The effect of the isomeric state ^{229m}Th on the observed hyperfine structure pattern

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The study of the structure of ^{229}Th isotope is interesting both from the point of view of nuclear physics as well as its application to frequency standard, because the first excited isomeric state of the ^{229}Th nucleus exhibits the lowest known nuclear excitation energy which is about 8 eV.

The verification of the existence and determination of the energy of a low lying isomeric state can be easily done by a systematic study of the hyperfine structure for electronic levels of the ^{229}Th atom or ions by means of the LIF method in a Paul trap, in hollow cathode or on atomic beam.

The effects of the mixing of the wave functions for ground and isomeric nuclear states should be observed in the hyperfine structure patterns of spectral lines.

As an example we present the simulation for the transition 34543.556 cm^{-1} $\rightarrow$ 17121.620 cm^{-1}. The values of the hyperfine constants were taken from the paper of Kälber *et al.* [1]. The corresponding values for the isomeric state were calculated using the values of nuclear moments μ and Q equal 0.45 μ_N [2], 3.11 b [3] and -0.08 μ_N [4], 1.74 b [4], for the ground and the isomeric nuclear states respectively. The same occupancy of the ground and isomeric states was assumed. The solid lines show the intensities of the line components, for the ground nuclear state, for the transitions $F' = 0 \rightarrow F = 1$ at the beginning to $F' = 5 \rightarrow F = 4$ at the end of x-axis. For the isomeric state, the dashed lines illustrate the line components for transitions $F' = 0 \rightarrow F = 1$ and $F' = 3 \rightarrow F = 4$, respectively.

Depending on the line width observed in the experiment, the existence of the isomeric state will be revealed in the middle of the hyperfine structure pattern as broadening and distortion of the line components or as additional line components. Therefore the hyperfine structure constants derived from the observed spectral line shape will differ from those determined in the absence of nuclear isomeric state admixture.

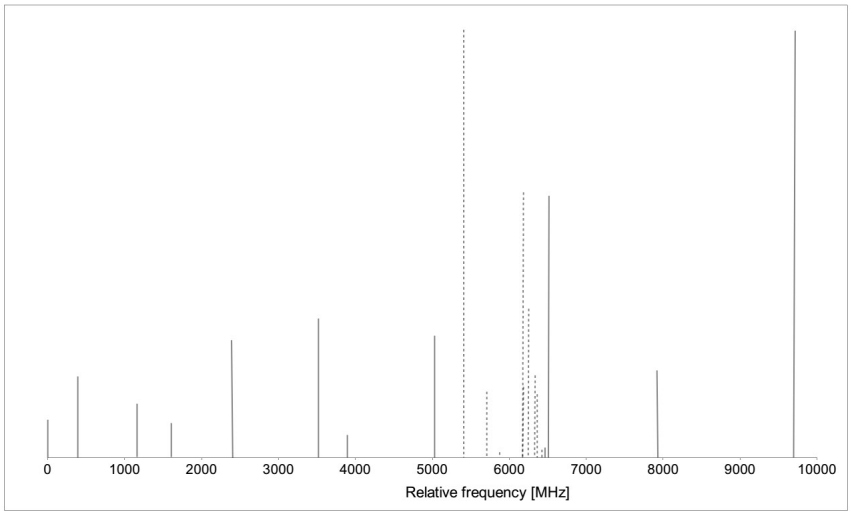

Figure 1: *Simulation of the line structure for the transition 34543.556 cm^{-1} $\rightarrow$ 17121.620 cm^{-1}.*

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References

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