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Cold Controlled Chemistry[1]

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The development of experimental techniques for controlling chemical reactions externally has long been a major research goal in chemical physics. Many ground-breaking experiments demonstrated the possibility of controlling uni-molecular reactions by laser fields. External field control of bi-molecular chemical reactions, however, remains a significant challenge. External control of bi-molecular reactions is complicated by thermal motion of molecules that randomizes molecular encounters and diminishes the effects of external fields on molecular collisions. The effects of the thermal motion can be reduced by cooling molecular gases to low temperatures. Electromagnetic fields may influence molecular collisions significantly only when the translational energy of the molecules is smaller than the perturbations due to interactions with external fields. Static magnetic and electric fields as well as off-resonant laser fields readily available in the laboratory shift molecular energy levels by up to a few Kelvin so external field control of gas-phase molecular dynamics can be most easily achieved at temperatures near or less than one Kelvin. The purpose of this talk is to demonstrate that molecular collisions at low temperatures can be effectively controlled with static and laser electromagnetic fields and discuss possible applications of external field control of molecular collisions in cold gases. I will discuss molecular collisions at both cold (~ 1 Kelvin) and ultracold (< 1 milliKelvin) temperatures. I will demonstrate that static electric fields can be used to tune scattering resonances in ultracold gases and modify chemical reactions of cold and ultracold molecules. I will show that superimposed electric and magnetic fields may dramatically alter collision dynamics of cold molecules in a magnetic trap and describe interactions of molecules in a microwave laser cavity. Finally, I will argue that confining the motion of ultracold molecules by laser fields to two dimensions may suppress inelastic collisions and chemical reactions at ultracold temperatures and present results indicating that inelastic collisions of confined atoms or molecules in weak electromagnetic fields may be controlled by varying the orientation of the external field axis with respect to the plane of confinement.

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