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Highly-Charged Radioactive Molecules: Amplifying Sensitivity for New Physics

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One possible extension to the Standard Model of Particle Physics (SM) is one which provides a mechanism, active in the early universe that has lead to the matter-antimatter asymmetry that we observe today. One of the most prominent proposed solutions to this asymmetry relates this imbalance of matter and antimatter to new sources of CP violation which may manifest, for instance, in permanent electric dipole moments (EDMs). Searches for EDMs and their associated CP-violating effects, including those that originate inside the atomic nucleus have been performed for decades. One novel concept in this search is the combination of precision atomic, molecular, and optical (AMO) techniques with rare isotopes that can be synthesized at accelerator facilities such as TRIUMF. Certain species of radionuclides, such as the well-studied ^{225}Ra exhibit an octupole deformation that can enhance sensitivity to nuclear CP-violating effects by up to three orders of magnitude. Recent calculations have shown that ^{229}Pa may increase sensitivity to nuclear CP-violating effects by an additional 40 times when compared ^{225}Ra. Parallel advancements in experimental techniques have led to the use of molecular systems to enhance precision by three to four orders of magnitude via an increase in the effective electric fields experienced by valence electrons in the presence of the nucleus. One further advantage that can be taken advantage of is the ability to laser-cool the molecular system in order to improve sensitivity even further. In this case, it is necessary to create a system that is isoelectronic to neutral RaF which has shown evidence of a suitable laser-cooling scheme. For these reasons, the ambition of the newly formed RadMol collaboration is to study ^{229}PaF^{3+}. This contribution will present opportunities and challenges for studies of ^{229}PaF^{3+} as well as progress towards forming highly-charged radioactive molecules in general.

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