Investigation of Photon-Photon Angular Correlations in Atomic Mercury

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By application of the time differential coincidence technique developed in nuclear spectroscopy, for the first time the angular correlation of light quanta of atomic decays was observed. The experiments were carried out with the $^7\text{3S}_1 \rightarrow ^6\text{3P}_1 \rightarrow ^6\text{1S}_0$ cascade of mercury excited by electron impact at energies of 50 eV. The two transitions of 4358 and 2536 Å were selected by interference filters and detected by photomultipliers. Time differential coincidence spectra were measured at the two angular positions $\theta = 90^\circ$ and $\theta = 180^\circ$. It was found that the excitation of the $^7\text{3S}_1$-state by the electron beam leads to no alignment. Therefore the usual $\gamma$-$\gamma$ angular correlation theory is applicable. Perturbations occur by static interaction with external magnetic fields and by free hyperfine interaction in the odd isotopes of mercury. The interaction frequencies of the free hyperfine interaction are in all cases too high to be resolved. Measurements were performed using mercury of natural abundances, with and without external magnetic fields. First of all the spin rotation in the magnetic field of the earth (690 mG) was observed, giving for the $g$-factor of the $^6\text{3P}_1$-state

$$g(\text{Hg},^6\text{3P}_1) = 1.35 \pm 0.10.$$ 

This value is in agreement with the more precise values determined by other techniques. Shielding of the earth’s field gave a nearly unattenuated angular correlation, with an integral attenuation factor of

$$G_2 = 0.98 \pm 0.06.$$ 

The value of the angular correlation coefficient $A_2$,

$$A_2 = -0.188 \pm 0.009,$$

is in good agreement with the expected average value for the natural isotope mixture

$$A_2^{\text{theor}} = -0.196.$$

A third measurement in an external magnetic field of 5.6 G showed several complete spin rotations. A nice fit was possible by using the superposition of all six participating cascades in the hyperfine level schemes of the different isotopes. The theoretical anisotropies, $g_F$-values, and intensities were inserted according to natural isotope abundances.

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From the time differential measurements also a value for the lifetime of the Hg-6$^2P_1$-level was derived. The result

$$\tau(\text{Hg}, 6^2P_1) = (120 \pm 2) \text{ nsec}$$

is in agreement with earlier measurements. Further applications of the method are discussed.

I. Introduction

Application of nuclear coincidence techniques to cascades of electromagnetic transitions in atomic shells—especially in the range of the visible and ultraviolet light—is difficult because of the rather small quantum efficiency of the detectors. Following the first work of Brannen et al.\(^1\) some coincidence experiments were reported in the last years. Most of them were carried out in order to determine lifetimes of atomic levels\(^1-6\). In addition, influences of polarisation\(^7\) and coherence\(^8\) on the coincidence rates have been detected. Investigations of angular correlations of light quanta, however, have not been reported before. These experiments are more difficult since higher accuracy is required, whereas the restriction of the detector solid angles reduces severely the coincidence counting rates. Measurements of angular correlations in atomic physics are therefore primarily limited by technological problems. Though angular correlation measurements with light quanta today do not promise many new fundamental results on atomic structure we found it interesting to study the phenomenon of angular correlation in light emission itself, to observe the influences of the special conditions in the atomic shell especially of the hyperfine interaction, and to prove the validity of the theory of $\gamma-\gamma$-angular correlations for atomic transitions.

II. Experimental Arrangement

For detection of single light quanta high gain photomultiplier tubes are used. Special types with very sensitive cathodes reach today quantum efficiencies of about 20–30\%. With few exceptions, however, for single photons only single electrons are drawn out of the cathode. Therefore the height of output signals is independent of the photon energy or wave-length. There is no difference in height to those pulses which are

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