THERMODYNAMIC EQUILIBRIUM GROWTH OF CO-N_2 CRYSTALS IN CONDITIONS OF THE INTERSTELLAR MEDIUM

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The densest and coldest parts of the interstellar medium, called dense molecular clouds or dense cores, have temperatures as low as 10 K and pressures of 10^{-13}–10^{-11} Pa. These clouds consist mostly of gaseous H_2 and microscopic dust particles. Such Most of molecules (except H_2) in these clouds condense on dust grains forming icy mantles. regions are cradles of young stars, which form after the gravitational collapse of dense cores. The two main components of icy mantles in these regions are H_2O and CO. The former forms amorphous icy structure on dust surfaces, while the latter forms in the gas phase and then partially condenses. It is believed that rapid CO condensation upon a temperature decrease leads to the formation of a separate CO-rich ice layer above the H_2O-rich layer. Recent findings have shown that CO molecules are sufficiently mobile to form equilibrium crystals on the surface of H_2O ice even at temperatures close to 10 K. The thin-film mode of CO crystal growth is the equilibrium Stranski–Krastanov mode, where a CO adsorbate layer wets the surface of H_2O ice and then segregated CO crystallizes, forming the α-CO phase [1].

Molecular nitrogen, though not detected but likely present in molecular clouds, exhibits gas–grain interaction behaviour similar to that of CO, and the CO–N_2 binary system forms a continuous series of solid solutions. Thus, N_2 should be involved in the equilibrium between the adsorbate layer, CO segregates, and the α-CO phase, as we assume in this study.

The recent launch of the James Webb Space Telescope has allowed the investigation of dangling OH (dOH) features of H_2O ice, which have been detected but not yet studied in detail. These features correspond to free OH groups that are not hydrogen-bonded, carrying information about the composition of apolar molecules in the bulk of H_2O ice and on its surface. In this study, we grew a series of H_2O ices at 10 K and then separately deposited on it a CO–N_2 mixture with specified CO:N_2 molecular ratios (1:0, 1:0.5, 1:1, 1:2, 1:4) at 20 K; the latter temperature is required to reach equilibrium within timescale of laboratory experiment. We recorded the infrared spectra of the resulting layered ices. We traced the CO:N_2 ratio in CO-rich crystals through the dependence of the CO band position on N_2 content, which was preliminary obtained, and determined this ratio on the H_2O ice surface via the dOH features of dOH–CO and dOH–N_2 clusters. The results allowed us to determine how N_2 distributes between adsorbate and CO crystals in conditions of thermodynamic equilibrium. This study may help to determine N_2 abundances in interstellar ices through the analysis of interstellar dOH features.

1. Kouchi, Akira, et al. "Formation of chiral CO polyhedral crystals on icy interstellar grains." *Monthly notices of the royal astronomical society* 505.1 (2021): 1530-1542.

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