Chapter 2: Particles of Matter

Detailed Chapter Summary

This chapter begins with an introduction to the world of the submicroscopic, which is the world where particles are so small they are invisible to even to the most powerful optical microscopes. This is the realm of atoms and molecules, which is the realm of chemistry.

Our modern understanding of the particulate nature of matter has been thousands of years in the making. Early Greek philosophers, for example, coined the term atom from the Greek phrase *a tomos*, which means "not cut" or "that which is indivisible". The French chemist Antoine Lavoisier (1743–1794) is most widely recognized as the originator of modern chemistry. Key to Lavoisier's success was his infusion of scientific methods of inquiry into his experiments and observations. Perhaps his greatest accomplishment was his discovery of the law of mass conservation—that matter is neither created nor destroyed during a chemical reaction. This idea paved the way for a new understanding of elements as the fundamental building blocks from which materials are made.

Enough clues were thus available to allow an English schoolteacher, John Dalton (1766–1844), to develop an atomic theory similar to that of the early Greeks. Dalton's theory was adopted and praised for its great explanatory powers. According to Dalton, for example, mass is conserved in a chemical reaction because atoms are indestructible and during a chemical reaction they simply change partners. The work of Dalton helped to pave the way for Dmitri Mendeleev (1834-1907) to create the periodic table of elements. Notice how what one generation discovers enables the next generation to make even further discoveries. Our current knowledge is the result of the cumulative efforts of many individuals who came before us.

Mass is a measure of how much stuff. A common unit of mass is the gram or the kilogram. The gravitational force between that mass and the planet is known as its *weight*. Mass is a simpler concept than weight (it remains the same no matter where it is located), which is why chemists tend to talk in terms of mass rather than weight. *Volume* is the amount of space a material object occupies, commonly measured in units of liters or milliliters.

Density is the relationship between an object's mass and volume. In other words, it is a measure of the object's "compactness." The more dense a material, the less volume it occupies. Gold is a dense material because it contains a lot of mass scrunched into a relatively small volume. Styrofoam is not very dense because it contains a relatively small mass in a relatively large volume. Because of their different densities, a kilogram of gold occupies much less volume than does a kilogram of Styrofoam.

Energy is the capacity to move matter. It is not something we can hold or observe directly. Rather, we only witness its effects. Energy that is stored and ready to be released is known as *potential energy*. The energy pent up within chemical substances is called *chemical potential energy*. *Kinetic energy* is the energy of motion.

Temperature and heat are related but different concepts. Temperature is a measure of the average kinetic energy of the atoms and molecules of a substance. The greater the motion of the atoms and molecules, the greater the temperature. Heat is the energy that flows when a higher-temperature material is placed in contact with a lower- temperature material. Heat always flows from the higher temperature material to the lower- temperature material.

There are three common phases of matter, including solid, liquid, and gas. In a *solid*, the atoms or molecules are vibrating about fixed positions. In a *liquid*, the atoms or molecules are tumbling around one another much like a bunch of marbles in a bag. In the *gaseous* phase, the atoms or molecules have so much kinetic energy that they have flown apart from each other and are bouncing around violently. For this reason, gases occupy much more volume than do solids and liquids.

The behavior of gases is neatly described by the gas laws. *Boyle's Law* tells us that when we decrease the volume of a parcel of air the density of the air increases. More dense air, in turn, has a greater number of air molecules colliding with the inner surface of the container, which thus experiences a greater internal pressure. Therefore, as a parcel of air is scrunched into a smaller volume, the pressure of that air increases. Conversely, an increase in volume results in a decrease in pressure.

Charles's Law tells us that the volume of air increases with increasing temperature. Add heat to an inflated balloon, for example, and the balloon will expand to a greater size. Conversely, the volume that a gas occupies decreases as the temperature also decreases. At some theoretical super-low temperature, absolute zero, which is –273.15°C, the gas contains no volume. *Avogadro's Law* tells us that the volume of a gas increases as more gas particles are added to it. This, of course, explains why a balloon gets bigger as you blow air into it.

The above three laws can be combined into a single law called the *ideal gas law*, which is represented by the equation $PV = nRT$. This law allows you to calculate any one of the four quantities of a gas given the other three. It is called an "ideal" gas law because it only holds true for an ideal gas, which is one in which the gas particles have zero mass and also have no stickiness. From these laws has been developed the *kinetic molecular theory of gases*.