properties (9), dosimetry data (7), level half-lives (6), adopted levels and their properties (6), and conversion coefficients (6). Three to five requests were obtained for each of the following: detailed x-ray data including fluorescence yields, photon absorption coefficients, particle binding energies, resonance integrals, the total energy associated with each decay mode, γ-ray multipolarities and mixing ratios, and range-energy curves and tables.

There are two ways to view the results of question III concerning the Handbook size. On the one hand, there is a three-way split between 1) including all the data in one volume, 2) dividing it into 2 volumes on the basis of tabular data and decay schemes, and 3) producing two volumes with a convenient A-chain division. On the other hand, the results can be interpreted as a greater than 2 to 1 preference for a two-volume publication. Some of those scientists who favored publication in one volume also suggested the publication of an additional compact handbook for field use. Another suggestion (6 responses) was to reduce the size by omitting the energy-ordered γ-ray table. Since Atomic Data and Nuclear Data Tables plan to publish the energy-ordered γ-ray catalog of U. Reus and co-workers in 1981, omission of such a table in the Handbook seems justified and would reduce the final size by at least 100 pages. There were a few comments to the effect that 1500 pages were not considered too cumbersome but future editions of the Handbook should not be allowed to grow in size. Half of those who wanted a very compact book (option 3) would achieve it by eliminating decay schemes. The other half would include complete radiation data on the decay schemes and eliminate the gamma and electron listings.

As a final comment, the answers to question IV would indicate that we have a ready audience.

Figure 1

RADIOACTIVITY HANDBOOK SURVEY

Please take a few minutes to let us know your reaction to the contents and format proposed for the Radioactivity Handbook.

I. a) NAME: Total responses 806 (Optional)

OCCUPATION: Foreign responses 95 (12%)

Professional society from which you received this Handbook survey: ____________

b) Do you use or encounter radioisotopes, nuclear reactors, or charged-particle accelerators, or deal with nuclear properties in your work?

81% radioisotopes — 50% reactors
54% accelerators — 73% nuclear properties

c) For what purpose? (Type of application, e.g.: tracers in chemical studies, medical diagnostics, reactor design, etc.)

II. The following data categories are proposed for inclusion in the Handbook. Please indicate the types of data important to you.

95% a) half-lives of radioactive substances

84% b) natural isotopic abundances

66% c) nuclear masses

46% d) nuclear spins and parities

69% e) neutron and fission cross sections

93% f) nuclear decay modes and genetic (parent-daughter) relationships

55% g) isotope production methods

98% h) energies and intensities of radiations:

97% gamma rays
74% x-rays
75% α particles
38% Auger electrons
38% protons
82% β- and β+ particles
____ other radiations (specify)

53% conversion electrons
46% "delayed" p,n,α, and fission data
38% average e⁻ energy (β^-+ce+Auger)
34% average e+ energy (β+ + pair)
41% average photon energy (γ+x-ray)

85% i) decay scheme for each parent isotope ____j) other types of data (specify)

III. The Handbook, as defined in the attached material, will be ~1500 pages and will include all the above data categories under one cover. There is some concern about the resulting size of such a complete volume. The question then arises as to possible trade-offs between the size of the Handbook and the scope of the data included - portability vs completeness. It can be seen in the Handbook descriptive material that two types of data account for ~2/3 of the bulk - photon and electron listings (500 pages) and decay schemes (500 pages). Any compromise aimed at significantly reducing the size of the Handbook must involve some manipulation and/or sacrifice of at least one of these data categories. Please indicate your feelings about any compromise by checking one of the following three statements.

26% 1) Completeness of the data in a single volume is the most important consideration.

69% 2) Completeness of the data is more important but there should be some compromise with portability. The Handbook should contain all the above data catagories but it should be published as two (or more) smaller volumes. Possible ways to do this are suggested below. Please indicate your preference.

31% a) All tabular data could be contained in one volume (~1000 pages) and decay schemes in a second volume.

34% b) Mass-chain data could be divided into two or more volumes. For example, all data for masses A=1-130 could be published in one volume and all data for A>130 in a second volume.

0.6% c) other (specify)

2.7% 3) Portability is a more important factor than completeness of the data. What data are you willing to give up in order to obtain a more compact book?

1.1% 4) Either 1) or 2)

1% 5) No preference

IV. What is the likelihood that you will use the Handbook defined in the attached material?

75% definitely	4% possibly	____ definitely not
19% probably	0.7% not likely	0.9% no response

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TABLE I

SURVEY QUESTION		SOCIETY								
		APS	ACS	NNDC	ANS-RPSD	ANS-IRD	ASTM	HPS + AAPM	OTHERS	TOTAL
I.	a) total responses	303	120	116	127	92	9	4	35	806
	foreign responses	30	6	24	3	5			27	95
		Responses (in %)								
	b) radioisotopes	80	93	72	71	92	100	100	94	81
	accelerators	73	51	62	31	29	---	75	40	54
	reactors	30	63	58	76	57	89	---	43	50
	nuclear properties	82	67	75	65	59	56	75	83	73
II.	a) half-lives	92	98	97	95	97	100	100	100	95
	b) abundances	82	83	95	80	82	100	75	80	84
	c) masses	75	65	78	49	57	78	50	51	66
	d) spins/parities	71	38	56	10	12	---	25	51	46
	e) neutron cross sections	58	75	83	73	75	100	75	60	69
	f) decay modes	93	93	97	93	86	100	100	94	93
	g) production methods	47	59	47	66	70	67	100	63	55
	h) radiations	97	98	98	99	97	100	100	97	98
	gamma rays	96	98	96	99	96	100	100	97	97
	x-rays	70	80	70	76	76	100	100	83	74
	α particles	77	78	76	73	65	100	50	83	75
	Auger electrons	35	38	41	35	42	56	75	46	38
	protons	45	33	40	35	33	22	25	31	38
	$\beta^{\pm}$ particles	78	87	76	84	86	100	100	83	82
	conversion electrons	57	60	49	44	45	56	50	66	53
	delayed particles	44	48	52	50	43	33	25	43	46
	ave e^- energy	31	39	37	44	50	67	75	29	38
	ave e^+ energy	29	35	35	42	43	56	50	23	34
	ave photon energy	34	33	41	54	60	44	75	29	41

TABLE I, Continued

SURVEY QUESTION	SOCIETY								
	APS	ACS	NNDC	ANS-RPSD	ANS-IRD	ASTM	HPS + AAPM	OTHERS	TOTAL
i) decay schemes	87	85	87	76	85	78	75	91	85
III. 1) one volume	24	32	28	28	25	--	25	23	26
2) two volumes	72	65	68	64	68	100	75	69	69
a) division by data category	29	40	21	30	39	33	25	20	31
b) division by A chain	38	23	42	28	27	56	--	49	34
IV. Usage									
definitely	79	78	80	61	67	100	75	83	75
probably	16	17	17	32	24		25	14	19
possibly	3	3	2	6	7				4

TABLE II

SURVEY QUESTION		FIELD OF APPLICATION							
		Basic	Chem	React	Med	HP	Envir	Other	Total
I.	a) total responses	345	158	131	59	37	35	41	806
	foreign responses	60	17	11	1	4	2		95
		Responses (in %) for each profession							
	b) radioisotopes	79	96	57	93	84	94	88	81
	accelerators	79	35	19	75	41	20	46	54
	reactors	36	59	88	41	51	49	37	50
	nuclear properties	87	60	66	54	59	66	76	73
II.	a) half-lives	93	97	98	97	86	100	95	95
	b) abundances	83	89	79	80	81	91	88	84
	c) masses	83	59	59	58	38	29	51	66
	d) spins/parities	84	19	15	15	8	9	29	46
	e) neutron cross sections	61	74	83	61	70	63	85	69
	f) decay modes	92	91	94	97	92	94	93	93
	g) production methods	49	61	56	86	68	51	39	55
	h) radiations	97	98	98	98	100	97	95	98
	gamma rays	96	97	98	97	100	97	93	97
	x-rays	71	82	66	92	84	71	66	74
	α particles	81	70	71	69	89	83	54	75
	Auger electrons	41	30	28	66	62	31	17	38
	protons	49	23	33	46	46	20	27	38
	$\beta^{\pm}$ particles	80	82	79	93	95	86	66	82
	conversion electrons	64	45	40	66	62	34	29	53
	delayed particles	50	37	62	34	41	23	51	46
	ave e^- energy	30	38	43	61	65	37	27	38
	ave e^+ energy	28	30	39	61	65	31	27	34
	ave photon energy	30	35	56	64	76	40	46	41
	i) decay schemes	87	84	79	92	84	74	83	85
III.	1) one volume	26	25	21	36	35	31	19	26
	2) two volumes	70	70	73	59	62	57	71	69
	a) division by data category	25	37	34	32	27	37	37	31
	b) division by A chain	41	30	35	22	30	14	24	34
IV. Usage									
	definitely	79	77	67	81	70	60	76	75
	probably	18	15	27	10	24	34	24	19
	possibly	2	5	6	7		6		4

Program Delta

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The program determines permissible values of spins and multipole mixing ratios from gamma-gamma angular correlation data. Other data, e.g., conversion coefficient data, can easily be included to resolve inherent ambiguities. The sign convention for multipole mixing ratios is that of Krane and Steffen.

The gamma-gamma cascade studied is

```
                         unobserved
        gamma(1)         transitions        gamma(2)
J(1)   ------->   J(2) --> ...   J(N-1)   ------->   J(N)
```

where gamma(i) is of mixed multipoles L(i) and L(i)+1 with mixing ratio delta(i).

Treatment of data

The program recognises three different types of experimental data:

1) A(2) and A(4) coefficients for angular correlations.

2) delta(1) and delta(2) values (from other experiments).

3) Conversion coefficients for gamma(1) and gamma(2). When using conversion coefficients one should remember that the theoretical values are known only to maybe 5% accuracy, so errors smaller than this value should not be used.

The program calculates the sum of the squared residuals S, and searches the parameter space for acceptable values of S.

Other features of the program

1) For input description, limitations and input/output examples (TEST1 for ANGCOR is used), see appendices.

2) Since correlation coefficients are calculated by the program there are no other restrictions on spins and multipolarities than those imposed by storing factorials of large numbers.

3) A plot of S/(degrees of freedom) as a function of delta is produced.

4) The programming language is IBM 370 FORTRAN IV (G1).

Advantages compared with ANGCOR presently used by the network

i) Since other data than correlation data are used this usually results in fewer allowed spin/delta combinations.

ii) Errors in mixing ratios are calculated. A word of caution however: If the A(2) and A(4) coefficients are correlated the error in delta may be unrealistic. The correct procedure would be to use the individual angular correlation data points in the fitting procedure. These data points are, however, rarely available.

iii) The program can handle cases with unobserved transitions.

iv) The output is easy to interpret: one directly obtains a value of one delta irrespective of the other delta.

Comments to ANGCOR output (appendix 3)

i) There are too many solutions of (delta1, delta2) in the results table; some of the solutions are really the same.

ii) One gets the impression from the delta1-delta2 map that there are at least three solutions for delta2 if delta1 = 0. This is incorrect, since A(2) in this case is a quadratic function of delta2 (A(4) is zero for all delta2), and there can thus be at the most two solutions - namely delta2 = 0.23 and 11.4.

iii) In order to get an adopted value of delta from the ANGCOR output one has to project the map onto the appropriate axis taking into account all other restrictions on deltas. This is a rather difficult process, which is taken care of in one step by the program DELTA.

Appendix 1. Input description.

```
PROGAM DELTA
VERSION MARCH 1981, L.P. EKSTROM, LUND.
ANALYSES ANGULAR CORRELATION AND CONVERSION COEFFICIENT DATA,
AND CALCULATES THE BEST VALUES OF MIXING RATIOS. THE SIGN
CONVENTION IS THAT OF KRANE AND STEFFEN, PHYS.REV. C2(1970)724.

THE GAMMA-GAMMA CASCADE STUDIED IS:

          ---------- J(1)
                I
                I  DELTA(1)     (TRANSITION NUMBER 1)
                I
                V
          ---------- J(2)
                I                     .
                I  DU(1)              .
                I                     .
                V                     .
          ---------- J(3)             .
                                      . UNOBSERVED TRANSITIONS
          ---------- J(NLEV-2)        .
                I                     .
                I  DU(NLEV-3)         .
                I                     .
                V                     .
          ---------- J(NLEV-1)
                I
                I  DELTA(2)     (TRANSITION NUMBER 2)
                I
                V
          ---------- J(NLEV)

DELTA(1) AND DELTA(2) CAN BE VARIED. THE MIXING RATIOS OF
THE UNOBSERVED TRANSITIONS (MAXIMUM 3) ARE FIXED.
POSSIBLE DATA ITEMS ARE:
 1) A(2) AND A(4) FOR GAMMA-GAMMA CORRELATION.
 2) DELTA VALUES FROM OTHER INDEPENDENT MEASUREMENTS (ATAN(DELTA)
    IS USED INTERNALLY).
 3) CONVERSION COEFFICIENT DATA.
ALL DATA ITEMS ARE TREATED AS INDEPENDENT, AND ERRORS
AS STATISTICAL. NOTE THAT A MEASURED A(2) ONLY GIVES VERY LITTLE
INFORMATION IF BOTH MIXING RATIOS ARE UNKNOWN. A MEASURED INTERNAL
CONVERSION COEFFICIENT HELPS A LOT! NOTE THAT DELTA VALUES COULD
BE SUSPECT WHEN THE MINIMUM IS NOT APPROXIMATELY PARABOLIC.

LIMITATIONS:
 1) NO TRIPLE CORRELATIONS.
 2) SPINS UP TO 10 ARE ALLOWED.
 3) EFFECTS OF INTERNAL CONVERSION ON THE DEORIENTATION
    COEFFICIENTS FOR MIXED TRANSITIONS ARE NEGLECTED. SEE
    ANICIN ET AL, NUCL.INSTR. 103(1972)395 FOR THIS USUALLY
    VERY SMALL EFFECT.

*INPUT*
ALL CARDS HAVE THE FOLLOWING FORMAT:
 COL. 1-2   SYMBOL THAT DETERMINES TYPE OF CARD.
 COL. 3-72  FREE FORMAT REALS OR INTEGERS.
ONLY DATA AND GO CARDS ARE NECESSARY. ERROR=0 FOR DELTA MEANS
THAT DELTA IS KEPT FIXED. NEW DATA WITH SAME NAME AS EXISTING
DATA REPLACE THE LATTER.
```

```
OPTIONS
 CL -                                  CLEAR DATA
 DU -                                  DUMP COMMON BLOCKS
 EN -                                  END PROGRAM
 GO RJ1,RJ2,RJ3,ETC                    READ SPINS AND GO. RJ ARE REALS OR
                                        INTEGERS. (E.G. 5/2-=-2.5, 2+=2,
                                        0-=-0.1)
 HE ANY TEXT                           HEADER (70A1)
 LI A,B,C,D                            LIMITS ATAN(DELTA1) TO A TO B
                                        AND  ATAN(DELTA2) TO C TO D
 UN DU(1),DU(2),DU(3)                  UNOBSERVED TRANSITIONS, DELTAS.
                                        DEFAULTS=0.0

CORRELATION AND DELTA DATA
 A2 A2,DA2
 A4 A4,DA4
 D  NTR,DELTA,DDELTA                   NTR IS TRANSITION NUMBER.
                                        DEFAULTS: NONE,0,0

CONVERSION COEFFICIENT DATA (MAXIMUM 5 ITEMS)
 ** NTR,EXP,DEXP,L,H
  WHERE **    IS ANY UNIQUE COMBINATION OF SYMBOLS (E.G. CC)
        NTR   NUMBER OF TRANSITION (1 OR 2)
        EXP   EXPERIMENTAL VALUE
        DEXP  ERROR
        L     THEORETICAL VALUE FOR THE LOWER MULTIPOLE
        H     THEORETICAL VALUE FOR THE HIGHER MULTIPOLE

TIMING AND CORE REQUIREMENTS FOR IBM 370:
CORE <90K. TIME <7 SEC. FOR ONE SPIN SEQUENCE AND BOTH DELTAS
VARIED.
```

Input example

```
HE  ANGCOR EXAMPLE WITH CONVERSION COEFFICIENT DATA
A2 0.166 0.001
A4 0.000 0.001
CC 1 0.200 0.015 0.20 0.40
CC 2 0.39 0.03 0.20 0.40
GO 1.5 2.5 3.5
EN
```

Appendix 2. DELTA output (somewhat shortened).

```
 ANGCOR EXAMPLE WITH CONVERSION COEFFICIENT DATA
SPIN SEQUENCE      3/2+ --->  5/2+ --->  7/2+
KRANE-STEFFEN SIGN CONVENTION FOR MIXING RATIOS
+++++++ DATA +++++++
A2 =     0.166+-   0.001
A4 =     0.000+-   0.001
CC =    0.2000+-  0.0150 FOR TRANSITION 1. THEORETICAL VALUES=   0.2000 FOR M1 AND   0.4000 FOR E2
CC =    0.3900+-  0.0300 FOR TRANSITION 2. THEORETICAL VALUES=   0.2000 FOR M1 AND   0.4000 FOR E2
ATAN(D1) VARIED FROM -60.0 TO  60.0 IN STEPS OF 1.3 DEGREES
ATAN(D2) VARIED FROM -90.0 TO  90.0 IN STEPS OF 2.0 DEGREES
++++++++++++++++++++
```

STEPPING IN ATAN(DELTA1)

SQ.RES.	A2	A4	ATAN(D1)	ATAN(D2)	CC(1)	CC(2)
43.766	0.157	0.002	-27.5	-21.8	0.2426	0.2275
41.327	0.156	0.003	-26.2	-23.3	0.2390	0.2313
39.199	0.169	0.003	-24.9	-25.4	0.2355	0.2368
37.167	0.157	0.003	-23.6	-28.4	0.2321	0.2451
35.313	0.156	0.004	-22.3	-33.2	0.2289	0.2599
113.285	0.157	0.005	-21.0	-40.9	0.2257	0.2856
822.427	0.133	0.004	-19.7	-41.0	0.2227	0.2862
2316.130	0.118	0.004	-18.4	-41.1	0.2199	0.2863
4632.944	0.093	0.003	-17.1	-41.1	0.2173	0.2864
7805.466	0.075	0.003	-15.8	-41.1	0.2148	0.2864
11860.002	0.057	0.002	-14.5	-41.1	0.2125	0.2864
16816.250	0.036	0.002	-13.2	-41.1	0.2104	0.2865
22687.018	0.015	0.002	-11.9	-41.2	0.2085	0.2866
23990.563	0.011	0.002	-10.6	49.0	0.2068	0.3141
12813.246	0.053	0.001	-9.3	49.0	0.2052	0.3138
5104.439	0.095	0.001	-8.0	49.0	0.2039	0.3138
835.853	0.136	0.001	-6.7	49.0	0.2027	0.3139
1.833	0.156	0.001	-5.4	61.1	0.2018	0.3533
0.266	0.166	0.000	-4.1	72.6	0.2010	0.3625
0.097	0.166	0.000	-2.8	78.3	0.2005	0.3917
0.095	0.165	0.000	-1.5	82.0	0.2001	0.3961
0.096	0.156	0.000	-0.2	84.6	0.2000	0.3953
0.113	0.156	0.000	1.1	86.7	0.2001	0.3993
0.151	0.166	0.000	2.4	88.2	0.2004	0.3998
32.454	0.160	0.002	3.7	90.0	0.2008	0.4000
56.641	0.173	0.001	5.0	-90.0	0.2015	0.4000
1.133	0.166	0.001	6.3	-68.5	0.2024	0.3999
2.261	0.166	0.001	7.6	-87.8	0.2035	0.3997
4.123	0.166	0.002	8.9	-87.2	0.2048	0.3995
39.785	0.156	0.000	10.2	4.4	0.2063	0.2012
11.138	0.166	0.003	11.5	-66.1	0.2079	0.3991
16.898	0.166	0.004	12.8	-85.7	0.2098	0.3989
24.611	0.166	0.005	14.1	-85.3	0.2119	0.3987
40.792	0.156	0.000	15.4	2.8	0.2141	0.2005
41.163	0.166	0.000	16.7	2.5	0.2165	0.2004
41.607	0.166	0.000	18.0	2.3	0.2191	0.2003
42.135	0.166	0.000	19.3	2.0	0.2218	0.2003
42.759	0.166	0.000	20.6	1.8	0.2248	0.2002
43.491	0.156	0.000	21.9	1.7	0.2275	0.2002
44.344	0.166	0.000	23.2	1.5	0.2310	0.2001
45.328	0.156	0.000	24.5	1.4	0.2344	0.2001
46.456	0.166	0.000	25.8	1.3	0.2379	0.2001
47.737	0.166	0.000	27.1	1.2	0.2415	0.2001
49.182	0.156	0.000	28.4	1.1	0.2452	0.2001
50.801	0.166	0.000	29.7	1.0	0.2491	0.2001
52.603	0.166	0.000	31.0	0.9	0.2531	0.2001

DELTA(1) MINIMUM

SQ.RES.	A2	A4	ATAN(D1)	ATAN(D2)	CC(1)	CC(2)
0.095	0.166	0.000	-1.4	82.2	0.2001	0.3963

DELTA(1)= -0.025 + 0.068 - 0.061 SIGMA= 1.095

DELTA(1) MINIMUM

SQ.RES.	A2	A4	ATAN(D1)	ATAN(D2)	CC(1)	CC(2)
1.598	0.166	0.001	6.9	-88.2	0.2029	0.3998

DELTA(1)= 0.121 + 0.017 - 0.012 SIGMA= 2.598

DELTA(1) MINIMUM

SQ.RES.	A2	A4	ATAN(D1)	ATAN(D2)	CC(1)	CC(2)
12.858	0.166	0.004	11.9	-80.0	0.2085	0.3990

DELTA(1)= 0.211 + 0.023 - 0.018 SIGMA= 18.988

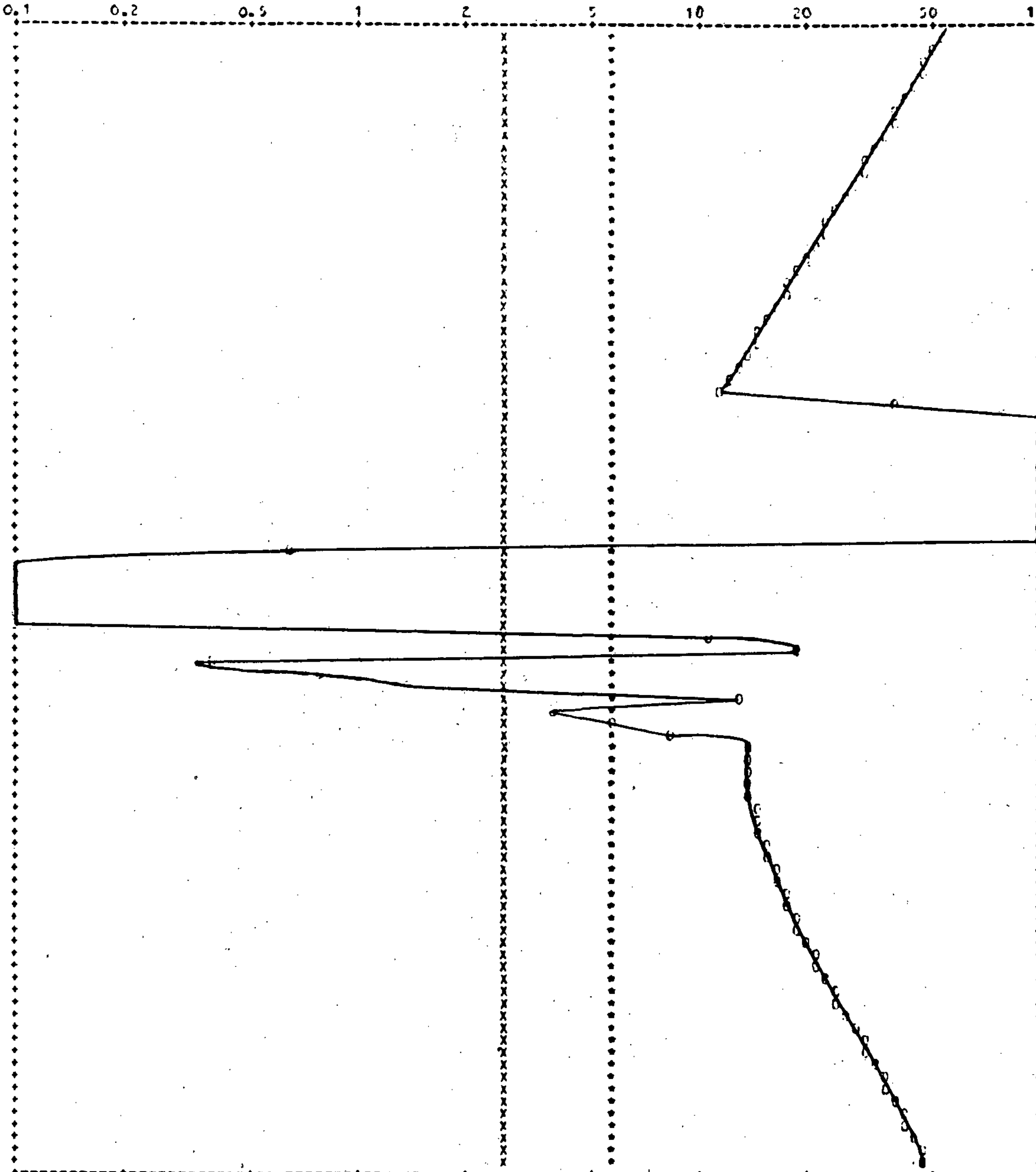
Appendix . (cont.)

ANGCOR SAMPLE WITH CONVERSION COEFFICIENT DATA

SPIN SEQUENCE 5/2+ ---> 5/2+ ---> 7/2+

KRANE-STEFFEN SIGN CONVENTION FOR MIXING RATIOS

ATAN(DELTA)	NSQRD
-60.000	50.20
-58.700	48.115
-57.400	46.6
-56.100	44.08
-54.800	42.795
-53.500	40.177
-52.200	38.306
-50.900	36.437
-49.600	34.72
-48.300	33.006
-47.000	31.345
-45.700	29.73
-44.400	28.139
-43.100	26.706
-41.800	25.347
-40.500	24.133
-39.200	22.985
-37.900	21.856
-36.600	20.711
-35.300	19.55
-34.000	18.528
-32.700	17.32
-31.400	16.865
-30.100	16.076
-28.800	15.299
-27.500	14.539
-26.200	13.776
-24.900	13.366
-23.600	12.396
-22.300	11.771
-21.000	37.702
-19.700	274.14
-18.400	77.343
-17.100	1544.315
-15.800	2601.32
-14.500	3953.334
-13.200	5605.417
-11.900	7362.339
-10.600	7996.554
-9.300	4271.082
-8.000	1701.48
-6.700	295.284
-5.400	0.611
-4.100	0.089
-2.800	0.032
-1.500	0.032
-0.200	0.032
1.100	0.038
2.400	0.350
3.700	10.813
5.000	16.880
6.300	0.373
7.600	0.754
8.900	1.374
10.200	13.262
11.500	3.713
12.800	5.633
14.100	8.204
15.400	13.597
16.700	13.721
18.000	13.869
19.300	14.045
20.600	14.253
21.900	14.497
23.200	14.731
24.500	15.109
25.800	15.435
27.100	15.912
28.400	16.394
29.700	16.934
31.000	17.534
32.300	18.197
33.600	18.925
34.900	19.71
36.200	20.579
37.500	21.507
38.800	22.50
40.100	23.568
41.400	24.70
42.700	25.898
44.000	27.161
45.300	28.489
46.600	29.875
47.900	31.319
49.200	32.816
50.500	34.361
51.800	35.951
53.100	37.579
54.400	39.239
55.700	40.927
57.000	42.636
58.300	44.35
59.600	46.09



DEGREES OF FREEDOM = 3
X = 5 PERCENT LIMIT = 7.6050
* = 0.1 PERCENT LIMIT = 5.4221

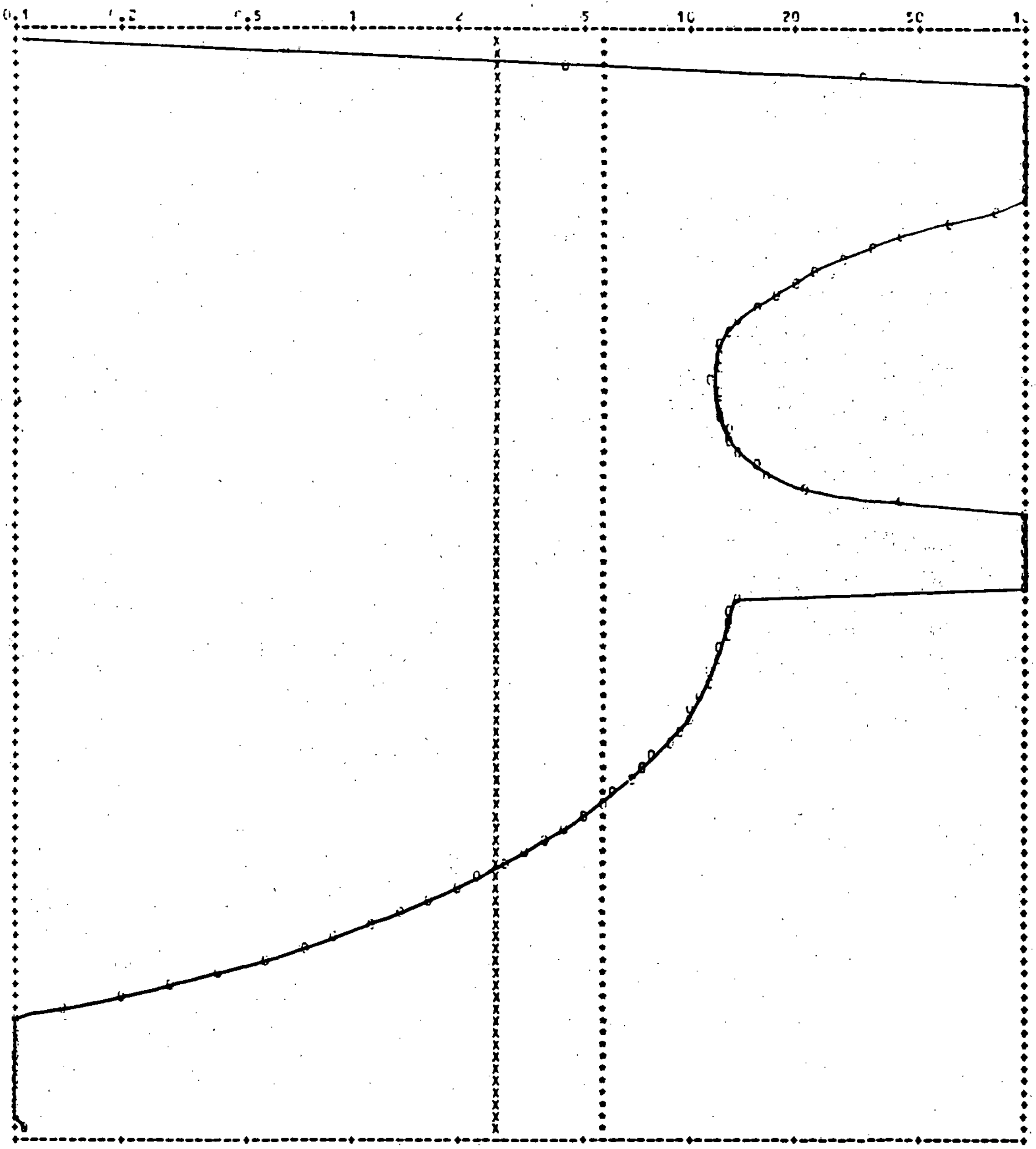
Appendix 2 (cont.)

ANGCOR EXAMPLE WITH CONVERSION COEFFICIENT DATA

SPIN SEQUENCE 3/2+ ---> 5/2+ ---> 7/2+

KRANE-STEFFEN SIGN CONVENTION FOR MIXING RATIOS

ATAN(DELTA2)	NSQRES
-90.000	0.110
-88.000	0.623
-86.000	4.126
-84.000	33.696
-82.000	430.839
-80.000	1262.963
-78.000	5789.636
-76.000	8450.719
-74.000	5609.795
-72.000	2524.234
-70.000	1058.350
-68.000	417.00[illegible]
-66.000	204.070
-64.000	120.971
-62.000	80.531
-60.000	57.795
-58.000	42.748
-56.000	34.473
-54.000	28.555
-52.000	23.437
-50.000	20.[illegible]73
-48.000	17.564
-46.000	15.683
-44.000	14.287
-42.000	13.272
-40.000	12.557
-38.000	12.088
-36.000	11.329
-34.000	11.747
-32.000	11.808
-30.000	11.998
-28.000	12.341
-26.000	12.804
-24.000	13.428
-22.000	14.285
-20.000	15.496
-18.000	17.464
-16.000	21.422
-14.000	41.146
-12.000	565.262
-10.000	2059.754
-8.000	4634.757
-6.000	8382.590
-4.000	5227.941
-2.000	1827.061
0.000	174.616
2.000	14.093
4.000	13.329
6.000	13.079
8.000	12.836
10.000	12.539
12.000	12.182
14.000	11.776
16.000	11.322
18.000	10.817
20.000	10.285
22.000	9.714
24.000	9.125
26.000	8.516
28.000	7.894
30.000	7.270
32.000	6.650
34.000	6.039
36.000	5.442
38.000	4.865
40.000	4.312
42.000	3.789
44.000	3.297
46.000	2.842
48.000	2.423
50.000	2.042
52.000	1.701
54.000	1.398
56.000	1.132
58.000	0.905
60.000	0.707
62.000	0.542
64.000	0.405
66.000	0.294
68.000	0.205
70.000	0.139
72.000	0.090
74.000	0.053
76.000	0.028
78.000	0.019
80.000	0.012
82.000	0.020
84.000	0.026
86.000	0.033
88.000	0.045
90.000	0.110



DEGREES OF FREEDOM = 3
X = 5 PERCENT LIMIT = 2.6050
* = 0.1 PERCENT LIMIT = 5.4221

+++++++ END OF ANALYSIS FOR THIS SPIN COMBINATION ++

------- PROGRAM END

Appendix 3. ANGCOR output (somewhat shortened).

PROGRAM A N G C O R VERSION 2(3) AS OF 25-JUN-81.

TEST1
KRANE-STEFFEN SIGN CONVENTION FOR DELTAS
ANGULAR CORRELATION STUDY FOR A=143
A2= 0.1660 +- 0.0010 A4= 0.0000 +- 0.0010
ERROR OF A2 USED ALSO FOR A4

RESTRICTIONS ON J SPINS UP TO 8 ARE CONSIDERED
JTOP..MUST BE 3/2,
JMID..MUST BE 5/2,
JBOT..MUST BE 7/2,

RESTRICTIONS ON DELTA
NO RESTRICTIONS

CASCADES THAT ARE CONSISTENT

CASCADE JTOP	JMID	JBOT	A2	CLOSEST VALUES A4	DELTA 1	DELTA 2	RANGE	CHI2
3/2	5/2	7/2	0.1660	0.0006	0.087	-99.955		0.39
3/2	5/2	7/2	0.1660	0.0000	0.072	0.143		0.00
3/2	5/2	7/2	0.1660	0.0000	0.006	0.217		0.00
3/2	5/2	7/2	0.1660	0.0000	-0.002	0.232		0.00
3/2	5/2	7/2	0.1660	0.0000	0.004	0.221		0.00
3/2	5/2	7/2	0.1660	0.0000	-0.016	0.259		0.00
3/2	5/2	7/2	0.1660	0.0000	-0.015	8.632		0.00
3/2	5/2	7/2	0.1660	0.0000	0.006	13.007		0.00
3/2	5/2	7/2	0.1660	0.0000	-0.000	11.429		0.00
3/2	5/2	7/2	0.1660	0.0000	0.006	13.509		0.00
3/2	5/2	7/2	0.1660	0.0000	0.016	16.018		0.00
3/2	5/2	7/2	0.1660	0.0001	0.034	25.327		0.01
3/2	5/2	7/2	0.1660	0.0002	0.047	40.545		0.03
3/2	5/2	7/2	0.1660	0.0001	1.479	0.041		0.01

CASES THAT FALL WITHIN TWICE THE ERRORS

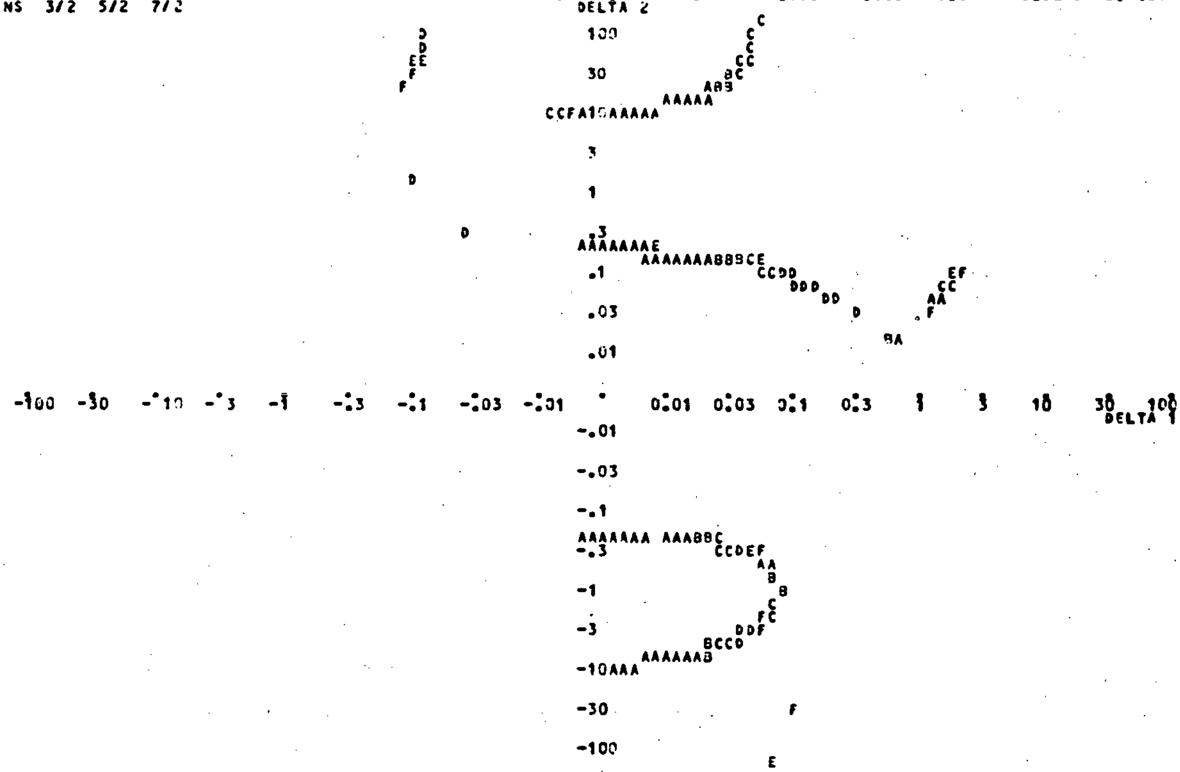
CASCADE JTOP	JMID	JBOT	A2	CLOSEST VALUES A4	DELTA 1	DELTA 2	CHI2

CASES THAT FALL OUTSIDE TWICE THE ERRORS

CASCADE JTOP	JMID	JBOT	A2	CLOSEST VALUES A4	DELTA 1	DELTA 2	CHI2
3/2	5/2	7/2	0.1660	0.0023	-0.760	-0.289	5.49
3/2	5/2	7/2	0.1653	0.0083	0.335	-10.064	69.14
3/2	5/2	7/2	0.1658	0.0026	-0.958	-0.264	6.71

MAP OF POSSIBLE MIXING RATIOS A2= 0.1660 +- 0.0010 A4= 0.0000 +- 0.0010
F'S 0.2742 -0.9487 -0.1909 0.1336 0.8944 0.3245 0.0829

SPINS 3/2 5/2 7/2



Radius Parameters for α-Decaying Even-Even Nuclei

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As part of our data evaluation activities, experimental α-decay rates are systematically examined and compared with theoretical rates for nuclei which undergo that particular mode of decay. The spin-independent formalism developed by Preston[1] is utilized for calculations of theoretical α-transition rates. In Preston's equations the nuclear potential, V, is taken to be simply a rectangular well; i.e., V is constant for distances (r) less than R and equal to $2Ze^2/r$ for $r > R$. The radius, R, and atomic number, Z, used in the calculations are those of the daughter nuclei; R and V are considered as parameters to be determined from α transitions that proceed between the ground states of even-even nuclei. These transitions are assumed to be unhindered, and their theoretical partial half-lives are taken to be identical to experimental values.

For odd-mass and odd-odd nuclei, R values are chosen from neighboring even-even nuclei and used together with experimental α-decay energies to calculate theoretical rates. Alpha-hindrance factors, defined as the ratios of experimental and theoretical partial half-lives, can be useful in helping one to make spin and parity assignments.

As in the case of other decay modes, α systematics can be used to estimate the undetermined decay properties of nuclei. One convenient way to study the systematics of α-decay rates is to examine the trends with both neutron and atomic numbers of the r_0 parameter, defined by $r_0 = R\,A^{-1/3}\,10^{13}$. When deduced r_0 parameters for even-even isotopes are plotted as a function of neutron number, the curves for each element vary rather smoothly in the regions between the closed neutron shells. It is therefore possible to obtain reasonably accurate r_0 parameters by extrapolation or interpolation. These extrapolated (or interpolated) values can be used to estimate α-decay branching ratios.

The r_0 parameters for even-even nuclei with $A \geq 178$ calculated from available data are listed in Table I. The parent nucleus, its half-life and α-decay branching, and the intensity and energy of the α transition to the daughter ground state are given in columns 1-5. These experimental values are taken from the Nuclear Data Sheets,[2] unless otherwise noted. The Table of Isotopes,[3] which is an excellent source for getting an overall picture on the behavior of nuclei throughout the periodic table, as well as for obtaining information concerning recent data, was also consulted. Nuclei either with estimated α branching ratios or with poorly determined decay energies and half-lives are not included in Table I. Transitions with intensities of $\geq$99.99 are given as $I_\alpha = 100$. Intensities in parentheses are assumed.

The information presented here has been updated through October 1981.

TABLE I

Parent	$T_{\frac{1}{2}}$	α branching (%)	I (α_0) per 100 α	E (α_0)	r_0 (daughter)
^{178}Pt	21.0 s 7	7.5[a] 3	97.3 11	5440[b] 3	1.573 7
^{182}Hg	11.3 s 5	15.2[a] 8	99.3[c]	5867[c] 5	1.519 7
^{184}Hg	30.6 s 3	1.11[a] 6	99.6 29	5535 15	1.508 12
^{186}Os	2.0 x 10^{15}[d] y 11	100	(100)	2756[e] 3	1.49 4
^{186}Hg	1.42 m 10	0.016 5	(100)	5094 15	1.50 3
^{188}Pt	10.2 d 3	2.5 x 10^{-5}[fc] 5	100	3910[fc] 10	1.475 20
^{188}Hg	3.25 m 15	3.7 x 10^{-5}[c] 8	(100)	4610[c] 20	1.48 3
^{188}Pb	22[g] s 2	22[g] 7	100	5980[g] 5	1.541 25
^{190}Pt	6 x 10^{11} y 1	100	100	3175[e] 20	1.48 3
^{190}Pb	1.2[h] m 1	0.9[h] 2	100	5577[h] 5	1.530 18
^{192}Pb	3.5[i] m 1	5.7 x 10^{-3}[i] 10	100	5112[i] 5	1.499 13
^{198}Po	1.76 m 3	63[j] 2	(100)	6183[b] 3	1.501 4
^{200}Po	11.5 m 1	14 3	(100)	5863 2	1.490 13
^{202}Po	44.7 m 5	2.0 2	(100)	5588 2	1.474 6
^{204}Po	3.53 h 3	0.66 1	(100)	5377 1	1.4619 16
^{204}Rn	75 s 2	68 4	(100)	6417 3	1.500 5
^{206}Po	8.8 d 1	5.45 5	(100)	5223.4 15	1.4548 18
^{206}Rn	5.67 m 17	68 3	100	6260[b] 3	1.495 5
^{208}Po	2.898 y 2	99.9982 2	100	5116 2	1.4293 12
^{208}Rn	24.35 m 13	52 6	99.953[k] 4	6139[k] 3	1.468 7

TABLE I. Continued

Parent	$T_{\frac{1}{2}}$	α branching (%)	I (α_0) per 100 α	E (α_0)	r_0 (daughter)
^{210}Pb	22.3 y 2	2.0 x 10^{-6} 6	100	3720 20	1.45 4
^{210}Po	138.378 d 7	100	100	5304.38[b] 7	1.4089 1
^{210}Rn	2.5 h 1	96 1	100	6040[b] 3	1.456 4
^{212}Po	0.298 μs 3	100	(100)	8784.15[b] 7	1.5217 6
^{212}Rn	24 m 2	100	99.950 5	6264 3	1.435 5
^{214}Po	164.3 μs 20	100	99.99	7686.90[b] 6	1.5394 7
^{214}Rn	0.27 μs 2	100	(100)	9037 10	1.532 7
^{214}Ra	2.46 s 3	99.941 4	100	7136 5	1.456 3
^{216}Po	0.15 s 1	100	100	6778.3[b] 5	1.539 4
^{216}Rn	45 μs 5	100	(100)	8050 10	1.565 9
^{216}Ra	182 ns 10	100	100	9349 8	1.541 5
^{216}Th	0.028 s 2	100	(100)	7921 8	1.467 6
^{218}Po	3.05 m	99.98	100	6002.40[b] 9	1.534
^{218}Rn	35 ms 5	100	99.8 1	7133 2	1.558 8
^{218}Ra	14 μs 2	100	100	8390 8	1.593 10
^{218}Th	109 ns 13	100	100	9665 10	1.555 9
^{220}Rn	55.6 s 1	100	99.93 2	6288.13[b] 10	1.5556 2
^{220}Ra	23 ms 5	100	99	7455 10	1.54
^{220}Th	9.7 μs 6	>90	(100)	8790 20	1.562 14
^{222}Rn	3.8235 d 3	100	99.92 1	8489.52[b] 30	1.5487 2

TABLE I. Continued

Parent	$T_{\frac{1}{2}}$	α branching (%)	I (α_0) per 100 α	E (α_0)	r_0 (daughter)
^{222}Ra	38.0 s 5	100	96.9 1	6555^b 5	1.545 3
^{222}Th	2.8 ms 3	100	100	7982 8	1.541 8
^{224}Ra	3.66 d 4	100	95.1 4	5685.42^b 15	1.5420 8
^{224}Th	1.04 s 5	100	81^l 3	7170 10	1.539 7
^{226}Ra	1600 y 7	100	94.45 5	4784.38^b 25	1.5397 4
^{226}Th	30.9 m	100	75.5 3	6337.5 50	1.538
^{226}U	0.5 s 2	100	100	7430 30	1.567 34
^{228}Th	1.91313 y 88	100	72.7 4	5423.20^b 22	1.5335 4
^{228}U	9.1 m 2	≥95	70 5	6684 10	1.523 11
^{230}Th	75381^m y 295	100	76.3 3	4687.7^b 15	1.5326 14
^{230}U	20.8 d	100	67.4 4	5888.3^b 7	1.531
^{232}Th	14.05 x 10^9 y 6	100	77 3	4013^b 3	1.535 5
^{232}U	68.9^n y 4	100	68.6 4	5320.17^b 14	1.5292 6
^{234}U	2.445 x 10^5 y 10	100	72.5 20	4774.8^b 9	1.5229 19
^{234}Pu	8.8 h 1	6	68	6202 5	1.52
^{236}U	2.342 x 10^7 y 4	100	74 4	4494 3	1.527 5
^{236}Pu	2.851 y 8	100	68.1 8	5767.7^b 10	1.5097 12
^{238}U	4.468 x 10^9 y 3	100	77 4	4197^b 5	1.536 6
^{238}Pu	87.74 y 4	100	71.6 6	5499.07^b 20	1.5080 7
^{240}Pu	6569^p y 6	100	73.5^r 4	5168.17^b 15	1.5167 4

TABLE I. Continued

Parent	$T_{\frac{1}{2}}$	α branching (%)	I (α_0) per 100 α	E (α_0)	r_0 (daughter)
^{240}Cm	27 d 1	>99.5	71.1 6	6290.6[b] 6	1.495 3
^{242}Pu	3.74×10^{5}[t] y 2	100	77.5 30	4900.5[b] 12	1.516 11
^{242}Cm	162.8 d 4	100	74.1 5	6112.77[b] 8	1.5014 5
^{244}Pu	8.1×10^{7}[u] y 1	99.98 1	80.6 8	4589 1	1.5058 16
^{244}Cm	18.11 y 2	100	76.4 2	5804.82[b] 5	1.4979 2
^{246}Cm	4730 y 100	99.9739 1	79 1	5385[b] 2	1.4945 25
^{246}Cf	35.7 h	100	78.0 2	6750.0[b] 10	1.4946 11
^{248}Cm	3.40×10^{5} y 4	91.74 3	81.9 4	5078.45 25	1.4973 9
^{248}Cf	333.5 d 28	99.9971 3	83.0 5	6262 5	1.485 3
^{250}Cf	13.08 y 9	99.923 3	84.6 12	6030.6[b] 6	1.4835 12
^{252}Cf	2.638 y 10	96.908 8	84.2 3	6118.1[b] 5	1.5014 6
^{252}Fm	25.39 h 5	99.997 2	~85	7040 20	1.467
^{252}No	2.30 s 22	73.1 19	~75	8415 6	1.484
^{254}Cf	60.5 d 2	0.310 16	83[v] 1	5834 5	1.517 5
^{254}Fm	3.240 h 2	99.9408 2	85 1	7190[b] 5	1.4897 24

[a]Ref. 4
[b]Ref. 5
[c]Ref. 6
[d]Ref. 7
[e]Ref. 8
[f]Ref. 9
[g]Ref. 10
[h]Ref. 11
[i]Ref. 12
[j]Ref. 13
[k]Ref. 14
[l]Ref. 15
[m]Ref. 16
[n]Ref. 17
[p]Ref. 18
[r]Ref. 19
[t]Ref. 20
[u]Ref. 21
[v]Ref. 22

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*Operated by Union Carbide Corporation under contract W-7405-eng-26 with the U.S. Department of Energy.

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Are Logft Values Reliable Guides for Spin and Parity Assignments?

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The ENSDF rules for assigning nuclear spins, on the basis of logft values, fail to address some important problems pertinent to this usage. For the decay of a nucleus far from stability it is generally not possible to completely determine the decay scheme. Numerous weak γ rays are not observed, yet their total intensity can be substantial.[1] Thus, many derived logft values must be considered only as limits, unless the missing γ-ray feeding intensity is determined. An example of this problem has been demonstrated in the decay of ^{145}Gd.

In 1971, a ^{145}Gd level scheme with 23 levels and 32 γ rays was published.[2] The important low-lying level feedings, with their associated decay intensities and logft values, are indicated at the left in figure 1. The spin assignments shown are inferred from ^{144}Sm(^{3}He,d)^{145}Eu reaction data. Taken separately, the low logft values to all of these levels would have restricted the final spins to 1/2 or 3/2 by the ENSDF rules, yet spin (5/2+) and 7/2+ levels are populated. Had no reaction data existed, incorrect spin assignments would have been made. New data on ^{145}Gd decay were published in 1982.[3] There, 136 levels deexcited by 326 γ rays were placed, and the apparent logft anomalies disappeared. Levels originally fed by as much as 5% of the total decay, at the right in figure 1, were shown not to be directly populated.

It is apparent that the ENSDF logft rules must be applied with great care. Logft values for all weak beta transitions and for decays of nuclei with partially known decay schemes must be presumed to be only limits. Specifically, the apparent decay intensity to a low-lying level usually yields a lower limit for the logft value. This makes the application of logft rules in such cases precarious unless the higher energy part of the level scheme is well known. Conversely, the decay intensity to a high-lying level generally provides an upper limit for the logft value because any indirect feeding from above is unlikely. In those cases, missing transitions deexciting the levels may become important, and increased uncertainty in the decay Q-value may be significant. The ENSDF logft spin assignment rules can still be considered as useful with the caveat that the decay scheme must be demonstrably well determined before they are applied.

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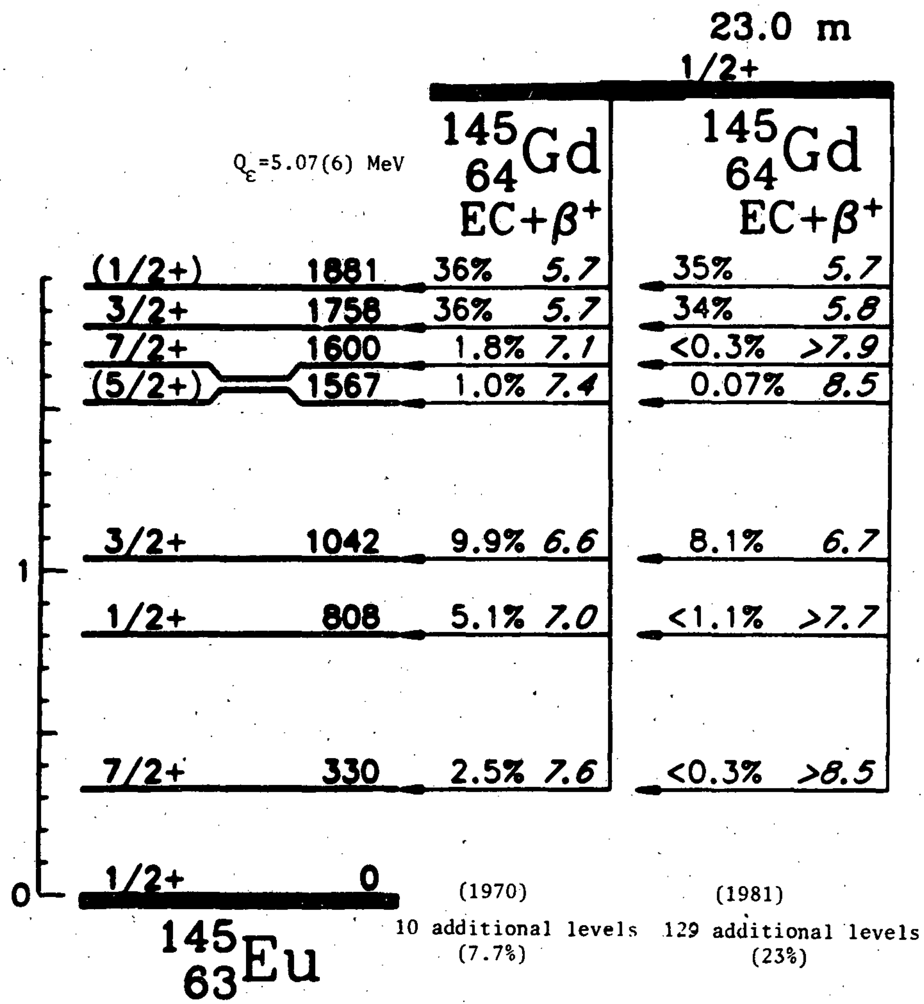

Figure 1. Comparison of ^{145}Gd β-decay intensities to low-lying levels in ^{145}Eu, measured in reference 2 (left) with poorer statistics, and in reference 3 (right) with much better statistics.

Reevaluation of the Logft Systematics for the Assignment of Spins and Parities

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The ENSDF rules for the assignment of spins and parities on the basis of logft values were derived primarily from the paper of Raman and Gove.[1)] This work provides the range of values of some well-known transition probabilities for various beta-decay multipoles.

Several important points were not discussed by Raman and Gove. First, the probability distribution for the logft values was not adequately investigated. In order to effectively utilize logft values for determining spins and parities, a knowledge of the likelihood of the lower-limits on the logft value for various transition types must be known. Also, the systematics of logft values as a function of A, Z, decay energy, and other quantities can be useful for applying the logft rules to specific cases. Thus, when information about nuclear structure exists, better logft restrictions can be adopted. Finally, a study of logft values is not complete without a thorough theoretical investigation of the permissible values. The f-values for nonunique-forbidden transitions differ from the ordinary allowed f-values commonly used, and simple models may be employed to predict the nuclear matrix elements for simple decays.

A preliminary study of logft systematics has been initiated at LBL using the nuclear structure database established from the Table of Isotopes.[2,3)] This computer searchable file contains many thousands of beta decay intensities updated through 1977. A preliminary search of this file was performed to select beta groups associated with nuclei having low decay energies and simple, well-characterized decay schemes. These data have been sorted in several ways with the object of reevaluating the logft systematics. In figure 1, the distribution of allowed logft values separates those for decays between nuclei whose neutron and proton numbers occupy the same shell from those for decays in which these shells differ. A pronounced enhancement of the shell model strength at low logft is observed in the same-shell case, but is not observed in the different-shell case. Figure 2 shows the distribution of first-forbidden logft values as a function of proton number. Both average and minimal logft values are seen to decrease considerably as Z increases. This trend is consistent with an expected $(\alpha Z)^2$ dependence in the first forbidden f-corrections, but the degree to which the trend exceeds the simple expectations is indicative of systematic nuclear structure contributions. Finally, in figure 3, the various higher order multipoles are presented. Too few cases of each are generally available for conclusions to be drawn.

It must be emphasized that these logft distributions are preliminary and are not yet definitive guidelines. Further analysis of the entire logft dataset is currently in progress. Particularly, values close to the lower experimental limits will be reinvestigated to better obtain minimal permissible logft values. Complete systematic logft results will be published at a later date.

References

1. S. Raman and N. B. Gove, Phys. Rev. C 7, 1995 (1973).

2. R. B. Firestone and E. Browne, "Nuclear Structure Database", LBL-11089 (1980).

3. Table of Isotopes, 7th edition: C. M. Lederer and V. S. Shirley, editors; E. Browne, J. M. Dairiki, and R. E. Doebler, principal authors; A. A. Shihab-Eldin, L. J. Jardine, J. K. Tuli, and A. B. Buyrn, authors, John Wiley and Sons, Inc., New York (1978).

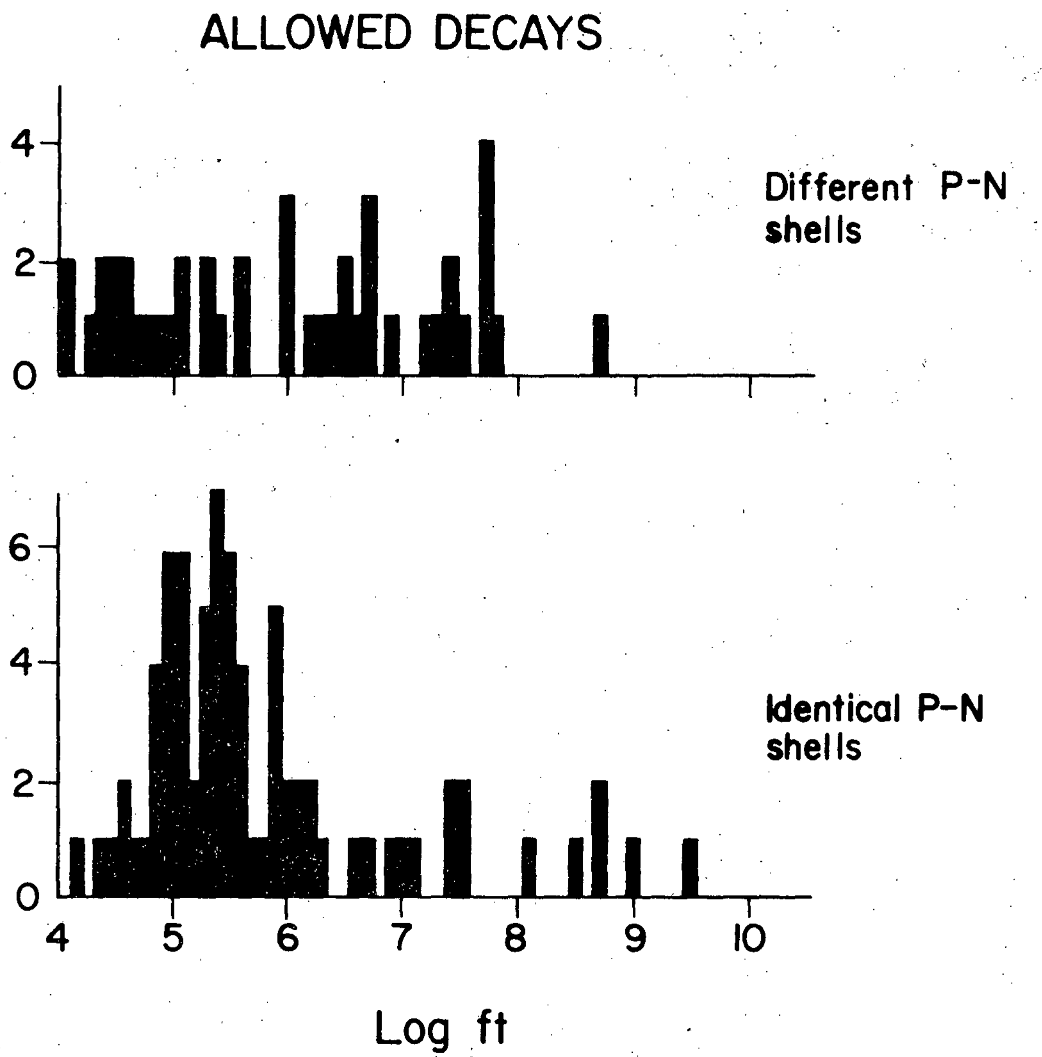

Figure 1. Comparison of logft values with decaying proton and neutron in the same shell versus different shells.

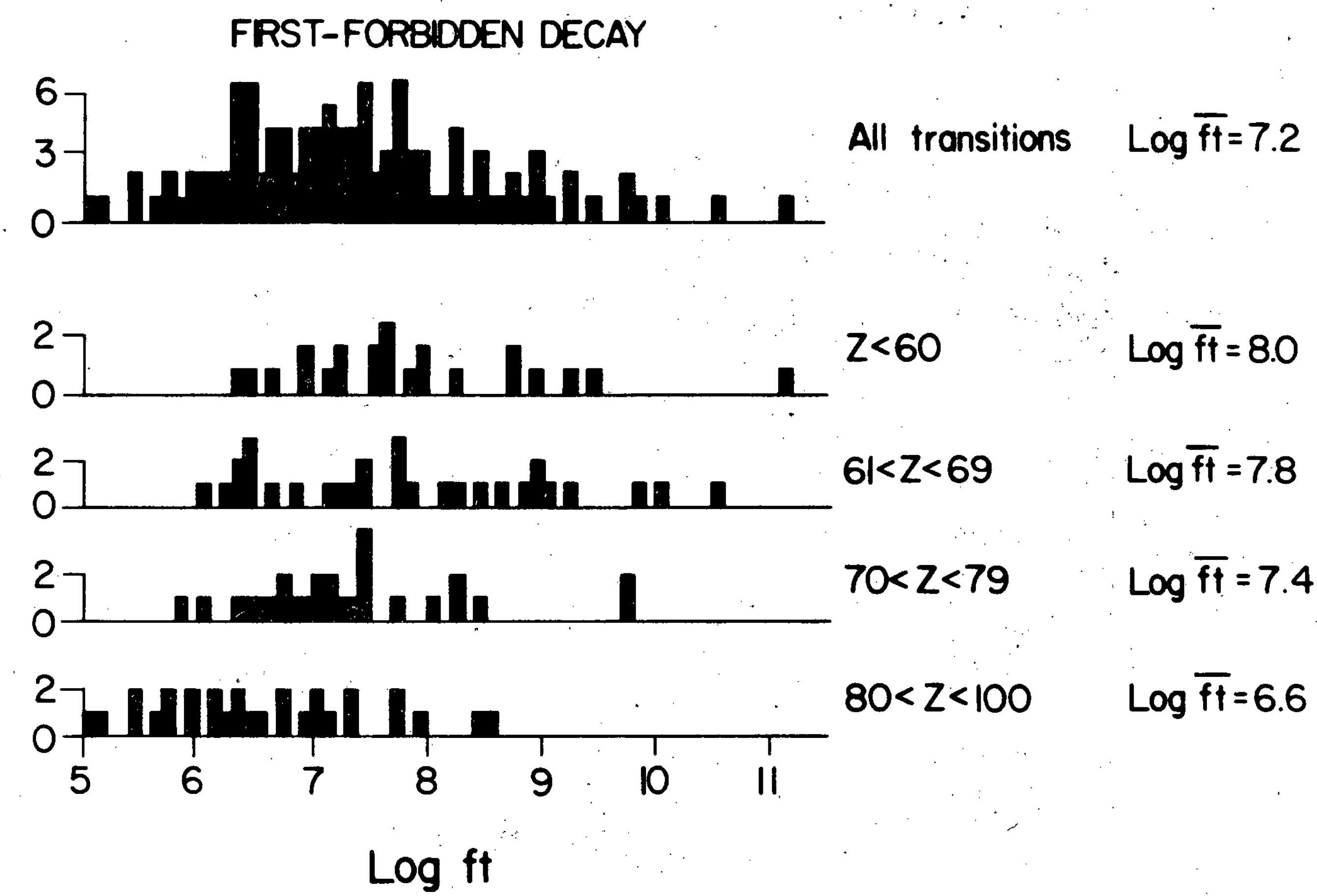

Figure 2. Comparison of first-forbidden logft values plotted as a function of Z.

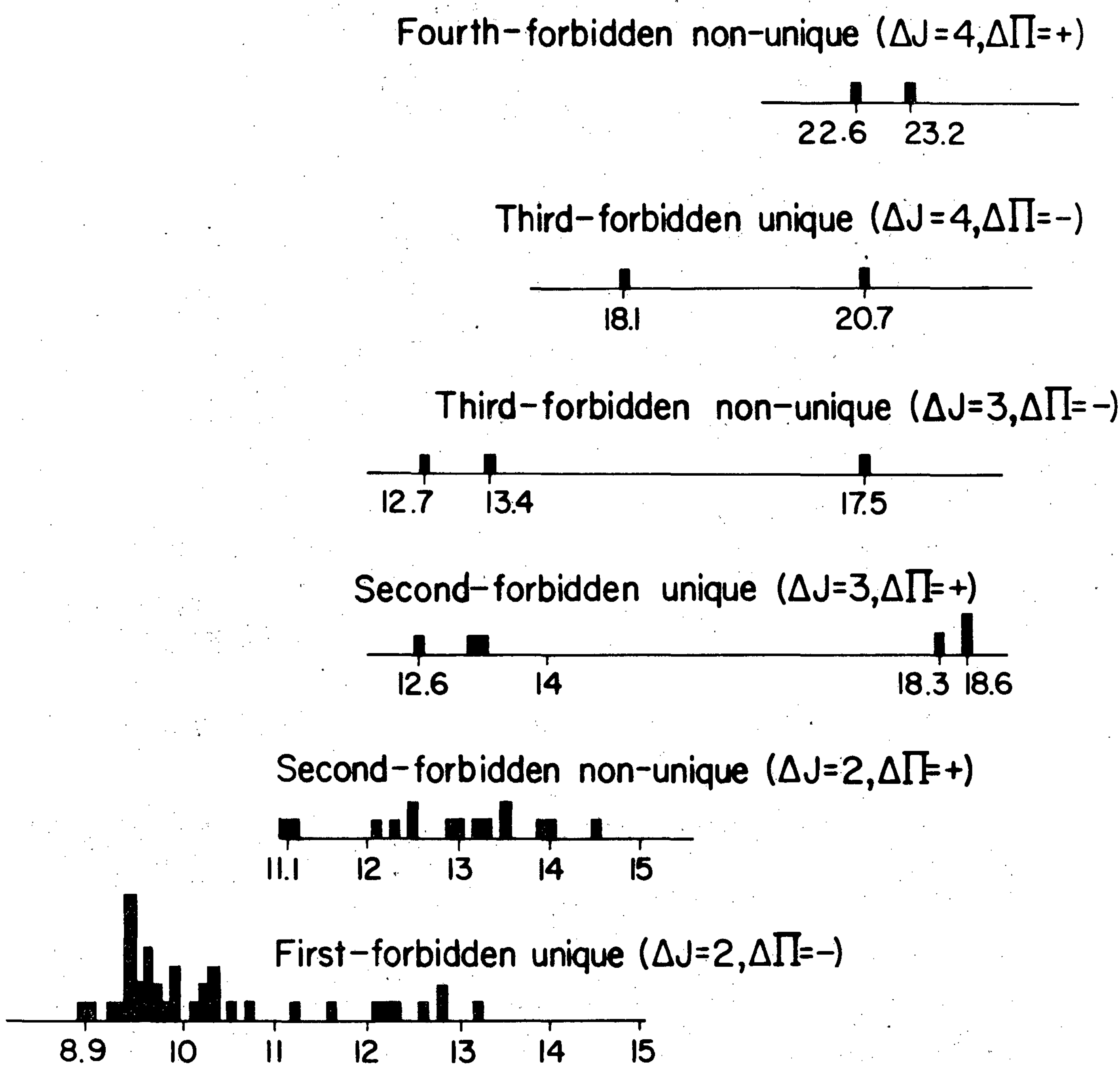

Figure 3. Comparison of logft values for higher-order multipoles.

[Outline for]* Compilation, Evaluation and Extrapolation of Nuclear Mass Data

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and
University of Technology, Delft

1. Structure of body of available data

a) A multiply connected system of many highly accurate mass spectroscopic and nuclear reaction and decay data, in a narrow band along the line of β-stability ("backbone"). Determination of best values of atomic masses for pure nuclides from the "primary data" requires complicated least squares methods.

b) Secondary data, connecting secundary nuclei with the body of primary data in essentially unique ways, and therefore not requiring least squares methods.

2. Compilation

Most important new data since last published evaluation (Atomic Data and Nuclear Data Tables 19 (1977) 177, 20 (1977) 1):

New absolute mass spectroscopic data on Er, Hf, W, Os and Hg isotopes, essentially replacing all earlier (pre-1970) results in the backbone for A = 130 - 240.

Many new precise reaction energies in the backbone, outstanding among them very precise (n,γ) reaction energies. Masses of some very light isotopes changed rather considerably.

Probably most important: mass spectroscopic measurements on long series of partly very unstable alkali isotopes: $^{23-27}$Na, $^{74-99}$Rb, $^{117-147}$Cs, $^{204-228}$Fr. In interaction with them: determination of beta decay energies of very neutron-rich Rb and Cs isotopes and their daughters.

Many new accurate α-decay energies for very neutron deficient isotopes in the regions A = 106 - 114 and A > 150. Near the first region: determinations of decay energies in capture-delayed alpha and proton emission decay. In the beginning of the second region, some decay- and reaction energies connecting long α-decay chains (starting with ^{172}Pt and ^{178}Hg) with the backbone.

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*Added by the editors

3. Evaluation

A new least squares adjustment has been made but its evaluation is not yet complete. Some major problems:

The alkali mass spectroscopy measures, at some A, average masses for isomer mixtures. The present computer program has to be extended to allow smooth treatment of such mixtures, or of isomers in general. This will probably allow inclusion of lowest isobaric analogue levels, felt to be useful for other reasons.

The absolute Hg mass doublet measurements disagree with the backbone (recently considerably fortified in this region), the other absolute mass spectroscopic results and earlier ^{232}Th + $^{235,8}U$ ones.

For several more local discrepancies between input data, solutions can be suggested, often by evaluating the consequences of different choices in systematics of derived quantities. For them, I use α-decay, two-beta decay, two-proton and two-neutron separation energies adding recently four-beta decay energies.

Even if no direct discrepancies exist between measured data, such analyses can lead to doubt the correctness of some experimental data. This happens, e.g., to most of the capture-delayed particle decay energies. Often, in such cases, discussions are started with the authors.

4. Extrapolation

In several cases as just mentioned, where I feel that an experimental (secondary) value is definitely less dependable than one derived from systematics, I have replaced them by the latter ones.

Many experimental data are not connected to the backbone, a.o. many far neutron deficient α-chains. I connect them by adding data derived from the systematics studies mentioned in all nuclei involved, an often rather laborious procedure but yielding, in my experience, quite dependable results. In the past I did not publish estimated errors in values derived from systematics; it is planned to do this in the future. I have not tried to extend this procedure beyond N vs Z-lines smoothly connecting places for which experimental data exist; in this respect, it is more interpolation than extrapolation.

Nuclear Structure Data Base and Related Services*

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By July 1, 1981, the transfer of responsibility for the maintenance of the Evaluated Nuclear Structure Data File (ENSDF) and the Nuclear Structure References (NSR) and for the publication of Nuclear Data Sheets from the Nuclear Data Project (NDP), Oak Ridge National Laboratory, to the National Nuclear Data Center (NNDC), Brookhaven National Laboratory, was completed. This transfer went smoothly with excellent cooperation between the staffs of the Project and the Center. In this paper, we will briefly describe the current contents of ENSDF, retrieval and other nuclear-structure related services currently available from the NNDC, and some future plans.

ENSDF is maintained by the NNDC on behalf of the International Atomic Energy Agency-sponsored Nuclear Structure and Decay Data Network. The centers contributing to the file are given in Table 1. ENSDF contains nuclear structrure and decay data for all nuclei between A=1 and A=263. The file is used to publish Nuclear Data Sheets for A≥45. For A<45, data are obtained from the evaluations published in Nuclear Physics by F. Ajzenberg-Selove and by C. van der Leun and P. Endt. In general, ENSDF contains only adopted level and gamma and decay data for these lighter nuclei. The current contents of ENSDF are summarized in Table 2.

These data may be retrieved on several general criteria. The most general types of criteria are by identification of the data sets, by atomic mass or atomic number, by nuclide, or by ranges of atomic masses, atomic numbers, or nuclides. Additional criteria may be used for decay and reaction data. For decay data these include the type of decay ($\beta-$, $\varepsilon-$, $\alpha-$, IT-, and spontaneous fission decay); for reaction data, the target, incident particle, and outgoing particles may be specified. More specific criteria may also be used. Most of the data contained within the tabular portion of Nuclear Data Sheets may be used as retrieval criteria. Some examples of such retrievals would be all levels with $T_{1/2}>1$ sec. and all gammas with $E_{\gamma}\geq 100$ keV.

The most general form of output for the retrievals is a computer file in the ENSDF format.[1] Tables and level schemes similar to those appearing in Nuclear Data Sheets are also available. By processing decay data sets through the program MEDLIST,[2] we may obtain atomic and nuclear radiations in tabular form and in a computer file in the ENDF format.[3] Other specialized outputs are occasionally provided on a time-available basis. There are also other files maintained at the NNDC in support of ENSDF. Retrievals from these files, including internal-conversion coefficients and the Wapstra mass tables, may also be made.

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* Research sponsored by the Office of Basic Energy Sciences, US Department of Energy, under contract No. DE-AC02-76CH00016.

[1] W. Bruce Ewbank and Marcel R. Schmorak, *Evaluated Nuclear Structure Data File. A Manual for Preparation of Data Sets*, Oak Ridge National Laboratory Report ORNL-5054/R1, 1978.

[2] M.J. Martin, computer code MEDLIST (Oak Ridge National Laboratory, Oak Ridge, TN).

[3] R. Kinsey, *ENDF-102: Data Formats and Procedures for the Evaluated Nuclear Data File ENDF*, Brookhaven National Laboratory Report BNL-NCS-50496, 1979.

Several samples of the retrievals discussed above are given in Figs. 1–5. Fig. 5, part of a tabular listing of fission-product half-lives, is of special note. The Evaluated Nuclear Data File (ENDF),[4] which also resides at the Center, was used to obtain a list of all possible fission products.

In the future, we plan to continue development of specialized retrievals and outputs from ENSDF. We are also investigating the possibilities of providing on-line access to portions of our various data bases. The current emphasis is on-line retrievals from the Nuclear Structure References (NSR) file. The possibility of providing on-line access or microfiche of a limited subset of data from ENSDF, ENDF, and BNL-325[5] is also being pursued.[6] This subset of data would correspond roughly to the data contained on the GE Chart of the Nuclides.[7]

In closing, it should also be noted that, in addition to the nuclear-structure files discussed above, the Center maintains bibliographic, experimental, and evaluated data files which cover a significant portion of low-energy nuclear physics. For further information, or to request data, please contact

Mrs. F.M. Scheffel
National Nuclear Data Center
Building 197D
Brookhaven National Laboratory
Upton, NY 11973.

Non-US users should contact the appropriate center in their region for nuclear-structure data. Service centers for reaction data are listed in the introductions to CINDA[8] and the Bibliography of Integral Charged-Particle Nuclear Data.[9]

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[4] R. Kinsey, compiler, *ENDF-201. ENDF/B Summary Documentation*, Brookhaven National Laboratory Report BNL-NCS-17541, 3rd Edition (ENDF/B-V), 1979; P.F. Rose and T.W. Burrows, *ENDF/B Fission Product Decay Data*, Brookhaven National Laboratory Report BNL-NCS-50545, 1976.

[5] S.F. Mughaghab, M. Divadeenam, and N.E. Holden, *Neutron Cross Sections, Vol. 1 Neutron Resonance Parameters and Thermal Cross Sections, Part A. Z=1-60* (New York: Academic Press, 1981); *ibid., Part B. Z=61-100* (in preparation).

[6] S. Pearlstein, *Computope Chart*, 1982 (to be published).

[7] F. William Walker, George J. Kirouac, and Francis M. Rourke, *Chart of the Nuclides, Twelfth Edition*, distributed by Educational Relations, General Electric Company, Schenectady, NY, 1977.

[8] *An Index to the Literature on Microscopic Neutron Data*, CINDA-A (1935–1976), CINDA 81 (1977–1981), CINDA 81 Supplement (Vienna: International Atomic Energy Agency, 1976–1981)

[9] T.W. Burrows and P. Dempsey, *The Bibliography of Integral Charged Particle Nuclear Data, Archival Edition*, Brookhaven National Laboratory Report BNL-NCS-50640, Fourth Edition, 1980; T.W. Burrows and G. Wyant, *ibid.*, Supplement 1, 1981; N.E. Holden and T.W. Burrows, *ibid.*, Supplement 2, in press.

Table 1

DATA EVALUATION CENTERS

a. National Nuclear Data Center†
Brookhaven National Laboratory
Upton, NY 11973, U.S.A.

b. Nuclear Data Project
Oak Ridge National Laboratory
Oak Ridge, TN 37830, U.S.A.

c. Isotopes Project
Lawrence Berkeley Laboratory
Berkeley, CA 94720, U.S.A.

d. Idaho National Engineering Laboratory
E.G. and G. Idaho, Inc.
P.O. Box 1625
Idaho Falls, ID 83401, U.S.A.

e. Physics Department
University of Pennsylvania
Philadelphia, PA 19174, U.S.A.

f. Institut Atomnoi Energii†
I.V. Kurchatova
46 Ulitsa Kurchatova
Moscow, D-182, U.S.S.R.

g. Data Centre
Leningrad Nuclear Physics Inst.
Gatchina, Leningrad Region
188350, U.S.S.R.

h. Fysisch Laboratorium
Princetonplein 5, P.P. Box 80 000
3508 TA Utrecht, The Netherlands

i. Oliver Lodge Laboratory†
University of Liverpool
Liverpool L69 3BX, U.K.

j. Fachinformationszentrum Energie, Mathematik GmbH†
Kernforschungszentrum
D-7514 Eggenstein-Leopoldshafen 2, F.R.G.

k. Centre d'Etudes Nucleaires de Grenoble
Cedex No. 85
F-38041 Grenoble Cedex, France

l. Division of Physics†
Japan Atomic Energy Research Institute
Tokai-Mura, Naka-Gun
Ibaraki-Ken 319-11, Japan

m. Institute of Physics
University of Lund
Sölvegatan 14
S-223 62 Lund, Sweden

n. Kuwait Institute for Scientific Research
P.O. Box 5969
Kuwait, Kuwait

o. Laboratorium voor Kernfysica
Proeftuinstraat 86
B-9000 Ghent, Belgium

p. Tandem Accelerator Laboratory
McMaster University
Hamilton, Ontario L8S 4K1
Canada

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† Service center. Data may also be requested from:
Banque de Données de l'AEN
NEA Data Bank
B.P. 9
F-91190 Gif-sur-Yvette
France
and
IAEA Nuclear Data Section
P.O. Box 100
A-1400 Vienna
Austria

Table 2

CURRENT CONTENTS OF ENSDF

Card images:	$\approx 8.2 \times 10^6$
Data Sets	
Adopted Levels, Gammas‡	2017
Decay Data (including spontaneous fission)	2229
Reactions	3915
Comments	86
References	263
Total	8241

‡ Includes decay and reaction data sets for nuclei which have no adopted level data sets.

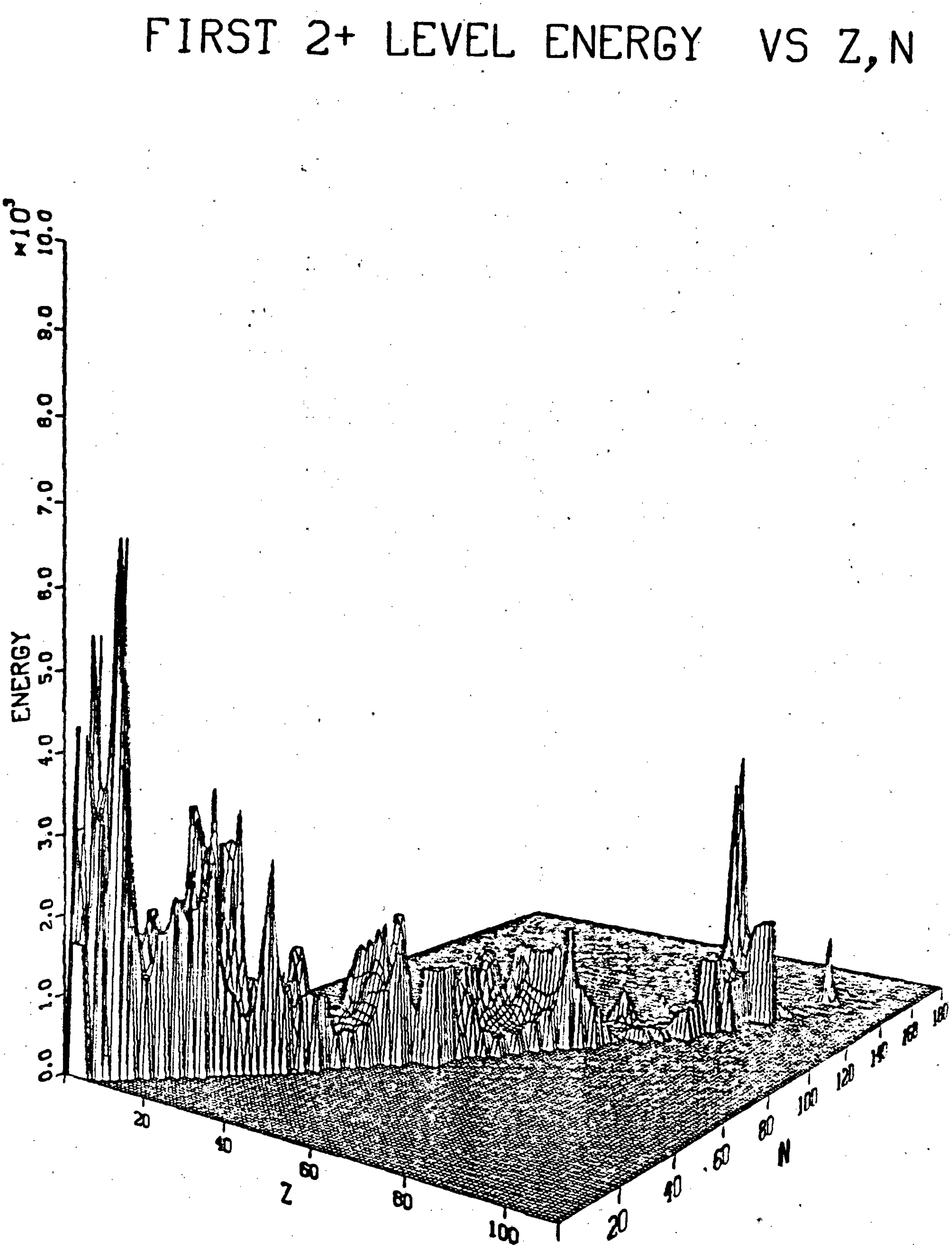
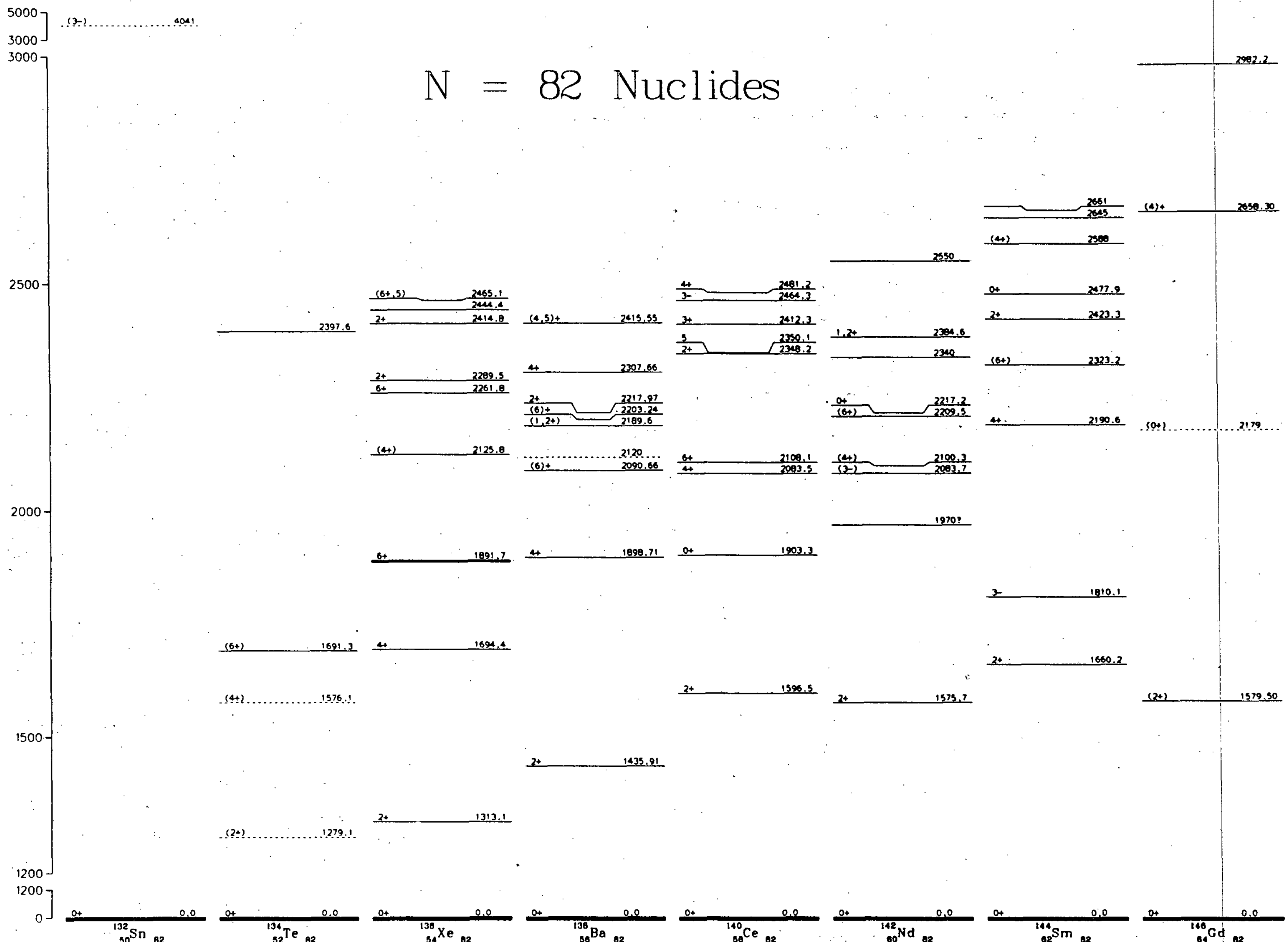

FIRST 2+ LEVEL ENERGY VS Z,N
ENERGY
x10³
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Z
20
40
60
80
100
N
20
40
60
80
100
120
140
160
180

Figure 1.



N = 82 Nuclides
5000
3000
3000
2500
2000
1500
1200
1200
0
(3-) 4041
0+ 0.0
132 50 Sn 82
2397.6
(6+) 1691.3
(4+) 1576.1
(2+) 1279.1
0+ 0.0
134 52 Te 82
(6+,5) 2465.1
2444.4
2+ 2414.8
2+ 2289.5
6+ 2261.8
(4+) 2125.8
6+ 1891.7
4+ 1694.4
2+ 1313.1
0+ 0.0
136 54 Xe 82
(4,5)+ 2415.55
4+ 2307.66
2+ 2217.97
(6)+ 2203.24
(1,2+) 2189.6
2120
(6)+ 2090.66
4+ 1898.71
2+ 1435.91
0+ 0.0
138 56 Ba 82
4+ 2481.2
3- 2464.3
3+ 2412.3
5 2350.1
2+ 2348.2
6+ 2108.1
4+ 2083.5
0+ 1903.3
2+ 1596.5
0+ 0.0
140 58 Ce 82
2550
1,2+ 2384.6
2340
0+ 2217.2
(6+) 2209.5
(4+) 2100.3
(3-) 2083.7
1970?
2+ 1575.7
0+ 0.0
142 60 Nd 82
2661
2645
(4+) 2588
0+ 2477.9
2+ 2423.3
(6+) 2323.2
4+ 2190.6
3- 1810.1
2+ 1660.2
0+ 0.0
144 62 Sm 82
2982.2
(4)+ 2658.30
(0+) 2179
(2+) 1579.50
0+ 0.0
146 64 Gd 82

Figure 2.

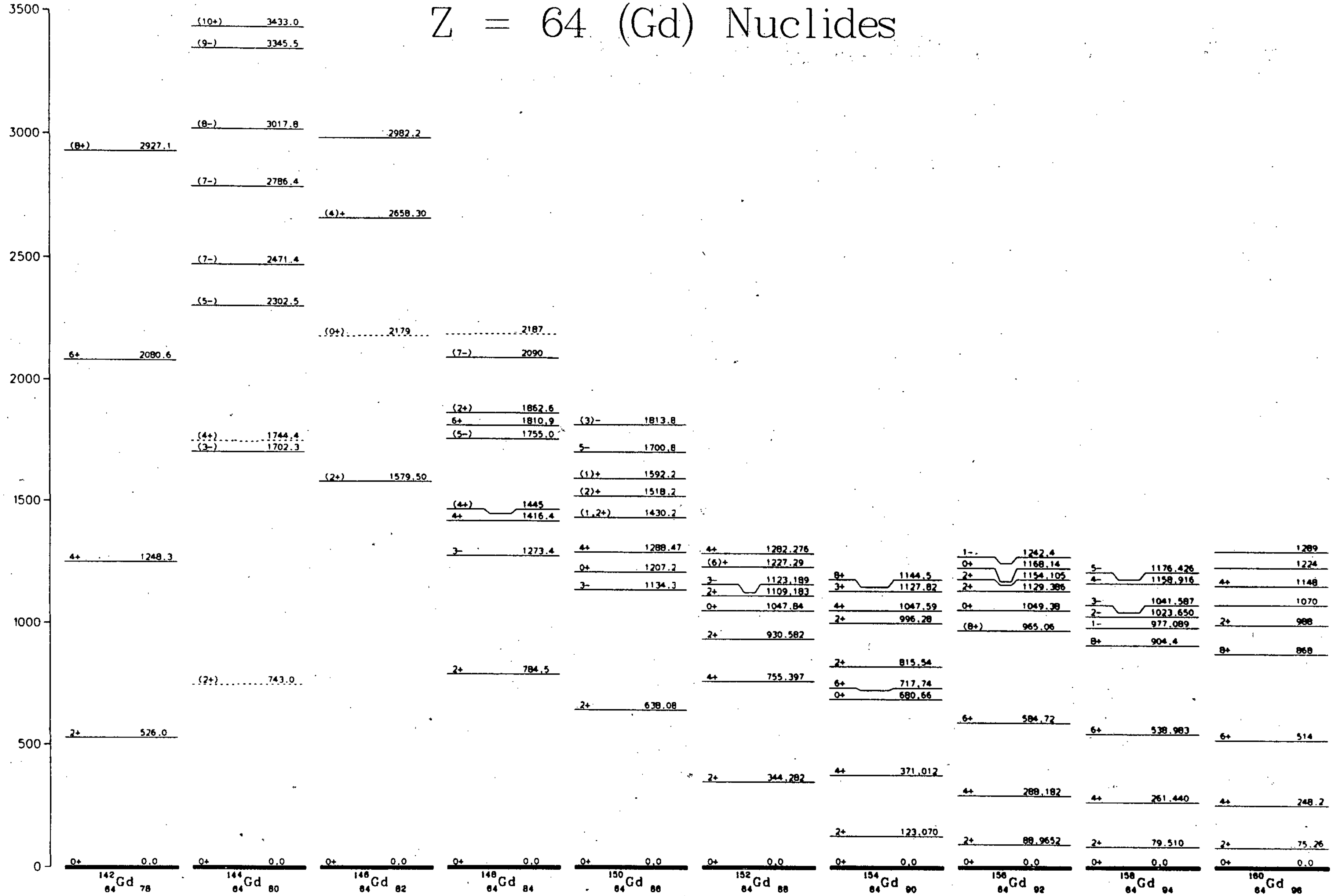

Z = 64 (Gd) Nuclides
3500
3000
2500
2000
1500
1000
500
0
(8+) 2927.1
6+ 2080.6
4+ 1248.3
2+ 526.0
0+ 0.0
142 64 Gd 78
(10+) 3433.0
(9-) 3345.5
(8-) 3017.8
(7-) 2786.4
(7-) 2471.4
(5-) 2302.5
(4+) 1744.4
(3-) 1702.3
(2+) 743.0
0+ 0.0
144 64 Gd 80
2982.2
(4)+ 2658.30
(0+) 2179
(2+) 1579.50
0+ 0.0
146 64 Gd 82
2187
(7-) 2090
(2+) 1862.6
6+ 1810.9
(5-) 1755.0
(4+) 1445
4+ 1416.4
3- 1273.4
2+ 784.5
0+ 0.0
148 64 Gd 84
(3)- 1813.8
5- 1700.8
(1)+ 1592.2
(2)+ 1518.2
(1,2+) 1430.2
4+ 1288.47
0+ 1207.2
3- 1134.3
2+ 638.08
0+ 0.0
150 64 Gd 86
4+ 1282.276
(6)+ 1227.29
3- 1123.189
2+ 1109.183
0+ 1047.84
2+ 930.582
4+ 755.397
2+ 344.282
0+ 0.0
152 64 Gd 88
8+ 1144.5
3+ 1127.82
4+ 1047.59
2+ 996.28
2+ 815.54
6+ 717.74
0+ 680.66
4+ 371.012
2+ 123.070
0+ 0.0
154 64 Gd 90
1- 1242.4
0+ 1168.14
2+ 1154.105
2+ 1129.386
0+ 1049.38
(8+) 965.06
6+ 584.72
4+ 288.182
2+ 88.9652
0+ 0.0
156 64 Gd 92
5- 1176.426
4- 1158.916
3- 1041.587
2- 1023.650
1- 977.089
8+ 904.4
6+ 538.983
4+ 261.440
2+ 79.510
0+ 0.0
158 64 Gd 94
1289
1224
4+ 1148
1070
2+ 988
8+ 868
6+ 514
4+ 248.2
2+ 75.26
0+ 0.0
160 64 Gd 96

Figure 3.

Figure 4. Listing of Atomic and Nuclear Radiations from MEDLIST

^{145}Pr β- Decay (5.98 h 2)   I(min)=0.0010%

Radiation Type	Energy (keV)	Intensity (%)	(G-Rad/ μCi-h)
Auger-L	4.230	0.58 10	
ce(K) 1	23.53 10	0.025 14	
ce(K) 2	28.931 10	0.62 13	0.0004
Auger-K	30.50	0.052 19	
ce(L) 1	59.97 10	0.036 20	
ce(L) 2	65.374 10	0.087 18	0.0001
ce(M) 1	65.52 10	0.008 5	
ce(NOP) 1	66.78 10	0.0022 12	
ce(M) 2	70.925 10	0.018 4	
ce(NOP) 2	72.185 10	0.0052 11	
β- 1 Max	278. 10		
Avg	78. 4	0.013 3	
β- 2 Max	401. 10		
Avg	118. 4	0.072 15	0.0002
β- 3 Max	466. 10		
Avg	140. 4	0.0017 4	
β- 4 Max	555. 10		
Avg	172. 4	0.006 1	
β- 5 Max	643. 10		
Avg	203. 4	0.008 2	
β- 6 Max	644. 10		
Avg	204. 4	0.020 4	
β- 7 Max	655. 10		
Avg	208. 4	0.19 4	0.0008
β- 8 Max	754. 10		
Avg	245. 4	0.30 6	0.0016
β- 9 Max	884. 10		
Avg	295. 4	0.18 4	0.0011
β- 10 Max	1057. 10		
Avg	364. 4	0.80 16	0.0062
β- 11 Max	1733. 10		
Avg	651. 5	0.28 11	0.0039
β- 12 Max	1738. 10		
Avg	654. 5	0.05000	0.0007
β- 13 Max	1805. 10		
Avg	683. 5	97. 19	1.41
Total β-			
Avg	677. 5	99. 19	1.43
X-ray L	5.230	0.102 22	
X-ray K_{α_2}	36.8474 3	0.17 4	0.0001
X-ray K_{α_1}	37.3610 3	0.31 6	0.0002
X-ray K_β	42.30	0.118 23	0.0001

Radiation Type	Energy (keV)	Intensity (%)	(G-Rad/ μCi-h)
γ 1	67.1 1	0.007 4	
γ 2	72.50 1	0.20 4	0.0003
γ 3	91.1 2	0.0060 11	
γ 5	242.91 3	0.0013 3	
γ 6	262.9 1	0.0023 5	
γ 7	263.0 1	0.0034 6	
γ 8	303.19 1	0.0054 9	
γ 9	318.67 1	0.0113 19	
γ 11	352.48 1	0.030 5	0.0002
γ 12	353.54 1	0.0030 7	
γ 17	467.03 3	0.0021 4	
γ 18	475.61 3	0.0035 6	
γ 19	492.62 1	0.023 4	0.0002
γ 21	516.07 2	0.0060 11	
γ 22	606.42 6	0.0014 4	
γ 23	623.50 1	0.018 3	0.0002
γ 24	657.67 1	0.048 8	0.0007
γ 25	675.79 1	0.38 7	0.0054
γ 26	707.95 2	0.0082 14	0.0001
γ 27	713.22 2	0.0069 12	0.0001
γ 29	748.28 1	0.43 7	0.0069
γ 31	780.45 3	0.0034 7	
γ 32	848.24 2	0.055 9	0.0010
γ 36	920.71 1	0.12 2	0.0024
γ 37	937.05 5	0.0022 6	
γ 38	978.97 2	0.19 4	0.0040
γ 40	1012.75 2	0.0045 8	
γ 41	1018.0 1	0.0078 13	0.0002
γ 42	1051.41 1	0.144 24	0.0032
γ 43	1088.52 3	0.0046 8	0.0001
γ 44	1089.9 1	0.0014 3	
γ 45	1093.78 2	0.0044 8	0.0001
γ 46	1150.26 1	0.16 3	0.0040
γ 47	1161.04 4	0.0123 21	0.0003
γ 48	1162.32 7	0.0072 13	0.0002
γ 49	1177.22 3	0.0031 6	
γ 53	1249.73 3	0.0019 4	
γ 56	1271.45 9	0.0012 3	
γ 58	1331.42 2	0.0054 10	0.0002
γ 59	1336.65 4	0.0014 3	
γ 61	1403.92 4	0.0039 8	0.0001
γ 62	1527.05 4	0.0013 3	

FISSION PRODUCTS HALF-LIFE

14-Sep-81

NUCLIDE	LEVEL ENERGY	HALF-LIFE
90SR	0.0	28.6 Y 3
91SR	0	9.52 H 6
92SR	0.0	2.71 H 1
93SR	0.0	7.6 M 2
94SR	0.0	78 S 2
95SR	0.0	26 S 1
96SR	0.0	4.0 S 2
97SR	0.0	0.2 S LE
98SR	0.	0.845 S 43
89Y	909.2	16.06 S 4
90Y	0.0	64.1 H 1
90Y	682.04	3.19 H 1
91Y	0	58.51 D 6
91Y	555.61	49.71 M 4
92Y	0.0	3.54 H 1
93Y	0.0	10.1 H 2
94Y	0.0	19.1 M 4
95Y	0.0	10.7 M 2
96Y	0.0	2.3 M 1
97Y	0.0	1.11 S 14
98Y	0.	0.3 S
99Y	0.0	0.8 S 7
101Y		1.10 S 15
102Y	0	0.9 S 3
90ZR	2319.10	809.2 MS 20
93ZR	0.0	1.53E6 Y 10
95ZR	0.0	63.98 D 6
97ZR	0.0	17.0 H 2
99ZR	0.0	2.4 S 1
100ZR	0.0	7.1 S 4
101ZR		2.1 S 3
102ZR	0	0.8 S 3
93NB	30.4	13.6 Y 3
94NB	0.0	2.03E4 Y 16
94NB	40.95	6.26 M 1
95NB	0.0	35.15 D 3
95NB	234.70	86.6 H 8
96NB	0.0	23.35 H 5
97NB	0.0	72.1 M 7
97NB	743.36	60 S 8
98NB		2.8 S 2
98NB		51.5 M 10
99NB	0	14.3 S
100NB		1.5 S 3
100NB		3.1 S 3
101NB	0.0	7.1 S 3
102NB	0.0	2.9 S 4
103NB	0.0	1.5 S 2
105NB	0.0	1.8 S 8
106NB	0.0	1.1 S 1
93MO	0.0	3.5E3 Y 7
93MO	2425.2	6.85 H 7
99MO	0	66.02 H 1
101MO	0.0	14.6 M 1
102MO	0	11.1 M 3
103MO	0.0	67.5 S 15
104MO	0.0	1.3 M 3
105MO	0.0+X	36.7 S 10
105MO	0.0+Y	50 S AP
106MO	0.0	8.4 S 5
108MO	0.0	1.5 S 5
99TC	0.	2.13E5 Y 5
99TC	142.63	6.02 H 2
100TC	0.0	15.8 S 1
101TC	0.0	14.2 M 1

NUCLIDE	LEVEL ENERGY	HALF-LIFE
101TC	207.53	636 US 8
102TC	0	5.28 S 15
102TC	500	4.35 M 7
103TC	0.0	54.2 S 8
104TC	0.0	18.2 M 5
105TC	0.0	7.7 M 2
106TC	0.0	36 S 1
107TC	0.0	29 S 3
108TC	0.0	8.3 S
109TC	0.0	1.4 S 4
110TC	0.0	0.83 S 4
97RU	0.0	2.9 D 1
103RU	0.0	39.35 D 6
103RU	238.0	1.69 MS 7
105RU	0.0	4.44 H 2
106RU	0.0	371.63 D 17
107RU	0.0	4.2 M 3
108RU	0.0	4.5 M 2
109RU	0.0	35 S 3
110RU	0.0	15.9 S 5
111RU	(0.0)	2.2 S 7
112RU	0.0	4.65 S 14
103RH	39.75	56.12 M 1
104RH	0.0	42.3 S 4
104RH	128.956	4.34 M 5
105RH	0.0	35.36 H 6
105RH	129.59	45 S
106RH	0.0	29.80 S 8
106RH	140	130 M 2
107RH	0.0	21.7 M 4
108RH	0.0	16.8 S 5
108RH		5.9 M 2
109RH	0	80 S 2
110RH	0.0(+X?)	3.0 S 2
110RH	0.0(+X?)	28.5 S 15
111RH		11 S 1
112RH	0.0	0.8 S 1
103PD	0.0	16.96 D 2
107PD	0	6.5E6 Y 3
107PD	214.	21.3 S 3
109PD	0	13.46 H 2
109PD	188.9	4.69 M 1
111PD	0.0	23.4 M 2
111PD	172.2	5.5 H 1
112PD	0.0	21.045 H +29-65
113PD	0.0	1.4 M 1
114PD	0.	2.4 M 1
115PD	0.0	41 S 3
116PD	0.	12.72 S 44
117PD	0	5.0 S +5-7
118PD	0.0	3.1 S 3
107AG	93.08	44.3 S 2
108AG	0.0	2.37 M 1
108AG	109.58	127 Y
109AG	88.032	39.6 S 2
110AG	0.0	24.6 S 2
110AG	117.76	249.9 D 1
111AG	0.0	7.45 D 1
111AG	59.82	64.8 S 8
112AG	0.0	3.14 H 2
113AG	0.0	5.37 H 5
113AG		1.20 M 15
114AG	0.	4.52 S 7
115AG	0.0	20.0 M 5
115AG	0.0	18.0 S 7

Figure 5.

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