



FIGURE 13–22 Vapor appears above a liquid in a closed container.

TABLE 13–3 Saturated Vapor Pressure of Water

Temperature (°C)	Saturated Vapor Pressure	
	torr (= mm-Hg)	Pa (= N/m <sup>2</sup> )
–50	0.030	4.0
–10	1.95	$2.60 \times 10^2$
0	4.58	$6.11 \times 10^2$
5	6.54	$8.72 \times 10^2$
10	9.21	$1.23 \times 10^3$
15	12.8	$1.71 \times 10^3$
20	17.5	$2.33 \times 10^3$
25	23.8	$3.17 \times 10^3$
30	31.8	$4.24 \times 10^3$
40	55.3	$7.37 \times 10^3$
50	92.5	$1.23 \times 10^4$
60	149	$1.99 \times 10^4$
70 <sup>1</sup>	234	$3.12 \times 10^4$
80	355	$4.73 \times 10^4$
90	526	$7.01 \times 10^4$
100 <sup>1</sup>	760	$1.01 \times 10^5$
120	1489	$1.99 \times 10^5$
150	3570	$4.76 \times 10^5$

<sup>1</sup> Boiling point on summit of Mt. Everest.

<sup>2</sup> Boiling point at sea level.

Because it is the fastest molecules that escape from the surface, the average speed of those remaining is less. When the average speed is less, the absolute temperature is less. Thus kinetic theory predicts that *evaporation is a cooling process*. You have no doubt noticed this effect when you stepped out of a warm shower and felt cold as the water on your body began to evaporate; and after working up a sweat on a hot day, even a slight breeze makes you feel cool through evaporation.

### Vapor Pressure

Air normally contains water vapor (water in the gas phase), and it comes mainly from evaporation. To look at this process in a little more detail, consider a closed container that is partially filled with water (or another liquid) and from which the air has been removed (Fig. 13–22). The fastest moving molecules quickly evaporate into the empty space above the liquid’s surface. As they move about, some of these molecules strike the liquid surface and again become part of the liquid phase: this is called **condensation**. The number of molecules in the vapor increases until a point is reached when the number of molecules returning to the liquid equals the number leaving in the same time interval. Equilibrium then exists, and the space above the liquid surface is said to be *saturated*. The pressure of the vapor when it is saturated is called the **saturated vapor pressure** (or sometimes simply the vapor pressure).

The saturated vapor pressure does not depend on the volume of the container. If the volume above the liquid were reduced suddenly, the density of molecules in the vapor phase would be increased temporarily. More molecules would then be striking the liquid surface per second. There would be a net flow of molecules back to the liquid phase until equilibrium was again reached, and this would occur at the same value of the saturated vapor pressure, as long as the temperature had not changed.

The saturated vapor pressure of any substance depends on the temperature. At higher temperatures, more molecules have sufficient kinetic energy to break from the liquid surface into the vapor phase. Hence equilibrium will be reached at a higher pressure. The saturated vapor pressure of water at various temperatures is given in Table 13–3. Notice that even solids—for example, ice—have a measurable saturated vapor pressure.

In everyday situations, evaporation from a liquid takes place into the air above it rather than into a vacuum. This does not materially alter the discussion above relating to Fig. 13–22. Equilibrium will still be reached when there are sufficient molecules in the gas phase that the number reentering the liquid equals the number leaving. The concentration of particular molecules (such as water) in the gas phase is not affected by the presence of air, although collisions with air molecules may lengthen the time needed to reach equilibrium. Thus equilibrium occurs at the same value of the saturated vapor pressure as if air weren’t there.

If the container is large or is not closed, all the liquid may evaporate before saturation is reached. And if the container is not sealed—as, for example, a room in your house—it is not likely that the air will become saturated with water vapor (unless it is raining outside).

### Boiling

The saturated vapor pressure of a liquid increases with temperature. When the temperature is raised to the point where the saturated vapor pressure at that temperature equals the external pressure, **boiling** occurs (Fig. 13–23). As the boiling point is approached, tiny bubbles tend to form in the liquid, which