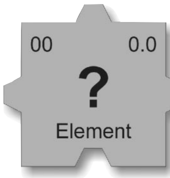
Integrated Physics & Chemistry



Lesson 5
Elements

Chapter 1

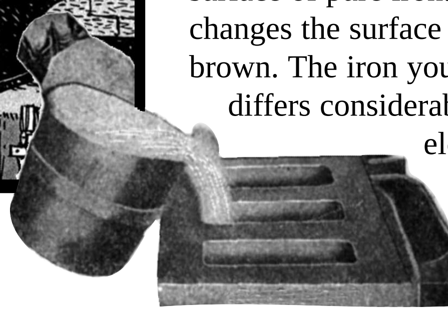
Section 1
Lessons 1-5

THE WORKING METALS

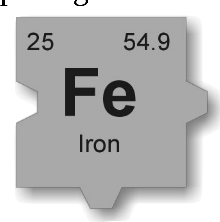
In addition to gold, silver and copper, ancient people worked with iron, lead, tin and mercury. All of these are metals and elements. This lesson describes the main chemical and physical properties of iron and lead.

IRON

Pure *iron* is a silvery, lustrous metal that is soft and ductile. This does not sound like the iron you know because you seldom see the surface of pure iron. Iron rusts quickly. Rust changes the surface color to a scaly dark red or brown. The iron you see in everyday life differs considerably from pure iron. Other elements are added to create iron mixtures conducive to various tasks. Most iron in everyday use contains carbon that makes utensils harder than pure iron.



The symbol for iron is *Fe*. It comes from *ferrum*, the Latin (Roman) word for *iron*. One of the most surprising aspects of iron is its magnetic property. *Magnetite*, also known as *lodestone*, is a naturally occurring magnetic iron ore. The word *lodestone* means *leading stone.* When lodestone is suspended from a string, it aligns itself to the North Pole. The first crude compasses were made from lodestone.



Iron is the fourth most abundant element in Earth's crust at 4.5 percent by weight. It is the second most common metal. Aluminum, which is almost twice as abundant, is the most common. Iron is easier to smelt than aluminum. The word *smelt* means to separate a metal from its ore. Iron is the least

VOCABULARY

Ore: a compound from which a metal can be profitably mined and extracted
Sulfide: a compound that contains sulfur
Oxide: a compound that contains oxygen
Reduction: a chemical reaction that removes oxygen from a compound

expensive and most used metal. From every 100 pounds of metal used in industry, iron makes up 96 pounds.

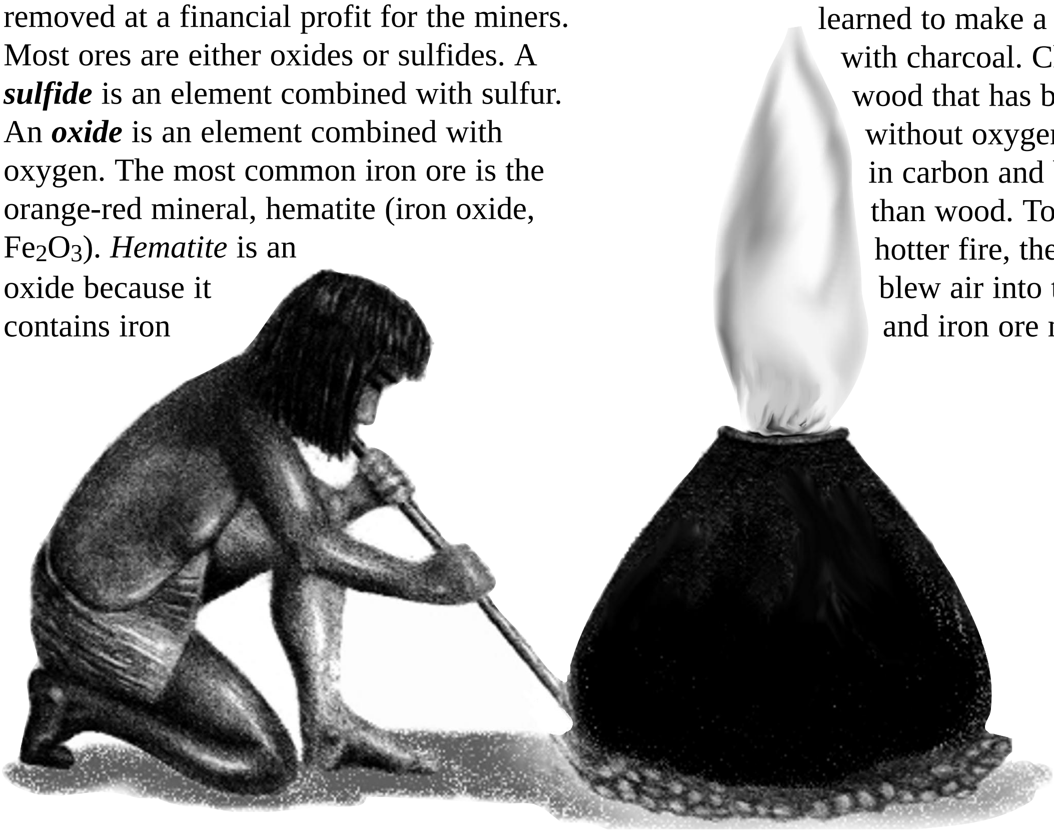
The ancient money metals of gold, silver and copper can be found in the free state and in ores. They are easy to extract from their ores. Copper can be separated from its ore by a hot fire. Iron, on the other hand, is seldom found in the free state because it reacts too quickly with oxygen in the air.

Although iron is abundant in the Earth's's crust, it cannot be removed easily except in locations where its ores are found. An ore is not merely a compound containing a metal. An ***ore*** is a compound that contains the metal in a form that is profitable to extract and mine. Of course, the value of a metal may increase dramatically depending on the difficulty of mining and extracting. Alternatively, a chemist may develop a cheaper way to free the metal from a compound. In either case, a compound is not considered an ore until the metal can be removed at a financial profit for the miners. Most ores are either oxides or sulfides. A ***sulfide*** is an element combined with sulfur. An ***oxide*** is an element combined with oxygen. The most common iron ore is the orange-red mineral, hematite (iron oxide, Fe_2O_3). *Hematite* is an oxide because it contains iron with oxygen. Iron is found in other minerals such as magnetite or lodestone. Black sand beaches are rich in magnetite.

Another well-known iron compound is *pyrite*, (FeS_2), or iron disulfide. It is a yellow mineral known as *fool's gold.* It received that name because inexperienced gold prospectors were misled into thinking they had found gold. Because it contains sulfur, pyrite is a sulfide. Pyrite is not processed for iron because removal of sulfur is too difficult. It is a compound of iron but not an ore of iron.

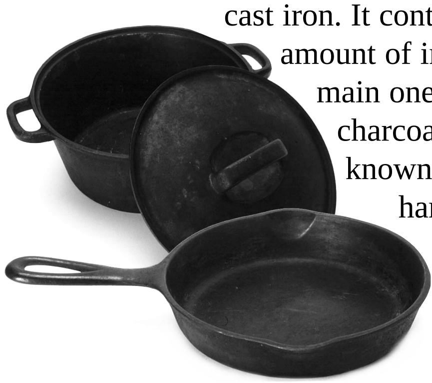
Ancient people learned how to smelt iron to form implements. The book of Genesis, from the Old Testament, states that Tubal-Cain "forged all kinds of tools out of bronze and iron." Smelted iron artifacts dated around 3000 B.C. have been discovered.

Iron is harder to extract than copper. A hot fire is needed to smelt iron. A wood fire is hot enough to extract copper, but a greater heat is needed for iron. The Egyptians learned to make a hotter fire with charcoal. Charcoal is wood that has been baked without oxygen. It is richer in carbon and burns better than wood. To make a hotter fire, the Egyptians blew air into the charcoal and iron ore mixture.



An Egyptian blast furnace was made of clay and stone and shaped like a beehive. It had a hole at the top for tossing in the charcoal and iron ore. Around the bottom were smaller openings for sending in the blast of air. Men blew air into the fire through clay tipped hollow reeds.

Charcoal supplies carbon as part of the chemical reaction. Charcoal does more than merely supply heat. Carbon from the charcoal enhances iron production by drawing oxygen from the iron. This leaves iron in the free state. The removal of oxygen from a compound is known as ***reduction***. More iron can be extracted by adding an additional source of carbon, such as limestone.

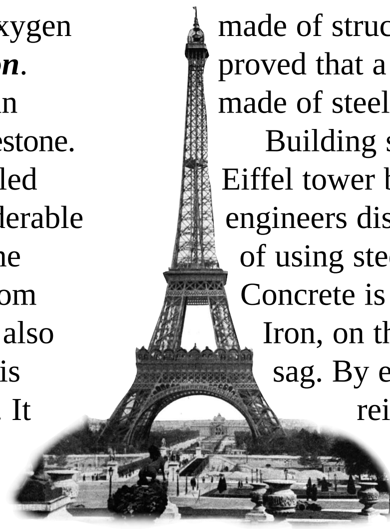


Iron produced in this way is called cast iron. It contains a considerable amount of impurities. The main one is carbon from charcoal. *Cast iron*, also known as pig iron, is hard but brittle. It contains about 3% carbon.

Heating it with iron ore and limestone refines cast iron. The impurities are removed. When refined, the pure iron is known as *wrought iron*. It can be beaten into decorative designs. Metal fences, handrails and ornamental fixtures around windows are made of wrought iron. Except for making ornamental designs, wrought iron is much too soft for most commercial products.

Between brittle cast iron and soft wrought iron is steel, the most useful and strongest form of iron. Cast iron, steel and wrought iron differ only in the amount of carbon they contain. Wrought iron has the least amount of carbon, while cast iron has the most. The amount of carbon in steel is between 0.5 and 1.5 percent. The smelting process that the Egyptians and others of the ancient world used contained the right amount of carbon to make a good grade of steel. By heating the steel and then plunging it quickly into water, the steel becomes tempered. It becomes hard and retains a sharp edge. Tempered steel is used for cutting blades, such as saws, knives and chisels.

Iron has been used in construction since the 1800s. In 1889, Gustav Eiffel, a French engineer, designed the Eiffel Tower. The Eiffel Tower is 948 feet high and made of structural steel. Gustav Eiffel proved that a large structure could be made of steel alone.



Building structures higher than the Eiffel tower became possible when engineers discovered the advantages of using steel with concrete. Concrete is rigid but not very strong. Iron, on the other hand, tends to sag. By embedding steel reinforcing rods in concrete, the combination is both rigid and strong. Steel is the most common form of iron used in construction today.

Iron is cheap and strong but has one major flaw, it easily combines with oxygen. *Oxidation* is a chemical combination of a substance with oxygen. Oxidation may be rapid or slow. *Burning* is rapid oxidation. Iron itself will burn under certain conditions. If a lighted match is touched to fine steel wool, the steel will burst into flames and burn. Holiday sparklers are made of iron particles coated on a metal holder. The sparklers present a huge surface area to the air. This makes rapid oxidation possible. *Rusting* is a form of slow oxidation. Even though the oxide coating protects the metal underneath, iron exposed to a moist climate will rust rapidly. The moisture causes a slight electrical current that aids the formation of additional iron oxide. The upper layers of rust flake away to expose a new layer to the air. Rust continues to do its damage on iron.

To prevent rust, iron can be coated with another substance, such as paint or a layer of another metal, such as zinc. Iron coated with zinc is called *galvanized* iron.

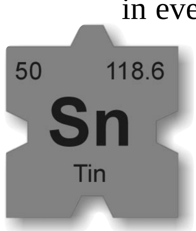
Iron compounds are essential to all life. For example, iron carries oxygen in the hemoglobin molecule found in the blood stream. *Hemoglobin* transports oxygen from the lungs throughout the body. The iron atoms in hemoglobin readily accept oxygen atoms from the lungs. Just as readily, they release the oxygen to the cells of body tissues. Blood is red because of the hemoglobin which contains iron.

TIN

Tin is a silver white metal with a very slight bluish tinge. The chemical symbol for tin is *Sn*, from its Latin (Roman) name of *stannum*.

The primary use of tin in ancient times was as an alloy. Bronze is an alloy of copper and tin. Another important alloy of tin is pewter, a bright and shiny mixture of tin with another metal, such as copper or lead. Pewter was used to make inexpensive kitchen utensils and tableware as a substitute for the more expensive silver dishes. Lead pewter, however, is poisonous to humans and should not be used to prepare food. Another common alloy is *solder*, which is tin mixed with lead. It is used to join metal parts, such as pipes for water systems.

Compared to other metals in everyday use, tin is rare and expensive. It is used only in applications where its chemical and physical properties are clearly superior to other substances that could be used. Tin can be beaten into thin sheets and used as tin foil to wrap foods. However, cheaper aluminum has replaced tin as a food wrapper.



Tin is relatively inert and may be safer than aluminum for processing food. Tin does not tarnish or corrode, and it can withstand weak acids. Tin does combine with oxygen to form a thin, invisible film of stannic oxide (SnO_2). The oxide layer does not affect tin's shiny surface. Instead, the oxide layer protects the tin from further reaction.

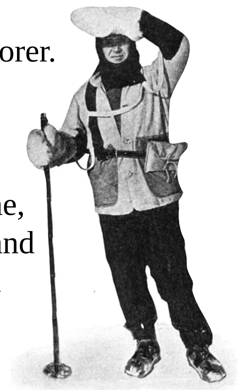
Tin is not toxic and does not discolor food. Because of these properties, the metal is used to make tin cans. Cans of pure tin would be too expensive. Instead, a thin layer of tin is plated on steel. A tin can is actually a steel can coated with a layer of tin only about 0.01 millimeter (1/250th inch) thick.

The main ore of tin is *cassiterite*, (SnO_2) stannic oxide. A small amount of tin is mined each year. The principle source of tin is the recovery from scrap metal.

As temperatures fall below 13°C (55°F), tin begins a dramatic change. It turns gray in color and becomes brittle. This changed form is known as gray tin. It is more like a nonmetal. As the temperature falls, tin crumbles into a powder.

One of the great tragedies of Antarctic exploration occurred when tin was used to weld the seams of kerosene cans. In 1911, Captain Robert Scott, a British explorer, organized an expedition to reach the South Pole. He led his party across 1,800 miles of ice and snow. Along the way men stored caches of fuel and food to be used on the return trip.

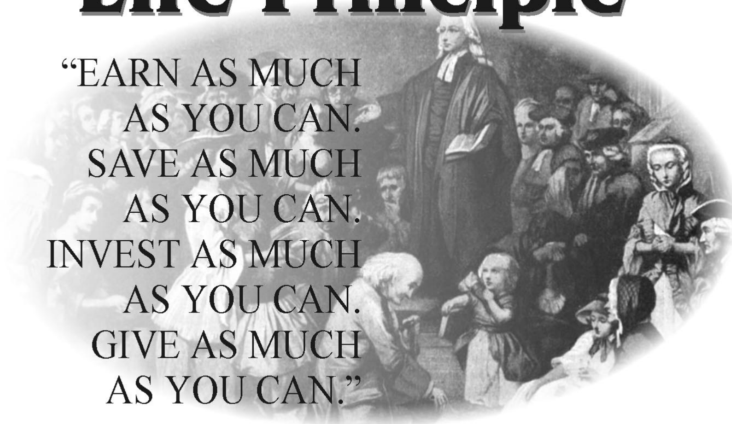
The Scott expedition reached the South Pole on January 18, 1912, only to discover that a marker was left there one month earlier by Roald Amundsen, a Norwegian explorer. Disheartened, Scott's men retraced their journey while fighting a blizzard. When the weary men arrived at the cache, the tin had turned to powder and their kerosene fuel had leaked through the seams. The desperate men raced to the next cache. The cans there were empty, too. The entire expedition party froze to death. They perished partly because of the little known fact that tin turns brittle in extremely cold temperatures.



Roald Amundsen

The next lesson provides an inside look at "the Mad Hatter."

Life Principle



—John Wesley