BioUpdate Foundation

Anomalous Water

A friend recently gave me a copy of the book “Polywater” by Felix Franks. It took me back to being a teenager, when I can remember alarmist television reports of this new form of water. If it ever got out of the lab, the oceans, and all the water in the world, would polymerise, and that would be the end of life on earth.

Although not known in the West until about 1966, the first reports of “polywater” were published in the Soviet Union in about 1962. In a somewhat bizarre twist of fate, Kurt Vonnegut published a novel “Cat's Cradle” in 1963 in which “Ice Nine” a fictional high melting form of ice accidentally contaminates the oceans, turning them into solid water and killing all life within a few days. It is said that Vonnegut credited the concept of ice nine to real life scientist Irving Langmuir, who supposedly came up with the idea, in the 1930's, when asked to entertain the author H. G. Wells who was visiting General Electric, Langmuir's employer.

Truth, they say, is stranger than fiction, and in this case it is true. If you are interested in anomalous water you don't need to study polywater, which it turns out does not exist, nor do you need to invent fictional ice nine. If any material in this universe has anomalous properties it is water – plain ordinary water.

Water is the only inorganic liquid that occurs naturally on planet earth, and the only substance on the planet that occurs naturally in all three phases of matter – solid, liquid and gas.

Most school children learn about the anomalous density of water. Most materials are denser in the solid state than in the liquid state. Water, of course, expands on freezing to give a lower density solid phase (ice) that floats on liquid water. The density anomaly does not stop there; between its melting point (0 °C) and 4 °C water contracts, becomes more dense. How can a liquid contract when heated?

Another everyday phenomenon that we take for granted is the persistence of ice on rivers and lakes even when the temperature is above freezing point. This is because water has an abnormally high specific heat. The definition of a calorie is the amount of heat requires to raise the temperature of 1 gram of water by 1 °C. By comparison the value for a brick is 0.22 cal/g/°C; it takes a lot of heat to warm a gram of water by 1 °C. By way of a more direct comparison, there is a general relationship that specific heat increases with molecular size. Ethanol (MW 46) has a heat capacity of 0.5 cal/g/°C. Water also breaks the “rule” that the specific heat of a solid is higher than that of the material in the liquid state.

Another rule of thumb says the boiling point of a liquid is related to its molecular size. Comparing water to other hydrides, such as ammonia (NH_3) or hydrogen sulphide (H_2S), one might expect water's boiling point to be about -93 °C. One might also expect it would freeze only a few degrees

below that temperature.

Life depends on water and although we tend to think of life on earth as carbon based, it is in fact water based. A human being is about 18% carbon but 60 to 70 % water. There is not, as Felix Franks once pointed out to me, a single biochemical reaction which does not involve water. Yet the water molecule cannot participate in covalent bond formation. Its interactions are limited to weak hydrogen bonds.

Arguably the liquid state is essential to life. It is hard to imagine a completely solid phase life form, without molecular motion there can be no reproduction. A solid phase/gas phase life form is conceivable but the liquid state does bring the benefit of density, and therefore concentration (think 1^{st} and 2^{nd} order rate equations). Certainly, life on this planet could not exist if water did not have anomalous properties. Could it exist anywhere else? That is a more difficult question!

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