RECENT RESULTS ON ^{131}Xe AND ^{133}Xe FROM NUCLEAR ORIENTATION STUDIES

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From a measurement of the directional distribution and the degree of linear polarization of γ-radiation emitted by oriented nuclei one can derive several nuclear quantities. At a given degree of orientation of the parent nuclei the directional distribution and linear polarization of a γ-transition depend on the spins of the initial and final levels, on the mixing ratio of the multipoles contributing to the transition and on changes of orientation parameters due to unobserved preceding transitions. Additionally, the sign of the linear polarization gives information on the electric or magnetic character of the radiation. Nuclear orientation of implanted ^{131}I Fe and ^{133}I Fe sources was obtained by cooling the samples to temperatures between 25 and 50 mK and by fully magnetizing the iron foils at the same time. The directional anisotropies of emitted γ-rays were measured with Ge(Li) detectors. In the case of ^{131}I we also determined the linear polarization, P_ℓ, of γ-radiation emitted perpendicular to the axis of orientation. A Compton polarimeter was used in which both the scatterer and side detector were Ge(Li) crystals of 65 cm^3 active volume. The quality Q of the polarimeter was determined experimentally by comparing the measured quantity $P_\ell Q$ with the P_ℓ-value from the relation $|P_\ell| = |(W(90^\circ)-W(0^\circ))/W(90^\circ)|$, which is valid for radiation of pure multipolarity. Here, $W(\theta)$ is the γ-ray intensity observed at an angle θ with respect to the orientation axis. The quality ranged between 52% at 284 keV and 33% at 835 keV.

TABLE 1

Nuclear orientation results for transitions from the 341 keV and 667 keV levels in ^{131}Xe.

γ-energy (keV)	A_2G_2 a)	P_ℓ b) $f_2 = 0.226\pm0.004$	P_ℓ b) $f_2 = 0.127\pm0.005$
503	-0.63 ± 0.06	-0.33 ± 0.25	-0.38 ± 0.21
326	-0.16 ± 0.24 c)		
177	-0.15 ± 0.17		

a) The directional distribution is written as $W(\theta)-1 = \sum_{k=\text{even}} A_k G_k f_k P_k(\cos\theta)$, where the parameters f_k describe the degree of orientation of the parent nucleus, the G_k are desorientation parameters and A_k depend on the properties of the observed transition. In our case only the f_2 orientation parameter is important.

b) Results from experiments at two nuclear temperatures, characterized by the parameter f_2.

c) Corrected for the contribution from the 405 keV → 80 keV component in the 326 keV doublet.

The results from the directional distribution measurements have been reported earlier |1,2|. In the case of ^{131}Xe spin assignments were obtained for all populated levels with the exception of the states at 341 and 667 keV (see fig. 1). The recently measured linear polarization of the 503 keV transition, together with improved directional distribution data (see table 1) and earlier internal conversion data, allows the unique assignments $J^\pi(341)=9/2^-$ and $J^\pi(667)=7/2^-$. The E2/M1 mixing ratios of the 177 and 326 keV transitions are $\delta(177)=4.5\pm1.5$ and $\delta(326)=-4.4\pm1.6$.

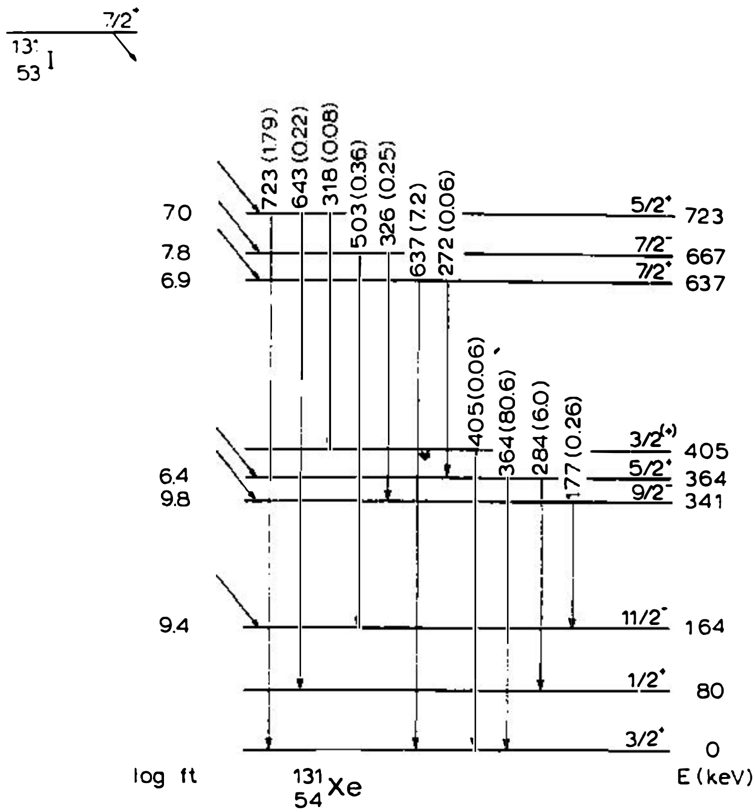

Fig.1. Level scheme of ^{131}Xe. Only transitions studied by nuclear orientation are shown.

Linear polarization measurements further confirm that the levels at 364, 637 and 723 keV have positive parity.

With the known half-life of the 341 keV level, the mixing ratio of the 177 keV transition gives B(E2;177) = $= 0.12 \pm 0.01$ $(e \cdot b)^2$, B(M1;177) = $1.3^{+1.5}_{-0.6} \times 10^{-4}$ $(n.m.)^2$. The $9/2^-$ level at 341 keV cannot be accounted for by the coupling of one (quasi-) particle to a collective quadrupole mode. Kisslinger |3| pointed out that the three quasi-particle state $(h^3_{11/2})9/2$ may be much lowered by

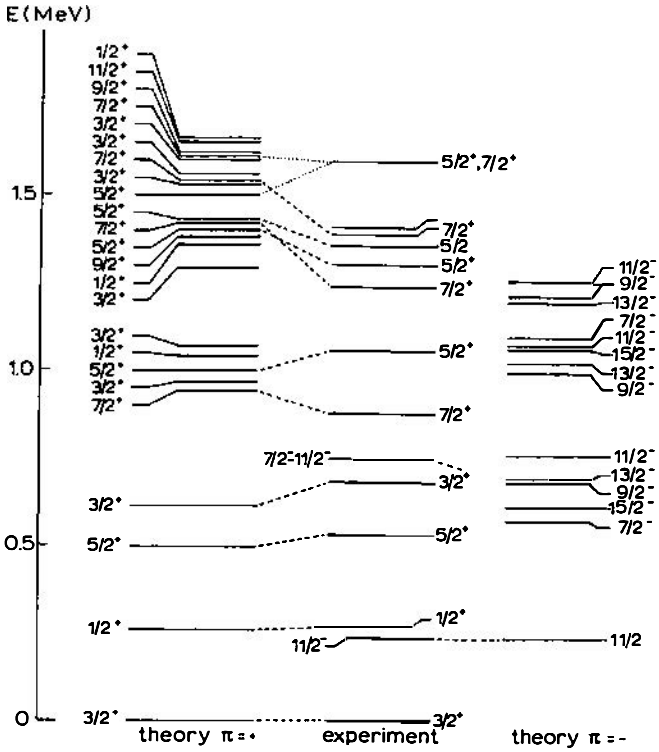

Fig.2. Comparison of theoretical states with the experimental level scheme of ^{133}Xe.

the quadrupole force. The M1 matrix element between this state and the one quasi-particle state vanishes, in agreement with the observed strong retardation of the M1 component of the 177 keV transition. Also, the E2 enhancement of this transition is well accounted for (cf. table 1 in ref. |3|).

The nuclear orientation results for the decay of ^{133}I were reported in ref. |2|. Spin values were deduced for nearly all populated ^{133}Xe levels and multipole mixing ratios of eighteen γ-transitions were given. The N=79 nucleus ^{133}Xe was described by coupling a three-neutron-hole cluster, moving in the $d_{3/2}$, $s_{1/2}$, $h_{11/2}$ and

TABLE 2

Comparison of experimental data on transition rates in ^{133}Xe with model predictions.

Transition	B(E2)/B(M1) Theory[a)]	B(E2)/B(M1) Experiment		Theory[a)]	Experiment
$5/2_1^+ \to 3/2_1^+$	14	18 ± 2	$\frac{B(E2;5/2_1^+ \to 3/2_1^+)}{B(E2;5/2_1^+ \to 1/2_1^+)}$	3.7	22 ± 2
$5/2_2^+ \to 3/2_1^+$	0.19	0.04 ± 0.01 or 100^{+70}_{-30}	$\frac{B(E2;5/2_2^+ \to 3/2_1^+)}{B(E2;5/2_2^+ \to 1/2_1^+)}$	0.30	0.10 ± 0.03 or 3.2 ± 0.8
$7/2_2^+ \to 5/2_1^+$	1.6	0.61 ± 0.08 or 50 ± 10	$\frac{B(E2;7/2_2^+ \to 5/2_1^+)}{B(E2;7/2_2^+ \to 3/2_1^+)}$	145	2.9 ± 0.4 or 15.5 ± 1.2

a) Effective charges $e_{s.p.} = 0.5$, $e_{vib} = 3$ and effective gyromagnetic ratios $g_R = Z/A$, $g_\ell = 0$, $g_s = 0.6\, g_s^{free}$ were used.

and $d_{5/2}$ shell-model states, to a quadrupole vibrational field. Both the results from diagonalization |2,4| and approximate solutions based on Generalized Vibrational Intensity and Selection Rules show good overall agreement with the experimental data. In fig. 2 the experimental level scheme is compared with the theoretical spectrum obtained with a particle-field coupling strength $a \equiv \frac{1}{\sqrt{4\pi}} \langle k \rangle \left(\frac{\hbar\omega_2}{2C_2}\right)^{1/2} = 0.3$ MeV, a residual pairing force of effective strength G=0.1 MeV and phonon and single-hole energies chosen on the basis of experimental data. In table 2 experimental data on transition rates are compared with model predictions. In many cases the directional distribution data yield two possible values for the mixing ratio of a γ-transition. Conversion electron experiments with a "mini-orange" spectrometer are now under way in an attempt to eliminate some of these ambiguities. A first result has been obtained for the 707 keV $7/2^+_2 \rightarrow 5/2^+_1$ transition: the value $\alpha_k(707) = (4.4 \pm 0.6) \times 10^{-3}$ eliminates the higher of the two possible B(E2)/B(M1) ratios, in agreement with the theoretical prediction (see table 2).

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