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COMPARISON OF EXPERIMENTAL AND THEORETICAL INTERNAL CONVERSION COEFFICIENTS OF OCTUPOLE TRANSITIONS

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Abstract: Total ICC of the 163.92 keV E3 transition of ^{136}Ba is determined to be 2.21(8). Twenty-six accurately measured ICCs of E3 and M3 transitions are compared with the theoretical ones of Hager and Seltzer and Rösel et al. Multiplication of the theoretical values of Rösel et al. by a factor of 0.970(15) is suggested to obtain more reliable ICCs. Discrepancies among the ICCs of Hager and Seltzer and the experimental data are revealed to be dependent on transition energy.

Introduction

When calculating the total intensity of a γ-transition the lack of accurately measured internal conversion coefficients (ICCs) are often forces the experimentalist to consider a theoretical value. Tabulated theoretical ICCs of Hager and Seltzer[1] and Rösel et al[2] are usually used for this purpose. A great number of experiments verify the reliability of these calculations for dipole and quadrupole transitions. However, comparing the theoretical ICCs of Hager and Seltzer[1] with 19 accurately measured ones, Raman et al.[3] found the experimental values of higher multipole order transitions to be 2-3% smaller. The existence of the discrepancies was recently confirmed by Németh and Veres[4], although their scale was not satisfactorily decided in the third order case.

Comparison of ICCs of octupole transitions determined with an accuracy better than 5% with the theoretical values of Rösel et al[2] is reported here for the first time. The number of entries (26) is 50% larger than in the previous paper[4]. This fact encourages us to make a new comparison with the calculations of Hager and Seltzer[1] in order to draw decisive conclusions about the third order case also. In an endeavour to enlarge the number of entries we determined the total ICC of the 163.92 keV E3 transition of ^{136}Ba using the intensity balance method. This is the first time than an accurate ICC for an isomeric transition in an even-even nuclide has been reported.

Experimental procedure and results

The level scheme of ^{136}Ba, which is shown in Fig. 1, was investigated by many authors and it is well-established[5]. In our experiment ß-decay of ^{136}Cs produced by ^{137}Ba(γ,n) and ^{138}Ba(γ,pn) reactions was used to populate the levels of ^{136}Ba. The 7^- metastable state at 2030.52 keV with a half-life of 0.3084 s[5] is fed only by two γ-transitions (and possibly by a weak ß-branch) having energies close to that of the isomeric transition. This fact strongly reduces the uncertainties caused by detector efficiency- and attenuation corrections.

A 218 mgcm^{-2} thick $BaCl_2 \cdot 2H_2O$ sample was irradiated for 8 hours by the 50 MeV bremsstrahlung of the Tohoku University LINAC. The electron beam intensity was 100 μA. γ-ray spectra were recorded by an Ortec Ge(Li) detector with an active volume of 50 cc after 2 days cooling while the short lived activities decayed. Measurement times varied between 50-60×10^3 s. The detector efficiency was determined with ^{152}Eu and ^{182}Ta sources.

The total ICC of the 164 keV transition was obtained by the intensity balance method using the expression

$$BN_\gamma^{164}(1+\alpha_T^{164}) = N_\gamma^{110}(1+\alpha_T^{110}) + N_\gamma^{177}(1+\alpha_T^{177}) \quad (1)$$

where N_γ are the respective γ-intensities corrected for efficiency and attenuation, while α_T are the relevant total ICCs. The ICCs of the 110 keV and 177 keV transitions, which are believed to be pure E2 and E1, respectively, are taken from the tables of Rösel et al[2] bearing in mind the good agreement among the experimental and theoretical ICCs for dipole and quadrupole transitions. The factor B takes into account the possible direct ß-feeding of the metastable level. Compilation of Burrows[5] suggests the intensity of that ß-branch to be less than 0.2%, which gives B=0.991(9).

Substituting the N_γ and the constants in eq. 1 we obtained α_T^{164}=2.21(8) which is 2.2±3.5% and 2.6±3.5% smaller than the theoretical value of Hager and Seltzer[1] and Rösel et al[2], respectively, which are 2.26 and 2.27, respectively. Both discrepancies are in agreement with the general trend (see below).

Discussion

Comparison of ICCs of 26 octupole transitions determined to an accuracy better than 5% with the aforementioned theoretical ones is shown in Table I. Only data with an error limit of ≤5% were used, seven entries of the previous comparison[4] are not taken into account here. The new data set makes it possible to get a clearer picture. ICCs of Rösel et al[2] tend to be 1.5-4.5% smaller than the experimental ones independent of transition energy, nuclear charge and shell. Twenty-four of the twenty-six experimental data support the hypothesis that one can obtain more reliable ICCs by multiplying the theoretical values of Rösel et al[2] by a factor of 0.970(15).

Discrepancies among the experimental data and the theoretical values of Hager and Seltzer[1] exhibit a dependence on transition energy; viz.

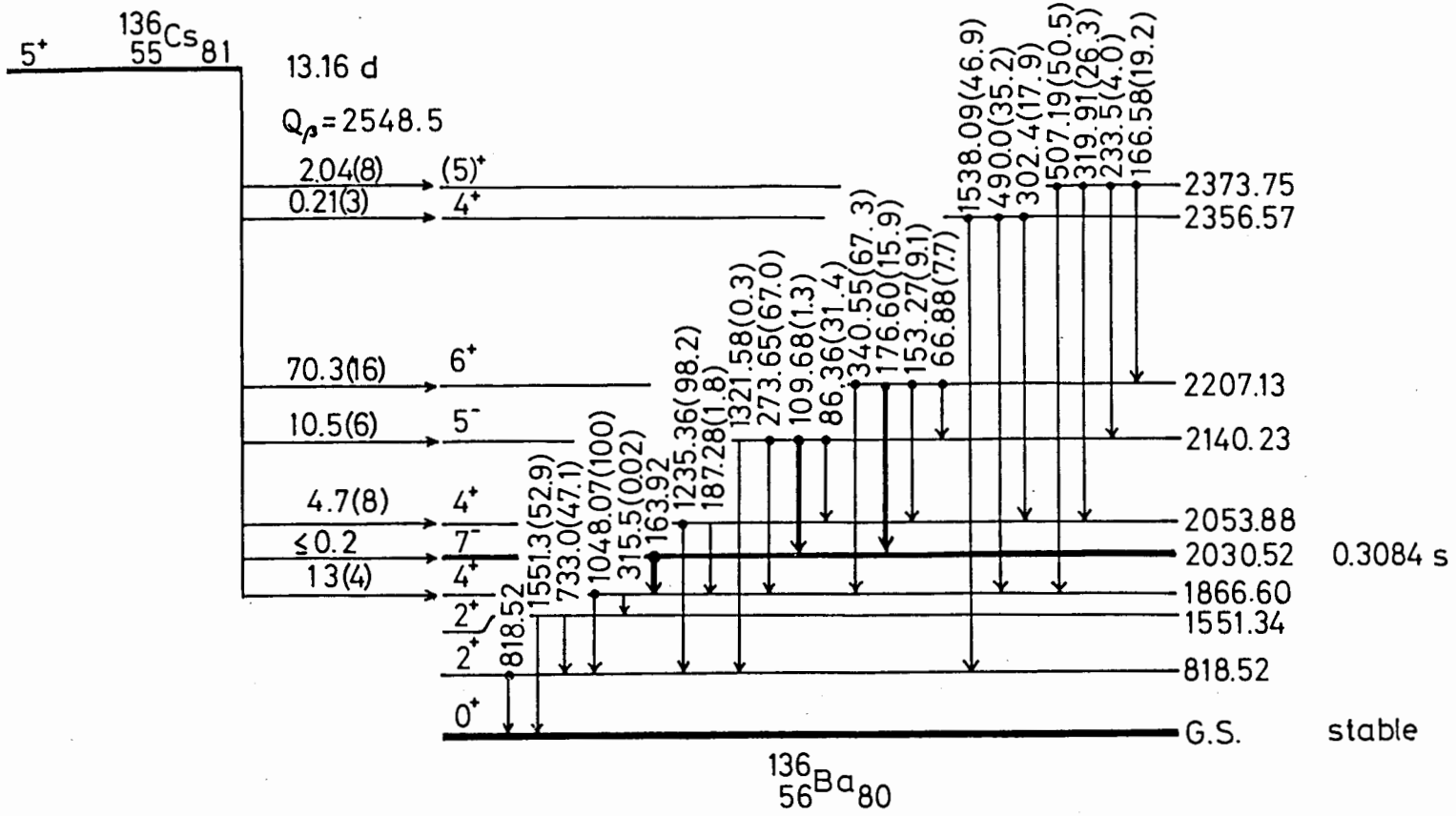

Figure 1. Level scheme of ^{136}Ba. All data are from Ref. 5. Energies in keV.

Table I.

Nuclide	γ-energy (keV)	Shell	α(R)	α(HS)	α(exp)	$\frac{\alpha(exp)-\alpha(R)}{\alpha(R)}$ (%)	$\frac{\alpha(exp)-\alpha(HS)}{\alpha(HS)}$ (%)
E3 transitions							
^{75}As	303.9	K	0.0471	0.0471	0.0463(21)	-1.7±4.5	-1.7±4.5
		T	0.0542	0.0540	0.0536(24)	-1.1±4.4	-0.7±4.4
^{83}Kr	32.16	K	476	498	454(15)	-4.6±3.3	-8.8±3.0
^{87}Zr	134.8	T	2.70	2.67	2.61(11)	-2.3±4.1	-2.2±4.1
^{103}Rh	39.75	K	133	139	127(3)	-4.5±1.8	-8.6±2.1
		T	1458	1462	1531(30)	5.0±2.1	5.0±2.1
					1430(89)	-1.9±6.2	-1.9±6.2
^{107}Ag	93.15	K	9.25	9.40	9.3(3)	0. ±4.3	-1. ±4.2
^{109}Ag	88.03	T	26.5	26.7	25.4(5)	-4.2±2.0	-4.9±2.0
					26.4(4)	-0.4±1.6	-1.1±1.6
		K	11.4	11.6	11.4(3)	0.0±2.6	-1.7±2.6
					10.7(3)	-6.1±2.6	-7.8±2.6
		L	12.43	12.20	12.22(51)	-1.7±4.1	0.2±6.0
		M	2.55	2.47	2.40(8)	-5.9±3.2	-2.8±3.2
^{127}Xe	172.5	T	1.64	1.64	1.61(8)	-1.8±5.0	-1.8±5.0
^{134}Cs	127.4	K	2.72	2.78	2.60(4)	-5.1±1.5	-5.8±1.5
					2.64(7)	-3.6±2.5	-4.3±2.5
^{136}Ba	163.9	T	2.27	2.26	2.21(8)	-2.6±3.5	-2.2±3.5
^{182}W	960.3	K	0.00864	0.00864	0.00836(23)	-3.2±2.6	-3.2±2.6
^{191}Ir	41.85	L	12450	12400	12160(210)	-2.3±1.7	-1.9±1.7
		M	3830	3790	3710(140)	-3.1±3.7	-2.1±3.7
		N	974	1030	890(22)	-8.6±2.2	-13.6±2.1
		T	17400		16900(410)	-2.9±1.8	
M3 transitions							
^{80}Br	48.85	K	221	223	216(8)	-2.3±3.6	-3.1±3.6
		T	306	308	301(13)	-1.5±4.3	-2.3±4.3
^{179}W	221.9	K	6.55	6.57	6.56(30)	0.2±4.6	-0.2±4.6

Comparison of accurately measured third order ICCs (α(exp)) with the theoretical values of Rösel et al.[2] (α(R)) and of Hager and Seltzer[1] (α(HS)). T stands for total ICC. For reference list and detailed discussion, see Ref. 6.

they increase strikingly when the transition energy approaches the K binding energy. This fact prevents one from creating a simple correction rule to these calculations[1] and makes one to prefer the theoretical values of Rösel et al.[2] We note that this energy dependence had not been observed by Raman et al.[3] because of their small entry set (5), so their conclusions do not remain valid in the original form.

Independence of the Rösel-discrepancies of transition energy, nuclear charge and shell may be virtual; viz. the limited accuracy of the available data does not reveal any dependences on these quantities. Nevertheless, the given general accuracy level excludes strong dependences on these quantities. Limited space prevents us from giving a discussion of the individual entries or explaining the obtained results in detail; this will be done in a follow-up paper soon[6].

Summarizing the results of this contribution

- on the basis of an extensive comparison we suggest multiplying the theoretical ICCs of Rösel et al.[2] by a factor of 0.970(15) to obtain more reliable values
- we found the discrepancies among the theoretical ICCs of Rösel et al.[2] and the accurately measured experimental ones to be (virtually) independent of transition energy, nuclear charge and shell
- we observed the dependence on transition energy of the discrepancies among the ICCs of Hager and Seltzer[1] and accurately determined experimental ones for the first time. (Each statements are valid for third order transitions.)
- we determined the total ICC of the 163.92 keV E3 transition of ^{136}Ba to be 2.21(8).

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