PLASMA CHEMISTRY and ASTROPHYSICAL PLASMAS Differences and similarities

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The question whether in molecular astrophysical plasmas the notion of chemistry on passivated surfaces could be a mechanism of molecule generation is discussed. At the hand of an example and using a global formulation of the mass and energy balances a more heuristic approach is discussed of dark cloud plasma chemistry. In this model the main formation mechanism is the association of radicals at surfaces. The exact nature of adsorbing radicals is less important and thus information on dissociation of molecules is sufficient as long as the dissociated fragments contribute to molecule formation. It will be advocated to analyse documented plasmas to be able to conclude on general trends in molecule formation.

The main function of low temperature plasmas is to ionize and to dissociate the atoms and molecules present in the plasma. Ions, electrons and radicals will go to the walls by diffusion and convection, as long as electrons and ions do not recombine by dissociative recombination and radical fragments do not associate to new molecules. In low pressure plasmas and low to moderate electron densities, recombination of charged particles and association of radicals will be at surfaces, as radical reactions are absent or lead only to new radicals. Formation of new molecules will thus take place by association of radical fragments at surfaces, in astro-chemistry made up by clusters and dust. Analysis of the molecules will thus show the measure of dissociation and the contribution of molecule association.

The starting point is the mass balance of charged particles of the ionizing part of the plasma, assuming that secundary ionization following photoionization is at least so important. Ionization has thus to be balanced by loss by transport and at high n_e by (commonly dissociative) recombination. If the latter is unimportant (low value of n_e) it can be concluded that all charged particles are lost to surfaces. The n_e production can be deduced from measurements of electron density *and decay time constant* τ. The latter is usually requires not much extra effort (but nevertheless is hardly done). The value of n_e/τ integrated over the ionizing plasma volume gives the production of charged particles. Then the production of radical fragments by dissociation is typically a factor $\xi^{rad} \sim 3 - 10$ higher than the production of charged particles. In this picture the electrons (or more general the charged particles) are the essential (indirect) precursors to molecule formation. There needs to be more emphasis for this aspect, not only for molecular fragments. The electron production is related to the power absorption which can be estimated from the admitted power and the volume of the ionizing plasma and a power factor ξ^P. which describes the ratio of total losses and the losses associated with the formation of electrons and ions. Calculation of these factors ξ^P and ξ^{rad} forms of course the challenge of plasma physics. But it would be possible to deduce from models these factors and compare these with experimental reasults therewith acquiring estimates for comparable plasmas.

Commonly plasmas consist of an ionizing part embedded in a usually larger "recombining" part. The latter has a lower electron temperature and the charged particle density depends on the creation in the ionizing part and the (absence of) recombination in the recombining part. For many low pressure industrial plasmas the recombining part is only at the surface (including the surfaces of clusters and powder). In this case the analysis is relatively simple: T_e depends in first order only on pressure and the electron production can be estimated if an estimate of ξ^P can be made. At low n_e usually the dissociation is not complete and thus new molecules are less abundant than injected molecules. This is usually a good condition for high abundances of saturated radicals and thus production of more complex organic molecules as CH_3OH.

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The medium in the various types of interstellar media are without doubt (molecular) *plasmas* in all sense: the Debye length is much larger than the interelectron distance, the chemical excitation plays a dominant role in the chemistry and charge transfer is an important process. The plasmas are molecular with hydrogen as a dominant gas and with many other molecules as CO, NH_3, hydrocarbons and organic molecules. Here we will discuss the mechanisms at the hand of very large cold (10 K) dark clouds, with neutral (H_2) densities in the 10^{10} m^{-3} range and ionization ratios in the order of $10^{-6} – 10^{-7}$. Surface is provided by clusters and dust particles with dimensions between nm and µm. Though dimensions, densities, temperatures and time scales are vastly different there are possible analogous mechanisms which lead to molecule formation. Strange enough column denisties of electrons and of molecules are commonly in the same range.

Possible mechanisms of molecule formation will be discussed. Presently it is assumed that the surface must have more influence than previously thought also for more complex molecules as CH_3OH. The new FIR data indicate that in many of these media there is abundant generation of molecules. A complicating factor forms the fact that structure of the plasma and the presence of magnetic fields. In the analysis we will take into account the structure as higher neutral densities will lead to higher electron densities in these photon ionization dominated media.

One aspect will be the modified surface by passivation of the surface by radicals produced in the plasma which will arrive at the surface if there are no siginificant three body formation reactions. Then the ratio of radical arrival rate and thermal desorption rate of formed molecules could be taken as a measure of comparison. If the arrival rate is large enough then surfaces are passivated and modified chemistry results.

The contribution will indicate that the further exploration of plasma physics in fundamental analysis may have impact on other disciplines and that this may easily be as important as direct application of low temperature plasma physics. At the other hand the abundance of new detail from other plasmas may help to futher develop the plasma physics/ chemistry as new discipline and help to find new ways for applications of ionized media.