

Water, O₂ and Ice in Translucent and Dense Molecular Clouds: PDR Models with Grain-Surface Chemistry and Photodesorption

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Abstract.

SWAS and ODIN observations of giant molecular clouds have shown conclusively that the gas-phase abundances of H₂O and O₂ in GMCs are far below values predicted by gas-phase astrochemical models. Absorption line measurements of translucent interstellar clouds, however, show gas-phase column-averaged abundances of such oxygen-bearing species as H₂O and OH that are significantly higher than those observed in GMCs. We propose a model to explain both the translucent and dense cloud observations by including the effects of adsorption and freezeout of O and C based species on dust grains, as well as the effects of photodesorption in the surface layers of clouds exposed to the ambient far-ultraviolet radiation field. This model naturally explains: (a) the translucent cloud observations, where a significant fraction of O remains in the gas phase (allowing gas-phase H₂O and OH to form) due to photodesorption of H₂O-ice from dust grains; (b) the dense cloud observations, where O is frozen out as H₂O-ice on dust grains over most of the cloud volume, leading to the low column-averaged H₂O abundances measured by SWAS and ODIN; and (c) the environment-dependent threshold column for freeze-out seen by Chiar et al (1995) and Tanaka et al. (1990). We show that our models are also able to explain measurements of H I narrow self-absorption (HINSA) clouds with OH 18 cm emission seen by Li & Goldsmith (2003).

Keywords. astrochemistry, ISM: molecules, ISM: clouds, ISM: abundances

References

- Chiar, J.E., Adamson, A.J., Kerr, T.H. & Whittet, D.C.B.. 1995, *Ap.J.* 455, 234
Li, D. & Goldsmith, P.F. 2003, *Ap.J.* 585, 823
Tanaka, M., Sato, S., Nagata, T. & Yamamoto, T. 1990, *Ap.J.* 352, 724