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INTERNATIONAL NUCLEAR DATA COMMITTEE

# BULLETIN OF THE DATA CENTRE OF THE LENINGRAD INSTITUTE OF NUCLEAR PHYSICS (LIYaF)

Issue 2

Translated by the IAEA

February 1976

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

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# BULLETIN OF THE DATA CENTRE OF THE LENINGRAD INSTITUTE OF NUCLEAR PHYSICS (LIYaF)

Issue 2

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# CHOICE OF FORMAT FOR THE PRESENTATION OF DATA ON NUCLEAR STRUCTURE

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When one is compiling a machine library of nuclear level schemes, the question of the format for presenting the data naturally arises. For a complete description of the properties of the excited states of a nucleus it is sufficient to know the energy of the levels, their spins and parities, the electric and magnetic moments, and the partial widths of the processes determining the formation and decay of these states. Such data are needed both for fundamental research (comparison with predictions of different nuclear models) and for applied research (calculations of radiation intensities, etc.).

Recently, it has been proposed a number of times that the ENDF and EXFOR formats for neutron data be adapted for data on nuclear structure [1]. Furthermore, the Nuclear Data Group at Oak Ridge is already using a format designed especially for describing nuclear level schemes [2]. The evaluated data published in Nuclear Data Sheets are presented in this format. It has been sufficiently formalized, but at the same time it offers the possibility of expanding the list of described quantities, which means that it can also be used for presenting the results of practical work on the structure of excited nuclear states.

The LIYaF Data Centre has attempted to use this format both for the evaluated schemes of excited nuclear states and for the results of individual practical studies. Evaluated characteristics of the levels of the $^{31}P$ nucleus and data from the work of V.L. Alekseev et al. [3] on the scheme of the excited states of $^{134}Cs$, obtained from the reaction $^{133}Cs(n,\gamma)^{134}Cs$, are presented in this format by way of example.

A detailed description of the format is given in Ref. [2]; here we give the information necessary for understanding the tables. A set of data

describing level properties determined experimentally or estimated on the basis of many reports and the transitions between them consists of a sequence of punched cards to each of which one row in a table corresponds. There are several types of card with a fixed format, certain punched card columns corresponding to each recorded quantity. The set must start with an identification card indicating the type of data (reaction, decay, gamma transitions, etc.) and must end with a blank card. The cards used carry the following information (with errors where these are known):

Q - binding energy of neutron in nucleus;

L - level energy, spin, parity and lifetime;

G - gamma transition energy, relative intensity and multipolarity;

N - normalization factor for converting relative to absolute gamma transition intensity;

I - data on K-, L- and M-conversion coefficients.

Commentaries relating to the rows of the table are given on a C card in free text. If the need arises to record data not defined by the card description, use is made of additional cards (numbered from 2 to 9) on which these data appear in textual form. For example, MOMMI = + 1.13167 6 in the second row of the table means that the magnetic moment of the ground state of $^{31}P_{\mu}$ = + (1.13167 $\pm$ 0.00006).

When necessary, the format of cards is redefined by means of an F card. In Ref. [1], the I card is not defined; it became necessary to introduce it, however, in order to describe the data on internal conversion electrons contained in Ref. [3]. In the F card, for describing the I card use was made of the designations $\alpha_K$, $\alpha_L$, $\alpha_M$, $\alpha_N$ - EKC, ELC, EMC and ENC adopted in Ref. [2]; DEKC, DELC, etc. denote the errors associated with the corresponding quantities in the units of the last sign.

The last columns of the cards are used for references to commentaries, for indicating doubtful levels and transitions, and - in the case of G cards - for identifying coincidences of a gamma transition with the preceding and subsequent cascades.

When the experimental results of practical work on nuclear structure are presented in this format, difficulties arise in connection with the recording of multiparameter tables - for example, the intensities of gamma-gamma coincidences. Similar difficulties in representing multiparameter distributions

are also inherent in the two other formats mentioned [1]. With appropriate refinement, however, the format adopted by the Nuclear Data Group at Oak Ridge can serve as a basis both for creating an international file of evaluated data on nuclear structure and for the establishment of libraries containing the results of practical work.

REFERENCES

[1] PEARLSTEIN, S., INDC(NDS) - 61/W+spec. (1974) 20.

[2] Nuclear Structure Data File, INDC(NDS) - 61/W+spec. (1974) 20.

[3] ALEKSEEV, V.L. et al., preprint LIYaF-121, Leningrad, 1974.

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26.06.1979

```
ENTRY      ER790001
TITLE      Evaluated data      31P
KEYWORDS   L,31P,LEVELS,J,PI
DATA       31P          ADOPTED LEVELS
           31P     L 0.                          1/2+
           31P  2  L                                          MOMM1=+1.13167 6
           31P     L 1266.13     12              3/2+
           31P     L 2233.8       3              5/2+
           31P     L 3134.3       4              1/2+
           31P     L 3299.0       2              5/2+
           31P     L 3414.6       3              7/2+
           31P     L 3506.1       6              3/2+
           31P     L 4190.9      10              5/2+
           31P     L 4260.4      10              3/2+
           31P     L 4431.2       4              7/2-
           31P     L 4592.3      10              3/2+
           31P     L 4634.2       8              7/2+(5/2+)
           31P     L 4783.4      11              5/2+
           31P     L 5014.9      10              3/2 (1/2-)
           31P     L 5019.2       8              1/2 (5/2+)
           31P     L 5116         2              (5/2-7/2)
           31P     L 5253         2              1/2+
           31P     L 5344         2              7/2 (5/2+)
           31P     L 5557         2              3/2+
           31P     L 5672.4      10              5/2
           31P     L 5773         3              (5/2,7/2+)
           31P     L 5892         2              9/2+(7/2+)
           31P     L 5968         2              5/2-
           31P     L 6049         7
           31P     L 6078.1      12              (7/2+,9/2+)
           31P     L 6103         3
           31P     L 6232         3
           31P     L 6332        10
           31P     L 6381         3              5/2+
           31P     L 6399.0      10              7/2
           31P     L 6459.2      10              (5/2,5/2)+
           31P     L 6499         3
           31P     L 6503         3              (7/2-,9/2)
           31P     L 6507         2
           31P     L 6594         2              9/2-
           31P     L 6610         2              5/2-
           31P     L 6792         3              (7/2-11/2)
           31P     L 6828         3              (7/2,9/2)-
           31P     L 6843         2              9/2+
           31P     L 6908         3              5/2-
           31P     L 6932         2              5/2+
           31P     L 7077         9
           31P     L 7117.7      10              CE 3/2
           31P     L 7139         3              1/2+
           31P     L 7211         4              (1/2,3/2)-
           31P     L 7316         4
           31P     L 7356         9
           31P     L 7441.4      10              CE 3/2
           31P     L 7466         3              (7/2-11/2)
           31P     L 7718         9              (5/2,5/2)+
           31P     L 7780         2              3/2-
           31P     L 7825        12
           31P     L 7850         4
           31P     L 7898         2              1/2-
           31P     L 7946         2              5/2
           31P     L 8035         2              5/2
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| | | | | |
|---|---|---|---|---|
| 31P | L | 8090 | 2 | 3/2 |
| 31P | L | 8105 | 2 | 5/2 |
| 31P | L | 8209 | 2 | 3/2 |
| 31P | L | 8226 | 2 | 7/2 |
| 31P | L | 8244 | 2 | 5/2- |
| 31P | L | 8249 | 2 | 3/2 |
| 31P | L | 8545.9 | 15 | (7/2-,9/2) |
| 31P | L | 8728 | 4 | |
| 31P | L | 9365 | 7 | |

ENTRY 60750002
TITLE Levels 134CS and photons from the reaction 133CS(N,G)
KEYWORDS R,133CS,(N,G),EG,IG,CG-COIN,CG-DELAY:L,134CS,LEVELS,J,PI,T1/2,ICC,BR
DATA

| | | | | | |
|---|---|---|---|---|---|
| 134CS | 133CS(N,G) | | | | 74AL0121 |
| 134CS C | PHOTON INTENSITY IN QUANTA PER 100 CAPTURE | | | | |
| 134CS | R | | 6E91.4 12 | | 74AL0121 |
| 134CS | N | 1.00 | 12 | | |
| 134CS | G | 662.50 | 30 | 0.44 | |
| 134CS | G | 646.57 | 16 | 0.57 | |
| 134CS | G | 645.84 | 15 | 0.55 | |
| 134CS | G | 636.20 | 20 | 0.37 | |
| 134CS | G | 633.18 | 20 | 0.45 | |
| 134CS | G | 622.17 | 15 | 0.76 | |
| 134CS | G | 558.36 | 25 | 0.27 | |
| 134CS | G | 556.785 | 50 | 0.47 | |
| 134CS | G | 547.40 | 25 | 0.19 | |
| 134CS | G | 540.716 | 50 | 0.30 | |
| 134CS | G | 529.635 | 40 | 0.80 | |
| 134CS | G | 528.62 | 10 | 0.33 | |
| 134CS | G | 524.054 | 70 | 0.41 | |
| 134CS | G | 469.22 | 10 | 0.26 | |
| 134CS | G | 467.437 | 36 | 0.28 | |
| 134CS | G | 464.464 | 20 | 0.24 | |
| 134CS | G | 461.144 | 15 | 0.22 | |
| 134CS | G | 458.808 | 60 | 0.20 | |
| 134CS | G | 452.45 | 20 | 0.10 | |
| 134CS | G | 429.800 | 35 | 0.20 | |
| 134CS | G | 426.40 | 15 | 0.08 | |
| 134CS | G | 421.63 | 20 | 0.07 | |
| 134CS | G | 421.02 | 15 | 0.08 | |
| 134CS | G | 417.332 | 18 | 0.20 | |
| 134CS | G | 414.50 | 25 | 0.07 | |
| 134CS | G | 412.50 | 20 | 0.09 | |
| 134CS | G | 408.066 | 35 | 0.29 | |
| 134CS | G | 406.779 | 30 | 0.21 | |
| 134CS | G | 405.481 | 20 | 0.19 | |
| 134CS | G | 403.10 | 15 | 0.16 | |
| 134CS | G | 386.902 | 12 | 0.41 | |
| 134CS | G | 384.384 | 60 | 0.10 | |
| 134CS | G | 383.942 | 80 | 0.081 | |
| 134CS | G | 381.495 | 25 | 0.130 | |
| 134CS | G | 370.359 | 15 | 0.09 | |
| 134CS | G | 367.884 | 12 | 0.44 | |
| 134CS | G | 365.934 | 20 | 0.31 | |
| 134CS | G | 349.80 | 10 | 0.102 | |
| 134CS | G | 347.82 | 12 | 0.05 | |
| 134CS | G | 347.172 | 6 | 0.19 | |
| 134CS | G | 345.378 | 20 | 0.18 | |
| 134CS | G | 339.818 | 15 | 0.104 | |

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```
134CS  G 336,074    60 0,098
134CS  G 335,03     10 0,041
134CS  G 322,702    35 0,068
134CS  G 316,399    20 0,077
134CS  G 310,130    35 0,05
134CS  G 309,419    11 0,19
134CS  G 294,20     12 0,071
134CS  G 290,658    30 0,063
134CS  G 289,893    12 0,047
134CS  G 274,39     20 0,022
134CS  G 272,22     11 0,21
134CS  G 267,450    30 0,064
134CS  G 266,686    36 0,028
134CS  G 260,58     12 0,070
134CS  G 257,750    50 0,043
134CS  G 254,762     9 0,174
134CS  G 240,664    13 0,105
134CS  G 224,90     10 0,039
134CS  G 207,671     6 0,23
134CS  G 194,[illegible]  11 0,197
134CS  G 190,[illegible]   5 0,096
134CS  G 184,275    60 0,035
134CS  G 184,05     10 0,030
134CS  G 177,975    25 0,059
134CS  G 149,518    10 0,154
134CS  G 146,423    25 0,[illegible]31
134CS  G 143,897     6 0,00[illegible]
134CS  G 134,247    25 0,034
134CS  G 132,762     6 0,091
134CS  G 131,177    14 0,050
134CS  G 111,219    50 0,039
134CS  G  97,560    10 0,13
134CS  G  73,570     3 0,22
134CS  G  61,168    15 0,15
134CS  G  61,117    10 0,18
134CS  L 0,0            4+                  2,046 V
134CS CL T          63DIC797
134CS  L 11,247     2  5+                   49,7 NS  12
134CS CL T          72TUC599
134CS  L 60,031     1  3+
134CS  G 60,030     1  8,5    5  M1                                          C
134CS FI EKC=22,DEKC=30,ELC=32,DELC=40,EMC=42,DEMC=50,ENC=52,DENC=60
134CS  I                3,4    3  0,48    5  0,107  9
134CS  L 130,742    3  8-                  2,899 H  5
134CS CL T          61KEC180
134CS  G 127,502    2  1,13    2  E3
134CS  I                2,64    7  3,27       0,78   2
134CS CI ELC        127,502 ASSUMED TO BE PURE E3 FOR NORMALIZATION
134CS  G 126,721    10 5,1E-4 3  M4
134CS  I                77     10
134CS  L 173,795    2  3+(2+)                                               CC
134CS  G 113,764    3  4,59    12 M1
134CS  I                0,64    4  0,079  7
134CS CI EKC        IF 114,329 IS M1
134CS  G 173,794    10 0,070
134CS  L 176,403    2  3-                  .49,7 NS  8
134CS  G 116,373    2  12,15   23 E1                                         CC
134CS  G 176,403    2  10,3    3  E1                                         C
134CS  I                0,040  1
134CS  L 176,642    1  3+                                                   C
134CS  G 116,612    1  1,22    2  E2
134CS  I                0,75    3  0,14    2  0,021  15
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134CS  L 190,264   2  4+
134CS  G 130,232   2  7,43    17 M1                                        CC
134CS  I                0,336  14 0,046  3  0,014  2
134CS  G 179,018   1  0,114   6  M1,E2                                    C
134CS  I                0,46   7
134CS  L 193,685   6  4-
134CS  G 17,29     3
134CS  G 133,591   3  0,142
134CS  G 162,391   25 0,044
134CS  G 193,717   10 0,113
134CS  L 197,755   3  3+
134CS  G 7,5                                                              S
134CS  G 24,0                                                             S
134CS  G 127,761   3  0,106
134CS  G 197,705   10 0,165
134CS  L 209,550   3  4+
134CS  G 196,302   3  3,77    9  M1,E2                                    C
134CS  I                0,127  4  0,0178 15
134CS  G 209,553   6  0,27    1  M1,E2                                    C
134CS  I                0,19   3  0,022  27
134CS CI EKC       IF 174,306, 179,018 AND 211,924 ARE M1
134CS  L 234,337   1  3+
134CS  G 44,1                                                             S
134CS  G 174,306   1  1,71    5  M1                                       CC
134CS  I                0,173  5
134CS  G 234,339   2  3,7     1  M1,E2                                    C
134CS  I                0,074  2
134CS  L 257,112   3  6-                    12,3 MS  11
134CS  G 118,365   1  1,13    2  E2                                       C
134CS  I                0,67   5  0,25   7
134CS CI ELC       IF 113,764 IS M1
134CS  G 243,864   3  2,31    6  E1                                       C
134CS  I                0,016  2  0,0035 17
134CS  L 267,737   6  5-
134CS  G 74,032    2  2,84    8  M1                                        C
134CS  I                1,4    2  0,34   3
134CS CI EKC ELC   IF 72,57 IS M1
134CS  L 271,355   2  3+
134CS  G 37,0                                                             S
134CS  G 211,321   3  0,74    3  M1,E2                                    C
134CS  I                0,18   2  0,016  4
134CS CI EKC       IF 176,402 IS E1, 211,924 IS M1
134CS CI ELC       IF 205,613, 211,924 ARE M1
134CS  G 271,353   4  0,42    1  M1,E2                                    C
134CS  I                0,074  7
134CS  L 290,968   2  3+
134CS  G 93,185    4  0,53    3  M1                                        C
134CS  I                0,83   13
134CS  G 114,327   4  0,26    1
134CS  G 117,173   9  0,23
134CS  L 344,362   3  2-
134CS  G 87,251    1  1,07    3                                           CC
134CS  I                0,75   8              0,41   5
134CS  G 205,613   2  5,63    24 M1                                       C
134CS  I                0,089  15 0,010  1
134CS CI EKC       IF 174,306 IS M1, 176,403 IS E1
134CS  L 377,104   2  3+,4+
134CS  G 142,769   2  0,37                                                C
134CS  G 186,838   3  1,09    4  M1                                       C
134CS  I                0,134  9
134CS  G 317,082   13 0,39    2  M1,E2
134CS  I                0,028  5
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134CS  L 383.064   6  6-
134CS  G 38.65     5            M1
134CS  G 119.336   30 0.05
134CS  G 371.798   15 0.32
134CS  L 434.193   5  6+
134CS  G 177.020   25 0.11
134CS  G 293.644   6  0.55   2  M1,E2
134CS  I                0.036  4
134CS  L 450.317   6  5-                                          CC
134CS  G 67.253    1  1.20   29 M1,E2
134CS  I                2.7    7  0.40   E
134CS CI EKC       IF 97.560 IS M1
134CS  G 256.642   8  0.71   2  M1,E2
134CS  I                0.059  6
134CS  G 439.025   20 0.32
134CS  G 450.315   12 1.91       (E1)
134CS  L 451.662   3  3+(4+)
134CS  G 180.085   3  0.34   1  M1,E2                             C
134CS  I                0.19   2
134CS CI EKC       IF 149.510 AND 150.787 ARE M1
134CS  G 253.670   12 0.06
134CS  G 261.180   7  1.83   5  M1,E2                             CC
134CS  I                0.088  5
134CS  G 274.96    10 0.05
134CS  G 277.646   10 0.22   1  M1,E2                             C
134CS  I                0.049  14
134CS  G 391.459   24 0.18
134CS  G 451.440   15 0.33
134CS  L 454.101   4  4+
134CS  G 219.760   9  1.31   6  M1,E2                             C
134CS  I                0.079  8
134CS  G 244.546   25 0.064
134CS  G 263.850   8  0.26   1  M1,E2                             C
134CS  I                0.045  16
134CS CI EKC       IF 256.339 IS M1
134CS  G 394.007   30 0.146
134CS  G 442.851   10 0.69
134CS  G 454.094   23 0.2
134CS  L 483.662   3  3-,4+,5-
134CS  G 307.298   3  4.15   15 M1\E2                          CC
134CS  I                0.0354 14 0.0096 5
134CS CI ELC       IF 328.018 IS M1
134CS  L 502.844   3  3+(4+)
134CS  G 211.924   20 0.07   1
134CS  G 293.290   4  0.46   2  M1,E2                             C
134CS  I                0.039  9
134CS  G 305.063   12 0.19                                        C
134CS  G 502.868   75 0.65
134CS  L 519.338   8  3+(4+)
134CS  G 142.217   50 0.023
134CS  G 285.001   10 0.15   1  M1,E2                             C
134CS  I                0.031  11
134CS CI EKC       IF 254.782 IS M1
134CS  G 309.790   15 0.64   3  M1,E2                             C
134CS  I                0.014  3
134CS  G 329.036   7  0.19   LE
134CS  G 519.291   40 0.72
134CS  L 570.908   7  4-,5-                                       CC
134CS  G 120.591   2  2.26   9  M1
134CS  I                0.45   3
134CS  G 303.107   8  0.37   2  M1,E2
134CS  G 336.47    10 0.07
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134CS  G 361,39     12 0,04
134CS  L 579,148    10 2+,3+
134CS  G 127,709    10 0,06
134CS  G 344,790    30 0,06
134CS  G 402,41     15 0,09
134CS  L 624,031    6  5-
134CS  G 189,837    4  0,29    1  M1                                  C
134CS  I                0,141   25
134CS  G 279,664    12 0,21    1  M1,E2                               C
134CS  I                0,033   14
134CS  G 356,301    10 0,021   2  M1,E2
134CS  I                0,022   3
134CS  L 634,448    5  5-,6-
134CS  G 150,787    5  0,095
134CS  G 251,397    10 0,14
134CS  G 377,326    11 0,07
134CS  L 684,506    6  3-,3+,4-,5-
134CS  G 200,844    5  0,44    1  M1,E2                               C
134CS  I                0,15    2
134CS  G 624,42     20 0,34
134CS  L 702,010    5  3-,4+,5-
134CS  G 210,347    4  1,14    4  M1,E2                               C
134CS  I                0,09    1
134CS  G 434,47     20 0,17
134CS  G 529,60     10 0,62
134CS  L 719,842    5  2-,3+,4-,5-
134CS  G 232,180    4  0,65                                          C
134CS  G 444,481    20 0,3
134CS  G 539,390    30 1,01
134CS  L 752,787    12 4-,5-
134CS  G 302,468    10 0,29    2  M1,E2                               C
134CS  G 462,052    30 0,22
134CS  G 495,68     10 0,17
134CS  L 839,909    9  5-,6-
134CS  G 269,001    6  0,65    2  M1,E2                               C
134CS  I                0,041   4
134CS CI EKC        IF 234,339 IS M1
134CS  G 663,28     25 0,36                                         C
```

UDK 539.166

# $0^+$ STATES AND ELECTRIC MONOPOLE TRANSITIONS IN ATOMIC NUCLEI

N.A. Voinova

Much experimental and theoretical work has been devoted to the study of $0^+$ states in atomic nuclei, and the interest in them is undoubtedly growing. In particular, it is known from experiments that for many deformed and transition nuclei there are two - sometimes even three - $0^+$ states below the transition energy. There is at present no single theoretical description of the various $0^+$ excitations in nuclei. A particularly large number of difficulties arises when one is describing $0^+$ excitations near and above the transition energy. Many studies have been done of the characteristics of electric monopole transitions. This is understandable, for one obtains considerable information about the form of the nucleus and its structural details.

It is known that E0 transitions are purely a penetration effect. They are non-zero only when a transition is accompanied by a change at the surface of the nucleus - i.e. when calculating the probability of such transitions one cannot use the adiabatic approximation. In nuclear models where the form of the nucleus is fixed, E0 transitions are strictly forbidden. E0 transitions can occur between nuclear states having the same spin and parity. If $I \neq 0$, M1 and E2 components usually blend in with the E0 component. In the investigation of transitions of the type $I \to 1$ for $I \neq 0$, it is not the absolute value of the monopole component which is important but that information about the structure of the nuclear levels which can be derived from study of the matrix elements of the monopole transition.

Several authors [1-4] have tried to systematize the experimental and theoretical information about excited states of the $0^+$ type and electric monopole transitions. However, Refs [1-3] contain information only about deformed nuclei, while only the probabilities of electric monopole transitions are considered in Ref. [4]. In the present paper we have collected - from reports published up to the start of 1975 - and systematized experimental data on $0^+$ states and the characteristics of electric monopole transitions

for all even-even nuclei; the information presented in Ref. [4] is also included here. We present the energies of $0^+$ states and the probabilities of Coulomb excitation of levels from which E0 transitions have been observed. As regards the energies of $0^+$ levels, we usually indicate the papers in which the level was first reported and the latest, most reliable data; as regards the probability of E2 transitions, we present only the latest results. The table contains also values of the ratio of probabilities of E0 and E2 conversion transitions: $q^2 = W_e(E0)/W_e(E2)$. If the ratio of the K-conversion electron intensity of an E0 transition to the gamma component intensity of an E2 transition has been measured, the table contains values for $\mu_K = I_K(E0)/I_\gamma(E2)$. It should be noted that $q^2$ is usually obtained from measurements of the conversion coefficients; from measurements of the angular correlation of conversion electrons, on the other hand, it is possible to obtain q, which determines the ratio of the amplitudes of the E0 and E2 components of the conversion electrons. Since $e\gamma$ angular correlation measurements enable one to determine not only the value but also the sign of q, the table contains also values of q with the sign in cases where they have been measured. From the experimental value of q it is possible to calculate the value of the nuclear matrix element of penetration:

$$\rho(E0) = q\sqrt{\frac{\alpha(E2)\,W_\gamma(E2)}{\Omega(Z,k)}} \quad .$$

In a mixed E0 + M1 + E2 transition, the M1 conversion process may depend on the penetration effect. The table contains values of $\lambda$ characterizing the penetration effect in the M1 component. Lastly, the table contains values of the dimensionless parameter X introduced by Rasmussen [5]:

$$X = \frac{B(E0,\ 0_K^+ \rightarrow 0_I^+)}{B(E2,\ 0_K^+ \rightarrow 2_I^+)} = 2{,}54 \cdot 10^9 \cdot A^{4/3} \frac{E_\gamma^5,\ \text{МэВ}}{\Omega(Z,k)}\, q^2 \alpha\ (E2),$$

$$B(E0,\ 0_K^+ \rightarrow 0_I^+) = e^2 \rho^2 R_o^4 \qquad \text{where}$$

$R_o$ - radius of nucleus,

$0_k^+$ - $0^+$ level with number k,

$0_1^+$ - ground state of nucleus.

For transitions between zero-spin levels, the table gives the ratio

$$X = \frac{B(E0, I_k \rightarrow I_1)}{B(E2, I_k \rightarrow I_1)} ,$$

here the spins of the k-th and the 1st level are equal. Both these ratios re denoted by X in the table. If experimentalists have determined the atios of the probabilities of other E0 and E2 transitions, they are specially oted in the table. For the 0.586 MeV E0 + E2 transition of the 0.931 MeV $2^+$ evel of $^{152}$Gd, for example, the ratio B(E0)/B(E2, 22→01) is given. This enotes the relation between the given probability of an E0 transition from he $2^+$ level in question to the level of the fundamental rotation band $2^+$ nd the B(E2) value of a transition from a second excited state of type $2^+$ o the ground state of the $^{152}$Gd nucleus. Occasionally we have determined he ratio of B(E0) to the sum of the given probabilities of E2 transitions rom the level under consideration to the level of the fundamental rotation and. Such ratios appear as B(E0)/sB(E2)in the table.

The table has 11 columns:

1-3 - Isotope

4 - Level energy, in MeV

5 - Quantum characteristics of level

6 - Energy of transition in question, in MeV

7 - Multipolarity of transition

8 - Quantity represented:

| | |
|---|---|
| QSQ | - $q^2$, |
| Q | - $q$, |
| IK(E0)/IG(E2) | - $\mu_k$, |
| RHO | - $\varrho(E0)$, |
| X | - X, |
| E | - $\sqrt{X}$, |
| B(E2)U | - B(E2)↑, |
| LAMBDA | - $\lambda$. |

9 & 10 - Numerical value of the quantity and the associated error, in units of the last sign. The numbers in parentheses denote an order of magnitude; for example, 1.78(-2) means $1.78 \times 10^{-2}$. Values of B(E2) are given in $e^2 \cdot barn^2$.

11 - Work in which given quantity is measured.

Experimental data on $^{152}Gd$ are presented for purposes of illustration. The levels are given in order of rising energy; the transitions from each level are given in order of decreasing energy.

Experimental data on $0^+$ states and electric monopole transitions in even-even atomic nuclei are recorded on magnetic tape at the LIYaF Data Centre.

REFERENCES

[1] DZHELEPOV, B.S., SHESTOPALOVA, S.A., Proc. Dubna Symp. Nucl. Instr. 1968, IAEA, Vienna (1968) 39.

[2] BJORNHOLM, S., Nuclear excitations in even isotopes of the heaviest elements, Thesis, Munksgaard, Copenhagen (1965).

[3] PYATOV, N.I., preprint P4-5422, Dubna (1970).

[4] ALDUSHCHENKOV, A.V., VOINOVA, N.A., Nucl. Data Tables, A11 (1973) 299.

[5] RASMUSSEN, J.O., Nucl. Phys., 19 (1960) 85.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 64 | GD | 152 | 0.615 0+ | 0.615 E0 | IK(E0)/IG(E2) | 1.31(-1) | 10 | 71Z00513 |
| 64 | GD | 152 | 0.615 0+ | 0.615 E0 | X | 1.5(-2) | | 60TO03[illegible] |
| 64 | GD | 152 | 0.615 0+ | 0.615 E0 | X | 1.05(-2) | | 61HA17[illegible] |
| 64 | GR | 152 | 0.615 0+ | 0.615 E0 | X | 1.04(-2) | | 67GR0585 |
| 64 | GD | 152 | 0.615 0+ | 0.615 E0 | X | 1.3(-2) | 1 | 71Z00513 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | IK(E0)/IG(E2) | 1.2(-2) | 1 | 71Z00513 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | QSQ | 4.2(0) | 10 | 69MU0592 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+M1+E2 | Q | >= 3.55(-1) <= 1.195(0) | | 72KA0615 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+M1+E2 | LAMBDA | >= -1.38(+2) <= +2.5(+1) | | 72KA0615 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | X | 1.1(0) | | 60TO0389 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | X | 1(-1) | | 63LU0042 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | X | 5(-2) | | 67GR0585 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | X | 6.0(-2) | 4 | 71Z00513 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | B(E0)/B(E2,22-02) | 5.5(-3) | | 60TO0389 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | B(E0)/B(E2,22-01) | 2.8(0) | | 67GR0585 |
| 64 | GD | 152 | 0.931 2+ | 0.586 E0+E2 | B(E0)/B(E2,22-02) | 1.5(-2) | | 67GR0585 |
| 64 | GD | 152 | 1.048 0+ | | | | | 71FL1285 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | | | | 69AD0109 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | IK(E0)/IG(E2) | 1.2(-2) | 2 | 71Z00513 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | X | >= 2.5(-1) | | 60TO0389 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | X | 6.7(-2) | | 61HA17[illegible] |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | X | > 6.2(-2) | | 67GR0585 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | X | 8.7(-2) | 15 | 71Z00513 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | B(E0,03-02)/B(E0,03-01) | 2.8(+1) | | 60TO0389 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | B(E0,03-02)/B(E0,03-01) | 6.3(+1) | | 61HA17[illegible] |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | B(E0,03-02)/B(E0,03-01) | 5.9(+1) | | 67GR0585 |
| 64 | GD | 152 | 1.048 0+ | 1.048 E0 | B(E0,03-02)/B(E2,03-02) | 1.5(-2) | | 67GD050[illegible] |
| 64 | GD | 152 | 1.048 0+ | 1.048 E | B(E0)/B(E2,03-22) | 1.25(-4) | | 67GR0585 |
| 64 | GD | 152 | 1.048 0+ | 0.4325E0 | IK(E0)/IG(E2) | 8.8(0) | 24 | 71Z00513 |
| 64 | GD | 152 | 1.048 0+ | 0.4325E0 | B(E0)/B(E2,03-22) | 1.7(-2) | 5 | 71Z00513 |
| 64 | GD | 152 | 1.053 0+ | | | | | 72EL0473 |
| 64 | GD | 152 | 1.109 2+ | 0.764 E0+E2 | QSQ | 2.5(0) | 11 | 69MU0592 |
| 64 | GD | 152 | 1.282 4+ | 0.5269E0+E2 | IK(E0)/IG(E2) | 7.3(-2) | 7 | 71Z00513 |
| 64 | GD | 152 | 1.282 4+ | 0.5269E0+E2 | X | 2.34(-1) | 23 | 71Z00513 |
| 64 | GD | 152 | 1.31842+ | 0.9741E0+E2 | IK(E0)/IG(E2) | 2.4(-3) | 3 | 71Z00513 |
| 64 | GD | 152 | 1.31842+ | 0.9741E0+E2 | X | 8.8(-2) | 11 | 71Z00513 |
| 64 | GD | 152 | 1.31842+ | 0.3878E0+E2 | IK(E0)/IG(E2) | 3.6(-1) | 10 | 71Z00513 |
| 64 | GD | 152 | 1.31842+ | 0.3878E0+E2 | X | 3.1(-1) | 8 | 71Z00513 |
| 64 | GD | 152 | 1.484 (0+) | | | | | 69AD0109 |
| 64 | GD | 152 | 1.484 (0+) | 1.484 E0 | | | | 67GR0585 |
| 64 | GD | 152 | 1.862 2+ | 0.5437E0+E2 | IK(E0)/IG(E2) | 2.6(-1) | 5 | 71Z00513 |
| 64 | GD | 152 | 1.862 2+ | 0.5437E0+E2 | X . | 9.3(-1) | 18 | 71Z00513 |
| 64 | GD | 152 | 2.721 (0+) | 2.721 E0 | | | | 67GR0585 |

UDK 539.166.3

# TABLE OF NUCLEAR LEVEL LIFETIMES

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Yu.N. Novikov, Yu.V. Sergeenkov

The table of lifetimes includes experimental data obtained from direct and indirect measurements of the lifetimes of excited states of atomic nuclei. It is a continuation of the table contained in Ref. [1]. The data have been systematized on the basis of an information retrieval system developed by the Data Centre of the Leningrad Institute of Nuclear Physics (LIYaF) [2]. Tables with data published up to the start of 1974 have been issued in a LIYaF preprint [3].

The table contains values for the lifetimes of bound states - i.e. of nuclear levels below the binding energy of a peripheral proton and a neutron in the nucleus and, in the case of light nuclei ($Z \leq 20$), below the alpha particle binding energy.

The table has nine columns. Column 1 gives the atomic number of the element and column 2 its chemical symbol; column 3 gives the mass number; column 4 gives the energy of the excited state in MeV; column 5 indicates the quantity measured (the half-life $T_{\frac{1}{2}}$, the level width $\Gamma$, or the reduced probability, B(EL), of an electric transition of multipolarity L).

The reduced probabilities of transitions, B(EL), in the table correspond to transitions connecting ground with excited nuclear states. The values of B(EL) are given in the following units: $e^2\sigma^L = e^2 \cdot (10^{-24})^L$ cm$^2$. The EB(EL) quantities denote partial reduced probabilities of transitions.

The level width associated with a transition to the ground state of a nucleus is denoted by $\Gamma 0$. The partial width in respect of the gamma discharge of a level is represented by $\Gamma G$ and the total width by G. The G in front of the $\Gamma 0$ denotes a statistical factor and J denotes the level spin.

The half-life ($T_{\frac{1}{2}}$), level width ($\Gamma$) and reduced probability B(EL) data are presented in column 6, where the first number is the measured quantity and the number in parentheses is the order of magnitude. The values of the level half-lives is in seconds and $\Gamma$ is in eV.

Column 7 contains the measurement error in the last significant figures of the result; thus, 5.20(- 12)28 means $(5.20 \pm 0.28) \cdot 10^{-12}$.

The experimental method by which the value in column 7 is obtained is indicated in column 8 as follows:

ВИ - time measurements, including observation of the decline in radiation activity, comparison of the number of excited nuclei with the number of excited nucleus disintegration events, pulsating beam method, oscilloscope and long-range alpha methods, method of delayed coincidences of electrons and gamma rays with gamma rays, and microwave method.

КВ - Coulomb excitation of nuclei by charged particles and heavy ions.

Р4 - Particle scattering. This sympol covers work on the inelastic scattering of heavy particles and of electrons.

РР - resonance scattering of gamma rays by nuclei.

М - Mössbauer effect measurements.

Д - Doppler effect; measurements of line broadening and of "weakening of the Doppler shift" and measurements - by means of the Doppler shift - of the velocities of recoil nuclei.

П - recoil nucleus method with measurement of the recoil distance (plunger method).

The cited literature is presented in column 9.

An automatic table print-out sample is presented on the next page.

REFERENCES

[1] BERLOVICH, Eh.E., VASILENKO, S.S., NOVIKOV, Yu.N., Lifetimes of excited states of atomic nuclei (in Russian), "Nauka" (1972).

[2] KONDUROV, I.A., PETROV, Yu.N. et al., in "Bulletin of the LIYaF Data Centre", issue 1, Leningrad (1974) 19.

[3] BERLOVICH, Eh.E., VAJSHNENE, L.A. et al., preprint LIYaF-145, Leningrad (1975).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | LI | 6 | 2.180 | B(E2) | 5.5(-3) | | KB | 72OS1835 |
| 3 | LI | 6 | 3.560 | Γ | 6.5 | +24-17 | PP | 73SA0001 |
| 3 | LI | 7 | 0.477 | T1/2 | 3.8(-14) | 7 | A | 72CA0009 |
| 3 | LI | 7 | 0.477 | T1/2 | < 7(-14) | | A | 72BE0178 |
| 3 | LI | 7 | 0.477 | T1/2 | 5.5(-14) | 17 | A | 73BE0249 |
| 3 | LI | 7 | 0.4779 | B(E2) | 7.4(-4) | 1 | KB | 72BA0193 |
| 3 | LI | 7 | 0.478 | B(E2) | 8.3(-4) | 6 | K | 73HA0613 |
| 3 | LI | 8 | 0.981 | T1/2 | 9.7(-15) | 3 | A | 72CO0176 |
| 5 | B | 10 | 0.717 | T1/2 | > 4.1(-13) | | A | 72BE0178 |
| 5 | B | 11 | 2.120 | Γ | 2.3(-1) | 9 | PP | 73SA0001 |
| 5 | B | 11 | 2.120 | T1/2 | 2.0(-15) | 8 | PP | 73SA0001 |
| 5 | B | 11 | 2.120 | T1/2 | < 6.9(-14) | | A | 72NY0175 |
| 5 | B | 11 | 2.140 | T1/2 | < 7(-14) | | A | 72BE0178 |
| 5 | B | 11 | 4.440 | T1/2 | < 6.9(-14) | | A | 72NY0175 |
| 5 | B | 11 | 4.440 | Γ | 5.3(-1) | 21 | PP | 73SA0001 |
| 6 | C | 12 | 4.450 | T1/2 | < 3.5(-14) | | A | 72BE0178 |
| 6 | C | 12 | 15.109 | Γ | 3.70(+1) | 11 | P4 | 73CH0023 |
| 6 | C | 14 | 6.090 | T1/2 | < 6.9(-14) | | A | 72NY0175 |
| 6 | C | 14 | 6.89 | T1/2 | 2.5(-14) | 3 | A | 73SE0052 |
| 7 | N | 13 | | Γ | 3.615(+4) | 54 | | 73CL1770 |
| 7 | N | 14 | 2.310 | T1/2 | 5.2(-14) | 13 | A | 72RE0470 |
| 7 | N | 14 | 2.310 | T1/2 | < 6.9(-14) | | A | 72NY0175 |
| 7 | N | 14 | 2.31 | T1/2 | 7.9(-14) | 2 | A | 73HA0289 |
| 7 | N | 14 | 3.95 | T1/2 | < 1.9(-14) | | A | 73HA0289 |
| 7 | N | 14 | 3.950 | T1/2 | < 1.4(-13) | | Γ | 72NY0175 |
| 7 | N | 14 | 4.910 | T1/2 | < 1.4(-13) | | A | 72NY0175 |
| 7 | N | 14 | 4.91 | T1/2 | < 1.9(-14) | | A | 73HA0289 |
| 7 | N | 14 | 5.110 | T1/2 | > 6.9(-12) | | A | 72NY0175 |
| 7 | N | 14 | 5.690 | T1/2 | < 8.3(-15) | | A | 72RE0470 |
| 7 | N | 14 | 5.690 | T1/2 | < 6.9(-14) | | A | 72NY0175 |
| 7 | N | 14 | 5.69 | T1/2 | < 1.5(-14) | | A | 73HA0289 |
| 7 | N | 14 | 5.830 | T1/2 | > 6.9(-12) | | A | 72NY0175 |
| 7 | N | 14 | 6.20 | T1/2 | 1.40(-13) | 31 | A | 73HA0289 |
| 7 | N | 14 | 6.44 | T1/2 | 4.4(-13) | 7 | A | 73HA0289 |
| 7 | N | 15 | 7.300 | T1/2 | < 6.9(-14) | | A | 72ST0353 |
| 7 | N | 15 | 8.310 | T1/2 | < 6.9(-14) | | A | 72ST0353 |
| 7 | N | 15 | 8.570 | T1/2 | < 6.9(-14) | | A | 72ST0353 |
| 7 | N | 15 | 9.050 | T1/2 | < 6.9(-14) | | A | 72ST0353 |
| 7 | N | 15 | 9.152 | T1/2 | < 2.7(-14) | | A | 72ST0353 |
| 7 | N | 15 | 9.220 | T1/2 | < 8.9(-14) | | A | 72ST0353 |
| 7 | N | 15 | 9.930 | T1/2 | < 6.9(-14) | | A | 72ST0353 |
| 7 | N | 17 | 1.850 | T1/2 | > 2(-12) | | | 73BE0079 |
| 7 | N | 17 | 1.907 | T1/2 | > 3(-12) | | | 73BE0079 |
| 7 | N | 17 | 2.526 | T1/2 | > 2(-12) | | | 73BE0079 |
| 7 | N | 17 | 3.204 | T1/2 | < 2(-12) | | | 73BE0079 |
| 7 | N | 17 | 3.629 | T1/2 | > 1(-12) | | | 73BE0079 |
| 8 | O | 16 | 6.05 | T1/2 | 6.7(-11) | 5 | BИ | 73BI0217 |
| 8 | O | 16 | 6.13 | T1/2 | 1.84(-11) | 5 | BИ | 73BR0617 |
| 8 | O | 16 | 6.92 | Γ | 1.30(-1) | 9 | P4 | 73BE0609 |
| 8 | O | 16 | 9.85 | Γ | 8.8(-3) | 17 | P4 | 73BE0609 |
| 8 | O | 16 | 10.34 | Γ | 5.6(-8) | 20 | P4 | 73BE0609 |
| 8 | O | 16 | 11.52 | Γ | 6.1(-1) | 2 | P4 | 73BE0232 |
| 8 | O | 18 | 1.980 | T1/2 | 2.25(-12) | 37 | | 73OL2239 |
| 8 | O | 18 | 1.982 | T1/2 | 2.25(-12) | 14 | | 73MC0013 |
| 8 | O | 18 | 1.98216 | T1/2 | 2.0(-12) | +6-4 | A | 73OL2239 |
| 8 | O | 18 | 3.550 | T1/2 | < 5(-12) | | | 73OL2239 |
| 8 | O | 18 | 3.553 | T1/2 | > 3.5(-12) | | | 73MC0013 |
| 8 | O | 18 | 3.55507 | T1/2 | > 3(-12) | | A | 73OL2239 |
| 8 | O | 18 | 3.630 | T1/2 | 1.69(-12) | 35 | | 73OL2239 |
| 8 | O | 18 | 3.632 | T1/2 | 1.01(-12) | 17 | A | 73WA0418 |
| 8 | O | 18 | 3.632 | T1/2 | 9.2(-13) | 14 | | 73WA0418 |
| 8 | O | 18 | 3.65450 | T1/2 | 9.2(-13) | 14 | A | 73OL2239 |
| 8 | O | 18 | 3.920 | T1/2 | 1.0(-13) | 6 | | 73OL2239 |
| 8 | O | 18 | 3.9206 | T1/2 | 1.7(-14) | 7 | A | 73OL2239 |
| 8 | O | 18 | 4.450 | T1/2 | < 3.5(-14) | | | 73OL2239 |
| 8 | O | 18 | 4.4561 | T1/2 | 4.5(-14) | 10 | A | 73OL2239 |
| 8 | O | 18 | 5.0985 | T1/2 | 4.3(-14) | 17 | A | 73OL2239 |

UDK 539.16

# TABLE OF EXPERIMENTAL (ABSOLUTE) VALUES OF THE MOMENTS OF GROUND AND EXCITED NUCLEAR STATES

M.P. Avotina, A.V. Zolotavin

The purpose of this work is to bring together and keep up to date a file with as much data as possible on the moments of ground and excited nuclear states, so as to save the time of experimentalists and indicate a number of problems still to be solved. The file also contains the results of old work, since they have been recalculated in different compilations on the basis of different assumptions, which has created the impression that one is dealing with independent measurements. The necessity of such a detailed approach also follows from the fact that the compilations published in recent years have contained either information about nuclei obtained by some single method [1] or material collected for only a group of nuclei [2, 3] - or have contained virtually no Soviet results [4].

In the table are presented experimental (absolute) values of nuclear moments. The values published outside the Soviet Union before 1972 are taken mainly from Refs [2, 4-13]. In the case of Soviet sources, Refs [14 and 15] were used in part. Most of the data from Soviet journals is included in such a system for the first time.

The structure of the file can be understood from the following table, which contains ten columns:

| | | |
|---|---|---|
| 1-3 | Isotope | |
| 4 | Level energy, in MeV | |
| 5 | Level lifetime | |
| 6 | Designation of quantity represented: | |
| | I | level spin, |
| | MU | magnetic dipole moment in units of nuclear magnetons (in the table all MUs are corrected for diamagnetic effect), |
| | Q | observed nuclear quadrupole moment, in e · barn, |
| | MU3 | nuclear octapole magnetic moment, $\mu_3 \equiv \Omega$, in nuclear moments · barn, |
| | M7 | magnetic moment, in nuclear moments · barn$^3$, |
| | G | g-factor of state. |

| | |
|---|---|
| 7-8 | Value of quantity and associated error, in units of the last sign |
| 9 | Measurement method and comments concerning corrections made (not made) |
| 10 | Reference to original or compilation |

REFERENCES


[1] CHRISTY, A., HAUSSER, O., Nucl. Data Tables, A11 (1973) 281.

[2] International Conference on Hyperfine Interactions, Uppsala, 10-14 June (1974).

[3] ZAMYATIN, Yu.S., Jadernye konstanty (Nuclear constants), issue 14, Atomizdat (1974).

[4] FULLER, G.H., COHEN, V.W., Nucl. Data Tables, A5 (1969) 433.

[5] FRISCH, S.E., Spectroscopic determination of nuclear moments, OGIZ, Leningrad-Moscow (1948).

[6] DZHELEPOV, B.S., PEKER, L.K., SERGEEV, V.O., Decay schemes of radioactive nuclei with A > 100 (in Russian), Izd. Akad. Nauk SSSR, Moscow-Leningrad (1963).

[7] LINDGREN, I., in Perturbed angular correlations; KARLSSON, E., MATTHIAS, E., SIEGBAHN, K., Eds., North Holland Publ. Company, Amsterdam (1964) 379.

[8] LINDGREN, I., Ark. Fys., 29 (1965) 553.

[9] DZHELEPOV, B.S., PEKER, L.K., Decay schemes of radioactive nuclei with A <100 (in Russian), "Nauka", Moscow-Leningrad (1966).

[10] GRODZINS, L., Ann. Rev. Nucl. Sci., 18 (1968) 291.

[11] SHIRLEY, D.A., in Hyperfine structure and nuclear radiations; MATTHIAS, E., SHIRLEY, D., Eds. (1968).

[12] KHRYNKEVICH, A.Z., Fiz. elementar. chastits i atom. yadra (Physics of elementary particles and of the atomic nucleus) 2 (1971) 355.

[13] Proc. Int. Conf. Nucl. Moments and Nucl. Struct., HORIE, H., SUGIMOTO, K., Eds., Osaka (1972). Suppl. to J. Phys. Soc. Japan, 34 (1973).

[14] ARTAMONOVA, K.P., SERGEEV, V.O., Soviet work in nuclear spectroscopy; bibliographic index 1917-1960 (in Russian), Biblioteka Akad. Nauk SSSR, Leningrad (1965).

[15] VOROB'EV, V.D., Soviet work in nuclear spectroscopy; bibliographic index 1961-1965, Biblioteka Akad. Nauk SSSR, Leningrad (1968).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 38 | SR 86 | 1.0772 | | I | 2 | | AC | 62YA0068 |
| 38 | SR 86 | 2.232 | | I | 4 | | AC | 62YA0068 |
| 38 | SR 86 | 2.996 | | I | 3 | | AC | 62YA0068 |
| 38 | SR 86 | 3.003 | | I | (3) | | AC | 62YA0068 |
| 38 | SR 86 | 3.644 | | I | 3 | | AC | 73BE0048 |
| 44 | RU 101 | 0 | | I | 5/2 | | ESR | 52GR0951 |
| 44 | RU 101 | 0 | | I | 5/2 | | O | 55MU0919 |
| 44 | RU 101 | 0 | | MU | -0.69 | 15 | O | 55MU0919 |
| 44 | RU 101 | 0 | | MU | -0.68 | 3 | O | 65LI0553 |
| 44 | RU 101 | 0 | | MU | -0.68 | 3 | MO | 66KI0990 |
| 44 | RU 101 | 0 | | MU | 0.698 | 24 | IMPACT | 74MU0634 |
| 44 | RU 101 | 0.127 | 5.5(-10) S | I | (3/2) | | | 66AU0367 |
| 44 | RU 101 | 0.127 | 5.5(-10) S | MU | -0.311 | 26 | IPAC | 66AU0367 |
| 82 | PB 208 | 2.6145 | 2.1(-11) S | I | 3 | | AC | 65LI0553 |
| 82 | PB 208 | 2.6145 | 2.1(-11) S | MU | 1.89 | 29 | IPAC | 72HO0034 |
| 82 | PB 208 | 2.6145 | 2.1(-11) S | Q | -1.0 | 4 | RC | 69BA1205 |
| 82 | PB 202 | 2.6145 | 2.1(-11) S | Q | -1.3 | 6 | CE | 75GU0225 |

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# LIBRARY OF PROBLEM-ORIENTED PROGRAMS FOR SOLVING PROBLEMS OF ATOMIC AND NUCLEAR PHYSICS

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The Data Centre of the Leningrad Institute of Nuclear Physics (LIYaF) is continuing work on the establishment of a library of problem-oriented programs for solving problems of atomic and nuclear physics. The programs at present available to the Data Centre are listed and described briefly below. Before giving the list, however, we would recall some general facts about the functioning of the library. ALGOL-60 [1] and FORTRAN-CERN [2] have been adopted as the official algorithmic languages. All the programs at present in the library are written for the BESM-6 computer, with the BESM-ALGOL (Computer Centre of the USSR Academy of Sciences) [3] and ALGOL-GDR [4] translators being used for ALGOL problems and one FORTRAN-DUBNA translator for FORTRAN problems. The two last-mentioned translators form part of the "Dubna" monitor system [5]. Besides its designation and the names of the authors, we give for each of the programs below a brief description and certain cataloguing data, including:

1. The program cipher, consisting of three letters and three digits. The first two letters of the cipher indicate the subject-matter of the problem to be solved, while the third letter indicates the language in which the program is written; the three digits constitute a serial number. The subject breakdown is as follows: AP - atomic physics; NP - nuclear physics; QM - quantum mechanics; CT - the purely mathematical methods used most often in physics calculations;
2. The language in which the program is written;
3. The translator for which the program is designed;
4. The program scope. When the FORTRAN-DUBNA and ALGOL-GDR translators are used, the program scope is determined on the basis of the loading instructions [5] - i.e. with allowance for all duty sub-programs of the "Dubna" monitor system. When the BESM-ALGOL translator is used, the program scope is indicated without allowance for duty sub-programs;

5. A description of the program - i.e. the literature source which describes or will describe the formulation of the problem, the method of solving it, the structure of the program, the rules for data input and the print-out text.

All programs in the Data Centre's library can be supplied on request in the form of a listing and a set of punched cards.

REFERENCES

[1] The algorithmic language ALGOL-60, revised report (in Russian), Mir, Moscow (1965).

[2] The FORTRAN language (in Russian), edited by SHIRIKOV, V.P., Dubna (1970).

[3] KUROCHKIN, V.M. et al., The BESM-6-ALGOL system (in Russian), Computer Centre of Moscow State University, Moscow (1969).

[4] HIRR, R., STROBEL, R., ALGOL in the "Dubna" monitor system (in Russian), translated from German by B.P. Primochkin, I.V. Kurchatov Institute of Atomic Energy, Moscow (1972).

[5] MAZNY, G.L., Guide for working with the "Dubna" monitor system (in Russian), Joint Nuclear Research Institute, Dubna (1972).

# I. A T O M I C  P H Y S I C S

## The "ATOM" system of mathematical aids for atomic calculations

### I. PROGRAM FOR SOLVING HARTREE-FOCK SELF-CONSISTENT FIELD EQUATIONS FOR ATOMS

| | |
|---|---|
| Cipher: | APA001 |
| Language: | ALGOL-60 |
| Translator: | BESM-ALGOL |
| Program scope: | $10110_8$ cells |
| Description: | L.V. Chernysheva, N.A. Cherepkov, V. Radoevich Preprint FTI-486, Leningrad (1975) |

The program calculates wave functions of the ground state of an atom or ion in the Hartree-Fock non-relativistic approximation. The system of self-consistent equations is solved by the method of successive refinements of functions. The solution is sought in the form of one Slater determinant or a linear combination of several determinants corresponding to a certain configuration and term.

## The "ATOM" system of mathematical aids for atomic calculations

### II. PROGRAM FOR CALCULATING THE HARTREE-FOCK WAVE FUNCTIONS OF DISCRETE AND CONTINUOUS SPECTRA IN THE FIELD OF A "FROZEN" ATOMIC CORE

| | |
|---|---|
| Cipher: | APA002 |
| Language: | ALGOL-60 |
| Translator: | BESM-ALGOL |
| Program scope: | $13001_8$ cells |
| Description: | L.V. Chernysheva, N. Cherepkov, V. Radoevich Preprint FTI-487, Leningrad (1975) |

The program calculates Hartree-Fock excited electron wave functions of discrete or continuous spectra in the field of a "frozen" atomic core - i.e. without self-consistency with the functions of the occupied states. The core + electron system can be characterized by a term or merely by the values of the projections of orbital moments and spins of electrons. The wave functions thus found are orthogonal to the occupied states. The phase is calculated for functions of the continuous spectrum.

The "ATOM" system of mathematical aids for atomic calculations

III. PROGRAM FOR CALCULATING GENERALIZED OSCILLATOR STRENGTHS OF ATOMS WITH WAVE FUNCTIONS IN THE HARTREE-FOCK APPROXIMATION AND WITH ALLOWANCE FOR MULTI-ELECTRON CORRELATIONS IN ONE TRANSITION

| | |
|---|---|
| Cipher: | APA003 |
| Language: | ALGOL-60 |
| Translator: | BESM-ALGOL |
| Program scope: | $15347_8$ cells |
| Description: | L.V. Chernysheva, M.Ya. Amusya, S.I. Sheftel<br>Preprint FTI-493, Leningrad (1975) |

The program calculates generalized oscillator strengths of atoms with wave functions in the Hartree-Fock approximation (single-particle calculation) and with allowance for multi-electron correlations in the approximation of random phases with exchange. It enables one to take into account correlations only within the framework of one transition.

The "ATOM" system of mathematical aids for atomic calculations

IV. PROGRAM FOR CALCULATING GENERALIZED OSCILLATOR STRENGTHS OF ATOMS WITH ALLOWANCE FOR MULTI-ELECTRON CORRELATIONS IN TWO TRANSITIONS

| | |
|---|---|
| Cipher: | APA004 |
| Language: | ALGOL-60 |
| Translator: | BESM-ALGOL |
| Program scope: | $20277_8$ cells |
| Description: | L.V. Chernysheva, M.Ya. Amusya, S.I. Sheftel<br>Preprint FTI-495, Leningrad (1975) |

The program calculates generalized oscillator strengths of atoms with wave functions in the Hartree-Fock approximation (single-particle calculation) and with allowance for multi-electron correlations in the approximation of random phases with exchange. It finds generalized oscillator strengths with allowance for correlations in two transitions simultaneously.

The system of programs entitled "The atom in the relativistic approximation.

THE INTERACTION OF GAMMA RADIATION AND OF THE NUCLEUS WITH THE ELECTRONS OF THE ATOM"

| | |
|---|---|
| Cipher: | APF005-012 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| System scope: | $40000_8$ cells |
| Description: | I.M. Band, M.B. Trzhaskovskaya, M.A. Listengarten (in press) |

The proposed system of programs is designed for studying atomic structures by the Hartree-Fock method in the relativistic approximation and for investigating the processes involved in the interaction of gamma radiation and of the nucleus with the electrons of the atomic shell. At present, the system comprises the following programs:

APF005: Program for calculating the self-consistency of a field of an atom in accordance with Hartree-Fock with statistical allowance for exchange in accordance with Slater in the (HFSD) relativistic approximation;

APF006: Program for making the field of an atom self-consistent in the condensed state with boundary conditions of the Wigner-Seitz type in the (HFSD) approximation;

APF007: Calculation of radial wave functions of an electron in a discrete spectrum for any set of arguments;

APF008: Calculation of radial wave functions of an electron with boundary conditions of the Wigner-Seitz type for any set of arguments;

APF009: Calculation of radial wave functions of an electron in a continuous spectrum with definite orbital and total angular moments for any set of arguments;

APF010: Calculation of amplitudes at zero and phase differences at infinity of wave functions of continuous-spectrum electrons in the self-consistent field of an atom;

APF011: Calculation of coefficients of internal conversion of gamma radiation and of conversion matrix elements in any atomic shell with the "no penetration" and "surface currents" models;

APF012: Calculation of photo-effect cross-sections in the relativistic cross-section in any atomic shell.

Within the above range of problems the system of programs will be added to and expanded. Beside the programs enumerated, each of which has an independent field of application, the system includes a number of duty programs. The system is a closed one - i.e. it does not require the use of programs not forming part of it.

# II. NUCLEAR PHYSICS

## PROGRAM FOR CALCULATING PAIR MATRIX ELEMENTS FOR VELOCITY-INDEPENDENT NUCLEAR FORCES AND THE COULOMB INTERACTION IN A SPHERICALLY SYMMETRIC OSCILLATOR BASE (jj COUPLING SCHEME)

| | |
|---|---|
| Cipher: | NPA001 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $12332_8$ cells |
| Description: | V.I. Isakov, Yu.I. Kharitonov |
| | Preprint LIYaF-47, Leningrad (1973) |

The program calculates pair matrix elements of Wigner, singlet, tensor and Coulomb forces. The base consists of two-particle wave vectors with a definite total angular momentum which are derived from single-particle wave functions of a spherically symmetric harmonic oscillator in accordance with the jj coupling scheme. The radial dependence of the forces can be in the form either of a $\delta$-function or of a Gaussian well; in the latter case, there is provision for changing the interaction radius. The program enables one to calculate pair matrix elements for any single-particle states within the limits of the shell model. The Pauli principle is not taken into account in the variant of the program.

## PROGRAM FOR CALCULATING ANTISYMMETRIC PAIR MATRIX ELEMENTS FOR VELOCITY-INDEPENDENT NUCLEAR FORCES AND THE COULOMB INTERACTION IN A SPHERICALLY SYMMETRIC OSCILLATOR BASE (jj COUPLING SCHEME)

| | |
|---|---|
| Cipher: | NPA002 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $12722_8$ cells |
| Description: | V.I. Isakov, Yu.I. Kharitonov |
| | Preprint LIYaF-47, Leningrad (1973) |

This program is a variant of program NPA001, in which the same matrix elements are calculated with respect to antisymmetric two-particle wave functions.

PROGRAM FOR CALCULATING PAIR MATRIX ELEMENTS OF CENTRAL FORCES WITH SINGLE-PARTICLE WAVE FUNCTIONS IN SAXON-WOODS POTENTIALS AND A HARMONIC OSCILLATOR

| | |
|---|---|
| Cipher: | NPFO03 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| Program scope: | $26210_8$ cells |
| Description: | S.A. Artamonov, Yu.I. Kharitonov |
| | Preprint LIYaF-69, Leningrad (1973) |

The first part of this program solves the single-particle Schrödinger equation with a Saxon-Woods potential, in which spin-orbit interaction and Coulomb potential are also taken into account. With the help of the single-particle wave functions obtained, the second part of the program constructs two-particle wave functions with a definite total angular momentum and calculates pair matrix elements of Wigner, spin-spin, singlet, triplet and Coulomb forces. The radial dependence of the forces can be in the form of a Gauss or a Yukawa potential, for which the action radius can be changed, and also in the form of a $\delta$-function. For a given set of single-particle quantum numbers the matrix elements are calculated either for a given value of the total angular momentum or for all its possible values.

PROGRAM FOR CALCULATING PAIR MATRIX ELEMENTS OF THE n-p INTERACTION PRODUCED BY CENTRAL FORCES IN DEFORMED ODD-ODD NUCLEI

| | |
|---|---|
| Cipher: | NPA004 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $12406_8$ cells |
| Description: | I.S. Guseva, Yu.I. Kharitonov |
| | Preprint LIYaF-112, Leningrad (1974) |

The program calculates pair matrix elements of Wigner and spin-spin forces. Functions describing the motion of a particle in a Nilsson potential are used as single-particle wave functions. The radial dependence of the forces can be in the form either of a Gaussian well, for which the action radius can be changed, or of a $\delta$-function. For the program to function, one must introduce as numerical material the expansion coefficients of a single-particle wave function in a deformed potential with respect to wave functions of a spherically symmetric harmonic potential.

## THE "DEPTH" PROGRAM FOR DETERMINING THE DEPTH OF A SPHERICALLY SYMMETRIC POTENTIAL FOR THE WAVE FUNCTION OF A NEUTRON WITH GIVEN QUANTUM NUMBERS

| | |
|---|---|
| Cipher: | NPF005 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| Program scope: | $13504_8$ cells |
| Description: | S.G. Ogloblin |
| | Preprint LIYaF-118, Leningrad (1974) |

The "DEPTH" program determines the depth of a spherically symmetric Saxon-Woods potential at which a neutron - in a certain discrete state or near a single-particle resonance - has a given energy E. For a discrete spectrum, the state of the neutron is defined by specifying the main quantum number N, the orbital angular momentum $\ell$ and the total angular momentum j. For a continuous spectrum, near the single-particle resonance the state of the neutron is also defined by, in addition to the above quantum numbers, the scattering phase $\delta$ - $(45° \leq \delta_{\ell j} \leq 135°)$. Besides the potential well depth, the program gives values of the radial wave function as a function of the radius.

## PAIR MATRIX ELEMENTS OF A TWO-PARTICLE SPIN-ORBIT INTERACTION IN A SPHERICALLY SYMMETRIC OSCILLATOR BASE (jj COUPLING SCHEME)

| | |
|---|---|
| Cipher: | NPA006 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $12250_8$ cells |
| Description: | V.I. Isakov, Yu.I. Kharitonov |
| | Preprint LIYaF-154, Leningrad (1975) |

The program calculates pair matrix elements of a two-particle spin-orbit interaction. The base is comprised of two-particle wave functions with a certain total angular momentum derived from single-particle wave functions of a spherically symmetric harmonic oscillator in accordance with the jj coupling scheme. The radial dependence of the forces is in the form of a Gaussian well with a variable action radius. The program enables one to calculate matrix elements both between non-symmetrized wave functions (neutron-proton interaction) and between antisymmetric wave

functions (identical nucleons). In both cases, the matrix elements can be calculated either for one specified value of the total momentum J or for all its possible values. With this variant of the program one can use single-particle wave functions with a principal oscillator quantum number $N = 2n + l \leq 7$.

RADIAL INTEGRALS OF A PAIR INTERACTION FOR GAUSS, DELTA-SHAPED AND COULOMB POTENTIALS IN AN OSCILLATOR BASE

| | |
|---|---|
| Cipher: | NPA007 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $10305_8$ cells |
| Description: | V.I. Isakov, Yu.I. Kharitonov, I.V. Nikitina (in press) |

The program calculates pair radial integrals for Gauss, delta-shaped and Coulomb potentials in a spherically symmetric oscillator base. For specified single-particle quantum numbers of the four wave functions, the radial integrals are calculated for all possible ranks, which are resolved by the selection rules attributable to the angular parts of the corresponding total matrix elements of the residual interaction. With this program, which is based on program NPA001, one can use single-particle radial functions relating to states with the principal oscillator quantum number $N = 2n + l \leq 7$.

PROBABILITIES OF ELECTROMAGNETIC TRANSITIONS IN ODD DEFORMED NUCLEI

| | |
|---|---|
| Cipher: | NPA008 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $15000_8$ cells |
| Description: | I.S. Guseva, Yu.I. Kharitonov (in press) |

The type and multipolarity (xL) of the most intense gamma transitions (not more than two) are determined on the basis of specified characteristics of the initial and final states of an odd deformed nucleus. On the basis of the Nilsson model, the reduced probabilities B(xL), the probabilities W(xL) and the partial half-lives $T_{\frac{1}{2}}$ are calculated for these electromagnetic transitions. The wave functions of the initial and final states are found by means of a sub-program which solves the Schrödinger equation with a Nilsson potential and which is one of the procedures making up the program.

Consequently, as characteristics of the initial and final states it is enough to specify the level spins, their projections onto the symmetry axis of the nucleus and the asymptotic quantum numbers of the corresponding Nilsson orbitals. Provision is made for varying the deformation parameter and other parameters of the potential.

PROBABILITIES OF ELECTROMAGNETIC TRANSITIONS IN ODD-ODD DEFORMED NUCLEI

| | |
|---|---|
| Cipher: | NPA009 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $16334_8$ cells |
| Description: | I.S. Guseva (in press) |

The type and multipolarity (xL) of the most intense transitions (not more than two) are determined on the basis of specified characteristics of the initial and final states of an odd-odd deformed nucleus. The reduced probabilities B(xL), the probabilities W(xL) and partial half-lives $T_{\frac{1}{2}}$ are calculated for these electromagnetic transitions. The single-particle wave functions of the neutron and proton are calculated by means of a sub-program which solves the Schrödinger equation with a Nilsson potential and which is one of the procedures making up the program. All possible neutron and proton wave function coupling schemes are considered. Provision is made for varying the deformation parameter and other parameters of the Nilsson potential.

PAIR MATRIX ELEMENTS OF A TWO-PARTICLE SPIN-ORBIT NEUTRON-PROTON INTERACTION (OSCILLATOR BASE)

| | |
|---|---|
| Cipher: | NPA010 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $13251_8$ cells |
| Description: | I.S. Guseva (in press) |

The program calculates pair matrix elements of a two-particle spin-orbit interaction. The base is comprised of two-particle wave functions with a certain total angular momentum derived from single-particle wave functions of a spherically symmetric harmonic oscillator in accordance with the jj coupling scheme. The radial dependence of the forces is in the form of a Gaussian well with a variable action radius. The method of calculating pair matrix elements is based on the use of Talmi-Moshinsky coefficients,

which enable one to isolate in a two-particle wave function the movement of the centre of gravity and the relative motion. This program duplicates program NPA006. Hence, the two programs, which calculate the same matrix elements but by completely different methods, can be used for mutual verification of the correctness of the calculations performed.

THE "DISP" PROGRAM FOR CALCULATING THE DISCRETE SPECTRUM OF THE INTRINSIC ENERGIES AND EIGENWAVE FUNCTIONS OF A SINGLE-PARTICLE SCHRÖDINGER EQUATION WITH A SPHERICAL POTENTIAL OF FINITE DEPTH

| | |
|---|---|
| Cipher: | NPF011 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| Program scope: | $25364_8$ cells |
| Description: | L.P. Lapina (in press) |

The "DISP" program solves a radial Schrödinger equation with a Saxon-Woods potential in which Batty-Greenlees parametrization (Nuclear Physics A 133 (1969) 673) is used. The possibility is provided of solving this equation for any other spherically symmetric potential of finite depth. With the "DISP" program it is possible to obtain the whole discrete spectrum of energies, calculate the energies of several levels for specified initial approximations and determine the radial wave function and its derivative with respect to the argument at a specified energy for one level.

THE "ME2P1H" PROGRAM FOR CALCULATING MATRIX ELEMENTS OF A RESIDUAL INTERACTION FOR STATES OF THE TYPE 2p-1h (CENTRAL FORCES)

| | |
|---|---|
| Cipher: | NPF012 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| Program scope: | $45716_8$ cells |
| Description: | S.A. Artamonov, S.G. Ogloblin (in press) |

The "ME2P1H" program is designed for calculating, in spherical nuclei, matrix elements of a residual nucleon-nucleon interaction produced by Wigner and singlet forces for states of the type 2p-1h. The radial dependence of the forces can be in the form either of a $\delta$-potential or of Gauss or Yukawa potentials. Single-particle wave functions are calculated in a Saxon-Woods potential. The wave functions of states of the type 2p-1h are constructed as follows: first the angular momenta of the particles are added, the resulting momentum then being added together with the angular momentum of the hole to the total spin of the state under consideration. There is provision for the transfer of the calculated matrix elements

to external storage (magnetic tape, drum, disk, punched cards) for further processing.

EIGENVALUES AND EIGENFUNCTIONS OF A SINGLE-PARTICLE MODEL OF A NUCLEUS WITH A FINITE DEFORMED POTENTIAL HAVING A BLURRED EDGE; SPECIFICATION OF THE SHAPE OF THE NUCLEAR SURFACE IN THE LEMNISCATE SYSTEM OF CO-ORDINATES

| | |
|---|---|
| Cipher: | NPFO13 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| Program scope: | $35633_8$ cells |
| Description: | V.V. Pashkevich, V.A. Rubchenya (in press) |

The program is designed for calculating the single-particle spectrum and eigenvectors of single-particle states in a nuclear potential of finite depth with a blurred edge. The shape of the nucleus is specified in lemniscate co-ordinates. This enables one to perform calculations for axially symmetric nuclei, the shape of which may vary from oblate to separation of the nucleus into two fragments. The eigenvalue problem is solved by the diagonalization method. Functions of a deformed, axially symmetric, oscillator potential are used as the base set of functions.

# III. QUANTUM MECHANICS

## PROGRAM FOR CALCULATING CLEBSCH-GORDAN COEFFICIENTS WITH ZERO MAGNETIC QUANTUM NUMBERS

| | |
|---|---|
| Cipher: | QMA001, QMF001 |
| Language: | ALGOL-60, FORTRAN-CERN |
| Translator: | ALGOL-GDR, FORTRAN-DUBNA |
| Program scope: | $6735_8$ and $6602_8$ cells respectively |
| Description: | S.A. Artamonov, V.I. Isakov, Yu.I. Kharitonov<br>Preprint LIYaF-73, Leningrad (1973) |

These programs enable one to calculate the values of individual Clebsch-Gordan coefficients with zero magnetic quantum numbers provided that the arithmetic sum of the angular momenta under consideration does not exceed 43. Print-out both of the initial parameters and of the computational results in tabular form is provided for. The procedures (sub-programs) making up these programs can be used as ready blocks when programming the more complex problems which contain such coefficients as component parts.

## PROGRAMS FOR CALCULATING CLEBSCH-GORDAN COEFFICIENTS OF A GENERAL FORM

| | |
|---|---|
| Cipher: | QMA002, QMF002 |
| Language: | ALGOL-60, FORTRAN-CERN |
| Translator: | ALGOL-GDR, FORTRAN-DUBNA |
| Program scope: | $7167_8$ and $7133_8$ cells respectively |
| Description: | S.A. Artamonov, V.I. Isakov, Yu.I. Kharitonov<br>Preprint LIYaF-73, Leningrad (1973) |

The programs enable one to calculate values of individual Clebsch-Gordan coefficients for specified values of three angular momenta and also their projections provided that the arithmetic sum of the angular momenta under consideration does not exceed 43. Print-out both of the initial parameters and of the computational results in tabular form is provided for. The procedures (sub-programs) making up these programs can be used as ready blocks when programming the more complex problems, which contain Clebsch-Gordan coefficients of a general form as component parts.

PROGRAMS FOR CALCULATING RACAH COEFFICIENTS

| | |
|---|---|
| Cipher: | QMA003, QMF003 |
| Language: | ALGOL-60, FORTRAN-CERN |
| Translator: | ALGOL-GDR, FORTRAN-DUBNA |
| Program scope: | $7005_8$ and $7113_8$ cells respectively |
| Description: | V.N. Guman, S.A. Artamonov, Yu.I. Kharitonov<br>Preprint LIYaF-76, Leningrad (1973) |

These programs enable one to calculate the values of individual Racah coefficients provided that the factorals n! encountered in the calculations are limited by the quantity n! = 44. This range of variations of the parameters is quite sufficient for most spectroscopic calculations. Print-out of the initial parameters and of the computational results in tabular form is provided for. The procedures (sub-programs) making up these programs can be used in solving those problems which contain Racah coefficients as component parts.

PROGRAMS FOR CALCULATING 9j-SYMBOLS

| | |
|---|---|
| Cipher: | QMA004, QMF004 |
| Language: | ALGOL-60, FORTRAN-CERN |
| Translator: | ALGOL-GDR, FORTRAN-DUBNA |
| Program scope: | $7160_8$ and $7364_8$ cells respectively |
| Description: | S.A. Artamonov, Yu.I. Kharitonov<br>Preprint LIYaF-116, Leningrad (1974) |

The program enables one to calculate individual values of 9j-symbols provided that the arithmetic sum of the angular momenta in any of the six triads does not exceed 43; this is quite sufficient for most spectroscopic calculations. Print-out of the initial parameters and of the computational results in tabular form is provided for. The procedures (sub-programs) making up these programs can be used in solving those problems which contain 9j-symbols as component parts. There is some limitation to the program for calculating 9j-symbols which forms part of the ALGOL program whose text is presented in Preprint LIYaF-116. In the Comment on the program for calculating 9j-symbols published in the present Bulletin, this question is considered in detail and the text of the corrected procedure is presented.

PROGRAM FOR CALCULATING $d^{I}_{MM'}(\beta)$ WIGNER FUNCTIONS

| | |
|---|---|
| Cipher: | QMA005 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $7435_8$ cells |
| Description: | I.S. Guseva |
| | Preprint LIYaF-124, Leningrad (1974) |

The program calculates $d^{I}_{MM'}(\beta)$ Wigner functions with given quantum numbers I, M and M' and angle $\beta$ varying through 5° intervals from 0° to 90°. Quantum numbers I, M and M' can assume whole and semi-whole values. For angles greater than 90°, d-function values are easy to obtain by using the appropriate relation presented in the preprint. Print-out of the initial parameters and of the computational results in tabular form is provided for.

THE "CFP1A" PROGRAM FOR CALCULATING GENEALOGIC COEFFICIENTS OF SEPARATION OF A SINGLE PARTICLE FOR ANTISYMMETRIC STATES OF IDENTICAL FERMIONS (jj COUPLING SCHEME)

| | |
|---|---|
| Cipher: | QMF006 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| Program scope: | $54727_8$ cells |
| Description: | S.A. Artamonov, Yu.I. Kharitonov (in press) |

The "CFP1A" program calculates genealogic coefficients of separation of a single particle (GCl) from antisymmetric states $|j^n s\alpha JM\rangle$ constructed in accordance with the jj coupling scheme and belonging to configurations of the type $\{j^n\}$. For angular momenta j = 5/2, 7/2, 9/2 and 11/2, the GCls are calculated with a number of particles n ranging from 3 to j + 1/2 for j = 13/2 with n = 3, 4 and for j = 15/2 only for three-particle states. At the same time, the GCls are calculated for all possible values of the total angular momentum J, of the seniority quantum number s and the additional quantum number $\alpha$. The GCls can be calculated either for the whole parameter variation range indicated above or for any part of it. Print-out of the computational results in the form of tables similar to those of Bayman and Lande (Nuclear Physics 77 (1966) 1) is provided for, as is external storage of the results (on magnetic tape, drum, disk, punched cards). The GCls are calculated by diagonalizing matrices of Casimir operators of a special unitary and a symplectic group.

THE "CFP1B" PROGRAM FOR CALCULATING GENEALOGIC COEFFICIENTS OF SEPARATION OF A SINGLE PARTICLE FOR ANTISYMMETRIC STATES OF IDENTICAL FERMIONS (jj COUPLING SCHEME) IN QUANTUM-MECHANICAL COMPUTATIONS

| | |
|---|---|
| Cipher: | QMF007 |
| Language: | FORTRAN-CERN |
| Translator: | FORTRAN-DUBNA |
| Program scope: | $10763_8$ cells |
| Description: | S.A. Artamonov, Yu.I. Kharitonov (in press) |

The "CFP1B" program is designed for use as a sub-program in the case of quantum-mechanical problems where it is necessary to calculate various quantities which include a GCl. The range of variation of the parameters for which GCls can be calculated is the same as in the case of program "CFP1A" (see above). Program "CFP1B" is used for economizing on internal memory, it transfers the GCls calculated by program "CFP1A" from external storage (magnetic tape, drum, disk, punched cards) into the internal memory. The transfer is effected on the basis of specified parameters which uniquely determine the desired set of GCls. The parallel print-out of GCls in tabular form is provided for.

PROGRAM FOR CALCULATING CLEBSCH-GORDAN COEFFICIENTS IN SIMPLE FRACTIONS

| | |
|---|---|
| Cipher: | QMA008 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $23462_8$ cells |
| Description: | T.V. Alenicheva (in press) |

The program enables one to calculate Clebsch-Gordan coefficients in the form $(a/b)\sqrt{c/d}$, where a is a whole number (with a sign), b, c and d are natural numbers, and a/b and c/d are irreducible fractions. The form $(a/b)\sqrt{c/d}$ is a general one; if the value obtained for the Clebsch-Gordan coefficients has an arithmetically simpler form, the corresponding simplified expression is printed out. Clebsch-Gordan coefficients in a form which is convenient for theoretical calculations by hand should if possible be used before they become cumbersome. This limits the range of variation of the initial parameters and thus determines the possibilities of the program. The present program enables one to calculate Clebsch-Gordan coefficients in the form indicated as long as the arithmetic sum of the

three momenta under consideration does not exceed 36. The values of the initial parameters and the computational results are printed out in the form indicated and also in the form of a decimal fraction.

PROGRAM FOR CALCULATING RACAH COEFFICIENTS IN SIMPLE FRACTIONS

| | |
|---|---|
| Cipher: | QMA009 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $22512_8$ cells |
| Description: | T.V. Alenicheva (in press) |

The program enables one to calculate individual Racah coefficients in the form $(a/b)\sqrt{c/d}$, where a is a whole number (with a sign), b, c and d are natural numbers, and a/b and c/d are irreducible fractions. The program is best used in cases where the arithmetic sum of the angular momenta in any of the four coefficient triads does not exceed 36. With higher triad values, the expressions for the Racah coefficients become very cumbersome and hence inconvenient for calculations by hand. The form of print-out of the initial data and the computational results is the same as in the case of program QMA008.

TALMI-MOSHINSKY TRANSFORMATION COEFFICIENTS

| | |
|---|---|
| Cipher: | QMA010 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $10358_8$ cells |
| Description: | I.S. Guseva (in press) |

This program calculates Talmi-Moshinsky transformation coefficients, which enable one to go from a description of the independent motion of two particles in the field of a three-dimensional spherically symmetric harmonic oscillator to a description of the movement of the centre of gravity of these particles and of their relative motion. Print-out of the initial parameters and of the computational results in tabular form is provided for. The program is based on a procedure-function which can be used in more complex calculations involving Talmi-Moshinsky coefficients.

PROGRAMS FOR CALCULATING 12j-SYMBOLS OF THE FIRST AND SECOND KIND

| | |
|---|---|
| Cipher: | QMA011, QMF011 |
| Language: | ALGOL-60, FORTRAN-CERN |
| Translator: | ALGOL-GDR, FORTRAN-DUBNA |
| Program scope: | $10427_8$ and $11023_8$ cells respectively |
| Description: | B.F. Gerasimenko, V.K. Khersonsky (in press) |

These programs enable one to calculate the values of individual 12j-symbols of both the first and the second kind provided that the sum of the elements in any of the eight triads which can be constructed from the parameters of a 12j-symbol does not exceed 48. The same condition must be fulfilled for a minimum value of the doubled sums of pairs of corresponding parameters of the upper and lower lines in a 12j-symbol of the first kind - or only of the lower line for a 12j-symbol of the second kind. Such a range of variation of the parameters of 12j-symbols is quite sufficient for most spectroscopic calculations. The programs can be used as sub-programs in solving problems which involve 12j-symbols. Print-out of the initial parameters and of the computational results in tabular form is provided for.

PROGRAM FOR CALCULATING $d^{I}_{MM'}(\beta)$ WIGNER FUNCTIONS

| | |
|---|---|
| Cipher: | QMA012 |
| Language: | ALGOL-60 |
| Translator: | ALGOL-GDR |
| Program scope: | $7160_8$ cells |
| Description: | I.S. Guseva<br>Preprint LIYaF-124, Leningrad (1974) |

The program calculates $d^{I}_{MM'}(\beta)$ Wigner functions with given quantum numbers I, M and M' for any range of variation of the angle $\beta$ between 0° and 90° with any given increment (or step). Quantum numbers I, M and M' can assume whole and semi-whole values. Print-out of the initial data and computational results in tabular form is provided for.

# TABLES OF ELECTRON ENERGY EIGENVALUES, DENSITIES NEAR ZERO AND MEAN VALUES IN SELF-CONSISTENT FIELDS OF ATOMS AND IONS

I.M. Band, M.B. Trzhaskovskaya

The tables contain quantities calculated in self-consistent fields of atoms and ions. Self-consistency was achieved in a relativistic variant of the Hartree-Fock-Slater method with allowance for the finite dimensions of the nucleus. The calculations were performed, both with and without Letter's correction, for many atoms and ions from helium to plutonium ($2 \leq Z \leq 94$). In the tables are presented electron energy eigenvalues, the coefficients $\tilde{N}$ associated with electron density $\varrho(r)$ near zero ($\tilde{N} = N \cdot 137.0388^{-(2j-1)}$, where $N = \lim 4\pi\varrho(r)r^{-(2j-1)}$ for $r \to 0$) and the mean values of the potential energy and the degrees of the radius $r^n$ ($n = -3, -1, 1, 2$) and also the total energy of the atom. Singly charged positive and negative ions and multiply ionized atoms were considered. In individual cases, computational results are presented for several different electron configurations of the same element.

The tables are published as LIYaF preprints:

for the elements $2 \leq Z \leq 52$ - Preprint 90, 1974;

for the elements $53 \leq Z \leq 63$ - Preprint 91, 1974;

for the elements $64 \leq Z \leq 94$ - Preprint 92, 1974.

UDK 539.144



# COMMENT ON THE PROCEDURE FOR CALCULATING 9j-SYMBOLS

B.F. Gerasimenko, Yu.I. Kharitonov

Reference [1] contains the texts of programs for calculating 9j-symbols written in ALGOL-60 and FORTRAN-IV. Practical use of these programs has revealed certain limitations of the 9j-symbol calculation procedure forming part of the ALGOL program; in this program, the 9j-symbols are calculated as the sum of the products of three Racah coefficients, the summation index being able in the general case to assume either whole or semi-whole values. In the ALGOL text in Ref. [1], on the other hand, the variant uses only whole values of the summation index. Generally speaking, in those cases where the summation index assumes semi-whole values the initial 9j-symbol may - by line or column transpositions - be reduced to a form corresponding to whole values of the summation index. Let us consider, for example, a 9j-symbol whose j parameters are semi-whole and whose L parameters are whole - i.e.

$$\begin{Bmatrix} j_1 & j_2 & L_{12} \\ j_3 & j_4 & L_{34} \\ L_{13} & L_{24} & L \end{Bmatrix} = \sum_K (2K+1) W[j_1 j_3 L L_{24}; L_{13} K] W[j_2 L_{24} L_{34} j_3; j_4 K] W[j_1 j_2 L L_{34}; L_{12} K]. \quad (1)$$

Here, the limits of variation of summation index k are determined by the conditions

$$\max \begin{bmatrix} |j_1 - L| \\ |j_2 - L_{34}| \\ |j_3 - L_{24}| \end{bmatrix} \leqslant K \leqslant \min \begin{bmatrix} j_1 + L \\ j_2 + L_{34} \\ j_3 + L_{24} \end{bmatrix}. \quad (2)$$

It follows that the index k assumes semi-whole values. On the basis of symmetry properties, the 9j-symbol determined by formula (1) can be written in the form

$$\begin{Bmatrix} j_1 & j_2 & L_{12} \\ j_3 & j_4 & L_{34} \\ L_{13} & L_{24} & L \end{Bmatrix} = \begin{Bmatrix} L_{12} & j_1 & j_2 \\ L_{34} & j_3 & j_4 \\ L & L_{13} & L_{24} \end{Bmatrix} = \sum_{K_1} (2K_1+1) W[L_{12} L_{34} L_{24} L_{13}; L K_1] \times \quad (3)$$

$$\times W[j_1 L_{13} j_4 L_{34}; j_3 K_1] W[L_{12} j_1 L_{24} j_4; j_2 K_1].$$

In this formula, summation index $k_1$ determined by the conditions

$$\max\begin{bmatrix}|L_{12}-L_{24}|\\|L_{13}-L_{34}|\\|j_1-j_4|\end{bmatrix} \leq K_1 \leq \min\begin{bmatrix}L_{12}+L_{24}\\L_{13}+L_{34}\\j_1+j_4\end{bmatrix}, \qquad (4)$$

assumes (as can be seen) whole-number values.

It should be noted that, when one uses the procedure of 9j-symbols for calculating the coefficients of transformation A{jj→LS} from the jj coupling scheme to the LS coupling scheme which are frequently encountered in nuclear calculations, the index k assumes whole values and hence in this case the procedure described in Ref. [1] gives correct results. The same applies to 9j-symbols all of whose parameters assume whole values.

Having in mind the same general case, one should regard the summation index k as a variable of the real type and hence introduce changes into the text of the 9j-symbol procedure. The corrected text of this procedure, in which the designations from Ref. [1] have been retained as far as possible, has the form

```
'REAL''PROCEDURE'J9(A,B,C,D,E,F,G,H,J);'VALUE'A,B,C,D,E,F,G,H,J;
'REAL'A,B,C,D,E,F,G,H,J;
'BEGIN''REAL'P,Q,R,K,KM,S;
S:=0;
P:=ABS(A-J);Q:=ABS(D-H);R:=ABS(B-F);
K:=P;'IF'K<Q'THEN'K:=Q;'IF'K<R'THEN'K:=R;
P:=A+J;Q:=D+H;R:=B+F;KM:=P;'IF'KM>Q'THEN'KM:=Q;
'IF'KM>R'THEN'KM:=R;KM:=KM+0.001;
'FOR'K:=K'STEP'1'UNTIL'KM'DO'
S:=S+(2*K+1)*W(A,D,J,H,G,K)*W(B,H,F,D,E,K)*
W(A,B,J,F,C,K);J9:=S 'END'J9;
```

Otherwise the ALGOL program for calculating 9j-symbols presented in Ref. [1] remains unchanged.

## REFERENCE

[1] ARTAMONOV, S.A., KHARITONOV, Yu.I., Preprint LIYaF-116, Leningrad (1974).