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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 $I \to I$ 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 λ characterizing the penetration effect in the M1 component. Lastly, the table contains values of the dimensionless parameter X introduced by Rasmussen [5]:

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

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

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

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

nere 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) - μ_k,
RHO - $\varrho(E0)$,
X - X,
E - $\sqrt{X}$,
B(E2)U - B(E2)↑,
LAMBDA - λ.

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 1.78×10^{-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.

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[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)		60TO0339
64	GD	152	0.615 0+	0.615 E0	X	1,05(-2)		61HA1738
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)		60TO0339
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)		60TO0339
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+					71FL1235
64	GD	152	1.048 0+	1.048 E0				69AD0119
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)		60TO0339
64	GD	152	1.048 0+	1.048 E0	X	6,7(-2)		61HA1738
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)		60TO0339
64	GD	152	1.048 0+	1.048 E0	B(E0,03-02)/B(E0,03-01)	6,3(+1)		61HA1738
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)		67GD0538
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