PHYS.ORG

Researchers identify fundamental property of how water, other liquids move at different temperatures

January 14 2011, By David L. Chandler

In a finding that has been met with surprise and some controversy in the scientific community, researchers at MIT and elsewhere have discovered a basic property that governs the way water and many other liquids behave as their temperature changes.

Liquids have long been known to exhibit a rapid change in properties near a point called the glass transition temperature, where the viscosity of the liquid — its "thickness," or resistance to flow — becomes very large. But MIT professor Sow-Hsin Chen and his co-researchers have found a different transition point at a temperature about 20 to 30 percent higher, which they call the dynamic crossover temperature. This temperature may be at least as important as the glass transition temperature, and the viscosity at the dynamic crossover temperature seems to have a universal value for a large class of liquids (called glass-forming liquids) that includes such familiar substances as water, ammonia and benzene.

At this new transition temperature, "all the transport properties of the liquid state change drastically," Chen says. "Nobody realized this universal property of liquids before." The work, carried out by physics professor Francesco Mallamace of the University of Messina, Italy (who is a research affiliate at MIT) and four of his students from Messina, along with Chen, an MIT professor emeritus of nuclear science and engineering, and Eugene Stanley, a physics professor at Boston

University, was published on Dec. 28 in the Proceedings of the National Academy of Sciences.

This is very basic research and Chen says it is too early to predict what practical applications this knowledge could produce. “We can only speculate,” he says, because “this is so new that real practical applications haven’t really surfaced.” But he points out that one of the most widely used building materials in the world, concrete, flows as a liquid-like cement paste during construction, and a better ability to understand its process of transition to solid form might be significant for improving its durability or other characteristics.

Controversial finding

The team had previously published their findings about the new transition temperature in water, but the new work extends this to the whole class of liquids. While the findings remain somewhat controversial, Chen says that last month an international symposium devoted to the study of this phenomenon was held in Florence, Italy involving about 50 scientists from various nations.

Benjamin Widom, an emeritus professor of chemistry at Cornell University, says that the researchers’ demonstration of the universality of this crossover phenomenon and the fact that the liquids studied all show roughly the same level of viscosity at their crossover point “is striking,” and adds that “These observations are certain to arouse much interest among those who work in the field, and perhaps even controversy because they contradict long-accepted ideas.”

Liquids become much more viscous as they approach their freezing temperature — that is, they begin to move less like water and more like honey. But the exact progression of this transition is difficult to measure, so the details are still poorly understood. The new research draws on published studies detailing the behavior of 84 different liquids, and the researchers found that a fresh analysis of the data, along with their own experimental work on water, shows a previously unrecognized universal property they all share in terms of how their viscosity and other characteristics change with temperature.

"Measuring viscosity is a very tedious process," Chen says, and measuring how it changes over tiny increments of temperature is even more difficult. But Chen and his colleagues found that they were able to measure relaxation time of water — which is directly proportional to its viscosity — using a state-of-the-art instrument at the National Institute of Standards and Technology in Washington that shoots neutrons at the material. "We discovered we can measure relaxation time very effectively with this instrument," Chen said, and they have been carrying out such measurements over the last several years.

This story is republished courtesy of MIT News (web.mit.edu/newsoffice/), a popular site that covers news about MIT research, innovation and teaching.

Provided by Massachusetts Institute of Technology