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2.11 High Precision Spectroscopy on the Electromagnetic Moments of ^{7}Li by Coulomb Scattering of Aligned Li Ions

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The use of aligned heavy ion beams for Sub-Coulomb-Scattering on various targets has turned out to be a very useful tool to do high precision spectroscopy on electromagnetic nuclear moments of the projectile nuclei. Due to the beam alignment, nuclear moments as for example the groundstate spectroscopic quadrupole moment Q_S show up to be in first order in the observables T_{2q} and are therefore measurable with much higher precision as compared to Coulomb-Excitation experiments with unpolarized beams. The strong coupling to higher excited states helps to make detectable in addition other nuclear moments such as B(E2) values and moments of the nuclear polarizability. So the present experiment is the only one which is able to measure the tensor moment of the nuclear polarizability of the groundstate. The possibility to measure a whole set of nuclear moments in a consistent way in the same experiment makes possible a sensitive test of theory which is highly desirable not only in the view of nuclear theory but also as a test for calculations of electric field gradients in atoms and molecules.

In order to make such an extensive investigation of the small analyzing powers feasible with sufficient accuracy, much care was taken to optimize the experimental arrangement. Its most important part is an ionization chamber[1)] with a large solid angle (1.8 sr) and rotational symmetry with respect to the beam axis, which allowed to detect backscattered Li ions with an average counting rate of about 10 kHz. The spin alignment of the beam was monitored continuously at the position of the target by observing the deexcitation γ-rays from the $1/2^-$ state in coincidence with backscattered Li ions. For each run taken, 2 observables T_{20}^{el} (for pure elastic scattering) and $T_{20}^{el+inel}$ (for the sum of elastic and inelastic scattering) were observed.

The analysis of the data was performed in terms of quantum mechanical coupled channel theory using the program ECIS79. It turned out that 4 contributions have to be taken into account (see Fig. 1) whereas all additional terms were found to be negligible on the present level of accuracy. The code was run with 4 independent parameters Q_S, B(E2), τ_{11} and τ_{12} using a deformed Coulomb potential and a coupling potential taking into account the 1. excited state. The effect of virtual excitation via higher lying states was taken into account using an effective polarization potential

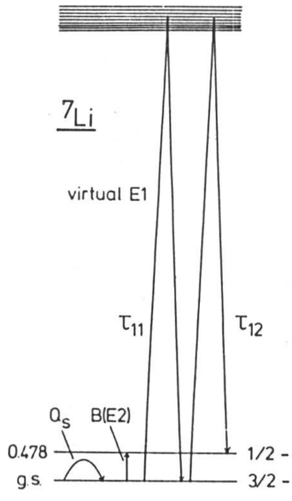

Fig. 1. Symbolic representation of the contributing effects.

$$V_{pol} = -\frac{1}{2} Z^2e^2 \frac{\alpha}{r^4} - \sqrt{\frac{9\pi}{5}} (Z^2e^2/r^4)\ \tau_{if}\ Y_{20}(\hat{s}\cdot\hat{r})$$

The observable $T_{20}^{el+inel}$ turned out to be determined by the parameter Q_S with a small contribution due to τ_{11}, whereas $T_{20}^{el+inel} - T_{20}^{el}$ was dominated by B(E2) with a small contribution due to τ_{12}. The characteristic dependence of the different parameters on the incident energy and the charge Z of the target helped to separate the parameters τ_{if} from Q_S and B(E2) by a χ^2-analysis.

The data corresponding to the scattering of ^{7}Li on ^{58}Ni and ^{120}Sn at different energies and scattering angles are displayed in Fig. 2. All data are described consistently with one single parameter set (solid lines in Fig. 2). No significant dependence of the parameters on angle, energy or target is observed, provided the bombarding energy does not exceed a critical value, i.e., the assump-

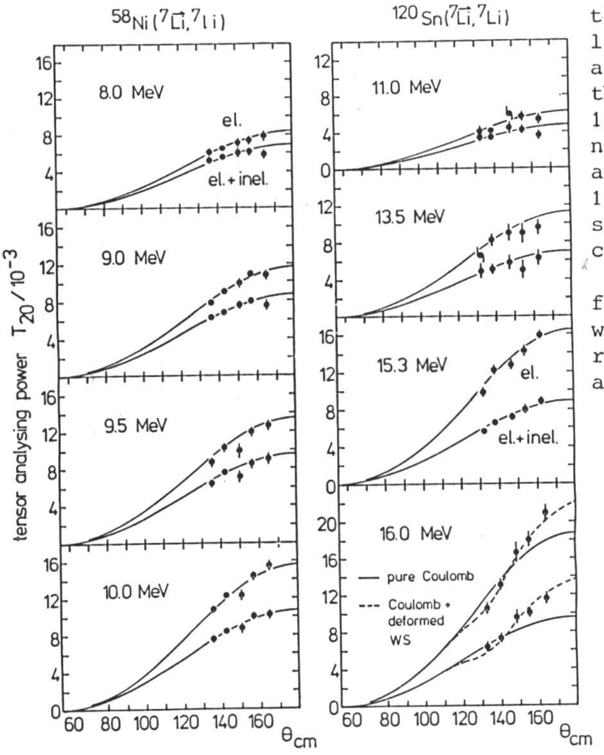

Fig. 2. Angular distributions of T_{20}^{el} and $T_{20}^{el+inel}$ for ^{7}Li scattering of ^{58}Ni and ^{120}Sn.

tion of pure Coulomb interaction is valid. Measurements at higher energies allowed to determine this critical threshold in our experiment to be 10.3 MeV and 15.4 MeV for the target nuclei ^{58}Ni and ^{120}Sn, respectively. As an example, the scattering on ^{120}Sn at 16 MeV is shown in Fig. 2, where the onset of Coulomb-nuclear interference becomes visible.

The observed results are shown in the first column of table I. The comparison with other experimental and theoretical results (see table I) may be summarized as follows:

Our measurement of Q_S observed by an independent method with high precision may test electric field gradients in the Li-atom and the LiH-molecule. Our result proves an analysis of molecular spectroscopy data based on the calculation of the LiH field gradient of Green[2] to be correct whereas a very recent reanalysis[3] using the same data gets a much higher value.

For the first time a consistent set of 4 parameters Q_S, B(E2), τ_{11}, τ_{12} could be measured. The deviations of B(E2) and τ_{12} from the results of some Coulex-experiments using unpolarized beams may be due to the problem of correct weighting of both quantities in these experiments. Whereas Q_S and B(E2) are reproduced quite well by recent cluster- and shellmodel calculations, all attempts to explain the high values of τ_{11} and τ_{12} as due to virtual excitation of the giant dipole resonance fail by a factor 2 to 3[4]. Further calculations are highly desirable to clarify this point which will be of importance for the understanding of the structure not only of ^{7}Li but also of other loosely bound nuclei.

References

1) A. Weller and P. Egelhof, Nucl. Instr. Meth. 220 (1984) 425.
2) S. Green, Phys. Rev. A4 (1971) 252.
3) D. Sundholm et al., submitted to Chem. Phys. Lett. (1984).
4) T. Mertelmeier and H.M. Hofmann, private communication.

Table I.

	Q_S	B(E2)	τ_{12}	τ_{11}	reference
present experiment	-3.70±0.08	8.3 ±0.5	0.23±0.06	0.23±0.06	
atomic and	-4.1 ±0.6				Orth et al (1975)
molecular	-3.66±0.03				Green (1971)
spectroscopy	-4.06				Sundholm et al (1984)
coulex with	-1.0 ±2.0	7.4 ±0.1			Bamberger et al (1972)
unpolarized		8.3 ±0.6	0.21±0.03		Häusser et al (1973)
beams	-4.0 ±1.1	7.42±0.14	0.15±0.01		Vermeer et al (1984)
nuclear	-3.62	6.26			Bouten et al (1981)
theory	-3.50	6.61			Kajino et al (1984)
	-3.71	6.80			Hofmann et al (1984)