The quantum secret to alcohol reactions in space

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Chemists have discovered that an 'impossible' reaction at cold temperatures actually occurs with vigour, which could change our understanding of how alcohols are formed and destroyed in space.

To explain the impossible, the researchers propose that a quantum mechanical phenomenon, known as 'quantum tunnelling', is revving up the chemical reaction. They found that the rate at which the reaction occurs is 50 times greater at minus 210 degrees Celsius than at room temperature.

It's the harsh environment that makes space-based chemistry so difficult to understand; the extremely cold conditions should put a stop to chemical reactions, as there isn't sufficient energy to rearrange chemical bonds. It has previously been suggested that dust grains—found in interstellar clouds, for example—could lend a hand in bringing chemical reactions about.

The idea is that the dust grains act as a staging post for the reactions to occur, with the ingredients of complex molecules clinging to the solid surface. However, last year, a highly reactive molecule called the 'methoxy radical' was detected in space and its formation couldn't be explained in this way.

Laboratory experiments showed that when an icy mixture containing methanol was blasted with radiation—like would occur in space, with intense radiation from nearby stars, for example –methoxy radicals weren't released in the emitted gases. The findings suggested that methanol gas was involved in the production of the methoxy radicals found in space, rather than any process on the surface of dust grains. But this brings us back to the problem of how the gases can react under extremely cold conditions.

"The answer lies in quantum mechanics," says Professor Dwayne Heard, Head of the School of Chemistry at the University of Leeds, who led the research.

"Chemical reactions get slower as temperatures decrease, as there is less energy to get over the 'reaction barrier'. But quantum mechanics tells us that it is possible to cheat and dig through this barrier instead of going over it. This is called 'quantum tunnelling'."

To succeed in digging through the reaction barrier, incredibly cold temperatures—like those that exist in interstellar space and in the atmosphere of some planetary bodies, such as Titan—are needed. "We suggest that an 'intermediary product' forms in the first stage of the reaction, which can only survive long enough for quantum tunnelling to occur at extremely cold temperatures," says Heard.

The researchers were able to recreate the cold environment of space in the laboratory and observe a reaction of the alcohol methanol and an oxidising chemical called the 'hydroxyl radical' at minus 210 degrees Celsius. They found that not only do these gases react to create methoxy radicals at this incredibly cold temperature, but that the rate of reaction is 50 times faster than at room temperature.

To achieve this, the researchers had to create a new experimental setup. "The problem is that the gases condense as soon as they hit a cold surface," says Robin Shannon from the University of Leeds, who performed the experiments. "So we took inspiration from the boosters used for the Apollo Saturn V rockets to create collimated jets of gas that could react without ever touching a surface."

The researchers are now investigating the reactions of other alcohols at very cold temperatures. "If our results continue to show a similar increase in the reaction rate at very cold temperatures, then scientists have been severely underestimating the rates of formation and destruction of complex molecules, such as alcohols, in space," concludes Heard.

The findings are published in the journal *Nature Chemistry* on 30 June 2013.

More information: Accelerated chemistry in the reaction between the hydroxyl radical and methanol at interstellar temperatures facilitated by tunneling, DOI: 10.1038/nchem.1692

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