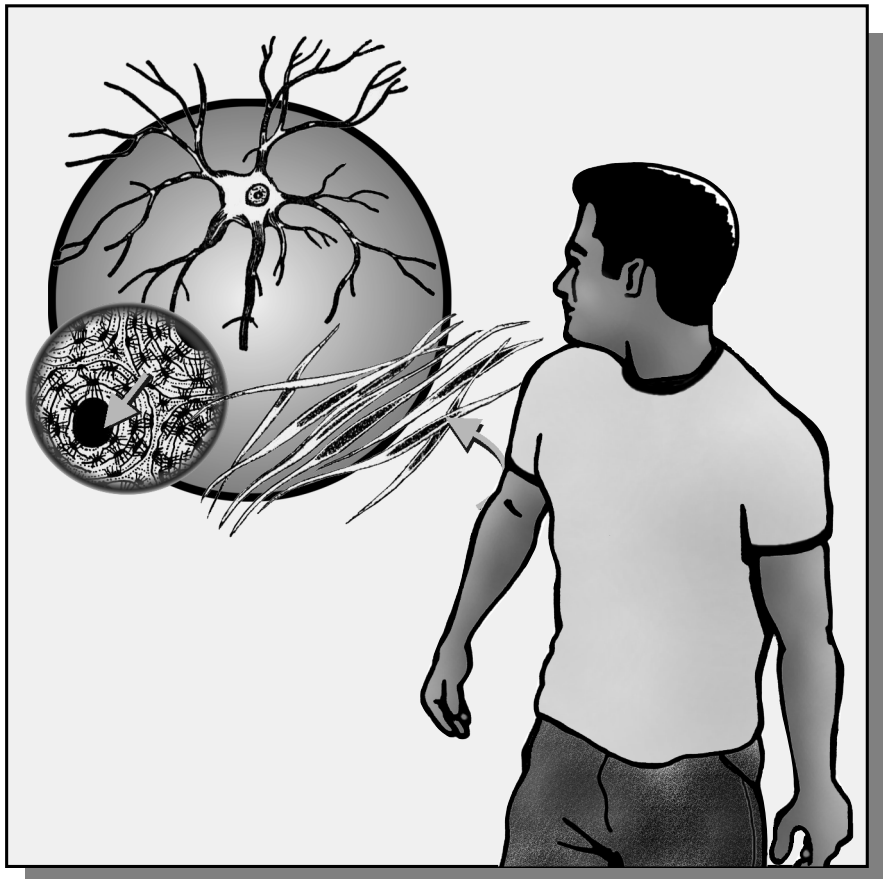
Natural Science Mysteries



Chapter 3

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Chapter 3

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PAC
TM
TM

Lesson 1
Light and Sound

Chapter 3

Pitch, Loudness, and Vacuum

Section 1

Lessons 1-5

SOUND



Bryan and Tom awoke to fog that was so thick it seemed like a gray blanket had been thrown over their cabin. 1

Bryan's uncle, the park ranger, gave the boys daily assignments. Ranger Eldridge announced, "We're getting into the summer season. The ferry will run more often and the number of visitors will increase. Although some will stay at the lodge, many will be daytime backpackers. We must get the trails in shape right away!" 2

A long, mournful sound interrupted his instruction. Tom asked, "What is making that call? It sounds like the cry of a lovesick sea monster!" 3

Del heard Tom's question about the strange sound. She was quick to explain, much to Tom's irritation. "The sound is from the foghorn at the lighthouse on Schooner Shoal. It's about ten miles away. Normally, we cannot hear it, but today the air is especially still." 4

Ranger Eldridge said, "In dense fog, light can penetrate less than a half mile. At such times, the sound of the foghorn becomes more important to warn ships of danger. The lighthouse has a horn that sounds in foggy weather." 5

The first manufactured foghorns used compressed air that was forced through openings in a rapidly rotating disk. Modern horns have a metal disk that vibrates back and forth to sound an alarm. It is set in motion by magnetic fields that alternately pull and release the metal. A ***low pitch*** is used because it carries better through fog. All ocean-going vessels are required by law to sound foghorns when traveling in dense 6

VOCABULARY

Low pitch: a sound with a frequency well below middle C, the lowest-pitch that the human ear can hear is about 20 waves per second

Sound: vibrations transmitted through a solid, liquid or gas with a frequency (pitch) of between 20 and 20,000 vibrations per second that are capable of being heard by the human ear

fog. Each ship has a distinctive foghorn that indicates the size of the vessel.

7 Sometimes you will hear the expression, "The house was still and quiet." The word "still" describes a quiet house. For ***sound*** to occur, something has to move. For the sound of a door closing, the door has to move. For the sound of footsteps, a person has to walk across the floor. For the sound of wind in the trees, the leaves and branches have to move back and forth.

8 Most sounds that we hear travel through air. A disturbance such as a door being slammed sets the air in motion. It moves back and forth. First, air is compressed, and the air pressure is greater than normal. Molecules that make up the air are shoved closer together. Then the air is released, and the air pressure is less than normal. Molecules expand farther apart. These changes in air pressure cause our ear drums to vibrate back and forth. The motion is changed to nerve impulses that are carried to the brain where they are interpreted as sound.

9 In a sound wave, air molecules do not travel far. First they are shoved forward, and then they spring back. Sound is a wave motion. Like a wave traveling as a pulse along a coiled spring, the wave goes forward, but the coils of the spring vibrate around a set point. The coils move forward a little and then snap back. Sound waves spread out, although any particular molecule of air does not move far from its position of rest.

10 Sound waves cannot travel through empty space. Sound does not carry in a ***vacuum*** because no object there moves back and forth. Suppose two astronauts in their space suits were on the Moon where no atmosphere is present. The astronauts cannot talk to one another. Even if one yelled, the sound would go no farther than his helmet. Astronauts communicate through electric powered radios.

11 Sound waves must be conducted through a substance. The conducting medium does not have to be air. Suppose the astronauts were on the Moon and their radios quit working. They could communicate with one another in an emergency by standing close together and touching their helmets together. Although the sound would be muffled, the vibration of one helmet would carry over to the other helmet. Sound can carry through solids such as metal, glass, wood and plastic.

12 Sound can carry through a liquid such as water. If you bang two rocks together underwater, a dull thud can be heard in the water, as the molecules of the water vibrate back and forth.

13 Sometimes the goal is not to conduct sound but to *dampen* it. Advancing technology required the use of ***soundproof*** rooms. Surrounding a room with a vacuum was not practical. Instead, the inner wall and the outer walls were built so they were not in contact. This prevented the vibration in one wall from

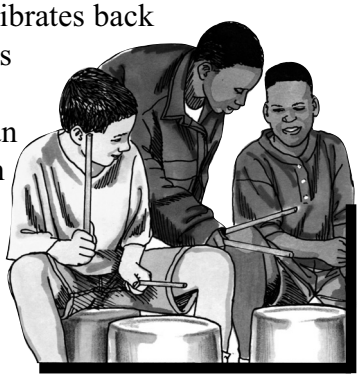
VOCABULARY

Vacuum: an enclosed space in which air has been removed so that the outside pressure is greater than the inside pressure
Soundproof: a structure designed to prevent or reduce penetration by sound waves
Frequency: the number of cycles per time period, usually vibrations per second; for a sound the frequency is the pitch, or the number of waves created per second
Pitch: the frequency of sound waves
High pitch: a sound with a frequency well above middle C, the highest-pitch that the human ear can hear is about 20,000 waves per second
Middle C: a sound with a frequency (pitch) of 256 waves per second; a musical note in the center between the treble and bass clef
Loudness: the volume of a sound, loudness depends primarily on the size of the waves but not on their frequency

reaching the other wall. A sound-insulating material was placed between the walls.

14 Scientists discovered that the insulating material did not spring back and forth easily. Architects used a fluffy material with air pockets because it conducted sound poorly. Scientists learned that totally soundproofing a room is not possible. However, outside sounds can be reduced so they are not noticeable. In many homes, the chief conductors of outside noise are the windows. In areas where homes are built near noisy highways or where airplanes lift off, the windows are made of double or triple layers of glass with a gas inside that does not conduct sound as well as does air.

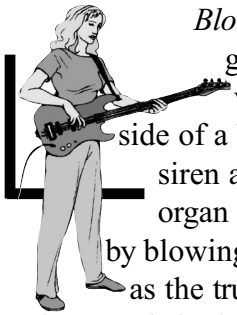
15 Sound is always made by something in motion. How the material is set in motion can vary considerably. *Hitting* can make the sound. The bang of metal trash can lids, the crack of a bat against a ball, and the thump of feet on a floor are examples of sounds made by striking two objects together. A drum has a membrane that vibrates back and forth when it is struck.



16 *Rubbing* can set some objects in back and forth motion. The screech of chalk on a blackboard, the scream of tires when a car is brought to panic stop, and the tones of a violin are examples of sound produced by rubbing. A violinist rubs his bow over the stretched strings to make them vibrate.

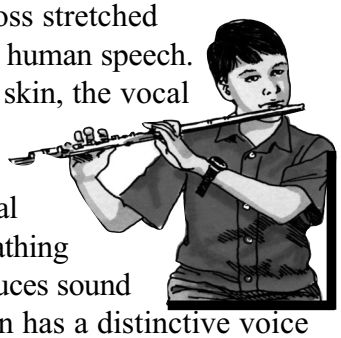
17 *Plucking* is the third way that sounds can be produced. A stretched rubber band makes a "twang" sound when pulled and released. The strings of a guitar, banjo, harp or bass (base) fiddle are plucked.





18 *Blowing* across an opening can generate sound. The howl of wind coming around the side of a building, the sound of a siren and the deep tones of a pipe organ are examples of sounds made by blowing. Wind instruments such as the trumpet, flute or harmonica make sounds by blowing.

19 The human voice is a wind instrument. Blowing wind across stretched membranes makes human speech. Two thin pieces of skin, the vocal cords, are at the back of the throat. Tightening the vocal cords and then breathing through them produces sound waves. Each person has a distinctive voice because of the size and weight of the vocal cords and the size and shape of the mouth.



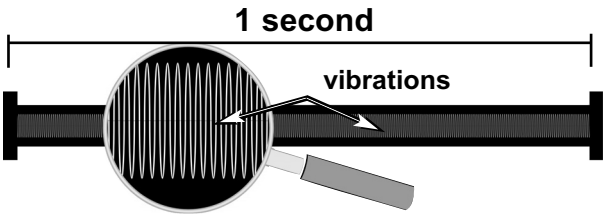
20 The rate at which an object vibrates is its ***frequency***. Humans can wiggle their hands back and fourth about four times a second. The rapidly waving back and forth motion of the hand disturbs the air at a frequency of four vibrations per second. This frequency is not fast enough for the ear to detect. If a person could cause his hand to vibrate about 20 times per second, then this motion would generate a sound with a frequency just barely perceptible to a person with good hearing.

21 The frequency of a sound is also known as its ***pitch***. A sound with a low frequency has a *low pitch*. A foghorn or the deepest sounds from an organ are low frequency sounds. The lowest pitch that people who have healthy ears can hear is about 20 vibrations per second.

22 A sound with a high frequency has a ***high pitch***. The highest pitch that people with healthy ears can hear is about 20,000 vibrations per second. Some animals, such as bats and dogs, have ears that can respond to sounds of even higher pitch.

23 Most people have their best hearing at a frequency of ***middle C***, which is 256 vibrations per second.

24 As humans get older, their ability to hear at both the high and low end of the frequency range becomes less. The hearing impairment usually starts with high frequencies. A sound at 20,000 vibrations per second is inaudible to most elderly people. They can still easily hear sounds at other frequencies.



middle C = 256 vibrations per second

25 Pitch and ***loudness*** are not the same quantities. A low-pitched hum may be very quiet; or, a sound may be booming. The loudness is a measure of how greatly the air is disturbed, not how rapidly the back and forth disturbance occurs. On a device with sound speakers such as a radio or television, the knob, marked volume, controls the loudness.

26 The speed of sound depends on the media that is transmitting it. Sound travels fastest in a metal such as steel, slower in a liquid such as water, and slowest in a gas such as air.

27 In steel, the atoms are right next to one another. When one moves, it immediately causes its neighbor to move; therefore sound travels more quickly in steel than in air. Air molecules travel longer distances before they strike their neighbors and bounce back.

28 The speed of sound in air also varies, depending on temperature and air pressure. At sea level at normal temperature, the speed of sound is about 344 meters per second, or about 1,129 feet per second, or about 770 miles per hour.

29 The speed of a sound in air is the same, regardless of how it begins. A low-pitched sound, a high-pitched sound, a soft sound, a loud sound, the sound of a drum, the sound of a horn, the sound of a person speaking: all travel in air at the same speed. You cannot hurry a sound by speaking louder or using a different pitch.

30 The only way for sound to travel faster is to send the sound through a medium other than air. In steel, for instance, all sounds travel at about 5,200 meters per second. In a race between the sound of a train whistle in air and the sound of the train's wheel on iron rails, the sound in the rails travel 15 times faster.

31 Ranger Eldridge said, "I've categorized trails as high, medium and low priority for maintenance. The Shore Trail and the Ridge Trail are the ones most used and have first priority. The next most important are the connecting trails such as those to the lodge, ferry landing at Rocky Port, and other main sites on the island."

32 "Where do we start?" Bryan asked. Ranger Eldridge explained, "The Ridge Trail suffers the most damage during winter. I've inspected it, and I have not seen any safety concerns; however, some washouts do need to be repaired. The regulations require that you wear a hard hat. You'll find hard hats and Pulaskis at the toolshed."

33 "Who or what is a Pulaski?" Tom asked. He looked at Del. "I suppose you know?"

34 She grinned, "Sure! A Pulaski is not a 'who`; it's a 'what`!"

Life Principle

"Welcome sounds uplift our spirits."

—Anonymous



Lesson 2
Light and Sound

Chapter 3

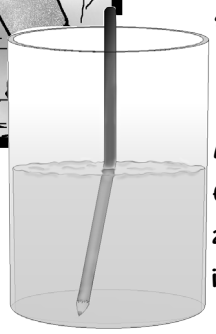
Reflection and Refraction; Convex and Concave; Mediums of Sound

Section 1

Lessons 1-5

LIGHT





VOCABULARY

Medium: a substance that carries a wave; medium is the singular form of the plural word *media*
Transparent: clear; transparent glass passes parallel rays of light through without changing their position relative to one another
Electromagnetic waves: waves made of electric and magnetic components; light is an electromagnetic wave
Refraction: the bending of a wave as it passes from one medium into another of different density

At the toolshed, Ranger Eldridge gave each boy a Pulaski. It was an all-purpose tool with an ax on one side of the head and a heavy bladed hoe on the other. The ranger explained, "You can do just about anything with a Pulaski! It's named after the American forest ranger, Edward Pulaski, who developed it." 1

The first part of the trail was in good repair. The boys hiked three miles before they came to the first side trail that was not on the map. 2

Bryan said, "Let's see where this trail goes!" 3

The trail took them to a grassy knoll. Although it had a great view of the ocean, an especially messy camper had littered the area. In addition to repairing the trail, the boys were instructed to clean unsightly campsites. 4

The camper had discarded his trash inside a fire ring. Tom read the label of an empty can that had held canned meat. He saw a wrapper for a power bar, some orange peelings and an empty package of powdered milk. Tom was puzzled. "This stuff looks vaguely familiar." 5

Bryan had stopped for a moment to admire the ocean. The fog had lifted and the sound of the foghorn had stopped. Rays of sunlight were shining through the clouds and illuminating the sea. Waves did not disturb its surface. Instead, the sea rose and fell with gentle swells. 6

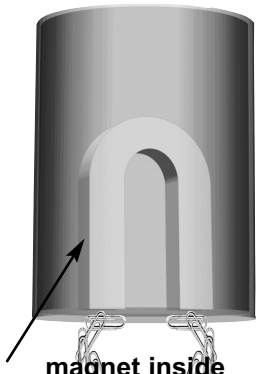
Suddenly Tom exclaimed, "Hey! I had items like these in my backpack that was stolen!" 7

The sound of the foghorn and the rays of sunlight are both wave motions. Some types of waves require a substance to carry them. Most sounds are carried through air, such as a school bell, 8

a teacher's voice, or a foghorn. Water waves travel on the surface of the water. For instance, when you toss a rock into a pond, the waves move across the surface of the water. The surface of the water moves up and down and the ripples move outward from where the stone plopped into the water. A water wave needs the water to carry it. The water is the ***medium*** through which the wave moves. Sound waves, like water waves, require a medium to vibrate and carry them. Sound cannot travel through a vacuum.

9 Because it does not require a medium, light can travel through a vacuum. Sunlight travels the 93 million miles to the Earth through the vacuum of space. In fact, light travels fastest in a vacuum and is slower in other ***transparent*** media.

10 Light is made of ***electromagnetic waves***. If a magnet is placed inside a vacuum, the magnet will still pick up pieces of metal. A magnet can act in a vacuum. If a plastic comb that has been rubbed to give it an electric charge is placed in a vacuum, the comb will still pick up pieces of lint and bits of cork. An electric charge can act in a vacuum. Light is made of a combination of electric and magnetic fields that allow the light to travel in a vacuum.



11 Sound and light differ in their speeds. The speed of light in air is almost 900,000 times faster than the speed of sound in air. Sound travels slowest in air and fastest in a denser medium such as steel. The speed of sound in air is about 334 meters per second, but it is 15 times faster in steel.

12 Light travels fastest in a vacuum and slowest in a denser medium such as diamond. The speed of light in a vacuum is about 186,000 miles per second, but about 50 miles per second slower in air. When entering water, light slows to 135,000 miles per second. In diamond, the speed of light is only 78,000 miles per second.

13 Light changes direction when it enters a new medium at an angle. The same effect can be seen when a car runs off the road onto soft shoulders (unpaved edge of a road). Tires that sink into mud slow their rotation speed because of resistance. The car pulls to one side and changes its direction. When striking a surface at an angle, light slows and its path is bent. ***Refraction*** is the bending of light rays as they speed up or slow down. A simple example is a pencil that is resting against the inside of a glass partially filled with water. The straight line of the pencil seems to change at the point where the pencil enters the water. The shape

VOCABULARY

Convex lens: a lens curved like the outer surface of a sphere, a convex lens is thicker in the middle than at the edge, a convex lens can produce a real image

Real image: an image that can be projected on a screen; a camera projects a real image on film; a microscope or telescope produces a real image that can be further magnified by an eyepiece

Reflection: to send back, light is reflected from a mirror

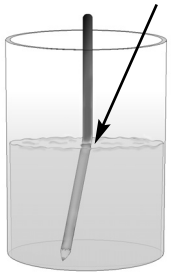
Concave mirror: a mirror curved like the inner surface of a sphere; brings parallel light rays to a focus and can produce a real image

Diffraction: the change in intensity and direction of waves after they pass through a small opening

Color: the frequency of visible light

Visible spectrum: the electromagnetic spectrum that can be detected by human eyes

of the glass also has an effect on the image. A curved glass may make the pencil seem larger. This, too, is caused by refraction.

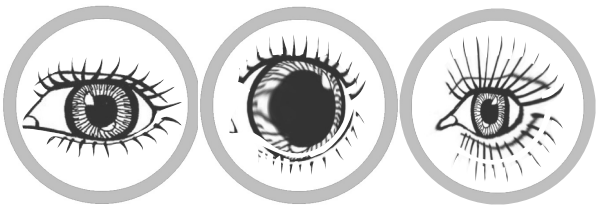


14 Another example of refraction of light can be seen with a large glass aquarium tank filled with water. As you move around the tank, its size and shape appears to change. When viewed from one side, the far side appears closer than it actually is. You can look in from above and the bottom of the tank appears closer than when the tank is empty of water. All of these effects are due to the refraction and changing speed of light in air and water.

15 The bending effect of light rays enables glass lenses to form images in cameras, telescopes or microscopes. Light rays in air travel in a straight line until they strike the surface of the glass. If the glass is curved, then the rays bend away from their straight-line path.

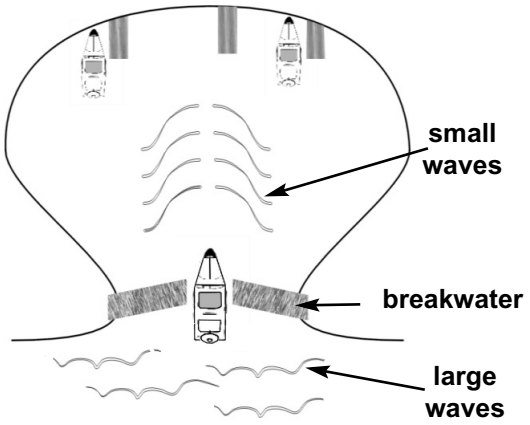
16 A ***convex lens*** is thicker at the middle than at the edges. A convex lens bends rays so they are brought to a focus and form an image. A magnifying glass is an example of a convex lens. If you hold a magnifying glass near the opposite wall from a window and move the glass nearer or farther away from the wall, you could produce on the wall a ***real image*** of the window and the scene outside.

17 Rays of light can also change direction by ***reflection***. Rays of light bounce from the surface of a mirror. A ***concave mirror*** has a concave shape, meaning that it is curved or hollowed inward. The rays of light bounce off and are brought to a focus. Like a convex lens, a concave mirror can produce a real image and project it onto a screen.

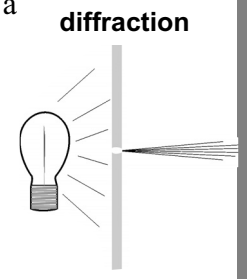


18 In addition to reflection and refraction, light waves can be diffracted, or spread out, after passing through a hole. This spreading out is ***diffraction***.

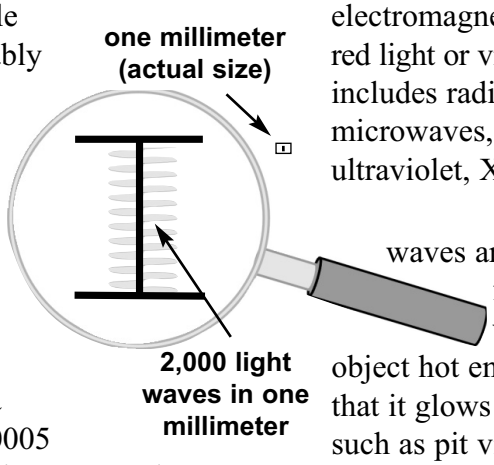
19 As an example of diffraction, some harbors for ships are protected from large waves by a wall called a *breakwater*. This wall is built across the mouth of the harbor and has a small channel for the ships to enter. Waves crash against the breakwater but can enter only through the small opening. As the waves pass through the opening they are smaller and spread out as if the opening were a source of waves. The waves are *diffracted* through the opening.



20 The fact that light is a wave motion was not obvious to scientists at first, because the light waves were so small. Small waves require small openings to cause diffraction. Scientists who tested light for diffraction were using holes that were too large. Making a tiny pinprick hole in a piece of aluminum foil can reveal diffraction. A beam of light that passes through the hole spreads out as if the pinhole were itself a tiny light bulb.



21 Sound and visible light do differ considerably in the size of their waves. A sound wave is far longer than a light wave. A sound with a pitch of middle C (256 vibrations per second) has a wavelength of about 1.34 meters. Light has a wavelength of about 0.0005 millimeters. You would have to stack 2,000 light waves placed end to end to equal one millimeter. A sound wave is well over two million times longer than a light wave.



22 The frequency of sound is its *pitch.* For visible light, the frequency is its ***color***. The shortest waves that human eyes can detect are violet. Violet light has a frequency of about $8 * 10^{14}$ vibrations per second and a wavelength of about 0.0004 millimeters. The longest waves the human eye can detect are red. Red light has a frequency of $4 * 10^{14}$ vibrations per second and a wavelength of about 0.00075 millimeters.

23 The colors from longest wavelength to shortest wavelength are red, orange, yellow, green, blue (indigo), and violet. These six colors are the colors of the ***visible spectrum***. The lengths of the waves of the colors of the spectrum differ only slightly from one another. Red light waves are only about twice as long as waves of violet light.

24 Human eyes see only a small part of the entire electromagnetic spectrum. The electromagnetic spectrum does not end with red light or violet light. The complete spectrum includes radio waves, television waves, radar, microwaves, infrared waves, visible light, ultraviolet, X-rays and gamma rays.

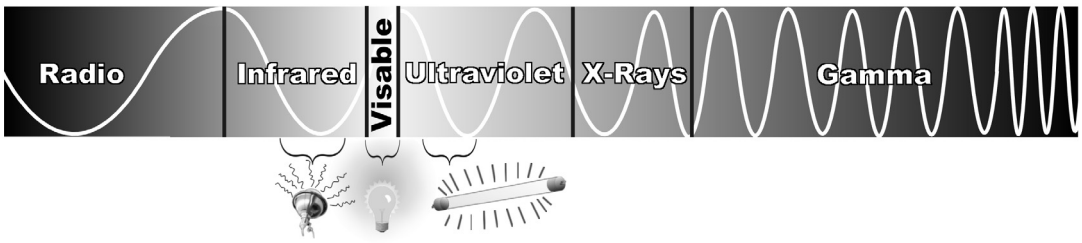
25 Infrared electromagnetic waves are longer and have a lower frequency than red light. Infrared waves are those given off by an object hot enough to emit heat but not so hot that it glows with visible light. Some animals such as pit viper snakes (cobras, rattlesnakes, etc.) have sense organs that can detect infrared light. They can detect the body heat of their prey.

26 Still longer waves below infrared include radio waves, television, FM radio, radar and microwaves.

27 Going the other way, ultraviolet electromagnetic waves are shorter and of higher frequency than visible light. Ultraviolet light is emitted by the Sun and can be harmful to the skin. The body partially protects itself from ultraviolet by tanning the skin. When exposed to sunlight, the human skin undergoes a gradual tanning as a result of an increase in a pigment known as *melanin*. The Earth's ozone layer also plays a role in filtering out some of the ultraviolet rays.

28 Above ultraviolet are X-rays and gamma rays. X-rays are so penetrating they are used by doctors and dentists to take pictures of your teeth or bones, which can be helpful in revealing internal problems. However, radiation can accumulate in the body to dangerous levels. Therefore, too

Electromagnetic Spectrum



much exposure to ultraviolet rays, gamma rays or X-rays can produce cancer or other health problems.

29 (While Tom and Bryan had waited to board the ferry to Danger Island, a man in green coveralls had grabbed Tom's backpack and escaped with it. The captain of the ferry had identified the man as James Olsen.)

30 "I'm certain all of this camping gear belongs to me!" Tom persisted. "I had everything needed for camping except a stove, because I planned to share yours."

"The guy who left this mess had to build a fire to cook his meals. The thief has got to be on this island!"

31 Although Bryan agreed that the wrappers were fresh, he suggested, "James Olsen may have already left the island."

32 "No," Tom insisted, "I think he stole my backpack to get a tent, sleeping bag and camping supplies to use here on Danger Island! But why?"

Life Principle



"Our actions are reflections of thoughts we repeatedly allow to enter our minds."

—Old Proverb

Lesson 3
Light and Sound

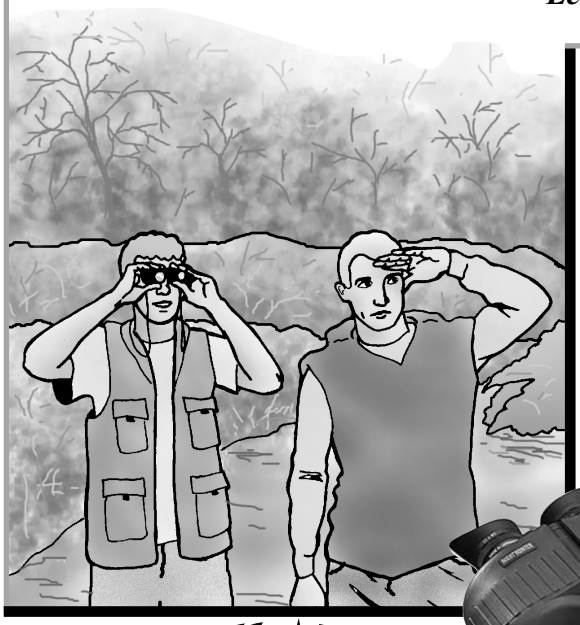
Chapter 3

Near and Farsightedness; Convex and Concave Lenses

Section 1

Lessons 1-3

READING LENSES AND TELESCOPES



"The thief is on this island!" Tom insisted as he kicked the rocks to scatter them so they looked more natural.

Breaking up fire rings had been one of the tasks Ranger Eldridge had given the boys. The ranger had explained that years earlier people built campfires inside stone rings. Most rangers now consider stone fire rings as unsightly impacts on natural environments. Instead, many backpackers carry small gas stoves to avoid open fires. The boys restored the site to a natural state.

Bryan said, "You do not know he is still on the island! He may have left. He had a boat."

Tom looked out over the sea. The swells rose and fell. Tom said stubbornly, "He's here. Only a desperate person would cross from the mainland to this island in a little open boat! Once he got here, he would stay until he accomplished his mission. We'll keep an eye out for a guy in green overalls that goes by the name of James Olsen!"

Bryan said, "All right." From the camping site, they could see the Schooner Shoal lighthouse. Bryan opened his compact binoculars and scanned the ocean for a sign of the small boat. None was visible.

Bryan's binoculars were marked 10 x 20. The first number gives the magnification and the second number gives the diameter of the main lens in millimeters. Binoculars are two small telescopes that are adjusted so a person can view the same scene through each eye. Binoculars marked 10 x 20 have a magnification of 10 times and lenses that are 20 millimeters across. Binoculars that are marked 7 x 50 have a magnification

VOCABULARY

Farsighted: able to see objects in the distance better than those at close range, the correction for farsightedness is a convex lens

Real image: an image that can be projected on a screen; cameras, telescopes and microscopes produce real images

Camera obscura: a forerunner to the camera that was used by artists to project an image on a sheet of paper so they could trace around the scene

Focal length: the distance from the center of a lens to the image

of 7 and main lenses that are 50 millimeters in diameter. Binoculars marked 7 x 50 do not give as much magnification as binoculars marked 10 x 20 (7 power as opposed to 10 power) but they do collect more light (50 millimeters compared to 20 millimeters). Binoculars marked 7 x 50 would be better for use in low light conditions or at night. Binoculars 10 x 20 would be better for bright, sunny days.



Binoculars, telescopes, microscopes and magnifying glasses use lenses to bring light to a focus and form images. Lenses came into use about 800 years ago to help people read small print. Some people can see distant objects easily. However, when they try to focus close to read a book, the letters are blurred. They are ***farsighted***. Their eyes cannot focus up close. In the 1200s, English scholar Roger Bacon experimented with lenses to correct poor vision. He discovered that a *convex* lens helped the eye focus up close. A convex lens is also known as a *reading lens*.

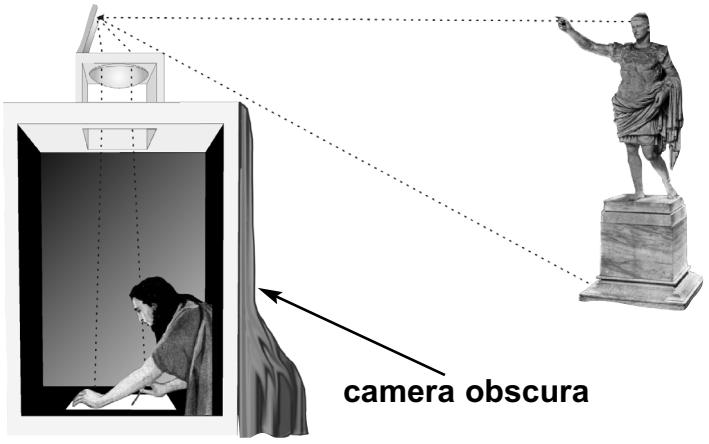
A convex lens is one that is thicker in the middle than at the edges. A magnifying glass is an example of a convex lens, and when held next to the eye, lets a person focus his or her eyes closer than normal. An object that is viewed through the lens appears larger than normal.



convex view of eye

A convex lens brings parallel rays of light to a focus to form a ***real image***. A real image is one that can be cast on a screen or sheet of paper. When held the right distance from a sheet of paper, a convex lens projects an image onto a white surface. The image, however, is projected upside down on the paper.

Artists found the image produced by a magnifying glass especially helpful when attempting to draw a three dimensional subject on a two dimensional sheet of paper. The artist mounted a convex lens at the front of a box and pointed it toward a scene to be drawn. The lens projected an image of the scene onto a sheet of paper. An angled mirror reflected the image so that it could be viewed right side up. The artist then traced around the image to produce the drawing. The device became known as a ***camera obscura***.



camera obscura

VOCABULARY

Nearsighted: able to see objects close at hand clearly but not those in the distance; the correction for nearsightedness is a concave lens
Concave lens: a lens that is thinner in the middle than at the edges, has a surface that bulges inward as the inner surface of a sphere; a concave lens spreads out parallel rays of light and cannot form a real image; a concave lens is the correction for nearsightedness
Milky Way: a spiral galaxy of innumerable stars, including our solar system; seen from Earth as a wide, luminous, milky or foggy band of stars
Refractor: a refracting telescope that has a lens to gather light from a distance subject and bring the light to a focus
Primary lens: the main lens of a telescope
Reflector: a reflecting telescope that has a mirror to gather light from a distance subject and bring the light to a focus

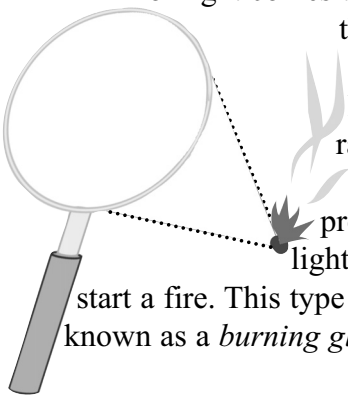
Focal length is the distance from the lens to the image. A typical magnifying glass has a focal length of about six inches. The magnification of a simple lens depends on its focal length. The shorter the focal length the greater the magnification. Most magnifying glasses make an object appear about 2.5 times life size. A jeweler's glass is stronger. It can produce a magnification of eight to ten times.



concave view of eye

Some people can see up close without an optical aid, however, distant subjects are blurred and indistinct. Such persons are ***nearsighted***. The correction for this vision defect is a ***concave lens***. A concave lens is thinner in the middle than at the edges and causes parallel rays of light to separate. When a person looks through a concave lens, nearby objects appear smaller and farther away. A concave lens cannot form a real image. Unlike a magnifying glass, a concave lens cannot project an image onto a sheet of paper.

Because of the way modern eyeglass lenses are shaped, most people cannot distinguish between a concave or convex lens. The way to distinguish is to notice the way light passes through them. Hold the glasses of a nearsighted person in a beam of light. You will notice that the circle of light spreads out after it passes through the lens. Hold the glasses of a farsighted person in a beam of light. You will notice that the circle of light comes together after it passes through the lens.



A large convex lens will bring the rays of sunlight to a focus. The heat produced by the spot of light can be hot enough to start a fire. This type of convex lens is also known as a *burning glass*.

Hans Lipperhey operated an optical shop in Holland. One day in 1608, an assistant held two lenses to his eye. To his astonishment, a church steeple in the distance appeared closer. The assistant showed his discovery to Hans Lipperhey. The Dutch spectacle maker instantly grasped the usefulness of the device. He mounted the lenses in a tube and sold it to the military as a way to spy on the enemy. Not surprisingly, the telescope became known as a *spyglass*. The military ordered Lipperhey to keep his discovery secret. But good things cannot be kept secret.



Galileo's telescope

Galileo in Italy heard about the invention. Although he had not seen one, he figured out its construction. He built a telescope and was the first person to turn the new scientific tool to the heavens. He improved on the telescope so that it magnified about 30 times. He saw mountains, valleys and craters on the moon, four big moons of Jupiter and the phases of Venus. In addition to magnification, objects too dim to be seen by the eyes alone became visible. Galileo found in the Milky Way numerous stars, where no individual stars could be seen without the telescope.

Because it used lenses to bend light to a focus, a telescope like the one Galileo built is known as a ***refractor***. To refract means to bend. A modern refractor has a large ***primary lens*** to gather light and bring it to a focus. The image is then examined with an eyepiece. The light-gathering power of the telescope depends on the diameter of the main lens. Even a small telescope with a lens two inches in diameter can collect about 70 times as much light as the eye alone.

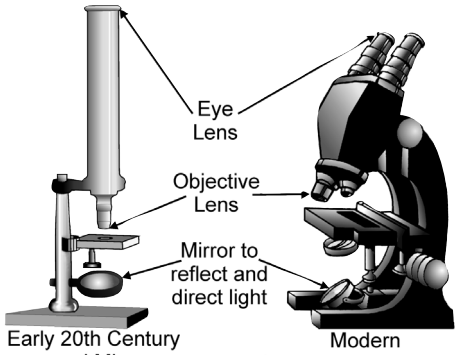
The magnifying power of a telescope depends on the focal length of the main lens and the magnifying power of the eyepiece. A small telescope with a focal length of 45 inches

can magnify from 50 to 150 times depending on the eyepiece.

Galileo built his telescope in 1609. About sixty years later, Isaac Newton built a telescope that used a mirror to bring the light to a focus. In Newton's telescope, the main mirror was at the bottom of the tube. Light rays traveled the length of the tube and struck the mirror. The light reflected toward a focus at the top of the tube. Before coming to a focus, a small secondary mirror reflected the rays through an opening in the side of the tube. The image formed outside the tube. The image could be examined with an eyepiece that magnified the image even more.

Because the image was formed by a mirror that reflected light to a focus, telescopes of Isaac Newton's design were called ***reflectors***. The largest telescopes in use today are reflecting telescopes used to study the heavens. Isaac Newton, the world's greatest scientist, developed the telescope in order to verify planets and stars such as: Orion, Pleiades and Arcturus listed in the Bible in the Book of Job, one of the oldest literary pieces known to mankind.

The first microscopes used a single convex lens. For great magnification, the lens had to be sharply curved and very tiny. The most powerful early microscopes were made of single lenses, each the size of a pinhead. The single lens had to be held nearly touching the eye. Working with such single lens microscopes required exceptional skill.



The microscope was improved by the addition of two lenses. The first formed an image, and the second one examined the image. The magnification was done in stages. The first lens at the bottom of the microscope tube magnified the object to be viewed. It produced a real image at the top of the microscope tube that was about ten times as large as the object. Then the real image was viewed through an eyepiece that magnified the image still more, usually about ten times.

The total magnification of a microscope is the product of the magnification produced by the two lenses. The first lens gives an image ten times larger than the object being viewed. The eyepiece magnifies the image ten more times. The total magnification is 10 * 10 = 100. Changing to different focal length lenses at either end of the tube changes the total magnification.

Ranger Eldridge's instructions were to block unmarked side trails and eliminate shortcuts damaged by erosion. The boys walked back to the main trail and then pulled brush and fallen limbs over the side trail to keep people from taking it by mistake.

As soon as they finished the task and began hiking the main Ridge Trail, Bryan and Tom saw footprints. "These are fresh enough to have been made this morning!" Bryan exclaimed. He put his foot down next to one of the prints. His shoe size and the print were nearly identical. However, Bryan's shoe did not sink as deeply into the soft earth.

Tom looked at the difference in the prints. "James Olsen is a small person, but kind of round-faced and pudgy. He probably weighs more than you do, but not that much more. Why are his prints so deep?"

Life Principle

“ Whoever has searched the heavens with a telescope and found no God would not have found the human mind if he had searched the brain with a microscope.”

—George Santayana



Lesson 4
Energy

Chapter 3

Conduction, Convection and Radiation

Section 1

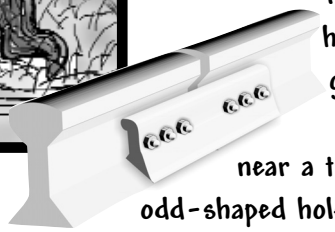
Lessons 1-5

HEAT



Bryan and Tom began following the tracks.

The boys were convinced the person who made the tracks had been on the trail only a few hours earlier. The drizzly weather the night before would have washed out older tracks. Soon the boys found where the man had stopped to rest. The wrapper from a power bar was discarded on the ground. "He's not the smartest person in the world!" Tom quipped. "We can almost follow him by the litter he drops on the ground!"



Bryan looked at the soft earth near a tree beside the trail. "Here are some odd-shaped holes in the ground where he leaned something against the tree."

"He rested my backpack there!" Tom declared. "That is why his prints are so deep—he's carrying my backpack! I'd packed it for our entire stay. It weighs about 65 pounds. He's really carrying a load and cannot move quickly. Come on, maybe we can catch him!"

The boys raced ahead. Suddenly, Bryan came to a stop. "We've lost his footprints! He's left the trail." Bryan looked at the map. "There's a side trail to Gull Cove."

The two ran back to the side trail. It was a steep trail and dropped quickly toward the ocean. The boys could see where James Olsen had slid as he descended the trail. "Watch out!" Bryan cautioned, "The footing is treacherous!"

Suddenly, Tom slipped and landed heavily. He lay on his back, motionless.

Two of the items Tom had in his backpack were his ground pad and sleeping bag. The ground pad had a waterproof cover and was filled with a foam material. It made

VOCABULARY

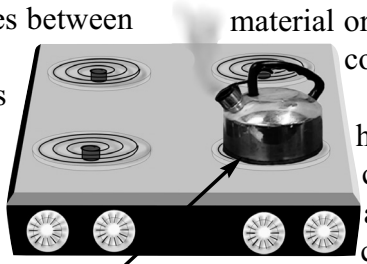
Insulator: a material that is a poor conductor of heat; prevents or inhibits heat transfer

Heat: a form of energy due to the motion of the atoms and molecules of a substance; heat is capable of being transferred through solids by conduction, through fluids (liquids and gases) by conduction and convection, and through empty space by radiation

Conduction: heat transfer by direct contact, the only heat transfer in solids is by conduction

sleeping on the ground more comfortable, not only by the padding it offered against sharp rocks but also because of the insulation it provided. The ground pad acted as an ***insulator***. It prevented ***heat*** from escaping from Tom's sleeping bag to the ground. The sleeping bag had artificial fibers with air spaces between them. They, too, were poor conductors of heat. Body heat was kept in and did not escape to the cool air.

Conduction is transfer of heat by direct contact. Conduction is the only way for heat to move from one point to another in solids. Atoms in solids are very close together. If one gains motion, it upsets those nearby and they start moving, too. A metal teakettle on a cooking stove transfers the heat of the burner to the water being warmed. The heat enters the metal by setting the molecules in motion. The speed at which heat moves through a body by conduction differs, depending on its composition (the material or substance of which a body is composed).


conduction

A ***conductor*** easily transfers heat. Most metals are good conductors of heat. Metals also are good conductors of electric current because atoms of conducting metals hold their outer electrons loosely. Scientists think the electrons flying about help move heat energy along in a conductor.

An *insulator* is a poor conductor of heat. Many nonmetals are poor conductors of heat. We pickup the handle of a hot teakettle with a fabric potholder because the nonmetallic potholder conducts heat less readily than the metal. Insulators control heat transfer. Hot water pipes are wrapped in insulators such as fiberglass or wool felt. The felt is a poor conductor and the effect is enhanced by the presence of numerous pockets of air. The insulating effect of air trapped in coats and blankets is what makes them warm. For example, the feathers of birds and the hair of furry animals trap air and help insulate the creature.

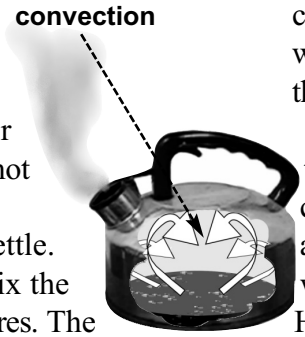
Some buildings are made of steel beams that are good conductors of heat. If a fire starts, the metal beams quickly absorb the heat. They weaken and sag, as they become hot. The building can collapse. Some building codes call for metal beams to be coated with insulating foam so the heat does not reach the metal as quickly.

Convection is the movement of heat by currents. Only substances that flow can transfer heat by convection. Both gases and liquids can flow, and are able to transfer heat by both conduction and convection.

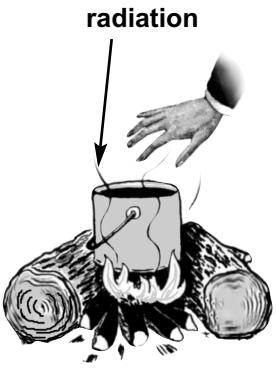
VOCABULARY

Conductor: a material that conducts heat readily; most metals are good heat conductors
Convection: heat transfer by currents, fluids (liquids and gases) such as water and air can transfer heat by convection
Radiation: heat transfer by electromagnetic waves; radiation can transfer heat through empty space
Energy: the capacity to do work; energy can be due to motion or position
Temperature: a measure of the average velocity of the atoms and molecules that make up a substance
Heat capacity: the amount of heat a substance is able to retain, expressed as calories per gram (cal/g); water has a high heat capacity of 1.0 cal/g; the heat capacity of iron is 0.11 cal/g.
Calorie: a measure of heat energy that will raise one gram of liquid water by a temperature of one degree Celsius; abbreviated *cal*
Food calorie: the calorie listed in dietary information on food packages, equal to 1,000 calories; also known as a *kilocalorie*, *large calorie* or *nutritionist's calorie*

The water at the bottom of a teakettle accepts heat from the metal container. The heat reaches the water by conduction. As the water becomes warm, it expands. The less-dense, warm water rises. A circular current of hot water rising and cold water falling is set up in the teakettle. The convection currents mix the water of different temperatures. The entire container of water then has about the same temperature.



Radiation is the third way that heat is transferred. In this process, heat energy changes to electromagnetic radiation. The warmth we feel from a hot fire is partially due to electromagnetic waves emitted by the burning fuel. Radiation is the only method of heat transfer that can pass through the vacuum of space. The Earth is warmed by the radiation of sunlight.

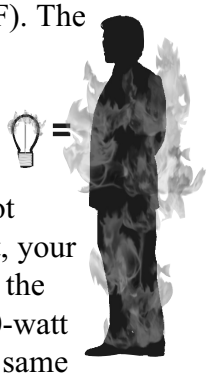


Heat is a type of ***energy***. The heat of a steam engine can do the work of putting a ship or locomotive into motion. The energy of steam is from the heat that it contains. Heat is a form of motion but at the molecular level. When you look at a kettle of hot water, the water may appear still. However, inside the water the tiny atoms and molecules are moving around. The faster they zip about, the greater the heat energy they carry.

Temperature is the average speed of the molecules of a substance. Molecules of steam move more briskly than molecules of liquid water. Steam has a higher temperature than liquid water.

Heat energy always moves from a region of higher temperature to a region of lower temperature. For example, in a glass of water with ice cubes, you expect the ice cubes eventually to melt. The heat of the water flows into the ice. After a few minutes, the ice cubes become warm and start melting.

Temperature alone does not describe the total heat energy in a body. An electric current heats the filament of a light bulb to about 3,000ºC (about 5,400ºF). The wire is definitely very hot. However, its heat content is low. Your body has a temperature of 37ºC (98.6ºF), which is far lower than the hot filament of the light bulb. Yet, your body releases to the air about the same amount of heat as a 100-watt light bulb. Your body has the same heat energy as a light filament because your body has far greater mass than the filament.



The total heat energy of a body also depends on its total mass. A small pond may freeze solid on a bitterly cold winter night. That same night, a larger lake may have a layer of ice on top, but the water underneath stays liquid. The greater amount of liquid water in the lake holds more heat than the water of the small pond.

As another example, suppose a single ice cube and a large block of ice are put on a countertop. You expect the block of ice to melt, but not as quickly as a single ice cube. The large block of ice has greater mass than the ice cube. More heat must be added to the block of ice to melt it.

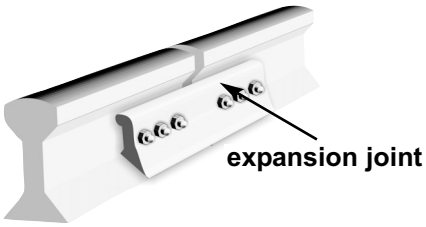
In addition to temperature and mass, the total heat energy of a body also depends on its type of substance. Some materials have greater ***heat capacity*** than others. Water, for instance, is well known for its high heat capacity. Generally, more heat is needed to raise the temperature of water by a degree Celsius than an equal mass of any other substance.

The difference in water's heat capacity is illustrated by a simple experiment. Scientists measured out equal amounts by weight of a solid (iron) and liquid water. The iron was heated to a temperature 10ºC above the temperature of the water. Next, the iron was dumped into the water. The iron warmed the water, and the water cooled the iron. If they both had the same heat capacity, water would warm by 5ºC and the iron would cool by 5ºC. That is not what happened. Instead, the final mixture had a temperature only about 1ºC above the temperature of the water. Suppose the temperature of the water was 70ºC and the temperature of the iron was 80ºC. After they were mixed, the water would warm in temperature to 71ºC, an increase of 1ºC. The iron would cool to 71ºC, a decrease of 9ºC.

The ***calorie*** is the standard metric unit for measuring heat; that is, the amount of heat needed to raise the temperature of one gram of liquid water by one degree Celsius. To warm 1.0 gram of liquid water from 0ºC (its melting temperature) to 100ºC (its boiling temperature) takes 100 calories. The ***food calorie***, listed in nutritional information on packages of food, is equal to 1,000 metric calories, or heat units.

Notice that heat and temperature are measured with different units. Heat is measured in the metric system in calories. Temperature is measured in the metric system in Celsius degrees.

Almost all substances expand as they are heated. Their molecules gain energy and rush about more rapidly. They collide with one another more vigorously. Greater activity forces the molecules farther apart. Concrete highways can buckle on hot summer days because of increased temperature. Railway rails expand and contract with temperature changes. Railroad track rails are put in place with a gap between them. The gap gives the rails room to expand on a hot day. The gap is an ***expansion joint***. Bridges also have expansion joints. A mile-long bridge may be a meter longer on a hot day than on a cold day. Without expansion joints, increased temperatures could cause steel beams to twist out of shape.



Bryan gave his friend a hand. "Are you all right?"

"Yes," Tom said as he got up slowly. "I knew I was in trouble when I looked down at my feet and saw clouds instead. Let's go! We can still catch the thief!"

Bryan and Tom followed the footprints down the side trail to Gull Cove. The boys avoided making noise because they sensed the man they were chasing could be just ahead of them. The trail descended through a tight gap in the bluffs to a small, rocky beach. The two ducked behind a boulder and Tom looked ahead. He whispered, "I see him!"

Life Principle

"A hot temper is a mental condition that cools friendships."

—Anonymous



Lesson 5
Energy

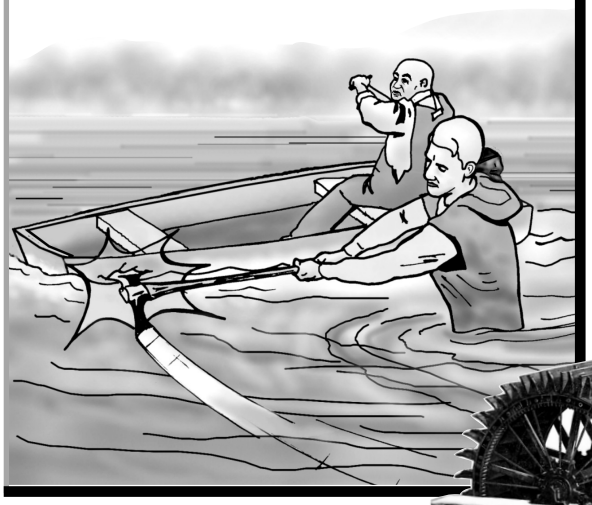
Chapter 3

Fuels to Power Men and Machines

Section 1

Lessons 1-5

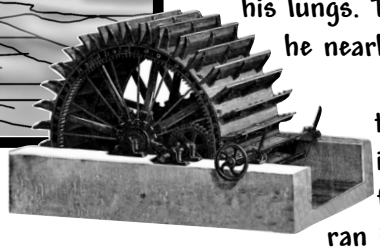
ENERGY



A small boat with an outboard motor was pulled up on the beach. A man was sitting on Tom's backpack beside the boat. 1

Bryan spoke quietly, "He appears to be reading something. Maybe it is a map or chart." As Bryan spoke, the man stood up to push his boat toward the water, then turned to grab Tom's backpack. Bryan whispered, "He's leaving!" 2

Tom jumped up and ran for the beach. Racing toward the man, Tom yelled at the top of his lungs. The man whirled around so quickly he nearly fell down. 3



Dropping Tom's backpack, the man quickly pushed the boat into the water. As the boat began to float, the man jumped into it. Tom ran into the water after him, then let out a cry of frustration as the man started the outboard motor with one mighty pull. Tom made a swing at the side of the boat with his Pulaski. The axe cut a six-inch gash in the aluminum skin, just above the water line. 4

The man gave the throttle a quick twist. In seconds, he was out of reach. 5

Tom stood waist deep in the cold water and watched in frustration as the man escaped. As Tom waded ashore, he began shivering violently. 6

"Quick," Bryan commanded, "Get out of your wet clothes! You'll have dry clothes in the backpack. I'll start a fire with drift wood." 7

"No," Tom said. "I'll be all right once I'm in warm clothes." Then quickly, he reconsidered Bryan's offer, "But a cup of hot cocoa would be great!" 8

Bryan pulled a small camp stove weighing less than two pounds from the backpack. He heated water and made two cups of hot cocoa. 9

VOCABULARY

Matter: one of the two chief components of the physical world; matter has mass, takes up space and can be perceived by the senses

Work: the transfer of energy from one object to another; usually work is thought of as a force that puts matter into motion

Glucose: a simple sugar; main source of energy for all living organisms

Flume: a narrow channel or trough for conducting water from one location to another

10 To start a fire or heat water to make cocoa, Bryan needed fuel. Driftwood would have been one source. The gasoline that Bryan used in his camp stove was another example of a fuel. Either one contained energy that would generate heat.

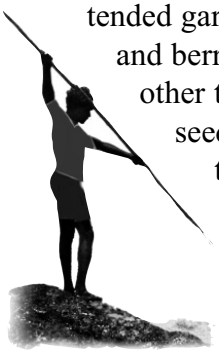
11 Almost all branches of science are concerned with ***matter***, energy or both. *Matter* is that which occupies space and has mass. *Energy* is the ability to do ***work***. Energy gives motion to matter. With this definition, an automobile engine does work by causing the car to accelerate from zero miles per hour to 65 miles per hour.

12 *Work* is the ability to put matter in motion. Today among scientists, work has an additional meaning. Work is the transfer of energy from one place to another. When work is done on an object, the object always gains energy. For instance, when you turn on a flashlight, the chemical energy of the battery generates electrical energy that goes to the flashlight bulb. The electrical energy heats the filament and causes it to glow and emit light. Work is done in transferring chemical energy from the battery to the electromagnetic radiation of the flashlight bulb.

VOCABULARY

Potential energy: stored energy, or energy due to position rather than motion
Peat: a fuel of dried vegetable matter from bogs; peat contains about 60 percent carbon
Coal: a fuel formed from fossilized plants that contains from 70 to 100 percent carbon
Fossil fuel: a hydrocarbon fuel derived by natural processes from long dead organisms; fossil fuels include coal, natural gas and petroleum
Fossil: the remains or trace of life from a past geological age
Natural gas: a gaseous hydrocarbon fossil fuel usually found with petroleum deposits, composed primarily of methane and other light hydrocarbons
Methane: the simplest of the hydrocarbons, consisting of one carbon atom and four hydrogen atoms (CH_4)
Petroleum: a liquid hydrocarbon fossil fuel formed from ancient, microscopic plants and bacteria that lived in the ocean
Porous: filled with pores, or tiny openings smaller than pinpoints

13 The first source of energy produced by living beings was muscle power. Humans threw spears to bring down game for a meal. They wielded knives and other cutting tools to dress the game. They planted crops, tended gardens, and collected nuts and berries. They used hoes and other tools to prepare the soil for seeds. They pulled up weeds that choked the crops. They cracked nuts with stones. All of these activities are types of work that used energy provided by muscles.

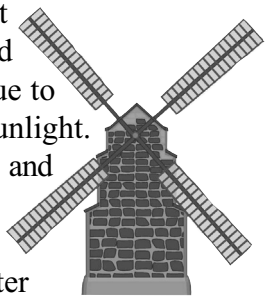


14 Sometimes the muscles of animals performed work. Dogs hunted and retrieved game. Horses carried riders. Oxen pulled heavy wagons and plowed fields.

15 Muscles derive their energy from ***glucose*** in the blood. Glucose comes from the food a person eats. The food comes from plants and animals. Animals eat other animals or plants. Regardless of the source of food, it can be traced back to plant life. Plants make their food by photosynthesis from soil, air and the energy of sunlight. Food is grown by the energy of sunlight; therefore, muscle energy can be traced to the Sun as the ultimate source.

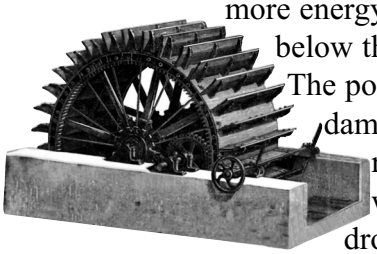
16 In addition to muscle power, people used wind as a source of energy to do work. Rather than rowing a boat, a sail caught the wind and carried the boat along. Windmills were built in land areas with a steady breeze.

The power of the wind turned the windmill. A series of gears converted the motion so that the windmill could grind grain, saw wood or pump water. The wind that passed over land and turned windmills was primarily due to the heating effects of the sunlight.



17 In the United States and elsewhere, the energy of moving water was used in addition to wind. River water passed under a paddle wheel to give it motion. In other designs, a ***flume*** led water from a pond to the top of a water wheel. The water fell into bucket-like containers at the top of the wheel. The weight of the water caused the wheel to turn. The wheel was attached to a shaft that rotated a large grindstone or gear.

18 Sometimes a stream would be dammed. The purpose of the dam was to raise the water level so it was above the level of the top of the waterwheel. The water behind the dam had ***potential energy***. Water at a level higher than the waterwheel has more energy than water below the waterwheel. The pond behind the dam also was a reliable source of water in case of drought. The storage pond became potential energy stored for later use.

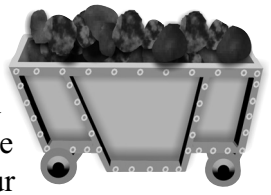


19 Rays of sunlight heat water in the oceans. The water evaporates into the air as water vapor and wind transports it over land. Falling temperatures change the vapor to a liquid which falls as rain. The rain fills streams and rivers that pour back into the oceans and into lakes behind dams. Therefore, in reality, sunlight energizes the water cycle which keeps the ponds supplied with water to turn the waterwheels.

20 Wood is a heating fuel that has been in use for centuries. Carbon is the substance in wood that burns. When wood burns, carbon in the wood combines with oxygen in the air to produce carbon dioxide and release heat.

21 ***Peat*** is another fuel that contains carbon. Peat forms in bogs of plants and some animal material. The fallen material becomes pressed together. The complex compounds found in living things break down and bubble out as gases. Most carbon remains behind and this is what allows peat to be used as a fuel. Peat is dug up and dried. Peat is used as a fireplace fuel in many countries, including Ireland and Scotland.

22 ***Coal***, chemists believe, was formed when ancient vegetable matter in peat was put under extreme pressure. Coal is called a ***fossil fuel***. A ***fossil*** is the remains of ancient life from the distant past. Coal is a fossil fuel derived from once living vegetation of long ago, which according to some theories took millions of years to form. However, coal can be produced in a laboratory in a matter of hours. This would indicate that a cataclysmic event such as a global flood in the not-too-distant past could have supplied the pressure necessary to formulate our coal supplies.



23 Fuels with high carbon content generate more heat and are cleaner burning than fuels with less carbon. Wood is about 50 percent carbon. Once the moisture is eliminated, peat contains about 60 percent carbon and burns freely. Coal, depending on the quality, can contain from 70 to nearly 100 percent carbon.

24 Wood, peat and coal are fuels that come from plants. Plants grow because of sunlight. Wood, peat and coal can be traced back to the Sun as the primary source of energy contained in fossil fuels.

25 ***Natural gas*** is another form of fossil fuel. Natural gas forms whenever plant and animal matter decays. ***Methane*** is the simplest natural gas. When mud and decayed plant matter at the bottom of a pond is stirred, methane bubbles to the surface. Methane and similar natural gases are also found trapped in rocky pockets deep in the earth. Natural gas is a common home heating fuel. It is either stored in metal tanks or comes into homes through metal gas lines.

26 ***Petroleum*** or crude oil is another fossil fuel. Petroleum has many uses. It is burned as heating oil, sold as gasoline to run the engines of cars and trucks, and used as a raw material to make other products such as plastics.

27 How petroleum formed is not fully understood. The best explanations seems to be that sea vegetation and dead animals became trapped below a layer of sediment at the bottom of the sea. The mud hardened into shale. Shale is a ***porous*** rock. Pressure squeezes the oily material from the shale. The crude oil travels upward until it is trapped by a different type of rock that will not let it pass. There the crude oil collects in pockets. Oil wells are drilled down until they strike one of these pockets and pump the oil from the ground.

28 Natural gas and petroleum are hydrocarbons. The word hydrocarbon is made from hydrogen and carbon. A hydrocarbon such as methane or gasoline for an automobile is made of hydrocarbon molecules. A central chain of carbon atoms has hydrogen atoms on either side. When petroleum burns, the carbon joins with oxygen in the air to form carbon dioxide. The hydrogen also chemically combines with oxygen in the air to form water.

29 Methane burns with a steady blue flame without undesirable by-products. However, most fuels contain by-products that burn with the fuel and produce undesirable pollutants. If the fuel were pure hydrocarbons and burned in a sufficient supply of oxygen, the fuel would be clean burning.

30 The boys began the long climb back up the trail. Once he was dry and warm, Tom brightened. "He got away, but I have my clothes! And to be wearing clothes that fit is a real pleasure!"

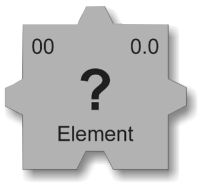
31 That night in the cabin, Tom took everything out of his backpack. "Everything appears to be here except for some missing food supplies." He felt in one of the small side pockets and pulled out a sheet of paper. "I didn't put this here," Tom said. "Look! It's an old map!"

Life Principle



"A smile is the lighting system of the face and the heating system of the heart."

—Anonymous



Lesson 6
Elements

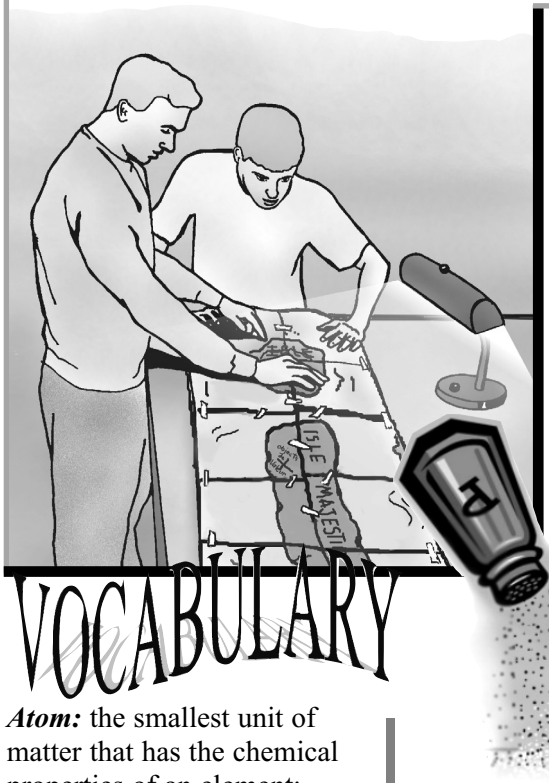
Chapter 3

Atoms, Mixtures; Compounds and Chemical Formulas

Section 2

Lessons 6-10

ELEMENTS AND COMPOUNDS



VOCABULARY

Atom: the smallest unit of matter that has the chemical properties of an element; consists of a central dense core (nucleus) containing protons with a positive charge and neutrons with no charge; orbiting around the nucleus are electrons with a negative charge

Subatomic: particles smaller than the entire atom; the best known subatomic particles are the proton, neutron and electron

Element: a substance that cannot be divided into simpler substances; all of the atoms of an element are the same; atoms of the same element have the same number of protons

Tom took the map over to the table and turned on the desk light. He began to examine the map carefully. It was made of several photocopied pages that had been taped together. "This is a copy," Tom said. 1

"Yes," Bryan agreed. They unfolded the sheets of paper, which made a map about two feet wide by five feet long. Bryan reasoned, "It looks like a larger map was copied in sections and taped together. The original was hand drawn. It must have been too old and precious to take into the field." 2

"Or, James Olsen stole the original long enough to copy it!" Tom suggested. The map showed two islands. One was long and narrow. The second one was much smaller and had a nearly circular shape. The larger one was marked *Isle Majestic* and the smaller one marked *Isle Petite*. Tom said, "I've never heard of those islands. Where are they located?" 3

"I think the writing is in French," Bryan said. He read the names by the features. "*Abre de Sorcère, cuivre pierres and tonnerre trou*. Wait a minute! I recognize these islands! The map doesn't show all of the coves, bays and inlets, and the middle of the map is pretty much blank; but the big island is Danger Island and the little one is Shell Island!" 4

Tom had been studying the map. "Here are some pencil marks. There's an exclamation point under the words *cuivre pierres*. Right beside it is an X on the original map with the words *objet de valeur*." 5

Bryan questioned, "*Objet de valeur*? I don't know French, but it sounds like '*object of value*!'" 6

7 Tom said, "Mr. Murphy disappeared just before he announced an important discovery. The island has a copper mine. Maybe he discovered a more
8 important mineral, such as gold!"

Gold is one of the most valuable of all substances. It has a beautiful luster and does not rust or change color. Gold can be hammered into very thin sheets. An experienced goldsmith can beat gold as thin as a sheet of paper. Gold foil can be used for lettering on office windows and as gold names in books. Despite gold being expensive, gold foil is so thin that the gold letters do not cost much.

VOCABULARY

Mixture: two or more substances that are capable of being physically separated; the substances in a mixture are not chemically combined

Compound: a substance consisting of atoms of two or more different elements in chemical combination in which the atoms are always found in the same ratio; often the compound has physical and chemical properties unlike those of the elements that make it

Chemical symbol: a one or two letter abbreviation for an element; the chemical symbol of oxygen is O, the chemical symbol of carbon is C and the chemical symbol of gold is Au

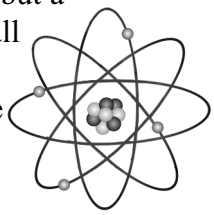
Chemical formula: a shorthand way of representing a compound by using the chemical symbols of the elements that make it; H_2O is the chemical formula for water, CO_2 is the chemical formula for carbon dioxide and CH_4 is the chemical formula for methane; the subscript shows the number of atoms (if no number is shown, then only one atom is present)

Ratio: the relation of two quantities expressed as whole numbers; the ratio of the number of hydrogen atoms to oxygen atoms in water (H_2O) is two to one (2:1)

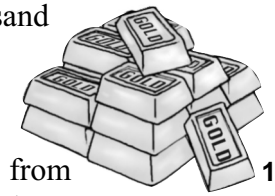
9 Scientists wondered if a goldsmith could hammer a piece of gold into the smallest possible particle. Scientists beat a small lump of gold into a thin sheet and cut a tiny section from the sheet. Then they beat that section into a still thinner sheet and cut a tiny bit from it. They attempted to reduce the piece of gold to the smallest possible piece.

10 Although they wanted to discover the smallest piece of gold and other substances, scientists were unable to do so until about 200 years ago.

11 Many questions were answered when scientists learned that all matter is made of atoms. An ***atom*** is the smallest particle of a substance. If you cut and re-cut a lump of gold, you will eventually have but a single atom. An atom is as small as you can get and still have gold. If you cut any farther, the division will give ***subatomic*** particles that do not have the chemical and physical properties of gold.



12 Because of its value, some people tried to make gold from other materials. For instance, lead is heavy like gold. Sulfur is a substance with a yellow color like that of egg yolk. For almost two thousand years, chemists tried in vain to mix lead and sulfur to make gold. Other metals such as mercury were mixed with substances such as yellow egg yolks. Despite two thousand years of trying, no one succeeded in making gold from cheaper materials.



13 Gold cannot be made from other substances because all substances are composed of their own distinctive atoms. An atom has all the chemical properties of a substance. Mixing two different atoms together, such as the atoms of lead and of sulfur, will not give gold. Gold can be formed only with gold atoms. The quest for making

gold by combining other atoms was doomed to failure. Elements such as gold, silver, copper and lead were created in their natural state and could only be discovered and refined by man. Man simply learned about elements and learned how to use them.

14 Gold contains only gold atoms. Each gold atom is like all the other gold atoms, especially by weight. Also, gold atoms are different from all other kinds of atoms, especially by weight.

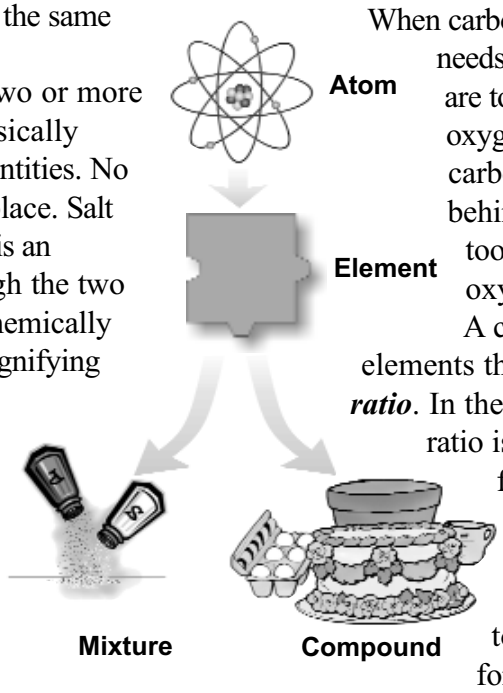
15 An ***element*** is a substance made of atoms that are all alike. Pure gold is an element because it contains only gold atoms. Other elements include carbon, oxygen and hydrogen, to name a few. In all, chemists have found 92 naturally occurring elements. Elements are the building blocks from which all other substances are made. Look around you. Amazingly, every substance you see or can think of is composed of only about 100 elements, either singly or in some combination.

16 Atoms make up all elements. An atom is the smallest sample of a particular element. When atoms of the same element are combined, the result is a larger sample of the same element.

17 A ***mixture*** contains two or more substances that are only physically combined and retain their identities. No chemical reaction has taken place. Salt and pepper sprinkled together is an example of a mixture. Although the two mix *physically*, they do not chemically combine. With patience, a magnifying glass and tweezers, you could separate salt from pepper.

18 A ***compound*** contains two or more substances that are *chemically* combined. Chemical changes alter the identities of the substances involved. Shape or color may be affected. Heat is often part of a chemical reaction. Carbon dioxide is an example of a compound. When oxygen from the atmosphere burns with the carbon in wood or coal, the oxygen and carbon chemically combine to give carbon dioxide. The ***chemical symbol*** for carbon is *C* and the chemical symbol for oxygen is *O*. The formula for the combination of carbon and oxygen in carbon dioxide is CO_2. The subscript "2" shows the presence of two oxygen atoms for every carbon atom. The expression CO_2 is the ***chemical formula*** for carbon dioxide. Carbon dioxide always has two oxygen atoms for each carbon atom.

19 Chemists who first experimented with burning oxygen and carbon were surprised to discover the need for exactly the right amount of carbon and oxygen. If chemists applied too much carbon, then all of the oxygen would combine and some of the carbon would remain. If chemists used too little carbon, then some of the oxygen would be left over. This observation was easy to understand when scientists learned that matter was made of atoms.

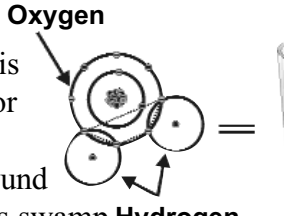


20 When carbon burns, each carbon atom needs two oxygen atoms. If there are too many carbon atoms for the oxygen atoms, then some of the carbon atoms will remain behind as carbon. If there are too few carbon atoms, then oxygen atoms will be left over.

21 A compound is formed by elements that combine in a simple ***ratio***. In the case of carbon dioxide, the ratio is 1 to 2—one carbon atom for two oxygen atoms.

22 Another well-known chemical formula is H_2O, the chemical shorthand way to write *water*. The *H* stands for the element, hydrogen.

The *O* stands for the element, oxygen. The formula shows that the water compound is made of two hydrogen atoms and one oxygen atom. Like all other chemical compounds, the atoms combine in simple ratios that are whole numbers. For water, the ratio is 2 to 1: two hydrogen atoms for one oxygen atom.



23 Another simple compound is methane. It is also known as swamp gas. It forms in the mud at the bottoms of ponds that contain decaying plant and animal matter. Methane is made of hydrogen and carbon. The formula is CH_4. This shows that the compound methane is made of one atom of the element carbon and four atoms of the element hydrogen. The ratio is 1 to 4: one carbon atom to four hydrogen atoms.

24 Carbon dioxide, water and methane have carbon, hydrogen or oxygen atoms in definite ratios of whole numbers. The ratios can change, but the result is no longer carbon dioxide, water or methane.

25 For instance, carbon *monoxide* is *CO*. It is the deadly chemical cousin to carbon *dioxide*. Carbon monoxide has one carbon atom and one oxygen atom. Their chemical properties differ considerably. The atmosphere that we breathe always contains a small amount of carbon dioxide. As long as we also have oxygen, we can breathe the carbon dioxide in small amounts and it does not hurt us. Carbon monoxide, on the other hand, is dangerous to breathe in even small amounts, because it interferes with the blood's ability to carry oxygen.

26 Hydrogen peroxide (H_2O_2) is an example of a compound that contains hydrogen and oxygen, as does water (H_2O). However, hydrogen peroxide has hydrogen atoms and oxygen atoms in the ratio of 2 to 2: two hydrogen atoms for every two oxygen atoms. The chemical properties of water and hydrogen peroxide differ considerably. Water is safe to drink. Strong hydrogen peroxide solutions can blister the skin and bleach the hair. The atoms that combine to form the peroxide break apart when exposed to bright light and explode if heated to the boiling point. Sometimes dilute hydrogen peroxide is used as an antiseptic and a mouthwash. The home version is a solution that contains only about 3 percent hydrogen peroxide. It is kept in a brown bottle to prevent light from causing it to break down chemically.

Bryan said, "We should show the map to someone." 27

"Who?" Tom asked. 28

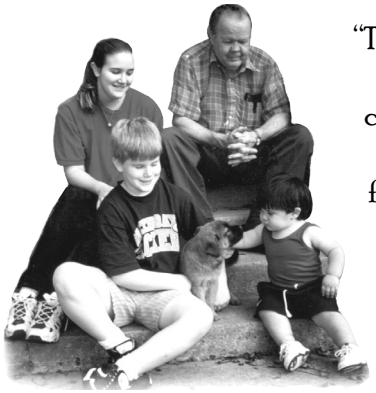
"The girl—Del. She knows a lot about the area." 29

Tom was already shaking his head. He had a knack for mimicking people's voices. He gave his voice a higher pitch and spoke in the girl's voice. "You boys with your long legs. You can go so-o-o-o much faster than I can." 30

Bryan laughed. "So she rubs you the wrong way. But she can help us, and you know it! I'll show her the map and we can see what she has to say." 31

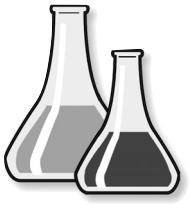
Reluctantly, Tom agreed. 32

Life Principle



"The compound of happiness is composed of the elements love, forgiveness and gratitude."

—Nancy Johnson



Lesson 7
Compounds

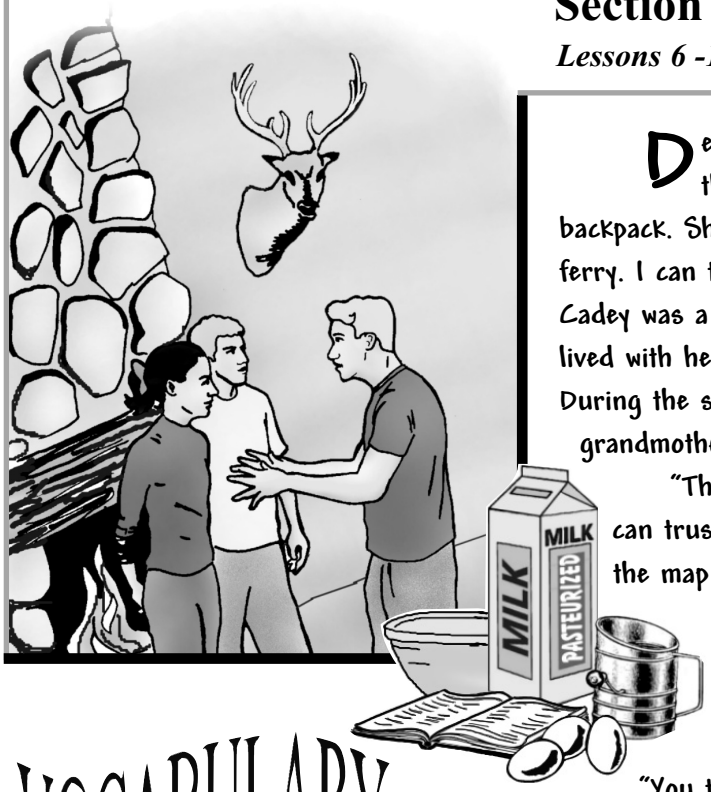
Chapter 3

Protons, Electrons, Neutrons, and Atomic Numbers

Section 2

Lessons 6 -10

ATOMS AND MOLECULES



VOCABULARY

Chemical reaction: a process that changes the molecules making up a substance; atoms that make up the molecules of the reactants (beginning materials) are rearranged to give molecules that make up the products (ending materials)
Molecules: groups of two or more different atoms, each held together by chemical forces; a molecule is the smallest particle of a compound that has all the properties of the compound

Del could not translate the French writing on the map that the boys found in Tom's backpack. She said, "I'm going to Cadey on tomorrow's ferry. I can take it with me and have it translated." Cadey was a small resort town on the mainland. Del lived with her mother in Cadey during the school year. During the summer months, she stayed with her grandmother on Danger Island. 1

"The map needs to be read by someone we can trust," Bryan cautioned, "We've only shown the map to you — " 2

"And," Tom broke in, "We can't give you the map to take to Cadey. Can you make a copy?" 3

Del gave him a withering glare. "You think I might lose it! All right, we have a copy machine in the lodge office. I'll make a copy for my use! The ferry runs twice a week now. I'll catch it at two o'clock tomorrow and be back on Friday." 4

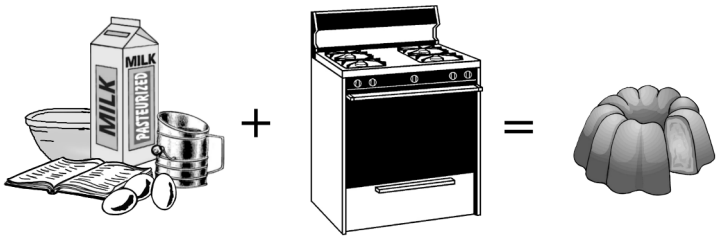
After Del made a copy of the map, Tom folded his copy carefully, put it in a small canvas bag and hid it under his mattress. 5

That evening at dinner, the large banquet hall was chilly. Mrs. Murphy asked Tom and Bryan to start a fire in the fireplace. Being by the fire and enjoying the good food was a pleasant experience. For dessert, each person had large slices of German chocolate cake with thick icing. It was delicious! 6

Logs in a fireplace do not begin burning on their own. A match ignites kindling that then sets the logs ablaze. The head of a match contains the elements sulfur and phosphorus. These two elements do not react until the match is struck on 7

the sandpaper side of a match box. The friction generates heat energy that causes sulfur and phosphorus to react.

8 A ***chemical reaction*** causes atoms or ***molecules*** to combine to give a new product. Outside energy may be needed to start the reaction. Once it starts, the reaction may produce enough heat that additional energy is no longer required. A match and kindling cause logs in a fireplace to start burning. Once the logs ignite, the chemical reaction combines carbon in the wood with oxygen in the air. The reaction produces heat to warm the room and continue the reaction.



VOCABULARY

Proton: a subatomic particle found in the nucleus of an atom; a proton has the same charge as an electron but opposite in sign; its mass is 1,836 times that of an electron
Neutron: a subatomic particle with no charge, found in the nucleus of an atom; a neutron has about the same mass as a proton
Electrons: subatomic particles that orbit outside the nucleus of an atom; an electron has the same charge as a proton but opposite in sign; it is far less massive than either the proton or neutron
Atomic number: the number of protons in the atoms of a particular element which cannot be changed by ordinary chemical reactions; always a whole number
Neutral: with no overall electrical charge
Positive ion: an atom with an overall positive electrical charge caused by the atom losing one or more of its (negative) electrons
Negative ion: an atom with an overall negative electrical charge caused by the atom gaining one or more (negative) electrons

9 Some chemical reactions require energy to be continually applied. Baking a cake is an example of a chemical reaction where external heat must be applied to keep the reaction going. The milk, eggs, flour and other ingredients are combined in a baking pan and then put in the oven. Heat from the oven causes a chemical reaction that changes the mixed dough into a cake. Without heat, the molecules of the ingredients in the cake mix would not combine. The chemical reaction produces new molecules that gives cake its taste, flavor and texture.

10 A molecule of a compound is a combination of the atoms of two or more elements. A molecule can have properties that are very different from the elements that compose it. For instance, sodium is a metal so active it burns when exposed to water. Chlorine is a choking, poisonous gas. Together, however, they make the harmless and even beneficial sodium chloride, or ordinary table salt.

11 *Compounds* are chemical substances made of identical molecules. Each molecule in a compound is the same as the other molecules in the compound. For example, hydrogen atoms and oxygen atoms combine to make the water molecule. All water molecules are identical. Water is a compound because it contains molecules that are all alike.

12 Chemists have identified several million compounds. A compound can be very simple like that of water or carbon dioxide. Or it may be more complex such as glucose. Glucose is a simple sugar that contains carbon, hydrogen and oxygen. The chemical formula is $C_6H_{12}O_6$. Some molecules found

in living organisms contain hundreds and even thousands of atoms.

13 A molecule always has the atoms in the same ratios. Methane (CH_4) is made of molecules that contain carbon and hydrogen. The atoms are always found in the simple ratio of 1 to 4 in methane: 1 carbon atom to 4 hydrogen atoms.

14 The number of carbon and hydrogen atoms in methane can be changed, but the result is a molecule that is no longer methane. For instance, the compound butane is also made entirely of carbon and hydrogen. However, the molecules of butane have atoms in the ratio of 4 carbon atoms for 10 hydrogen atoms. The chemical formula for butane is C_4H_{10}.

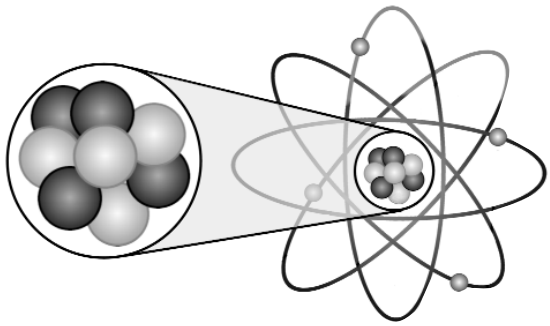
15 Although they are different compounds, methane and butane are alike in some ways. Both methane and butane are colorless and flammable, or will burn in the air. They are different in other ways. Butane is a heavier gas than methane. Butane changes into a liquid easily by cooling it or putting it under pressure.

16 Molecules can be broken apart into individual atoms or they can combine with other molecules to give new compounds. In either case, when the molecules of a compound change, the result is a new compound. The old one no longer exists. For instance, when methane (CH_4), burns in air the carbon in the methane combines with oxygen to give carbon dioxide (CO_2). The hydrogen in methane combines with oxygen to give water (H_2O). Methane has disappeared to give up its atoms to form carbon dioxide and water.

17 A *mixture* contains molecules that are different from one another and are not combined chemically. Such molecules can be mixed together and they do not react with one another. They keep their own chemical properties. Air is an example of a mixture. The atmosphere contains a variety of gases, including oxygen, nitrogen, argon, carbon dioxide and water vapor. Although the gases are found in the atmosphere together, each one retains its chemical properties. The atmosphere is an example of a mixture.

18 Chemical reactions cannot create atoms. A chemical reaction takes existing atoms and rearranges them to produce new molecules. During chemical reactions atoms move around and join other atoms. The number and type of atoms stay the same. Atoms can neither be created nor destroyed by ordinary chemical reactions.

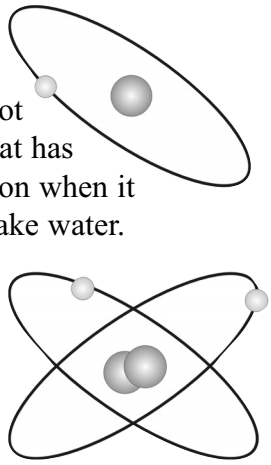
19 Chemists have discovered that electrons circle around the nucleus, the dense central core of an atom. The nucleus contains two types of particles, a ***proton*** with a positive charge and a ***neutron*** with no charge. Circling far from the nucleus are the ***electrons*** with a negative charge.



20 The electron has small mass when compared to the proton. As many as 1,836 electrons are needed to weigh as much as a proton. However, both electrons and protons have equal electric charges: equal but opposite.

21 The simplest atom is the hydrogen atom. It has one proton, no neutrons and one electron. A more complex atom is the helium atom. Helium is a lightweight gas that does not take part in chemical reactions. The helium atom is made of two protons and two neutrons in the nucleus. Two electrons fly at great speed around the nucleus. The most complex naturally occurring atom is the uranium atom. Uranium has 92 protons, 146 neutrons, and 92 electrons.

22 During chemical reactions, the number of protons and neutrons does not change. A hydrogen atom that has one proton still has one proton when it combines with oxygen to make water. Carbon, oxygen, helium, uranium and all other elements are the same way. The number of protons they have never changes during chemical reactions.



23 Because the proton count remains the same, chemists sometimes identify an atom by its number of protons. Hydrogen is element number 1 because each of its atoms has one proton. Helium is element 2 because each of its atoms has two protons. Next is the light metal lithium, element 3, with three protons. Carbon is element 6 and has 6 protons. Oxygen is element 8 and has 8 protons. Uranium, the heaviest atom, is element number 92.

24 The ***atomic number*** of an element is the number of protons it possesses. The atomic number is always a whole number because you cannot have fractional protons. The atomic number of hydrogen is 1. The atomic number of helium is 2. There is no element with an atomic number of 1.5 because no element has a fraction of a proton.

25 Normally, an atom has as many protons as electrons. The total positive charge of the protons equals the total negative charge of the electrons. The positive charge cancels the negative charge. The atom as a whole is electrically ***neutral***.

26 Sometimes an atom loses an electron. When that happens, the number of protons in the nucleus outnumbers the electrons, and the atom as a whole is no longer neutral. It has a positive charge and is a positive ion. A ***positive ion*** is an atom that has a positive charge.

27 Sometimes an atom gains an electron. When this happens, the number of electrons circling around the nucleus outnumbers the protons. Overall, the atom then has a negative electric charge. If an oxygen atom gains two electrons, the atom as a whole is no longer neutral. It has a negative charge and is a negative ion. A ***negative ion*** is an atom that has a negative charge.

28 The next day, Ranger Eldridge interrupted Bryan and Tom's work on repairing the trails. "A question has come up about whether we should try to save the old Barnett Lumber Mill. I want you to document the current state of the site. Here is a checklist of things for you to do."

29 Bryan looked over the list. "So, you want us to take photographs?"

30 "Right," Ranger Eldridge said. "I'll give you a good quality 35-mm camera."

31 Bryan added, "Let us take a telephoto lens, too."

32 The telephoto lens turned out to be heavy, but Bryan was happy to carry it. He told Tom. "Not only can we photograph animals, but we can take pictures of distant subjects. It pulls them in real close, like looking at them through binoculars. A photograph will prove that what we saw was not a figment of our imagination!"

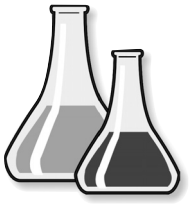
33 Tom asked, "What are you talking about?"

Life Principle



"Dropping negative attitudes allows us to become more positive."

—David Browder



Lesson 8
Compounds

Chapter 3

Alloys, Covalent and Ionic Bonds, and Photography Usages

Section 2

Lessons 6-10

CHEMICAL BONDS



Bryan explained why he wanted the telephoto lens. "When we first hiked out to the twisted tree, we had a good view of Shell Island from the bluff. When the fog cleared, we saw a village on the island. The buildings had stone walls and straw roofs. The map doesn't show a town, and everyone tells us the island has never been inhabited!"

"The town does exist!" Tom said stubbornly. "We saw it!"



Bryan fitted the long telephoto lens to the camera. "We'll take a photograph of the mystery town to prove it is not a figment of our imagination!"

Bryan pondered the map and decided the fastest way to the Barnett Lumber Mill was up the Ridge Trail and then down a secondary trail. Making all of the measurements called for by Ranger Eldridge's checklist would take some time. "We'll need to spend the night there," Bryan said.

The boys loaded their backpacks and set out. "Why is the trail always uphill?" Tom grumbled. "Going or coming, it is always uphill!"

"It just seems uphill," Bryan said. "You always pack too much!"

The mill was downhill from a pond made by damming a small creek. Buildings at the mill were spread out: a storage building, a shed for firewood, and a repair shed. The buildings appeared to be in good condition.

Tom stopped. He examined something at his feet. "Here is a recent footprint and it is not one of ours!"

Bryan took a picture of the unexpected footprint.

VOCABULARY

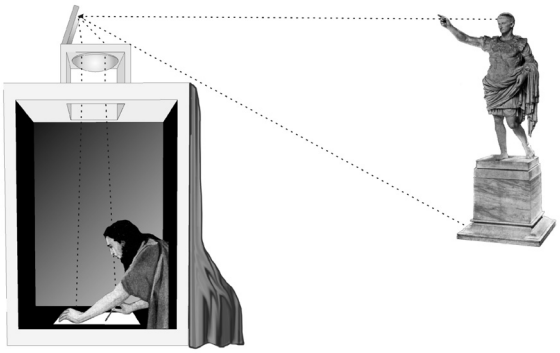
Alloy: a mixture of two or more metals; the alloy of tin with another metal (usually lead) is known as pewter

Ion: an atom with an electric charge

Ionic compounds: compounds made of charged atoms; one of the atoms of the compound gives up electrons and the other atom accepts electrons; both atoms become charged ions of opposite sign and attract one another

Covalent bond: formed by the sharing of a pair of electrons by two atoms

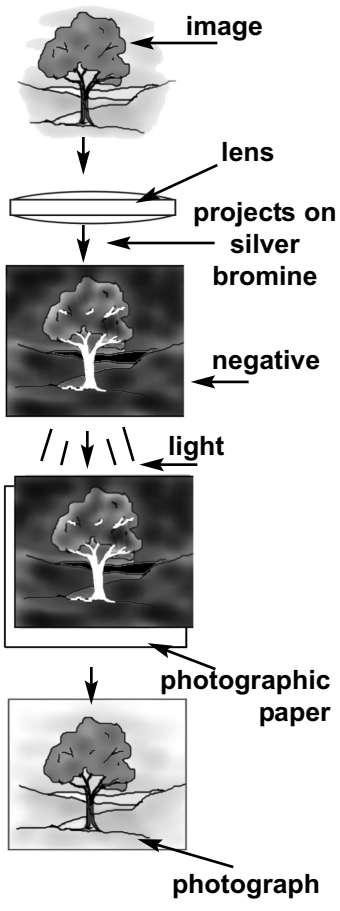
Photography is a chemical process. It was invented more than a hundred fifty years ago by two Frenchmen, Joseph Niépce and Louis Daguerre. Years earlier scientists had discovered that some chemicals turn black when exposed to light. Niépce made the first photograph. His film was a sheet of pewter, an ***alloy*** of tin, that he exposed to light for eight hours. Niépce died soon after he began working with Louis Daguerre in 1829. Daguerre experimented with a copper plate coated with silver. After six years, Daguerre developed the process that proved successful.



camera obscura

To expose the sheet of silver, Daguerre used a camera obscura, an instrument that had been in use for hundreds of years. It projected an image of a scene on a sheet of paper. Artists could then trace around the image to make a permanent record of the scene. Rather than a sheet of paper, Daguerre used a sheet of copper coated with silver. After exposure in the camera, he placed the sheet in a closed container and heated liquid mercury so it gave off fumes. The fumes condensed on the silver. Tiny beads of mercury combined with the silver in those areas struck by light. He made the image permanent by washing it in a saltwater solution.

The Daguerre process gave clear, sharp images. However, working with mercury vapors was difficult and dangerous. Mercury is a poison. Just holding mercury in one's hand can cause health problems. Breathing the fumes is even more dangerous. The second problem was that the image was one of a kind. It could not be easily duplicated.



The Englishman William Henry Fox Talbot invented a second way to take pictures. He coated a sheet of paper with a jelly-like material that contained silver bromide. Silver bromide is a compound of silver and bromine. Where light struck the paper, grains of silver formed. The grains absorbed light

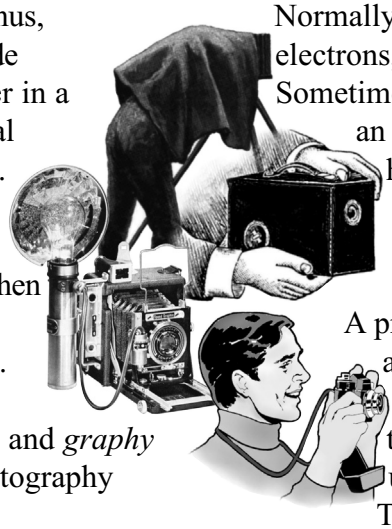
VOCABULARY

Covalent compounds: compounds made of atoms that share electrons
Diamond: a substance that is especially hard because covalent bonds arrange diamond atoms in a strong three-dimensional pyramid-like structure; diamond is made of pure carbon
Graphite: a substance that acts as a dry lubricant because covalent bonds arrange graphite atoms in sheet-like crystals; graphite is made of pure carbon
Active: a chemically active element readily reacts with other atoms to form compounds, by accepting, donating or sharing electrons with other elements to complete the arrangement of outer electrons
Inert: does not react with other atoms to form compounds; generally its atoms have a stable electron arrangement; examples include helium, neon and argon

and made the image look black. The image was a *negative*. Light and dark were reversed. Talbot placed the negative over a second sheet of photographic paper. The second sheet was exposed. The second photograph was a positive version of the original image. Talbot had discovered how to make an endless number of copies of an original photograph.

Unfortunately, the image would darken if exposed to light. Talbot had to make the image permanent in some way. He soaked the photograph in salt water to wash out the unexposed silver. However, it was inadequate; the image darkened with time.

John Herschel, son of the astronomer who discovered the planet Uranus, suggested that the image be made permanent by soaking the paper in a compound containing the metal sodium and sulfur, a nonmetal. The solution washed out the unexposed silver bromide so that the scene did not darken when exposed to light. Herschel invented the word *photography*. He formed it from two Greek words: *photo* meaning "light," and *graphy* meaning "to write." Thus, photography means *writing with light*.



The main problem with early photography was the need for long exposure. People did not want to sit still long enough for a portrait. Photographers fastened people in a special chair with an iron clamp in the back to keep their heads from moving. You have probably noticed that people in old photographs were not smiling. That was because people could not "hold" a smile for the long exposure time required in the early 1800s. Better cameras and chemical advances shortened exposure times. By the 1860s, photographers could take pictures in a fraction of a second instead of several minutes.

Photography is still a chemical process. Today, photographic film contains a compound of silver and bromine. Bromine is very similar to chlorine that is found in ordinary table salt. Normally, a silver atom has the same number of protons and electrons. Protons carry a positive charge and electrons carry a negative charge. Positive and negative charges are equal but opposite. If the number of protons equals the number of electrons, then the silver atom is electrically neutral.

Silver, however, easily loses one of its electrons. When that happens, the silver atom has more protons than electrons. The loss of the electron gives it a positive charge. It is a positive ***ion***.

Bromine is a nonmetallic element. Normally, it has as many protons as electrons, so it is electrically neutral. Sometimes the bromine atom will capture an extra electron. When that happens, the bromine atom has more electrons than protons and carries a negative charge. It is a negative ion.

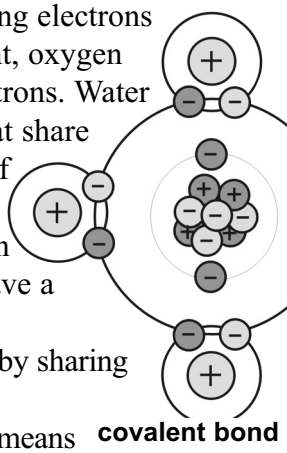
A predictable reaction happens when a positive silver ion comes near a negative bromine ion. According to the laws of static electricity, unlike charges attract one another. The positive silver ion and bromine ion attract one another. They come together and form a silver bromide molecule. When the film is developed, the silver atoms that have been exposed to light separate from the bromine atoms.

In a modern photographic color film, the silver compound is laid down in several layers. In a complicated series of steps, colored dyes are chemically attached to the silver to produce the full color image.

Giving up and accepting electrons is one way that compounds are formed. One atom gives up one or more electrons. Another atom accepts the electrons. Both atoms then become charged ions. The ions carry opposite

electric charges and attract one another. Substances formed by attraction between ions are ***ionic compounds***.

Another way for atoms to form compounds is to share electrons. Normally, oxygen has eight protons and eight electrons. Although oxygen is electrically neutral, the electrons are not in their most stable arrangement. Oxygen atoms need two electrons to become more stable. Oxygen can fill the gap in its pattern of electrons by sharing electrons. Rather than taking electrons away from another element, oxygen atoms merely borrow electrons. Water is an example of atoms that share electrons. Water is made of two hydrogen atoms sharing their electrons with one oxygen atom. They have a ***covalent bond***.


covalent bond

Substances formed by sharing electrons are ***covalent compounds***. The prefix *co* means "partner." The word *valent* is from a word meaning "power." The atoms of a covalent compound are equal partners in producing the compound.

Methane (CH_4) is an example of another covalent compound. Carbon shares electrons with four hydrogen atoms. Four hydrogen atoms are needed because each hydrogen atom has but one electron, and carbon is four electrons short of its most stable arrangement. Carbon can also share electrons with oxygen as in carbon dioxide (CO_2). Carbon shares electrons with more substances and forms more compounds than any other element.

If carbon cannot find other atoms with which to share electrons, it will share electrons with other carbon atoms. ***Diamond*** is made of carbon. Each carbon atom shares electrons with four other carbon atoms. They arrange themselves in a three-dimensional pyramid-like style. The bonds connect each atom in diamond with four other atoms. Chemical bonds among the carbon atoms are identical and equally strong. The individual carbon atoms cling together and resist being separated; thus, diamond is the hardest substance known.

Graphite is also made of carbon. Each carbon atom shares electrons with three other carbon atoms in a two-dimensional layers. Within each layer, the bonds between atoms are strong. Each carbon atom also shares an electron with an atom in one of the other layers. However, this bond is not very strong. The layers of graphite can slide over each other. It is used as a dry lubricant. Metal parts coated with graphite will slide over one another with reduced friction because of the graphite layers.

Elements that form compounds are described as chemically ***active***. Examples of chemically active elements include silver, bromine, oxygen, hydrogen and carbon. There are many others. However a few elements do not take part in chemical reactions. They have the right number of electrons, so they do not need to lose, gain or share electrons. Helium does not bond with other elements because it has no need to gain or lose electrons. For that reason, helium is chemically ***inert***.

Bryan studied the markings in the soft earth. "The tread is not the same as the ones James Olsen made. This tread is smoother. Notice the clipped heel. That design is common on hiking boots, the tall ones that you lace up."

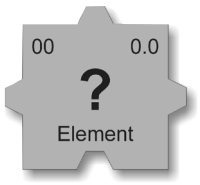
"Who could have made the boot print?" Tom asked. He reasoned, "Backpackers register at Rocky Port for a free back-country permit. I checked the list before we left, but nobody had indicated the mill as a destination."

Life Principle



"To bring out the best in yourself, bond with people of high character."

—Old Proverb



Lesson 9
Elements

Chapter 3

Alloys, Gold, Silver, Iron, Copper and Aluminum; Bronze and Iron Ages

Section 2

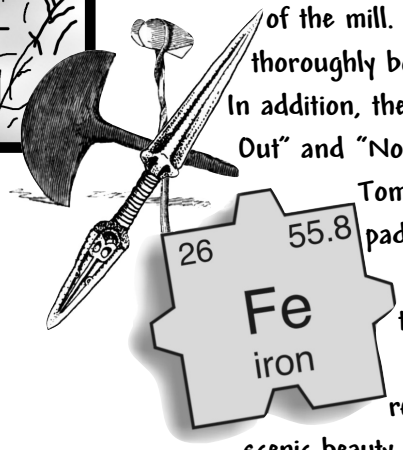
Lessons 6-10

METALS



Bryan and Tom made camp down by the mill. They pitched their tent next to a building that had served as a woodshed. The next morning they measured the size of the mill and sketched its location relative to the woodshed and repair shed. They wrote descriptions of both the inside and outside of the buildings. They noted any damage that needed repair. 1

The boys finished at the mill site and walked up the hill to the old Barnett home, which was out of sight of the mill. All of the buildings had been thoroughly boarded up and the doors locked. In addition, the buildings were posted with "Keep Out" and "No Trespassing" signs. Bryan and Tom had the keys to open the padlocks and enter the structures. 2



"Why are we doing all of this?" Tom asked. 3

Bryan said, "Most nature reserves are intended to preserve the scenic beauty as well as the plants and animals. Historic sites are saved, too. My uncle must recommend whether to keep the mill and the other buildings and estimate the cost of restoring them." 4

As they came into the clearing, Tom pointed silently to a wisp of smoke curling out of the stone fireplace chimney of the two-story Barnett home. All of the windows were shuttered except one on the second floor. The boys saw movement inside. Bryan said, "Let's knock on the door and see who answers!" 5

In addition to protecting plants and animals and preserving historic sites, national and state parks are also intended for recreation. People find that spending time in wild 6

VOCABULARY

Bronze: an alloy of copper and tin (although other metallic elements also may be present)
Alloy: a mixture of two or more metals
Stone Age: a description of a culture that depended primarily upon stone tools, such as primitive tribes
Bronze Age: a description of a culture that depended primarily upon bronze tools, cultures emerged from the Stone Age and entered the Bronze Age at different times depending on the development of their technology

areas is easier than ever before. Modern metals have greatly reduced the total weight that backpackers must carry. Backpack frames are lightweight. Mountain bikes use alloys of magnesium and other metals that are especially light and strong. Canoes have a "skin" made of lightweight aluminum. Today, metals are an important part of daily life.

7 Historians describe stages of development of a civilization by the metals people used. When scientists examine stone buildings made long ago, they may find tiny flakes of copper in the stone. That may mean the stones were shaped using copper tools.

VOCABULARY

Brass: an alloy of copper and the metal zinc; brass can be sharpened into a cutting edge that is harder than copper

Iron Age: a term applied to a culture that makes and uses iron tools and weapons; most countries in Europe had entered the Iron Age by 900 B.C.

Strata: layers of sedimentary rock (or other materials); singular is *stratum*

Charcoal: wood that has been baked in the absence of oxygen, charcoal has a higher proportion of carbon than wood and burns hotter than wood

Steel: a hard, strong mixture of iron and carbon

Luster: the surface appearance of a metal or mineral, its color and how it reflects light; shine, sheen, gloss

Metal: an element that has a shiny surface, conducts heat and electricity, and can be hammered into sheets and drawn out into wires; most metals combine with oxygen to form oxides

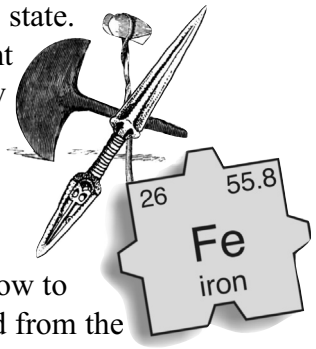
Oxide: a compound of oxygen and another element; most metals form oxides with oxygen, such as iron oxide (rust)

Corrosion: to weaken a metal by the chemical action of oxygen or acid

Ancient people also used copper for knives and weapons. Pure copper is soft. Ancient metalsmiths mixed tin with copper to produce ***bronze***. The ***alloy*** of copper and tin kept a better cutting edge. An alloy is not a compound. It is mixture of two or more metals. The alloy of copper and tin often contained other metals as well.

8 Before the invention of bronze, people used stones as cutting tools and weapons. These people lived in cultures which archaeologists call the ***Stone Age***. When people learned to make tools of copper and tin, they advanced to the ***Bronze Age***. People in Greece began using bronze tools about 3000 B.C. Another common alloy of copper is ***brass***, a mixture of copper and the metal, zinc.

9 Although bronze and brass are an improvement over copper for making cutting tools, neither one had the strength of iron. Iron can be given a sharper edge and is more durable than copper. Because it was more difficult to separate from ores, iron was seldom found in a free state. However, when ancient people discovered how to smelt iron, they produced a metal with properties superior to brass or bronze. Those cultures that learned how to make iron tools moved from the Bronze Age to the ***Iron Age***. By 900 B.C. most countries in Europe were using iron tools.



10 We normally think of iron as having a reddish or black color. However, when a bar of pure iron is cut, the revealed surface has a silvery white surface, like most other metals. However, the iron combines quickly with oxygen in the air. Iron rusts and the surface takes on a rusty-red appearance. Iron is often painted to prevent the surface from rusting.

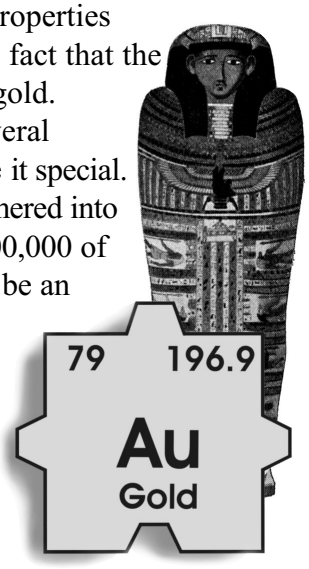
11 A 20th century discovery in Texas has brought various scientific theories about iron into question. An ancient iron hammer with a fossilized wooden handle was discovered in ***strata*** that evolutionists claim to be 140 million years old (during supposed dinosaur times and long before man). The fact that the hammer did not rust prompted laboratory tests to determine the composition, which turned out to be iron (96.6%), sulfur (.74%), chlorine (2.6%)—and no carbon—not the way iron is now produced. Further testing established that the iron could not even be duplicated under present atmospheric conditions. Evidence continues to mount, suggesting that prehistoric/ancient world conditions may have been very different from what we know, both physically and atmospherically.

12 Pure iron is a soft metal and can be beaten into various shapes. Soft iron is used to make handcrafted ornamental designs for fences as well as railing and balconies around homes.

13 Iron is removed from its ore by mixing it with ***charcoal***, which contains carbon. A blast of hot air is sent through the iron and charcoal mixture, releasing the iron from its ore. This smelting process gives *cast iron*, which contains about 4 percent carbon. Cast iron is brittle and will shatter when struck hard.

14 Ancient metalsmiths found they could reduce the carbon and make ***steel***. Steel is an alloy of iron with a small amount of carbon, usually between one half and two percent. In the case of the "prehistoric" iron hammer head, no carbon was detected in the laboratory tests.

15 Almost every element has some property that sets it apart from others. Suppose an element is yellow in color. It has a metallic ***luster*** and can be beaten into sheets. It is dense. A sample of the ***metal*** is 19 times heavier than an equal volume of water. All of these properties point strongly to the fact that the mystery element is gold.



16 Gold has several properties that make it special. It can be easily hammered into sheets so thin that 200,000 of them are required to be an inch thick. An ounce of gold can be stretched out and fashioned into wire more than 60 miles long.

17 People have always been attracted to the luster of gold. It has a beautiful yellow color that does not tarnish with age and resists the action of heat and moisture. Gold was hammered into sheets to cover the coffins of the ancient Pharaohs. The gold covering is as beautiful today as when it was first made 5,000 years ago. Because gold is inert and does not combine easily with other elements, gold is often found free in nature.

18 The main use of gold is in coins and jewelry. Pure gold is soft and would wear away with daily use. Other metals such as silver or copper are mixed with gold to make coins and jewelry harder and to resist wear. When used in coins, the mixture is 90 parts gold by weight and 10 parts silver by weight. The yellow "gold" that is used for jewelry is only about half gold, with equal amounts of silver and copper composing the remainder of the alloy.

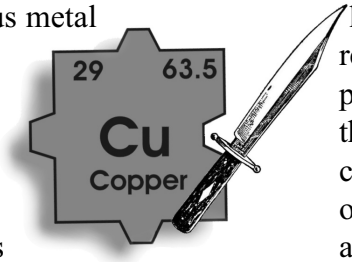
19 Today, gold is plated onto the contacts that connect electronic equipment. Other elements are better conductors of electricity than gold. It, however, does not tarnish, therefore, the electrical connection is better with gold contacts.

20 Silver has a brilliant white color. Like gold, silver can be hammered into sheets and stretched into thin wires. Although, it resists combining with oxygen in the air, silver will

react with sulfur and will tarnish. Silver is the best conductor of electricity known and therefore is the champion for conducting heat. Silver is harder than gold but softer than copper. Silver is made more durable by mixing it with copper .

21 Both silver and gold are precious metals because they are rare and are used to make coins and jewelry. Silver is not as expensive as gold. An ounce of gold is usually worth more than the same amount of silver.

22 Another precious metal is copper, but copper is far more common and less expensive than either silver or gold. For centuries, copper was used to make coins of low value. Copper is a good conductor of electricity and heat. Copper is used in wires to conduct electricity and on the bottoms of pans to conduct heat. Gold and copper are the only metals that do not have a silvery luster.

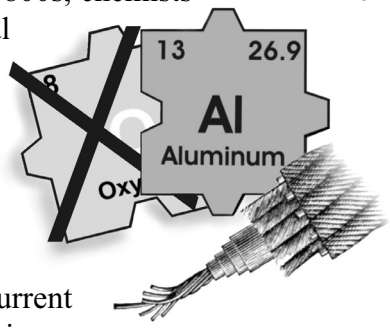


23 Several other metals were known to ancient people. In addition to gold, silver, copper, and iron, ancient people knew of lead, tin and mercury. Mercury is the only metal that is a liquid at room temperature. However, ancient scientists correctly listed it as a metal because it had a shiny surface, it was heavy like silver and lead, and it was usually found in the same ores.

24 Not all metals are dense like gold, silver or lead. Aluminum, for instance, is only about 2.7 times as heavy as an equal volume of water.

25 Aluminum is not as rare as most other metals. About eight percent of the Earth's surface is aluminum by weight. Only oxygen (at 46.6 percent) and silicon (at 27.7 percent) are more common. Aluminum is in even greater concentration in its ore, bauxite. However, removing aluminum from bauxite is not easy. Bauxite is a combination of aluminum and oxygen. Many metals can be refined from their ores by heating them with charcoal. Others can be freed with acids. However, these methods could not separate aluminum from oxygen in bauxite.

26 In the early 1800s, chemists learned that chemical bonds involve electrons. With the discovery of electricity, chemists had a new tool for refining metals. By passing an electric current through molten aluminum ore, chemists were able to pry aluminum from oxygen. At first, aluminum was as expensive as gold. However, as chemists learned better ways to produce it, the price of aluminum dropped.



27 Today, aluminum is inexpensive. It is lightweight and resists the effects of air and water (including seawater) and is a favorite building material. Like many metals, aluminum combines with oxygen in the air. However, the layer of aluminum ***oxide*** does not flake off and protects the aluminum underneath from further ***corrosion***. Currently, aluminum is the second most common construction metal. Iron is first. Aluminum does not conduct electricity quite as well as copper, but aluminum wires can be made thicker so that it does as well. Because it is lightweight and low cost, aluminum wires are not as heavy as copper and do not cost as much. Most cross-country high-voltage electrical transmission lines conduct electricity by means of aluminum wires.

28 As soon as the boys stepped on the porch, they heard a clatter of someone running down the stairs. Rather than coming toward the front door, the person making the noise headed for the back door.

29 The boys ran to the back of the house. A man was already running down the trail. Bryan saw that the fugitive wore tall hiking boots and had a long flowing beard. He wore a seaman's cap and bright, white canvas trousers and shirt. As he turned to glance at the boys, he clutched a cardboard box tightly to his chest. The container looked like an overstuffed shoebox.

30 "Stop! Wait!" Bryan called. But, the man bolted away, then scrambled up a rocky ledge. The boys followed, but the man outran them and disappeared into the woods.

Life Principle



"Progress consists largely of learning to apply laws and truths that have always existed."

—John Allan May

Lesson 10
Elements

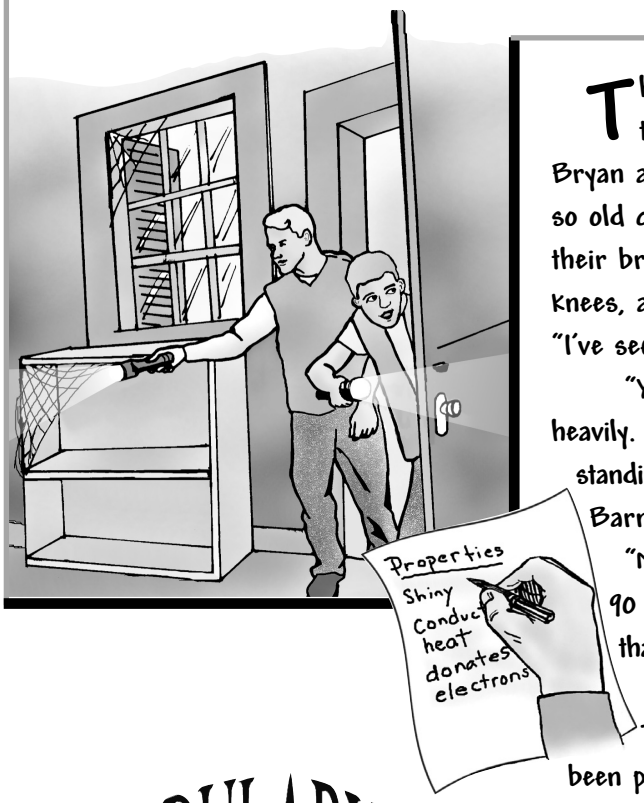
Chapter 3

Periodic Table, Chemical Families, Nonmetals, Noble Gases, pH, and Acids

Section 2

Lessons 6-10

FAMILIES OF ELEMENTS



The bearded man carrying the shoebox climbed the ridge and disappeared quickly into the woods. Bryan and Tom were amazed that a person who looked so old could be so nimble. The boys stopped to catch their breaths. Tom bent over, put his hands on his knees, and drew in deep breaths of air. Tom huffed, "I've seen him before!" 1

"Yes!" Bryan agreed. He was also breathing heavily. "We saw his photograph at the lodge. He was standing by the mill in those identical clothes! It's Mr. Barnett!" 2

"Not possible!" Tom declared, "—He's supposed to be 90 years old!— Unless the secret of Danger Island is that it has a fountain of youth!" 3

Bryan and Tom walked back to the house. The hasp holding the lock on the back door had been pried off. The boys used flashlights to explore the building. Most of the rooms were empty, although an old, iron wood-burning kitchen stove had been left behind. 4

The boys carefully examined the small upstairs bedroom where the shutters had been opened. An empty bookcase stood along one low wall. A small metal bed frame without mattress occupied the other wall. 5

Bryan was pensive. "This looks like a room for a young boy. Maybe the man we chased was not Mr. Barnett. We judged his identity by the clothes and the fact that he looked like the man in the photograph. Suppose a boy once lived in this room. He could have grown up, moved away and then returned to retrieve the shoebox because it contained family momentos!" 6

Tom nodded thoughtfully. "If he were Mr. Barnett's son or grandson, that would explain the family resemblance." 7

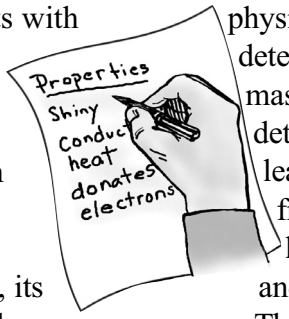
VOCABULARY

Nonmetals: elements that accept electrons during chemical reactions; most nonmetals have dull surfaces, conduct heat and electricity poorly and are brittle (or they are gases)

Noble gases: a family of elements that include helium, argon and neon that are chemically inert because their electrons are in the most stable arrangement

8 Just as members of the same family often have similar physical appearances, so do members of chemical families. Chemists have found 92 naturally occurring elements. The elements can combine to produce millions of compounds. As the number of elements and compounds increased, chemists looked for ways to simplify the information they knew about the elements. To make their task easier, they grouped together elements with simpler properties into chemical families.

9 Elements are described by their physical and chemical properties. When chemists discovered a new substance, they described it first based on the senses: its color, its touch, its dryness, its smoothness and whether it was a solid, liquid or gas. It was stretched and beaten into sheets to determine whether it would withstand pressure or bending.



10 Chemists who lived years ago would taste chemicals to determine whether they were bitter, sweet, salty or sour. Chemists would sniff to determine a chemical's odor. Chemists today are far more cautious about tasting or inhaling the dangerous fumes of chemicals.

11 Chemists also checked the physical properties of a new substance to determine the density of the material, its mass per cubic centimeter. Scientists determined whether it was heavy like lead or light like wood, its boiling or freezing temperatures, its solvency or how well it conducted electricity and heat.

12 They would also put an element through a series of chemical tests to determine whether the substance was highly active or inert. Tests also determined whether the chemical would combine with oxygen. Chemists wanted to learn whether the substance would form acids, bases or salts.

13 One way to group substances is by whether they are metals or ***nonmetals***. A nonmetal has the opposite properties of a metal. Nonmetals generally do not have shiny surfaces, they conduct heat and electricity poorly and they are brittle. A metal such as gold can be beaten into sheets. A nonmetal such as iodine shatters when struck. All of the metals except mercury are solids at room temperature. About half of the nonmetals are solids, one is a liquid and 10 are gases. The gases are nitrogen, oxygen, fluorine, chlorine and the ***noble gases***—helium, neon, argon, krypton, xenon and radon.

14 Of the 92 naturally occurring elements, 21 are nonmetals. The rest are metals. Many of the metals have very similar properties. Many are found together in the same ore and are often difficult to separate from one another because of their similar chemical properties.

VOCABULARY

Periodic Table of the Elements: an arrangement of the elements based on their chemical properties; in most charts those elements in an up-and-down column have similar chemical properties and are called *chemical families*; chemical properties change in a regular way going across the rows, (called *periods*); on most charts, metals are on the left and nonmetals are on the right

Chemical families: vertical columns on the Periodic Table of the Elements; members of a chemical family have similar chemical properties; the number of electrons in the outer shell is the same for all members of each chemical family

Acids: have a sour taste and will corrode metal; turn blue litmus to red

pH meter: an electrical device that measures the concentration of hydrogen ions to determine the acid content of a solution

Litmus: a chemical dye that changes color from blue to red when immersed in an acid

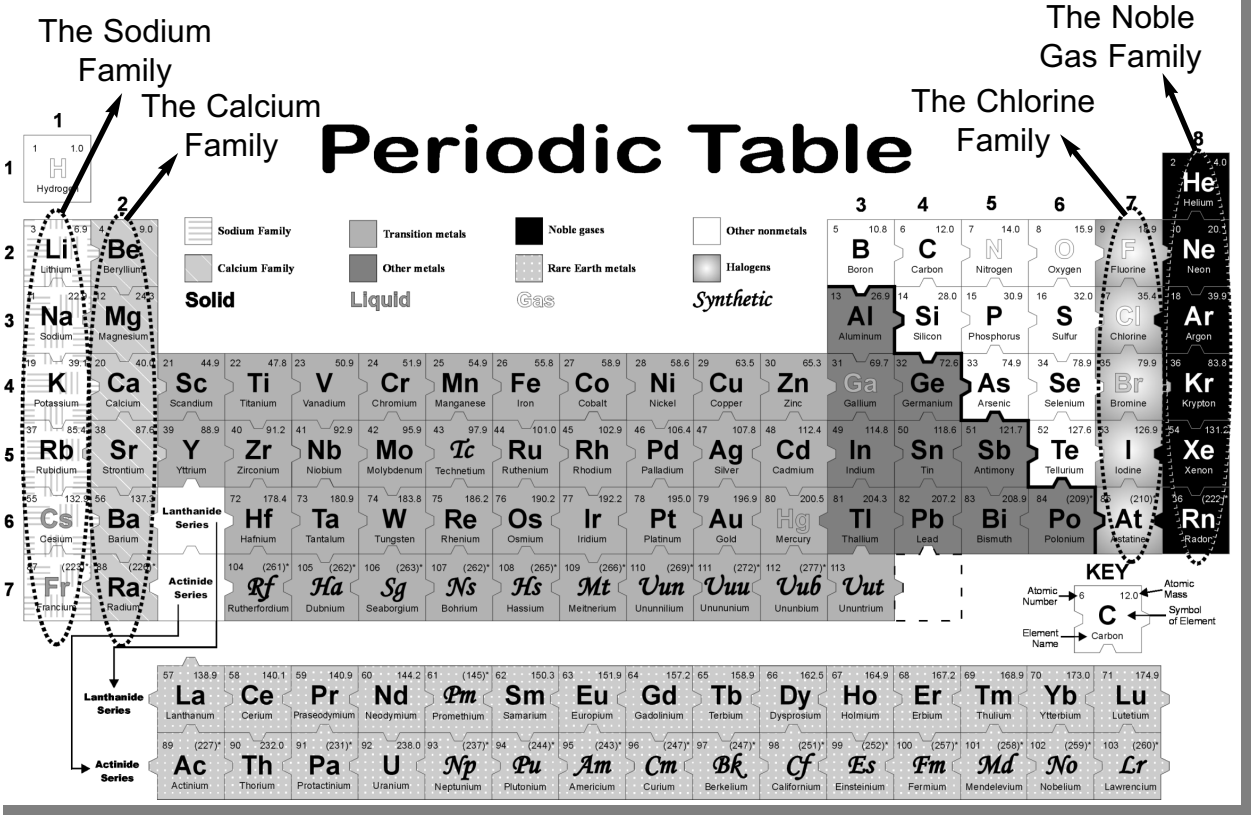
15 Although physical properties are a good guide for detecting a metal from a nonmetal, chemists have another test. If the element donates electrons during chemical reactions, then it is a metal. If it accepts electrons during chemical reactions, then it is a nonmetal.

16 Today, chemists have a powerful way for understanding chemical reactions. They refer to the ***Periodic Table of the Elements***. This arrangement was prepared about 150 years ago by the Russian chemist, Dmitri Mendeleev. Only about 60 elements were known when Mendeleev made the table. Since then the rest of the 92 naturally occurring elements have been discovered. In addition, elements with an atomic number greater than 92 have been produced during nuclear reactions. They have been inserted in the Periodic Table in their proper places.

17 The Periodic Table groups elements together vertically in ***chemical families*** with similar chemical properties. For instance, lithium, sodium and potassium have many similar chemical and physical properties. All three are metals. They are shiny and good conductors of heat and electricity. They are solid at room temperature and can be hammered into thin sheets. They combine with oxygen in the ratio of two to one.

18 Chemists learned that the sodium family of elements has one extra electron in the outer electron shell. Lithium, sodium and potassium easily give up that electron to form ionic compounds. Other members of the sodium family include rubidium, cesium and francium. On a Periodic Table of the Elements, the sodium family is in the first column on the left. (See chart below.)

19 Fluorine, chlorine, bromine and iodine are nonmetals. They have similar chemical properties, including being highly active. All three are nonmetals. They form brittle crystals and are poor conductors of heat and electricity. Fluorine and chlorine are gases at room temperature. Bromine is a liquid at room temperature. Other members of the chlorine family include iodine and astatine.



20 Chlorine, bromine and the other members of the family readily accept electrons to form ionic compounds with the metals. The reason became clear when chemists learned that each element of the chlorine family has a single gap in its outer electron shell. Each element readily accepts an electron to fill that gap. On a Periodic Table of the Elements, the chlorine family is in the next to last column on the right.

21 The far right column of the Periodic Table lists the noble gases. These elements include helium, neon and argon. All are gases at room temperature. None of them form compounds. The noble gases have no need to donate, accept or share electrons because their electrons are already in the most stable arrangement. Other members of the noble gas family include krypton, xenon and radon.

22 One of the real advantages of the Periodic Table of the Elements is that it can be used to predict how compounds will form. For example, sodium will react with chlorine to give sodium chloride, which is ordinary table salt. The reaction requires one atom of sodium for each atom of chlorine. Lithium is in the same family a sodium. The periodic table predicts that lithium will also react with chlorine to produce lithium chloride. Lithium chloride will require one atom of lithium for each atom of chlorine.

23 In most formats of the Periodic Table of the Elements, hydrogen is above sodium and lithium. Most charts show hydrogen in a box detached from the others. This is an indication that hydrogen has unique properties that set it apart from the other elements.

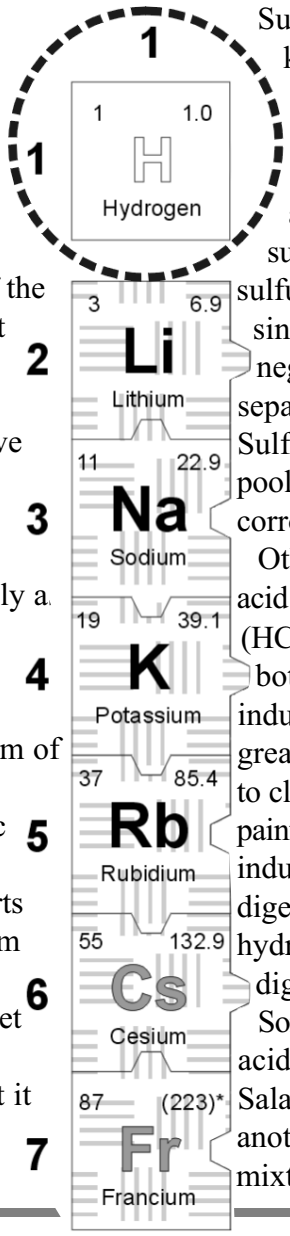
24 Hydrogen has an electron that it will donate or share during chemical reactions. However, hydrogen is the simplest atom and has only one proton and one electron. When it loses that electron, hydrogen becomes a single proton. The hydrogen ion, shown as H^+, cannot stay free for long. It readily attaches itself to other elements to produce compounds.

25 ***Acids*** are compounds that always contain hydrogen. Not all compounds that have hydrogen are acids, but all acids do have hydrogen. Acids have a sour taste and will corrode metals. Suppose an iron nail is dropped into a container of sulfuric acid. Pits will appear on the surface of the nail as it corrodes. Hydrogen gas will bubble to the surface.

26 Sulfuric acid is probably the best known acid. It is, however, very dangerous to use. Its chemical formula is H_2SO_4. It is made of two hydrogen atoms, one sulfur atom and four oxygen atoms. When sulfuric acid is mixed with water, the sulfur and oxygen stay together as a single group of atoms with a double negative charge. The hydrogen atoms separate as individual hydrogen ions. Sulfuric acid is used to clean swimming pools, cement products and other non-corrosive materials.

27 Other important acids include nitric acid (HNO_3) and hydrochloric acid (HCl). Acids find numerous uses in both manufacturing and the chemical industry. Most acids will dissolve grease. Metal parts are treated with acid to clean the surface so they can be painted. In addition to their use in the industry, acids are important to the digestive process of humans. Mild hydrochloric acid in the stomach helps digest food.

28 Some acids give drinks their taste. Citric acid gives lemonade its sour taste. Salad dressings contain vinegar, another acid. However, tasting a liquid mixture to detect an acid is dangerous.



Chemists use a ***pH meter*** to detect hydrogen ions and measure the strength of the acid. Another way to test for an acid is to use an indicator dye that changes color when exposed to hydrogen ions. One common indicator is ***litmus***. It is a complex chemical extracted from lichens. Blue litmus paper turns red when put into an acid.

29 "Where was the shoebox hidden?" Bryan wondered. They tapped on the boards and looked for a loose one. Success came when Tom pulled out a loose board in the closet. He said, "Look!" "This space is just large enough to hide a shoebox!" Pressed against one corner was a photograph that apparently had fallen from the box. The photo showed a man standing by the mill. He looked very much as he had in the photograph at the lodge. However, in this photograph he had his hands on the shoulders of a small boy who stood in front of him.

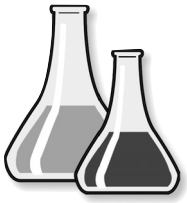
30 Bryan turned the photograph over. Triumphantly, he read, "Papa Ed Barnett and grandson Jory!"

Life Principle



"A person is known and evaluated by his family name and by the company he keeps."

—Old proverb



Lesson 11
Compounds

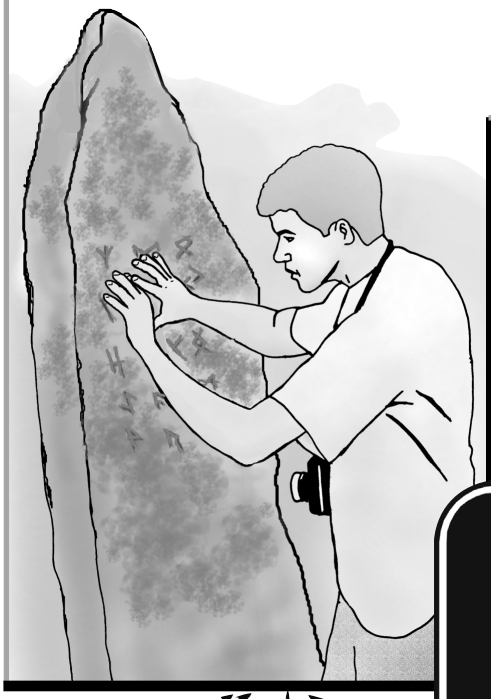
Chapter 3

Characteristics of Strong and Weak Acids and Bases; Salt and Chemical Formulas

Section 3

Lessons 11-15

ACIDS, BASES AND SALTS





Bryan had taken a large number of photographs of the buildings at the mill. Tom asked, "Do we still have enough exposures left for the mystery town on Shell Island?" 1

Bryan looked at the counter on the camera. "This is my last roll, but I have five shots left. That should be plenty! Let's hike to the Ridge Trail and tie our packs out of the reach of bears. Then, without the weight of the packs to slow us, we can double-time to the bluff. We'll retrieve our packs on the way back." 2

When they arrived at the Ridge Trail, Bryan suggested they find a spot at least a hundred feet from the trail for their packs. Bryan explained, "I wouldn't want James Olsen to find them." 3

Tom got out the rope and tossed it over a limb several feet above the ground. He grumbled at the extra effort. "I thought those cans your uncle gave us were bear proof." Ranger Eldridge had given each boy a large canister with a screw-off top to store his food. Each canister was about eight inches in diameter and a foot long. All of the food fit inside. 4

Bryan said, "The canisters eliminate odor and are bear proof. But the bears will go after the packs anyway unless we put them out of reach." 5

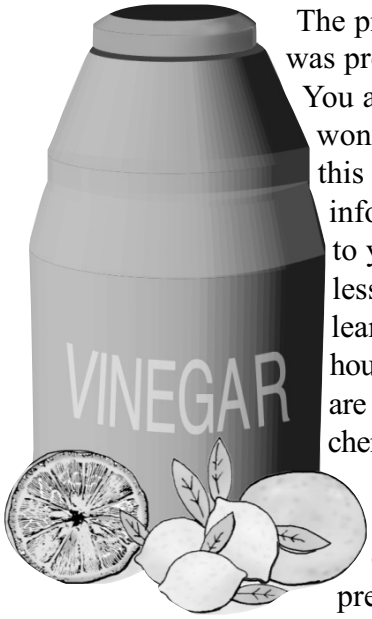
Tom opened his food canister for a snack before raising his pack. He found an orange and pulled it into sections to eat. He stuffed the big can back into his pack. As Tom raised the pack, the canister fell out and clattered down the side of the 6

VOCABULARY

Weak acid: an acid that is a poor source of hydrogen ions
Strong acid: an acid containing molecules which readily separate in water and release an abundant supply of hydrogen ions
Antacid: a base that is taken internally to work against and neutralize the acid content in the stomach
Base: a chemical that has the opposite properties of an acid; a base releases hydroxide ions into water; a base feels slippery to the touch, tastes bitter, and turns red litmus paper blue

rocky ridge. Tom chased after it. He began working his way down the steep slope. At the base, Tom called out, "It fell into a deep, narrow ravine!"

7 A few minutes later, Tom's excited voice came up muffled from the ravine. "Bryan, climb down here!" Tom insisted, "You have to see this!"

8 

The previous lesson was pretty complex. You are perhaps wondering how all this complex information relates to you. In this lesson you will learn how everyday household products are the results of chemistry.

9 The sour taste of the orange is caused by the presence of *citric acid* that is found in oranges and other citrus fruits. Although often sweet, citrus fruits have a tart, sour, acidic taste. Other examples of citrus fruits include the lemon, lime, grapefruit and tangerine.

10 From a chemical point of view, the primary property of an acid is that it is a source of hydrogen ions. When an acid mixes with water, the acid molecule comes apart and releases hydrogen ions into the solution. The hydrogen ion is a hydrogen atom that has lost its electron. This gives the hydrogen atom a positive charge. Chemists show a hydrogen ion as H^+. The superscript plus sign (+) shows that it has a positive charge.

11 The acid in citrus fruits is a ***weak acid***. A weak acid is one that provides only a small number of hydrogen ions when it is dissolved in water. Another common weak acid is *acetic acid* that gives vinegar its sour taste. Both are weak acids, because only about two molecules in one hundred come apart in water and release hydrogen ions.

12 The acid used in the greatest amounts in the United States is *sulfuric acid* (H_2SO_4). When mixed with water, it comes apart and gives 2 hydrogen ions, H^+, and one sulfate group with a double negative charge, SO_4^-. Sulfuric acid is a ***strong acid*** because it is a good source of hydrogen ions. Almost all of the sulfuric acid molecules come apart in water and each one gives up two hydrogen ions.

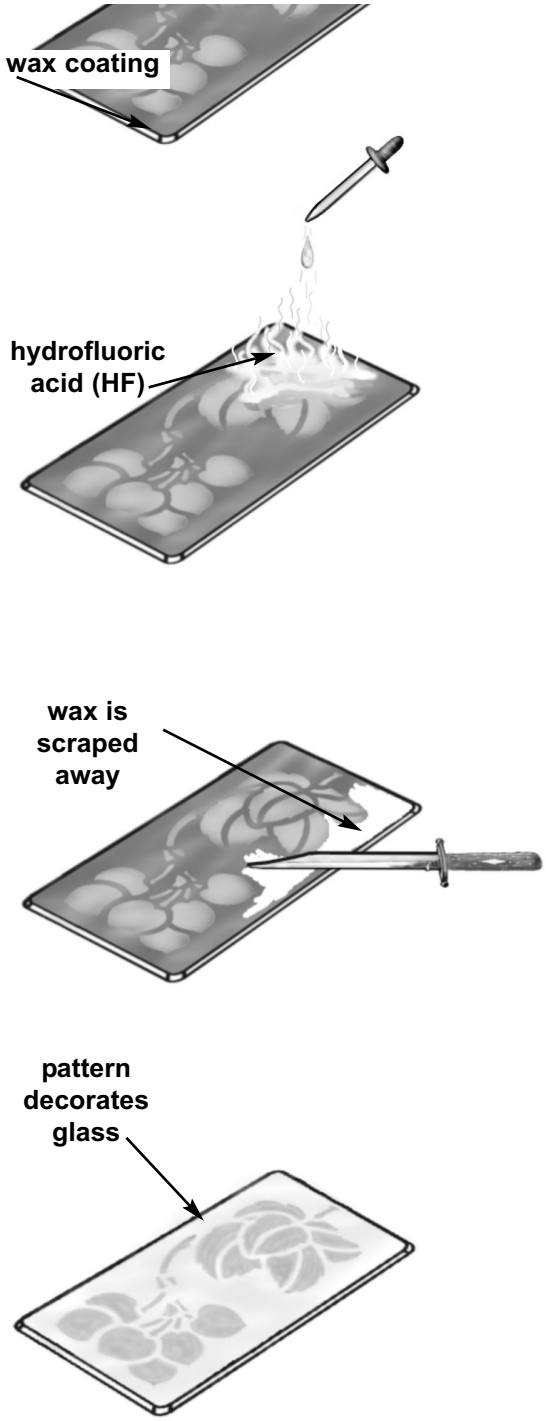
VOCABULARY

Hydroxide ion: the ion (OH-) with a single negative charge that is made of one oxygen and one hydrogen atom
Neutralize: to counterbalance opposing effects, an acid and base neutralize one another by removing the hydrogen and hydroxide ions from solution
Strong base: a base containing molecules that readily separate in water and release a large number of hydroxide ions
Caustic: capable of destroying plant and animal tissue
Weak base: a base that is a poor source of hydroxide ions
Salt: formed by the reaction of an acid with a base



13 Sulfuric acid is found in automobile batteries and in fertilizers, paints and explosives. Despite being a very beneficial chemical, sulfuric acid has to be treated with care. The positively charged hydrogen ions released by sulfuric acid have a very strong attraction for other atoms, including those in human flesh.

Process for Etching Glass



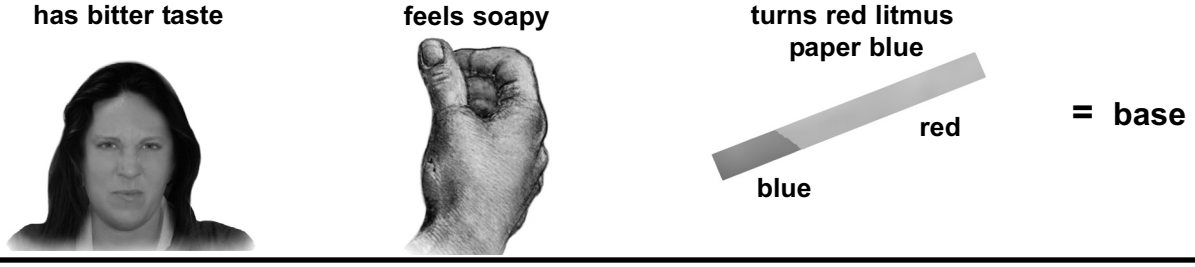
14 Suppose you accidentally spilled sulfuric acid on your skin. The hydrogen ions would seek out atoms with which to combine to regain the lost electron. It would tear oxygen atoms away from the compounds that make up your flesh. Your skin would char as if physically burned. You would experience a *chemical* burn.

15 One way to treat an acid spill on human skin is immediately to rinse it with large amounts of water. The water provides oxygen that hydrogen ions need. The hydrogen ions react with the water rather than removing oxygen from compounds in the skin.

16 *Hydrofluoric acid* is another strong acid. It contains hydrogen and fluorine, a member of the chlorine family. The formula for hydrofluoric acid is *HF*. It is used for etching glass. Glass is coated with a wax that resists the acid. Then the wax is scraped away from the pattern to be etched. The acid eats a pattern into the area where the glass is not protected by wax.

17 An acid, whether strong or weak, removes grease, will corrode metal and turns blue litmus paper red. Strong acids such as sulfuric and hydrofluoric acid must be handled with care. Weaker acids, however, are found in many foods. In addition to citric acid in citrus fruits, weak acids are also found in meat, tea, coffee, and juices like tomato juice. Foods containing acids would be too dangerous to consume if the acid content were any stronger. Even weak acids can cause an upset stomach in a person who consumes too much acidic food. Those who suffer from an acid stomach may take an ***antacid*** to reduce the discomfort. An antacid contains a ***base***, which combines with the hydrogen ions released by the acid.

Characteristics of a Base



18 A base is the opposite of an acid. A base has a bitter taste, feels soapy, and turns red litmus paper blue. The chemical definition of a base is that it removes hydrogen ions from a solution to neutralize acids.

19 Like sulfuric acid, ammonia (NH_3), is in the top ten most common chemical substances produced in the United States. Ammonia is combined with water to give ammonium hydroxide, a base. Ammonium hydroxide with water is sold as Ammonia, a household cleaner for floors and windows.

20 Although ammonium hydroxide contains hydrogen, it is a base and not an acid. An acid must contain hydrogen, but a substance can contain hydrogen without being an acid. When ammonia is mixed with water, it produces ***hydroxide ions*** (OH^-). Hydroxide is oxygen and hydrogen paired together with a negative charge. The minus sign (–) shows that the oxygen and hydrogen combination has a single negative charge.

21 The hydroxide ion from ammonium hydroxide base (OH^-) has a negative charge. When mixed with an acid, the hydroxide ion (OH^-) joins the hydrogen ion (H^+), and they ***neutralize*** one another. The result is water, $H^+ + OH^- \rightarrow H_2O$.

22 A ***strong base*** is a good source of hydroxide ions. *Ammonium hydroxide* is a strong base. In concentrated form, ammonium hydroxide can cause burns to the skin. The ordinary household cleaner known as *ammonia* is dilute ammonium hydroxide. The dilute cleaning solution has a very powerful, pungent odor. The fumes can burn your eyes. Even in the dilute form, it is very strong and must be kept out of the reach of children.

23 Another common base is *sodium hydroxide* (NaOH), also known as *lye*. The symbol for sodium is Na. The letter *S* cannot be used because it is taken by sulfur. Na as the symbol for sodium is from *natron*, a French word for one of sodium's compounds. Sodium hydroxide is used in the manufacture of soap and as a drain cleaner.

24 Like strong acids, strong bases are ***caustic***. They are highly destructive to animal and vegetable tissue. They attack oils, greases and fats but are not as damaging as acids to metal pipes. For that reason, a sodium hydroxide product such as *Draino* is used as a cleaner for sink and shower drains. The caustic action of the base destroys greases, hair or other plant and animal matter that may clog a drain.

25 Both ammonium hydroxide and sodium hydroxide are far too strong to be used as antacids. Instead, a weak base is used. A ***weak base*** is one that does not release as many hydroxide ions into solution. *Sodium bicarbonate* ($NaHCO_3$), commonly called "Baking Soda," is a base that is a common antacid. It is does not come apart as readily in water, and when it does, it generates fewer OH^- ions. When used as an antacid to treat an upset stomach, sodium bicarbonate provides hydroxide ions to neutralize the hydrogen ions.

26 Bases and acids contain atoms other than the hydrogen ions and hydroxide ions. For instance, hydrochloric acid contains

hydrogen and chlorine (HCl). When hydrochloric acid dissolves in water, the molecules separate and hydrogen becomes a positive hydrogen ion (H^+). The chlorine then becomes a negative chlorine ion (Cl^-).

27 Ions are also made of the atoms that compose a base. When sodium hydroxide (NaOH) dissolves in water, the molecules separate. Oxygen and hydrogen form the negative hydroxide ion (OH^-). The sodium then becomes a positive sodium ion (Na^+).

28 When an acid and base neutralize one another, the hydrogen ion (H^+) and hydroxide ion (OH^-) come together to produce water (H_2O). The other atoms then form a compound. In the case of hydrochloric acid and sodium hydroxide, the sodium ion (Na^+), and chlorine ion (Cl^-) come together to form sodium chloride (NaCl), or table ***salt***. This reaction can be written as a chemical equation:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

29 Notice that all of the elements on the left side of the arrow (—›) also appear in the same numbers on the right side. However, they have been rearranged.

30 A similar reaction occurs when other acids and bases are combined. The result is a salt and water. Chemists summarize this with the equation:

$$acid + base \rightarrow salt + water$$

31 Ordinary table salt, sodium chlorine, is essential to the human diet. It is also sprinkled on food to enhance flavor. During ancient Roman times salt was more valuable than it is today, because it was not readily available. Roman soldiers received part of their pay in salt. The expression "he is worth his salt" dates from Roman times. The word *salary* comes from the Roman word for *salt*. Other salts include Epsom salts for soaking feet to reduce swelling and a variety of salts spread on highways during winter to melt snow and ice.

32 Bryan found the ravine deeper than he expected. The bottom was shaded. The mossy face of a huge slab of stone stood against a large oak tree. An overhanging cliff protected most of the ravine floor. Tom was standing in the gloom and running his fingers across the flat stone.

33 "What is it?" Bryan asked.

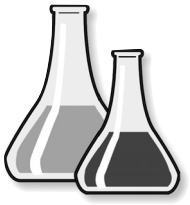
Tom said, "See—here—they are nearly invisible. You have to look closely. Ancient pictures are carved in the stone!"

Life Principle



"Wise people strive to be efficient and 'worth their salt.'"

—Anonymous



Lesson 12
Compounds

Chapter 3

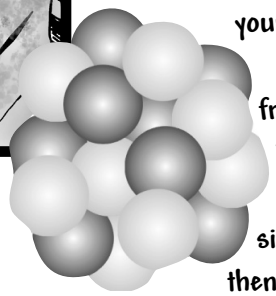
Chemical Reactions, Atomic Weight, Isotopes and Models

Section 3

Lessons 11-15

ATOMIC SCIENCE





VOCABULARY

Chemical reaction: a change in the number or arrangement of electrons of an atom
Atomic weight or ***atomic mass:*** the weight of the atoms of an element compared to carbon-12; atomic weight is approximately equal to the total number of protons and neutrons; expressed as a decimal on the Periodic Table of the Elements
Isotopes: two atoms with the same number of protons but differing numbers of neutrons; isotopes have the same atomic number but different atomic weights (or mass)

After Bryan saw the first designs carved in the stone, he noticed several others in a straight line across the stone. The figures were about shoulder high, at what seemed a comfortable height for a person to carve. "Are they pictures or letters?" he wondered. 1

Tom traced around one of the designs and said, "Either way, they are ancient! This is hard stone. Yet, the edges of the carving are smooth and rounded by weathering. These are old, old, old! Does your map show them?" 2

Bryan's map of the island was from the United States Geological Survey. The map included a wealth of information and identified prehistoric sites. Bryan studied the map carefully, then reported "It does not show any petroglyphs or pictographs in this area." Bryan continued, "Such information is probably known to the authorities, but they don't publicize it so vandals or treasure hunters will not ruin the rock drawings." 3

Tom doubted that anyone knew of the stone writings. "This ravine is deep in shadow and well-hidden from sight. Normally, sunlight does not penetrate down here. I saw the markings only because the light was just right. A few minutes earlier or a few minutes later and they would have blended in with the moss. What should we do? Can you take a picture?" 4

Bryan said, "The light is really dim. I'll take one shot of it. You make a record of the drawings. We can ask my uncle what he knows about it." 5

The rock drawings were faint and difficult to see. The boys were not certain if the marks were letters or figures. About 6

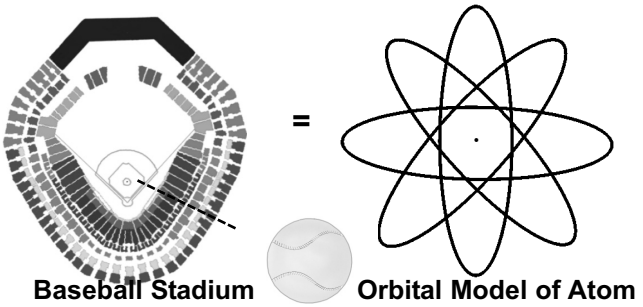
one hundred years ago, chemists were in a similar state of uncertainty about the atom. Chemists agreed that all matter was made of tiny atoms that could not be destroyed by ordinary chemical reactions. Although they agreed that matter was made of atoms, they could not decide on a model, or picture, of the atom. The reason agreement could not (and still cannot) be reached was/is because no one has ever actually seen an atom. Neither can we see the wind; but we know it is there because we see what it does.

7 Scientists knew that the atom contained electrons and protons. Later, they discovered that the atom also contained neutrons. Scientists disagreed over organization of electrons, protons and neutrons in the atom. Most chemists pictured the atom as negative electrons and positive protons mixed together as a solid sphere, called a spherical or "plum pudding" model.

8 Chemists knew that electrons separated during chemical reactions, but protons did not separate in chemical reactions. This was a clue that the electrons were somehow on the outside of the atom but the protons were located deeper in the atom. Additional experiments showed that high-speed, subatomic particles passed through most atoms as if they were empty space. The particles seldom struck anything except electrons, which were so light they were brushed aside.

9 Chemists began to portray the orbits of the electrons as if the nucleus were the Sun and the electrons were the planets. These are known as planetary models, with either circular or elliptical orbits. Soon, scientists realized that the pattern of the electrons around the nucleus was far more complex. Some electrons do travel in circular orbits. Other orbits resemble patterns that look like dumbbells and four leaf clovers. In addition, the exact location of an electron at any one moment cannot be predicted with certainty.

10 Chemists developed an improved model of the atom, called an *orbital model*. They pictured the atom as made of a very small, dense central core called the nucleus. The nucleus contained protons with a positive charge and neutrons with no charge. Electrons with a negative charge orbited far outside the nucleus. If an atom could be enlarged to the size of a baseball stadium, the nucleus would be about the size of a baseball. The electrons would be flying around the nucleus at a distance as far out as the bleachers.



Baseball Stadium **Orbital Model of Atom**

Most of the atom is empty space, which explains why particles could fly through the atom without hitting anything.

11 The paths of electrons change when they absorb energy. The energy can be due to the atom being struck by light or other electromagnetic waves such as heat or X-rays.

VOCABULARY

Radioactive decay: the sudden and unpredictable breakdown of an atom; the atom emits subatomic particles and separates into smaller atoms

Nuclear reaction: a change in the nucleus of an atom such as its composition or structure; nuclear reactions are sometimes called atomic reactions

Breeder reactors: nuclear reactors that generate more nuclear fuel than they use; most breeder reactors convert the relatively stable uranium-238 into highly radioactive plutonium (plutonium can be used as a nuclear fuel and in nuclear weapons)

Although each electron has a specific orbit and definite energy state, knowing the exact location of a particular electron at a specific time is impossible. Scientists speak of the electrons as forming a cloud around the nucleus. Picturing the electrons as forming a cloud emphasizes the fact that the exact location and energy content of an electron is not known.

12 A ***chemical reaction*** changes how electrons are arranged around an atom. Electrons have the primary role in chemical reactions. The number of electrons that atoms possess, or how the atom shares its electrons, changes when the atom bonds with other atoms.

13 The number of protons does not change during chemical reactions. Protons are in the nucleus deep in the atom where they are unaffected by chemical activity. This is the reason the early chemist could not make gold from a cheaper metal. Lead is element number 82. It has 82 protons in its nucleus. Gold is element number 79. It has 79 protons in its nucleus. To change lead to gold requires that 3 protons be removed from the lead nucleus. This is not possible with ordinary chemical reactions.

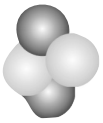
14 The nucleus also contains neutrons. A neutron has about the same mass as a proton but it does not carry a charge. It is neutral. The neutron explains why atoms have more mass than can be explained by the protons alone. For instance, a helium atom has two protons. It also has two neutrons. Overall, it has a mass (weight) of four. An oxygen atom has 8 protons but it has a mass (weight) of 16. It has 8 neutrons. The mass (weight) of the protons combined with the neutrons gives the total mass of 16.

15 Atoms of the same element can vary in the number of neutrons they possess. For instance, some carbon atoms have 6 protons and 6 neutrons. Other carbon atoms have 6 protons and 8 neutrons.

16 ***Atomic weight*** (or ***atomic mass***) is the combined total of protons and neutrons. *Carbon-12* has six protons and six neutrons. Its atomic weight is 12. *Carbon-14* has six protons and eight neutrons. Its atomic weight is 14. *Carbon-14* is often used by scientists who attempt to assign dates to ancient civilizations or animal remains. *Uranium-238* has an atomic weight of 238 because the total number of its 92 protons and 146 neutrons is 238.

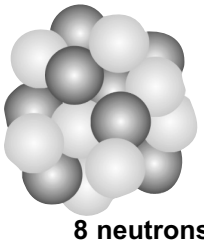
17 ***Isotopes*** are atoms with the same number of protons but a different number of neutrons. The word *isotope* is made of *iso* meaning "same" and *tope* meaning "step" or "place." Two isotopes are both given the same location in the Periodic Table of the

Atomic mass/weight = combined total of protons and neutrons



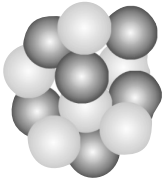
helium

2 neutrons
2 protons
4 (atomic mass/weight)



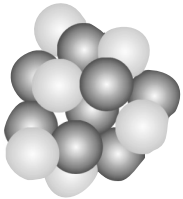
oxygen

8 neutrons
8 protons
16 (atomic mass/weight)



carbon-12

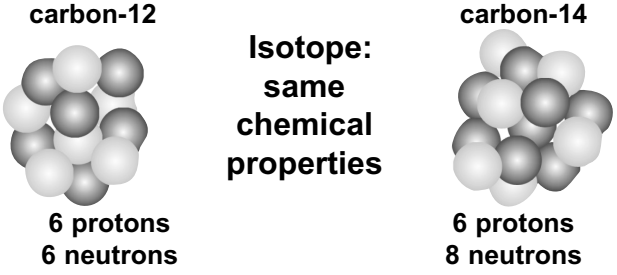
6 neutrons
6 protons
12 (atomic mass/weight)



carbon-14

8 neutrons
6 protons
14 (atomic mass/weight)

Elements because they are both the same element. Both *carbon-12* and *carbon-14* are isotopes of carbon and have identical chemical properties. The extra neutrons do not affect how carbon forms compounds with other elements.



18 *Uranium-238* and *uranium-235* both have the same number of protons (92) but they have differing numbers of neutrons. *Uranium-238* has 146 neutrons. *Uranium-235* has 143 neutrons. Both isotopes have the same atomic number (92) but differ in the number of neutrons they possess.

19 Nuclear chemists think neutrons act as bonding agents to hold together protons. Protons have a positive charge. Electric charges that are alike repel one another. The uranium atom has 92 protons. Neutrons have a role in keeping the nucleus stable.

20 Chemists are concerned about counting subatomic particles because of insight gained into the important topic of atomic energy. An element that has the wrong mix of protons and neutrons is unstable. It undergoes ***radioactive decay***, and the nucleus comes apart. Subatomic particles traveling at great speeds escape from the nucleus. Some elements are naturally radioactive. Uranium, thorium, radium and radon are naturally occurring radioactive elements.

21 Sometimes one isotope of an element is radioactive while another isotope is stable. For instance, the *uranium-235* isotope is radioactive. It is unstable. It separates into smaller atoms and releases high-speed particles.

22 One of the most common particles released by radioactive breakdown of a nucleus are alpha particles. An alpha particle contains two protons and two neutrons. An alpha particle travels at a very high speed, about 25,000 miles per second. When it strikes the nucleus of another atom, that atom can change. By absorbing two protons from the alpha particle, the atom can change into an entirely different element.

23 A ***nuclear reaction*** is one that changes the nucleus of an atom. The atom loses protons, neutrons or both. Nuclear reactions require far more energy than chemical reactions.

24 *Uranium-238*, the more stable isotope, can be made radioactive by exposing it to alpha particles. When hit by alpha particles, *uranium-238* absorbs protons and its atomic number changes. Instead of its original 92 protons, the atom gains two protons, for a total of 94 protons, which converts it to element number 94.

25 Element number 94 is not found in a natural state on Earth. It is an artificial element that was first created during nuclear reactions. Nuclear chemists named the new element plutonium after the planet, Pluto. (uranium had been named after the planet Uranus.) Plutonium has 94 protons. It is radioactive and will break down to release other subatomic particles and generate heat. Some nuclear reactors are designed to produce plutonium. *Uranium-238* is packed around *uranium-235*. The reaction changes *uranium-238* into plutonium. These ***breeder reactors*** generate more nuclear fuel than they use, thus they provide a source for nuclear fuel to produce electric energy.

26 Americium is an artificial element that is found in the home. It has 95 protons. Like all of the elements above uranium, americium is radioactive. It is used in most smoke detectors. As americium breaks down, it generates subatomic particles. Smoke in the air reduces the number of particles, causing a sensor to react and the smoke alarm to sound.

27 In addition to the subatomic radioactive particles, the breakdown of radioactive elements generates heat that can be changed into electric current. Nuclear power plants produce electric power from steam-driven electric turbines. The heat of the nuclear reaction produces the steam. The amount of energy released by a nuclear reaction is tremendous. For instance, 15 pounds of *uranium-235* will generate as much heat as 40 million pounds of coal.

28 Bryan took a picture of the stone. The shutter stayed open so long he knew it would be blurred. The stone was about eight feet high, four feet wide and more than a foot thick. It stood in a nearly vertical position that would have helped keep it free of ice and snow. The carvings were about four inches high. "It looks almost like a stone billboard!" Bryan exclaimed. "Can you make a rubbing?"

29 Tom said, "No—The paper will not lay flat because of the moss. Most of the drawings are hidden under the moss. But, we could clean it off."

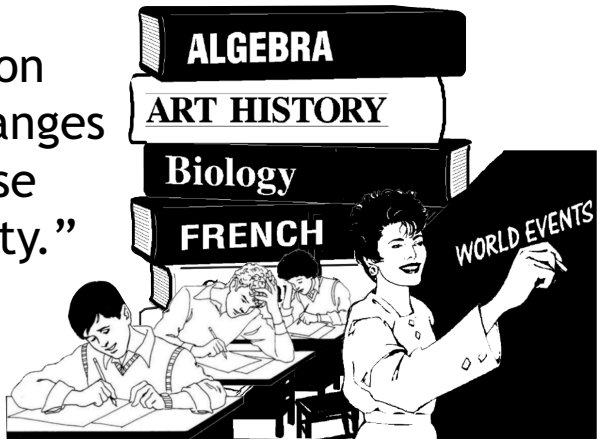
30 "No," Bryan decided. "We should leave it untouched. Sketch the letters as best you can."

31 "I don't think they are letters," Tom said, "They look like a line of threatening warriors! The markings probably mean something like, 'Death awaits those who violate this sacred valley'!"

Life Principle

"A stable person endures life's changes without a sense of great adversity."

—Anonymous



Lesson 13
Energy

Chapter 3

Solar Cells and Batteries

Section 3

Lessons 11-15

MAKING ELECTRICITY



As they hiked to the bluff with the twisted tree, Bryan and Tom talked about the strange markings on the stone. Tom wondered, "Who could have made them?" 1

Bryan guessed, "I suppose some visitor could have scratched them into the stone as a practical joke." 2

Tom disagreed, "That stone is hard. Making those letters is not like spray painting your name on a brick wall. A lot of effort was required to carve those lines! If it is a practical joke, it must be an ancient practical joke. Those markings have been there for hundreds of years." 3

Bryan said, "If the marks are pictures, then they were probably made by Native Americans. If the markings are letters, they could have been left by explorers such as the French or Dutch. I don't think the Spanish came this far north. The early European explorers had an alphabet similar to English, but I didn't see a single figure that looked like a letter I recognized." 4

"Who else could have done it?" Tom asked. 5

Bryan ventured, "Vikings, maybe. They are supposed to have landed along the North American coast sometime about a thousand years ago. I don't know if they used letters or pictures for their writing." 6

The boys heard the thundering pound of surf against the bluff where the twisted tree grew. While Bryan fitted the telephoto lens on the camera, Tom walked out to the edge of the bluff for a good look at the mystery town on Shell Island. 7

VOCABULARY

Photoelectric effect: having to do with electronic effects produced by light
Solar cells: semiconductors that change the energy of sunlight into electricity
Semiconductors: elements such as silicon that is neither a good conductor nor a good insulator; it is a partial or somewhat conductor of electricity
Positive electrode: the solid conductor through which electrons enter a battery, also called the *positive terminal*

8 Bryan turned on the camera and checked the exposure by the light meter. Bryan said, "The light is perfect. We should get—"

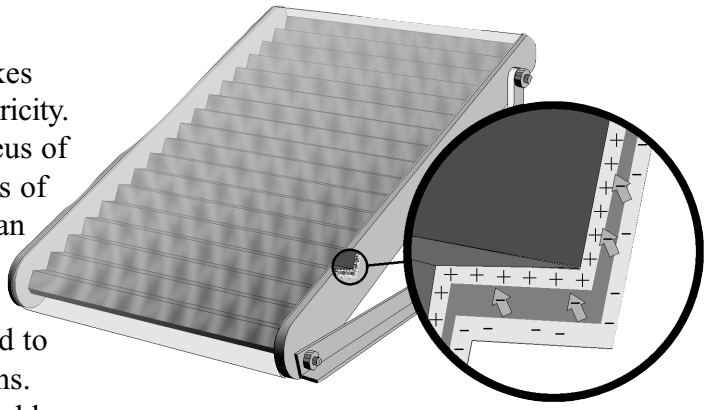
9 He stopped talking in disbelief. The town on Shell Island had vanished!

10 The light meter on a camera makes use of the fact that light can generate electricity. A cloud of electrons surrounds the nucleus of an atom. The electrons at the outer edges of the electron cloud are lightly held and can escape if they are given additional energy. When light strikes metal, electrons receive the extra energy needed to escape. Electricity is the flow of electrons.

11 Cesium is a metal with a weak hold on its outer electrons. When light strikes cesium, the electrons gain so much energy they fly away from the atom in what is known as a ***photoelectric effect***. Electric "eyes" that "know" when a door is opened, and some camera light meters which measure the brightness of light make use of this principle.

12 ***Solar cells*** for generating electricity from sunlight are based on a similar process. A solar cell is made of silicon, the element found in sand. Silicon crystals are between metals and nonmetals in their ability to conduct electricity. They are ***semiconductors***. The solar cell is made of two layers of silicon that differ slightly from one another. Each layer has impurities intentionally added to change the way electrons flow.

Solar cell



13 Normally, silicon holds onto its electrons. However, light gives the electrons enough energy to escape from their atoms. The border between the two layers acts as a one-way gate. Electrons can pass more easily in one direction than in the other. This gives rise to a small electric current. The side of the cell that loses electrons becomes the ***positive electrode***. The side of the cell that gains electrons becomes the ***negative electrode***. If the two electrodes are connected to a circuit, then electrons will flow as they would in a battery with a positive and negative electrode.

14 Although sunlight is free, making solar cells is expensive. Electricity generated in this way is still about twice as expensive as energy produced from other sources. Solar cells find use in remote devices that transmit information. Power for telephone lines in desert communities, devices that report on the depth of rivers, and automatic weather stations in out-of-the-way places use solar cells. Most satellites out in space are powered by solar cells. The solar cells charge storage batteries that provide power when the Sun is hidden from view.

15 Another way to separate electrons is by friction. Benjamin Franklin used friction to give rubber and glass rods a charge by rubbing them with fur or silk.

VOCABULARY

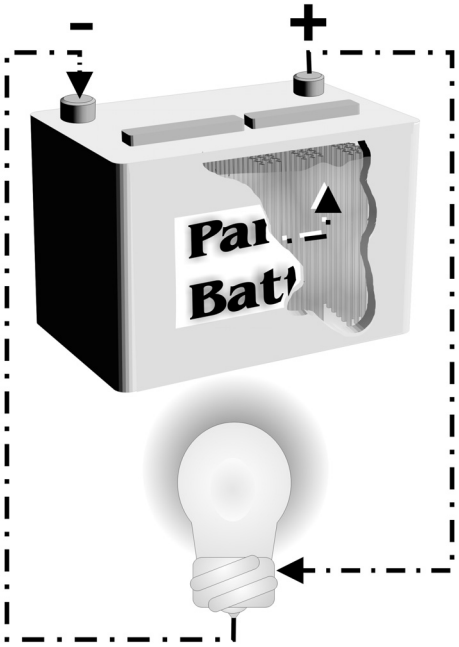
Negative electrode: the solid conductor through which electrons leave a battery, also called the *negative terminal*

Circuit: a complete path for electrons to follow, a circuit has a source of electricity and at least one device that uses the electricity

Lead-acid battery: a battery made of a negative lead electrode, a positive lead oxide electrode and sulfuric acid mixed with water

16 Making electricity by friction was a clumsy method. It produced only a static charge and not a steady flow of electricity. In the early 1800s, chemists learned how to make electricity by chemical means. The first battery was made of two different metals such as copper and zinc separated by a paper disk that had been soaked in an acid. Almost any pair of metals would produce some current, especially if the metals were immersed in a solution containing water and an acid.

17 An automobile battery is made of two electrodes attached to sheets of metal (lead) in a solution of sulfuric acid and water. The negative electrode is marked with a minus sign, and usually the battery cable connected to it is covered with black insulation. The positive electrode is marked with a plus sign and usually the battery cable connected to it is covered with red insulation.



18 The negative electrode is connected to sheets of lead. The positive electrode is connected to sheets of lead oxide. Lead oxide is lead chemically combined with oxygen. Both the lead and lead oxide sheets are immersed in a solution of sulfuric acid (H_2SO_4). When mixed with water, the sulfuric acid molecules come apart and form hydrogen ions (H^+), and sulfate ions (SO_4^-).

19 When a battery is in use, a chemical change takes place. Lead is a metal and gives up electrons during the chemical reaction. The electrons leave the negative electrode and go around the wire ***circuit***. Along the circuit are the devices that need electricity such as the radio, lights or starter of the car. The electrons go around the circuit because they are being repelled by the negative charge of the lead sheets. At the same time, they are being attracted to the positive charge of the electrode attached to the sheets of lead oxide.

20 At the negative electrodes, lead atoms give up electrons, become positive lead ions, and go into solution. The lead ions combine with the SO_4^- part of sulfuric acid to form lead sulfate. The lead sulfate coats the lead electrode.

21 At the positive electrode of lead oxide, a different reaction takes place. Hydrogen ions from the sulfuric acid receive the arriving electrons. The hydrogen joins with oxygen to produce water. The oxygen comes from the lead oxide. When the oxygen leaves lead oxide, it produces lead ions that go into solution. The lead ions combine with the SO_4^- part of sulfuric acid and also form lead sulfate.

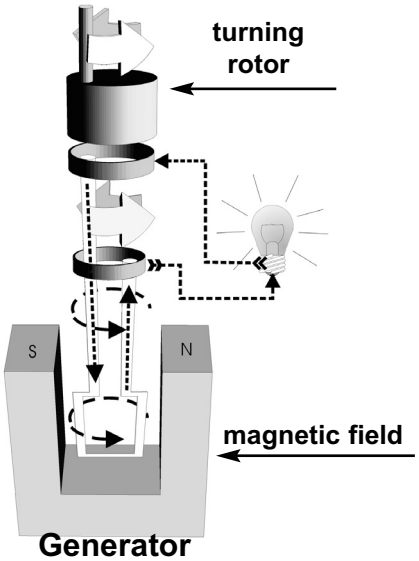
22 As the ***lead-acid battery*** is used, the sulfuric acid becomes diluted with water, and the plates become coated with lead sulfate. After a time of use, the battery can no longer generate electricity.

23 A lead-acid battery has the advantage of being able to be recharged. Once the battery starts the engine of an automobile, the engine then turns a generator to supply electricity to the battery. By reversing the flow of electrons, the chemical reactions also reverse. The battery is recharged and can again provide electricity when needed. Although the lead-acid battery was invented in 1859, it is still widely used in cars and trucks.

24 About twenty years after Gaston Plante, a French scientist, invented the first chemical (lead-acid) battery to generate electricity, scientists made a remarkable discovery involving electricity and magnetism. Suppose an insulated wire is coiled around an iron nail and the wire is connected to a battery. The iron nail becomes magnetic. Electrons flowing through the coil of wire cause a magnetic field. The iron nail is magnetic as long as the electricity flows. When the electricity is turned off, the nail looses its magnetism. Discovery of this process led to the invention of several useful products including the electromagnet, the telegraph and the electric doorbell.

25 Although scientists knew how to use electricity to make magnetism, scientists did not immediately discover how to make electricity from magnetism. After several years of experiments, Michael Faraday, an English chemist, unveiled the secret: a magnetic field in motion and passing through a conducting wire causes electrons to flow.

26 The generator of a car applies this process to produce electricity to recharge the vehicle battery that powers electrical devices. A series of wire coils are spun inside a magnetic field. Electrons then flow through the wire. Motion is the key. If a wire runs across a magnet but neither the wire nor the magnet moves, then no electrons move. If either one moves, then electricity flows.



Generator

27 Electricity that comes into the home from power generating stations uses generators that are turned by steam or falling water. Most of these generators operate with coils of wire that stand still while magnets spin rapidly around the coils.

28 Most electricity is made by the chemical action of batteries or by electric generators. However, electricity can be made in many other ways. For instance, certain crystals squeezed very hard will emit tiny sparks of electricity. When the pressure is released, the crystals each emit another spark. Some lighters, and the pilot lights that start gas stoves, operate on this principle.

29 Bryan and Tom stood in dumbfounded silence. "I don't believe this!" Tom said. "How can an entire town disappear into thin air?"

30 Bryan shook his head as if to clear the image. Shell Island rose in bright sunlight from a clear blue sea. Gulls circled around it as if nothing were amiss. The grassy knoll where the boys had previously seen a complete town was now completely bare. Bryan scanned the location through the telephoto lens. The scan revealed nothing to show where the town had been. Even so, Bryan took a picture of the scene.

31 "Why did you take a picture?" Tom asked. "The town has vanished!"

32 Bryan replied, "Should it mysteriously reappear, at least we'll have proof that it was not there today."

Life Principle

"The best way to overcome your own problems is to help someone else overcome his problems."

—Anonymous



Lesson 14
Energy

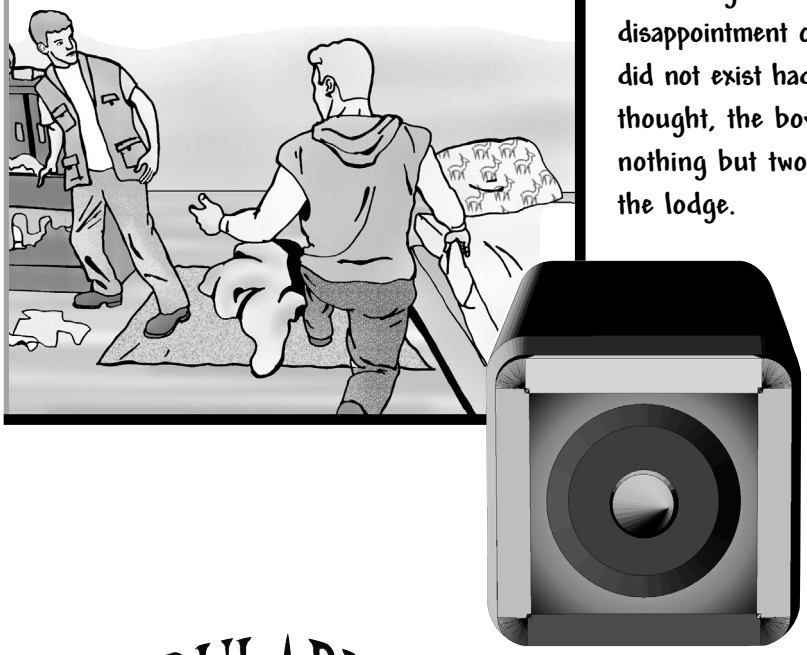
Chapter 3

Voltage, Lighting, and General Uses

Section 3

Lessons 11-15

USING ELECTRICITY



The Sun did not set until nine o'clock, but the boys were still on the trail when the sunlight faded. The long hike and the disappointment of finding that the mysterious town did not exist had dampened their spirits. Lost in thought, the boys walked silently the last hour with nothing but two small flashlights to guide them to the lodge. 1

Lights glowed from the windows of the ranger's cabin. The boys stopped there first. Bryan gave the ranger their notes and the exposed film taken at the mill site. Ranger Eldridge reviewed their work carefully. "First rate!" he pronounced. 2

Bryan asked, "Do you know if anyone should have been in the Barnett home site?" Bryan told his uncle about the running man. 3

Ranger Eldridge said, "Most of the island belongs to the nature reserve. You two were the only ones authorized to enter any of the buildings. Ed Barnett was about 90 years old when he moved to the mainland. He died recently at a retirement home in Cadey. He does have a grandson named Jory Barnett who is a grown man. My opinion is that Jory visited Cadey to close out his grandfather's affairs. While he was in the area, he probably came to the island to retrieve the shoebox that he had hidden as a small boy. You surprised him. He knew he shouldn't be in the building, so he ran. He probably caught the ferry this afternoon and is off the island by now. You should not give this incident much significance." 4

VOCABULARY

Arc lamp: a device that produces a brilliant white light by a source of high voltage electricity jumping the gap between two carbon electrodes

Voltage: the force that causes electrons to move around a circuit

Incandescent: the ability to emit visible light as the result of being heated

5 Tom blurted out. "What about the town on Shell Island? How did it disappear?"

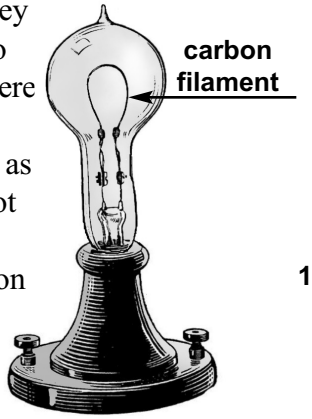
6 Ranger Eldridge looked at Tom as if the boy suffered from a fever. "You need a rest! There has never been a town on Shell Island! Not in the past, not now, and because of the unexploded shells, probably never."

7 One of the most important uses of electricity is in producing light. The boys used their flashlights to follow the trail after dark. They saw by the glow of light from the windows that Ranger Eldridge was in his cabin.

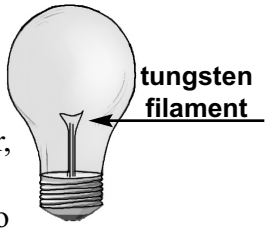
8 Dependable electric lights changed the world when they came into common use in the early 1900s. Before the advent of electric lights, people seldom ventured out at night. If a friend came to visit and did not leave before dark, he was asked to stay over until morning rather than risk walking home on dark, dangerous roads.

9 The first electrical device to produce light was the ***arc lamp***, invented in the mid 1800s. Carbon is one of the few nonmetals that will conduct electricity. A high ***voltage*** source of electricity was connected to two rods of carbon. They were first touched together to get the electricity flowing in the circuit. Then they were separated. A brilliant arc of electricity jumped between the rods.

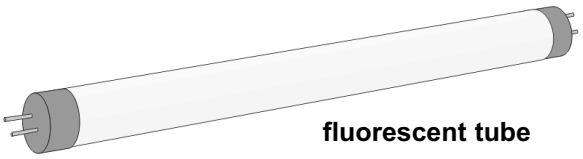
10 An arc lamp produced a very bright light. However, the carbon rods had to be adjusted continually as they burned. The light was so intense that arc lamps were used as street lights, spotlights in theaters and as searchlights, but were not suited for home use.



11 Thomas A. Edison made the first successful light for home use. His ***incandescent*** bulb had a fine carbon filament. Electricity heated the carbon until it glowed. Edison invented and began selling electric light bulbs in 1879; however, the carbon was brittle, and shaking the lamp caused it to break. African-American Lewis Latimer developed a long-lasting, inexpensive carbon filament for light bulbs that greatly enhanced the field of electric lighting. Early in the 1900s, the carbon filament was replaced with the longer-lasting metal, tungsten.



12 ***Fluorescent*** lights were invented in the early 1900s. The fluorescent tube contains mercury vapor at low pressure. When electricity flows through the tube, the mercury vapor emits electromagnetic waves. They are ultraviolet and not visible to human eyes. However, the ultraviolet waves strike a special coating on the inside walls of the glass tube. The coating absorbs the energy of the ultraviolet light and re-emits it as visible light.



VOCABULARY

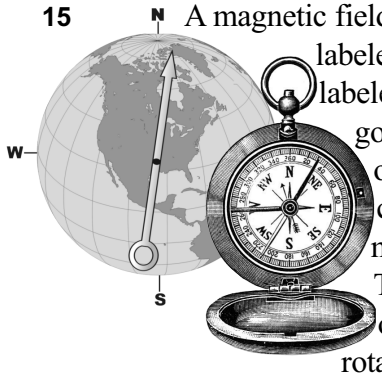
Fluorescent: the ability to emit light when struck by electromagnetic waves; a fluorescent light (tube) is coated on the inside with a material that glows when struck by ultraviolet light, the ultraviolet light is produced by a high voltage discharge through mercury vapor or sodium vapor inside the tube

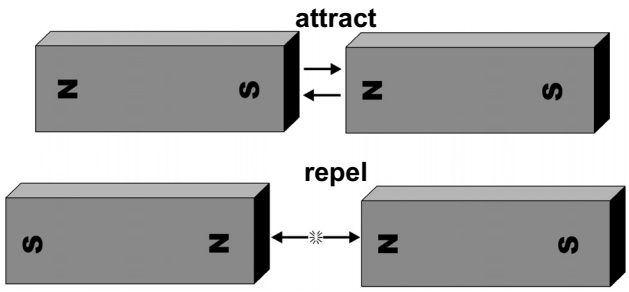
Neon lights: glass tubes filled with neon gas at low pressure that glow when a high voltage discharge of electricity is sent through them; a neon light may contain other gases besides neon; also known as an electric discharge lamps

13 ***Neon lights*** operate on nearly the same principle as the glow caused by a bolt of lightning. Neon lights are filled with one of the noble gases such as neon, krypton or xenon. The gases are at a very low pressure. When electricity passes through the gas, electrons in the atoms of the noble gas gain energy and move to a higher orbit. Then, a moment later they fall back to their normal position. When the electrons fall back, they release the energy as visible light.

14 Electricity is a form of energy that is easy to change into other forms of energy. In addition to light, electricity can be used to produce heat and mechanical motion such as found in an electric motor. An electric motor is set into a spinning motion by the interaction of electricity with magnetic fields. About two hundred years ago, scientists learned about a strong relationship between electricity and magnetism. A moving current of electricity that passes through a wire gives rise to a magnetic field around the wire.

15 A magnetic field has two poles. One is labeled as *north*. The other is labeled as *south*. The poles got their names because of a compass needle. A compass is made with a magnetic metal needle. The needle is balanced on a pivot and is free to rotate and align itself with the earth's magnetic field. One end of the needle points in the direction of the earth's North Pole. The other end of the needle points in the direction of the earth's South Pole.

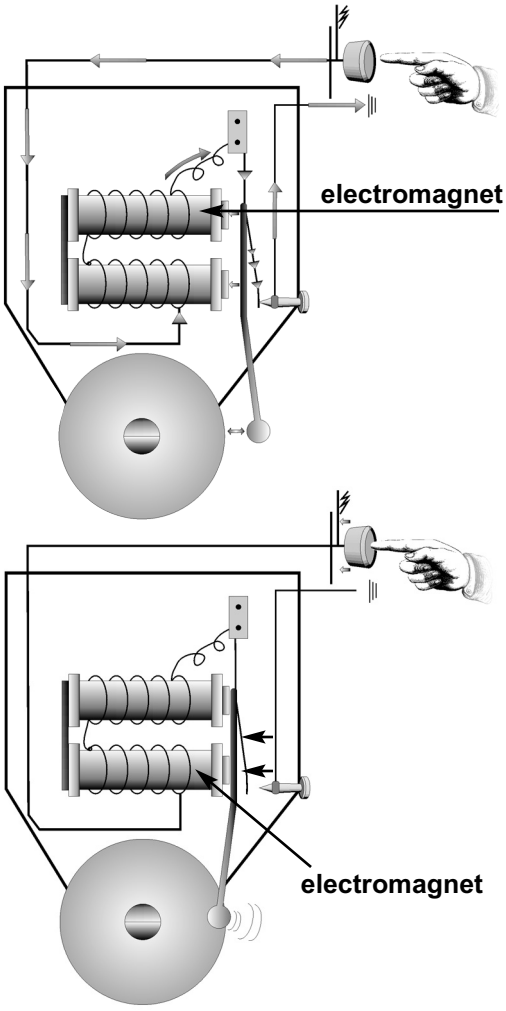




Magnetic poles of the same type repel one another. Unlike magnetic poles attract. For instance, a north pole of one magnet will attract a south pole of another magnet. Two north poles repel one another, as do two south poles. Either pole, north or south, will attract iron.

16 Electric current flowing through a wire produces a magnetic field that has north and south poles like those of a magnet. If the wire is wound into a coil, then a north pole is at one end of the coil and a south pole is at the other end. If the direction the electricity flows in the wire is changed, then the poles reverse.

17 One of the first uses for electricity was in electromagnets. Each was made of a bar of soft iron wrapped many times around with a coil of insulated copper wire. Electricity



flowing in the wire generated a strong magnetic field in the iron bar. The electromagnet found a use in the home as an electric doorbell. When a visitor pushed the button near the door, an electric circuit was completed. The electricity passed through an electromagnet that lifted a metal rod to strike a bell.

18 Electricity can also be used for communication. The telegraph was the first device to use electricity to send messages. The telegraph operator sent the message by making and breaking an electric circuit. The electric circuit was attached to an electromagnet in a distant city by means of wires, or high lines. The electromagnet raised and lowered a pen that drew dots and dashes on a strip of paper that passed under the pen. The dots and dashes stood for letters that spelled out the messages.

audio speaker



19 A rapidly changing electric field produces a rapidly changing magnetic field. Audio speakers such as those installed in stereos, radios, and telephone handsets make use of the relationship between electricity and magnetism. To transmit a sound, an electric current is made to vary in the same manner as the sound. The electric signal is then transmitted by radio, television or through wires to the speaker. At the speaker, electric current operates an electromagnet. The magnetic field varies in the same way as the electricity field. The changing magnetic field alternately attracts and releases a metal disk. This rapid vibration of the disk produces sound waves that reproduce the original sound.

20 An electric motor changes electricity in mechanical action. The first electric motors were made of a series of electromagnets on a shaft that could rotate. Positioned around the electromagnet were permanent magnets. When electricity flowed, the electromagnet was attracted to one of the poles of a nearby magnet. As the electromagnet came near the pole of the magnet, the direction of the electricity was reversed. The electromagnet was then near the opposite magnetic pole, which caused the electromagnet to be repelled. The alternating pull and push caused the shaft to spin.

21 The attraction of static electricity is used in copy machines and computer printers. The printer controls a beam of laser light. The light draws an image of the page to be printed on a sheet of metal. The sheet of metal is usually aluminum, coated with selenium. Selenium is a semiconductor like silicon. Where the light strikes, electrons flow and neutralize the static charge. Dry ink particles made of black or colored plastic are sprinkled on the sheet of metal. They stick where the sheet has retained a static electric charge. The particles fall away where there is no charge. A sheet of paper is pressed against the ink particles and heated to make them stick. In this way, the paper picks up the ink particles to make a copy of the page being printed.

22 Electricity can produce heat. This fact was known before electric devices were invented, as people observed lightning strikes. Lightning is a form of electricity. When trees are struck by lightning, the bark is blasted away from the trunk. A lightning bolt causes the moisture in the sap of the tree to change into steam. The sudden expansion of the steam peels the bark away from the tree and sends it flying through the air. In the desert, when lightning strikes directly on sandy soil, enough heat is generated to melt sand and produce glass.

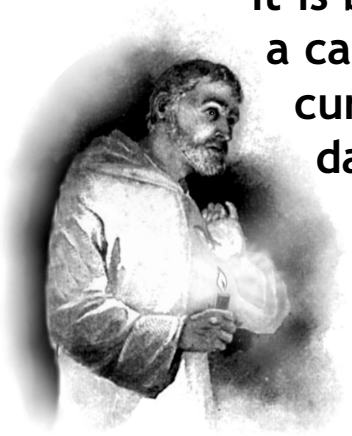
23 Devices such as hair dryers, clothes dryers, electric heaters, electric blankets, electric coffee makers and toasters make use of the heating effects of electricity. Inside the devices, wire is wound around a nonconducting sheet of the mineral, mica. The wire is a metal alloy that can conduct electricity. The alloy has a high melting temperature, so it can withstand the hot temperature produced by the flow of electricity.

24 Wearily, the boys trudged to their cabin. Tom said, "Point me to my bed, I'm exhausted." Bryan opened the door and turned on the lights. The inside was a shambles! All of the drawers had been yanked open and the clothes thrown onto the floor. The bed covers were tossed onto the floor, also. The desk drawer had been pulled out and its contents dumped onto the floor.

25 Tom had put his map of the island in a small canvas pouch and left it under his mattress. "It's gone!" Tom exclaimed, "Someone broke in and stole the map!"

Life Principle

"It is better to light a candle than to curse the darkness."



—Chinese proverb



Lesson 15
Geology

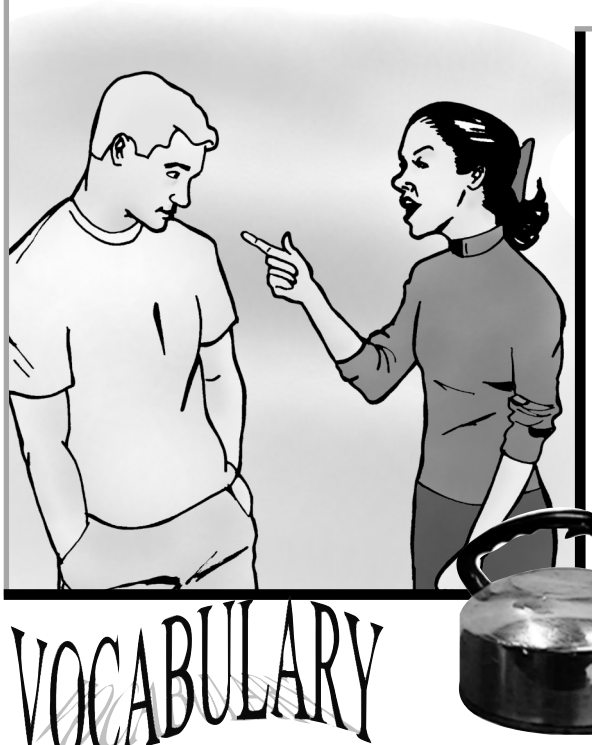
Chapter 3

Lithosphere, Hydrosphere and Troposphere

Section 3

Lessons 11-15

THREE SPHERES



The next morning Bryan and Tom put everything back where it belonged. Tom checked around the outside of the cabin for evidence of the intruder. He reported, "All I found was a candy wrapper." 1

Bryan said, "If James Olsen is true to his past littering standards, then he's the one who trashed our cabin; and is in possession of the map!" 2

At breakfast, Del did not notice how subdued the boys were. She bubbled over with excitement. She was pleased with what she had accomplished. 3

Del said, "I didn't show your map to anyone! I copied the words on a plain sheet of paper and looked them up in a French-to-English dictionary at the library. *Abre de Sorcére* means 'witch tree.' I think it is what we call the 'twisted tree'. The words *cuivre pierres* mean 'copper stones.' I'm sure these marked the location of the copper deposits, because that's where the copper mine was later opened!" 4

Bryan examined her copy of the map. "What is *tonnerre trou*?" 5

Del said, "The words mean 'thunder hole.' It is near the twisted tree. Let me have your map and I'll pencil in translations of all the words for you." 6

"Uh —-," Tom stalled. 7

Dell looked at Tom suspiciously. "You lost the map! After cautioning me to be careful, you're the one who lost it!" 8

VOCABULARY

Topographic maps: maps that represent the surface features of the Earth
Lithosphere: the crust and upper mantle of the Earth
Nautical charts: maps for use by navigators that provide information of interest to shipping (such as the depth of the water at low tide and the position of aids and hazards to navigation)
Hydrosphere: the liquid water surrounding the surface of the Earth; all freshwater, oceans and water vapor of the atmosphere

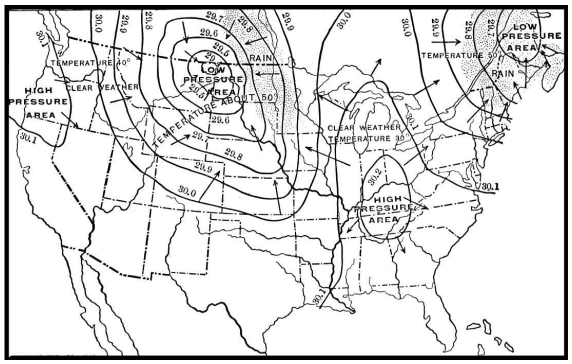
9 ***Topographic maps*** show natural and man-made features of the Earth's surface. Such maps show the shape of land, give elevations above sea level and indicate man-made features such as towns and cities, roads, railroads, airfields and power lines. Maps use colors to distinguish open fields, forests, and deserts. Topographic maps show the surface of the ***lithosphere***, the solid part of the Earth. Most topographic maps also show small bodies of water such as lakes, streams and rivers.

10 Backpackers in the United States use topographic maps prepared by the United States Geological Service. These maps, usually called *topo maps*, are helpful for planning a hike through a wilderness area, because the maps show mountain elevations and obstacles along routes.

11 ***Nautical charts*** show larger bodies of water. The charts also provide information for navigation such as the depth of water at low tide, location of islands, rocks, wrecks and other hazards to navigation. Nautical charts also show the aids to navigation such as lighthouses and channel markers. Features on shore are shown only if they can be seen from sea and aid navigators. Nautical charts cover the ***hydrosphere***, the sphere of liquid water around the Earth.

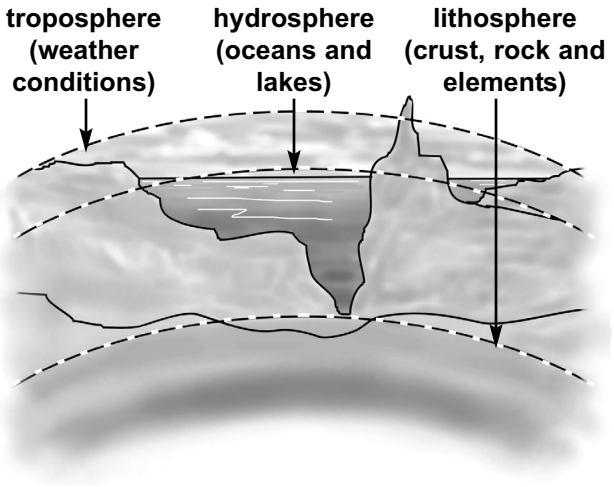
12 The third sphere of the Earth is the ***atmosphere***. *Meteorological charts* show the condition of the atmosphere. Meteorological charts also show wind speed, wind direction, temperature, humidity and air pressure, which are used in weather forecasting.

Meteorological Chart



13 The three states of matter are solid, liquid and gas. The Earth has three spheres or layers around it. Each one is a state of matter. The *atmosphere* is the sphere of *gases*. The *hydrosphere* is the sphere of *liquid water*. The *lithosphere* is the sphere of *rocks and soil*.

Earth's States of Matter



14 The first layer of the atmosphere is the ***troposphere***. This is the layer in which life breathes. The troposphere begins at the surface and towers over the tallest mountain, extending to a height of about 16 kilometers (10 miles). Most of the clouds and other weather conditions are found in the troposphere.

15 The main gases in the atmosphere are nitrogen (N_2), at 78 percent, oxygen (O_2), at 21 percent, argon (Ar), at about 0.9 percent,

VOCABULARY

Atmosphere: the layer of gases that surround the Earth

Troposphere: the lowest layer of the atmosphere that extends upward from Earth's crust about 10 miles; most weather occurs in the troposphere

Freshwater: water that contains little or no salt

and carbon dioxide (CO_2), at about 0.03 percent. The abundance of gases is measured by volume. Other gases include water vapor (H_2O), ozone (O_3), hydrogen (H_2), methane (CH_4), carbon monoxide (CO), and trace amounts of the noble gases such as helium, neon, krypton and xenon.

16 The percentages of nitrogen, oxygen and carbon dioxide in the air are essentially the same at all levels of the atmosphere. The abundance of the other compounds changes somewhat with height. Water vapor is usually more abundant in the lower levels because water evaporates from oceans. The lower atmosphere also contains a higher proportion of dust and ash, compounds released by combustion, salt from sea spray, and sulfur from burning coal and volcanic eruptions.

17 Ozone is formed in the higher regions and filters out some of the Sun's harmful ultraviolet rays. Hydrogen is a light element and rises to the higher levels of Earth's atmosphere. When sunlight heats hydrogen, the molecules move so fast that they can escape from Earth's gravity. Hydrogen is constantly leaking into space. Hydrogen is replaced by the breakdown of compounds such as water, acids or bases.

18 The hydrosphere is made of all the liquid forms of water including the oceans, salt seas, fresh water lakes, rivers and ground water. The word *hydrosphere* comes from the prefix *hydro* that means "water." Water is the most abundant substance on the surface of the Earth. Water is by far the most common liquid. The liquid forms of water cover about three-fourth's of Earth's surface. In addition, water is found in its solid form as glaciers and in gaseous form as water vapor that becomes visible as fog and clouds. During winter, water can coat the surface of the Earth as snow, ice or frost. Water can be found as deep as three miles in the Earth and as high as nine miles in the atmosphere. At times, as much as 90 percent of Earth's surface is covered with water in one state (form) or another.

19 Over the entire Earth, the average temperature is about 61ºF. The temperature varies from night to night, season to season, and from the equator to the North Pole. Although slight compared to other bodies in the solar system, the temperature changes are enough to cause water to be present in all three phases. No other planet in the solar system has water in all three states as solid, liquid and gas. The Earth is a marvelous planet, uniquely designed to support life.

Three States of the Hydrosphere



SOLID = glacier (ice)



LIQUID = ocean (water)



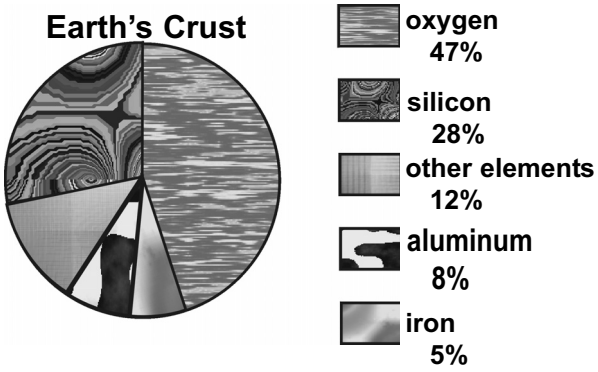
steam, fog, or GAS = clouds (mist)

20 The most abundant elements in the oceans are oxygen, hydrogen, chlorine and sodium. Oxygen and hydrogen are bound together in the water molecule (H_2O). Water is a good solvent. It dissolves other substances. When rain falls, it dissolves substances in rocks and minerals and carries them to the sea. The most abundant of the compounds carried to the sea is salt. If a quart of seawater were evaporated, it would leave behind about one ounce, or two tablespoons, of salt.

21 Water from the ocean is not fit to drink. The salt content is too high. The human body uses water to eliminate wastes from cells and the bloodstream. One of these wastes is salt. Suppose a person were stranded on a lifeboat in the middle of the ocean. Although water is all around, it would not satisfy the person's thirst. Rather than reducing salt in the bloodstream, drinking seawater would add still more salt to the bloodstream.

22 Water in streams, rivers and lakes is described as ***freshwater***. It does not contain much salt.

23 The *lithosphere* is the solid part of the Earth. The topmost layer is the crust. It is made of rocks and minerals. The contents of rocks and minerals can vary considerably from one place to another. On average, the four most common elements in the crust are oxygen (O), at about 47 percent, silicon (Si), at about 28 percent, aluminum (Al), at about 8 percent and iron (Fe), at 5 percent. Most of the other naturally occurring elements are found in the crust.



24 The four most abundant elements in the crust are never found in a free state. Instead, they combine with other elements to form rocks and minerals. Silicon and oxygen combine to give silicon dioxide (SiO_2), the main compound in sand. Oxygen also combines with aluminum and iron to form oxides. Most minerals can contain a variety of elements. For instance, feldspar is an abundant mineral that makes up about 60 percent of the Earth's crust. One common type of feldspar is potassium aluminum silicate ($KAlSi_3O_8$). (The chemical symbol for potassium is *K*.)

25 Notice that oxygen is the most abundant element in the lithosphere and hydrosphere and the second most abundant element in the atmosphere. The planets Mercury, Venus and Mars are believed to have oxygen in abundance in the solid parts of their surfaces. However, the amount of oxygen in their atmospheres is quite small.

26 Oxygen is a very active element. It will combine with most of the other elements. It forms oxides with the metals. It forms compounds with nonmetals such as hydrogen. Of all the elements, only fluorine is more active than oxygen. Because it is so chemically reactive, oxygen in the atmosphere of the planets soon reacts with elements in the crust, causing the oxygen to be removed from the atmosphere.

27 Earth, however, also has free oxygen in the atmosphere because plants produce oxygen during photosynthesis. All green plants, whether growing in water or on land, release oxygen into the atmosphere. Oxygen is continually reacting with the elements in the crust and being returned to the lithosphere. However, only on Earth do plants return the oxygen back into the air.

28 Bryan countered, "We didn't lose it! Someone broke into our cabin and stole it! At least we are glad we gave you a copy. James Olsen probably made his copy from the original, and we made a copy of the copy to give to you. I wish we could see the original. The original may have details that were lost on the copies."

29 Del said, "The town of Cadey has a private historical museum. The man who runs it charges tourists a small admission. He has been collecting stuff about the history of the area for years. He may have the original or know who does."

30 Bryan offered, "We're free this weekend. Let's go to Cadey and see if we can find some answers!"

31 Del said promptly, "I'll go and help!"

Life Principle

"Your attitude determines your altitude in life."

—Anonymous

