Study offers new recipe for oxygen on icy moons

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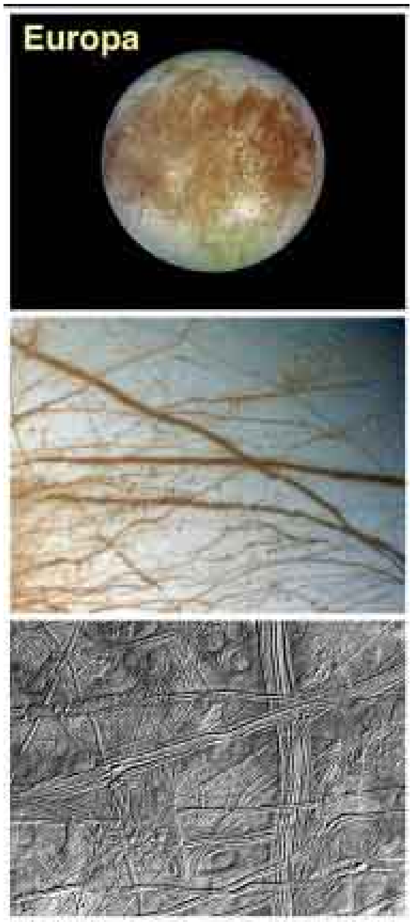
Some may be surprised to learn that bleach-blondes and the enabler of life elsewhere in our solar system have something in common. And, no, it's not intelligence. It is, in fact, hydrogen peroxide. But how that hydrogen peroxide emerges from ice to become life-sustaining oxygen has been unclear. Now, a new study at the Department of Energy's Pacific Northwest National Laboratory in Richland, Wash., offers the most detailed picture to date on how oxygen can be made in frigid reaches far from Earth.

Since its discovery on Jupiter's Europa and other icy moons orbiting large gaseous worlds, extraterrestrial ice as a source for oxygen has presented the tantalizing possibility of complex life around other planets. Yet planetary scientists have struggled to explain how, in the absence of sufficient heat, oxygen could be produced from the permafrost surfaces for use, in Europa's case, by whatever life forms that might inhabit oceans trapped beneath.



Europa, and detail of its icy surface. (NASA images.)

The standard explanation is that abundant high-energy particles from space--protons, ultraviolet photons, electrons--break the molecular bonds that chain oxygen to hydrogen. (The geophysics – how the oxygen gets into the ocean as ice is – is another story, one involving a conveyor-belt-like recycling of surface ice into the ocean.)

Those previous oxygen-production models, however, don't jibe with what staff scientist Greg Kimmel and his colleagues at the PNNL-based W.R. Wiley Environmental Molecular Sciences Laboratory have been seeing in experiments, Kimmel reported Monday at the annual meeting of the American Chemical Society.

"The previous model was a two-step process," Kimmel said. "First, an energetic particle produces a stable precursor"--say, two hydrogen atoms coupled with two oxygen atoms (hydrogen peroxide) or a hydrogen atom paired with two oxygen atoms. "In step two, another energetic particle produces O_2, or molecular oxygen, from the stable precursor."

Kimmel and colleagues grew a microscopically thin ice film on a platinum surface, under a vacuum, and bombarded the film with high-energy electrons. The bursts lasted 30 to 60 seconds at 30 to 130 degrees Kelvin, approximating the minus-hundreds-of-degrees-Fahrenheit temperatures on the icy moons. Afterward, they measured the amount and location, determined by the oxygen isotopes used to construct layers of the ice film, and discovered that intermediate species of hydrogen-oxygen permeated the films.

"We found that a simpler two-step could not account for our results," Kimmel said. "Our model is a four-step process." First, the energetic particle produces what is known as a common "reactive oxygen species" called a hydroxyl radical, or OH. Next, two OH molecules react to produce hydrogen peroxide. Third, another OH reacts with the hydrogen peroxide to form HO_2 (hydrogen coupled to two oxygen atoms), plus a water molecule. And, finally, an energetic particle splits an oxygen molecule from the HO_2.

The experiment introduced another new twist. "One might have expected O_2 to be produced throughout the region where the electrons penetrate in the film," Kimmel noted. "But this is not the case. It appears that the OH's can be made deeper in the film, but that they subsequently diffuse to and collect at the ice surface with the rest of the reactions (steps 2-4 above) preferentially occurring there."

Source: Pacific Northwest National Laboratory