

Gallium—A Smart Metal

As part of a broad mission to conduct research and provide information on nonfuel mineral resources, the U.S. Geological Survey (USGS) supports science to understand

- How and where gallium resources form and concentrate in the Earth's crust
- How gallium resources interact with the environment to affect human and ecosystem health
- How trends in supply of and demand for gallium differ in domestic and international markets
- Where future sources of gallium might be found

Why is this information important? Read on to learn about gallium and the important role it plays in the national economy, in national security, and in the lives of Americans every day.

Delta II rocket launching the Mars Exploration Rover, *Spirit*, June 10, 2003.



Gallium is a soft, silvery metallic element with an atomic number of 31 and the chemical symbol Ga. The French chemist Paul-Emile Lecoq de Boisbaudran discovered gallium in sphalerite (a zinc-sulfide mineral) in 1875 using spectroscopy. He named the element “gallia” after his native land of France (formerly Gaul; in Latin, *Gallia*).

The existence of gallium had been predicted in 1871 by Dmitri Mendeleev, the Russian chemist who published the first periodic table of the elements. Mendeleev noted a gap in his table and named the missing element “eka-aluminum” because he determined that its location was one place away from aluminum in the table. Mendeleev thought that the missing element (gallium) would be very much like aluminum in its chemical properties, and he was right.

Solid gallium has a low melting temperature (~29 degrees Celsius, or °C) and an unusually high boiling point (~2,204 °C). Because of these properties, the earliest uses of gallium were in high-temperature thermometers and in designing metal alloys that melt easily. The development of a gallium-based direct band-gap semiconductor in the 1960s led to what is now one of the most well-known applications for gallium-based products—the manufacture of smartphones and data-centric networks.

How Do We Use Gallium?

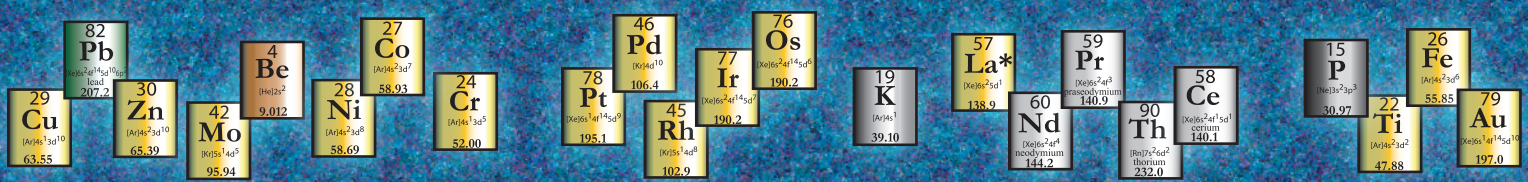
Gallium is used in the microelectronic components of a wide variety of products. The components include GaAs (gallium arsenide), GaN (gallium nitride), and CIGS (copper-indium-gallium selenide) direct band-gap semiconductors. GaAs and GaN are able to change electricity directly into laser light and are used in the manufacture of light-emitting diodes (LEDs), laser diodes, photo detectors, and solar cells. These devices are important for the aerospace and telecommunications industries. They are also used in the production of highly specialized integrated circuits, semiconductors, and transistors to help regulate the flow of electricity. These components are necessary for high-performance computers and smartphones (cellular telephones that have advanced personal computer-like functionality). Power transistors made with GaN operate at higher voltages and with a higher power density than those made with GaAs. The types and numbers of products that use advanced GaN-based transistors are expected to increase in the future. CIGS was developed to make lightweight and durable thin-film photovoltaics that have a high absorption coefficient; CIGS has potential applications in the manufacture of efficient solar cells. Gallium is also used in some unusual applications. Thermal convection in liquid gallium is used to study aspects of planetary and astrophysical magnetohydrodynamics, and because of its silvery color and ability to form metal alloys, gallium is used to make brilliant mirrors.



Gallium-arsenide and gallium-nitride technologies are used in advanced high-performance radio-frequency mobile devices, including third- and fourth-generation smartphones, fiber optic networks, wireless local area networks, global positioning systems, and defense and aerospace applications.

Where Does Gallium Come From?

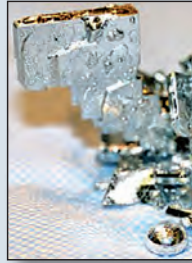
The abundance of gallium in the Earth's crust is small—generally less than 19 parts per million. Gallium does not exist in elemental form in nature, and the few high-gallium minerals that do occur are too rare to serve as a primary source of the element. Fortunately, gallium occurs in low amounts in many minerals where it substitutes for elements of similar size and charge. Gallium is found in small amounts (~50 parts per million) in many bauxite deposits, and it occurs in zinc deposits in about the same amounts as in bauxite deposits. Currently, gallium is obtained mainly from mining and mineral processing of bauxite ore for aluminum, although some gallium is also derived from the processing of sphalerite ore for zinc. Gallium is also recycled from scrap generated in the manufacture of GaAs- and GaN-based devices.



Worldwide Supply of and Demand for Gallium

In 2011, China, Germany, Kazakhstan, and Ukraine were the leading producers of gallium from raw ore. The principal producers of refined gallium, which includes gallium production from raw ore plus gallium that is recovered from impure gallium metal, were China, Japan, the United Kingdom, and the United States. Gallium was recycled from new scrap in Canada, Germany, Japan, the United Kingdom, and the United States. No primary production of gallium has taken place in the United States in recent years; instead, most of the gallium used in the United States comes from imports of gallium metal and GaAs wafers.

World demand for gallium is expected to remain high as demand for Ga-based products continues to increase. GaAs demand is increasing owing to the rapid growth in the popularity of feature-rich, application-intensive, third- and fourth-generation smartphones. Demand for GaN-based products is expected to increase in the cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets. The LED industry is also expected to increase demand for GaAs and GaN-based technologies that are used in the backlighting of computer notebook screens and flat-screen computer monitors and televisions, and in general lighting applications.



The gallium crystals shown in this photograph grew in a tank of liquid gallium. The drop in the foreground fell off the crystal as the liquid slowly cooled below a temperature of about 29 degrees Celsius. Photograph courtesy of Afshin Yaghmaei, Simulated Planetary Interiors Lab, University of California, Los Angeles.



Did you know...

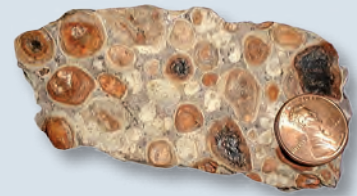
The NASA Mars Exploration Rovers Spirit and Opportunity are equipped with gallium-arsenide solar panels.

How Do We Ensure Adequate Supplies of Gallium for the Future?

U.S. bauxite deposits are mainly subeconomic resources that are not generally suitable for aluminum production owing to their high silica content; consequently, recovery of gallium from these deposits is unlikely. Some domestic zinc ores have the potential to be significant sources of gallium. The United States meets its current and expected future needs for gallium through imports of primary, recycled, and refined gallium as well as domestic production of recycled and refined gallium.

The U.S. Geological Survey (USGS) estimates that world resources of gallium in bauxite exceed 1 billion kilograms and that a considerable quantity of gallium could also be present in world zinc resources. Most of the gallium in bauxite resources cannot be considered to be available in the short term, however, because much of the bauxite will not be mined for many decades. Also, only a small percentage of the gallium metal contained in bauxite and zinc ores is economically recoverable using current separation methods. Larger amounts of gallium could be recovered from these ores if more efficient and improved extraction and separation methods are developed in the future.

To help predict where future gallium supplies might be located, USGS scientists study how and where identified aluminum and zinc resources are concentrated in the Earth's crust and use that knowledge to assess the likelihood that undiscovered resources containing gallium also exist. Techniques to assess mineral resources have been developed and refined by the USGS to support the stewardship of Federal lands and to better evaluate mineral resource availability in a global context. The USGS also compiles statistics and information on the worldwide supply of, demand for, and flow of gallium. These data are used to provide information for domestic and international policymakers and decisionmakers in the public and private sectors.



Bauxite is the primary ore from which most of the world's gallium is produced. Small amounts of gallium are distributed within the aluminum minerals that make up bauxite, which is the main source of aluminum metal. The U.S. penny in the photograph is for scale.



Did you know...

Gallium is one of the formal temperature reference points of the International Temperature Scale established by the International Bureau of Weights and Measures.

For More Information

- On production and consumption of gallium:
<http://minerals.usgs.gov/minerals/pubs/commodity/gallium/>
- On gallium deposit models:
<http://minerals.usgs.gov/products/depmod.html>

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The USGS Mineral Resources Program is the principal Federal provider of research and information on gallium and other nonfuel mineral resources. For more information, please contact:

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