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ANGULAR CORRELATION MEASUREMENT IN ^{80}Kr

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Abstract

A multipole mixing ratio of 3.9(9) of the $2_2^+ - 2_1^+$ 616 keV transition in ^{80}Kr was determined by gamma-gamma angular correlation using a Ge(Li)-NaI(Tl) spectrometer. Previous measurements of this mixing ratio with results 6(1), -0.5, 3(3) and 16_{-8}^{∞} are not in mutual agreement. Available conversion electron coefficient data can not explain the δ-value.

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Gamma-gamma directional angular correlation measurements were performed with a Ge(Li)-NaI(Tl) spectrometer to determine the mixing ratio (E2/M1) of the 639 keV $2_2^+ - 2_1^+$ transition in ^{80}Kr. Previous measurements have been performed using gamma angular distributions in the nuclear reactions $^{78}Se(\alpha,2n)$ [1], and $^{70}Zr(^{12}C,2n)$ [2], and $^{81}Br(p,2n)$ [3], and measuring the gamma-gamma angular correlation with a NaI(Tl)-NaI(Tl) spectrometer [4]. The available conversion electron coefficient data [1] are of a precision which make it impossible to distinguish between the M1 and E2 α_k-coefficients.

The sources were produced by the (γ,n) reaction on 99.5% chemically pure NaBr made from natural bromine. The gamma radiation was Bremsstrahlung provided by the 35 MeV linear electron accelerator of the University of São Paulo. The electron energy was 23 MeV and the current about 1 μA. Two samples of NaBr were irradiated during 4 hours and one for 6 hours. For the gamma measurements the material was placed in a cylindrical lucite ampoule 6.0 mm in diameter and 6.0 mm in height.

Measurements began 2 hours after the end of irradiation and the only detectable isotopes present were ^{77}Br, ^{80}Br and ^{82}Br. The ^{82}Br was produced by thermal neutron capture in ^{81}Br with neutron generated in the sample, irradiator, and environment.

A detailed description of the equipment and the measurement procedure has previously been published [5]. The γ-γ automatic spectrometer consists of a movable 3"x3" NaI(Tl) detector with an energy resolution of 6.4 keV and a fixed 50 cm^3 coaxial Ge(Li) detector with an energy resolution of 1.9 keV at 1332 keV. The distance from the sample center to the NaI(Tl) detector was 10.2 cm and to the Ge(Li) detector 5.7 cm. The automatic control of the spectrometer and the data acquisition were performed by a PDP11/45 computer coupled to a microprogramable CAMAC interface. A commercial fast-slow coincidence circuit with a time-to-pulse-height-converter was used with 8 ns of resolving time. Coincidence counting rates, $W_{exp}(\theta_i)$, were determined for 7 angles (θ_i = 90°, 120°, 150°, 180°, 210°, 240°, 270°) to minimize possible asymmetry. The measurement was realized in groups of 14 angles: 7 angles with the NaI(Tl) detector moving counter-clockwise (90° to 270°), and 7 angles with the NaI(Tl) detector moving clockwise. This procedure, with a suitable choice of counting time per angle, obviates the correction due to the decaying source activity [5]. The counting time per angle was 280 s. The final spectrum at each angle is the sum of all spectra for the same angle. The total counting time per angle was 12,320 s. No correction to the decaying source activity was necessary.

True-plus-chance and chance coincidence spectra were acquired with two ADC's simultaneously. The converted data from these ADC's were stored in histogram mode in the PDP11/45 computer memory through direct memory access (DMA). The net coincidence count is the difference between the peak area in the true-plus-chance spectrum and the peak area in the corresponding chance spectrum.

The multipole mixing ratio δ was obtained by using nonlinear χ-square minimization of the function [5]

$$s^2 = \sum_{i=1}^{7} [W_{exp}(\theta_i) - \alpha \sum_{n=0,2,4} Q_n^1 Q_n^2 B_n(\delta)\, A_n P_n(\cos\theta_i)]^2/\sigma_{exp}^2(\theta_i) \quad (1)$$

with δ and the sample activity α as parameters. The $B_n(\delta)$ and A_n can be found elsewhere [6,7]. The sign convention adopted in this work is that of Krane et al. [6]. The geometrical correction factors Q_n^i were calculated by Monte-Carlo simulation according to Hourani [8]. The Q_n-values obtained as above for the Ge(Li) detector were compared with calculations of Camp et al. [9] and with the experimental values of Bolotin [10]. The agreement is very good. The same occurs between our calculated Q_n-values for the NaI(Tl) detector and the calculated values of Yates [11]. The equipment as well as the measurement process were exhaustively tested and compared with well established results in the literature [5].

The measured cascades were $2_2^+ - 2_1^+ - 0_1^+$ with the energies 636-616 keV, and $0_2^+ - 2_1^+ - 0_1^+$ with the energies 704-616 keV. The region around the energy 516 keV was taken as a gate in the NaI(Tl) spectrum and is shown in figure 1. This figure also presents the Ge(Li) spectrum in coincidence with that gate for the angle of 90° between the detectors. The cascade $0_2^+ - 2_1^+ - 0_1^+$ was used as a quality control of the equipment and the measurement process. The result for A_2 and A_4 is shown in table 1 with the calculated values from theory and the values obtained by Ramayya et al. [4]. Our A_2 and A_4 values were obtained by fitting the function

$$W(\theta_i) = A_0 + A_2 Q_2^1 Q_2^2 P_2(\cos\theta_i) + A_4 Q_4^1 Q_4^2 P_4(\cos\theta_i) \qquad (2)$$

to experimental data.

Our result of $\delta = 3.9(9)$ for the $2_2^+ - 2_1^+$ 639 keV cascade is presented in an A_2 versus A_4 plot with $\delta' = \delta/|1+\delta|$ as a parameter in figure 2 with the results of other authors. The δ-value of Ramayya et al. [4] was obtained from the compilation of Lang et al. [13] and the δ-value of Yoshikawa et al. [3] was calculated by us from the given angular distribution data. The incompatibility between the δ-value of Sastry et al. [2] and the other data is evident.

Finally, the experimental conversion coefficient $\alpha = 13(2)$ of Funke et al. [1] for the 639 keV transition cannot define δ because both theoretical values $\alpha_T(M1) = 11$ and $\alpha_T(E2) = 14$ are inside its one standard deviation interval.

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TABLE 1

Angular correlation results for the $0_2^+ - 2_1^+$ 704-616 keV of ^{80}Kr

A_2	A_4	reference
0.38(4)	1.22(8)	this work
0.38(10)	1.28(18)	4
0.36	1.14	theory

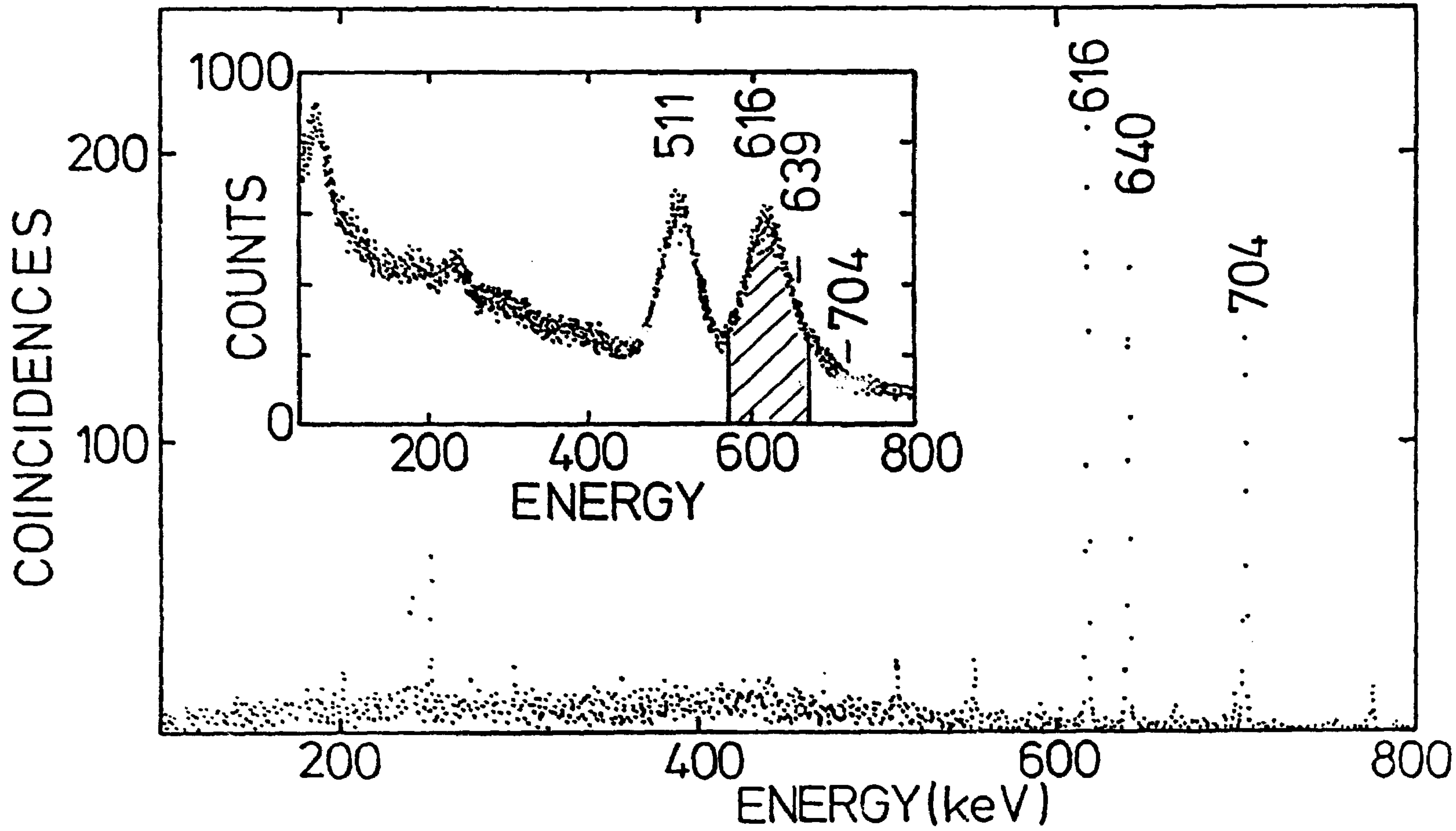
Figure captions

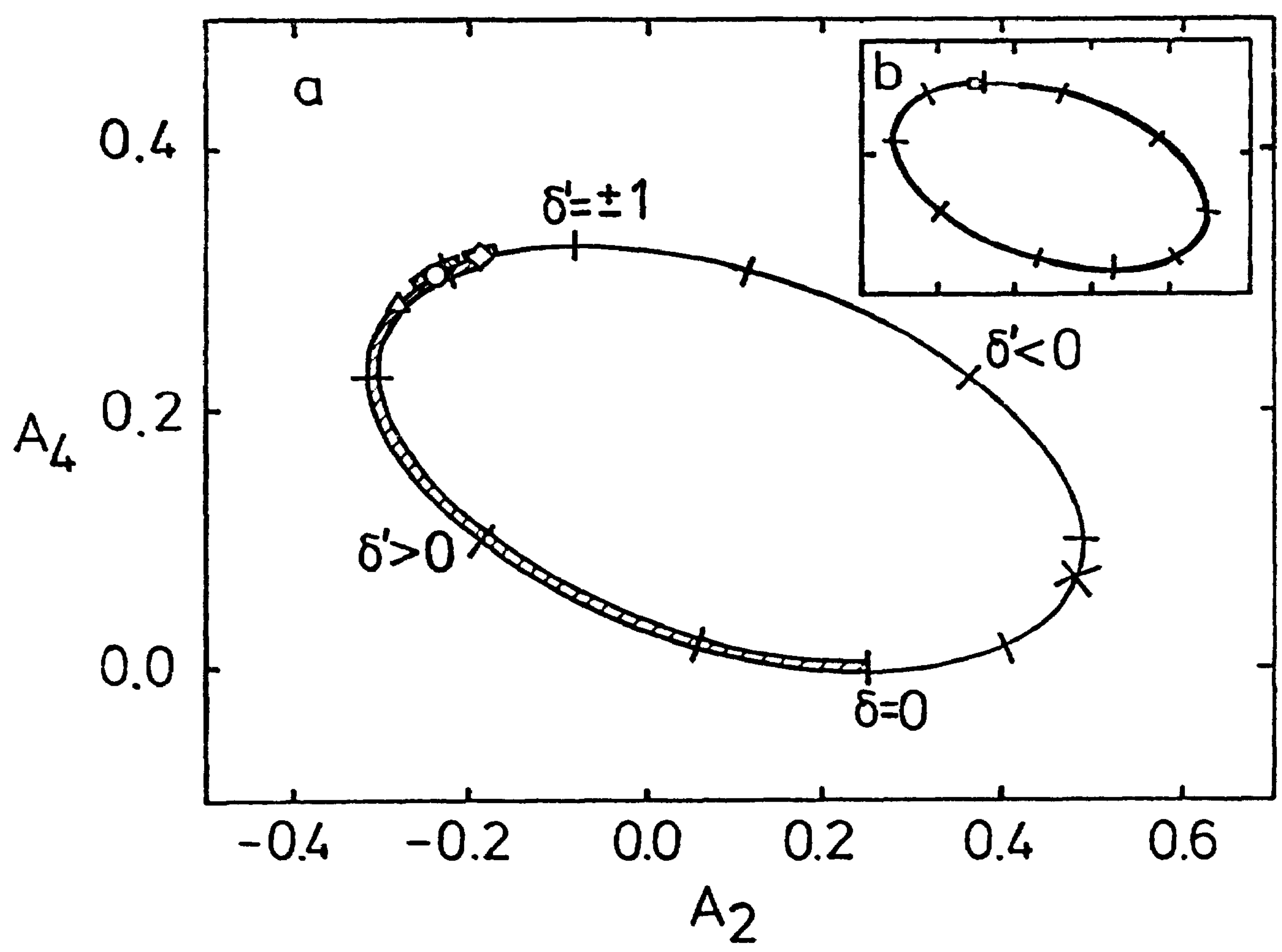
Figure 1

Spectra of the NaBr sample: a) NaI(Tl) single spetrum showing the coincidence gate, and b) Ge(Li) coincidence spectrum with the gate on the NaI(Tl) detector. The angle between the detectors was 90°.

Figure 2

Plot of A_2 versus A_4 with $\delta'=\delta/|1+\delta|$ as paramater. | indicates the δ' scale with $\Delta\delta'=.2$. The results are: in a) ◇ our work, ○ Funke et al. [1], and × Sastry et al. [2], and △ Yoshikawa et al. [3], in b) □ Ramayya et al. [4]. The bold line indicates the one standard deviation interval.


COINCIDENCES
200
100
200
400
600
800
ENERGY (keV)
616
640
704
COUNTS
1000
0
200
400
600
800
ENERGY
511
616
639
704


a
b
δ'=±1
δ'<0
δ'>0
δ=0
0.4
0.2
0.0
-0.4
-0.2
0.0
0.2
0.4
0.6
A4
A2