How acids behave in ultracold interstellar space

10 June 2019

The team at the Cluster of Excellence Resolv has investigated chemistry in interstellar space. Credit: RUB, Lehrstuhl für Astrophysik

A research group from Ruhr-Universität Bochum has investigated how acids interact with water molecules at extremely low temperatures. Using spectroscopic analyses and computer simulations, they investigated the question of whether hydrochloric acid (HCl) does or does not release its proton in conditions like those found in interstellar space. The answer depends on the order in which the water and hydrochloric acid molecules come together.

The group led by Professor Martina Havenith, Chair of Physical Chemistry II, and Professor Dominik Marx, Chair of Theoretical Chemistry, from Ruhr-Universität Bochum, together with the team led by Dr. Britta Redlich from Radboud University, Nijmegen, describes the results in the journal *Science Advances*, published online in advance on 7 June 2019.

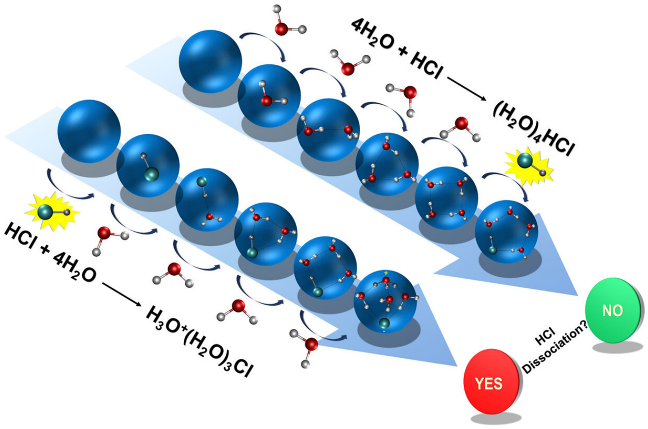
Understanding how complex molecules were formed

If hydrochloric acid comes into contact with water molecules under normal conditions, such as at room temperature, the acid immediately dissociates, releasing its proton (H+); one chloride ion (Cl-) remains. The research team wanted to find out whether the same process also takes place at extremely low temperatures below 10 Kelvin, i.e., below minus 263.15 degrees Celsius. "We would like to know whether the same acid-alkali chemistry as we know on Earth also exists in the extreme conditions in interstellar space," explains Martina Havenith, speaker for the Cluster of Excellence Resolv. "The results are crucial for understanding how more complex chemical molecules formed in space—long before the first precursors of life came into existence."

In order to replicate the extremely low temperatures in the laboratory, the researchers conducted the chemical reactions in a droplet of superfluid helium. They monitored the processes using a special type of infrared spectroscopy, which can detect molecular vibrations with low frequencies. The researchers used a laser with especially high brightness at Nijmegen for this. Computer simulations enabled the scientists to interpret the experimental results.

First, the researchers added four water molecules, one after the other, to the hydrochloric acid molecule. The hydrochloric acid dissociated during this process, donating its proton to a water molecule, resulting in a hydronium ion. The remaining chloride ion, the hydronium ion and the three other water molecules formed a cluster.

However, if the researchers first created an ice-like cluster from the four water molecules and then added the hydrochloric acid, they yielded a different result: the hydrochloric acid molecule did not dissociate; the proton remained bonded to the chloride ion.



The two possible pathways that muriatic acid can follow in the conditions like those found in interstellar space: Dissociate or absorb in icy water. Credit: D. Mani

"Under the conditions that can be found in interstellar space, the acids are thus able to dissociate, but this does not necessarily have to happen—both processes are two sides of the same coin, so to speak," says Martina Havenith.

Chemistry in space is not simple

The researchers assumed that the result can also be applied to other acids, as it represents the basic principle of chemistry under ultracold conditions.

"Chemistry in space is by no means simple; it might even be more complex than chemistry under planetary conditions," says Dominik Marx. After all, it depends not only on the mixing ratios of the reacting substances but also on the order in which they are added to each other. "This phenomenon needs to be taken into consideration in future experiments and simulations under ultracold conditions," says the researcher.

More information: Devendra Mani et al. Acid solvation versus dissociation at "stardust conditions": Reaction sequence matters, *Science Advances* (2019). DOI: 10.1126/sciadv.aav8179

Provided by Ruhr-Universitaet-Bochum