Section 6.1

Objectives

- **Trace** the development of the periodic table.
- **Identify** key features of the periodic table.

Review Vocabulary

atomic number: the number of protons in an atom

New Vocabulary

periodic law
group
period
representative element
transition element
metal
alkali metal
alkaline earth metal
transition metal
inner transition metal
lanthanide series
actinide series
nonmetal
halogen
noble gas
metalloid

Development of the Modern Periodic Table

MAIN Idea The periodic table evolved over time as scientists discovered more useful ways to compare and organize the elements.

Real-World Reading Link Imagine grocery shopping if all the apples, pears, oranges, and peaches were mixed into one bin at the grocery store. Organizing things according to their properties is often useful. Scientists organize the many different types of chemical elements in the periodic table.

Development of the Periodic Table

In the late 1700s, French scientist Antoine Lavoisier (1743–1794) compiled a list of all elements that were known at the time. The list, shown in **Table 6.1,** contained 33 elements organized in four categories. Many of these elements, such as silver, gold, carbon, and oxygen, have been known since prehistoric times. The 1800s brought a large increase in the number of known elements. The advent of electricity, which was used to break down compounds into their components, and the development of the spectrometer, which was used to identify the newly isolated elements, played major roles in the advancement of chemistry. The industrial revolution of the mid-1800s also played a major role, which led to the development of many new chemistry-based industries, such as the manufacture of petrochemicals, soaps, dyes, and fertilizers. By 1870, there were approximately 70 known elements.

Along with the discovery of new elements came volumes of new scientific data related to the elements and their compounds. Chemists of the time were overwhelmed with learning the properties of so many new elements and compounds. What chemists needed was a tool for organizing the many facts associated with the elements. A significant step toward this goal came in 1860, when chemists agreed upon a method for accurately determining the atomic masses of the elements. Until this time, different chemists used different mass values in their work, making the results of one chemist's work hard to reproduce by another. With newly agreed-upon atomic masses for the elements, the search for relationships between atomic mass and elemental properties, and a way to organize the elements began in earnest.

Table 6.1 Lavoisier's Table of Simple Substances (Old English Names)

Gases	light, heat, dephlogisticated air, phlogisticated gas, inflammable air
Metals	antimony, silver, arsenic, bismuth, cobalt, copper, tin, iron, manganese, mercury, molybdena, nickel, gold, platina, lead, tungsten, zinc
Nonmetals	sulphur, phosphorus, pure charcoal, radical muriatique*, radical fluorique*, radical boracique*
Earths	chalk, magnesia, barote, clay, siliceous earth

* no English name

Buthelezi, T., Dingrando, L., Hainen, N., Wistrom, C., & Zike, D. (2008). *Chemistry: Matter and change*. Columbus, OH: Glencoe/McGraw-Hill.

John Newlands In 1864, English chemist John Newlands (1837–1898) proposed an organizational scheme for the elements. He noticed that when the elements were arranged by increasing atomic mass, their properties repeated every eighth element. A pattern such as this is called periodic because it repeats in a specific manner. Newlands named the periodic relationship that he observed in chemical properties the *law of octaves,* after the musical octave in which notes repeat every eighth tone. **Figure 6.1** shows how Newlands organized 14 of the elements known in the mid-1860s. Acceptance of the law of octaves was hampered because the law did not work for all of the known elements. Also, the use of the word *octave* was harshly criticized by fellow scientists, who thought that the musical analogy was unscientific. While his law was not generally accepted, the passage of a few years would show that Newlands was basically correct; the properties of elements do repeat in a periodic way.

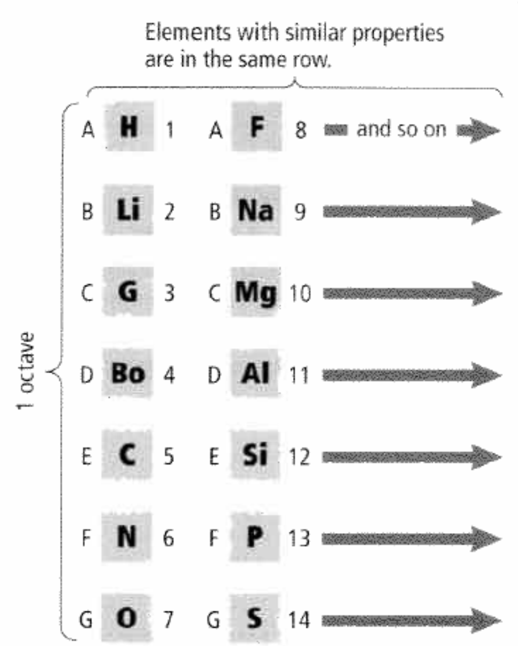


Figure 6.1 John Newlands noticed that the properties of elements repeated every eighth element, in the same way musical notes repeat every eighth note and form octaves.

Meyer and Mendeleev In 1869, German chemist Lothar Meyer (1830–1895) and Russian chemist Dmitri Mendeleev (1834–1907) each demonstrated a connection between atomic mass and elemental properties. Mendeleev, however, is generally given more credit than Meyer because he published his organizational scheme first. Like Newlands several years earlier, Mendeleev noticed that when the elements were ordered by increasing atomic mass, there was a periodic pattern in their properties. By arranging the elements in order of increasing atomic mass into columns with similar properties, Mendeleev organized the elements into a periodic table. Mendeleev's table, shown in **Figure 6.2,** became widely accepted because he predicted the existence and properties of undiscovered elements that were later found. Mendeleev left blank spaces in the table where he thought the undiscovered elements should go. By noting trends in the properties of known elements, he was able to predict the properties of the yet-to-be-discovered elements scandium, gallium, and germanium.

			K = 39	Rb = 85	Cs = 133	—	—
			Ca = 40	Sr = 87	Ba = 137	—	—
			—	?Yt = 88?	?Di = 138?	Er = 178?	—
			Ti = 48?	Zr = 90	Ce = 140?	?La = 180?	Th = 281
			V = 51	Nb = 94	—	Ta = 182	—
			Cr = 52	Mo = 96	—	W = 184	U = 240
			Mn = 55	—	—	—	—
			Fe = 56	Ru = 104	—	Os = 195?	—
Typische Elemente			Co = 59	Rh = 104	—	Ir = 197	—
			Ni = 59	Pd = 106	—	Pt = 198?	—
H = 1	Li = 7	Na = 23	Cu = 63	Ag = 108	—	Au = 199?	—
	Be = 9,4	Mg = 24	Zn = 65	Cd = 112	—	Hg = 200	—
	B = 11	Al = 27,3	—	In = 113	—	Tl = 204	—
	C = 12	Si = 28	—	Sn = 118	—	Pb = 207	—
	N = 14	P = 31	As = 75	Sb = 122	—	Bi = 208	—
	O = 16	S = 32	Se = 78	Te = 125?	—	—	—
	F = 19	Cl = 35,5	Br = 80	J = 127	—	—	—

Figure 6.2 In the first version of his table, published in 1869, Mendeleev arranged elements with similar chemical properties horizontally. He left empty spaces for elements that were not yet discovered.

Buthelezi, T., Dingrando, L., Hainen, N., Wistrom, C., & Zike, D. (2008). *Chemistry: Matter and change*. Columbus, OH: Glencoe/McGraw-Hill.

How is Silk Made?

Mark D. asks: How do they make real silk from worms?

One of the softest fabrics on the planet, shiny, breathable and comfortable, silk has been a highly prized cloth since it was first harvested thousands of years ago. And despite advances in production methods and new possibilities for cultivation, still today the only reasonable way to glean the thread in mass quantities is by killing the thing that made it.

Silkworms are caterpillars of (usually) the *Bombyx mori* moth. During its 3 to 8 day pupating period, the silkworm secretes fibroin, a sticky liquid protein, from its two sericteries (special salivary glands). Pushed through a spinneret (opening on the mouth), the twin pair of continuous threads harden when they come into contact with the air. Next, the silkworm secretes sericin, a bonding agent, from two other glands to hold the two filaments together. While constructing its cocoon, the silkworm will twist in a figure-8 motion about 300,000 times and produce around 1 kilometer of filament.

Since hatching from the cocoon destroys the thread, to harvest the silk, the cocoon is placed in either boiling water, or blasted with steam or hot air, all processes that kill the pupae. Less lethal methods were tried in the past, such as pulling the silk as the worms spun it, but the worms resisted and bit off the filaments (the longest thread harvested in this way was just 6 meters).

Besides killing the pupae, the heat softens the binding agent (sericin), so that the filaments may be unwound. Sometimes, the softened sericin is left on the fibers, and this product is called raw silk. In the end, it takes the deaths of about 2500 caterpillars to make a single pound of raw silk.

From there, raw silk strands are twisted together until a fiber of sufficient strength for knitting or weaving is produced, and different twisting methods produce a different type of thread: crepe, thrown, tram, organzine or singles. Crinkly fabrics are made with crepe, while sheer cloth is made with single thread. Spun silk is comprised of broken filaments that have been processed into a yarn.

To get the billions of cocoons necessary to have a viable silk industry (by some estimates, about 10 billion each year), the worms are cultivated. Called sericulture, it begins with female moths, each laying about 300-400 pin-sized eggs, shortly after which they (the moths) die. The eggs are incubated for 10 days. When they hatch, they are still tiny (about ¼ inch). Gluttons, they feast on mulberry leaves (although lesser-quality silks are made from silkworms that eat Osage orange and lettuce). After about 6 weeks of constant eating, the silkworm has grown to about 3 inches in length, weighs nearly 10,000 times what it did when it hatched and begins to work on spinning its own grave.

Although a few other plants are fed to silkworms, the mulberry has always been associated with its production. In fact, when the Emperor Justinian first stole the means of silk production in the 6th century AD (according to legend, he had two monks smuggle some eggs out of China), he also pinched a few seeds of the mulberry tree.

Prior to that, the Chinese had carefully guarded the secret to silk for millennia. According to Chinese records, the technique was discovered by Si-ling-chi (aka Leizu), the wife of the “Yellow Emperor” Huang-ti, about 2,700 BC. By some accounts, she found the secret after a silkworm cocoon fell into her cup of tea, and as she pulled it out, she realized she could unravel its exquisite thread. Of course, it may have been discovered by someone else, perhaps a lowly tailor, with the empress simply taking (or being given) credit for it. Whatever the case, so important was this discovery that she was later deified and given the name, Seine-Than, meaning Goddess of Silk Worms; and the silk she supposedly discovered became so crucial to international trade, that it lent its name to the great East-West route, the Silk Road.

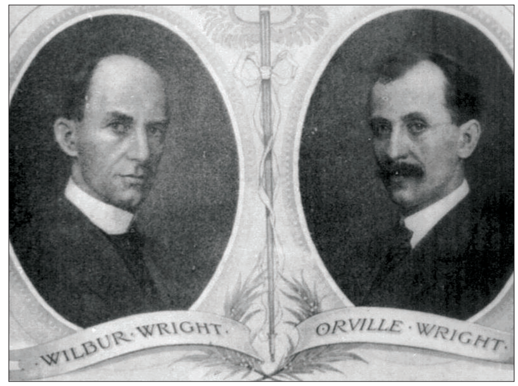
Today, China still leads the world in silk production, responsible for about 58,000 tons each year or about 74% of the world's supply of raw silk. Not wasted, in many places the leftover dead silkworms are seasoned, boiled, fried and eaten.

Still, things may be looking up for the humble silkworm. Some kindly researchers have recently discovered a method to harvest long filaments without killing the creature. Noticing that when injured the caterpillar will engage in self-paralysis in order to give itself time to heal, the scientists found a way to isolate the biochemical used by the insect to reach that state. By extracting it and injecting it into healthy worms, the researchers were able to induce partial paralysis, after which, one end of the worm's silk was attached to a slowly winding reel, which successfully gathered the silk. In its paralyzed state, the worm was unable to bite off the thread (as it otherwise would do). The record for gathering silk this way is 500 meters, or about half of that acquired through the traditional method.

Since hand-injecting billions of silkworms is beyond unrealistic, to turn this process into a commercial reality, the researchers are looking into ways to genetically modify silkworms so that the paralysis can be triggered by manufacturers "on demand."

The Inventive Wright Brothers

Everyone must crawl before they can fly. Such was the fate of Wilbur and Orville Wright, born four years apart, brothers by blood as well as by achievement...



The Nation, State and City Welcome The Worlds Greatest Aviators
http://hdl.loc.gov/loc.mss/mwright.05002589

Historical Background

Wilbur and Orville's parents, Milton and Susan Wright, encouraged their children's intellectual curiosity. Milton Wright was a bishop in a local church and he traveled extensively to preach. He also kept two large libraries that aided the brothers in their intellectual development from an early age.

A Well-Grounded Childhood

In 1878, a toy forever changed the lives of Wilbur and Orville. Milton gave the boys a toy helicopter, a simple device made of bamboo, paper, and cork and powered by a rubber band. Wilbur and Orville would later recall that their father's gift sparked their interest in the science of flight. The helicopter was based on the design of Alphonse Penaud of France, who made great strides in aeronautics during the 1860s and 1870s by developing the Planophore, which used propellers powered by rubber bands to sustain flight over short distances.

Milton moved his family to Richmond, Indiana, and became a circuit preacher. He began publishing a religious newspaper. Wilbur invented a machine that folded the papers for mailing, demonstrating a knack for engineering. In 1884, the family permanently moved back to Dayton, Ohio.

Brothers in Business

Wilbur was a star athlete and scholar bound for Yale, but a blow to the face during a game of hockey in 1886 changed his mind about studying there. Orville had also been an excellent student, but became disinterested in his studies and eventually dropped out of high school. He completed two printer's apprenticeships as a teenager and went into business printing small items such as business cards.

Wilbur helped Orville build a printing press, and their father bought 25 pounds of used type for print jobs. By 1889, they began printing under the name "Wright Bros." The printing presses they built attracted a number of admirers. They gradually ended their printing endeavors as they took up a growing national activity – cycling.

The Wright bicycle shop
http://www.loc.gov/pictures/collection/wri/item/2001696436/

Friends often came to them for help with bicycle repair and maintenance. In 1893, they began repairing and manufacturing bicycles. Within three years, Wilbur and Orville were running a bustling enterprise.

Their ventures with the bicycle turned their attention back to the pursuit of sustained human flight.

Wilbur and Orville Look to the Skies

Orville and Wilbur faced the momentous task of finding a way to control flight. They read voraciously to learn from others' experiences and they corresponded with aeronautical pioneers such as the American engineer Octave Chanute.

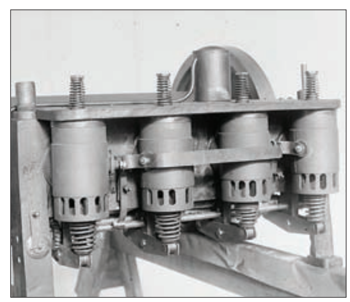
Otto Lilienthal, with wings of glider
http://www.loc.gov/pictures/item/2002722086/

In 1896, the death of German glider pilot Otto Lilienthal during a flight experiment led the brothers to think more about questions of aeronautics and flight. Lilienthal's study of the flight of birds as a possible basis for human flight also influenced the Wright brothers. Wilbur often observed buzzards near Ohio's Great Miami River. He noticed that the birds maintained their balance in flight by adjusting the angle and position of their wings. The brothers designed wings that could adjust their shape the way a bird's wings did and developed a kite with a biplane – two sets of wings. The tips of the wings were made to adjust and move at opposing angles to maintain balance.

They tested the new system in the sand dunes near Kitty Hawk, North Carolina in 1900 and 1901. The gliders did not yield the results the Wrights were looking for and the experiments sent them back to the drawing board.

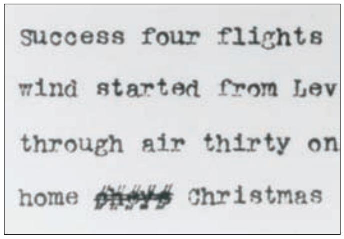
In 1901, Wilbur and Orville built a wind tunnel in order to study how their wing designs reacted to air resistance. This helped them improve the amount of lift provided by the wings. The glider they built using this data was the first to have three different sets of controls. Since a flying machine had to move on three different axes, each axis would need a control to maintain balance while in the air. One was the "warped wing," which stabilized the plane's horizontal movement. The "elevator" controlled the vertical angle of the nose. Finally, they added a moveable rudder, connected to the wing warping mechanism to prevent the craft from spinning out of control, to control the plane's forward movement.

When they tested their third glider at Kitty Hawk in 1902, it flew 622 feet in about 26 seconds. Their breakthroughs in wing design made this glider the world's first controllable aircraft. Nonetheless, to achieve powered flight the Wrights still needed to develop a propulsion system. They built an engine with the help of their mechanic, Charlie Taylor, and had devised a transmission and set of propellers for their plane by mid-1903.



The Wright brothers' reconstructed 1903 motor
http://www.loc.gov/pictures/item/2001696580/

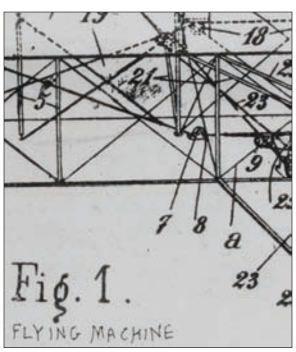
They tested the first powered craft at Kitty Hawk in September 1903. Wilbur was the test pilot of the Wright Flyer, which only stayed in the air for 3½ seconds. This didn't discourage them, and after repairs the brothers attempted to test the Wright Flyer once again on December 17. Orville's first flight of the day was the first manned, powered, and controlled flight in history. It lasted 12 seconds and spanned 120 feet. By the fourth flight, Wilbur managed to keep the Flyer in the air for 59 seconds and made a trip of 852 feet. They had been sending telegrams to their father detailing their progress. A December 17 telegram informed him that they would be home in time for Christmas. Their story, however, does not end with this great feat of human ingenuity.


Success four flights
wind started from Lev
through air thirty on
home ~~[illegible]~~ Christmas

Telegram from Orville Wright in Kitty Hawk, N.C.
http://www.loc.gov/pictures/item/2003680165/

The Business of Flight

As the brothers worked to achieve powered flight, they also worked to secure a patent for their invention. This was not only to recoup the significant costs of their experiments, but also to prevent others from stealing their design. Their aeronautical rivals had not come as close as they had to achieving powered and controlled flight, but they came close enough to make the brothers cautious. The brothers finally received a patent on May 23, 1906, but they spent many years in legal battles with aviators and inventors who made their own claims to originality. Among their rivals was famed inventor Alexander Graham Bell.



Wright brothers aeroplane - patented plans, 1908
http://www.loc.gov/pictures/item/2001695572/

The brothers worked tirelessly to perfect their flyers while attempting to attract the business of private firms and government entities such as the U.S. military. Although they won some contracts, the Wright Company's success was tentative. Pursuing their various patent suits against their numerous rivals and competitors absorbed much of their time and proved inconclusive. After Wilbur died of typhoid in May 1912, Orville became despondent and sold not only the Wrights' 1906 patent, but also the Wright Company in 1915. Though not always successful in their business lives, the Wright brothers will long be known for their momentous invention.