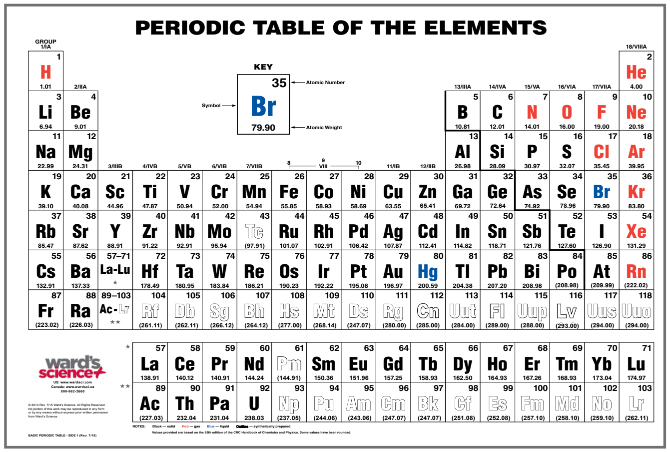
All About Elements:

Lithium

Boreal's All About Elements Series

Building Real-World Connections to the Building Blocks of Chemistry



A chemical element is the simplest form of matter that scientists can work with directly. All of the more complex substances are composed of elements in various combinations. But have you ever inquired about the properties of each of those individual chemical building blocks? Our universe is composed of trillions of substances that are all differing compositions of a finite number of elements. In this email series, we will delve deeper into each of the elements in order to gain more insight into their properties and uses and the substances they are used to create.

In our ***All About Elements*** series, we've brought together the most fascinating facts and figures about your favorite elements so students can explore their properties and uses in the real world and you can create chemistry connections in your classroom and beyond.

Look for a new featured element each month, plus limited-time savings on select hands-on materials to incorporate these element in your lessons.

Sign up to receive Boreal's Science emails at boreal.com and get a new element in your inbox each month.

Check back often at boreal.com/elements for the latest content and exclusive savings on new teaching tools each month.

Fun Facts About... Lithium

3

Li

6.94

1. Elemental Lithium can float in mineral oil!
2. Lithium was one of the elements produced during Big Bang Nucleosynthesis. The other two were helium and hydrogen.
3. Like many other elements, Lithium was discovered by accident!
4. Today, lithium carbonate is extracted from brine fields, mainly in South America. The lithium carbonate is converted to lithium chloride using hydrochloric acid. This lithium chloride is then fused with potassium chloride and used in the electrolysis operation that produces elemental lithium.
5. Lithium is commonly found today in batteries in our cell phones and laptops.

All About Lithium:

Lithium is the third element on the Periodic Table of Elements, found in group 1 (1A). Lithium contains just a single valence electron, with a configuration of $1s^2 2s^1$, making it the first alkali metal found on the table, as well as one of the most reactive metals. It is the least dense of all of the solid elements with a density of 0.534 g/cm^3 making it one of three elements that would actually float on water, the other two being sodium and potassium. In its pure elemental form it is a shiny metal that is so soft it can be cut with a knife. However, that shiny surface quickly disappears when the element is exposed to oxygen in the air, forming a dull grey layer of lithium oxide and hydroxide.

Lithium floating in mineral oil

Properties of Lithium

Lithium has the chemical symbol Li and the atomic number of 3. Like all alkali metals, it is a highly reactive metal, which is also quite flammable and therefore is typically found stored under an inert liquid such as a hydrocarbon, rather than water. In fact, like all other alkali metals, lithium reacts with water to form hydrogen gas and lithium hydroxide in aqueous solution. Due to its high reactivity, lithium is not found freely in nature as other elements are (it only makes up 0.0007% of the Earth's crust), and instead only appears bonded with other elements, typically in ionic compounds (such as LIf, LiCl, LiBr, LiI) due to its propensity to lose an electron to form Li^+. Because of its easy ability to form a cation, lithium is also a good conductor of heat and electricity. Lithium is a very soluble ion, and therefore is present in ocean waters and is harvested from natural brines and clays, which we will discuss further later. It is estimated that there are 230 billion tons of lithium in seawater, where it exists at a relatively constant concentration of 0.14 to 0.25 parts per million, although the water's near-hydrothermal vents have concentrations approaching 7 ppm.

In nature, lithium is composed of two stable isotopes, ^{6}Li and ^{7}Li, where lithium-7 is the more abundant isotope making up approximately 92.5% of the natural abundance. Lithium-7 is also one of the three primordial elements, or rather nucleotides, that were produced in the first three minutes of the Universe's existence during Big Bang nucleosynthesis, in addition to Hydrogen and Helium. Although a small amount of both lithium-6 and lithium-7 are believed to be produced in the stars, it is thought that they are burned off as quickly as they are produced. Older stars tend to have less lithium than expected due to Big Bang nucleosyntheis, while younger stars seem to have far more lithium than expected. The lack of lithium or cosmological lithium discrepancy in the Universe is thought to be caused by the combination of lithium into the inner parts of the stars where it transforms into two atoms of helium due to collisions with a proton at extremely high temperatures (2.4 million °C), inevitably being destroyed.

Despite being one of the first three elements synthesized in the Universe, lithium is much less abundant than other nearby elements, such as sodium or potassium, due to the low temperatures required to destroy it. Seven radioisotopes have been characterized, the most stable being ^{8}Li. The half life of this isotope is only 838 ms however. The next most stable radioisotope of lithium is ^{9}Li with a half life of 178 ms, whereas the least stable isotope, ^{4}Li, only lasts for 7.6×10^{-23} s before it decays through proton emission.

Discovery and History

Lepidolite Specimen

Lithium was discovered in 1817 by a 25 year old Swedish chemist named Johan Arfwedson. Arfwedson was searching for compounds of the recently discovered element potassium when he came across an entirely new element! The mineral that he was searching in was a translucent mineral called petalite ($LiAlSi_4O_{10}$). He based the new element's name on the Greek word lithos, which means 'stone'. Petalite was actually discovered in 1800 by a Brazillian chemist and statesman named José Bonifácio de Andrada e Silva in a mine on the island of Utö, Sweden. The reason Arfwedson knew that it was a new element rather than a compound of sodium or potassium, is due to the fact that lithium carbonate and lithium hydroxide were less soluble in water than the known sodium and potassium compounds, and the resulting solution was found to be more alkaline than expected. Actually, in a time with fewer safety considerations, chemists actually drank the liquid to determine the alkalinity of the solution rather than testing with a pH probe as we would today! He also showed that lithium was present in the minerals spodumene and lepidolite.

Where in the World is Lithium?

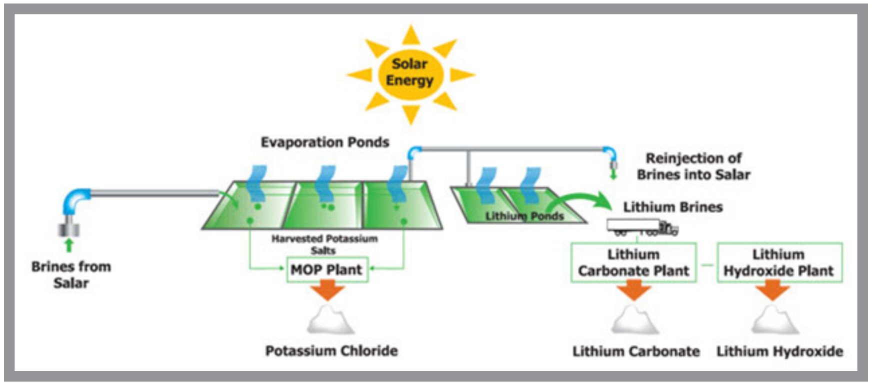
While it is possible for pure elemental lithium to be commercially extracted by electrolysis of the compound lithium chloride (LiCl), the lithium chloride must be harvested from somewhere! Lithium chloride is actually produced from lithium carbonate (Li_2CO_3), which is produced from rocks containing lithium. The Earth's crustal contents of lithium range from 20 to 70 ppm by weight, which makes it the 25th most abundant element, and lithium forms a minor part of many igneous rocks, with its largest concentrations in granites. Granite pegmatites also contain the highest concentration of lithium containing minerals, such as spodumene and petalite. Lithium salts can there for be extracted from water in mineral springs, brine pools and brine deposits across the globe.

In 2010, the country of Chili in South America was estimates to have the largest reserve of lithium salts with approximately 87.5 million tons and the highest annual production at 8,800 tons/year. Another large reserve is in Salar de Uyuni area of Bolivia, which has approximately 5.4 million tones. In the United States, lithium salts are recovered from brine pools in California, Nevada and a newly discovered deposit in Wyoming's Rock Springs Uplift.

Salt flats rich in Lithium in Bolivia

In the 1950s all the way through the 1980s, the US was the major manufacturer of lithium and by the end of the cold war it was estimated that there was roughly 42,000 tons of lithium hydroxide in US stockpiles. At the end of the cold war, the demand for lithium drastically decreased and the US began to sell of their stockpiles on the open market for reduced prices. At this time, brine mines began to close or shift their focus to other materials as only the ore from zones pegmatities could be mined for a competitive price. This only lasted from about 1990 to around 2007 when the development of the lithium ion battery increased demand for lithium and new companies began to expand brine extraction effort in order to meet the increased demand.

Today, brine evaporation produces most of the world's lithium, mainly in South America. During this process, underground sources of lithium-containing brine are utilized to extract the brine, and then concentrate the lithium through a process of solar evaporation. This process however takes many months to complete. Researchers are experimenting with other methods, in hope of discovering an alternative, faster method of lithium extraction. Reverse osmosis, a water purification process by which a semi-permeable membrane is used to remove ions, molecules and larger particles, has also been proposed as an alternative to standard brine evaporation. It is also believed that lithium can be extracted from geothermal wells. The fluids in geothermal wells carry leachates to the surface, and the recovery of lithium has been demonstrated successfully this way in the field. The lithium can be separated using simple filtration techniques and there is little negative environmental impact, as the well previously was in existence, however this process takes between 18 and 24 months to complete.



A second form of extraction that has been proposed is from seawater, as it is known that there is a presence of lithium in seawater, however a practical extraction procedure has not yet been developed in order to commercially extract the lithium on a large scale. In 2015 a new seawater extraction process was introduced, which uses a superconducting membrane for a dialysis cell. The only ion in the seawater that is able to pass through this membrane is lithium, thus concentrating the lithium out of the seawater. However, as mentioned above, the commercialization of this process is yet to occur.

The ore spodumene, $LiAl(SiO_3)_2$ is the most important commercial ore containing lithium. The alpha form is first converted into a softer beta form by heating to around 1100°C. This is mixed carefully with hot sulfuric acid and extracted into water to form lithium sulfate. The Li_2SO_4 solution is washed with sodium carbonate, Na2CO3, to form a precipitate of the relatively insoluble lithium carbonate, Li_2CO_3 by the below equation.

$Li_2SO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + Li_2CO_{3\ (solid)}$

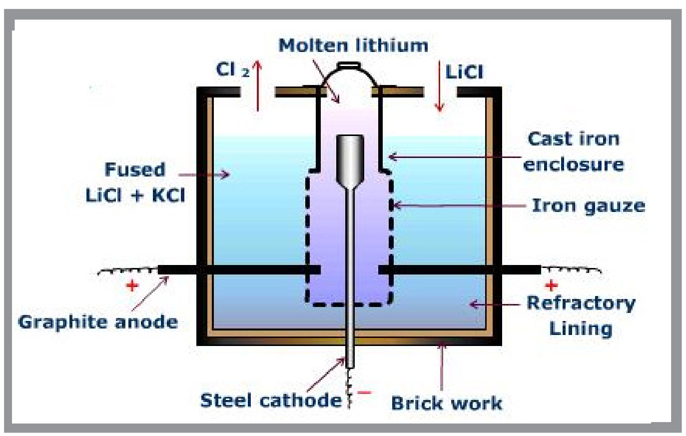
A reaction then takes place with lithium carbonate and hydrochloric acid, HCl, that provides lithium chloride, LiCl.

$Li_2CO_3 + 2HCl \rightarrow 2LiCl + CO_2 + H_2O$

Lithium chloride has a high melting point (>600°C) meaning that it should be expensive to melt in order to carry out electrolysis, however when mixed in 55:45 ratio with potassium chloride it melts at 430°C and so requires much less energy and expense to carry out the electrolysis process of producing elemental lithium.

Cathode: $Li^+_{(l)} + e^- \rightarrow Li_{(l)}$

Anode: $Cl^-_{(l)} \rightarrow ½\ Cl_{2(g)} + e^-$



Uses of Lithium Today

Lithium and its compounds can be found in a variety of different products and applications, some of which are industrial, while others are common products used each and every day. The most common lithium containing products that we encounter on a daily basis are lithium-ion rechargeable batteries. These batteries are commonly found in cameras, mobile phones, laptop computers, pacemakers, toys and clocks, and can also be found in electric vehicles. Lithium has a very low atomic mass and therefore a high charge. Consequently a typical lithium-ion battery can generate approximately 3 volts of energy per cell, compared to the typical 2.1 volts per cell for a typical lead-acid battery or 1.5 volts per cell for a zinc-carbon battery. Other industrial applications include lithium grease lubricants and flux additives for iron, steel and aluminum production. Some of the other interesting uses of lithium can be found below.

Ceramic Glass

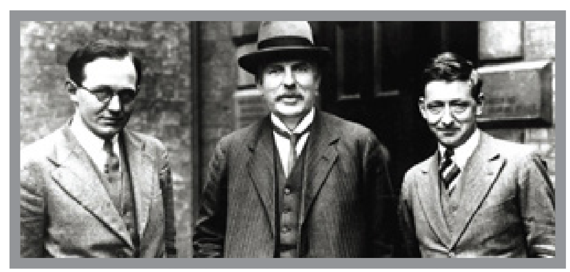
In order to reduce the melting point of the ingredients of glass and also to increase the heat resistance of glass and ceramic cookware, lithium compounds are incorporated into the manufacturing processes. Lithium is used to decrease the melting point of glass and to improve the melting behavior of aluminum oxide when using the Hall-Heroult process. Lithium oxide is widely used as flux for processing silica, reducing the melting point and viscosity of the material and leading to glazes of improved physical properties including low coefficients of thermal expansion. Therefore these lithium oxides are a main component of ovenware. This worldwide is the greatest use for lithium compounds. When used as a flux for welding or soldering, metallic lithium promotes the fusing of metals during the process and eliminates the formation of oxides by absorbing impurities. Alloys of the metal with aluminum, cadmium, copper, and manganese are used to make high-performance aircraft parts, bicycle frames and high-speed trains.

Medical Drugs

Lithium carbonate is one of the main ingredients in medicines used to treat psychological disorders. The Li^+ ion has been proven to have mood stabilizing neurological effects on the human body. Interestingly, lithium has been found to be present in all organisms, however the element serves no apparent biological function as both plants and animals can survive without it. However, the ion of lithium, when administered in this drug form, does have substantial effects on the human body. Other drugs made from lithium salts are used to treat related diseases such as schizoaffective disorder and cyclic major depression and cluster headaches.

Grease Lubricants

High temperature lithium greases were developed around the time of WWII for aircraft engines and similar heat sensitive applications. Greases made from lithium based soaps have a higher melting point than other alkali soaps and are also less corrosive than calcium based soaps. These greases also had applications in the mining industry around the United States. The third most common use of lithium is greases. Lithium hydroxide is a strong base and when heated with a fat, produces a soap made of lithium stearate. Lithium soap has the ability to thicken oils, and it is used to manufacture all-purpose high temperature lubricating greases.



Ernest Walton (Left), John Crokcroft (Right) and Ernest Rutherford (Center)

Nuclear Physics

In 1932, Crokroft and Walton discovered that lithium atoms transmuted to helium or alpha particles. This was the first fully man-made nuclear reaction and was called "splitting the atom" at the time. Lithium-6 deuteride serves as a fusion fuel in staged thermonuclear weapons still to this day.

Nuclear Weapons

During the cold war, nuclear weapon manufacturing ramped up, and both lithium-6 and lithium-7 were utilized. These two isotopes produce tritium when irradiated by neutrons, and therefore are useful for the production of tritium and a form of solid fuel that is used inside hydrogen bombs in the form of lithium deuteride. Some rocket propellants even used metallic lithium and its complex hydrides such as $Li(AlH_4)$. The Mark 50 torpedo stored chemical energy propulsion system used a small tank of sulfur hexafluoride gas, which was sprayed over a block of solid lithium. The reaction generated heat, which was used to generate steam and thrust the torpedo forward.

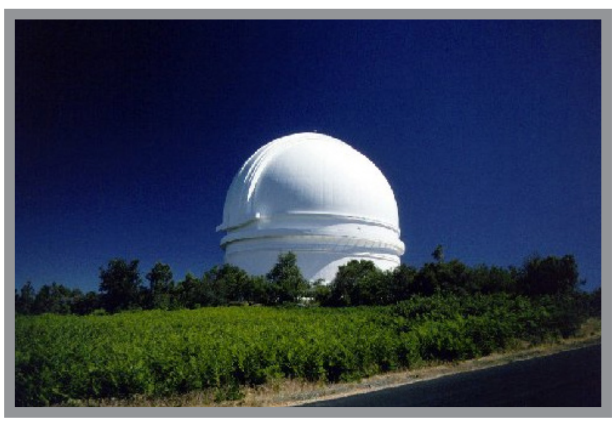
Mark 50 torpedo being fired

Fireworks

Lithium compounds are used in pyrotechnic colorants and oxidizers in red fireworks and flares. The light is produced by electrons that, after being excited by heat, drop to a lower energy level.

Optics

Because lithium fluoride is crystal clear, transparent and has one of the lowest refractive indexes, it is commonly used for specialty optics in IR, UV and VUV applications. It allows for the farthest transmission range in the deep UV of most common materials. Lithium fluoride is also used in focal lenses in telescopes. The glass for the 200-inch telescope at Mt. Palomer contains lithium as a major ingredient! Lithium niobate has uses in no-linear optical applications. One of the most common uses of non-linear optics is telecommunications products such as mobile phones. Lithium in fact is used in more than 60% of mobile phones!



Dome of the 200" Hale Telescope on Mt. Pamoler

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Lithium

Li

F.W.: 6.94 CAS#: 7439-93-2

Hazard: Flammable, Explosive when wet

FLAMMABLE

Shelf Life (months): 36

Storage: Red

Soluble: Water and Acids

bp (°C): 1340

mp (°C): 180

Density (g/mL): 0.53

Grade: Laboratory

470301-387 25 g Bottle

Ward's Safety Pack

Lithium Chloride

LiCl

F.W.: 42.39 CAS#: 7447-41-8

Shelf Life (months): 12

Storage: Green

General Storage

Soluble: Water and Alcohol

bp (°C): 1382

mp (°C): 605

Density (g/mL): 2.07

Grade: Laboratory, Granular

470301-381 100 g Bottle

No Hazardous Freight Charge

boreal science

Lithium Carbonate

Li_2CO_3

F.W.: 73.89 CAS#: 554-13-2

Hazard: Irritant

Shelf Life (months): 12

General Storage

Storage: Green

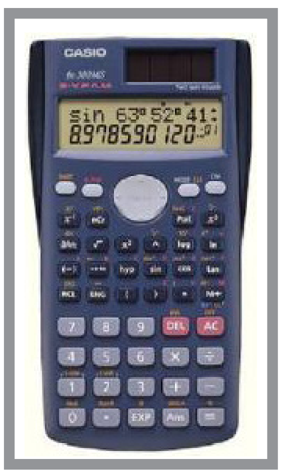
Soluble: Dilute Acid and Slightly, in Water

mp (°C): 720

Density (g/mL): 2.11

Grade: Reagent, Powder

470301-570 100 g Bottle



Casio FX-300MS Plus Scientific Calculator

Approved for use on College Entrance Exams, including the SAT and PSAT/NMSQT, this calculator features 229 built-in functions, including fractions, statistics, standard deviation, linear regression, trigonometry, and polar-rectangular conversions. A fraction key is also included for easy entry and calculation of fractions in addition to quick conversions of fractions to decimals. Other features include a 10 digit, two-line display;random number generator; automatic power down; and protective hard case. Operates on solar and battery power.

Item Number: 470143-884

Celestron PowerSeeker 114EQ Reflector Telescope

Ideal for the beginning astronomer, this telescope features slow motion controls for smooth tracking. Fully coated glass optics with high transmission coatings enhance image brightness and clarity for brilliant views everytime. A 3X Barlow lens triples the magnifying power of each eyepiece offering more detail than other novice telescopes. In addition to astronomical use, the telescope is equipped with erect image optics for terrestrial viewing. Includes accessory tray and The Sky-Level 1 software with 10,000 object database.

Features:

- 3X Barlow lens
- 900mm focal length; ƒ7.89
- 4mm and 20mm eyepieces
- 45X or 225X magnification
- Weight: 19 lbs.

Item Number: 252182

Lepidolite

Beautiful, violet-pink cleavage books of this uncommon lithium mica, 2″ x 2″. Brazil.

Item Number: 492785

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