



2013 Minerals Yearbook

STRONTIUM [ADVANCE RELEASE]

STRONTIUM

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Domestic apparent consumption of strontium increased by 73% in 2013 as the result of substantial increases in imports of the strontium mineral celestite. Apparent consumption of strontium peaked in 1997 and had shown a downward trend until 2011, when consumption began to increase again. The increased imports of strontium minerals, especially in the past few years, likely are the result of increased use of celestite in drilling muds instead of as raw materials for strontium compound production. Domestic strontium carbonate production, which required celestite as a raw material, ceased in 2006, and celestite imports were less than 1,000 metric tons (t) in 2005–07. Strontium minerals were not mined in the United States in 2013, although deposits have been identified and were mined in the past. World production of celestite decreased by 11% to 398,000 t in 2013 from 446,000 t in 2012 (tables 1 and 4).

Strontium composes about 0.04% of the Earth's crust, ranking 15th among elements in abundance (MacMillan and others, 2005). Owing to its high reactivity to air and water, strontium is not found in nature in metallic form. Two strontium-bearing minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), contain strontium in sufficient quantities to make recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient size to make mining attractive.

Production

Although strontium carbonate was not produced in the United States in 2013, it was the principal strontium compound produced globally, and most other strontium compounds were derived from strontium carbonate. Domestic production of strontium carbonate ceased in 2006 with the closure of the Chemical Products Corp.'s strontium carbonate and strontium nitrate operations in Cartersville, GA. A few companies continued to produce small quantities of downstream strontium chemicals elsewhere in the United States.

Consumption

Consumption patterns for strontium materials have shifted substantially during the past few years, with more strontium in minerals being consumed than strontium in chemicals in 2012–13, which had not happened since 1992. In 2013, 21,900 t of strontium contained in celestite was consumed in the United States, and 7,190 t of strontium was consumed as various strontium chemicals (table 1). Because no strontium carbonate was produced domestically from imported celestite in 2013, imported celestite likely was used directly in drilling muds and underwent no chemical processing. Celestite, and

thus strontium, consumption increased because of increased oil and natural gas well-drilling activity in the United States. Before 2006, nearly all imported celestite underwent chemical processes to be converted into strontium carbonate.

Strontium chemicals were mostly consumed by the ceramics, glass, and pyrotechnics industries, with smaller amounts consumed by a multitude of other industries. Strontium carbonate is used directly in some applications and also is converted into appropriate downstream chemicals such as strontium chloride, strontium hydroxide, or strontium nitrate. Celestite typically has been used as the raw material in strontium carbonate production and was consumed directly in small quantities as an alternative to barium sulfate as white filler in industrial products. Increased imports of celestite since 2010 most likely were the result of celestite being used in some drilling fluids used in natural gas and crude oil wells.

Permanent ceramic ferrite magnets are used extensively in small direct current motors for automobile windshield wipers, loudspeakers, magnetically attached decorative items, toys, and other electronic equipment. Strontium ferrite magnets possess the chemical and physical properties that are ideal for use in these applications, such as effectiveness at high temperatures, low densities, and resistance to corrosion and demagnetization. Strontium oxide and strontium carbonate are used as frits in ceramic glazes as a nontoxic alternative to barium and lead. Strontium oxide is used as a glass modifier to enhance optical glass properties, increase hardness and strength, and intensify light refraction. Strontium glass is colorless and absorbs ultraviolet and x-ray radiation, an ideal glass for cathode ray tube (CRT) faceplates, although flat panel displays have almost completely replaced CRTs. The fiberglass, lab glass, and pharmaceutical glass industries consume strontium in smaller amounts.

Strontium nitrate is used most often as a coloring agent in pyrotechnic applications, to produce a bright red and in combination with a copper compound to produce purple. Strontium carbonate, strontium chloride, strontium oxalate, and strontium sulfate can also be used. Strontium pyrotechnic applications include civilian and military flares, fireworks, and tracer ammunition.

In metallurgical applications, strontium metal is added to aluminum alloys to improve castings used in aerospace and automotive applications. Strontium can be used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate dissolved in sulfuric acid reduces the lead content of the electrolyte and of the zinc deposited on the cathode.

Strontium chromate was incorporated into paints as a corrosion inhibitor, effectively coating aluminum used in

the construction of aircraft fuselages and ships. Strontium chromate, however, was classified as a carcinogen in humans because of its hexavalent chromium content, leading many in the paint industry to seek safer alternatives. The European Chemical Agency proposed strict regulations for its use, although achieving comparable corrosion resistance proved difficult using more environmentally friendly materials. A mixed metal calcium-strontium-phosphate complex on a silicate core provides excellent corrosion resistance (Hodges and others, 2010; European Chemical Agency, 2012; Koleske and others, 2013, p. 41–42). Other strontium chemicals were used as catalysts to accelerate the drying of oils, paints, and printing inks (Koleske and others, 2013, p. 51).

The prescription drug strontium ranelate has been shown to reduce the incidence of fractures in osteoporotic patients by promoting the uptake of calcium into bones. No rigorous clinical studies have been completed that prove whether strontium dietary supplements, such as strontium carbonate and strontium citrate, are effective treatments for osteoporosis (Johannes, 2013). Further studies, however, have shown that strontium ranelate may present cardiovascular risks that outweigh its benefits (Price, 2014). The isotope strontium-89 has been used successfully in medical trials for the treatment of pain associated with advanced metastatic cancer (Porter, 1994). Strontium chloride is used in some toothpastes to treat tooth-sensitivity caused by temperature and pressure.

Strontium exhibits a high dielectric constant, making it an attractive material for use in wireless devices and memory chips. Strontium titanate is sometimes used as a substrate material for semiconductors and in some optical and piezoelectric applications. Research also was conducted on the use of strontium in superconductors and radiation detectors. As the technology improves and costs decrease, high-tech industries may consume more strontium (McCoy, 2009; McIntosh, 2009; Physorg.com, 2010; Walter, 2010; Singh and others, 2011).

Strontium oxide aluminate is used as a phosphorescent (glow-in-the-dark) pigment in applications such as emergency exit signs that glow brighter and longer than those using more common photoluminescent pigments (Merit Lighting, LLC, 2008). Strontium phosphate is used in the manufacture of fluorescent lights, and the entire range of strontium chemicals is used in analytical chemistry laboratories.

Prices

Based on data published by the U.S. Census Bureau, the average customs unit value for celestite imported from Mexico was \$50 per metric ton, virtually the same as that of 2012 (table 3). The average unit customs value of imported strontium carbonate was \$0.82 per kilogram, the same as that in 2012. In 2013, the unit value of imported strontium metal decreased by 8% to \$8.28 per kilogram from \$9.03 per kilogram. In 2013, the corresponding value for strontium nitrate was \$1.20 per kilogram, which was about the same as that of 2012. Strontium compound and mineral prices can vary widely from year to year, and reasons for significant changes are difficult to determine.

Foreign Trade

Strontium exports from and imports into the United States have become erratic from year to year. Adequate information to explain the variations is unavailable. Imports of strontium minerals, all of which were celestite, were 49,800 t by gross weight in 2013, two and one-half times those of 2012. The increase was most likely the result of expanded use of celestite in drilling muds. By gross weight, total strontium chemical imports were 12,900 t in 2013, 11% less than those of 2012 (table 3). Export and import data in table 1 represent only the strontium content of the imported celestite and strontium compounds.

Strontium carbonate exports by gross weight were 63 t in 2013—about one-half that in 2012. Exports to Canada and the Republic of Korea accounted for 89% of total strontium exports (table 2).

All celestite imports came from Mexico and were 49,800 t in 2013 (table 3). Total imports of strontium chemicals and metal decreased in 2013 compared with those of 2012. Strontium chemicals imported from China, Germany, and Mexico accounted for nearly 98% of total strontium chemical imports into the United States by gross weight, with Mexico representing 57%; Germany, 36%; and China, 6%.

World Review

Large deposits of high-grade celestite have been discovered throughout the world, but active mines were primarily in China, Mexico, and Spain. These countries accounted for 97% of total celestite produced in 2013. Smaller mines operated in Argentina and Morocco. Many large deposits are not economic to mine owing to high levels of barium and calcium, impurities requiring energy-intensive and cost-prohibitive methods for separation. Most strontium producers require a minimum of 90% strontium sulfate content to achieve profitability. Hand sorting and some washing are all that are necessary at many strontium mines; a few operations use froth flotation, gravity separation, or other methods to beneficiate ore. Major global producers for strontium chemicals and metal in 2013 were in China, Germany, and Mexico.

Outlook

Improved economic conditions worldwide could spur increased demand for strontium carbonate in more traditional applications. Use of strontium by the ceramics, glass, and pyrotechnics industries is expected to continue, with continued demand for strontium used in ferrite magnets. With developments in advanced applications, consumption of strontium in new end uses may increase.

References Cited

- European Chemical Agency, 2012, 4th draft recommendation of priority substances to be included in Annex XIV of the REACH regulation: European Chemical Agency, June 20, 2 p. (Accessed February 18, 2015, at http://echa.europa.eu/documents/10162/13640/draft_axiv_entries_summarytable_4th_en.pdf.)

- Hodges, S.A., Raurell, D.M., and Llovens, Xavier, 2010, New “eco-friendly” universal corrosion inhibitors: Paint & Coatings Industry, January 1. (Accessed February 18, 2015, at <http://www.pcimag.com/articles/90463-new-eco-friendly-universal-corrosion-inhibitors>.)
- Johannes, Laura, 2013, Can a metal help slow down the effects of osteoporosis: The Wall Street Journal, June 13, p. D3.
- Koleske, J.S., Springate, Robert, and Brezinski, Darlene, 2013, Additives reference guide: Paint & Coatings Industry, v. 29, no. 6, p. 22–104.
- MacMillan, J.P., Park, J.W., Gerstenberg, Rolf, Wagner, Heinz, Köhler, Karl, and Wallbrecht, Peter, 2005, Strontium and strontium compounds, *in* Ullmann’s encyclopedia of industrial chemistry (7th ed.): Weinheim, Germany, VCH Verlagsgesellschaft mbH, v. A25, p. 321–327.
- McCoy, Michael, 2009, Precursor powerhouse—Air Liquide finds success in a specialized electronic materials niche: Chemical & Engineering News, August 3, p. 18–19. (Accessed February 19, 2015, via <http://pubs.acs.org/doi/pdf/10.1021/cen-v087n031.p018>.)
- McIntosh, Paul, 2009, Improving mobile wireless performance: Electronic Products, February 19. (Accessed February 19, 2015, at http://www2.electronicproducts.com/Improving_mobile_wireless_performance-article-facnparatek_feb2009.html.aspx.)
- Merit Lighting, LLC, 2008, Photoluminescent exit signs: Pasadena, CA, Merit Lighting, LLC. (Accessed February 18, 2015, at <http://www.meritlighting.com/photoluminescent.html>.)
- Physorg.com, 2010, Roller coaster superconductivity discovered: Physorg.com, August 18. (Accessed February 19, 2015, at <http://www.physorg.com/news201355600.html>.)
- Porter, A.T., 1994, Use of strontium-89 in metastatic cancer—US and UK experience: *Oncology*, v. 8, no. 11, October 1, p. 25–29.
- Price, Caroline, 2014, Regulators consider withdrawing strontium ranelate over CV concerns: Pulse, February 3. (Accessed February 18, 2015, at http://www.pulsetoday.co.uk/clinical/more-clinical-/musculoskeletal/regulators-consider-withdrawing-strontium-ranelate-over-cv-safety-concerns/20005748.article#.VOTb_U0cSUK.)
- Singh, Ranjan, Azad, A.K., Jia, Q.X., Taylor, A.J., and Chen, H.-T., 2011, Thermal tunability in terahertz metamaterials fabricated on strontium titanate single-crystal substrate: *Optics Letters*, v. 36, no. 7, p. 1230–1232.
- Walter, Katie, 2010, A scintillating radiation detection material: *Science and Technology Review*, October/November, p. 4–5. (Accessed February 19, 2015, at <https://str.llnl.gov/OctNov10/cherepy.html>.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
Strontium. Ch. in Mineral Commodity Summaries, annual.

TABLE 1
SALIENT STRONTIUM STATISTICS¹

(Metric tons of contained strontium and dollars per metric ton unless otherwise noted)²

	2009	2010	2011	2012	2013
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption:³					
Strontium compounds	5,860	8,640	10,000	8,150	7,190
Strontium minerals	6,210 ^r	2,370	7,320	8,660	21,900
Exports, carbonate³					
Shipments from Government stockpile excesses	--	--	--	--	--
Apparent consumption ⁴	12,000	10,900	17,300	16,700	29,000
Price, average value of mineral imports at port of exportation	47	45	46	50	50
World, production of celestite, gross weight	369,000 ^r	382,000 ^r	449,000 ^r	446,000 ^r	398,000

^rRevised. -- Zero.

¹Data are rounded to no more than three significant digits.

²The strontium content of celestite is 43.88%, which was used to convert units of celestite.

³Source: U.S. Census Bureau.

⁴Production plus imports minus exports.

TABLE 2
U.S. EXPORTS OF STRONTIUM CARBONATE, BY COUNTRY¹

Country	2012		2013	
	Gross weight (kilograms)	Value ²	Gross weight (kilograms)	Value ²
Canada	20,700	\$24,300	26,200	\$31,900
Hong Kong	--	--	500	9,350
India	2,950	2,800	--	--
Japan	--	--	1,870	3,390
Korea, Republic of	14,800	14,100	29,600	28,200
United Kingdom	81,300	88,400	4,460	11,300
Total	120,000	130,000	62,600	84,000

-- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Free alongside ship value.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY¹

Compound and country	2012		2013	
	Gross weight (kilograms)	Value ²	Gross weight (kilograms)	Value ²
Celestite, Mexico	19,700,000 ^r	\$983,000	49,800,000	\$2,490,000
Strontium carbonate:				
China	152,000	529,000	129,000	406,000
Germany	4,060,000	3,190,000	4,600,000	3,520,000
Italy	6,000	40,700	8,000	54,300
Mexico	7,070,000	5,490,000	4,880,000	3,920,000
Spain	38,000	23,700	109,000	87,800
United Kingdom	--	--	6	8,080
Total	11,300,000	9,270,000	9,730,000	8,000,000
Strontium metal:				
China	121,000	1,090,000	111,000	915,000
France	9,000	72,100	7,320	60,200
Germany	265	5,190	--	--
Korea, Republic of	3	3,480	--	--
Russia	20	9,090	--	--
Taiwan	--	--	5,400	48,300
Total	130,000	1,180,000	124,000	1,020,000
Strontium nitrate:				
China	424,000	611,000	435,000	588,000
France	120	8,400	--	--
Hungary	300	6,630	--	--
India	600	5,400	--	--
Japan	--	--	13,000	36,800
Mexico	2,600,000	2,970,000	2,470,000	2,890,000
Spain	60,000	63,000	130,000	146,000
Total	3,090,000	3,670,000	3,050,000	3,660,000
Strontium oxide, hydroxide, peroxide:				
Brazil	--	--	2,660	8,260
China	1,160	20,400	40,000	44,000
Hong Kong	20,000	19,000	--	--
Japan	172	12,300	151	17,400
Norway	1	3,050	--	--
Total	21,300	54,700	42,800	69,600

^rRevised. -- Zero.

¹Data rounded to no more than three significant digits; may not add to totals shown.

²Customs value.

Source: U.S. Census Bureau.

TABLE 4
CELESTITE: WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons)

Country ³	2009	2010	2011	2012	2013 ⁴
Argentina	8,169	8,512	1,056	22,750 ^r	10,000
China ^c	210,000	200,000 ^r	200,000 ^r	190,000 ^r	180,000
Iran ^e	15,396 ⁴	--	40,000	20,000	--
Mexico	36,127	31,429	40,669	46,192 ^r	40,000
Morocco ^c	2,500	2,500	2,500	2,500	2,500
Spain ⁵	97,000 ^r	140,000 ^r	165,000 ^r	165,000 ^r	165,000
Total	369,000 ^r	382,000 ^r	449,000 ^r	446,000 ^r	398,000

^cEstimated. ^rRevised. -- Zero.

¹World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Includes data available through May 14, 2014.

³In addition to the countries listed, Tajikistan was thought to produce celestite, but information was not available to make reliable estimates.

⁴Reported figure.

⁵Spain reported data in Sr₂O₄ content; celestite production estimated by U.S. Geological Survey.