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Shaking Ordinary Ice (Very Hard) Transformed It Into Something Never Seen Before: The *Glass* Form of Liquid Water

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The research illustrates how much scientists still have to learn about a molecule as simple as water.

The researchers' setup for creating medium-density amorphous ice involved placing ordinary ice and steel balls in a jar. Photo Credit...Christoph Salzmann

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By Kenneth Chang
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Shaken and chilled — but not stirred — ordinary frozen water turns into something different: a newly discovered glass form of ice made of a jumble of molecules with unique properties.

"This is completely unexpected and very surprising," said Christoph Salzmann, a chemistry professor at University College London in England and an author of a paper published on Thursday in the journal Science that described the ice.

Water is a simple molecule that has been intently studied by scientists for centuries: two hydrogen atoms jutting off at a 104.5-degree angle in a V-shape from a central oxygen atom.

The new discovery shows, once again, that water, a molecule without which life is not known to be able to exist, is still hiding scientific surprises yet to be revealed. This experiment employed relatively simple, inexpensive equipment to reveal a form of ice that could exist elsewhere in the solar system and throughout the universe.

In day-to-day life, we encounter three forms of water: a vaporous gas like steam, flowing liquid water and hard, slippery ice. The ice of our everyday lives consists of water molecules lined up in a hexagonal pattern, and those hexagonal lattices neatly stack on top of each other. The hexagonal structure is not tightly packed, which is why ice is less dense than liquid water and floats.

With permutations of temperature and pressure outside what generally occurs on Earth, water molecules can be pushed into other crystal structures. Scientists now know of 20 crystalline forms of water. The 20th form of ice was discovered last year.

In addition, researchers also have documented two types of ice with jumbled molecules, what they call amorphous materials. Because one of the amorphous ices is denser than water, it is known as high-density amorphous ice; the other, with a density less than that of water, is low-density amorphous ice. Amorphous ices are not found on Earth, but they could be prevalent in outer space, in comets, interstellar clouds and icy worlds like Europa, a moon of Jupiter.

There is even a type of water that is both liquid and solid. In 2018, scientists announced the creation of "superionic water," which was simultaneously solid and liquid.

Dr. Salzmann and his colleagues were not looking to add to the catalog of water ices. They instead wanted to study very tiny ice crystals, because minuscule bits of something sometimes possess properties very different from larger bits of the same stuff.

So Alexander Rosu-Finsen, a postdoctoral scientist in Dr. Salzmann's research group and the lead author of the Science paper, started smashing up ice. The water ice was first chilled in liquid nitrogen to minus 320 degrees Fahrenheit and then placed in a container along with steel balls. A machine then shook the ice and steel balls, still chilled at ultracold temperatures, back and forth at 20 times per second, pulverizing the ice into tiny bits, a process known as ball milling.

Think of it as a high-tech cocktail shaker.

Dr. Rosu-Finsen then opened the container.

"Lo and behold, something completely unexpected happened," said Dr. Rosu-Finsen, who is now an associate editor at the journal Nature Reviews Chemistry.

The white material inside looked like what one would expect smashed-up ice to look like, but it had been transformed.

The material was now denser, and much of the crystalline structure had been destroyed, producing an amorphous material. The density, however, did not match the already known high- and low-density amorphous ices. Intriguingly, it fell in between; indeed, it was almost exactly the same density as liquid water. Until now, all of the solid forms of ice, crystalline or amorphous, were either significantly denser or less dense than liquid water.

The researchers named it medium-density amorphous ice, or MDA.

The banging of the steel balls applied a shearing force on the ice crystals, enough to knock the water molecules out of their crystal positions, allowing them to be packed more tightly.

“It’s really cool,” said Marius Millot, a physicist at Lawrence Livermore National Laboratory in California who led the experiment that created superionic water. “What it tells us is that there’s still a lot of things that we don’t understand.”

That medium-density amorphous ice has almost the same density as liquid water raises **the possibility it is actually a glass,** a liquid cacophony of molecules flowing until it cooled and slowed and froze in time without crystallizing, still disordered.

“This is the key question,” Dr. Salzmann said. “Is MDA the glass (form) of liquid water?”

Follow-up experiments could add impurities to the ice. “We’ve done the experiments with pure ice,” Dr. Salzmann said. “The next question is, what will happen if we start mixing in other things?”

The findings could be of use to planetary scientists. The temperatures fall within what is found on Europa, and Jupiter exerts huge tidal forces on the icy ocean moon, which will be visited and studied closely by NASA and European orbiters.

“You get exactly the same kind of shearing motion,” Dr. Salzmann said. “The speculation is now that there could be some MDA in the outer solar system.”

The researchers also found a property of MDA that is unique among water ices. For most materials, if you compress it and then release the pressure, it simply returns to how it was before. But compressing MDA and then releasing the pressure and heating it released a large burst of energy.

That energy, released as the amorphous ice recrystallizes, could set off icequakes, for example.

That means perhaps the physics of the new ice could play a role in the shaping of the icy crust of Europa and the dynamics of ice farther down in the moon’s ocean, with implications for whether conditions there could be hospitable for life.

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