USGS
science for a changing world

USGS Mineral Resources Program

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Lithium—For Harnessing Renewable Energy

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 lithium resources form and concentrate in the Earth's crust*
- *How lithium resources interact with the environment to affect human and ecosystem health*
- *Trends in the supply of and demand for lithium in the domestic and international markets*
- *Where undiscovered sources of lithium might be found*

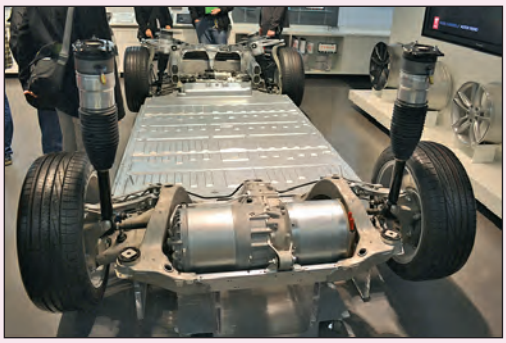
Why is this information important? Read on to learn about lithium and the important role it plays in the national economy, in national security, and in the lives of Americans every day.

Telephone-pole-sized crystals of the lithium ore mineral spodumene, from the Etta pegmatite, South Dakota. Note the miner for scale, inside red circle. From Schaller (1916, USGS Bulletin 610).

Lithium, which has the chemical symbol Li and an atomic number of 3, is the first metal in the periodic table. With a specific gravity of 0.534, it is about half as dense as water and the lightest of all metals. In its pure elemental form it is a soft, silvery-white metal, but it is highly reactive and therefore never is found as a metal in nature.

Lithium has an average concentration of 20 parts per million in the Earth's continental crust. It is more abundant than some of the better-known metals, including tin and silver. Lithium occurs in most rocks as a trace element, with the lithium substituting for magnesium in common rock-forming minerals. It was first recognized as an element in 1817 when the Swedish chemist Johan Arfvedson analyzed the mineral petalite. The metal itself was first isolated in useful quantities in 1855. In 1869, Dmitiri Mendeleev correctly positioned it adjacent to sodium, with the alkali metals, in his then-revolutionary periodic table of the elements.

How Do We Use Lithium?



View into a Tesla Model S® electric car showing the lithium-ion battery covering most of the bottom of the chassis. Various battery configurations use between about 10 and 22 kilograms of lithium. Photo by Oleg Alexandrov, downloaded from Wikimedia Commons.

Lithium has many uses, the most prominent being in batteries for cell phones, laptops, and electric and hybrid vehicles. Many other uses are behind the scenes and not obvious to consumers. Lithium is added to glasses and ceramics for strength and resistance to temperature change, it is used in heat-resistant greases and lubricants, and it is alloyed with aluminum and copper to save weight in airframe structural components. Lithium is used in certain psychiatric medications and in dental ceramics. The lighter of two lithium isotopes, ^{6}Li, was used in the production of tritium for nuclear weapons. Worldwide lithium consumption in 2012 by end-use industry was as follows: ceramics and glass, 35%; batteries, 29%; greases, 9%; air treatment, 5%; metallurgy, 6%; polymers, 5%; aluminum refining, 1%; and other uses, 10%.

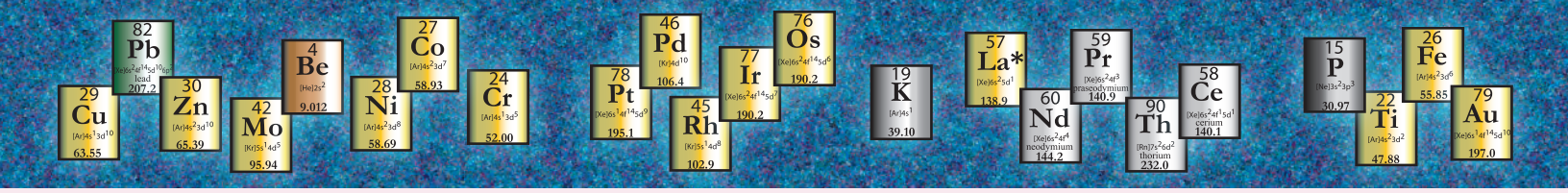
The use with the greatest potential benefit to the most people in the world is in rechargeable batteries, which take advantage of lithium's light weight and high electrochemical potential. Rechargeable batteries make it possible to power cars and trucks by using renewable, carbon-neutral sources of energy (for example, solar, hydro, or wind) instead of gasoline or diesel. As battery technology improves, lithium is expected to play a key role in efforts to reduce carbon dioxide emissions that are responsible for global warming.

Where Does Lithium Come From?

Worldwide sources of lithium are broken down by ore-deposit type as follows: closed-basin brines, 58%; pegmatites and related granites, 26%; lithium-enriched clays, 7%; oilfield brines, 3%; geothermal brines, 3%; and lithium-enriched zeolites, 3% (2013 statistics).

Closed-basin brines are currently the most important source of lithium. Dissolved lithium occurs in concentrations up to a few thousand parts per million in the saline groundwater beneath certain playas and salt lakes. Brine deposits form in closed basins in tectonically active, arid regions. The lithium builds up over time by weathering of rocks that contained only trace quantities. The lithium is subsequently extracted from these deposits by pumping the brine to the surface, where the lithium is concentrated by evaporation in a series of solar ponds. This lithium-rich solution is then processed into lithium carbonate or lithium hydroxide. The world's main brine producers are Chile, Argentina, China, and the United States. An enormous brine deposit in Bolivia has not yet been put into production.

Pegmatites are a type of granite characterized by giant crystals of the common rock-forming minerals quartz, feldspar, and mica. A few pegmatites—termed "LCT"—are enriched in the rare metals lithium, cesium, and tantalum, and it is these LCT pegmatites that are mined for lithium. The most important lithium ore mineral is spodumene. The largest recorded spodumene crystal in a pegmatite measured 14 meters (40 feet) in length. The world has hundreds of LCT pegmatite deposits, but only a handful of large ones are currently producing lithium, with the greatest production from deposits in Australia, Zimbabwe, Brazil, China, and Portugal. Lithium pegmatites are mined in open pits or in underground mines.



Worldwide Supply of and Demand for Lithium

There are over 39 million tons of lithium resources worldwide. Of this resource, the USGS estimates there to be approximately 13 million tons of current economically recoverable lithium reserves. Recycling of batteries is expected to play a key role in the supply of lithium in the medium to long term. Lithium is a resource that can be recycled repeatedly, thereby reducing future needs for new sources of lithium.

Prices for lithium metal and lithium compounds are not published, but approximate values can be gleaned from industry sources. Battery-grade lithium carbonate is currently (2013) valued between $6,500 and $7,000 per metric ton. In 2010, Japan imported pure lithium metal at a cost of $73,546 per metric ton ($33.36 per pound).

Watermelon tourmaline—green outside and pink within—is a lithium-bearing gemstone. In 1973, a single gem-filled pocket in a pegmatite in Maine produced about two tons of tourmaline that would be valued today (for gems and mineral specimens) at about $40 million. Courtesy of the Mineralogical & Geological Museum at Harvard University, specimen number MGMH 125525, Dunton Mine, Newry, Maine.

Did you know... ***Lithium is one of only three elements that were produced during the primordial Big Bang about 13.8 billion years ago. All other elements formed subsequently in stars or supernovas.***

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

Lithium, like most mineral resources, is mined and traded globally. The United States is fairly well endowed with lithium deposits that might be exploited in the future, even though current production is fairly limited. As of 2013, the only domestic production is from the lithium brines in Clayton Valley, Nevada. Production of lithium from the King's Mountain pegmatite district in North Carolina ceased in the early 1990s, leaving a substantial, though currently uneconomic, resource still in the ground.

To help predict where future lithium supplies might be located, USGS scientists study how and where identified resources are concentrated in the Earth's crust, and they use that knowledge to assess the likelihood that undiscovered resources 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 lithium. These data are used to provide information for domestic and international policymakers and decisionmakers in the public and private sectors.

Lithium-brine evaporating ponds at Clayton Valley, Nevada. The dark pond at the top is 1.7 kilometers long. Photo courtesy of Doc Searles, downloaded from Wikimedia Commons.

Did you know... ***There are about six billion cell phones in the world, about as many as there are people, and most of these are powered by a lithium battery.***

For More Information

- On production and consumption of lithium: http://minerals.usgs.gov/minerals/pubs/commodity/lithium/
- On lithium deposit models: http://pubs.usgs.gov/of/2013/1006/OF13-1006.pdf http://pubs.usgs.gov/of/2013/1008/OF13-1008.pdf

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The USGS Mineral Resources Program is the principal Federal provider of research and information on lithium and other nonfuel mineral resources.

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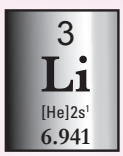

Did you know... ***An estimated 300 million people alive today will suffer from bipolar disorder at some point in their lives. Millions benefit from a daily dosage of lithium carbonate.***

Lithium battery courtesy of Krzysztof Woznica, downloaded from Wikimedia Commons at http://en.wikipedia.org/wiki/File:Battery-lithium-cr2032.jpg

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