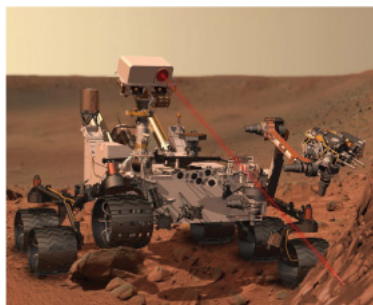


11.9: Water: An Extraordinary Substance

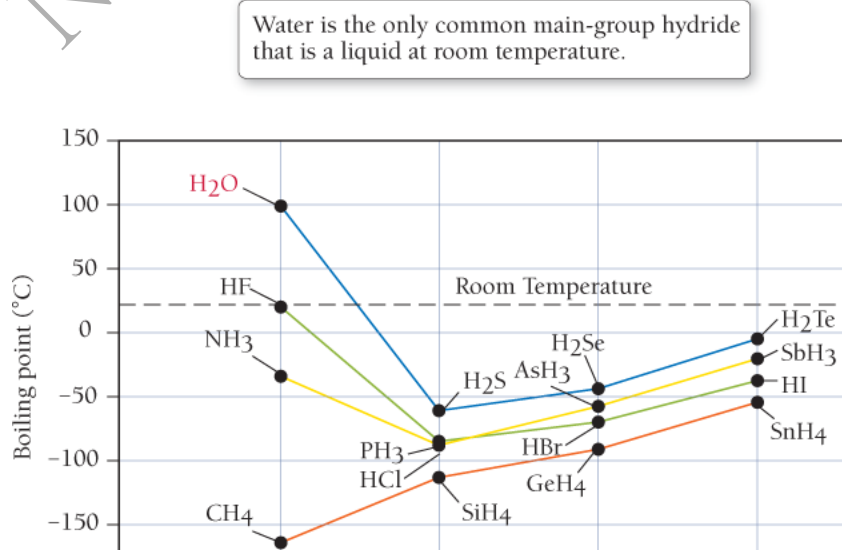
Water is the most common and important liquid on Earth. It fills our oceans, lakes, and streams. In its solid form, it caps our mountains, and in its gaseous form, it humidifies our air. We drink water, we sweat water, and we excrete bodily wastes dissolved in water. Indeed, the majority of our body mass is water. Life is impossible without water, and in most places on Earth where liquid water exists, life exists. Recent evidence for the past existence of water on Mars has fueled hopes of finding evidence of past life there. And though it may not be obvious to us (because we take water for granted), this familiar substance has many remarkable properties.



The *Mars Curiosity Rover* has found evidence that liquid water (which could possibly sustain life) once existed on the surface of Mars.

Among liquids, water is unique. It has a low molar mass (18.02 g/mol), yet it is a liquid at room temperature. Other main-group hydrides have higher molar masses but lower boiling points, as shown in Figure 11.37. No other substance of similar molar mass (except HF) comes close to being a liquid at room temperature. We can understand water's high boiling point (in spite of its low molar mass) by examining its molecular structure. The bent geometry of the water molecule and the highly polar nature of the O–H bonds result in a molecule with a significant dipole moment. Water's two O–H bonds (hydrogen directly bonded to oxygen) allow each water molecule to form strong hydrogen bonds with four other water molecules (Figure 11.38), resulting in a relatively high boiling point. Water's high polarity also allows it to dissolve many other polar and ionic compounds and even a number of nonpolar gases such as oxygen and carbon dioxide (by inducing a dipole moment in their molecules).

Figure 11.37 Boiling Points of Main-Group Hydrides



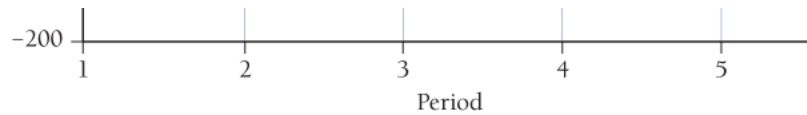
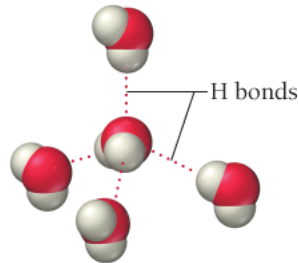


Figure 11.38 Hydrogen Bonding in Water

A water molecule can form four strong hydrogen bonds with four other water molecules.



Consequently, water is the main solvent within living organisms, transporting nutrients and other important compounds throughout the body. Water is the main solvent in our environment as well, allowing aquatic animals, for example, to survive by breathing dissolved oxygen and allowing aquatic plants to survive by using dissolved carbon dioxide for photosynthesis (the process by which plants convert carbon dioxide and water in glucose).

We already saw in [Section 9.4](#) that water has an exceptionally high specific heat capacity, which has a moderating effect on the climate of coastal cities. In some cities, such as San Francisco, for example, the daily fluctuation in temperature can be less than 10 °C. This same moderating effect occurs over the entire planet, two-thirds of which is covered by water. Without water, the daily temperature fluctuations on Earth might be more like those on Mars, where temperature fluctuations of 63 °C (113°F) occur between early morning and midday. Imagine awakening to below-freezing temperatures, only to bake at summer desert temperatures in the afternoon! The presence of water on Earth and water's uniquely high specific heat capacity are largely responsible for our planet's much smaller daily fluctuations.

The way that water freezes is also unique. Unlike other substances, which contract upon freezing, water expands upon freezing. Consequently, ice is less dense than liquid water, which is why ice floats. This seemingly trivial property has significant consequences. The frozen layer of ice at the surface of a winter lake insulates the water in the lake from further freezing. If this ice layer sank, it would kill bottom-dwelling aquatic life and possibly allow the lake to freeze solid, eliminating virtually all life in the lake.

The expansion of water upon freezing, however, is one reason that most organisms do not survive freezing. When the water within a cell freezes, it expands and often ruptures the cell, just as water freezing within a pipe bursts the pipe. Many foods, especially those with high water content, do not survive freezing very well either. Have you ever tried to freeze your own vegetables? If you put lettuce or spinach in the freezer, you will find that it is limp and damaged when you thaw it. The frozen-food industry gets around this problem by *flash freezing* vegetables and other foods. In this process, foods are frozen nearly instantaneously, which prevents water molecules from settling into their preferred crystalline structure. Consequently, the water does not expand very much, and the food remains largely undamaged.



When lettuce freezes, the water within its cells expands, rupturing them.

Not for Distribution