State-to-state collisional rates and characterization of products at low temperature

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To date more than 200 different molecules have been identified in the interstellar medium or in protoplanetary disks. However, the study of the molecular or atomic abundances or their spatial distribution has been so far limited by local thermodynamic equilibrium (LTE) modeling due to the lack of collisional data. The data are indeed necessary to model out-of-equilibrium (non-LTE) spectra or maser action, owing to the complex competition between the radiative and collisional processes. Non-LTE situations are very common in space where the frequency of collisions is low and to determine column densities with accuracy mainly limited by the calibration uncertainties, or to provide abundance ratios, the energy transfer state-to-state collisional rates become crucial.

Nowadays, a variety of theoretical methods is developed and used, from the coupled-channel theory to classical approaches. Experimentally, three main techniques in France produce complementary results: doppler broadening, double resonance in CRESU apparatus or cells and molecular beam technique. I will discuss on the advantages and limitations of these experimental techniques combined with some theoretical results.

However, to fully benefit from the diagnostic power of the molecular lines, the formation and destruction paths of the parent molecules must be quantitatively (and not just qualitatively) understood. Low temperature experimental kinetic data for only a few hundreds (KIDA database http:/ /kida.obs.u-bordeaux1.fr/) of neutral-neutral or ion-neutral reactions have been determined while astrochemical networks have 1000s of reactions, forcing modellers to use rate coefficients estimated from various levels of theory when no experimental data are available. Furthermore, little is experimentally known about the products of reactions and their branching ratios. Indeed, experimental measurements require either determining absolute concentrations or using a calibration reaction of known product yield(s) and they are still great experimental challenges. In this contribution, I will present recent advances and perspectives in the detection of products of gas phase reactions through various experimental techniques and methods for a better understanding of the chemistry of cold astrophysical objects.