Study of Disassociative Electron Attachment to Carbon Tetrafluoride (CF4) Using the Momentum Imaging Method

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Dissociative electron attachment (DEA) is a type of atomic-level process in which a low-energy (sub-ionization energy) electron attaches to a molecule, forming an anion. This molecular anion species is transitory and leads to bond relaxation. As the bond relaxes, it can eject the additional electron and return to the ground state neutral molecule. Otherwise, the bond (or multiple bonds) will break, and one fragment of the molecule will carry the negative charge.

We can study this process using momentum imaging of the anion fragments. This technique relies on crossed well-collimated beams of target molecules and electrons. After the pulsed electrons interact with the molecular beam and a DEA event occurs, we pulse a perpendicular electric field to extract all of the anion fragments formed during DEA. These molecules are randomly oriented; however, we can determine their momentum by measuring their time-of-flight to the detector and their position on the detector. After acquiring millions of DEA events, the data are post-processed to orient the molecules to the incoming electrons to study angular dependences and the energy released during dissociation.

This research provides a benchmark to test theories used to model atomic interactions and gain insight into bond properties, which could lead to achievable methods for controlling or enhancing bond cleavage for chemical processes. This knowledge can contribute to understanding how low-energy electrons cause bond cleavage in biological effects of radiation. Single and double DNA strand breaks seem to be directly linked to low-energy electron cascades caused by radiation. These electrons are in a range where DEA is the predominant process that can break bonds and lead to radical formation even below ionization energies.

Currently, we are studying the CF4 molecule as one of the many test cases to be benchmarked against this theory. We aim to measure the DEA dynamics related to this molecule as it seems to exhibit some mechanics that are not predictive based on other molecular systems. This abnormality has been hinted at by the observations of another research group, but the results we have obtained so far seem to contradict their results. This illustrates the primary importance of studying a wide range of molecular species for benchmarking and ensuring reproducibility.

Statement of Research Advisor:

Andy's work is an important part of the series of DEA studies we are aiming to complete to better understand the predictive nature of theoretical models. He has learned that such research requires a great deal of effort to overcome the tremendous hurdles that accompany such a complex, custom-made experimental apparatus. We always seem to uncover interesting artifacts in the molecular dynamics wherever we look. Andy's contribution has helped to enable these and future efforts in studying the DEA process.

–Alan Landers, Physics