ON THE POSSIBLE DETECTION OF SOLID O_2 IN INTERSTELLAR GRAINS

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ABSTRACT. In various models of the chemistry of interstellar grains, solid O_2 is formed by accretion as well as by surface reactions. In dense molecular cloud models, at a later stage of evolution of an interstellar grain, solid O_2 becomes a major grain mantle constituent at the expense of water ice abundance. If molecular oxygen is embedded in a "dirty" ice" matrix, the forbidden fundamental vibration of O_2 at 1550 cm^{-1} may become observable.

1. Introduction

Oxygen, the cosmic most abundant element after H and He plays an important role in interstellar chemistry. O_2, a diatomic homonuclear molecule shows no transitions in the infrared (IR). Therefore no direct estimates of the abundance can be obtained. We have studied the fundamental band of solid molecular oxygen at 1551 cm^{-1} in various matrices and discuss the detectability of solid O_2 in interstellar grains and its photolysis product, O_3.

2. Results and Discussion

We could detect the weak vibrational transition of molecular oxygen at 1559 cm^{-1} in a CO_2 matrix at 10 K and confirm the isotopic shift, using isotopically labelled $^{18}O_2$ (1469 cm^{-1}). Using the well defined integrated absorbance A_m of the bending mode of CO_2 at 15.2 µm (Sandford et al., 1988) we could estimate this value with some accuracy for molecular oxygen: A_m ($cm.mol^{-1}$) = 3×10^{-18}. Fig. 1 shows the IR spectum between 4000-500 cm^{-1} of a gas mixture containing $H_2O : CO : O_2 : CO_2$ (2 : 2 : 1 : 0.5). The cross section A_m ($cm.mol^{-1}$) is a factor 30 weaker in this complex mixture than in pure and highly diluted CO_2. The interaction of polar and polarizable molecules with molecular oxygen in a matrix may be responsible for the enhancement of the weak vibrational transition of O_2, a process which can also occur in interstellar grain mantles. Another way to estimate the abundance of O_2 on interstellar grains is from a study of its photolysis product O_3. Ozone is easily produced by the photodissociation of O_2 in the ISM and the ν_3 strongest vibrational transition becomes clearly visible at 1042 cm^{-1} (9.6 µm). Though this band can be obscured by the strong absorption band of silicates at 10 µm the sharp feature could be detectable, as well as the overtone of O_3 at 2110 cm^{-1}.

P. D. Singh (ed.), Astrochemistry of Cosmic Phenomena, 189–190.

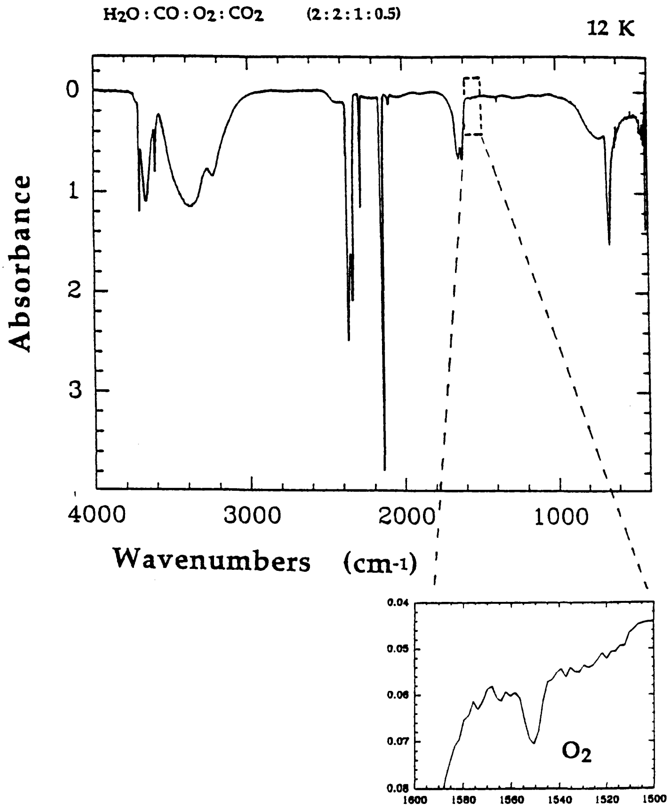

Figure 1. IR spectrum of a "dirty" ice mixture H_2O : CO : O_2 : CO_2 (2 : 2 : 1 : 0.5) at 10 K. The weak fundamental transition of molecular oxygen at 1551 cm^{-1} is shown in detail.

We want to point out that the results presented here indicate the possible detection of solid O_2 in interstellar space in the mid-IR. The calculated integrated absorbance is weak, but can be enhanced by interactions with molecules in the environment, disturbing the symmetry of molecular oxygen. In the theoretical models, O_2, becomes a major grain mantle constituent at later times in the evolution of an interstellar grain in dense molecular clouds (Breukers, 1991). The search for the fundamental transition of O_2 will probably be successful in astronomical targets like dense molecular clouds, with high extinction and where other grain mantle constituents have already been identified. Furthermore the photolysis product ozone can very likely be observed.

References

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