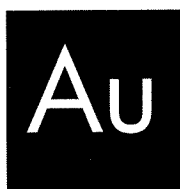


GOLD

IA												VIII A					
H	He											III A	IV A	V A	VIA	VII A	VIII A
Li	Be											B	C	N	O	F	Ne
Na	Mg	III B	IV B	V B	VIB	VII B	VIII B			IB	II B	Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq					
* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																	
† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																	



Gold is considered the most precious of metals. Its value as money, in the form of gold coins and bars, is well known. It is traded in commodities exchanges, and the fluctuations in its price are considered an index of the health of the economy. Many countries use it as a standard for their monetary systems.

In its pure state, gold is one of the most beautiful of elements. With its bright yellow color and resistance to corrosion, it has been highly prized since ancient times. Its chemical symbol comes from the Latin word *aurum*, which means “shining dawn.” Its name has even older roots, coming from the Sanskrit word *jval* and the Anglo-Saxon word *gold*, both meaning “gold.”



Gold is one of the most valuable and precious metals. The discovery of gold in California in 1849 attracted thousands of people who hoped to strike it rich.

Atomic Number 79

Chemical Symbol Au

Group IB—Transition
Element (Precious Metal)

In nature, gold is usually found as a pure metal, most often in the form of nuggets or flakes. It also occurs in veins of pure gold or deposits of a class of minerals called tellurides. It is fairly widely distributed throughout the world and is always found near deposits of quartz and pyrite. Most of the world's supply of gold comes from South Africa, and about two-thirds of the gold produced in the United States comes from Nevada and South Dakota. Gold is also found in seawater but in quantities too small to recover profitably.

The legendary gold rushes of California and Alaska have become an important part of the early history of the American West. The technique of panning for gold depends on its density, which is approximately nine times greater than that of sand or gravel. When the forty-niners swirled gold-bearing sand around in their shallow pans, the sand and gravel were washed over the rim, leaving the heavier gold dust behind.

Gold can also be recovered from its ore by treating the ore with mercury. Gold dissolves in mercury to form an amalgam, or alloy of mercury with another metal, that is similar to the amalgam used by dentists to fill teeth. The gold is then recovered by heating the amalgam and distilling away the mercury. Still another method of recovering gold is to treat its ore with a cyanide solution. Large ponds of cyanide solution are used in the extraction process. The gold dissolves in this solution to form a gold-cyanide ion. This solution is then separated from the residual ore by filtration, and the gold is recovered by treating the gold-cyanide with a more active metal, such as zinc, which displaces it from its complex with cyanide.

Gold can sustain its wonderful luster because it is one of the most unreactive of metals. Even concentrated nitric acid will not attack it. Gold will, however, dissolve very slowly in the solution of hydrochloric and nitric acids that was called aqua regia by the alchemists because of its ability to dissolve the king of metals.

Gold is very soft and is the most ductile and malleable of all metals. The gold leaf used for decoration is made by pounding



*Solid bars of gold.
Because gold is one of
the most unreactive of
metals, it can sustain its
brilliant luster.*



Modern hotels with large windows use glass coated with a thin film of gold to counter the greenhouse effect and prevent their lobbies from becoming overheated.

the metal into very thin sheets, which are often so thin that light can be seen through them. It has been estimated that one ounce of gold can be flattened to cover an area of 300 square feet. A stack of 10,000 gold leaves is only one millimeter thick.

Gold's resistance to corrosion and its ability to reflect infrared radiation and prevent excessive heating make it an excellent coating for space vehicles. Modern hotels with large windows use glass coated with a thin film of gold to counter the greenhouse effect and prevent their lobbies from becoming overheated. Dentistry and electronics are two other areas in which the chemical inertness of gold is of great value. Gold teeth can last for decades, and gold-coated switches and connectors remain efficient after years of electrical sparking, which always accompanies the opening and closing of switches.

The purity of gold is measured in carats. Pure gold is said to be 24-carat gold. Because gold is very soft, however, most gold jewelry, such as rings and necklaces, is made of 18-carat gold. This means that the object is only 75 percent gold. The remainder of the alloy is usually a metal such as nickel or copper added to the gold to harden it. The "white gold" used in jewelry is an alloy of nickel and gold. A radioactive isotope of gold, with a relatively short half-life of 2.7 days, is used for treating cancer. Known as gold-198, it is easily made by subjecting natural gold to a beam of neutrons in a nuclear reactor.

IA												VIII A							
H	He											B	C	N	O	F	Ne		
IIA												IIIA		IVA	VA	VIA	VIIA	VIII A	
Li	Be											Al	Si	P	S	Cl	Ar		
III B		IV B	V B	VI B				VII B		VIII B		IB	IIB						
Na	Mg	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq							
* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																			
† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																			

Hg

Mercury is the only metal that is liquid at room temperatures. It is an extremely heavy metal with a silvery-white color that accounts for the name quicksilver that is often given to it. It is a fairly good conductor of electricity but, unlike most metals, is a rather poor conductor of heat.

Mercury is rarely found as a pure metal in nature. Its chief ore is cinnabar, a bright red mineral that is also called vermilion. Cinnabar is composed of mercury sulfide and is found chiefly in Spain and Italy. Spain has mercury mines that have been operating continuously for the past 2,000 years. Metallic mercury is recovered from cinnabar by heating the ore in air and condensing the mercury vapor.

Mercury was well known to the ancient Chinese, and samples of the element have been found in Egyptian tombs dating back to 1500 B.C. It takes its name from the planet Mercury and its chemical symbol from the Latin word *hydragyrum*, which means "liquid silver."

Mercury freezes at -38.9°C and boils at 357°C , making it a liquid over a very wide and convenient range of temperatures. This accounts for its many uses in homes and scientific laboratories. Some common household products that contain mercury are thermometers, barometers, thermostats, silent wall switches, and fluorescent bulbs. Industrial applications of mercury include diffusion pumps that are used to produce powerful vacuums by efficiently evacuating the air from systems and mercury vapor lamps that generate the bluish-white light from streetlights.

An interesting property of mercury is its high surface tension. If, for example, you break a thermometer, the mercury that escapes from it forms little balls that roll around without adhering to

MERCURY

Atomic Number **80**

Chemical Symbol **Hg**

Group **IIB—Transition Element**

Mercuric nitrate was once used in the manufacture of felt hats. Workers in contact with this compound gradually began to develop serious problems—including loss of memory. This led to the common expression “mad as a hatter” for bizarre behavior.

anything and are hard to collect. A more useful property of mercury is its ability to dissolve other metals to form alloys known as amalgams. Dentists often use a silver-mercury amalgam to fill teeth. A silver filling actually consists of powdered silver dissolved in mercury. Gold also dissolves in mercury, and mercury is used to recover gold from its ore. The resulting gold-mercury amalgam is then heated until the mercury vaporizes, leaving behind the pure metallic gold. The mercury vapor can be condensed and reused.

Mercury is an extremely toxic element. Like many of the heavy metals, it combines chemically with enzymes in the body, causing them to lose their ability to act as catalysts for vital body functions. It is easily absorbed into the body from the gastrointestinal tract and can even enter the body through the skin. Because mercury is quite volatile, care must also be taken to avoid breathing its vapors even at room temperature. The vapor is much more harmful than the metal itself. It has been estimated that the vapors from a quantity of mercury as small as a teaspoon would saturate a fairly large room within a week and make it unsafe to work in.

Mercury is a major hazard for chemists working in laboratories, since small amounts are inevitably spilled during many chemical procedures. The mercury usually ends up in small cracks in the floor or laboratory bench, and is difficult to remove. The usual technique to lessen the danger is to sprinkle sulfur on the mercury. Not only does this reduce the production of mercury vapor, but the sulfur combines with the mercury to form a sulfide which is less dangerous.

Mercury acts as a cumulative poison, which means that small amounts absorbed over a long period build up in the body and can eventually become hazardous. A compound of mercury, mercuric nitrate, was once used in the manufacture of felt hats. Workers in contact with this compound gradually began to develop serious problems, including the loss of hair and teeth, loss of memory, and a general deterioration of the nervous system. This led to the common expression “mad as a hatter” for bizarre behavior.

The very properties that make mercury poisonous to humans make it effective in dealing with insect pests. Mercuric chloride (HgCl_2), for example, known commercially as corrosive sublimate, is a poison used as a fungicide and pesticide. Mercurous chloride (HgCl) is not quite as soluble as the mercuric form of the chloride, and so is not quite as toxic. It is called calomel and is used in agriculture to control root maggots and other pests on tubers and bulbs. Although no longer used in medicine, calomel was once used as a purgative and as a treatment for syphilis. Because

compounds of mercury are so damaging, a major effort is currently underway to eliminate all sources of pollution by this element. Many mercury-containing compounds have been banned in industry and agriculture.

The extent of the problem involving the contamination of the environment with mercury became clear when it was discovered that certain microorganisms living in lakes and rivers can actually metabolize mercury. Mercury-containing compounds that were discharged into these waters were taken up by these microorganisms and chemically changed to methylmercury compounds. Fish feeding on these microorganisms then began to accumulate these compounds in their tissues. By the time a fairly large fish came to the market for human consumption, the concentration of mercury that had built up in the fish was estimated to be as large as forty to fifty thousand times the concentration of mercury in the water itself. Major efforts are now underway to curtail the discharge of mercury-containing compounds into rivers and lakes, and to try to clean up areas where damage has already been done.

Although not generally considered a poison, an unusual compound of mercury known as mercury fulminate is extremely dangerous in another way because it is an unstable explosive. Commercially, it is used for making blasting caps.

Mercury batteries have become quite common in many portable electronic devices. The mercury battery consists of a zinc anode and a mercuric oxide cathode. The battery develops a voltage of about 1.35 volts and has the advantage of providing a constant voltage even as it ages.

Mercury is sold and traded on world markets in units called "flasks." One flask is equal to 76 pounds.

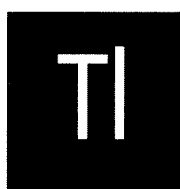
THALLIUM

Atomic Number **81**

Chemical Symbol **Tl**

Group **IIIA—Post-transition Metal**

IA																		VIII A	
H	He																	He	
IIA												IIIA		IVA	VA	VIA	VIIA	VIIIA	
Li	Be											B	C	N	O	F	Ne		
III B		IV B	V B	VI B		VII B			IB	II B									
Na	Mg										Al	Si	P	S	Cl	Ar			
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub						Uuq		
* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																			
† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																			



Thallium is a soft, heavy metal that resembles lead in appearance. Unlike lead, it is soft enough to be cut with a knife. It is also very malleable. It was discovered in 1861 by Sir William Crookes, who identified it by the brilliant green spectral line of its emitted light. The element was named for this line, using the Greek word *thallos*, which means “a green twig” or “shoot.”

Thallium is a rather scarce element. It is found sparsely distributed in several mineral ores such as crookside, lorandite, and hutchinsonite and also in manganese nodules distributed on the floor of the ocean. Since the extraction of thallium from these ores can be difficult, a more common source of the metal is as a by-product of lead and zinc refining.

Thallium is quite active and slowly corrodes when exposed to air. It reacts with the oxygen in the air to form a heavy gray oxide, which eventually flakes off to expose a fresh surface of the metal that is subject to further oxidation.

Thallium and its compounds are extremely toxic, and there is also evidence that thallium is carcinogenic. Even its contact with the skin can be dangerous, although thallium in extremely low concentrations has been used to treat skin disorders such as ringworm. Thallium sulfate is an odorless and tasteless poison that was formerly used to kill rats and insects, but it has now been banned in the United States.

Neither thallium nor its compounds have many commercial applications. The electrical conductivity of some compounds of thallium, such as thallium sulfide, changes when they are exposed to infrared radiation, and this property has made these compounds useful in some types of photoelectric cells and infrared detectors.

A radioactive isotope of thallium, thallium-201, is now being used to diagnose various types of disease. The isotope has a half-life of only 72.9 hours, so that it is quickly eliminated from the body. Also of great importance is the fact that when thallium decays it emits very penetrating gamma rays that can be detected outside the body.

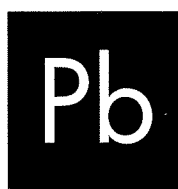
The technique depends on the “binding” of thallium-201 to the muscle tissue of the heart. This binding will occur, however, only if the tissue receives an adequate supply of blood. If the blood supply is restricted due to a narrowing or blockage of an artery, for example, the tissues supplied by the artery will not take up the thallium-201.

The radioisotope is usually administered first while the patient is at rest, and then after the patient is subjected to a period of exercise. The patient is scanned with a scintillation detector, a kind of “gamma ray camera” that can detect and identify gamma rays, both before and after the exertion. The resulting data are then fed into a computer that produces an image on screen. The physician can then compare the thallium-201 uptake before and after the exercise. An area of the heart that has impaired blood flow, for example, will show up on the screen as a dark spot.

Thallium was discovered in 1861 by Sir William Crookes, who identified it by the brilliant green spectral line of its emitted light.

LEAD

IA																		VIII A						
H	IIA																							He
Li	Be											III A						IV A	V A	VIA	VII A	Ne		
Na	Mg	III B	IV B	V B	VIB	VII B	VIII B				IB	II B	Al	Si	P	S	Cl	Ar						
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr							
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe							
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn							
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub							Uuq						
		* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																						
		† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																						



Lead is a relatively soft, dull-gray metal that is highly malleable and can be easily worked to make utensils of all kinds. It is a poor conductor of electricity. Lead has an ancient history.

Lead coins and sculpture have been found in Egyptian tombs dating back to 5000 B.C., and lead pipes and plumbing used by the Romans can still be found in Italy today. The alchemists associated lead with the planet Saturn and not only believed lead to be the oldest metal but also believed that all other metals eventually transformed themselves into lead. It is also mentioned in the Bible in Exodus and the Book of Job. The element takes its name from the Anglo-Saxon word *lead*, and its chemical symbol from the Latin word for the element, *plumbum*. The word *plumbing* is derived from this Latin word because of the Roman use of lead pipes for conducting water.

Lead is sometimes found as a pure metal in nature, but this form of the element is rather scarce. The most common ore of lead is galena, which consists of lead sulfide. The crushed ore, mixed with carbon, is roasted in a furnace and easily yields the metal.

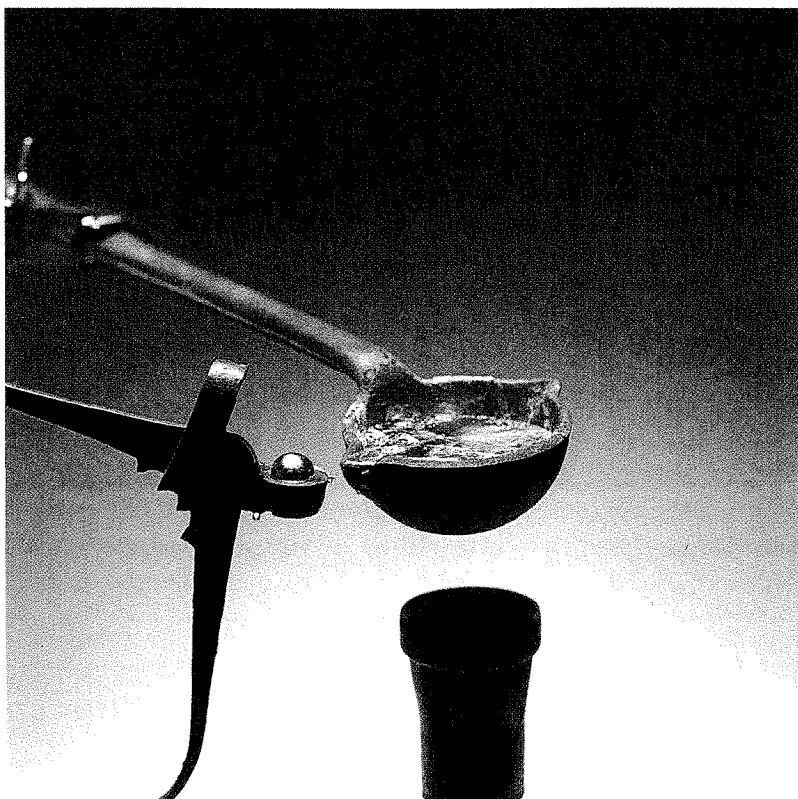
Most of the lead produced in the United States is used to make the electrodes of lead storage batteries. The anode, or positive terminal, of the lead storage battery is made of a very porous form of lead called spongy lead. The cathode, or negative terminal, is made by packing a paste of lead oxide, called litharge, into a lead metal grid.

Lead is an important component of the solder used for making electrical connections on the circuit boards in computers and television sets. The glass screens of TV sets also contain lead to shield the viewer from radiation. In fact, every TV set and

Atomic Number **82**

Chemical Symbol **Pb**

Group **IVA**



Molten lead being formed into a musket ball.

computer contains about one-half pound of lead. The disposal of this lead poses a major environmental problem. The U.S. Environmental Protection Agency estimated that approximately 50,000 tons of lead from consumer electronic products were discarded in 1991. This figure represents a good share of the total amount of lead stored in municipal solid-waste disposal sites.

Many compounds of lead are used as paint pigments because they are insoluble. Chrome yellow (lead chromate), red lead (lead oxide), and white lead (a basic lead carbonate) are all common pigments used to color paint. The use of lead in paint is now being restricted in many communities, however, because lead compounds have been found to be cumulative poisons. This means that the body retains the lead, and even small doses accumulated over a long period can be dangerous. Like many heavy metals, lead disables the enzymes in the body that are catalysts for essential biochemical reactions. In time, this can cause irreversible damage to the brain, liver, and kidneys. The lead poisoning of children living in tenements, caused by their eating flaking lead-based paints, has been a particularly serious problem.

“Leaded” gasoline has also been recognized as a health hazard, and its use has been curtailed in the United States. Such

Lead takes its chemical symbol from the Latin word for the element, plumbum. The word plumbing is derived from this Latin word because of the Roman use of lead pipes for conducting water.

gasoline contains lead tetraethyl as an additive to suppress engine “knocking,” or detonation of the fuel-air mixture before it is fully compressed. Lead is also prohibited in the fuel for modern automobiles because it “poisons” the catalysts used in catalytic converters. In addition to this, lead shot used for hunting has become illegal in many areas of the country. This action was necessary because waterfowl such as ducks and geese injured by birdshot showed high concentrations of lead in their bodies and were thought unsafe to eat. Despite their possible hazards, however, lead water pipes continue to be used throughout the world.

Lead oxide is still used to produce a very heavy fine glass called crystal. This glass has a high index of refraction, which means that it can bend light rays at sharp angles. When cut in a way that gives it many faces and angles, crystal glass sparkles with a characteristic brilliance.

Among other uses, lead is mixed with other metals to make the metal used for printing type and is used to make the lead bricks commonly employed as a radiation shield around nuclear reactors and X-ray machines, because the dense metal absorbs radiation very effectively.

Lead has many isotopes. Some are end products of the decay of naturally occurring radioactive elements such as uranium and thorium. Because the half-life of uranium is many billions of years—the same order of magnitude as the age of the Earth—geologists can use the concentration of lead isotopes in uranium-bearing rocks to determine the age of those rocks.

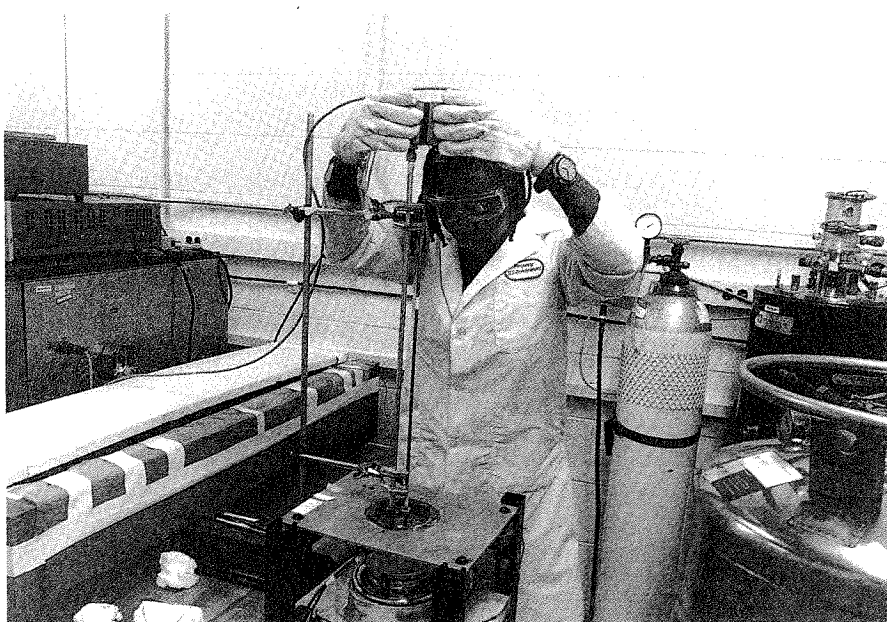
IA												VIII A					
H	He											III A	IV A	V A	VIA	VII A	VIII A
Li	Be											B	C	N	O	F	Ne
Na	Mg	III B	IV B	V B	VIB	VII B	VIII B			IB	IIB	Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq					
		* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu															
		† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr															

Bi

Bismuth is a white, heavy, brittle metal that has a slight yellowish tinge. It is the last element in Group VA and is fairly resistant to corrosion. When heated in air, it burns with a blue flame to produce yellow clouds of its oxide.

Bismuth has been known since the early 15th century but was long confused with tin and lead. Although its discovery is not well documented, Claude Geoffroy the Younger, a French nobleman, is usually credited with its identification in 1753. It derives its name from the German *weisse masse*, which means “white mass.”

Bismuth is sometimes found in its metallic state in nature but more often in its principal ores, bismite (bismuth oxide) and



A technician at Argonne National Laboratory tests a sample of a powder that uses bismuth as a strength-enhancing agent.

BISMUTH

Atomic Number **83**

Chemical Symbol **Bi**

Group **VA**—Post-transition Metal

Bismuth derives its name from the German weisse masse, which means “white mass.”

bismuth glance (bismuth sulfide). It is often found in the company of copper, tin, and lead, and in the United States is usually recovered as a by-product of the refining of these metals.

Bismuth subnitrate has been used in medicine as an antacid in the treatment of ulcers. Bismuth oxide is a popular yellow pigment used in cosmetics.

Like water, bismuth is one of the few substances that expands when it changes from a liquid to a solid. This property is used to make alloys whose volume remains constant when they solidify. Metals alloyed with bismuth, for example, can be used for casts and molds that retain their exact dimensions even when filled with molten metals. Bismuth alloys with low melting points, such as Wood’s metal—an alloy of bismuth, lead, tin, and cadmium—are used in fire alarms and sprinkler systems, and similar alloys are used as electrical fuses. Excessive electric current produces enough heat to melt these alloys, setting off fire alarms and sprinklers, and breaking the circuit, through an electrical fuse, thus preventing damage to the electrical system.

IA												VIII A					
H	He											B	C	N	O	F	Ne
Li	Be											Al	Si	P	S	Cl	Ar
Na	Mg	III B	IV B	V B	VIB	VII B	VIII B			IB	IIB	Ga	Ge	As	Se	Br	Kr
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq					
* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																	
† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																	

Po

The discovery of polonium by Marie and Pierre Curie in 1898 defines one of the great moments in the history of science. Their discovery of this element led to the modern concept of the atomic nucleus and an understanding of its structure.

The Curies were looking for the source of the radioactivity in the uranium-bearing mineral pitchblende. What puzzled them was that removing the uranium from this mineral still left radioactivity in the pitchblende. Their research finally led them to isolate two new elements, the first of which was polonium and the second, radium.

Polonium was named for Poland, the native country of Marie Curie. It is sometimes referred to by its older name, radium F. It is a rare element, formed chiefly through the decay of radioactive uranium and thorium. It is found in uranium mines in concentrations as low as 100 millionths of a gram per ton of ore. Polonium has 27 known isotopes, more than any other element, and all of them are radioactive.

The most common such isotope, and the one most readily available, is polonium-210. It has a



Marie Curie was awarded the Nobel Prize for chemistry in 1911 for the discovery of polonium and radium in 1898.

POLONIUM

Atomic Number **84**

Chemical Symbol **Po**

Group **VIA—Metalloid**

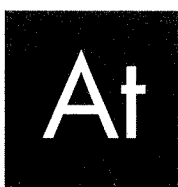
Polonium was named for Poland, the native country of its discoverer, Marie Curie.

half-life of only 138 days, making it approximately 5,000 times more radioactive than radium. Polonium-210 is quite dangerous, and great care has to be taken in handling even small amounts of this isotope.

Polonium-210 is a silvery metalloid that is quite volatile. It will almost completely vaporize at temperatures as low as 60°C. Its scientific and commercial uses are chiefly related to its radioactivity. As it decays, it emits alpha particles, each of which is essentially the nucleus of a helium atom, consisting of two protons and two neutrons. When an atom of polonium-210 ejects an alpha particle, it is changed, or “transmuted,” into lead-206, a stable isotope of lead.

Small amounts of polonium-210 are occasionally used on dust-removal brushes to remove the static electric charge that forms on photographic film. In this application, the radiation emitted by the polonium ionizes the air through which it passes, and the resulting ions neutralize the electric charge on the film. In radiological laboratories, polonium-210 mixed with powdered beryllium is often used to produce large amounts of neutrons without the use of a nuclear reactor. The alpha particles emitted by the polonium enter the beryllium nucleus, initiating a nuclear reaction that causes the beryllium to emit neutrons. A special license issued by the U.S. Nuclear Regulatory Commission is required to operate this neutron source. The Nuclear Regulatory Commission has also established a quantity of 0.8 million millionths of a gram as the maximum allowable amount of polonium-210 that can be ingested. This makes polonium-210 approximately 100,000 million times more toxic than cyanide.

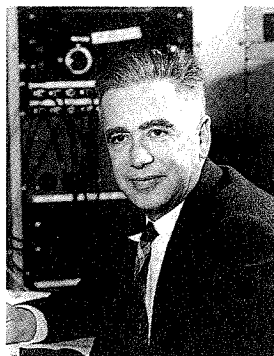
IA												VIII A					
H	He											B	C	N	O	F	Ne
Li	Be											Al	Si	P	S	Cl	Ar
Na	Mg	III B	IV B	V B	VIB	VII B	VIII B			IB	IIB	Ga	Ge	As	Se	Br	Kr
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq					
* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																	
† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																	



All 20 of the known isotopes of astatine are radioactive, and the element is very short-lived. The isotope with the longest half-life is astatine-210, with a half-life of only 8.3 hours.

Astatine was first made in 1940 by a team of radiochemists at the University of California at Berkeley. The principal members of the team were Dale R. Corsun, K. R. Mckenzie, and Emilio Segrè. They produced astatine by bombarding bismuth with alpha particles. They named the element from the Greek word *astatos*, which means “unstable.”

Small quantities of astatine are produced naturally as the decay products of isotopes of uranium and thorium. The total amount of astatine estimated to be present in the Earth’s crust at any one time is approximately one ounce. Only about 1 millionth of a gram of astatine has actually been produced artificially, and it is therefore not surprising that little is known about its properties. Astatine is a member of the halogen family, located just below iodine in Group VIIA of the periodic table, so that its chemistry should be fairly similar to that of iodine. There seems to be some evidence that astatine is slightly more metallic than iodine and that, like iodine, it is probably taken up by the thyroid gland.



Emilio Segrè was part of the team that created astatine in 1940.

ASTATINE

Atomic Number **85**

Chemical Symbol **At**

Group **VIIA—The Halogens**

RADON

Atomic Number **86**

Chemical Symbol **Rn**

Group **VIIIA—The Noble Gases**

IA												VIIIA																																	
H	He																																												
IIA												VIIA																																	
Li	Be											B	C	N	O	F	Ne																												
III		VIII										VI																																	
Na	Mg	Al	Si	P	S	Cl	Ar																																						
IV		VII										V																																	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr																												
V		VI										IV																																	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe																												
VI		VII										III																																	
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn																												
VII		VIII										II																																	
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq																																	
<table border="1"> <tr> <td>* Ce</td><td>Pr</td><td>Nd</td><td>Pm</td><td>Sm</td><td>Eu</td><td>Gd</td><td>Tb</td><td>Dy</td><td>Ho</td><td>Er</td><td>Tm</td><td>Yb</td><td>Lu</td> </tr> <tr> <td>† Th</td><td>Pa</td><td>U</td><td>Np</td><td>Pu</td><td>Am</td><td>Cm</td><td>Bk</td><td>Cf</td><td>Es</td><td>Fm</td><td>Md</td><td>No</td><td>Lr</td> </tr> </table>																		* Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	† Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
* Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu																																
† Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr																																

Rn

Radon is a gas with 20 known isotopes, all of which are radioactive. It is produced as one of the by-products of the radioactive decay of uranium and thorium, and it is the heaviest known gas, being about eight times heavier than air. As a noble gas, it is chemically unreactive.

Radon was discovered by the German physicist Friedrich Ernst Dorn in 1900 while studying the decay products of radium. He named it radium emanation because the gas seemed to come from the radium. William Ramsay and R. W. Whytlaw-Gray, two early investigators of the chemical properties of radon, later changed its name to niton, from the Latin word *nitens*, which means “shining.” Since 1923, however, the element has been called radon.

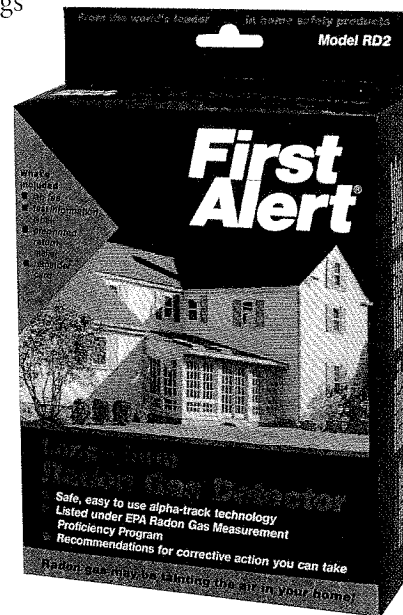
Radon-222 is the longest-lived isotope of radon, with a half-life of 3.82 days, and it is the isotope most generally available and studied. Radon-222 is found in substantial concentrations as a gas in the soil because trace amounts of uranium are present throughout the Earth’s crust. The gas diffuses through the soil and into the air. The amount of radon in the air varies from one region to another, but it is considered a potential hazard in many homes in certain areas. The gas can diffuse into the home through basement floors and walls because pressure inside the house is always lower than outside. Without a constant interchange of fresh air from outside for air within the house, radon can build up to dangerous concentrations. This situation is particularly critical during the winter months when windows are likely to be kept shut. Inexpensive detectors are available to measure the amount of radon present in a home.

As early as the 16th century, it was known that uranium miners in Bohemia often died prematurely from diseases of the

lung. We now know that the miners suffered from lung cancer caused by radon. As it decays, radon-222 emits alpha particles, which are essentially the nuclei of helium atoms, and simultaneously initiates a decay process that eventually produces lead-210. When radon-222 is inhaled, some of it will decay in the lungs before it can be exhaled. Exhaling removes much of the radon-222, but the decay product, lead-210, is also radioactive and settles in the lung. Its half-life of 20.4 years is much longer than that of radon-222, and it is not eliminated during breathing. It is this lead-210 that exposes the lungs to radiation for long periods and can produce lung cancer. Health officials in the United States have estimated that approximately 10 percent of all lung cancers are caused by radon.

Smoking a cigarette poses a radiation risk as well as a chemical one. While it is growing, tobacco is subject to contamination by radon from the soil, and the phosphate fertilizers used by planters are rich in uranium. As a result, the broad tobacco leaves become dusted with trace amounts of lead-210, and when this leaf is burned, the inhaled smoke subjects the smoker to levels of radiation 1,000 times higher than those encountered by a worker in a nuclear power plant.

Despite the advances made in radiation therapy through the use of particle accelerators and isotopes such as cobalt-60, radon is still used in many hospitals for cancer therapy. It is usually pumped from a radium source and sealed into tiny glass vials called "seeds," which are implanted in patients at the sites of tumors.



Many homeowners, increasingly aware of the dangers posed by the presence of radon in homes, have installed radon detectors to warn them of potentially harmful levels of the gas.

FRANCIUM

Atomic Number **87**

Chemical Symbol **Fr**

Group **IA**—The **Alkali Metals**

IA	IIA												IIIA	IVA	VA	VIA	VIIA	VIII
H	Li	Be											B	C	N	O	F	Ne
Na	Mg	IIIB	IVB	VB	VIB	VIIIB					IB	IIB	Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq						

*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
†	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



Francium is the heaviest of the alkali metals, and one of the most unstable known. All of its isotopes are radioactive, yet even its longest-lived isotope, francium-223, has a half-life of only 21 minutes. Of its 30 known isotopes, only francium-223 exists in nature. All of the other isotopes of francium are produced artificially in accelerators and nuclear reactors and are too unstable to be studied in any depth. The element was discovered in 1939 by Marguerite Perey, working at the Curie Institute in Paris. It is named for France, the country in which it was discovered.

Francium is produced by the radioactive decay of the elements uranium and thorium. It has been estimated that because of its short half-life, the Earth's crust contains less than one ounce of francium.

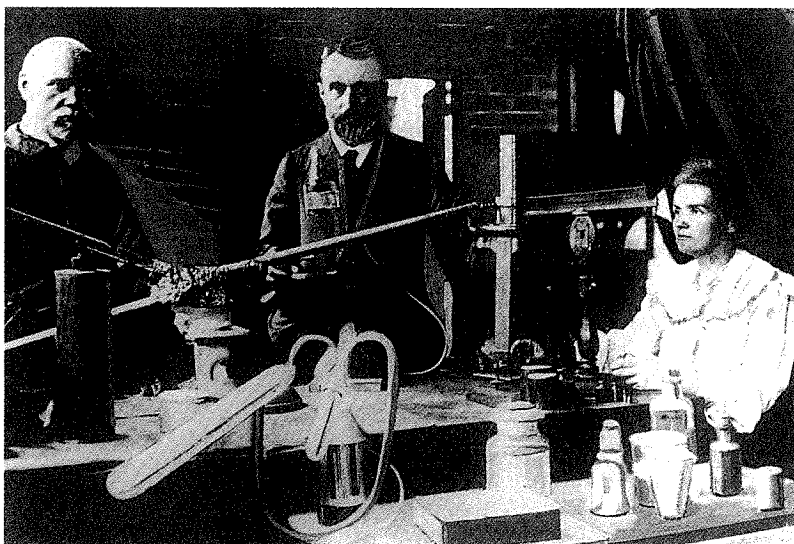
IA																	VIIIA																														
H																	He																														
IIA											IIIA	IVA	VA	VIA	VIIA	VIII																															
Li	Be											B	C	N	O	F	Ne																														
IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB																																						
Na	Mg									Al	Si	P	S	Cl	Ar																																
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr																														
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe																														
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn																														
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub																																				
<table border="1"> <tr> <td>*</td> <td>Ce</td> <td>Pr</td> <td>Nd</td> <td>Pm</td> <td>Sm</td> <td>Eu</td> <td>Gd</td> <td>Tb</td> <td>Dy</td> <td>Ho</td> <td>Er</td> <td>Tm</td> <td>Yb</td> <td>Lu</td> </tr> <tr> <td>†</td> <td>Th</td> <td>Pa</td> <td>U</td> <td>Np</td> <td>Pu</td> <td>Am</td> <td>Cm</td> <td>Bk</td> <td>Cf</td> <td>Es</td> <td>Fm</td> <td>Md</td> <td>No</td> <td>Lr</td> </tr> </table>																		*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	†	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu																																	
†	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr																																	

Ra

Radium was discovered in 1898 by the Polish-born French chemist Marie Sklodowska Curie and her husband, Pierre Curie. Along with the discovery of the electron and Einstein's theory of relativity, the discovery of radium

marked the beginning of the modern era in science.

In their investigation of the radioactive properties of a uranium-bearing mineral called pitchblende, the Curies discovered that removing the uranium from the pitchblende still left it radioactive. Working with tons of the ore, they finally separated out a radioactive mixture that seemed to consist chiefly of barium. The barium was used as a precipitating reagent for polonium and other elements in the ore. When the mixture was heated in a flame to produce spectral lines, the Curies saw a totally unexpected, beauti-



Marie Curie, with her husband, Pierre (center), and their laboratory assistant work with a device used to measure radioactivity.

RADIUM

 Atomic Number **88**

 Chemical Symbol **Ra**

 Group **IIA—The Alkaline-Earth Metals**

Radium was discovered in 1898 by Marie Curie and her husband, Pierre Curie. They named it radium from the Latin word radius, meaning “ray.”

ful red color in addition to the colors normally associated with barium. The newly discovered spectral line corresponded to a new element. The Curies named it radium from the Latin word *radius*, meaning “ray.” They also discovered the element polonium in the same way.

It took the Curies four more years to obtain a pure sample of radium, which they isolated from a solution of radium chloride by electrolysis. In 1911, Marie Curie was awarded the Nobel Prize in chemistry for her discovery of these elements. It was her second Nobel Prize; she had shared the first with her husband and the French scientist Henri Becquerel in 1903 for the discovery of radioactivity.

Radium is the last member of the alkaline-earth elements, and like them it is a metal. The pure metal has a brilliant white color and is so luminescent that it glows in the dark, giving off a faint blue color. Before the dangers of radioactivity were understood, radium was used to make luminous paints for the dials of watches and clocks so that they could be read in the dark. The “rays” emanating from radium probably served as the reason for choosing the Latin equivalent of “ray” for its name. The element darkens when it is exposed to air, forming a compound with nitrogen called a nitride. It also reacts with water, decomposing it and forming radium hydroxide. In research or medicine, radium is usually used in the form of a salt such as radium chloride.

Radium is present in all uranium-bearing ores because it is one of the decay products of uranium. About one gram of radium is present in every seven tons of pitchblende, deposits of which are found in the Czech Republic and Slovakia and parts of Africa. Deposits of uranium ore are also found in the United States, chiefly in Utah and New Mexico. The total world production of radium amounts to not much more than five pounds annually.

Radium has 25 known isotopes. The most common, and the one discovered by the Curies, is radium-226. It has a half-life of 1,630 years. The international unit of measurement of all radioactive substances is called the curie, in honor of the Curies, and uses radium-226 as its standard. One curie of radiation is defined as the radioactivity of one gram of radium-226. This corresponds to 37 billion radium nuclei disintegrating in one second. Most radioactive materials used in schools for demonstrations have much lower levels of activity, generally in the microcurie range. (The prefix *micro* means one-millionth.)

Radium is used in many medical facilities to generate the radioactive gas radon, which is used for cancer therapy.

IA																	VIIIA
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg	IIIB	IVB	VB	VIB	VIIIB	VIII B			IB	IIB	Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub				Uuq		

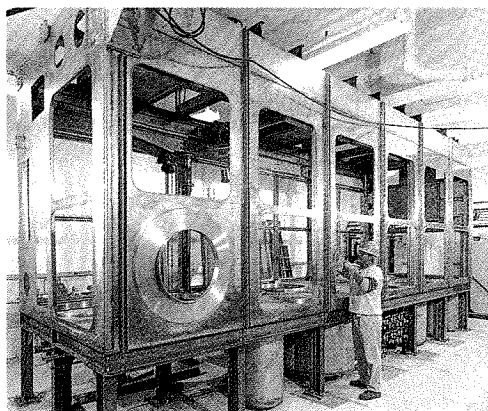
* Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
† Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Ac

Actinium is a radioactive element produced naturally by the radioactive decay of the long-lived elements uranium and thorium. Very small amounts of it have been produced artificially, and it has very limited commercial or scientific application.

Actinium is a metal, and like radium it glows in the dark. Its name is taken from the Greek word *aktinos*, which means “ray” or “beam.” It was first discovered by the French scientist André Debierne in 1899 and then rediscovered independently by the German chemist Friedrich Otto Giesel in 1902.

There are 26 known isotopes of actinium and all are radioactive. The most important is actinium-227, a product of the decay of uranium-235. It has a half-life of 21.6 years. Its chemical properties resemble those of the rare earth element lanthanum. Actinium also resembles lanthanum in that it is the first element in the series of elements called the actinides, which are analogous to the lanthanides. The actinide series, sometimes called the Second Inner Transition



Actinide recycling at Argonne National Laboratory.

Series, contains the elements from actinium through lawrencium (atomic number = 103). Like the rare earths, these elements add electrons to an inner orbital shell, the second such shell from the outer, valence shell, and consequently have similar chemical and physical properties.

ACTINIUM

Atomic Number **89**

Chemical Symbol **Ac**

Group **IIIB—Transition Element (The Actinides)**