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Astrochemistry simulated in electron-irradiated CO_2/NH_3 ices

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Low energy secondary electrons are abundantly produced in astrophysical or planetary ices by the various ionizing radiation fields encountered in space environments, and may thus play a role in the radiation processing of such ices (Moore et al. 2005). One approach to simulate their astrochemical effect is to irradiate nanometer thick molecular solids of simple molecular constituents in ultra-high vacuum (UHV) with energy selected electron beams, and to monitor changes in film chemistry with surface analytical techniques (Arumainayagam et al. 2010). Of particular interest is the formation of HCN, which is a signature of dense gases in interstellar clouds, and is ubiquitous in the ISM. Moreover, the chemistry of HCN radiolysis products such as CN^- may be essential to understand of the formation of amino acids (Vera et al. 2014) and purine DNA bases. Here we present new results on the UHV irradiation of cryogenic (22 K) multilayer films of CO_2 and NH_3 with 70 eV electrons, leading to CN, and other new bond formations. Mass resolved electron stimulated desorption yields of cations and anions are recorded as a function of electron fluence. The prompt desorption of cationic reaction/scattering products (Huels et al. 2008) is observed at low fluence. Detected ions that suggest formation of new chemical species include C_2^+, $C_2O_2^+$, C_2O^+, CO_3^+, $C_2O_3^+$ or CO_4^+ from pure CO_2, and N^+, NH^+, NH_2^+, NH_3^+, NH_4^+, N_2^+, N_2H^+ from pure NH_3, and NO^+, NOH^+ from CO_2/NH_3 mixtures. Most saliently, increasing signals of new negative ion products desorbing during prolonged irradiation of CO_2/NH_3 films included C_2^-, C_2H^-, $C_2H_2^-$, as well as CN^-, HCN^- and H_2CN^-. The identification of product ions was aided by using $^{13}CO_2$ and $^{15}NH_3$ isotopes. The chemistry induced by electrons in pure films of CO_2 and NH_3, as well as mixtures with composition ratios (3:1), (1:1), and (1:3), was also studied by X-ray photoelectron spectroscopy (XPS). The XPS results show that electron irradiation of CO_2/NH_3 mixed films produces new chemical species containing C=O, O−H, C−C, C−O, C=N and N=O bonds. (Work funded by NSERC).

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