

IA												VIII A						
H	He											III A	IV A	V A	VIA	VII A	He	
Li	Be											B	C	N	O	F	Ne	
Na	Mg	IIIB	IVB	VB	VIB	VIIB					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																		

Sb

In its pure form, the metal antimony is a hard, brittle, grayish crystalline solid at room temperature. Although known as a metal, it is a poor conductor of electricity. The ore that serves as the primary source of antimony is the mineral stibnite

(antimony sulfide), which has been known for thousands of years. A black compound, stibnite was used in ancient times to darken women's eyebrows. The alchemists often experimented with stibnite, mistaking for lead the metal that it produced upon heating.

The chemical symbol for antimony, Sb, was taken from its original name, stibium, apparently named after the mineral stibnite. The word *antimony* is thought to be of Greek origin.

A major use of antimony is for the common safety match. An item that is now taken for granted, the safety match was invented by the Swedish chemist Jerry Eugene Lundstrom in 1855. The head of this match consists of a mixture of antimony trisulfide and an oxidizing agent such as potassium chlorate.



Antimony oxide, a flame retardant, is often added to the plastic used to make credit cards.

The tip of the match, above the head, contains red phosphorus that, when struck against a rough surface, ignites and generates enough heat to set fire to the head of the match, which bursts into flame.

Antimony has few other commercial uses. As an alloy, it can increase the hardness of many metals. Antimony oxide, a white salt, is often added to polyvinyl chloride, or PVC, in which it acts as a flame retardant. PVC is a plastic polymer that is used to make wastewater pipes, credit cards, and electrical insulation.

ANTIMONY

Atomic Number **51**

Chemical Symbol **Sb**

Group **VA—Metalloid**

TELLURIUM

Atomic Number **52**

Chemical Symbol **Te**

Group **VIA—Metalloid**

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	II B	Ga	Ge	As	Se	Br	Kr	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	In	Sn	Sb	Te	I	Xe	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	Hg	Tl	Pb	Bi	Po	At	Rn
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																



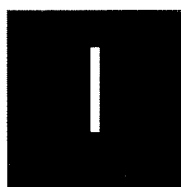
Tellurium is a rare, silvery-white metalloid belonging to the family of elements that includes such nonmetallic elements as oxygen and sulfur. It is not surprising then, that tellurium does not behave like a typical metal. It is very brittle, for example, and does not conduct electricity very well. And just as sulfur and oxygen can combine with other metals to form sulfides, tellurium combines with gold to form a telluride.

Tellurium is one of the few elements that combines with gold. The compounds it forms are called gold tellurides, and they make up a very important component of gold-bearing ores. As such, tellurium is often recovered as a by-product in the refining of gold. It is also found associated with copper-bearing ores and is therefore recovered as a by-product of the refining of copper as well.

The element was discovered in Germany in 1782 by an inspector of mines, Franz Joseph von Reichenstein, an amateur scientist, who was experimenting with ore he found in a gold mine in Transylvania. It was later named in Berlin from the Latin word *tellus*, meaning earth.

The chief use of tellurium is as an additive to such metals as copper and stainless steel to create an alloy that is easier to machine than the original metal.

IA																		VIIIA					
H																		He					
IIA																		VIIIA					
Li	Be																	B	C	N	O	F	Ne
III B		IV B	V B	VI B						VII 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												
* 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																							



Iodine is a violet-black solid that vaporizes to give a violet gas. It is found in seaweed and brine wells, as well as in the sea, in the form of inorganic salts and organic iodides. It is the heaviest element in the halogen family and is highly

reactive. Iodine was discovered in 1811 by Bernard Courtois, who noticed a purple vapor emanating from a sample of kelp to which he had added sulfuric acid. The color of the gas has determined its name, which is taken from the Greek word *iodēs*, meaning “violet-colored.”

Commercial quantities of iodine are usually recovered from the compound sodium iodate, which is contained in saltpeter, or potassium nitrate, mined in Chile. At one time Chile was among the largest producers of iodine. More recently, large quantities of iodine have been produced from the ashes of burned seaweed. The ocean contains large quantities of iodine concentrated in various kinds of seaweed, such as the giant kelp that grows off the coast of California. Iodine can also be recovered from the natural brines found in underground wells in Arkansas and Oklahoma. Chlorine gas is usually passed through the brine to liberate the iodine.

Although iodine is a poison, one of its most common uses is in the antiseptic solution known as tincture of iodine, which is a 50 percent solution of iodine in alcohol. Although tincture of iodine is no longer the antiseptic of choice for treating minor injuries to the skin, generations of children were subjected to the application of this stinging, dark-brown solution on minor bruises and scratches. Because iodine kills bacteria, campers often use it in the form of tablets or crystals to disinfect water. Iodine salts, such as potassium iodide, are produced in large quantities as additives

IODINE

Atomic Number **53**

Chemical Symbol **I**

Group **VIIA—The Halogens**

Iodine was discovered in 1811 by a scientist who noticed a purple vapor emanating from a sample of kelp to which he had added sulfuric acid. Iodine gets its name from the Greek word iodes, meaning “violet-colored.”

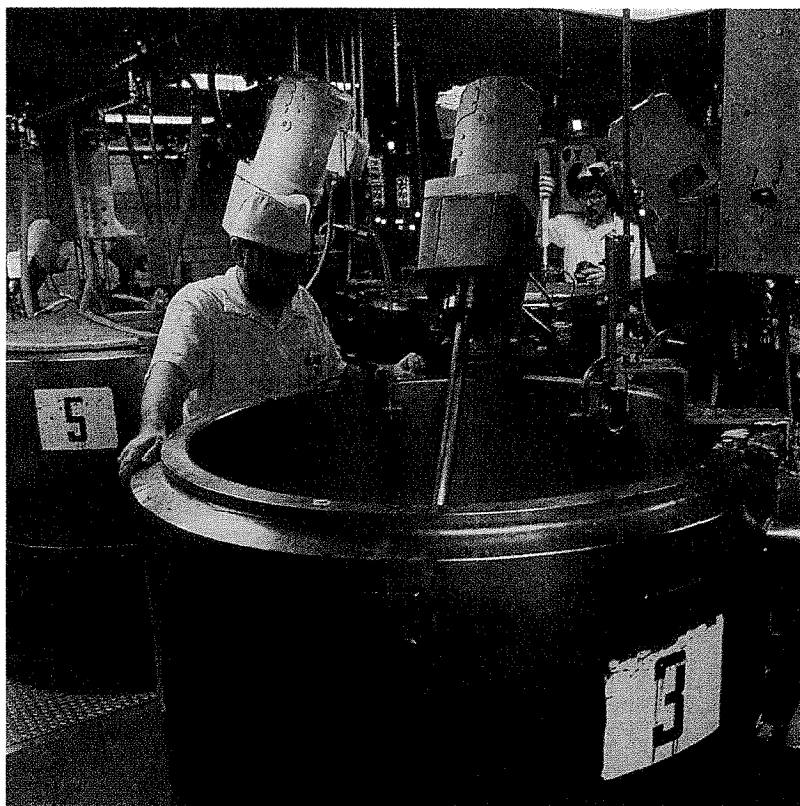
for table salt and animal feed and constitute an important dietary supplement for people who live inland and do not get enough food from the sea. This is done because iodine is an important constituent of the growth hormone thyroxine, produced in the thyroid gland, and therefore helps to ensure that the thyroid gland functions properly. A deficiency of thyroxine can result in the disease known as goiter. Iodized salt contains approximately 0.01 percent potassium iodide.

Iodine in the form of silver iodide is used in the preparation of photographic film and paper and as a cloud-seeding particle for rainmaking, as discussed in the section on silver. Silver iodide is a preferred agent for seeding clouds because it has the ability to form enormous numbers of tiny crystals. It has been estimated that one gram of silver iodide can form as many as 1 million billion seed crystals, which act as nuclei for raindrop formation.

A radioisotope of iodine, iodine-131, with a half-life of 8.1 days, is of great value in diagnosing thyroid diseases. It is usually administered in the form of a solution of radioactive sodium iodide that the patient drinks. Any iodine taken up by the body has a tendency to concentrate in the thyroid gland. Measuring the rate at which the gland takes up radioactive sodium iodide after the patient drinks a solution of it tells the physician how well the thyroid is functioning in the manufacture of thyroxine. Its half-life of eight days is short enough to ensure that most of the



Because iodine kills bacteria, campers often use it in the form of tablets or crystals to disinfect water.



Workers at Eastman Kodak prepare photographic film. Silver iodide is more sensitive to light than silver bromide and is used in the emulsions of high-speed black-and-white film.

iodine-131 in the solution will be eliminated from the body within several weeks.

The ability of iodine to concentrate in the thyroid gland also permits it to be used to treat severe illnesses of the thyroid, such as thyroid cancer. In this case, the radiation emitted by iodine-131 that concentrates in the thyroid gland destroys the cancer cells. This treatment causes minimum damage to other tissue and organs.

Small radioactive iodine pellets, the size of rice grains, are often used as a treatment for prostate cancer. With a half-life of 60 days, the iodine-125 isotope can deliver powerful doses of radiation to destroy the cancer and then disappear after several months. An isotope of palladium with a half-life of 17 days is also used for treatment. Hollow needles are used to carefully implant the tiny pellets into the prostate gland so that there is a minimum of damage to other organs of the body.

A popular chemistry demonstration uses iodine to detect starch. When iodine is applied to a potato, which is rich in starch, it turns a deep blue.

XENON

IA																	VIII A						
H																	He						
II A																	VIII A						
Li	Be																	B	C	N	O	F	Ne
III B	IV B	V B	VI B	VII B	VIII B	IX B	X B	XI B	XII B	III A	IV A	V A	VI A	VII A	VIII A								
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																							

Xe

Xenon is a noble gas that exists in the atmosphere in only trace amounts. One of the heaviest of the noble gas family, xenon has a density that is approximately five times that of air. Like the other gases in the family, it exists as a monatomic molecule that has no color, odor, or taste.

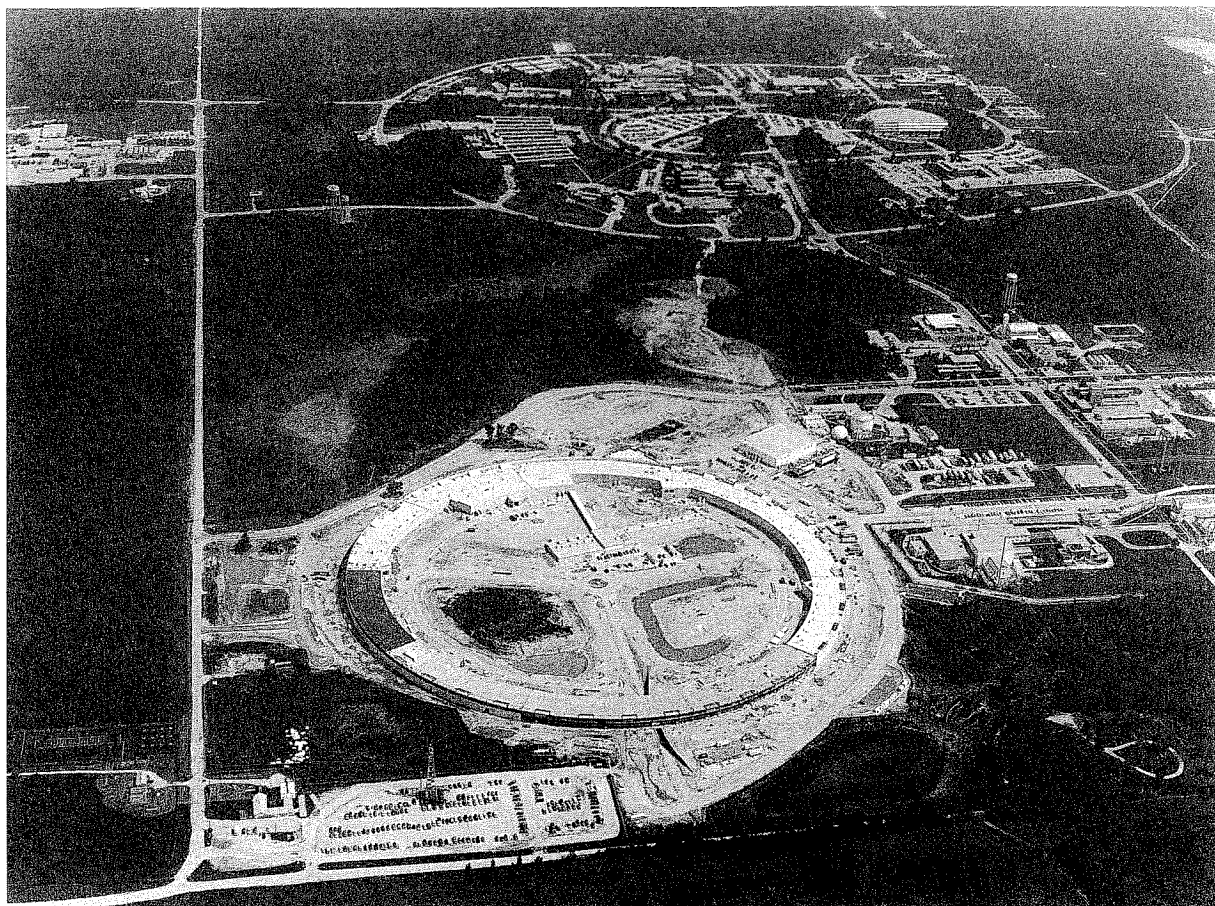
It was discovered by the English chemist Sir William Ramsay in 1898 and named by him. He chose the name from the Greek word *xenos*, which means the strange one. Ramsay succeeded in isolating xenon from a sample of air by using fractional distillation. Xenon is produced commercially today by essentially the same technique.

Until recently, the noble gases were thought to be completely inert, reacting with no other substances, not even themselves. All of the noble gases have monatomic molecules. In 1962, however, Neil Bartlett, an English chemist working at the University of British Columbia, made the first noble gas compound. He combined xenon and platinum hexafluoride, and much to his astonishment obtained a solid, yellow-orange compound. It consisted of molecules made up of xenon, platinum, and fluorine. Bartlett's success inspired other scientists. Within months, the search for other xenon compounds was taken up by scientists at the Argonne National Laboratory near Chicago. They discovered that xenon reacts directly with fluorine at 400°C, and that in the presence of sunlight, it reacts with fluorine even at room temperature. Their work led to three different xenon fluorides: xenon difluoride, xenon tetrafluoride, and xenon hexafluoride. They also managed to synthesize a number of xenon-oxygen compounds. To date, of the noble gases, only xenon and krypton have been shown to form compounds.

Atomic Number **54**

Chemical Symbol **Xe**

Group **VIII A—The Noble Gases**



An aerial view of Argonne National Laboratory, located 25 miles outside of Chicago. In the 1960s, scientists there successfully created several compounds of xenon.

Like all of the noble gases, xenon is used in electrical discharge tubes to produce light. When excited, it emits a brilliant white light. Like krypton, it responds rapidly to an electrical current, and a mixture of krypton and xenon is used in high-intensity, short-exposure photographic flash tubes. For this same reason, xenon is also the gas used in rapidly flashing strobe lamps, which supply bursts of intense light for extremely short periods. Cameras use these bursts to “freeze” a rapidly moving object, such as a bullet fired from a gun or a piece of glass in the process of shattering, on a photographic film.

CESIUM

IA																				VIIIA																													
H	IIA													IIIA	IVA	VA	VIA	VIIA	He																														
Li	Be													B	C	N	O	F	Ne																														
Na	Mg	IIIB	IVB	VB	VIB	VII	VIII	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																																			
<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																																			



Cesium is an alkali metal, a member of the group of metals that occupy the first column in the periodic table. Like all of the alkali metals, it is soft and silvery in its pure state and is, in fact, the softest metal known. It is also one of the most reactive of the alkali metals, reacting violently with water to release hydrogen gas. Like the alkali metals potassium and rubidium, cesium reacts with oxygen to produce superoxides of the general formula CsO_2 . When they react with water or carbon dioxide, these superoxides release oxygen. This property makes them very useful in self-contained breathing apparatuses used by emergency workers and fire fighters in regions where toxic fumes are released.

Cesium has the extremely low melting point of 29°C . Since the human body temperature is 37°C , cesium will melt when held in the hand. The only metal with a lower melting point is mercury.

Cesium was discovered in 1860 by the German chemists Robert Bunsen and Gustav Kirchhoff. They isolated it by observing the colors, or spectral emission lines, that cesium emits when it is heated. The observed lines were bright blue, which prompted the discoverers to name the element from the Latin *caesius*, which means “sky blue.”

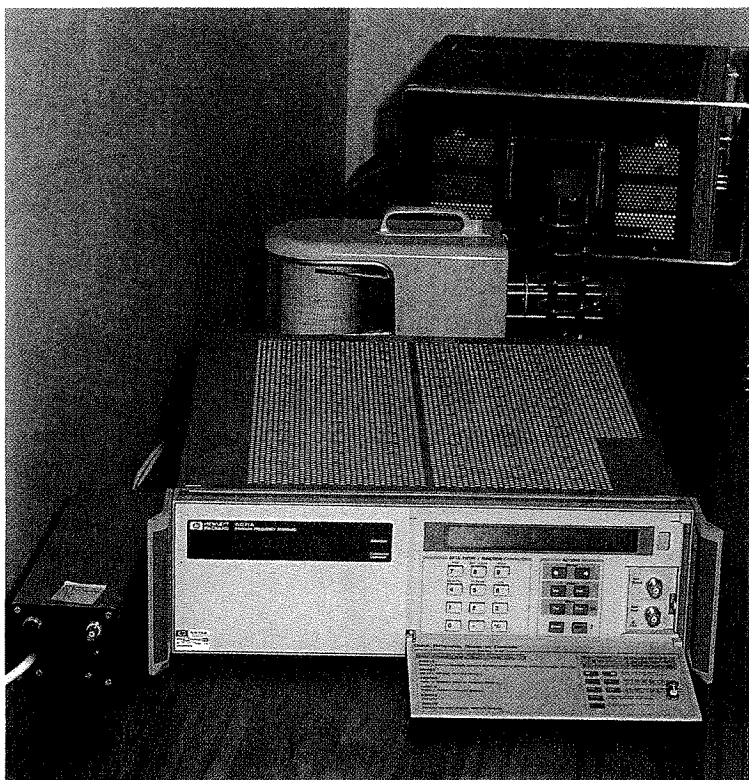


Cesium was discovered in 1860 by the German chemists Gustav Kirchhoff (above) and Robert Bunsen.

Atomic Number **55**

Chemical Symbol **Cs**

Group **IA—The Alkali Metals**



This atomic clock, containing an isotope of cesium, is one of about 200 around the world that together establish the world's time scale.

Cesium is far too active to be found in its free metallic state. Its major source is the mineral pollucite, a compound of silicon, aluminum, cesium, and oxygen.

The extreme reactivity of cesium has made it useful in removing unwanted gases from vacuum systems. It is important, for example, in insuring that the elements inside a television tube are kept in a vacuum, free from potentially harmful extraneous gases. A small amount of cesium in the interior of the tube acts as a scavenger by immediately reacting with such unwanted gas.

In 1960, an International Committee of Weights and Measures chose cesium-133, the only naturally occurring isotope of cesium, as the world's official measure of time. The second is now measured in terms of the radiation emitted by a cesium-133 atom when it is excited by an external energy source rather than in terms of the Earth's rotation around the sun, as it used to be. The second is now officially defined as the duration (the elapsed time) of exactly 9,192,631,770 vibrations of the radiation emitted by such an atom. Cesium iodide crystals are often used in a radiation detector known as a scintillation detector. Radiation interacting with the crystals produce scintillations of light which are then converted into electrical signals.

BARIUM

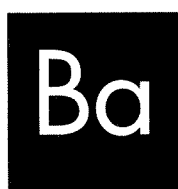
Atomic Number **56**

Chemical Symbol **Ba**

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

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	V I B	V II B	VIII B			IB	IIB	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

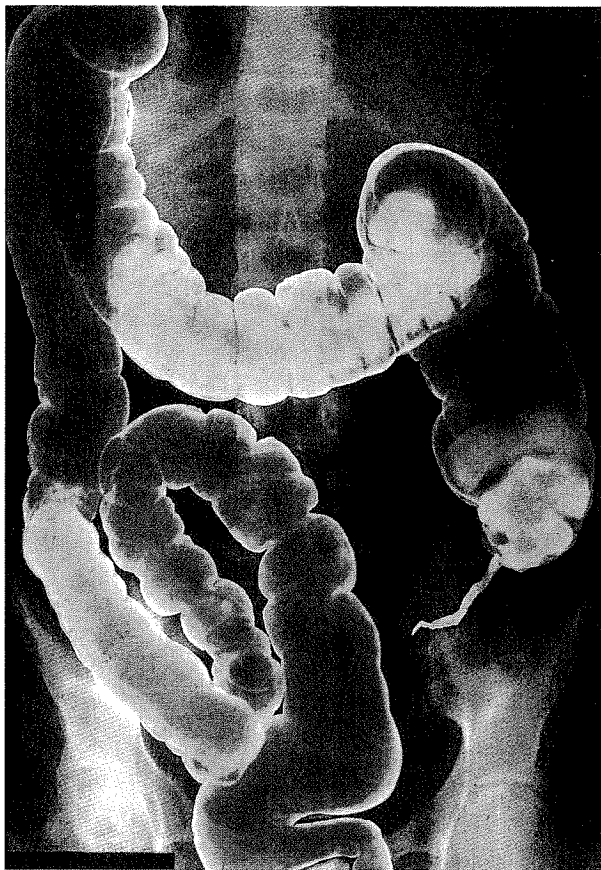


Barium is a soft, silvery-white metal that burns easily in air and reacts with water to produce hydrogen. As an alkaline-earth metal, it is extremely reactive. Barium is a fairly abundant element, ranking sixth in abundance among

the elements that make up the Earth's crust. It is found in the minerals witherite, a barium carbonate (BaCO_3), and baryte, a barium sulfate (BaSO_4). The element was discovered by the English chemist Sir Humphry Davy in 1808.

Barium is quite toxic. If ingested in the form of a soluble salt, such as barium chloride, it seriously impairs the heart's functioning and can produce the condition known as ventricular fibrillation, in which the heart beats erratically. On the other hand, barium in an insoluble form, such as in barium sulfate, can be swallowed without any damage to the body. Indeed, radiologists use barium sulfate to examine a patient's intestinal tract with X rays. This procedure is possible because barium sulfate is a highly dense salt that is opaque to X rays. When a patient either drinks a suspension of barium sulfate in water or is given a barium enema, consisting of a similar suspension, the barium sulfate particles temporarily fill the digestive tract. Since the barium sulfate absorbs X rays and blocks their transmission, the intestines and other organs will appear white in an X-ray picture, clearly showing the shape of the intestines and other organs outlined against a black background.

Barium metal has few commercial applications because of its readiness to react with oxygen and moisture. This property does make it useful as a scavenger in vacuum systems by removing unwanted gases. As a constituent of an alloy with other



After a patient ingests a solution of barium sulfate, a doctor can take an X ray of the person's digestive tract, which appears white wherever the barium sulfate accumulates.

Barium was discovered by the English chemist Sir Humphry Davy in 1808.

metals, however, it is used to make spark plugs, because it emits electrons very easily when heated.

Barium sulfate also has a number of uses based on its low solubility in water and brilliant white color. It is used as a whitener in photographic papers and as a filler in writing paper, plastics, and artificial fibers. A mixture of zinc sulfide and barium sulfate is used as a bright-white paint pigment called lithopone. Paradoxically, the green color of fireworks is often produced by barium compounds.

LANTHANUM

Atomic Number **57**

Chemical Symbol **La**

Group **IIIB—Rare Earth Element (Lanthanides)**

IA												VIII						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																



Lanthanum is the first element of a special series of elements called the rare earths. This series, also called the lanthanide series, consists of lanthanum and the next 14 elements that follow it across the periodic table. The last

member of the series is lutetium (atomic number = 71). All of the elements that make up this series are characterized by having their added electrons, the number of which increases with the atomic number of each element in the series, buried in the interior of the atoms of each element rather than contained in the outermost, or valence, orbital. Since the outermost electrons have the greatest influence on the properties of the elements, it should not be surprising that the variations in the properties of the rare earth elements are not as dramatic as the variations observed as one moves across the group A elements, to take but one example. Many of the properties of lanthanum are, for instance, more or less typical of all the elements in the rare earth series. It is quite common, for example, to find most of the rare earth elements, usually in the form of their oxide compounds, mixed together in the minerals that contain these elements.

Lanthanum was discovered in 1839 by the Swedish chemist Carl Gustaf Mosander, who extracted it as an impurity from a rare earth mineral called cerium nitrate. It was named from the Greek word *lanthanein*, meaning “to lie hidden.”

Lanthanum is a silvery-white metal, quite reactive, ductile and malleable, and soft enough to be cut with a knife. It forms an oxide fairly rapidly in air, and reacts vigorously in warm water, liberating hydrogen gas. The principal ores in which lanthanum is found are monazite sands and bastnasite. Monazite sands contain all of the rare earth elements as well as

calcium and thorium, usually in the form of their phosphate salts.

Probably the most important commercial use of lanthanide compounds is in fabricating the electrodes for the high-intensity carbon arc lamps used in searchlights, studio lighting, and motion-picture projectors. Lanthanum oxide improves the resistance of glass to attack by alkaline substances, and is used in making special glass for sophisticated optical equipment. Lanthanum and its compounds are considered moderately toxic.

Lanthanum and its isotopes are found in the fission fragments that are produced when uranium fissions. During the fission process the uranium nucleus, after absorbing a neutron, usually “splits” into two fragments whose nuclei are of intermediate size. There are many different ways of splitting, so that a great many mid-size elements are created. Lanthanum isotopes are among those formed. It was the discovery of these isotopes, as well as those of barium, by the German chemist Otto Hahn, that eventually led to the idea of nuclear fission. He published his findings in January 1939, and ended the report by stating that “it violated all previous experience in the field of nuclear physics.”

It was the German physicist Lise Meitner who first understood the significance of this discovery, and together with her nephew, the German physicist Otto Frisch, correctly guessed that when a uranium nucleus absorbs a neutron, it becomes unstable and divides into two parts, like the reproductive fissioning of a living cell.

Lanthanum was discovered in 1839 by a Swedish chemist who extracted it from a mineral called cerium nitrate. It was named from the Greek word lanthanein, meaning “to lie hidden.”

CERIUM

IA												VIII A					
H	IIA										III A		IV A	VA	VIA	VII A	He
Li	Be											B	C	N	O	F	Ne
Na	Mg	III B	IV B	VB	VIB	VII 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															



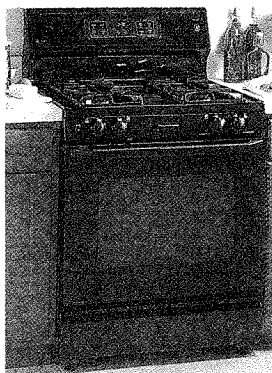
Cerium is the most abundant of the metals that make up the rare earth elements. It was simultaneously discovered by the Swedish chemist Jöns Jakob Berzelius and the German chemists

Wilhelm Hisinger and Martin Klaproth in 1803, as an impurity in the mineral bastnasite. It was named for the asteroid Ceres, whose discovery in 1801 had excited the scientific world.

The most important mineral ores containing cerium are monazite and bastnasite. Monazite sand contains all of the rare earth elements and is found in Florida beach sand, as well as in river sand in India and Brazil. Fairly large deposits of bastnasite exist in Southern California (see lanthanum).

Cerium in its pure metallic form was not prepared until 1875. It is an iron-gray metal that is quite malleable and ductile. It is also one of the most reactive of the rare earth metals, oxidizing

quite readily in moist air and decomposing fairly rapidly in heated water. The metal has been known to ignite spontaneously in air from the heat generated by scratching it.



The walls of some self-cleaning ovens are lined with a cerium compound that prevents the buildup of cooking residues.

Cerium compounds, like those of lanthanum, are used commercially to form the electrodes of the high-intensity carbon arc lamps used in searchlights and motion-picture projectors. As an oxide, cerium is used as an additive to the walls of “self-cleaning” ovens, where it seems to prevent the buildup of cooking residues. Its oxide is also used to polish lenses for cameras and telescopes.

Atomic Number **58**

Chemical Symbol **Ce**

Group **IIIB—Rare Earth Element (Lanthanides)**

IA																	VIII A						
H	IIA																	III A	IV A	V A	VI A	VII A	He
Li	Be																	B	C	N	O	F	Ne
Na	Mg	IIIB	IVB	VB	VIB	VII 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																							

Pr

Praseodymium, pronounced pra-si-oh-DYMI-um, is a rare earth metal that was finally isolated and identified as an element in 1885 by Carl Auer von Welsbach, an Austrian baron who had a love of mineralogy. He separated a mineral called

didymium into two new distinct elemental salts, one of which contained praseodymium. It was named from two Greek words—*prasios*, meaning “green,” and *didymos*, meaning “twin.” This name refers to the green color of the element’s oxide. The other salt contained the element neodymium.

Praseodymium is found chiefly in monazite and bastnasite ores. As already noted, monazite sands contain all of the rare earth elements, often in concentrations as high as 50 percent. Monazite is found in river sand in India and Brazil and in Florida beach sand. Large deposits of bastnasite are found in Southern California. Praseodymium metal is usually isolated from its ore by ion-exchange techniques. As the name implies, an ion-exchange process is used to isolate one kind of ion by substituting it with another. In one type of exchange process, the active ingredient is usually a resin made up of large molecules that have a netlike structure. The resin contains very mobile ions, such as sodium or potassium ions, that are loosely connected to the net. When a solution containing other ions is passed through the netlike structure of the resin, they replace the sodium or potassium ions that then diffuse out of the net.

Another type of resin consists of tiny plastic beads that have certain ions loosely attached to their surface. When a solution of the ion to be removed is passed through a column of these beads, the ions in solution replace the existing ions and are separated from the solution.

PRASEODYMIUM

Atomic Number **59**

Chemical Symbol **Pr**

Group **IIIB—Rare Earth Element (Lanthanides)**

Praseodymium was not prepared in its pure metallic form until 1931.

Praseodymium was not prepared in its pure metallic form until 1931. It is a soft, silvery-white metal that is malleable and ductile. Because it tarnishes to form a green oxide in air, it is usually kept sealed in plastic or covered with oil.

As with many of the rare earths, the oxide of praseodymium is used to fabricate the electrodes of the high-intensity carbon arc lamps used in searchlights and motion-picture projectors. Small quantities of the metal are added to magnesium to form an alloy that is both stronger and more corrosion-resistant than the original metals. This alloy is used to make both automobile and aircraft parts. Praseodymium salts are often added to enamels and glass to color them yellow.

IA																	VIIIA		
H																	He		
IIA												IIIA				IVA	VA	VIA	VIIA
Li	Be											B	C	N	O	F	Ne		
III		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	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																	

Nd

Neodymium is a rare earth metal discovered in 1885 by an Austrian amateur mineralogist, Baron Carl Auer von Welsbach. He separated a mineral called didymium into two new distinct elemental salts, one of which contained neodymium. Welsbach created the name for this element from two Greek words, *neos*, meaning “new,” and *didymos*, meaning “twin.” The other salt contained the element praseodymium.

The principal ores of neodymium are the minerals bastnasite and monazite. Monazite ores, often containing as much as 50 percent of their weight in rare earth elements, are found in river sands in India and Brazil and in Florida beach sand. Large deposits of bastnasite are found in Southern California. Ion-exchange techniques are used to isolate neodymium from its ore.

Pure neodymium metal was not isolated until 1925. It has a silver luster that quickly tarnishes in air and is therefore usually stored in a plastic wrapping or covered with mineral oil.

Neodymium and its oxides, which tend to be rose colored, are used to make colored glass for special purposes. Some examples of such glass are the colored glass in welder’s goggles and the “artificial ruby” used as a substitute for real rubies in certain types of lasers. Mischmetal, an important compound used for making steel alloys, contains about 18 percent neodymium.

About 24 percent of naturally occurring neodymium consists of the very weakly radioactive isotope neodymium-144. Because this isotope has a half-life of 2 million billion years, very little disintegrates during a short period.

Neodymium is a magnetic substance and is used to create some of the most powerful magnets on Earth. The neodymium

NEODYMIUM

Atomic Number **60**

Chemical Symbol **Nd**

Group **IIIB—Rare Earth Element (Lanthanides)**

A neodymium disc magnet with a diameter of only half an inch is strong enough to respond to magnetic materials in the printing ink used for paper money, and the element can be used to detect counterfeit currency.

supermagnets, known as NIB magnets since they consist of neodymium, iron, and boron, are so strong that two small magnets will press firmly to either side of one's hand without falling. Neodymium magnets will cling to each other with such force that it is almost impossible for most people to separate them by trying to pull them apart. Students and researchers are usually cautioned to wear eye goggles when working with these magnets, since they might inadvertently clamp together with such force that they fracture. Small splinters and fragments flying off from the point of contact might cause injuries to the eyes.

What makes the neodymium magnets especially useful is that they are relatively inexpensive. A small but powerful half-inch disc costs approximately ten dollars. These disc magnets are strong enough to respond to magnetic materials in the printing ink used for paper money, and can be used to detect counterfeit currency.

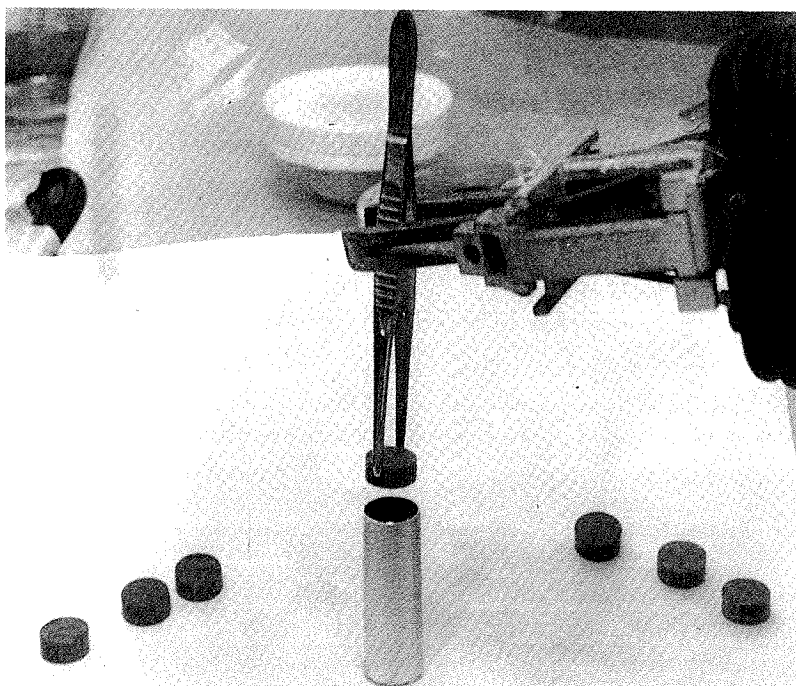
																VIIIA					
IA											IIIA	IVA	VA	VIA	VIIA	He					
H	IIA															B	C	N	O	F	Ne
Li	Be															Al	Si	P	S	Cl	Ar
Na	Mg	IIIB		IVB	VB	VIB	VIIIB				IB	IIB	Ga	Ge	As	Se	Br	Kr			
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
Cs	Ba	*La	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																					

Pm

Promethium is a synthetic rare earth element made in nuclear accelerators and nuclear reactors. No trace of the element has been found in the Earth's crust. It is named for the Greek god Prometheus who stole fire from the heavens. As

befits its name, promethium has been identified in the spectrum of several stars in the Andromeda Galaxy.

Study of the periodic table led several scientists at the beginning of the 20th century to predict the existence of an element between neodymium and samarium. The element whose atomic



Promethium was first discovered by a team of scientists at Oak Ridge National Laboratory in 1947. The laboratory continues to conduct research on the element and its properties. Here, promethium oxide is loaded into a capsule for testing.

PROMETHIUM

Atomic Number **61**

Chemical Symbol **Pm**

Group **IIIB—Rare Earth Element (Lanthanides)**

No trace of promethium has been found in the Earth's crust. Promethium has been identified in the spectrum of several stars in the Andromeda Galaxy.

number was 61 was simply missing. Many nuclear facilities throughout the United States tried to create and identify the element. Its existence was finally established in 1947 by J. A. Mirinsky, L. E. Glendenin, and C. D. Coryell, a team of scientists working at the National Laboratory at Oak Ridge, Tennessee. They found promethium among the many different nuclei of intermediate size, known as fission fragments, produced by the splitting of uranium atoms in a nuclear reactor. When neodymium is subjected to the intense neutron radiation present in a reactor, it is converted into promethium.

Twenty-eight isotopes of promethium have so far been synthesized, all of which are radioactive. Promethium-145 is the longest-lived of these isotopes with a half-life of 17.7 years, although promethium-147, an electron-emitting isotope with a half-life of 2.6 years, is the most useful for scientific applications. The electrons given off by promethium-147 when its nucleus disintegrates can be used to produce light from certain phosphors, to produce heat in nuclear-powered batteries, to produce X rays in portable X-ray units, and to measure the thickness of paper and sheet metal.

Very little is known of the chemical and physical properties of pure promethium. However, promethium salts have been made, and the radiation they emit causes the surrounding air to glow in the dark with a blue light.

IA																		VIII A					
H																		He					
II A																		VIII A					
Li	Be																	B	C	N	O	F	Ne
III B		IV B		V B		VI B		VII B		VIII B		I B		II B		VIII A							
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																							



Samarium is a rare earth metal that is fifth in abundance among the rare earth elements in the Earth's crust. It was discovered in 1879 by the French chemist Paul-Émile Lecoq de Boisbaudran, who correctly identified the

element's spectral absorption lines in a mineral called samarskite, which had been named for a Russian army officer, Colonel Samarski, a distinguished engineer. De Boisbaudran decided to name his newly discovered element for the mineral.

As in the case of so many of the rare earths, the principal ores of samarium are monazite and bastnasite. Monazite contains all of the rare earth elements, as well as thorium and calcium. It is found in river sand in India and Brazil and in Florida beach sand. Fairly extensive deposits of bastnasite exist in Southern California. Ion-exchange techniques are used to separate samarium from its ores.

In its pure metallic form, samarium has a silvery-white luster and is fairly resistant to oxidation in air. The metal will, however, ignite spontaneously at temperatures as low as 150°C. Because samarium has proven to be one of the most difficult elements to demagnetize, some compounds of this element are used to fabricate permanent magnets. Samarium oxide is an excellent absorber of infrared radiation and is added for this purpose to special types of glass and infrared-sensitive phosphors.

SAMARIUM

Atomic Number **62**

Chemical Symbol **Sm**

Group **IIIB—Rare Earth Element (Lanthanides)**