Sticking and desorption of small physisorbed molecules: laboratory experiments and astrophysical applications

G.W. Fuchs

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Abstract

Small molecules like O_2, N_2 and CO are key species in the chemical evolution of pre- and protostellar cores. Since O_2 and N_2 do not have an electric dipole moment, direct observations of these spieces in cold environments are difficult. Gaseous N_2 is known to be abundant in dense cores from indirect observations of the chemically related N_2H^+ ion, but gas-phase O_2 appears to be largely absent, with upper limits from space observations giving $N(O_2)/N(H_2) \leq 5{\cdot}10^{-8}$ [1]. At sufficiently high densities ($n(H_2) > 10^5$ cm^{-3}) and low temperatures (<20 K), even volatile molecules like CO, N_2 and O_2 freeze-out from the gas-phase onto grains, forming a water-poor icy mantle layer. This freeze-out significantly influences the gas-phase chemistry of many species including N_2H^+, since CO is one of its main destroyers. It also affects the abundance of H_3^+ and its level of deuterium fractionation [2]. Solid CO is readily observed through its stretching mode at 4.67 μm with an abundance comparable to, or larger than, that in the gas in the coldest regions [3]. Again, O_2 and N_2 cannot be detected directly in the ice but their presence may be inferred by their effect on the solid CO line profile. It is clear that in order to properly model the chemistry in cold dense cores, a good understanding of the freeze-out and desorption of these species is needed.

In this contribution laboratory experiments will be presented using our new ultra-high vacuum experiment CRYOPAD to determine fundamental properties of ices, in particular sticking probabilities at low temperatures and molecular desorption energies. CO, N_2 and O_2 have been deposited on a poly-crystalline gold surface at 14 K in pure, mixed and layered structures [4,5,6]. For astrophysical relevance, ices with different thicknesses between 10 and 160 mono-layers have been investigated using Temperature Programmed Desorption (TPD) and Reflection Absorption InfraRed Spectra (RAIRS) techniques. The TPD spectra are used to determine the binding energies and desorption kinetics of these species under various conditions. It is concluded that N_2 and CO molecules interact significantly with each other whereas O_2 and CO molecules do not. The sticking coefficients of CO, N_2 and O_2 are all close to unity at low temperatures. The RAIR spectra of mixed and layered N_2 -CO and O_2 -CO ices are discussed

and conclusions are drawn for the underlying intermolecular interactions. The astrophysical consequences will be discussed and kinetic models for use in astrochemical calculations are presented.

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