2 Discrete Level Schemes

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Summary

An entirely new discrete levels segment has been created by the Budapest group according to the recommended principles, using the Evaluated Nuclear Structure Data File, ENSDF as a source. The resulting segment contains 96,834 levels and 105,423 gamma rays for 2,585 nuclei, with their characteristics such as energy, spin, parity, half-life as well as gamma-ray energy and branching percentage. Isomer flags for half-lives longer than 1 s have been introduced. For those 1,277 nuclei having at least ten known levels the cutoff level numbers N_m have been determined from fits to the cumulative number of levels. The level numbers N_c associated with the cutoff energies U_c, corresponding to the upper energy limit of levels with unique spin and parity, have been included for each nuclide. The segment has the form of an ASCII file which follows the extended ENEA Bologna convention.

For the RIPL Starter File the new Budapest file is recommended as a Discrete Level Schemes Segment because it is most complete, up-to-date, and also well documented. Moreover, the cutoff energies have been determined in a consistent way, giving also hints about basic level density parameters. The recommended files are **budapest_levels.dat** and **budapest_cumulative.dat**.

As alternative choices, the libraries from Beijing, Bologna, JAERI, Obninsk and Livermore may also be used for special applications.

2.1 Introduction

Nuclear reaction model calculations require the knowledge of complete discrete nuclear level schemes, in order to specify all possible outgoing reaction channels. This knowledge is also important for the test of total level density models, which necessarily replace the discrete schemes at higher excitation energies, approaching the continuum regime. The term "completeness" means here that for a given nucleus all discrete levels are observed in a specified energy and spin window, and they are all characterized by unique energy, spin and parity values. The knowledge of particle and gamma-ray decay branchings is also required in addition, especially when isomeric states are populated by gamma-ray cascades.

Complete level schemes can be obtained only from complete spectroscopy using nonselective reactions. Statistical reactions, e. g. the $(n, n'\gamma)$ reaction and averaged resonance capture, are especially suitable from the viewpoints of nonselectivity of the excitation mechanism and completeness of information obtained with the rich arsenal of gamma-ray spectroscopy [2.1]. For practical reasons the vast majority of nuclei cannot be studied by such means, hence the degree of knowledge of the experimentally determined discrete level schemes varies widely throughout the nuclear chart. While this knowledge is incorporated in the Evaluated Nuclear Structure Data File, ENSDF [2.2], it has to be extracted and put in a format appropriate for practical applications.

In the course of the Co-ordinated Research Project *RIPL* a Discrete Level Schemes Segment, DLSS, had to be prepared for the RIPL Starter File, according to the following principles [2.3, 2.4]:

- A single recommended DLSS file has to be created on the basis of the Evaluated Nuclear Structure Data File, ENSDF, as the primary source of input data.
- The starter file should keep the format of the ENEA Bologna discrete levels file, LIVELLI [2.5], with some extensions to incorporate additional information.
- Separate cutoff energies must be defined for each nucleus to indicate the limits of completeness of level scheme with regard to levels as well as level spins and parities, respectively.
- The starter file should be compared with other existing files not used for creating it.

2.2 Budapest Discrete Levels File

A new discrete levels file has been created by the Budapest group according to the recommended principles. The ENSDF data set "Adopted levels and gammas", as of 23 February 1996 [2.2], has been used as data source. The major steps are outlined below.

- The adopted discrete nuclear levels and gamma-ray transitions have been retrieved on line, using the program NUDAT [2.6].
- The retrieved ENSDF data have been filtered for errors and converted into a file in the extended Bologna format, as described in detail below.
- The cutoff energy, U_{max}, and the cumulative number, N_{max}, of levels up to this energy have been determined from exponential fits to the staircase plots for those nuclei for which at least 10 levels were known [2.7] and have been included in the file as a cutoff value up to which the discrete level scheme is complete.
- A second energy cutoff, U_c, corresponding to the upper energy limit of levels characterized by an unique spin and parity has been determined for all nuclei on the basis of ENSDF data alone.

2.2.1 Retrieval of ENSDF Data

Filtering of adopted level and gamma data sets

The data on discrete levels and gamma-ray transitions were retrieved from the Online Nuclear Data Service at IAEA, with the help of NUDAT [2.6]. Adopted levels and gamma rays had to be retrieved separately, since attempts to retrieve adopted levels and gammas together had failed. Inspection of the retrieved files "Adopted Levels" and "Adopted Gammas" revealed a number of syntax errors.

After performing the syntactical tests the data have been loaded into a Borland PARADOX database, running on IBM-PC. The resulting *relational database of discrete levels and gammas*, consisting of the files 'ensdflev.db' and 'ensdfgam.db' [2.8], contains the mass and charge of each nuclide, the initial level energies with uncertainties, the gamma transition energies and relative intensities with their uncertainties, level half-lives, spins and parities, as well as the date of evaluation. ENSDF notations for ambiguous spins and parities had to be tokenized and level half-lives be converted to seconds, in order to facilitate further database operations.

The original ENSDF file (update as of 23 February 1996) contains 106,234 adopted levels for 2,807 nuclei within the range $A = 1 - 266$, $Z = 0 - 109$. There are 148,129 adopted gamma transitions in 1,592 nuclei with $A = 5 - 266$ and $Z = 3 - 103$. More details can be found in the database files 'l_zstat.db' and 'l_astat.db' for levels and in 'g_zstat.db' and 'g_astat.db' for gamma rays. The ASCII table versions of these database files are available on request [2.8].

Each discrete level has to be unique and has to be unambiguously placed in the level scheme. Hence only nuclides with a firmly established ground state can be kept. Duplicated ground states (isomers or band heads with unknown energy, e.g. 0 + X) as well as duplicated excited states - altogether 9,400 levels - had to be eliminated, leaving us with 96,834 levels in 2,585 nuclides.

The number of gamma rays has also been reduced by 13,650 due to the deletion of 9,214 level duplicates, decaying by gamma rays. Furthermore, 57 duplicated gamma rays were found which had to be deleted as well. Finally, another 11,425 gammas had to be deleted because they fell in at least one of the following classes:

- the energy of the initial level is zero or unknown - 744 cases
- the gamma-ray energy is zero - 13 cases
- the gamma-ray intensity is missing or zero - 11,242 cases

Eventually, 122,997 gamma rays have been kept in 1,354 nuclides.

Placement of gammas and calculation of branchings

The gamma-ray branching percentages can be calculated from the intensities of gamma rays de-exciting the given level. Unfortunately, for each gamma ray only the initial levels are usually specified in the ENSDF file, the final levels have not been encoded. Hence each gamma ray had to be placed anew in the level scheme.

For this purpose the energies of final levels were computed for all gamma transitions assigned to a given initial level, and the resulting energy values were identified with adopted level energies. This procedure was preceded by a correction for recoil shift of the transition energy, calculated as $\Delta E_\gamma = E_\gamma^2/(2 \cdot A \cdot 931.494 \text{ MeV})$. The correction exceeds 0.1 keV for 12,842 gamma rays, mainly belonging to light nuclides. The criterion for a proper assignment was that the difference between computed and adopted level energies had to be less than three standard deviations, where the latter were computed from the given uncertainties added in square.

Unfortunately, no energy uncertainties have been specified in ENSDF for 10,688 levels and 19,734 gammas, respectively. In these cases average uncertainty values, calculated for each individual nuclide, have been used. Whenever this average value exceeded the interval of 0.15 keV to 5 keV, the closest limiting value has been adopted instead. The distribution of generated uncertainties is given in Table 2.1 both for the levels and gamma rays, respectively.

Only for those gamma transitions which could be placed firmly could the branching percentages be computed, while gamma rays without placement or intensity value had to be omitted. Within the 3σ combined uncertainty 1,466 gammas could not be placed. On the other hand, 13,164 gammas matched more than one final level, and 11 gammas were duplicate placements (i.e. connect the same levels). Another 11 gammas were just marked as weak. After eliminating

Table 2.1: Distribution of levels according to energy uncertainty bins.

ΔE_{level} (keV)	Number of cases
5.00	540
$\geq$ 4.00	156
$\geq$ 3.00	248
$\geq$ 2.00	346
$\geq$ 1.00	1,236
$>$ 0.15	4,460
0.15	3,702
Total	10,688

Distribution of γ-rays according to energy uncertainty bins.

ΔE_{γ} (keV)	Number of cases
5.00	79
$\geq$ 4.00	0
$\geq$ 3.00	0
$\geq$ 2.00	2
$\geq$ 1.00	69
$>$ 0.15	551
0.15	19,033
Total	19,734

those falling in at least one of the enlisted categories there remained 108,345 uniquely placed gamma rays, for which the branching percentages have been determined.

2.2.2 Determination of Cutoff Energies

Determination of the cutoff energy up to which the discrete level scheme can be considered complete is a difficult task for which no universal recipes have been available. Therefore, a reliable automatic procedure had to be found.

Histograms of the cumulative number of levels against excitation energy (staircase plots) have been created first, using the database described above. At least 10 known levels have been required, including the ground state. This constraint has left us with 1422 nuclei. For 145 nuclei out of this selection ENSDF contains more than one zero-energy level, rendering the level scheme ambiguous. Hence those 145 nuclei also had to be excluded from the procedure which has been carried out for the remaining 1277 nuclei, from ^{6}Li to ^{251}Es.

The cutoff energies U_{max} and the corresponding *cumulative numbers of levels* N_m have been determined by fitting the histograms with the constant-temperature exponential formula:

$$N(E) = \exp((E - U_0)/T) \ , \tag{2.1}$$

where T is the nuclear temperature, and U_0 is the backshift energy. The excitation energy, E, has been used as a weighting factor in order to minimize the influence of $N(E)$ values at the high-energy end where our knowledge becomes incomplete.

Based on the fits T, U_0 and U_{max} have been determined for all 1277 nuclei considered. The whole procedure is described in detail elsewhere [2.7]. Here we only note that the level number associated with the minimal value of χ^2 determines in turn the cutoff energy, U_{max}, above which the level density starts deviating from the expected exponential law. The results have been presented in the form of tables and plots which may also be found in a separate publication [2.7]. Only a short description of those is given here, with some illustrative examples.

Fig. 2.1 is an example of the histograms of the cumulative number of levels, $N(E)$, created for the 1277 nuclei considered. In the plots the continuous line always represents the accepted level density fit as explained above. The diamond symbol marks the cutoff energy, U_{max}, and the associated cumulative level number, N_{max}, corresponding to that local minimum of χ^2 which is characterized by the maximal slope of $\ln(N(E))$. The other cutoff energy, U_c, is determined by the energy of the highest level up to (and including) which both the spin and parity are unambiguously established, while N_c is the corresponding level number. The numerical values of U_{max} and U_c are also indicated in the plots. The whole set of plots is included in Ref. [2.7].

Table 2.2: Excerpt from the file **budapest_cumulative.dat**. Notations: * means $U_{max} > S_n$ or S_p, # marks cases where the accepted local minimum is different from the absolute minimum.

						Accepted local minimum				Absolute minimum			
A	Z	n	Nc	Nmax	Uc (MeV)	Umax (MeV)	U0 (MeV)	T (MeV)	Chi^2	Umax (MeV)	U0 (MeV)	T (MeV)	Chi^2
6	3	13	12	13	26.600	31.000*	-25.167	21.027	0.026	31.000	-25.167	21.027	0.026
8	3	11	4	10	3.210	9.000*	-4.007	5.527	0.005	9.000	-4.007	5.527	0.005
8	4	26	15	22	20.900	24.000*	7.010	5.350	0.028	24.000	7.010	5.350	0.028
9	4	31	5	29	3.049	22.400*	-10.644	9.623	0.010	22.400	-10.644	9.623	0.010
9	5	18	1	15	0.000	17.076*	-10.841	10.621	0.014	15.290	-11.590	11.155	0.014#
10	4	16	8	11	7.542	10.570*	-0.328	4.252	0.046	10.570	-0.328	4.252	0.046
10	5	38	12	25	6.127	8.894*	-2.041	3.370	0.009	8.894	-2.041	3.370	0.009
11	4	15	2	12	0.320	7.030*	-2.706	3.842	0.009	7.030	-2.706	3.842	0.009
11	5	41	8	23	7.978	12.000*	0.182	3.740	0.003	12.000	0.182	3.740	0.003
11	6	36	13	17	9.200	10.083*	0.313	3.481	0.003	10.083	0.313	3.481	0.003
12	5	50	16	11	7.060	5.000*	-1.091	2.514	0.004	5.000	-1.091	2.514	0.004
12	6	56	4	10	9.641	13.352	2.987	4.413	0.006	13.352	2.987	4.413	0.006
12	7	19	5	10	2.439	5.600*	-3.009	3.558	0.012	5.600	-3.009	3.558	0.012
13	5	23	1	11	0.000	5.557*	1.075	1.861	0.017	5.557	1.075	1.861	0.017
13	6	73	5	33	6.864	14.582*	-1.484	4.509	0.008	14.582	-1.484	4.509	0.008
13	7	54	12	24	9.476	12.937*	-2.132	4.715	0.007	12.937	-2.132	4.715	0.007
14	6	46	11	23	10.425	12.963*	1.180	3.686	0.019	12.963	1.180	3.686	0.019
14	7	120	23	10	9.703	7.029	1.399	2.358	0.005	7.029	1.399	2.358	0.005
14	8	18	5	15	6.590	13.010*	-1.141	5.016	0.022	13.010	-1.141	5.016	0.022
15	6	31	6	21	4.780	8.110*	0.663	2.410	0.010	6.417	0.017	2.852	0.006#
15	7	113	22	36	10.804	12.551*	2.197	2.867	0.003	12.551	2.197	2.867	0.003
15	8	85	12	39	8.922	12.471*	2.024	2.811	0.003	12.471	2.024	2.811	0.003

...

The parameters obtained from the fits to the cumulative level numbers for 1277 nuclei have been tabulated in the form shown in Table 2.2. For increasing mass and charge numbers we have printed the results of the least-square fits for the accepted and absolute minima and other relevant quantities in one line. A and Z are mass and charge numbers, respectively, n is the total number of levels, N_c is the cumulative level number at cutoff energy U_c for completeness with respect to spin/parity and the rest comes from the fits. In 111 out of the 1277 fits the U_{max} value has been found to be larger than the lowest of the two single-nucleon separation energies S_n, S_p [2.9]. In other words, these fits include unbound states as well. In Table 2.2 the corresponding U_{max} values have been marked with an asterisk. The whole table is available in the form of an ASCII text file called **budapest_cumulative.dat** as part of the DLS Segment. A printed version is included in a separate report [2.7].

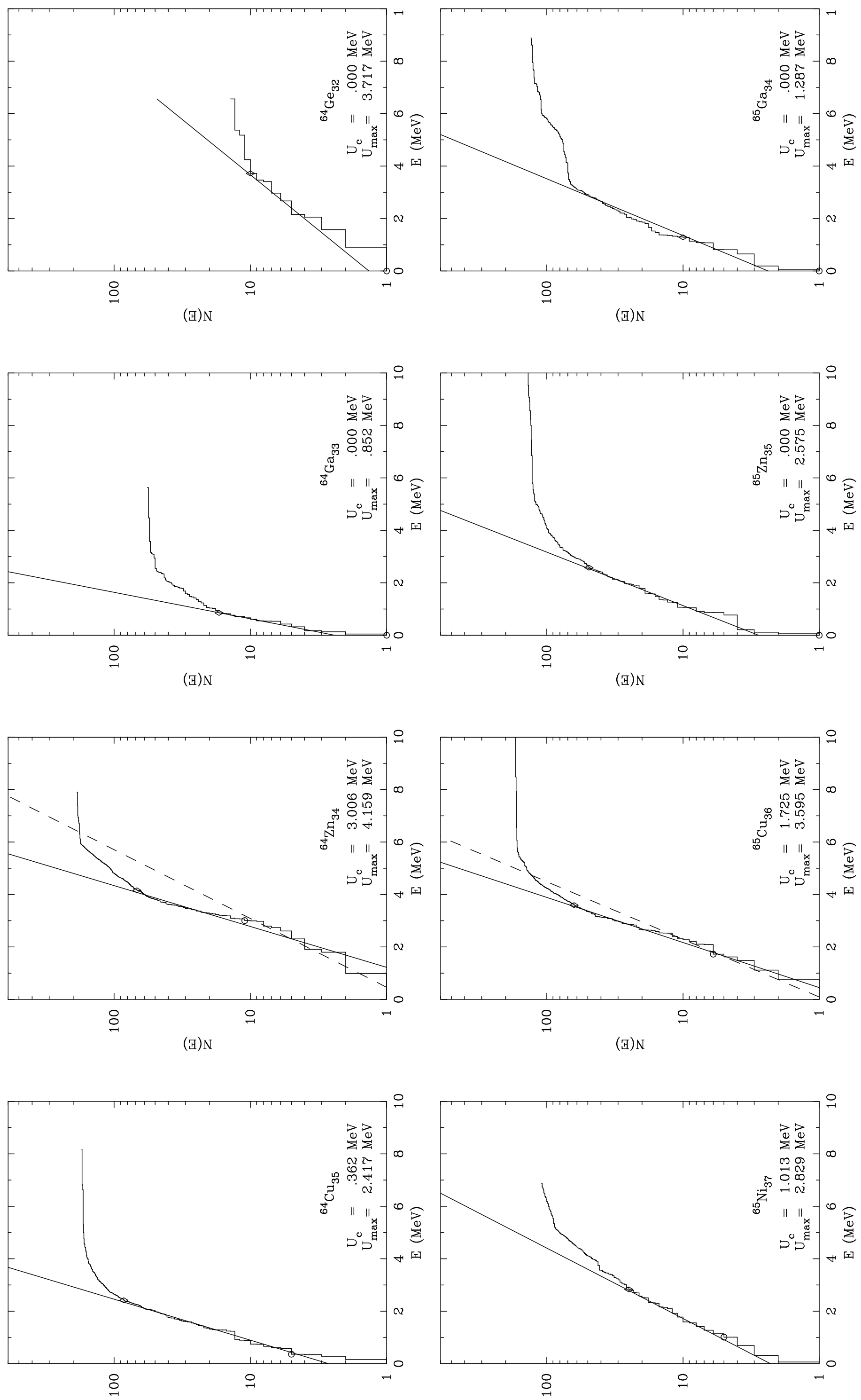

Figure 2.1: Sample histogram plots of cumulative number of levels versus excitation energy.

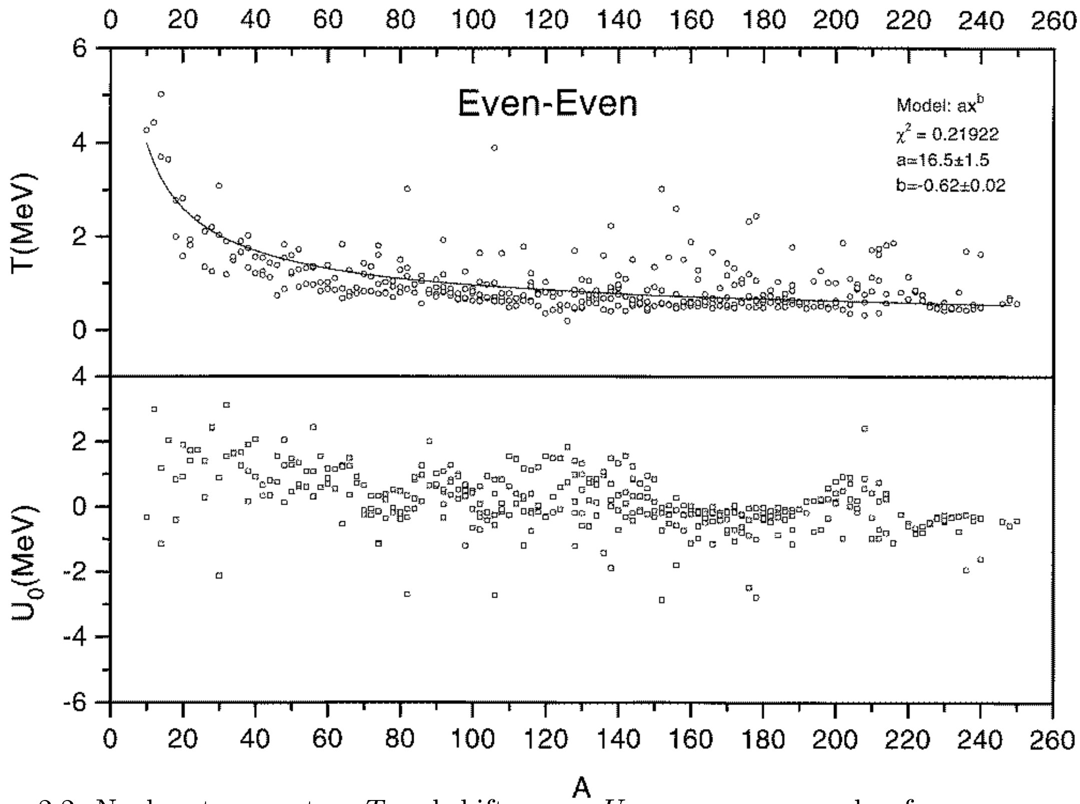

Figure 2.2: Nuclear temperature T and shift energy U_0 versus mass number for even-even nuclei.

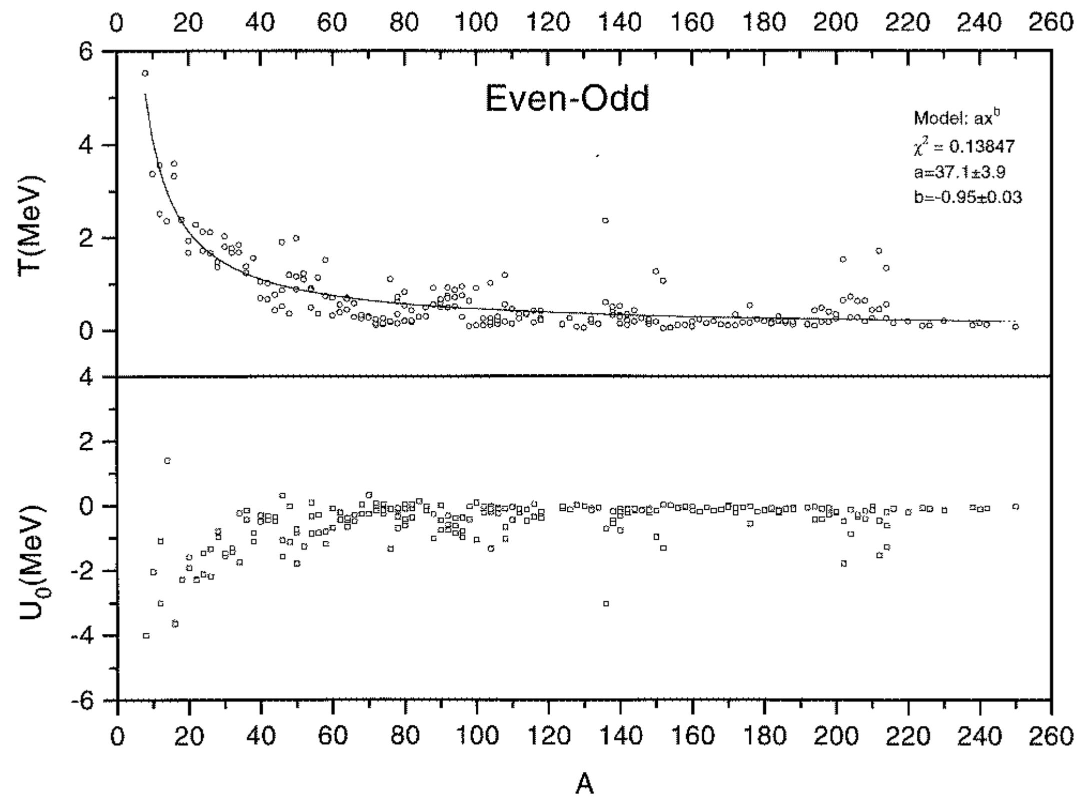

Figure 2.3: Nuclear temperature T and shift energy U_0 versus mass number for even-odd nuclei.

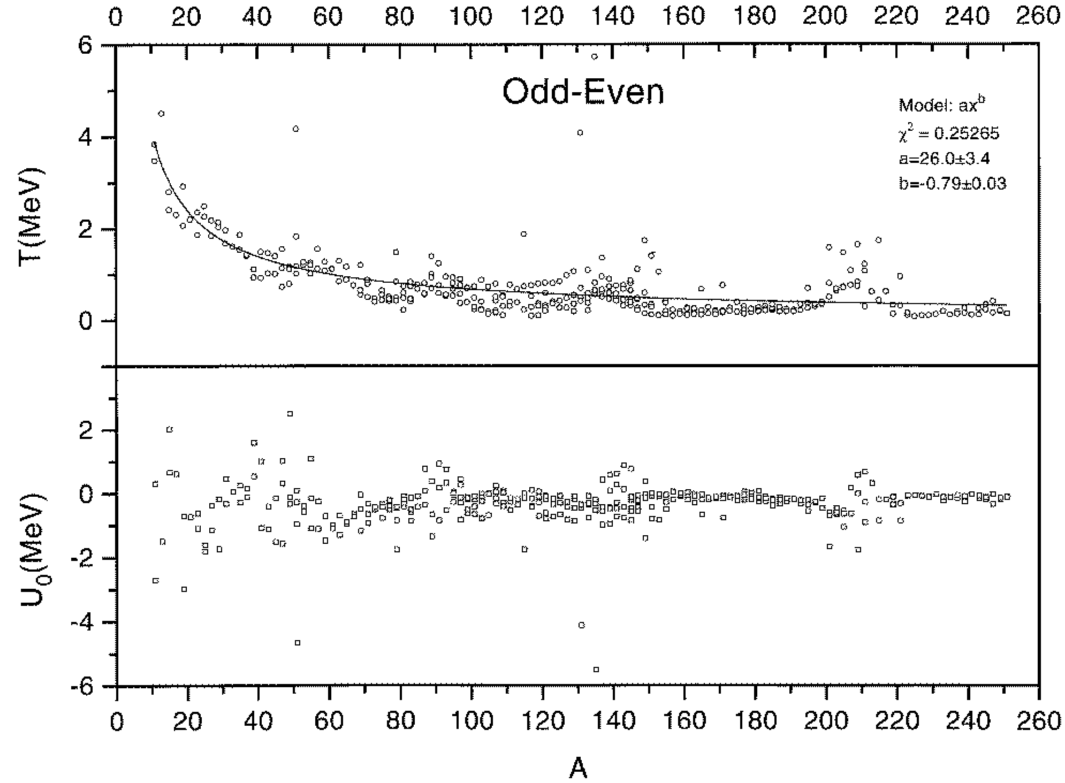

Figure 2.4: Nuclear temperature T and shift energy U_0 versus mass number for odd-even nuclei.

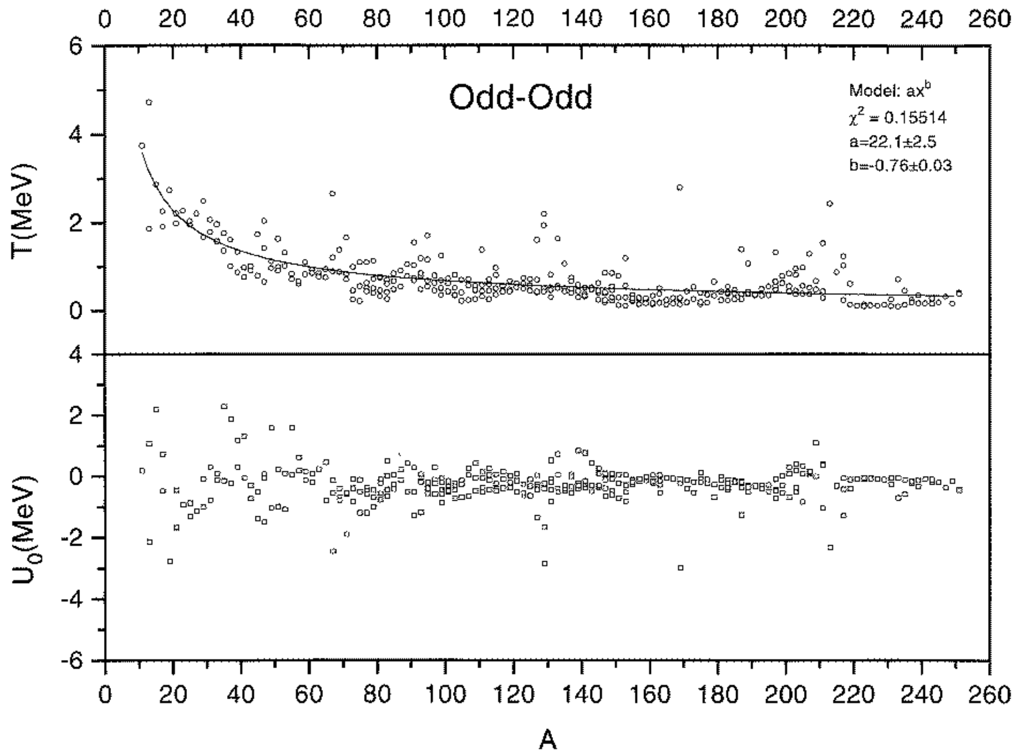

Figure 2.5: Nuclear temperature T and shift energy U_0 versus mass number for odd-odd nuclei.

Plots of nuclear temperature T and backshift energy U_0 against mass number have been created separately for even-even, odd-even, even-odd and odd-odd nuclei using the results from Table 2.2. The data points have been fitted (unweighted) with power trend lines. The corresponding plots are shown in Figs. 2.2 to 2.5 where the fitted power functions are also indicated.

Needless to say that the applied model is very crude and it has been meant only for finding an approximate cutoff energy for each nucleus in a uniform manner. **It should not be considered as a uniformly valid model for level density, nor should the parameters** T **and** U_0, determined with eq. (2.1), **be taken for "real" nuclear temperatures and backshift energies**. Nevertheless, they are indicative in that they show some regularity with mass, resembling the behavior of analogous parameters from more physical models (see Figs. 2.2 to 2.5).

2.2.3 Format

The discrete levels database, created at Budapest, contains *96,834 levels* and 108,345 placed gamma rays, in *2,585 nuclides*. In a final step, it has been converted into an ASCII file having the extended Bologna format, specified elsewhere [2.4]. The format and contents of the resulting Discrete Level Schemes Segment are described below.

In order to perform the conversion to Bologna format, the levels for each nuclide had to be numbered first. As in the Bologna format the final levels are identified by their two-digit integer serial number, the sets of gammas had to be truncated to keep the serial number of *final levels below 100* for each individual nuclide. (There is no limit to the number of initial levels, however.) Similarly, for branching percentages also only two digit integer numbers (100% is given as 00) are allowed by the Bologna format. Therefore all branching values had to be rounded to integers, and gammas with branchings below 0.5% had to be deleted. The truncation has affected 2,922 gammas, reducing their total number to *105,423 gamma rays.*

Level spins and parities have been included in the file. In cases of multiple spin choices tentative values have been inferred according to the following rule: out of two alternative spins the higher value, out of three the middle value has been adopted. For the rest of cases no spin values were given at all, and no attempts were made to infer parities either. Separate flags mark uncertain or undefined spin and parity, respectively. The extended Bologna format also allows the inclusion of half-lives. Those excited levels with half-lives greater than one second have been flagged as isomers. Detailed statistics are given in Table 2.3.

Finally, the *cumulative level numbers* N_{max}, corresponding to the cutoff energies U_{max} have also been included in the file for those 1,277 nuclides which have at least ten known levels. On the other hand, the cumulative level numbers N_c, associated with the upper energy limit U_c for levels characterized by unique spin and parity values, have been included for every nuclide.

The Budapest Discrete Level Schemes Segment consists of three files:

1. **budapest_levels.dat** - the actual segment, ASCII text file with 132-character lines, about 5 Mbyte size;
   first version: 16 November 1996, last modified: 15 September 1997
2. **budapest_cumulative.dat** - ASCII table of the fitted cumulative numbers, cutoff energies and level density parameters;
   first version: 16 November 1996, last modified: 15 September 1997
3. **budapest.readme** - describes the Segment's format, contains illustrative example;
   first version: 16 November 1996, last modified: 15 September 1997

The latter file describing the format is reproduced in Table 2.4 for convenience.

Table 2.3: Data statistics for the Discrete Level Schemes Segment file **budapest_levels.dat**.

Mass region	Nuclei #	Stable nuclei #	Level #	Gamma #	Spin No. unamb.	Parity # unamb.	J^π unamb.
1-10	36	8	245	31	131	145	129
11-20	62	10	2,206	1,211	1,123	1,157	1,089
21-30	86	10	3,047	3,929	1,468	1,687	1,368
31-40	97	13	3,238	3,573	1,321	1,722	1,236
41-50	111	14	5,192	4,332	1,473	1,870	1,357
51-60	107	12	6,767	4,863	1,783	2,079	1,656
61-70	100	12	4,251	3,563	933	1,141	858
71-80	109	14	4,699	5,577	919	1,266	869
81-90	113	14	4,703	4,788	877	1,241	862
91-100	119	17	5,491	6,076	979	1,420	907
101-110	126	13	4,547	5,870	1,114	1,391	1,030
111-120	119	16	4,279	4,858	1,023	1,287	994
121-130	119	18	4,564	4,591	606	945	564
131-140	119	15	4,653	6,635	963	1,192	888
141-150	139	15	5,571	6,546	1,475	1,688	1,312
151-160	124	14	5,777	8,434	2,155	2,296	2,058
161-170	118	13	5,436	6,617	1,662	2,013	1,594
171-180	109	14	4,784	5,132	833	1,084	783
181-190	94	14	4,258	5,593	916	1,498	875
191-200	75	13	3,034	3,872	623	920	615
201-210	97	11	4,323	4,013	1,155	1,618	1,088
211-220	85	0	1,315	1,049	254	327	246
221-230	77	0	1,063	1,502	225	309	217
231-240	76	4	2,165	2,040	606	658	575
241-250	58	1	965	600	170	197	164
251-260	71	0	221	128	39	42	39
261-270	39	0	40	0	9	9	9
All	2,585	285	96,834	105,423	24,835	31,202	23,382

2.3 Other Files

In the course of the present project several other discrete level schemes files have been provided by the participants of the RIPL project. These are characterized briefly below. The list goes according to laboratory. Description of the actual file formats may be found in the accompanying README files.

- File: *beijing.dat*
  Provided by Su Zongdi, as of 1 February 1996
  Chinese Nuclear Data Center, CIAE Beijing, China

  The Chinese Segment of Discrete Level Schemes and Gamma-Ray Branching Ratios, CENPL-DLS.1, contains a data file and a management-retrieval code system [2.10]. It is part of the Chinese Evaluated Nuclear Parameter Library, CENPL, version 1, as of 12 October 1995. Contains data for 79,461 levels and 93,177 gamma rays in 1,908 nuclides, originating from the 1991 version of ENSDF [2.2].

Table 2.4: Format description for the Discrete Level Schemes Segment file **budapest_levels.dat**, including an example.

```
IAEA Project RIPL - Phase I (1994/97)
DISCRETE LEVEL SCHEMES SUBLIBRARY - Version 1996
Prepared by: J. Ostor, T. Belgya and G. Molnar,
Institute of Isotopes, Budapest, Hungary
Format: ASCII, 132 characters per line
Data format: extended version of original Bologna format
by G. Reffo et al. (ENEA Bologna, Italy)

1. First line

Number of levels (format I5); 18 blanks; mass, charge, 0 (format 3I3);
40 characters for bibliographic information

2. Second line - new!

Level number for cutoff Umax,
level number for spin/parity cutoff Uc (blank if not available, format 2I3); 23 blanks;
                                                                              0 (format I3)

3. All other lines

Col 1: * flag = uncertain parity (blank otherwise)
Col 2-4: parity (+1 or -1 or blank, format I3)
Col 5-13: level energy in MeV (format F8.5)
Col 14-20: spin (format F8.5)
Col 21: X flag = isomeric level
Col 22: * flag = uncertain energy - not used!
Col 23: * flag = uncertain spin
Col 24-32: mass, charge, level number (format 3I3)
Col 33-112: data for 18 gamma decay events (format 18I4;
first 2 digits = number of final level, second 2 digits = branching percentage
                                                          /100 percent given as 00)
Col 113-119 : level half-life in seconds (scientific format)
---------------------------------------------------------------------------

Example: Co-60

  286                  60 27  0*** FROM NUDAT 1996 FEB 23
 10 10                        0
   1 0       5         60 27  1                   ...           4.017E7
   1 .05859  2      X  60 27  2 100               ...           6.28E2
   1 .2772   4         60 27  3
   1 .2884   3         60 27  4 200
   1 .43571  5         60 27  5 139 361
   1 .5062   3         60 27  6 299 4 1
   1 .54282  2         60 27  7 200
   1 .61455  3         60 27  8 296 3 4
   1 .7388   1         60 27  9 259 741
   1 .78571  4         60 27 10 153 444 5 2 8 1   ...           3.2E-12
*    .94             * 60 27 11
*    1.00391         * 60 27 12 249 323 4 2 726
*    1.0058  4         60 27 13 1 6 440 85110 2
*    1.13198         * 60 27 14 900
*  1 1.1507          * 60 27 15 400
   1 1.20783 5         60 27 16 129 371
   1 1.21645 6         60 27 17 100               ...           2.8E-13
...
```

- File: *bologna.dat*
  Provided by G. Reffo, as of 15 November 1995
  Nuclear Data Centre, ENEA Bologna, Italy

  The Bologna Nuclear Level File, BNLF, contains 81916 levels for 2258 nuclei and has a size of 3.26 Mbytes. It replaces the older Bologna file LIVELLI [2.5], version 1993-1994. Data were extracted from ENSDF [2.2] using the conversion code JANUS and stored in the old Bologna format. Uncertain or redundant data have been marked by warning asterisks.

  In the new file the maximal number of levels per nucleus is still limited to 99. Data affected by this truncation, as well as data for nuclei where the translation has failed, have been preserved in separate files.

- Files: *obninsk_levels.dat* and *obninsk_branchings.dat*
  Provided by A. V. Ignatyuk, as of 28 October 1994
  Nuclear Data Center, FEI Obninsk, Russia

  The evaluated data segment of discrete levels and branching ratio data from Obninsk consists of two files.

  The first version of the segment Schemes of Experimental Discrete Levels (SEDL) was prepared in 1989 [2.12]. Usage of SEDL in applied and fundamental fields shows that some improvements of the file are desirable. For example, more than 50 levels and lists of possible level spins must be added into the file. A modern version of the segment [2.13] contains experimental schemes (extracted from ENSDF [2.2]) for nuclei with $21 < A < 250$ (1170 nuclides): energy, spin and parity of levels (up to 400 levels in a nuclide).

  To provide input data for isomer yield calculations the SEDL-RADA file has been prepared [2.13]. In the current version of the file the following data are included for each nuclide: energy, spin and parity of γ-decaying levels, number of γ-transitions, number of final levels and the branching ratio for each transition.

- File: *jaeri.dat*
  Provided by T. Fukahori, as of 15 September 1997.
  Nuclear Data Center, JAERI Tokai-mura, Japan

  Discrete level scheme data for 644 nuclei from $^{4}_{2}$He to $^{255}_{100}$Fm were taken from ENSDF and were slightly modified for use in the Japanese Evaluated Nuclear Data Library (JENDL-3) evaluation. Level energies, spins and parities for 12109 levels are included. For some levels gamma-ray branching ratios are also given. A comparison with the LIVELLI file [2.5] of Bologna has shown no significant differences for overlapping nuclei.

  Basically, the level scheme data form part of the Evaluation Data File, EVLDF, which is mainly used in the Integrated Nuclear Data Evaluation System (INDES) to provide basic input parameters for various theoretical model codes. Description of the format is available in Ref. [2.11].

- File: *livermore.dat*
  Provided by M. B. Chadwick, as of 1 November 1994.
  LLNL Livermore, USA

  The Livermore Biological File of Discrete Levels contains information on discrete levels for $A < 18$ nuclei, from ^{4}He to ^{17}F. The number of the maximum level below which information on energy, spin and parity of levels was judged "complete" and the corresponding cutoff energy have been obtained from a level density analysis at Livermore in 1993, using evaluations by F. Ajzenberg-Selove [2.14] and other compilations. Note that not every nuclide with $A < 18$ is included.

2.4 Conclusions and Recommendations

To meet the needs of nuclear reaction model calculations, as well as level density analysis, a most complete and up-to-date Discrete Level Schemes Segment has been created by the Budapest group, using the 1996 version of the Evaluated Nuclear Structure Data File ENSDF [2.2] as input data. The segment contains data for 2,585 nuclei: 96,834 levels and 105,423 gamma rays with their characteristics such as energy, spin, parity, half-life, as well as gamma-ray placements and branching percentages, respectively.

The original data were retrieved from ENSDF using the NUDAT on-line database [2.6], exported into a relational database management system, carefully checked for consistency and converted into an ASCII file. The new segment is substantially larger than any earlier file and is virtually free of ambiguous data. Moreover, it contains cutoff values indicating the limit of completeness of the level scheme for those 1,277 nuclei having at least ten known levels, as well as other cutoffs with regard to complete knowledge of spin and parity for all 2,585 nuclei included. The Segment file has the recommended extended Bologna format [2.4], which is computer readable.

For the above reasons we *recommend* that the Budapest Discrete Levels File **budapest_levels.dat**, together with the data file **budapest_cumulative.dat** containing the fitted cutoff energies and level density parameters, be selected as the Discrete Level Schemes Segment of the RIPL Starter File. The U_0 and T parameters, obtained in a simplified model, should not be taken as realistic level density parameters, however. A brief description of the contents and formats of the above Budapest files is included in the accompanying file **budapest.readme**.

As alternative choices, the libraries from Beijing, Bologna, JAERI, Obninsk and Livermore, described in section 2.3, may also be used for special applications, but with the understanding of their limitations. The relevant files are: *beijing.dat*, *bologna.dat*, *obninsk_levels.dat*, *obninsk_branchings.dat*, *jaeri.dat* and *livermore.dat*.

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