

## 7.1: The Properties of Water

There is something very special about water,  $\text{H}_2\text{O}$ . For starters, it is essential for life. A human being can live for only three days without fresh water. Indeed, the cells in our bodies are made mostly of water.

For most organisms, it is important that cellular water remains in liquid form. Frostbite or death results if cells freeze.

Fortunately, we live on a remarkable planet. The median temperature on the surface of the earth is roughly 4 degrees celsius. That's a pretty good temperature for liquid water. Water is a liquid between 0 degrees celsius and 100 degrees celsius. If the earth were just a little colder -- if it were a few million miles farther from the sun, like Mars -- then it would be too cold for liquid water. Almost all the water on earth would be frozen. If the earth were a few million miles closer to the sun, like Venus, then the earth would be a little too hot for liquid water. Most of the water on earth would be water vapor in the atmosphere.

One of the reasons water is so special is the broad range of temperatures over which it stays in the liquid state. Molecules of similar size and complexity remain liquid over much narrower temperature ranges. For example, methane,  $\text{CH}_4$ , melts at  $-182\text{ }^\circ\text{C}$  and boils at  $-164\text{ }^\circ\text{C}$ . It is liquid only over a range of only 18 degrees celsius. On a summer day in Minnesota, the afternoon high may be  $95\text{ }^\circ\text{F}$  ( $35\text{ }^\circ\text{C}$ ) and the overnight low could drop to  $60\text{ }^\circ\text{F}$  ( $15\text{ }^\circ\text{C}$ ). That's a range of  $20\text{ }^\circ\text{C}$ . Methane goes all the way from a solid to a gas over a similar temperature span. If there were some methane-based organism subjected to a similar temperature change on a distant moon of Saturn, it could start its day as a popsicle, thaw out for a few productive hours of grazing in the morning, and float away like a balloon by lunchtime.

Not only is there a huge difference in the temperature range available to liquid water and liquid methane, but these two similar compounds freeze at very different temperatures. Other common small molecules like oxygen,  $\text{O}_2$ , nitrogen,  $\text{N}_2$ , carbon monoxide,  $\text{CO}$ , and hydrogen sulfide,  $\text{H}_2\text{S}$ , are gases at  $25\text{ }^\circ\text{C}$  at atmospheric pressure. That is a comfortable room temperature. Water freezes at  $0\text{ }^\circ\text{C}$ : a cold day in Chicago. Methane freezes at  $-182\text{ }^\circ\text{C}$ : a cold day on Saturn.

### Exercise 7.1.1

Explain why water other small molecules like methane and dinitrogen are gases at room temperature, whereas water is a liquid.

#### Answer

One difference between water and these other molecules is that water is polar: there is a significant electronegativity difference between the oxygen and the hydrogen. The charges in one water molecule may be interacting with charges in other water molecules.

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