Diffusion and reactivity of Oxygen atoms on cold surface

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Abstract

Any evolving system can change of state via thermal mechanism (hopping a barrier) or via quantum tunnelling. Most of the time, efficient classical mechanisms dominate at high temperatures. Which is why, an increase of the temperature can initiate the chemistry. We present here an experimental investigation of O-atom diffusion and reactivity on water ice. We explore the 6-25K temperature range, at sub-monolayer surface coverages. We derive the diffusion temperature law and observe, like in quantum physics handbooks, the dramatic transition from quantum to classical diffusion. Despite of the high mass of O, quantum tunneling is efficient even at 6K. As a consequence, the solid–state astrochemistry of cold regions should be reconsidered and should include larger organic molecules than previously expected.

Analysis and Methods

The experiments were conducted using the FORMOLISM setup (FORmation of MOlecula in the Interstellar Medium) based in the Physics Department of the Université de Cergy-Pontoise. The setup consists of an ultrahigh vacuum (UHV) chamber (base pressure of \( \sim 1 \times 10^{-10} \) mbar) containing a sample surface (SiO or Graphite) attached to the cold head of a closed-cycle He cryostat. The sample surface mimics a realistic analog of bare dust grains in molecular clouds. O-atom diffusion and reactivity on cold surface investigation of O-atom diffusion and reactivity on water ice. We explore the 6-25K temperature range, at sub-monolayer surface coverages. We determine the O-atom diffusion and reactivity on cold surface. We explore the 6-25K temperature range, at sub-monolayer surface coverages. We observe, like in quantum physics handbooks, the dramatic transition from quantum to classical diffusion. Despite of the high mass of O, quantum tunneling is efficient even at 6K. As a consequence, the solid-state astrochemistry of cold regions should be reconsidered and should include larger organic molecules than previously expected.

Conclusion

1) O-atom diffusion is governed by quantum tunnelling up to 20K. 2) Comparing the different morphologies of the ice allows us to conclude that the topological disorder of the substrate does not affect deeply the diffusion regime. 3) We found that the value for the diffusion of oxygen is of 300K.

Implications for solid state astrochemistry are of major importance.

Infact, we can affirm now that O addition chemistry is competitive with H additions, because of the comparable budget of O atoms and H atoms in dense and UV protected interstellar environments.