Solubility limits in the N_2-CH_4 binary system: Laboratory studies and applications to telescopic spectra

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Methane and nitrogen ices have finite solubilities in one another. Their solubility limits as functions of temperature are given by the N_2-CH_4 binary phase diagram. For bulk compositions that exceed the solubility limit of either ice in the other, under conditions of thermodynamic equilibrium two phases will be present instead of one - a nitrogen dominated phase and a methane dominated phase. Given the bulk composition, application of the lever rule to the binary phase diagram gives the equilibrium abundances of these two phases. The two phases are spectrally distinct from one another, enabling analysis of a remote spectral observation in terms of the abundances of the two phases, thus enabling determination of the bulk N_2:CH_4 ratio. A version of this analysis was presented in 2010 (Tegler et al. ApJ 725:1296), using pure CH_4 optical constants for the CH_4-dominated phase and pure-CH_4 optical constants shifted to account for dilution in N_2 for the N_2-dominated phase (using shifts from Quirico & Schmitt 1997, Icarus 127:354). A deficiency of that analysis is that the solubility limits are functions of temperature, and the shifts depend on concentration and thus temperature. The Quirico & Schmitt shifts are for CH_4 concentrations well below the solubility limit over most temperatures where the hexagonal β N_2 phase is stable. Shifts appropriate to the solubility limit at the relevant temperature would be preferable. Furthermore, dilution in N_2 does more than just shift the CH_4 bands. More subtle effects also occur, such as narrowing of the bands. So what is really needed is a library of spectra of the two phases at various relevant temperatures along the solubility limit curves. We will present data from a series of laboratory studies of N_2:CH_4 ices in the vicinity of the solubility limits designed to provide more appropriate end-member spectra for determinations of bulk N_2:CH_4 composition from telescopic spectra and will illustrate their application to telescopic data.