LITHIUM

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Chile strengthened its position as the leading producer of lithium carbonate in the world with increased capacity at one of its two lithium operations on the Salar de Atacama, although production there was virtually unchanged. The other South American lithium carbonate plant in Argentina on the Salar del Hombre Muerto closed after just one full year of production, reinforcing Chile's role as the world's low-cost, high-volume producer. The lithium chloride portion of the project in Argentina continued operation. One lithium carbonate plant continued to operate in Nevada; and Chinese and Russian lithium carbonate production decreased.

A large percentage of the material produced in South America was exported to the United States to replace the lost production resulting from the closure in 1998 of a spodumene mine and lithium carbonate plant in North Carolina. The United States remained the leading producer of value-added lithium compounds and also the leading lithium consumer, despite the lithium carbonate production shift to South America. Australia, Canada, and Zimbabwe were important sources of lithium ore concentrates.

Because lithium is electrochemically reactive and has other unique properties, many commercial lithium products are available. With an estimated market value of $400 million worldwide (Sheets and Rios, 1999), producers sell lithium as mineral concentrate, brine, compound, or metal depending on the end use. Most lithium compounds are consumed in the production of ceramics, glass, and primary aluminum.

Legislation and Government Programs

In 1997, the U.S. Naval Surface Warfare Center in Crane, IN, awarded a $10.5 million contract to recycle lithium batteries that had been used as backup power sources at underground missile silos. ToxCo, Inc., a recycling company based in Anaheim, CA, began processing the batteries at its Trail, British Columbia, Canada, plant in early 1998. Each battery weighs more than 250 kilograms (kg), and ToxCo will receive and process more than 1 million kilograms of batteries during the 4-year term of the contract. Aluminum, lithium, nickel, and stainless steel were being recovered from the batteries and recycled to use (McLaughlin, 1998). On December 1, 1998, ToxCo processed the one thousandth battery under this contract (W.J. McLaughlin, ToxCo, Inc., written commun., 1998). ToxCo continued to process the military batteries under contract with the U.S. Navy in 1999.

Production

The U.S. Geological Survey collects domestic production data for lithium from a voluntary survey of U.S. operations. The single remaining lithium carbonate producer responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data (table 1).

Chemetall Foote Corp., a subsidiary of the German company, Chemetall GmbH, produced lithium carbonate from brines near Silver Peak, NV. The company's other lithium operations included a lithium hydroxide plant in Silver Peak; a butyllithium plant in New Johnsonville, TN; and facilities for producing downstream lithium compounds and an idle spodumene (a lithium aluminum silicate ore) deposit in Kings Mountain, NC. Chemetall Foote also produced lithium carbonate at a brine deposit in Chile.

FMC Corp., Lithium Division, closed its spodumene mine and lithium carbonate plant near Bessemer City, NC, early in 1998. The company's lithium carbonate operation in Argentina, completed in 1997, and intended to replace lost production in North Carolina, closed in July 1999 when the company reached a long-term agreement with Chilean producer Sociedad Quimica y Minera de Chile S.A. (SQM) to supply FMC with lithium carbonate produced at SQM's brine operation. Lithium carbonate from SQM will be used as a low-cost feedstock for FMC's full range of downstream compounds, including lithium metal and organic lithium compounds (Brown, 1999). FMC produced downstream compounds in North Carolina and butyllithium in Bayport, TX.

ToxCo's subsidiary, LithChem International, produced lithium salts used in lithium battery electrolyte solutions at its facilities in Baltimore, OH. LithChem produces these salts from lithium compounds that are products of ToxCo's recycling operations (David G. Miller, ToxCo, Inc., written commun., 1999).

Lithium carbonate is the most important lithium compound produced from brine and ore deposits. In most cases, other lithium compounds require lithium carbonate as a feedstock for further processing. Domestic production of lithium carbonate is limited to a single brine operation in Nevada. Nevada brines enriched in lithium chloride, which averaged about 300 parts per million (ppm) when operations began in 1966 (Engineering and Mining Journal, 1970), are pumped from the ground and progress through a series of evaporation ponds. Over the course of 12 to 18 months, concentration of the brine increases to 6,000 ppm lithium through solar evaporation. When the lithium chloride reaches optimum concentration, the liquid is pumped to a recovery plant and treated with soda ash, precipitating lithium carbonate. The carbonate is then removed through filtration, dried, and shipped. A similar process is used to recover lithium from the Chilean brines, with slight adjustments to account for their different chemistries. The brine operation in Argentina used a different, proprietary technology that allowed for the lithium recovery as either carbonate or chloride (FMC Corp., 1998).

Until the mine closure in 1998, spodumene was the major raw material required for the production of lithium carbonate in North Carolina, and small amounts of spodumene concentrate were produced for sale. Spodumene is the most common lithium ore, but petalite and lepidolite are other types that are mined in different parts of the world. These three are beneficiated to produce lithium ore concentrates that can be consumed directly in certain applications.

Extracting lithium from spodumene entails an energy-intensive chemical recovery process, which is more costly than that used for brines. Because of the high cost of producing lithium carbonate from spodumene, most lithium carbonate production has shifted to the brine process. After mining, spodumene is crushed and undergoes a flotation beneficiation process to produce concentrate. Concentrate is heated to 1,075° C to 1,100° C, changing the molecular structure of the mineral and making it more reactive to sulfuric acid. A mixture of finely ground converted spodumene and sulfuric acid is heated to 250° C, forming lithium sulfate. Water is added to the mixture to dissolve the lithium sulfate. Insoluble portions are then removed by filtration. The purified lithium sulfate solution is treated with soda ash, forming insoluble lithium carbonate that precipitates from solution. The carbonate is separated and dried for sale or use by the producer as feedstock in the production of other lithium compounds.

Consumption

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries consumed most of the lithium minerals and chemicals sold in 1999. Estimated domestic consumption have been stable since 1997. Ceramics and glass production and aluminum smelters were the largest consumers of lithium carbonate and lithium concentrates in the United States, accounting for an estimated 20% and 18% of the lithium market, respectively. Other consuming industries were synthetic rubber and pharmaceuticals, 13%; chemical manufacturing, 13%; miscellaneous chemicals, 12%; lubricants, 11%; batteries, 7%; and air treatment, 4% (Cyprus Minerals Co., 1993). More recent estimates of end uses are unavailable.

The largest use of lithium in the United States was in lithium ceramics and glass manufacturing processes. Lithium additions, which can be made as lithium carbonate or ore concentrates, lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic chemicals. Lithium ore concentrates were consumed exclusively in the production of ceramics and glass products. The domestic manufacture of thermal shock-resistant cookware (pyroceramics) consumed the majority of lithium used in the ceramics and glass industry. The manufacture of black-and-white television picture tubes consumed significant amounts of lithium concentrates overseas. Low-iron spodumene and petalite were sources of the lithium used to improve the physical properties of container and bottle glass, and sources of alumina, another important component of the glass. Glass manufacturers used lithium in container and bottle glass, enabling them to produce lighter-weight, thinner-walled products. Until 1997, when lithium carbonate prices decreased dramatically, lithium ore concentrates were the only lithium products that were acceptable for most ceramics and glass applications because of their low cost in comparison to lithium carbonate. Applications sensitive to other elements and impurities that came with ore concentrates and the price of lithium carbonate were not able to take advantage of the benefits of lithium in their production processes. When the lithium carbonate price was cut to about one-half of its previous level, these specialty glass producers were economically able to change their glass formulations to take advantage of the improved properties made possible by lithium additions (Sheets and Rios, 1999).

The second largest use, aluminum production, added lithium carbonate to aluminum potlines to lower the melting point of the bath, allowing a lower operating temperature for the potline, and increasing the electrical conductivity of the bath. These factors contributed to increased production or reduced power consumption, as well as to the indirect benefits of lower fluoride emissions.

The third largest and the fastest growing end use for lithium compounds was as catalysts in the production of synthetic rubbers, plastics, and pharmaceuticals. N-butyllithium initiated the reactions between styrene and butadiene that form abrasion-resistant synthetic rubbers that require no vulcanization. Other organic lithium compounds were catalysts for the production of plastics, such as polyethylene. Lithium metal and compounds were catalysts in the production of vitamin A, some steroids, an anticholesterol agent, an analgesic, antihistamines, tranquilizers, sleep inducers, contraceptives, and other products. Pharmaceutical-grade lithium carbonate was used in the treatment of manic-depressive psychosis. This was the only treatment approved by the U.S. Food and Drug Administration in which lithium was consumed by the patient.

The multipurpose grease industry was another of the important markets for lithium in 1999. Lithium hydroxide monohydrate was the compound used for the production of lithium lubricants. Lithium-based greases were favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases continued to be used in military, industrial, automotive, aircraft, and marine applications.

The use of lithium in batteries and the belief that lithium batteries may be the best way to power electric vehicles (EV's) have spurred tremendous interest in lithium and lithium deposits to provide resources for the anticipated increased demand. Almost all major battery manufacturers marketed some type of lithium battery, and research and development continued. New battery configurations continued to be developed, and continued interest in EV's drove additional interest in battery research. New, more efficient types of rechargeable (secondary) lithium batteries have been developed and older designs improved to meet the requirements of this market and of electronic equipment, such as portable telephones and computers and video cameras. Work continued on lithium-ion batteries. These batteries were of particular interest because they take advantage of the large power capacity available from lithium batteries with fewer safety problems than are encountered when batteries contain lithium metal, a very reactive and volatile material when exposed to air and moisture. Nissan Motor Corp. U.S.A. introduced its first EV available in the United States at the 1998 Los Angeles Auto Show. The four-passenger minivan was powered by lithium-ion batteries developed jointly by Nissan and Sony Corp. This was the first EV from any automobile company that uses lithium-ion batteries (Advanced Battery Technology, 1998).

Nonrechargeable (primary) lithium batteries offer improved performance over alkaline batteries at a slightly higher cost and have been commercially available for more than 10 years. They are used in watches, microcomputers, cameras, small appliances, electronic games, and toys. The military purchased large and small lithium batteries for a variety of military applications. The *Mars Pathfinder* spacecraft, launched in December 1996 by the National Aeronautics and Space Administration (NASA), landed on Mars in July 1998. It contained lithium thionyl chloride batteries that powered communications between *Pathfinder* and NASA during the journey, provided backup power to the solar-powered Mars rover *Sojourner* in the event of the failure of the solar panels, and kept *Sojourner's* electronics operating during the night (ITE Battery Newsletter, 1998).

Aircraft manufacturers in several countries have considered using aluminum-lithium alloys for wing and fuselage skin or structural members in different types of aircraft. Use of these alloys could reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, were attractive to the aircraft and aerospace industries because of their reduced density and superior corrosion resistance compared with those of conventional aluminum alloys. These alloys, however, have not been as widely used in aircraft manufacture as was hoped at the initial introduction of the alloys. In airplane construction, these alloys faced direct competition from composite materials consisting of boron, graphite, or aramid fibers imbedded in polymers. McCook Metals LLC produced an aluminum-lithium alloy that is being used for a fatigue-critical aft bulkhead replacement and other parts on the F-16 fighter plane built by Lockheed Martin Corp. The alloy was produced at the McCook, IL, plant formerly owned by Reynolds Metals Co. (Light Metal Age, 1998).

NASA selected a new design by Lockheed Martin Manned Space Systems for the external space shuttle fuel tank; this is the only part that is not reused. The super-lightweight tank was made with another aluminum-lithium alloy containing 4% copper, 1% lithium, 0.4% silver, 0.4% magnesium, and the remainder aluminum. This alloy was 30% stronger and 5% less dense than the aluminum alloy previously used. The redesigned fuel tank weighed about 3,400 kg less than the original design; the weight savings were used to increase the payload capacity for shuttle missions. Reynolds and McCook were to produce 25 of the redesigned fuel tanks (Light Metal Age, 1998). The first new tank was used for the October 29, 1998, launch of the shuttle *Discovery*, on which astronaut John Glenn returned to space, almost 37 years after he became the first American to orbit the Earth in 1962 (Etris, 1999; National Aeronautics and Space Administration, October 29, 1998, STS-95—Mission Control Center—Status report #1, accessed March 25, 1999, at URL http://spaceflight.nasa.gov/shuttle/archives/sts-95/ reports/STS-95-01.html).

Small quantities of other lithium compounds were important to many industries. Lithium chloride and lithium bromide were used in industrial air-conditioning and commercial dehumidification systems and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contained lithium hypochlorite, as did dry bleaches for commercial laundries. Lithium metal was used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride was used as a component in fluxes for hard-to-weld metals, such as steel alloys and aluminum.

Prices

Although yearend published prices for lithium carbonate were the same as those listed in trade publications in 1998, actual prices paid by customers were believed to be significantly lower than those published. The vigorous entrance into the market of SQM in 1998 prompted Chemetall Foote and FMC to reduce their prices comparably, although actual price lists and quotations have been difficult to obtain since the price reductions began. SQM entered the market offering lithium carbonate at about $2.00 per kilogram ($0.90 per pound); effective October 1, 1999, the company raised its price by about 10% to around $2.20 per kilogram ($1.00 per pound) (Industrial Minerals, 1999c).

Customs values for lithium carbonate entering the United States from Chile are a good indication of the trends in lithium pricing, although they have never reflected exactly the producers' average prices for lithium carbonate. The average unit value calculated from U.S. Bureau of the Census data using Customs value and quantity imported, showed unit value of lithium carbonate has decreased by 46% since 1996. The unit value for lithium carbonate from Chile has decreased steadily from $2.70 per kilogram in 1996 to $1.46 in 1999. Imports from Argentina were recorded for the first time in 1998 and again in 1999; unit value for this material was $1.88 per kilogram. These values were significantly lower than the published price of $4.47 per kilogram (table 2).

Foreign Trade

Total U.S. exports of lithium compounds were virtually the same in 1999 as they were in 1998 after a nearly 29% decrease in 1998 from those of 1997, following a 13% decrease from 1996 to 1997. Because the closures of the spodumene mine and lithium carbonate plant in North Carolina, lithium carbonate production in the United States has decreased substantially. The reduced production made lower exports inevitable. Commitments to overseas customers were supplied from operations in South America. About 65% of all U.S. exports of lithium compounds were to Canada, Germany, India, Japan, and the United Kingdom (table 3).

Imports of lithium compounds increased slightly in 1999, after a 66% increase from 1997 to 1998, a dramatic increase that resulted from FMC's Argentina operation reaching full production and the North Carolina carbonate plant closure. The significant change from 1998 to 1999 was the source of the lithium carbonate. Chile's share of lithium imports increased to 91% of the total in 1999 from 53% in 1998; and lithium carbonate from Argentina decreased to 7% of total imports from 43% in 1998 (table 4). Lithium ore concentrates from Australia, Canada, and Zimbabwe were believed to have been consumed in the United States, but no import statistics were available.

World Review

A small number of countries throughout the world produced lithium ore and brine. Argentina, Chile, and the United States were the leading producers of lithium carbonate. Significant quantities of lithium compounds and ore concentrates also were produced in Australia, Canada, Chile, China, Portugal, Russia, and Zimbabwe. Brazil and Namibia produced smaller quantities, primarily concentrates; Rwanda, South Africa, and Zaire are past producers of concentrates. Production figures for lithium ore concentrates and lithium carbonate are shown in table 5. Pegmatites containing lithium minerals have been identified in Austria, France, India, Ireland, Mozambique, Spain, and Sweden, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Bolivia, China, and Israel. Companies in France, Germany, Japan, Taiwan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

Argentina.—After only one full year of lithium carbonate production from its lithium brine operation at the Salar del Hombre Muerto in the Argentine Andes, FMC shuttered the facility in July (Brown, 1999). The operation was designed to produce about 12,000 metric tons per year (t/yr) of lithium carbonate and about 5,500 t/yr of lithium chloride (North American Minerals News, 1998), but technical problems and poor market conditions forced FMC to reevaluate its project, choosing to close the facility and purchase its lithium carbonate requirements from other sources, SQM in particular. The lithium chloride production line continued to operate (Industrial Minerals, 1999a). A proprietary selective purification process developed by FMC reduced the number of steps required to recover lithium chloride from the brine and reduced the cost of production (FMC Corp., 1998).

Canada.—Tantalum Mining Corp. of Canada Ltd. (Tanco), a subsidiary of Hudson Bay Mining Co., operates a spodumene mine and concentrating plant at Bernic Lake, Manitoba. Avalon Ventures Ltd. was investigating the possibility of developing the company's Separation Rapids rare metals project in northwestern Ontario not far from the Tanco operation. Avalon developed a flotation process to optimize the petalite recovery and produce a high-grade ore concentrate, while removing the potassium and sodium components of the ore to make it more attractive for ceramics and glass applications (North American Minerals News, 1999b). Earlier in the year, tests conducted by Corning Engineering Laboratory Services determined that the Avalon material surpassed minimum specifications for these applications, although the potassium and sodium levels were close to the upper limits (North American Minerals News, 1999c). Another potential roadblock to the development of the project was averted when Avalon signed a memorandum of understanding with the Wabaseemoong Independent Nations First Nations of Whitedog. In return for supporting the development of the petalite project on their traditional land use area, the Wabaseemoong were assured by Avalon that the surrounding area would be protected from adverse environmental impact and that the Wabaseemoong people would benefit through opportunities for employment and training as well as other financial considerations (North American Minerals News, 1999a).

Raymor Resources Ltd. was exploring the prospect of developing the La Motte spodumene deposit in Quebec. A drilling project estimated reserves at 4.55 million metric tons (Mt) at 1.07% Li_2O from the surface to the depth of 100 meters with an additional 2.5 Mt below 100 meters. In the first phase of development, a concentration plant to process the ore from an open pit mine would be built. Following the successful development of the processing plant, Raymor planned to create a subsidiary to use a newly developed process to produce lithium metal directly from the spodumene ore without going through the steps required by more traditional lithium metal production (North American Minerals News, 1999d).

Chile.—With two large brine operations at the Salar de Atacama and their associated lithium carbonate plants, Chile has become the largest lithium carbonate producer in the world. Chemetall Foote's plant first produced lithium carbonate in 1984. SQM completed its first full year of production in 1997 and was planning to increase capacity by 8% to 10% over the original 20,000 t/yr (Industrial Minerals, 1999d). Both companies transport concentrated brines from the Salar to lithium carbonate plants in Antofagasta. Because of SQM's agreement to supply FMC's lithium carbonate requirements, the global market was divided evenly between Chemetall Foote and SQM except for smaller quantities from China and Russia (McCoy, 1999).

China.—Lithium carbonate production in China is from domestic and Australian spodumene ore. Production was limited in 1999 because of the availability of lower cost material from Chile (McCoy, 1999). China's Geological Research Institute (20%), Tibet Mineral Development Co. (40%), and Yuxin Trading Co. (40%) have formed Tibet Lithium New Technology Development Co. to develop a lithium project at the Zabuye Salt Lake in Tibet. A 10-year study at the salt lake has identified high concentrations of boron, bromine, cesium, lithium, and potassium. Lithium production within 3 years was the goal of the new company (Industrial Minerals, 1999b). Another lithium project at salt lakes in the Qinghai Province was being considered. Pacific Lithium Ltd., a New Zealand company, reached agreement with the Qinghai Province to create Qinghai Lithium Limited.

(QLL), a joint venture, to study and develop the salt lake resource that was discovered 1965. QLL's lithium resources were estimated at 1 Mt lithium, more than 1 Mt boron, and more than 17 Mt potassium (Pacific Lithium Ltd., 2000, Quinhai Lithium Limited (QLL), accessed April 4, 2000, at URL http://www.pacificlithium.com/technology/associations.html).

Taiwan.—As a result of the growth in the market for organic lithium catalysts, Chemetall opened a butyllithium plant in Taiwan. The German company also planned to expand butyllithium production in Germany and the United States (Industrial Minerals, 1999a).

Outlook

The health of the lithium industry remains closely tied to the performance of the primary aluminum and the ceramics and glass industries and the economy in general. Changes in consumption of lithium in these industries determine the performance of the entire lithium industry. Because these uses represent such a high percentage of the total lithium market, growth in other areas has a much smaller influence. Demand for N-butyllithium continued to increase, and producers increased capacity to meet that demand. Demand for lithium metal for batteries and to some extent for alloys will probably increase, but total consumption of metal will remain low in comparison with the demand for lithium compounds.

Lithium-ion and lithium-polymer batteries appear to possess the greatest potential for growth for the entire lithium industry. First introduced in 1993 with minimal sales, the market for these rechargeable batteries grew to $3 billion in 1998 and is expected to top $6 billion by 2005 (Pacific Lithium Ltd., 2000, Applications markets, accessed April 4, 2000, at URL http://www.pacificlithium.com/profile/markets.html). No estimates of the amount of lithium required for these batteries have been made; but this kind of value growth indicates that material demand could increase at a comparable rate, or quite probably more quickly.

Too many unknowns remain, however, to allow for a reliable forecast of the quantity of lithium that will be required for the future EV market. Not only is there the question of whether lithium will be part of the superior EV batteries, but also whether batteries or fuel cells will be the preferred sources of power. In addition, questions as to when and if EV's will comprise a significant portion of new car sales in the United States and around the world have been raised. Sales and leases currently lag behind expectations.

Other markets should remain stable with slight growth. Lithium demand could increase dramatically if the technology for nuclear fusion were perfected. This is not expected to take place within the next 25 years and, perhaps, ever.

References Cited

Advanced Battery Technology, 1998, Nissan minivan uses Li-ion technology: Advanced Battery Technology, v. 34, no. 2, February, p. 24-25.
Brown, Robert, 1999, FMC upgrades its core industrial, specialty chemicals: Chemical Market Reporter, v. 256, no. 11, September 13, p. 32 and 37.
Cyprus Minerals Co., 1993, Cyprus Minerals annual report 1992: Cyprus Minerals Co., p. 14.
Engineering and Mining Journal, 1970, Silver Peak gives bright look to Foote Mineral's lithium picture: Engineering and Mining Journal, v. 171, no. 4, April, p. 72.
Etris, Samuel, 1999, Precedent-breaking space shuttle flight relied on silver: Silver News, December 1998-January 1999, p. 1.
FMC Corp., 1998, FMC annual report 1998: Chicago, IL, FMC Corp., p. 23 and 25.
Industrial Minerals, 1999a, FMC suspends Li_2CO_3 production: Industrial Minerals, no. 383, August, p. 9.
———1999b, Lithium project in Tibet: Industrial Minerals, no. 380, May, p. 94.
———1999c, SQM raises Li_2CO_3 prices: Industrial Minerals, no. 386, November, p. 90.
———1999d, SQM to increase capacity for nitrates, lithium and potash: Industrial Minerals, no. 380, May, p. 9.
ITE Battery Newsletter, 1998, Three lithium-thionyl chloride batteries from Saft America: ITE Battery Newsletter, no. 1, p. 6.
Light Metal Age, 1998, Aluminum-lithium alloys: Light Metal Age, v. 56, no. 1-2, February, p. 102-105.
McCoy, Michael, 1999, Chilean inorganics muscle into the market: Chemical & Engineering News, v. 77, no. 31, August 2, p. 11.
McLaughlin, W.J., 1998, The recycling of large lithium batteries: International Seminar on Battery Waste Management, 10th, Deerfield Beach, FL, October 26-28, 1998, Proceedings, unpaginated.
North American Minerals News, 1998, FMC closes Cherryville spodumene; Bessemer City plant now importing Argentinean Li_2CO_3: North American Minerals News, no. 37, March, p. 4.
———1999a, Avalon gets "understanding" for Big Whopper development: North American Minerals News, no. 53, October, p. 4.
———1999b, Higher ore recovery achievable from Avalon's Big Whopper: North American Minerals News, no. 54, November, p. 3.
———1999c, Petalite testwork proves encouraging for Avalon Ventures' lithium project: North American Minerals News, no. 46, March, p. 6.
———1999d, Spodumene with 6% Li_2O obtained from Raymor's La Motte lithium deposit: North American Minerals News, no. 55, December, p. 6.
Sheets, Jack, and Rios, Sebastian, 1999, Market change encourages lithium carbonate demand in glass: Glass, v. 76, no. 11, p. 356.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

International Strategic Minerals Inventory Summary Report—Lithium. Circular 930-I, 1990.
Lithium. Ch. in Mineral Commodity Summaries, annual.[1]
Lithium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Lithium Resources and Requirements by the Year 2000. Professional Paper 1005, 1976.

Other

Chemical Market Reporter, weekly.
Chemical Week, weekly.
Engineering and Mining Journal, monthly.
European Chemical News (London), monthly.
Industrial Minerals (London), monthly.
Lithium. Ch. in Minerals Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Lithium. U.S. Bureau of Mines Information Circular 9102, 1986.
Roskill Information Services Ltd. (London; last reported on lithium in 1994).

[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT LITHIUM STATISTICS 1/

(Metric tons of contained lithium)

	1995	1996	1997	1998	1999
United States:					
Production	W	W	W	W	W
Producers' stock changes	W	W	W	W	W
Imports 2/	1,140	884	975	2,590	2,640
Exports 2/	1,900	2,200	1,880	1,340	1,330
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,600	2,700	2,800	2,800	2,800
Rest of world, production 3/	9,070 r/	10,800 r/	12,200 r/	12,400 r/	11,600 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits.
2/ Compounds.
3/ Mineral concentrate and carbonate.

TABLE 2
DOMESTIC YEAREND PRODUCERS' AVERAGE PRICES OF LITHIUM AND LITHIUM COMPOUNDS

	1998 e/		1999 e/	
	Dollars per pound	Dollars per kilogram	Dollars per pound	Dollars per kilogram
Lithium bromide, 54% brine: Truckload lots, delivered in drums	5.89	12.96	5.83	12.83
Lithium carbonate, technical: Truckload lots, delivered	2.03	4.47	2.03	4.47
Lithium chloride, anhydrous, purfied: Truckload lots, delivered	5.00	11.00	5.00	11.00
Lithium fluoride	7.43	16.35	7.70	16.94
Lithium hydroxide monohydrate: Truckload lots, delivered	2.61	5.74	2.61	5.74
Lithium metal ingot, technical grade: 1,000-pound lots, delivered	43.33	95.33	39.05	85.92
N-butyllithium in n-hexane (15%): Truckload lots, delivered	20.40	44.88	20.40	44.88

e/ Estimated.

Source: Chemical Market Reporter, v. 257, no. 7, February 14, 2000, p. 39 and 42, and v. 253, no. 1, January 5, 1998, p. 23 and 26. Chemical prices for week ending January 4, 1998, for 1998 data, and February 11, 2000, for 1999 data.

TABLE 3
U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY 1/

Compound and country	1998 Gross weight (metric tons)	1998 Value (thousands)	1999 Gross weight (metric tons)	1999 Value (thousands)
Lithium carbonate:				
Australia	23	$141	8	$92
Canada	788	2,830	683	2,450
China	279	1,010	189	681
Germany	492	1,810	346	1,480
India	20	61	14	51
Japan	846	2,840	901	3,090
Korea, Republic of	12	41	33	114
Mexico	43	157	11	50
Netherlands	34	121	70	250
Taiwan	29	104	25	90
United Kingdom	614	2,220	274	739
Other	62	231	132	471
Total	3,240	11,600	2,690	9,550
Lithium carbonate U.S.P.: 2/				
Israel	13	27	(3/)	18
Mexico	3	6	18	28
Venezuela	14	40	--	--
Other	9 r/	607 r/	5	69
Total	39	679	23	115
Lithium hydroxide:				
Argentina	141	517	132	489
Australia	167	679	205	851
Canada	91	359	150	591
Chile	181	659	95	380
China	20	103	19	80
Germany	590	2,210	545	1,770
Hong Kong	71	214	(3/)	6
India	419	1,520	450	1,410
Japan	1,160	5,560	1,410	7,870
Korea, Republic of	147	632	226	948
Mexico	117	506	141	979
Netherlands	216	772	161	571
New Zealand	16	67	54	224
Philippines	30	167	--	--
Singapore	101	435	108	466
Thailand	21	69	74	222
Taiwan	21	76	33	130
United Kingdom	2	443	178	612
Other	846	2,940	960	3,660
Total	4,360	17,900	4,940	21,200

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Pharmaceutical-grade lithium carbonate.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS 1/

	1998		1999	
Compounds	Gross weight (metric tons)	Value 2/ (thousands)	Gross weight (metric tons)	Value 2/ (thousands)
Lithium carbonate:				
Argentina	5,890	$10,700	911	$1,710
Canada	10	36	(3/)	13
Chile	7,320	12,200	12,800	18,700
Germany	257	434	17	66
Japan	3	24	15	75
New Zealand	16	33	21	88
Other	7 r/	25 r/	23	81
Total	13,500	23,500	13,800	20,800
Lithium hydroxide:				
Chile	29	160	--	--
China	241	478	96	249
Japan	5	148	25	572
Taiwan	42	142	14	50
Other	2	70	119	755
Total	319	998	254	1,630

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 5
LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1995	1996	1997	1998	1999 e/
Argentina:					
Spodumene and amblygonite e/	400	400 r/	697 r/ 4/	700 r/	700
Carbonate from subsurface brine	--	--	--	6,000 e/	1,000
Australia, spodumene	81,841	117,944	88,399	68,666	70,000
Brazil, concentrates e/	1,600	1,600	1,600	1,600	1,600
Canada, spodumene e/ 5/	21,000	22,000	22,500	22,500	22,500
Chile, carbonate from subsurface brine	12,943	14,180	24,246	28,313 r/	28,000
China, carbonate e/	12,800	15,000	15,500	13,000 r/	12,500
Namibia, concentrates, chiefly petalite	2,611	1,972	1,019	500 r/	--
Portugal, lepidolite	8,740	7,626	6,883 r/	7,000 r/ e/	7,000
Russia (minerals not specified) e/ 6/ 7/	2,000	2,000	2,000	2,000	2,000
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe 8/	33,498	30,929	49,833	28,055 r/	35,000

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ Table includes data available through March 30, 2000.
2/ Estimated data are rounded to three significant digits.
3/ In addition to the countries listed, other nations may produce small quantities of lithium minerals. Output is not reported; no valid basis is available for estimating production levels.
4/ Reported figure.
5/ Based on all Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).
6/ These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available.
7/ Lithium contained in concentrates and brine.
8/ Amblygonite, eucryptite, lepidolite, petalite, and spodumene.