Phonon-nuclear coupling matrix element for the low energy E1 transition in Ta-181 and applications

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Quite a few anomalies have been reported on in the past 29 years in which various stimulations provided by the local condensed matter environment result in effects either unambiguously nuclear, or which permit an interpretation of having a nuclear origin. Such effects seem anomalous, especially since what goes on inside of a nucleus is generally thought to be only weakly impacted by the local condensed matter environment, or by the associated relatively slow center of mass dynamics. The clean separation of the center of mass and relative degrees of freedom in the nonrelativistic quantum composite argues against the existence of a significant coupling between them. The second-order electric and magnetic interactions are just too weak to produce anomalies of the sort claimed.

Things are different for the relativistic quantum composite. In this case there is a low-order coupling between the center of mass motion and internal degrees of freedom [1]. This coupling was first noted by Breit in 1937, and has received only modest attention over the years. From our perspective, this obscure relativistic interaction has the potential to mediate anomalies. We have been interested in the development of theoretical estimates for the associated phonon-nuclear coupling matrix elements, and also in the question of whether this coupling can be isolated in simple physics experiments.

We have recently carried out a computation of the interaction matrix element in the case of Ta-181, which has a low-energy E1 transition at 6237 eV. This calculation was based on a boosted version of the LS-coupling interaction in the case of a single proton transition in a deformed nuclear potential. This approach accounts adequately for the systematics of shell occupation in this mass region, and agrees with the observed quadrupole moment. However, the radiative decay rate computed in this way is high by orders of magnitude, a problem which remains open even today in nuclear physics. We consider an R|ST separation which would allow for a screening effect that might account for the discrepancy in the radiative decay rate, but would have much less of an impact on the phonon-nuclear matrix element.

Experiments are ongoing in our lab focusing on the low energy M1+E2 nuclear transition in Fe-57 at 14.4 keV. Since the **a**.c**P** operator for phonon-nuclear coupling requires E1 symmetry, there cannot be nuclear transitions between the ground state and the 14.4 keV state mediated by single phonon exchange. Instead, coupling is possible through two E1 transitions, so that the lowest order interaction involves a two-phonon interaction.

[1] P. L. Hagelstein, “Quantum composites: A review, and new results for models for Condensed Matter Nuclear Science,” J. Condensed Matter Nuclear Science, vol. 20, pp. 139-225, 2016.
[2] G. Breit, “Approximately relativistic equations for nuclear particles,” Physical Review, vol. 51, pp. 248-262, 1937.