

# ARSENIC

Atomic Number **33**

Chemical Symbol **As**

Group **VA—Metalloid**

IA																		VIII A									
H	He																	B	C	N	O	F	Ne				
IIA												VIII B						IB		IIB							
Li	Be	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																
																		* 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									

**As**

Arsenic is a brittle, crystalline solid at room temperature. Lying between the nonmetals and metals in the periodic table, it is often thought of as a semimetal, or metalloid. For example, it is a poor conductor of electricity, yet it has a steel-gray color. When exposed to air, arsenic quickly tarnishes to a yellow color, eventually turning black.

Although a small amount of arsenic does occur in its free form in nature, most arsenic is found in a number of mineral compounds such as realgar and orpiment. Both are compounds of arsenic and sulfur. The history of arsenic dates back to ancient Greek and Roman times. Its name is probably derived from the Latin name *arsenicum* for orpiment, a common yellow pigment used at the time.

Arsenic is recovered from a mineral such as orpiment, which has a color almost like that of gold, by first roasting it in air to convert the arsenic to an oxide. The oxide is then heated with carbon to remove the oxygen and liberate the arsenic.

In the form of arsenious oxide, a white crystalline powder compound that is also known as white arsenic or arsenic trioxide, arsenic is a well-known poison. It is used as a weed killer and insecticide, being commonly sprayed on fruit to ward off damage by insects. The insecticide called Paris green also contains arsenic and is often sprayed from airplanes over cotton fields to destroy boll-weevil infestations.

Arsenic as a poison has captured the imagination of many a crime writer. The popularity of arsenic as an instrument of murder does have some basis in fact. Before recent advances in autopsy techniques, it was often impossible to detect arsenic in



*In Arsenic and Old Lace, Cary Grant came across two old women who use arsenic to poison their house guests.*

the body of a victim. The victim died with symptoms resembling those of pneumonia. Because arsenic is dangerous, it is one of the elements whose emission into the environment is being monitored and controlled. Although doses as small as one-tenth of a gram of arsenic can be fatal to humans, minute traces can actually stimulate the production of red blood cells.

Although a poison, arsenic compounds have had a history of producing useful medical products. Many skin diseases have been effectively treated with some of these compounds, as has amoebic dysentery. Newer, and potentially less dangerous treatments, have replaced many of these compounds. But perhaps the most celebrated arsenic-containing medicine is compound "606."

Compound "606" was developed by the German scientist Paul Ehrlich in 1910 as a cure for syphilis. Before the days of antibiotics, it was one of the few known treatments for this debilitating disease. Ehrlich named his famous compound 606 because it was the six hundred and sixth compound he tried during his extensive research in trying to find a cure for syphilis. Its chemical name is arsphenamine.

Arsenic has become a material of great importance in the world of solid-state electronics. Small amounts of arsenic are now added to such semiconductors as germanium and silicon to transform them into transistors. Arsenic also forms a compound with gallium, gallium arsenide (GaAs), that can transform electricity directly into light. This is used to produce light-emitting diodes, or LEDs.

*Doses as small as one-tenth of a gram of arsenic can be fatal, and before recent advances in autopsy techniques it was often impossible to detect arsenic in the body of a victim.*

# SELENIUM

Atomic Number **34**

Chemical Symbol **Se**

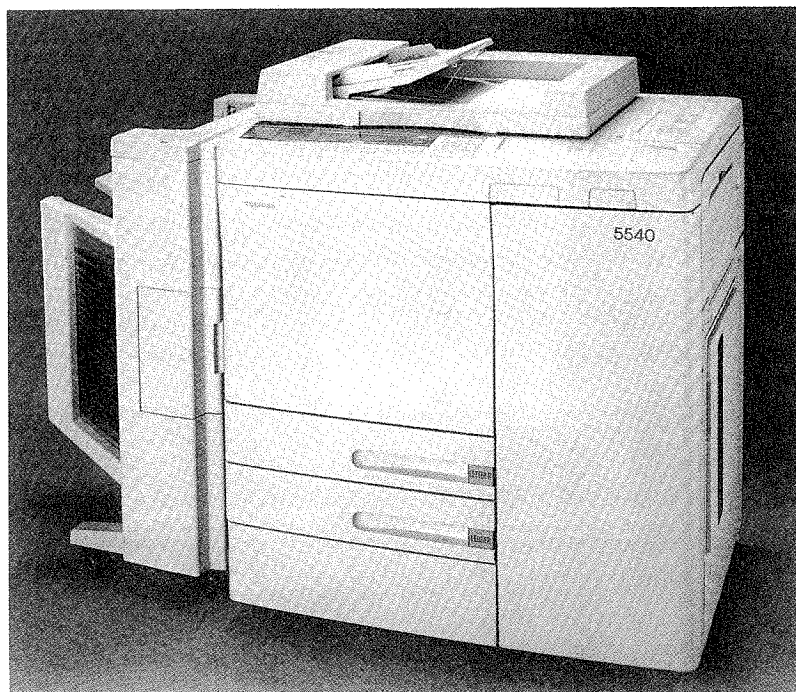
Group **VIA—Metalloid**

IA																	VIII A						
H																	He						
II A																	VIII A						
Li	Be											B	C	N	O	F	Ne						
III A	IV A	V A	VI A	VII A																			
Na	Mg	Al	Si	P	S	Cl	Ar																
III B	IV B	V B	VI B	VII B	VIII B	I B	II B																
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																							

## Se

Selenium is a metalloid that can exist in two different forms, red and gray, called allotropes. Red selenium is an amorphous, glasslike solid, while gray selenium is a soft, bluish-gray metal. Selenium was discovered by the great Swedish chemist Jöns Jakob Berzelius in 1817. It derives its name from *selene*, the Greek word for the moon.

Selenium-bearing minerals are too scarce to be mined profitably. Because selenium is usually found in the company of copper and sulfur, almost all commercially available selenium is



*Selenium's photoconducting ability is put to use in photocopy machines.*

recovered as a by-product of copper refining and the manufacture of sulfuric acid.

Gray selenium is a photoconductor. This means that although it is ordinarily a poor conductor of electricity, it becomes an excellent conductor in the presence of light. Its ability to conduct electricity can increase by a factor of 1,000 when light falls on it. This makes selenium very valuable as a light sensor, and it has found use in such applications as robotics and light-switching devices, as well as light meters.

A major use of the photoconducting ability of selenium is in photocopying. For this purpose a belt or plate is coated with selenium and given an electrostatic charge. It is then exposed to a printed page and light is made to shine through the page. The charge on the lighted parts of the belt is conducted away electrostatically, leaving a charge on the belt only where dark images are present on the original print. A toner, consisting of a finely powdered carbon, is then distributed over the belt and adheres to the electrostatically charged areas. The principle by which the carbon adheres to these areas is similar to the one that makes a rubbed balloon stick to your clothes. Finally, the carbon is fused to a sheet of paper by heat, producing a reproduction of the original document.

A great deal of recent interest has also been shown in the effect of selenium on human health. Selenium was recognized as being toxic soon after its discovery. Recent studies have suggested, however, that trace amounts of selenium in the diet can actually protect humans against cancer and heart disease. These results have not been fully confirmed, but it is known that selenium is involved in the activity of vitamin E and certain enzymes.

Compounds containing selenium have also proven useful in controlling dandruff and are often added to shampoos.

*Selenium was discovered by Swedish chemist Jöns Jakob Berzelius in 1817. It derives its name from selene, the Greek word for the moon.*



# BROMINE

Atomic Number **35**

Chemical Symbol **Br**

Group **VIIA**—  
The Halogens

IA																	VIIIA		
H																	He		
IIA												IIIA				IVA	VIA	VIIA	He
Li	Be											B	C	N	O	F	Ne		
III B		IV B	V B	VI B				VII B		VIII 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																			

## Br

Bromine is a reddish liquid with an acrid smell that produces thick, reddish-brown fumes when exposed to air. The simplest bromine molecule contains two bromine atoms and is called diatomic bromine. Bromine and mercury are the only two elements that are liquids at room temperature. The density of bromine is 3.12 grams/cm<sup>3</sup>, making it approximately three times as dense as water. It is, for example, almost impossible to transfer liquid bromine with an ordinary eye dropper because it is too heavy and will leak out. The process of pouring bromine into a beaker is quite striking to watch. Bromine vapor is so much denser than air that it will hug the bottom of the beaker.

Bromine was discovered by a young French student, Antoine-Jérôme Balard, in 1826. He first isolated the element by adding chlorinated water to the brackish water he found in the salt marshes near Montpellier, a city in southern France. The addition of chlorine turned the water brownish. The cause of the color change was found to be a new element that the French Academy named bromine, from the Greek word *bromos*, meaning “stench.”

Bromine can be found in seawater, underground salt mines, and deep brine wells. Much of it is taken from the ocean, but the major sources of bromine in the United States are the deep brine wells found in Arkansas, which contain a solution of one-half percent bromine. A modification of Balard’s method is still used for the commercial production of bromine. Chlorine gas is added to heated brine or seawater. This oxidizes the bromine ions in solution, changing them to elemental bromine, which is then driven out of solution by jets of air or steam.



*Bromine is used in the manufacture of photographic film. Black and white film consists essentially of silver bromide crystals placed in a gelatin to form a light-sensitive emulsion.*

A major use of bromine is in producing a gasoline additive called ethylene dibromide. This compound removes lead additives after the combustion of gasoline, preventing the lead in these additives from forming deposits in the engine. Instead, the lead combines with bromine to form lead bromide, a volatile gas, which leaves the engine through the exhaust system. Recent studies have shown that ethylene dibromide is a potent carcinogen.

Methyl bromide is another compound of bromine that has commercial value. It is used as a pesticide and is particularly effective against the parasitic worms known as nematodes. Bromine is also used in the manufacture of silver bromide for photographic films.

Bromine is extremely toxic and can cause severe burns on the skin. Moreover, its vapors are not only irritating and noxious but can also cause severe damage to the tissues of the nose and throat. Sodium bromide, a salt of bromine, is a mild sedative that was widely used in the late 19th and early 20th century. People still speak of taking a “bromide” to ease tension.

*Bromine is a red-dish liquid with an acrid smell. Its name is derived from the Greek word bromos, meaning “stench.”*

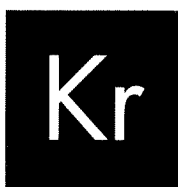
# KRYPTON

Atomic Number **36**

Chemical Symbol **Kr**

Group **VIIIA**—The Noble Gases

IA																	VIIIA																														
H																	He																														
Li	Be															B	C	N	O	F	Ne																										
Na	Mg	IIIB	IVB	VB	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																																			
		<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																																	



Krypton is a noble gas, one of the group of gases in the periodic table that also contains helium and argon; they are called noble gases because of their lack of chemical reactivity. Until recently, no compound of a noble gas was known to exist. The chemical inertness of the noble gases was challenged by the celebrated American chemist Linus Pauling, who in 1933 used quantum mechanics to demonstrate that a molecule containing krypton and fluorine should be stable enough to exist. Finally, in 1966, Neil Bartlett of the University of British Columbia produced the first compound of a noble gas, which as Pauling had predicted, was a compound of krypton and fluorine. Known as krypton fluoride ( $\text{KrF}_4$ ), it is the only known compound of the element.

Because none of the noble gases had been discovered when Mendeleev developed his periodic table in 1869, he made no provision for them in the table. It was the discovery of argon in 1894 that demonstrated the need for a new column in the table. The English chemist Sir William Ramsay, in 1898, isolated and identified krypton as an element. He named it from the Greek word *kryptos*, which means “hidden.”

Krypton exists in trace amounts in the air. Its atmospheric



*In 1933, the American chemist Linus Pauling challenged the idea that the noble gases were chemically inert by predicting the existence of a molecule containing krypton and fluorine. His claim was proved in 1966.*

abundance is 0.0001 percent by volume. The commercial preparation of krypton uses essentially the same method used by its discoverer, Ramsay. The gas is separated from liquid air by fractional distillation. It is an odorless, tasteless, colorless, and completely harmless gas. Its chief use is in the “neon” lights that have become an important part of the modern landscape. When sealed in a glass tube and subjected to an electrical discharge, krypton produces a pale violet color and is often used for airport runway and approach lights. It is sometimes mixed with other noble gases to produce subtle variations in their color or brightness. Since it has a fast response time to electric currents, it is often used, mixed with xenon, in high-intensity, short-exposure photographic flash bulbs or strobe lights.

When atoms are excited by the absorption of energy, they often release energy themselves by giving off light. Every element emits light that contains a specific, characteristic series of colors. These colors are called the emission spectrum of the element, and each color has a very precise, measurable wavelength. In 1960, an international committee selected the wavelength of one of the colors of krypton-86 to define the meter. One meter was no longer the distance between two arbitrary scratches on a platinum bar stored in Paris, but was now defined as exactly 1,650,762.73 wavelengths of the red-orange spectral line of krypton-86. The advent of the laser and the ability to measure the speed of light very precisely led, in 1983, to a redefinition of the meter. One meter is now defined so that the speed of light in a vacuum is exactly 299,792,458 meters per second.

*The English chemist Sir William Ramsay isolated and identified krypton as an element in 1898. He named it from the Greek word kryptos, which means “hidden.”*

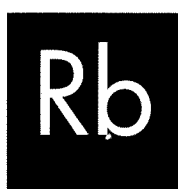
# RUBIDIUM

Atomic Number **37**

Chemical Symbol **Rb**

Group **IA—The Alkali Metals**

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



Rubidium is a very soft, silvery, highly reactive metal that burns spontaneously when exposed to air. It also reacts violently with water, giving off large quantities of hydrogen gas that immediately burst into flames because of the heat generated

by the reaction. The pure metal is usually stored in kerosene.

Rubidium is much too reactive to exist as a pure metal in nature, and few rubidium-bearing minerals are known.

Rubidium was discovered in 1861 by the German chemists Robert Bunsen and Gustav Kirchhoff. They found it as an impurity among the many alkali metals they were investigating. Bunsen and Kirchhoff identified rubidium by the spectral lines it emitted, one of which has a deep red color. They took its name from the Latin word *rubidus*, meaning “deep red.”

Rubidium has little commercial value. It is obtained as a by-product in the refining of such related metals as lithium and cesium, whose ores contain trace amounts of rubidium. The chief use of rubidium is in the manufacture of television and cathode-ray tubes, and as a “getter” for vacuum systems. A getter acts as a scavenger and removes unwanted gas that would contaminate the system.

The melting point of rubidium is 39°C (102°F). This is only slightly above the human body temperature of 37°C (98.6°F) and considerably below the boiling point of water 100°C (212°F).



IA																		VIIIA					
H	He																						
IIA												IIIA				IVIA		VA		VIA		VIIA	
Li	Be											B	C	N	O	F	Ne						
III B		IV B		V B		VI B		VII B		VIII B		I B		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																					

Sr

Strontium is a fairly active, silvery-white metal that quickly tarnishes when exposed to air. It is relatively soft and, when finely divided, will burn spontaneously in air.

The sources of strontium are the mineral ores celestite, which is a form of strontium sulfate, and strontianite, a strontium carbonate. Both strontium and the mineral strontianite were named in 1789 by the English scientist Dr. Adair Crawford, who first identified the element in the Scottish village of Strontian. The metallurgical process for obtaining the pure metal is first to treat its ores with hydrochloric acid, converting their strontium compounds to strontium chloride, and then to use electrolysis to separate the metal from the chloride.

One of the isotopes of strontium, strontium-90, is radioactive, with a rather long half-life of 28.8 years. It is a by-product of nuclear explosions and can often contaminate large areas of the environment through fallout from the atmosphere. Since the chemistry of strontium is similar to that of calcium, strontium-90 can pose a serious health hazard when it is taken up by cows that feed on hay and grass contaminated by fallout because it is incorporated into their milk. In humans who drink the milk, the strontium-90 replaces the calcium in bone tissue, where it can cause radiation damage to the sensitive bone marrow, in which blood cells are formed. Since strontium-90 is produced whenever uranium undergoes fission, the operators of nuclear reactors must be constantly on their guard to prevent its accidental release into the environment.

Strontium metal has little commercial use, and compounds of strontium have found only limited application in industry.

# STRONTIUM

Atomic Number **38**

Chemical Symbol **Sr**

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



*A fireworks display over the Brooklyn Bridge by Fireworks by Grucci. The red color in many fireworks comes from the presence of strontium salts.*

Since strontium salts, such as strontium carbonate, give off a characteristic red color when they burn, they are often used in highway warning flares and in fireworks.

The ability of strontium to replace calcium is used in medical research. In one such technique, strontium-87, a radioactive isotope of strontium, is introduced into a patient's body and is taken up by bone tissue. Radiation detectors are then used to locate the radioactive strontium and to assess any abnormalities. The half-life of strontium-97 is only 2.8 hours, so it is rapidly eliminated from the body, keeping exposure to radiation to a minimum.

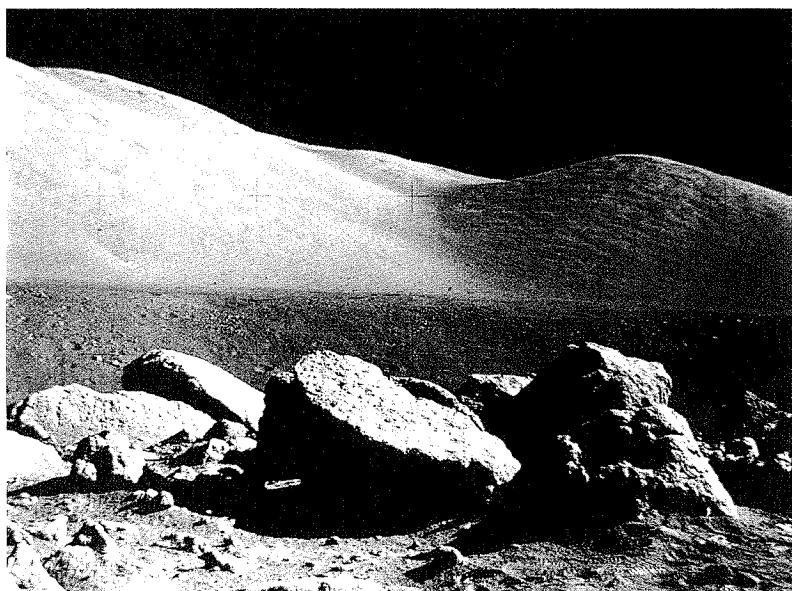
IA												VIIIA					
H	He											B	C	N	O	F	Ne
Li	Be											Al	Si	P	S	Cl	Ar
Na	Mg	III B	IV B	V B	VIB	VII B	VIII B			IB	II B	Ga	Ge	As	Se	Br	Kr
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	In	Sn	Sb	Te	I	Xe
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	Hg	Tl	Pb	Bi	Po	At
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	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															



Yttrium is found in small quantities in the Earth's crust. Rocks brought back from the moon by the Apollo astronauts, however, had an unexpectedly high yttrium content.

Yttrium owes its strange-sounding name to the Swedish village Ytterby, near Stockholm, where it was first identified in 1789 by Johan Gadolin. It is interesting to note that a quarry located in Ytterby has been the source of several new elements that have been named, in some fashion, for the town. In addition to yttrium, there are ytterbium, terbium, and erbium.

Yttrium is a silver-gray metal that is active enough to burn spontaneously in air when cut into small pieces. The metal itself has little commercial value, but the oxide of yttrium, a white



Scientists were surprised to discover that rocks brought back from the surface of the moon had a very high yttrium content.

# YTTRIUM

Atomic Number 39

Chemical Symbol Y

Group III B—Transition Element

*Yttrium owes its strange-sounding name to the Swedish village Ytterby, near Stockholm, where it was first identified in 1789 by Johan Gadolin.*

powder, has found use as the phosphor that produces the red color for color television tubes. Most yttrium is obtained from monazite sand.

Yttrium has recently also been employed in solid-state lasers. Yttrium aluminum garnet, a compound of yttrium, aluminum, and oxygen (usually referred to as YAG), has the ability to intensify and amplify light energy. As in the case of all substances that exhibit laser activity, the radiation emitted by YAG is concentrated in a very narrow band of wavelengths and is therefore nearly monochromatic (of one color). The YAG laser can operate at high power output and has proven particularly useful in the cutting and drilling of metals.

Metals such as copper have a small but significant resistance to the passage of electricity at room temperatures. This resistance usually results in a waste of energy in the form of heat and in a loss of electrical energy. When their temperature is lowered to only a few degrees above absolute zero, however, almost all metals become superconductors, showing no electrical resistance whatsoever.

Extremely low temperatures are impractical, however, and scientists have tried hard to find materials that would be superconducting at room temperatures. A major breakthrough in this work occurred in 1986 when Karl Alexander Muller and Johannes Georg Bednortz at the IBM laboratories in Zurich, Switzerland, discovered a class of ceramics that showed superconductivity at a temperature of 30°K, or 30° degrees above absolute zero. This still represents a rather cold environment, but it inspired further research to find materials that might become superconducting at still higher temperatures. In 1987, scientists at the University of Alabama and the University of Houston announced the discovery of an yttrium compound, basically an yttrium, copper, and barium oxide, that was superconducting at 93°K. This compound is sometimes called the "1-2-3 compound" because of its 1:2:3 ratio of yttrium to barium to copper. Other mixtures of these elements, called perovskites as a class, are being investigated, and scientists are optimistic that one of them will eventually lead to a practical high-temperature superconductor.

The ability to transmit electrical power without loss of energy would be a great step forward in the development of such devices as trains that ride without friction, levitated above their tracks by magnetic fields. The production of the huge magnetic fields needed for such a task requires enormous electrical currents. The losses due to electrical resistance in conventional wires at normal temperatures would make the operation of such new technologies too expensive.

IA												VIII A											
H	He																						
IIA												VIII A											
Li	Be																						
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																							

Zr

Zirconium is a strong, durable metal that is resistant to both corrosion and high temperatures. It reacts rapidly with the oxygen in air to form a tough zirconium oxide layer that protects the metal from any further reaction. Zirconium has played a major role in the construction of space-vehicle parts. Its resistance to high temperatures is critical in the design of those parts that are exposed to the extreme heat produced on the re-entry of space vehicles into the Earth's atmosphere.

It is difficult to isolate pure zirconium. Hafnium, the element located immediately below zirconium in the same column of the periodic table, is an inevitable impurity. Since the ions of hafnium and zirconium have the same charge and are approximately the same size, it is not surprising that they have similar properties, which make it difficult to separate the two elements from each other. Zirconium was discovered in 1787 by the German chemist Martin Heinrich Klaproth, while hafnium remained undiscovered until 1923, when it was found in zirconium ores.

Probably the best-known compound of zirconium is the mineral zircon. This mineral has been known since ancient times and is even referred to in the Bible. Zirconium actually derives its name from *zargun*, which is the Arabic name for zircon and means "gold color."

Zircon is a crystalline compound of zirconium silicate ( $ZrSiO_4$ ). It is found in a wide variety of colors, and when the crystal is cut and polished, it is regarded as a semiprecious gem. Zircon has an extremely high index of refraction, which means that it has the ability to bend light through large angles. Because of this, the colorless crystals of zircon have an unusual brilliance and are sometimes used as a substitute for diamonds.

# ZIRCONIUM

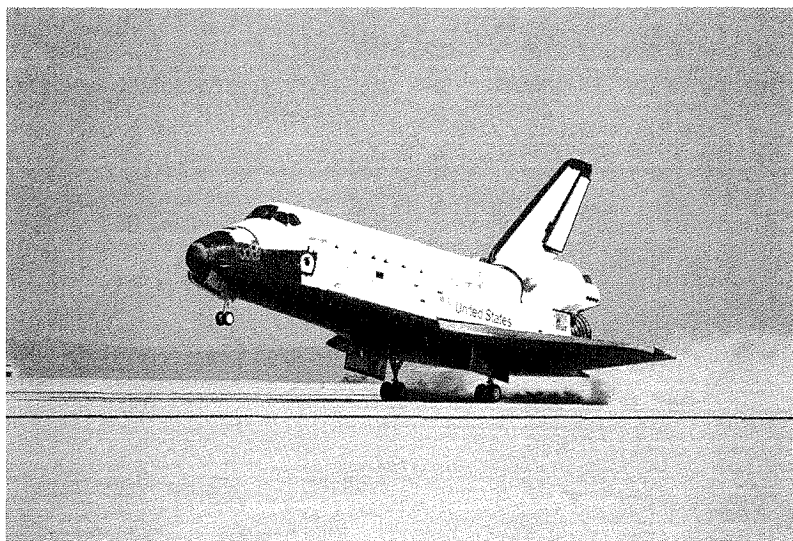
Atomic Number **40**

Chemical Symbol **Zr**

Group **IVB—Transition Element**



*The space shuttle Atlantis touches down after a 1992 mission. Zirconium's ability to withstand high temperatures makes it an ideal ingredient for the heat-resistant materials used in spacecraft.*



A major use of zirconium is in nuclear reactors. It is actually Zircaloy, a cheaper alloy of zirconium, that is used. Like zirconium itself, Zircaloy is extremely resistant to corrosion in water. To prevent direct contact of uranium with water, the fuel elements in many reactors usually consist of natural uranium pellets inserted into long Zircaloy tubes, called rods. Hundreds of these fuel rods are then inserted into a coolant, such as water, to absorb and carry away the energy produced by the fission of the uranium.

In certain types of experimental reactors being developed at such research centers as Oak Ridge National Laboratory, in Oak Ridge, Tennessee, the core of the reactor itself is constructed of Zircaloy. It is in the core, a pear-shaped, half-inch-thick Zircaloy container, that the fissioning of the uranium occurs.

Although Zircaloy is more expensive than stainless steel, it is used in reactors because it does not readily absorb neutrons. The chain reaction taking place in the reactor depends on neutrons, and any loss of neutrons would seriously interfere with the reactor.

IA																		VIII A	
H	He																	He	
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																			

**Nb**

Niobium is a soft, steel-gray metal that is largely found in the mineral columbite, an ore that also contains iron and manganese. It reacts with the air to form a tough niobium oxide layer that makes the remaining metal resistant to corrosion.

The chemical properties of niobium are very similar to those of tantalum, the element that lies directly below it in the periodic table, and the two are always found together. Their chemical similarities make it difficult to isolate pure niobium without contamination by tantalum.

Niobium was discovered by the Englishman Charles Hatchett in 1801 while working with a sample of columbite owned by the British Museum in London. After some confusion caused by its similarity to tantalum, the element was finally named niobium for the mythological goddess Niobe. As a historical note, niobium was originally called columbium, after the mineral in which it was found, and is still occasionally referred to by that name.

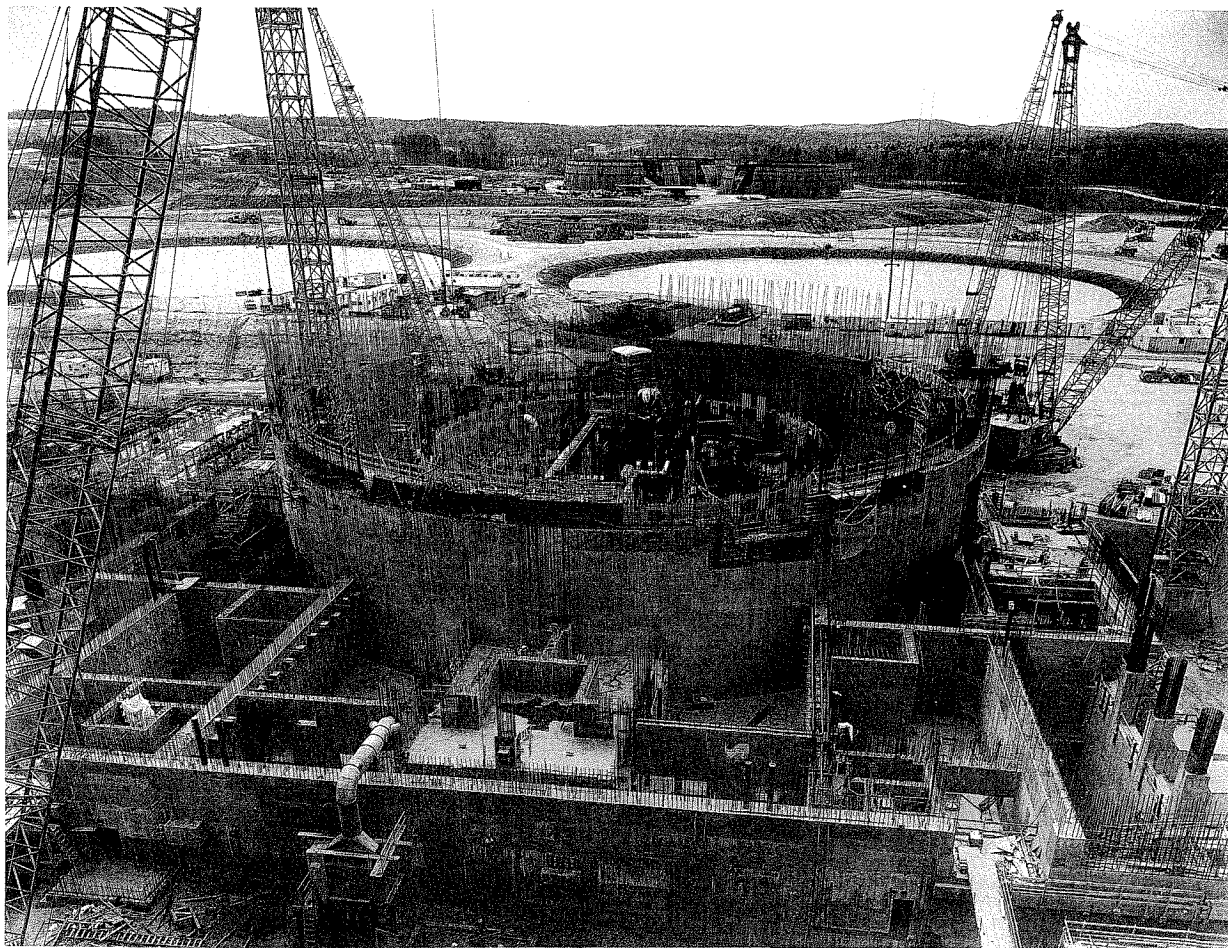
Niobium has been important in the history of high-temperature superconductivity. Before the work of Karl Alexander Muller and Johannes Georg Bednortz on high-temperature superconductivity (see yttrium), the scientific world became excited when it was shown that an alloy consisting of a compound of niobium and germanium, called an intermetallic compound, became superconducting at the relatively high temperature of 23.2°K. Equally exciting was that the alloy remained superconducting even with large currents flowing through it. This contrasted with many superconductors, which lose their superconductivity above a certain current range. The ability of the alloy to withstand large currents permitted the construction of super-

# NIOBIUM

Atomic Number **41**

Chemical Symbol **Nb**

Group **VB—Transition Element**



*Because niobium-enhanced steel is capable of withstanding high temperatures for long periods of time, it is used in the construction of nuclear reactors, such as this one in Tennessee.*

conducting magnets for such instruments as the nuclear magnetic resonance scanners used in diagnostic medicine.

Niobium is also added to steel for special purposes. At high temperatures, above about 1,000°F, the boundaries between the small crystal grains that make up stainless steel undergo a chemical change that weakens them and makes them vulnerable to damage. These weakened boundaries, for example, corrode more easily than the rest of the steel and often have a tendency to crumble under extreme stress. The addition of niobium to the steel prevents this from happening, allowing the steel to withstand much higher temperatures.

Niobium-stabilized stainless steel, as it is called, is often used in the construction of nuclear reactors because of its ability to withstand high temperatures over long periods of time. For the same reason, this special steel is also used in the construction of advanced aircraft, such as those used in the Gemini space program, and in special cutting tools.

IA												VIIIA						
H	He											B	C	N	O	F	Ne	
IIA												VIIA						
Li	Be											Al	Si	P	S	Cl	Ar	
III		IV		V		VI			VII			VIII			IX		X	
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																		



Molybdenum is a hard, silvery metal that is mined from an ore called molybdenite ( $\text{MoS}_2$ ).

In the United States, fairly large deposits of molybdenite are found in Colorado. In the 18th century, molybdenite was often thought to be an ore of lead. It was the Swedish chemist Carl Wilhelm Scheele who, in 1778, first isolated molybdenum from molybdenite and identified it as a new element. He named it after molybdenite ore.

One of the chief uses of molybdenum is as an additive to steel. In the manufacture of steel from iron, other metals are added to the iron to produce a steel alloy with properties that are particularly well suited for a specific function. Steel containing molybdenum, usually called “moly steel,” is well suited for automobile and aircraft-engine parts. It is able to withstand the pressure and temperature changes that are constantly taking place in an engine. For the same reason, it is also used in the manufacture of guns and cannons.

One of the radioactive isotopes of molybdenum, molybdenum-99, is used in hospitals to generate technetium-99, a radioactive isotope that is highly useful for producing pictures of the body’s internal organs after being taken internally. The radioactive molybdenum used for this purpose is stored in a fairly small container, usually absorbed into granules of alumina. When the molybdenum-99 isotope decays, it is transformed into technetium-99. When needed, the technetium is taken from the container and administered to the patient.

# MOLYBDENUM

Atomic Number **42**

Chemical Symbol **Mo**

Group **VIB**—Transition Element

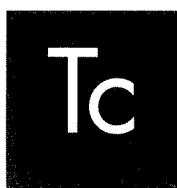
# TECHNETIUM

Atomic Number **43**

Chemical Symbol **Tc**

Group **VII B—Transition Element**

IA												VIIIA					
H	He											B	C	N	O	F	Ne
IIA												VIIA					
Li	Be											Al	Si	P	S	Cl	Ar
III A												IV A					
Na	Mg	III B	IV B	V B	VI B			VII B			VIII B		IB	II B	III A		
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																	



Technetium is a most interesting and unusual element. It was the first new element to be produced in the laboratory from another element. Logically, technetium takes its name from the Greek word *teknētos*, which means “artificial.”

Since every isotope of technetium is radioactive and decays to form an isotope of a new element, it is not surprising that technetium is not found naturally on Earth. However, trace amounts of the element have been found in certain stars.

Technetium was discovered in 1937 by Emilio Segrè and Carlo Perrier. The discovery was actually made in Italy using a sample of material sent to them by the University of California at Berkeley. The sample was made using the cyclotron at Berkeley to bombard the element molybdenum with deuterons. Deuterons are the nuclei of an isotope of hydrogen called deuterium, and they consist of one proton and one neutron. The new element was identified by studying its radioactivity. It is another example of an element whose existence was predicted by the periodic table.

Today technetium is also produced in nuclear reactors. In these reactors, enormous numbers of neutrons are used to bombard molybdenum and produce large quantities of one of the most useful isotopes of technetium, technetium-99m.

When a chemical compound of technetium-99m is injected into the veins of a patient, the isotope will concentrate in certain body organs and its radioactivity will expose a photographic plate, revealing how those organs are functioning. The *m* in technetium-99m means that the isotope is in an unstable form; its nucleus contains more energy than that of the nucleus of “ordinary” technetium-99, which means that it is on the verge of releasing this energy. When it finally does let go and decay, it



reverts back to the ordinary form of technetium-99. The energy it releases is in the form of gamma radiation only. A gamma ray is basically a very energetic kind of X ray. Like X rays, gamma rays are extremely penetrating and so can easily be detected outside the body.

In order to assess the condition of certain parts of the body, a doctor usually administers the technetium to the patient along with another chemical that will “bind” it to a certain location in the body. For example, the physician can inject a small amount of tin along with the technetium-99m. In the presence of tin, the technetium binds very strongly to red blood cells. On the other hand, in the presence of a phosphorus compound, called a pyrophosphate, the technetium will bind very strongly to the heart muscle. In each case, though, the gamma radiation given off by the technetium-99m can be detected by special equipment and provides an image of the heart so that the doctor can assess the damage done during a heart attack.

The half-life of technetium-99m is only 6.02 hours, which makes it an ideal radioisotope for this procedure. It allows measurements to be taken, yet within 24 hours will be almost completely gone from the body. Ordinary technetium-99, the material to which technetium-99m decays, has a long half-life of 212,000 years, so that in the small doses given a patient, its activity does not present a problem. It is quickly eliminated from the body by biological means.

There are actually 19 known isotopes of technetium, and many of them have extremely long half-lives. Technetium-97 and technetium-98, for example, have half-lives of several million years. A long half-life means that an isotope is only weakly radioactive and that very few of its atoms disintegrate within a fixed period of time.

Although difficult to fabricate, and rather expensive, some gram-size samples of metallic technetium have been made. It has a silver color when freshly prepared but slowly tarnishes when exposed to air. Trace quantities of the longer-lived isotopes are often added to steel to inhibit corrosion, but these special steels are used sparingly because of their radioactivity.

*Technetium was discovered in Italy in 1937 by Emilio Segrè and Carlo Perrier using a sample of material sent to them by scientists at the University of California at Berkeley.*



IA																	VIIIA
H																	He
IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA	
Li	Be											B	C	N	O	F	Ne
IIIB	IVB	VB	VIB	VIIB	VIIIB	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA			
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																	

# Rh

Rhodium is an extremely hard, corrosion-resistant, silvery-gray metal. It is quite rare and is usually found associated with the ores of platinum. It was discovered by the Englishman William Hyde Wollaston in 1803. He named it after the Greek word *rhodon* for “rose” because many of the salts of rhodium have a striking rose color.

Rhodium has rather limited commercial value and is used mainly as an additive for hardening platinum and as a catalyst for various commercial processes. It is used in the catalytic converters of automobiles manufactured in the United States. The exhaust gases produced by the internal-combustion engines of automobiles contain nitrogen dioxide, carbon monoxide, and various unburned hydrocarbons, all of which are major sources of air pollution. The catalytic converter of an automobile is filled with small catalytic beads containing platinum, palladium, and rhodium, which convert the hot exhaust gases that pass through them into harmless products. The carbon monoxide and unburned hydrocarbons are converted to carbon dioxide and water, while the nitrogen dioxide is converted to nitrogen and oxygen. Another use for rhodium in automobiles is in the construction of headlight reflectors.

# RHODIUM

Atomic Number **45**

Chemical Symbol **Rh**

Group **VIII**—Transition Element



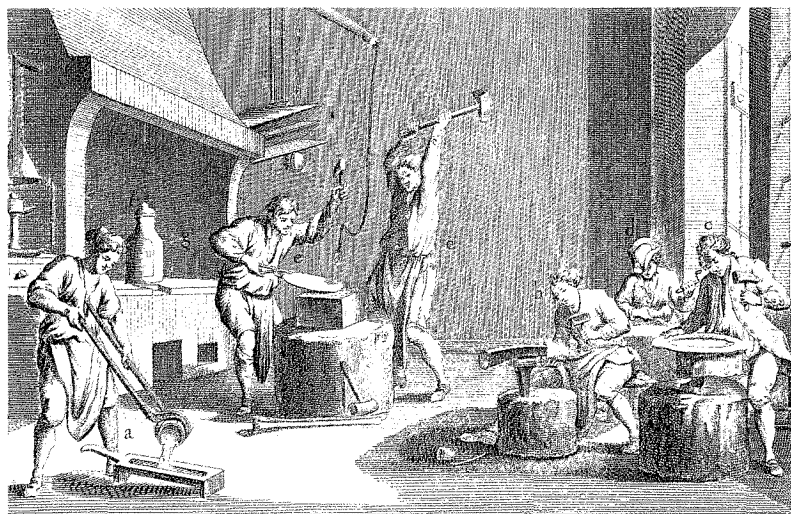
IA										IIA										IIIA										IVA										VA										VIA										VIIA										VIIIA																																																																																																													
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Li										Be										Al										Si										P										S										Cl										Ar																																																																																																													
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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																																																	

# Ag

Silver is one of the few metals found in its free state in nature. It is also found in fairly high concentrations in such ores as argentite, a silver sulfide, and as an impurity in copper-nickel ores.

Silver was known in ancient times and derives its chemical symbol, Ag, from the Latin word *argentum*, which means silver. The alchemists had a special symbol for it, consisting of a sign in the shape of a new moon. Silver has been used for money since biblical times and so is often referred to as a coinage metal. Its “silver” color and luster are well known and are used to describe the appearance of other metals. Of all the metals, silver is the best conductor of heat and electricity. It is not usually used in home wiring because of its expense, but it is extensively used in the manufacture of high-quality electronic equipment.

Silver is a soft metal that is extremely ductile and malleable.



Silver has been known and used since ancient times. An 18th-century French engraving shows silversmiths at work making jewelry and flatware.

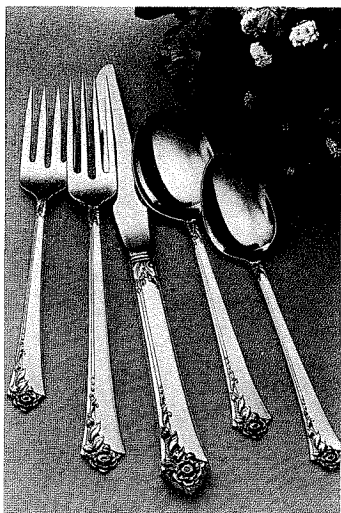
# SILVER

Atomic Number 47

Chemical Symbol Ag

Group IB—Transition  
Element (Coinage  
Metal)





*The sterling silver used to create these eating utensils is a mix of 7 percent copper and 93 percent silver.*

This means that it can be drawn into fine wires and hammered into extremely thin sheets for a variety of uses. In making jewelry, copper is usually alloyed with silver to harden the latter and give it the strength needed for jewelry. Sterling silver, for example, is 7 percent copper, while some so-called silver rings and bracelets can contain up to 20 percent copper. The amount of silver contained in jewelry is often expressed in terms of “fineness.” This is simply 10 times the percentage of silver contained in a piece of jewelry. Sterling silver, which is 93 percent silver, thus has a fineness of 930. Much of European silverware has a fineness of 800. When polished, silver can attain an exceptionally high luster, which makes it valuable as a reflective coating on mirrors.

Silver is often used to plate jewelry and eating utensils. In the plating process, an electrical current is used to deposit a thin, protective coating of silver onto less expensive metals, which greatly improves their appearance and durability. Silver electroplating is usually accomplished by connecting the electrically positive terminal, or anode, of a power source to a bar of silver, connecting the negative terminal of the source to the object to be plated, and immersing both in a bath of silver cyanide. As electrical current flows through this miniature battery cell, a bright, shiny film of silver forms on the object.

Metallic silver does not react with the oxygen in air, but it does slowly tarnish over time. The black film that forms on silver objects is silver sulfide. The decay of vegetable matter always results in the presence of small quantities of hydrogen sulfide in the air, and it is this pollutant that reacts with the silver to produce a tarnish. The tarnishing process can be very rapid if a silver utensil is left in contact with a food that contains sulfur, such as eggs or mustard.

Silver is used very extensively in a variety of commercial and scientific products. Industries in the United States use more than 175 million ounces of silver every year, with about 24 percent of this quantity used by the electronics industry. Much of the silver consumed in the United States is also used to make photographic film and paper.

One of the more common uses of silver is in the tooth fillings used in dentistry. A typical filling is a mixture of silver powder and mercury. The silver, usually added in excess amounts, dissolves in the mercury to form an amalgam. The amalgam is actually a solution of silver in mercury, which has the effect of cementing the silver particles together.

Silver compounds are very sensitive to light. Many silver salts, such as silver chloride and silver iodide, darken on exposure to

light. The darkening process, called photochemical decomposition, is caused by light energy decomposing the silver salt to form metallic silver. In photography, the emulsion used for photographic film and paper usually consists of a gelatin mixed with silver bromide. When you take a snapshot, light falling on the film energizes the silver ions in the molecules of the silver bromide. These “excited” silver ions then form silver atoms on the surface of the emulsion, producing a latent image of whatever was being photographed. A developing material is then added to “fix” this image.

Photochromic sunglasses, which darken in sunlight, also depend upon the decomposition of silver salts by light. In these glasses, small grains of silver chloride are mixed with the glass used for the lenses. In the presence of light, a thin layer of opaque metallic silver forms on the surface of the glass. The photochemical decomposition that causes this to happen is made reversible by the addition of copper ions to the glass. In the absence of light, the copper ions change the silver atoms back to their original form once again, yielding silver chloride.

Crystals of silver iodide, with their yellowish color, have found an interesting application outside of photography. They are used to “seed” clouds and produce rain. When dropped from an airplane, these tiny crystals cause water drops to form around them, which then enlarge until the weight of each drop is sufficient to make it fall to earth as rain. The silver iodide in the rain is relatively harmless to plants and animals and is dispersed by the rain itself.

*Much of the silver consumed in the United States is used to make photographic film and paper.*

# CADMIUM

Atomic Number **48**

Chemical Symbol **Cd**

Group **IIB—Transition Element**

IA												VIIIA					
H											He						
IIA												VIIA					
Li	Be											B	C	N	O	F	Ne
III A		III B	IV B	V B	VI B	VII B	VIII B			IB	IIB	VIIA					
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						
		* 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															

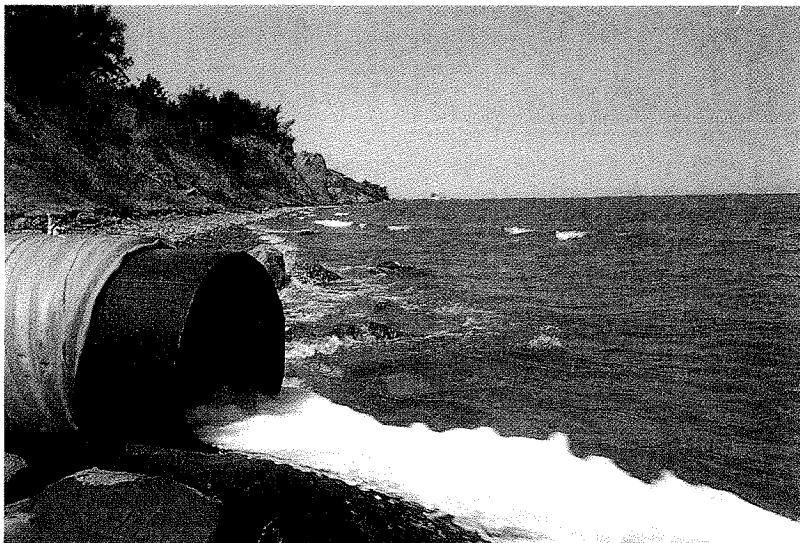


Cadmium is a silvery metal that is soft enough to cut with a knife. Its chemical properties greatly resemble those of zinc. It is a relatively rare element, with an abundance of only about one-thousandth that of zinc in the Earth's crust. Its principal ore is cadmium sulfide, but cadmium is present in such great quantities in zinc ores that it is generally collected as a by-product of zinc refining. Even its history is intertwined with that of zinc. It was discovered in 1817 by Friedrich Strohmeyer, a pharmaceutical chemist who was investigating the compound zinc oxide, known as calamine.

The major use of cadmium is in the electroplating of steel to protect it from corrosion. It is used less often than zinc for this purpose because it is less abundant than zinc and therefore more expensive and can cause a variety of health problems, including kidney failure and high blood pressure. However, it is much more durable than zinc in an alkaline environment. Only a very thin film of cadmium, about 0.05 millimeters, is required for the electroplating of steel.

Until quite recently the pollution of lakes and rivers by cadmium waste discharges from electroplating industries was a major problem. Tobacco leaves also contain some cadmium, so that both smokers and the smoke they exhale are likely to contain trace quantities of the element.

In addition to its use in electroplating, cadmium is used to make nickel-cadmium, or nicad, batteries. The nicad battery can be recharged an indefinite number of times and is therefore much more convenient to use than the rechargeable lead storage battery. It is also much more portable because it can be sealed and manufactured in a form very similar to the common dry cell. It produces



*The discharge of cadmium waste into lakes and rivers by electroplating companies was, until recently, a major source of pollution.*

an output of 1.4 volts, which is slightly less than the 1.5 volts of a common dry cell.

The ability of cadmium to absorb neutrons has made it of great importance in the design of nuclear reactors. Many reactors use cadmium in their control rods. During normal operation of the reactor, these rods are withdrawn from the containment vessel. To stop the reaction, the rods are lowered into the vessel, where they absorb enough neutrons to prevent the self-sustaining chain reaction from continuing.

An alloy called Wood's metal consists chiefly of bismuth but contains about 12.5 percent cadmium. It has an extremely low melting point of  $70^{\circ}\text{C}$  and is used to seal the overhead sprinkler systems installed in many factories and homes. A fire will melt the seal before it gets too hot, releasing water to quench the fire. Cadmium is also used as a red or yellow pigment in making paint.

*Tobacco leaves also contain some cadmium, so that both smokers and the smoke they exhale are likely to contain trace quantities of the element.*







*Tin is thought to take its name from the Etruscan god Tinia, and its chemical symbol from stannum, the Latin word for the element.*

a long time. The extreme cold not only caused the tin buttons worn by the Russian soldiers to crumble, but many of the tin pipes used for church organs crumbled as well. The problem came to be called the “tin disease.” The third allotrope of tin, called brittle tin, exists above 161°C. Its properties are obvious from its name.

Tin is too soft a metal to be of much value as a building material or a component of tools. It is very malleable and can be rolled into thin sheets of the tin foil that has been used for hundreds of years. At one time it was quite popular as a material for household utensils such as tin plates and cups. Today it is chiefly used as an alloying agent and to make tin plate, which is steel sheeting covered with a thin coating of tin that is applied electrolytically. Because the tin protects the steel from attack by food acids, tin plate was once used to make tin cans for food but has since been largely replaced by plastic and aluminum. As an alloying metal, tin is used with copper to make bronze and is used to make solder (33 percent tin and 67 percent lead), an easily meltable metal used with a heating iron to make secure electrical connections. Pewter (85 percent tin, 7 percent copper, 6 percent bismuth, and 2 percent antimony), another alloy of tin, has long been used for making cutlery, bowls, and plates. The alloy known as Wood’s metal contains about 12.5 percent tin and is used in fire sprinklers, described in the section on cadmium.

Another alloy of tin with lead and antimony is the metal used for casting printing type. Both the tin salts stannic chloride ( $\text{SnCl}_4$ ) and stannic oxide ( $\text{SnO}_2$ ) are used to produce glazes for ceramics and special coatings for fabrics.