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Ammonia ices under low-energy electron irradiation - Towards quantitative desorption rates and effective cross sections

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Synopsis Low-energy (< 20 eV) electron processing of NH₃ multilayer films, systems of interest in astrochemistry, leads to significant NH₃ desorption, fragmentation, and to a complex chemistry arising from recombination and secondary processes induced by reactive products. Quantitative desorption rates of neutral species and effective cross sections for selected processes were obtained by combining three surface-sensitive techniques: High Resolution Electron-Energy Loss Spectroscopy (HREELS), Temperature Programmed Desorption (TPD) and Electron Stimulated Desorption (ESD) of neutral species.

NH₃ is known to be a major component in ice mantles in molecular clouds with up to ~15 % of H₂O in certain regions of the interstellar medium [1]. Model predictions cannot account for the abundance of NH₃ [2], suggesting that desorption or conversion to other compounds should be considered. Among the various thermal and non-thermal mechanisms responsible [3], this study is dedicated to processes induced by low energy electrons (LEE, energy < 20 eV) [4]. LEE interactions with matter are considered to be the primary driving force in many radiation-induced desorption and chemical reactions in ices [5].

As schematized in figure 1, multilayers of NH₃ isotopologues (¹⁴NH₃, ¹⁵NH₃, and ¹⁴ND₃) (~10 ML) were deposited on copper at 28 K and crystallized under annealing at 60 K. High-Resolution Electron Energy Loss Spectroscopy (HREELS) and Temperature Programmed Desorption (TPD) were used to control the film morphology and estimate film thickness, respectively. LEE irradiation (1-20 eV) was performed at 28 and 60 K. Electron Stimulated Desorption (ESD) was used to detect neutral fragments/molecules desorbing during irradiation while HREELS and TPD were used to characterize processed residues.

The desorption of intact NH₃ was observed which resulted in the direct erosion of the film proceeding through a mechanism consistent with desorption processes induced by electronic transition (DIET). Different fragmentation and recombination processes were also observed as evidenced by the detection of neutral radicals NH_x (x = 1,2), and sta-

ble molecules N₂ and H₂. Aside from desorption, a wealth of chemical processes was also observed at 13 eV. Temporal ESD at this energy allowed for the estimation of the effective cross section of NH₃ desorption and observing the delayed desorption of N₂ and H₂. TPD analysis of the residues also provided evidence of diazene N₂H₂ and hydrazine N₂H₄ synthesis in the film.

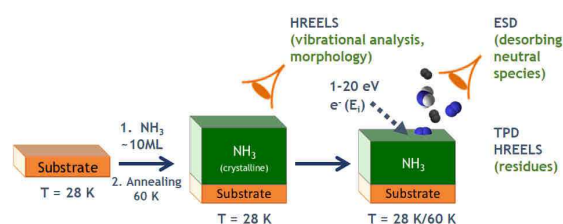


Figure 1. Scheme of the procedure used to study electron-induced processes in molecular layers of ammonia and its isotopologues.

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