

we've been calling intermolecular attractions. Surface tension occurs because there is an uneven attraction between particles on the surface of a liquid (see Figure 9.5).

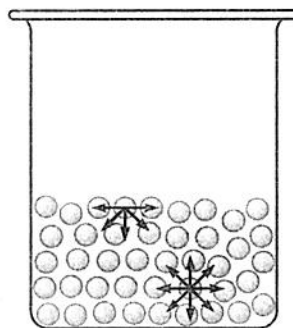


Figure 9.5

These uneven forces on the surface cause the molecules to pack more tightly together and create a more rigid surface.

Another type of force that can occur is known as **adhesion**, or adhesive force. These are the forces that bind different substances together. An example of adhesive forces (other than adhesive tape!) is the way that water adheres to different materials. When you first learned how to read a graduated cylinder, you had to learn to compensate for the **meniscus**, or the curved part on the surface of the liquid. The meniscus forms when you put water into a graduated cylinder because the adhesive force between the water molecules and the glass is stronger than the cohesive forces holding the water molecules together.

PHASE DIAGRAMS

For the most part, our discussion about states of matter and phase changes has been limited to temperature effects. The heating and cooling curves are illustrations of temperature effects on state. In the section on vapor pressure, you were introduced to the idea that variations in pressure can also cause changes in state. When water boils at low temperatures, it clearly illustrates that there are really two external factors involved in changes of the state of water: temperature and pressure. In this section, you will begin to review the effects of pressure on state. This will be done with the help of **phase diagrams**, which are diagrams that provide a graphical representation of the states of matter for a substance under all variations of temperature and pressure.

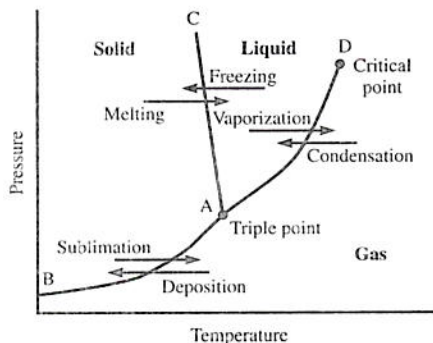


Figure 9.6

Phase diagrams contain a variety of information at various levels of complexity. The broadest distinctions are the three large areas that are contained on the graph. Referring to Figure 9.6, most of the left side of the chart (those portions above and to the left of the lines connecting points B-A-C) represents those temperatures and pressures at which the substance being shown exists as a solid. On the right, below the lines connecting B-A-D, are the temperatures and pressures at which the substance exists as a gas. The V-shaped region between the lines connecting C-A-D represents the liquid state. The lines themselves represent the temperatures and pressures at which the states on either side are in equilibrium. For example, the line B-A represents the temperatures and pressures where the gas state and the solid state are in equilibrium. Line A-C represents the temperatures and pressures at which the solid and liquid states are at equilibrium, and the curve A-D represents the equilibrium states between liquid and gas.

Two other special features on the diagram are designated by black dots. The dot at point D, known as the **critical point**, represents the **critical temperature** and the **critical pressure** (the point at which the liquid state no longer exists, regardless of the amount of pressure). The other dot represents the intersection of the three lines, known as the **triple point**. The triple point represents the temperature and pressure at which all three phases coexist simultaneously.

All of the phase changes listed earlier in the chapter are also detectable on the phase diagrams. The equilibrium lines, mentioned earlier in this section, represent those places where phase changes occur. For example, at any of the locations along line A-C, a transition from left to right represents melting.

The phase diagram in Figure 9.6 is the diagram for water, which is not representative of most substances. The main difference is the transition from solid to liquid, line A-C. For most substances, this will have a slightly positive slope. You will note that in the diagram for water, the slope is negative. The positive slope for most substances means that as pressure increases, so does the melting temperature. This should make sense on an intuitive level. Increasing pressure will squeeze the particles closer together, meaning it will take more energy to break them apart. Water, however, is one of the few substances whose liquid state is more compact than the solid state. In the solid state, water is less dense than it is in the liquid state, which is why ice floats on top of water. The reason that ice expands is because the crystals in solid H_2O arrange themselves in an organized hexagonal structure that takes up more space than the less organized, but more compact, arrangement of the liquid water molecules.

Sample: Use Figure 9.7 to answer the following question:

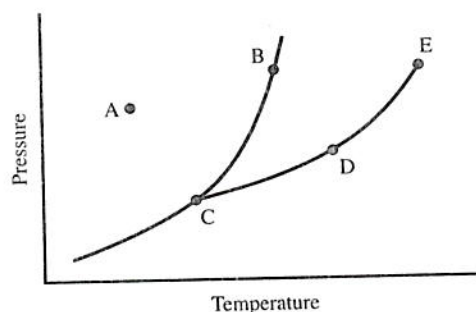


Figure 9.7

Which point represents the equilibrium between the liquid and gas phases during vaporization?

Answer: The correct answer is D. The entire line from C to the critical point E represents equilibrium between the liquid and gas phases.

You Try It!

Referring to Figure 9.7, indicate the point on the graph that represents a pure solid below its melting point.

Answer: The correct answer is A.

THE SOLID STATE

The particles in a solid are held together with sufficient force to maintain a rigid structure. In some cases, these forces consist of intermolecular forces, while in others, chemical bonds. Solids are typically classified according to the types of forces that hold the particles together. When classified this way, the four types of solid are molecular, ionic, covalent network, and metallic.

Molecular Solids

Just like the name suggests, these solids are composed of molecules that are held together by intermolecular forces of attraction. Ice would be a perfect example. Relative to the other solids, these tend to have much lower melting temperatures. This is easy to remember because they are not held together with chemical bonds, whereas the others are.

Ionic Solids

Ionic solids are actually crystalline salts composed of oppositely charged ions that are held together by electrostatic attraction (ionic bonds). If you recall from Chapter 6, the charged particles indiscriminately bond to other oppositely charged particles, forming large groupings of charged particles. The arrangements tend to be highly regular, a result of the similar