

## Abstract

This Thesis explores various regimes of atomic and atom - molecule collisions ranging from ultralow to high temperatures.

The first part of the work focuses on near-resonant vibrational energy transfer in collisions of diatomic molecules with atoms. It is illustrated that the resonance of vibrational energy transfer is stimulated by rotational rather than vibrational excitation of the diatomic molecule. The relation between the resonance of the vibrational energy transfer and the atom - diatom interaction potential is explored. It is shown that even relatively heavy diatomic molecules can exhibit resonant vibrational relaxation from the first vibrationally excited level if they are at high levels of rotational excitation. It is examined how the resonant energy transfer changes with collision energy and the consequences of the resonant vibrational relaxation for atom - diatomic molecule scattering at high temperatures are emphasized.

Spin - orbit transitions in atom - atom and atom - molecule collisions at ultracold temperatures are studied in the second part of the work. It is shown that the rates for the electronic transitions are substantial at zero temperature and the propensity rules observed in high energy collisions are more pronounced and control the collision dynamics in the ultracold limit. It is pointed out that symmetry constraints can modify electronic transitions near threshold. A possibility of trapping  $^3\text{P}$  atoms in an electronic excited metastable state at ultracold temperatures using the buffer gas loading technique is proposed.

Spin-flipping transitions in collisions of  $^2\Sigma$  diatomic molecules with atoms at cold and ultracold temperatures are investigated in the final part of the Thesis. It is demonstrated that the spin-flipping transitions in the rotationally ground state molecules can be induced by collisions with structureless targets and proceed through coupling to the rotationally excited  $N = 1$  level of the diatomic molecules. It is shown that the cross section for spin-flipping transitions in atoms or molecules in the state with angular momentum  $1/2$  is a quadratic function of collision energy in the ultracold limit.