

Chapter 14 Liquids and Solids

14.1 Intermolecular Forces and Phase Changes

Key Terms

intermolecular forces
hydrogen bonding
heating/cooling curve
molar heat of vaporization

intramolecular forces
London dispersion force
normal freezing point

dipole–dipole attraction
normal boiling point
molar heat of fusion

Summary

Intermolecular forces are forces that occur between molecules. Several types of intermolecular forces exist. Molecules with dipole moments can attract one another by lining up so that the positive and negative ends are close to each other. This is a *dipole–dipole attraction*. *Hydrogen bonding* is a type of particularly strong dipole–dipole force.

Another intermolecular force, the *London dispersion force*, is the only weak force that exists among noble gas atoms and nonpolar molecules. In order for the London dispersion force to hold atoms into a solid, the motions of the atoms must be greatly slowed down.

Pure water is a colorless, tasteless substance that at 1 atm vaporizes to form a gas at 100°C. This temperature is the *normal boiling point* for water. The temperature stays at 100°C until all the water has changed to vapor. At this point, the temperature begins to rise again. When liquid water is cooled, the temperature decreases until it reaches 0°C, at which it begins to freeze. This temperature is the *normal freezing point* of water. The temperature remains at 0°C until all the liquid water has changed to ice and then begins to drop again as cooling continues. This process is the *heating/cooling curve* for water.

Energy is needed to melt ice and vaporize water. The energy needed to melt 1 mol of a substance is the *molar heat of fusion*. The energy needed to change 1 mol of liquid to its vapor is called the *molar heat of vaporization*.

14.2 Vapor Pressure and Boiling Point

Key Terms

vaporization (evaporation)

condensation

vapor pressure

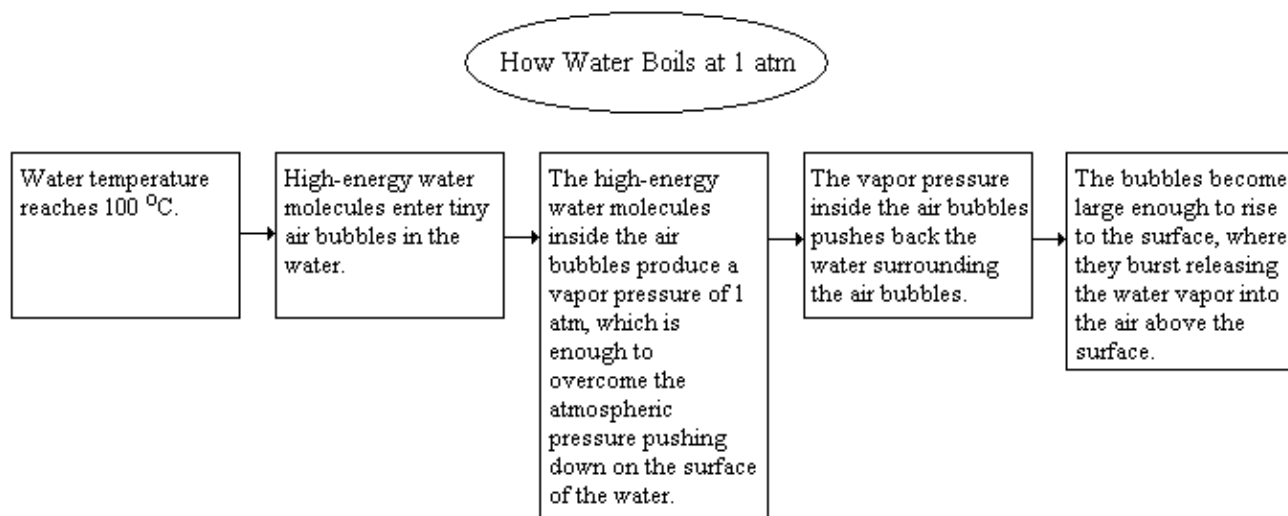
Summary

The escape of molecules from a liquid's surface to form a gas is called *vaporization* or *evaporation*. To escape into the vapor phase, an atom or molecule must have enough kinetic energy to overcome the liquid's intermolecular forces. Thus only the fastest-moving atoms or molecules can escape the surface of the liquid. The average energy of the remaining atoms or

molecules then decreases. As this happens, the temperature decreases. Therefore, evaporation is a cooling process. It is endothermic.

The process by which vapor molecules form a liquid is *condensation*. In a closed container, there is a transfer of molecules back and forth between the liquid and the vapor phases. Eventually, the same number of molecules is leaving the liquid as is returned to it: The rate of condensation equals the rate of evaporation. The system is at equilibrium. The pressure of the vapor present at equilibrium with its liquid is the *vapor pressure* of the liquid.

Water boils at 1 atm only when it reaches 100°C because of the relationship between temperature and vapor pressure.



14.3 Properties of Solids

Key Terms

crystalline solids
atomic solids
substitutional alloy

ionic solid
electron sea model
interstitial alloy

molecular solids
alloy

Summary

Many substances from *crystalline solids*, which have a regular arrangement of their atoms or molecules. An *ionic solid* contains ions. Molecules form *molecular solids*. *Atomic solids* contain atoms of only one element covalently bonded to one another.

The properties of a solid are determined mainly by the nature of the forces that hold the solid together, that is, differences in bonding. The particles of ionic solids are held together by the strong forces that exist between oppositely charged ions. In a molecular solid, the fundamental particle is a molecule.

According to the *electron sea model*, metal atoms are arranged in a regular pattern in a “sea” of freely moving valence electrons that are shared among the atoms in a nondirectional way. Because of the nature of the metallic crystal, other elements can be introduced relatively easily to produce substances called *alloys*. An alloy is a substance that contains a mixture of elements and has metallic properties.

Additional Active Reading Questions

1. What is a dipole–dipole attraction?
2. What is the normal freezing point of water? the normal boiling point?
3. Calculate the energy needed to melt 3.5 mol of ice. (The molar heat of fusion is 6.02 kJ/mol.)
4. Under what conditions is the vapor pressure of a liquid measured?
5. During the boiling of water, what force inside an air bubble makes the bubble larger?
6. What types of solids dissolve into neutral molecules?
7. What is the name for a substance that contains a mixture of elements and has metallic properties?