

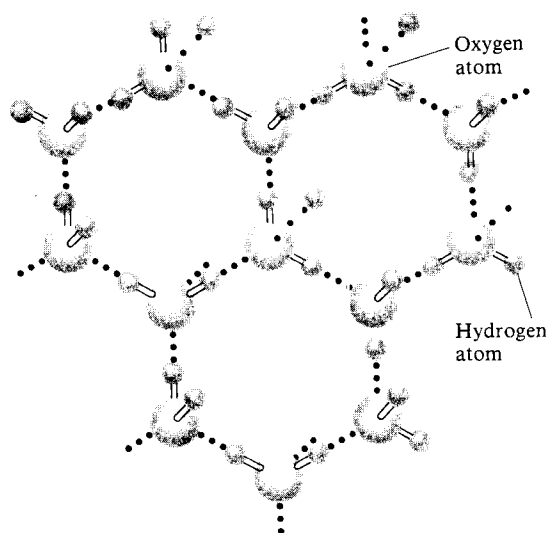
Table 14.1 Thermal Properties of Some Common Substances

SUBSTANCE	FORMULA	MELTING POINT (°C)	BOILING POINT (°C)	HEAT CAPACITY OF LIQUID (J/g · °C)	HEAT OF FUSION (J/g)	HEAT OF VAPORIZATION (J/g)
Water	H ₂ O	0	100	4.18	333	2257
Ammonia	NH ₃	-78	-33	4.48	341	1368
Ethanol	C ₂ H ₅ OH	-117	78	2.24	104	854
Benzene	C ₆ H ₆	6	80	1.63	127	395
Carbon tetrachloride	CCl ₄	-23	77	0.83	17	194
Mercury	Hg	-39	357	0.14	12	295

bonds. The tetrahedral angles give rise to a three-dimensional structure that contains open space. When ice melts, hydrogen bonds break, the ice structure partially disintegrates, and the molecules become more compactly arranged.

Even liquid water has significant hydrogen bonding. Only about 15% of the hydrogen bonds are broken when ice melts. We might view the liquid as composed of icelike clusters in which hydrogen bonds are continually breaking and forming, so clusters disappear and new ones appear. This is sometimes referred to as the "flickering cluster" model of liquid water.

As the temperature rises from 0°C, these clusters tend to break down further, giving an even more compact liquid. Thus, the density rises (see Figure 14.5). However, as is normal in any liquid, when the temperature rises, the molecules begin to move and vibrate faster, and the space occupied by the average molecule increases. For most other liquids this results in a continuous decrease in density with temperature increase. In water, this normal effect is countered by the density increase due to breaking of hydrogen bonds, but at 4°C the normal effect begins to predominate. Water shows a maximum density at 4°C and becomes less dense at higher temperatures.


Figure 14.4
The structure of a portion of ice.

Oxygen atoms are represented by large spheres, hydrogen atoms by small spheres. Each oxygen atom is tetrahedrally surrounded by four hydrogen atoms. Two are close, giving the H₂O molecule. Two are further away, held by hydrogen bonding (represented by three dots). The distribution of hydrogen atoms in these two positions is random.