STRONTIUM AND STRONTIUM COMPOUNDS

1. Strontium

Strontium [7440-24-6], Sr, is in Group 2 (IIA) of the Periodic Table, between calcium and barium. These three elements are called alkaline-earth metals because the chemical properties of the oxides fall between the hydroxides of alkali metals, ie, sodium and potassium, and the oxides of earth metals, ie, magnesium, aluminum, and iron. Strontium was identified in the 1790s (1). The metal was first produced in 1808 in the form of a mercury amalgam. A few grams of the metal was produced in 1860–1861 by electrolysis of strontium chloride [10476-85-4].

Strontium forms 0.02–0.03% of the earth's crust and is present in igneous rocks in amounts averaging 375 ppm. It is the fifth most abundant metallic ion in seawater, occurring in quantities of ca 14 grams per metric ton. Strontium rarely forms independent minerals in igneous rocks but usually occurs as a minor constituent of the rock-forming minerals. Independent strontium minerals do develop in or near sedimentary rocks mainly associated with beds or lenses of gypsum, anhydrite, or rock salt; in veins associated with limestone and dolomite; disseminated in shales, marls, and sandstones; or as a gangue mineral in lead–zinc deposits.

1.1. Occurrence. The principal strontium mineral is celestite, naturally occurring strontium sulfate. Celestite and celestine [7759-02-6] both describe this mineral. However, celestite is the form most widely used in English-speaking countries. Celestite has a theoretical strontium oxide content of 56.4 wt %, a hardness of 3–3.5 on Mohs' scale, and a specific gravity of 3.96. It is usually white or bluish white and has an orthorhombic crystal form.

Deposits of celestite in Gloucestershire, the United Kingdom, represented the main source of the world supply from 1884 to 1941 and provided up to 90% of the world strontium supply (5). During World War II, shipments to the United States and Western Europe from the United Kingdom were disrupted, and celestite deposits in Mexico and Spain were developed. In 2004, the leading celestite producing countries were Mexico, Spain, and China. (see Table 1).

Strontianite is the naturally occurring form of strontium carbonate. It has a theoretical strontium oxide content of 70.2%, but no economically workable deposits are known. There are some naturally occurring strontium–barium and strontium–calcium isomorphs, but none has economic importance.

The scale of celestite mining has never been big enough to justify highly efficient mining methods or extensive exploration. Hand digging of the mineral is not uncommon and the ore is usually sorted by hand. Celestite used in the United States has an average strontium sulfate content of 90 wt % with a range of 88–93 wt %. As production has increased, more automated methods, including gravity separation and flotation, have been used more frequently.

1.2. Properties. Strontium is a hard white metal having physical properties shown in Table 2. It has four stable isotopes, atomic weights 84, 86, 87, and 88; and one radioactive isotope, strontium-90 [10098-97-2], which is a product of nuclear fission. The most abundant isotope is strontium-88.

The chemical properties of strontium are intermediate between those of calcium and barium. Strontium is more reactive than calcium, less reactive than barium. Strontium is bivalent and reacts with H_2 to form SrH_2 [13598-33-9] at reasonable speed at 300–400°C. It reacts with H_2O, O_2, N_2, F, S, and halogens to produce the expected compounds corresponding to its valence (+2). Strontium and the alkaline-earth metals are less active than the alkali metals, but all are strong reducing agents. At elevated temperatures, strontium reacts with CO_2 to form the carbide [12071-29-3] and strontium oxide [1314-11-0] (4):

$$5\,\mathrm{Sr} + 2\,\mathrm{CO_2} \longrightarrow \mathrm{SrC_2} + 4\,\mathrm{SrO}$$

Metallic strontium dissolves in liquid ammonia. The metal and its salts impart a brilliant red color to flames.

1.3. Production. Metallic strontium was first successfully produced by the electrolysis of fused strontium chloride. Although many attempts were made to develop this process, the deposited metal has a tendency to migrate into the fused electrolyte and the method was not satisfactory. A more effective early method was that described in Reference (6). Strontium oxide is reduced thermally with aluminum according to the following reaction:

$$3\,\mathrm{SrO} + 2\,\mathrm{Al} \longrightarrow 3\,\mathrm{Sr} + \mathrm{Al_2O_3}$$

This reaction occurs in a vacuum and the gaseous metal is condensed in a cooler part of the apparatus. Nearly all strontium metal is produced commercially by the thermal reduction process in alloy steel retorts. More recently, some of the Chinese production is by an electrolytic process.

1.4. Uses. The main application for strontium is in the form of strontium compounds. The carbonate, used in cathode ray tubes (CRTs) for color televisions and color computer monitors, is used both in the manufacturing of the glass envelope of the CRT and in the phosphors which give the color.

Historically, strontium metal was produced only in very small quantities. Rapid growth of metal production occurred during the late 1980s, however, owing to use as a eutectic modifier in aluminum–silicon casting alloys. The addition of strontium changes the microstructure of the alloy so that the silicon is present as a fibrous structure, rather than as hard acicular particles. This results in improved ductility and strength in cast aluminum automotive parts such as wheels, intake manifolds, and cylinder heads.

Strontium metal was a very small part of total strontium consumption (7). Production of strontium metal increased rapidly as Timminco Metals and others commissioned facilities in the 1980's for production of high purity strontium metal. However more recently the rise of Chinese production facilities has resulted in the shutdown of all western production. Western producers are now mainly involved with "master-alloy" production, of the alloys discussed below, based on remelting of pure strontium metal purchased from China.

Small amounts of strontium added to aluminum makes it more suitable for casting. Prior to its addition to the aluminum casting alloys, the strontium metal is usually alloyed into the form of a master alloy. These master alloys are typically 10% Sr−90% Al or 90% Sr−10% Al, and improve the dissolution and handling characteristics of strontium in the foundry.

A second use for strontium metal is as an inoculant in ductile iron castings. Inoculants provide nuclei upon which graphite forms during the solidification of cast iron, thus preventing the formation of white cast iron. These inoculants are ferrosilicon alloys containing 50 or 75% Si, 0.8% Sr. Most of the balance is iron.

2. Strontium Compounds

Strontium has a valence of +2 and forms compounds that resemble the compounds of the other alkaline-earth metals (see Barium compounds; Calcium compounds). Although many strontium compounds are known, there are only a few that have commercial importance and, of these, strontium carbonate [1633-05-2],$SrCO_3$, and strontium nitrate [10042-76-9], $Sr(NO_3)_2$, are made in the largest quantities. The mineral celestite [7759-02-6], $SrSO_4$, is the raw material from which the carbonate or the nitrate is made.

2.1. Production. World production of strontium compounds averaged <20,000 t/yr throughout the 1950s and 1960s. Increased demand for strontium compounds led to a sharp rise in output between 1969 and 1971 as the use of strontium carbonate in the screens and glass envelopes of color televisions began to grow. Demand for strontium carbonate in the 1980s for computer monitors led to a steady rise in output of strontium compounds. Peak production of > 291,000t was reached in 1990. Demand then fell before stabilizing at 198,000 t in 1993.

Production facilities for strontium compounds are located in Canada, China, Germany, Japan, The People's Republic of Korea, Mexico, and the United States. The Solvay Group of Belgium joined with Chemical Products Corp. in 2004. The joint venture allows the two companies to operate their plants in Germany, India, and the Republic of Korea more efficiently in the changing markets, especially in Asia. China has become the leading producer of strontium carbonate (7).

Mexico, China, and Spain (8) are the principal producers of strontium minerals. Output in other major producing countries−Turkey, Iran, and the U.K., has dropped sharply in recent years. Whereas strontium mineral deposits occur widely in the United States, these are uneconomical in comparison to the main producing countries.

Strontium carbonate is the principal strontium compound consumed. Other commercial compounds include strontium nitrate and strontium hydrate. The latter is available in an anhydrous form or as the dihydrate or octahydrate form and is called strontium hydrate.

There are two main processes for conversion of celestite, ie, strontium sulfate, to strontium carbonate. The principal process is the black ash process. Strontium nitrate is produced by dissolving celestite in nitric acid and purifying it. Most other strontium compounds are produced from strontium nitrate.

Strontium carbonate is sold in two grades: granular and powder. Granular grade, also referred to as glass grade, is made by calcining the powder grade. The powder grade, also known as chemical or ferrite grade, has an average particle size of 1 μm.

2.2. Economic Aspects. China was one of the world's leading producers of strontium carbonate with a capacity of more than 200,000 t/yr in 2003. China uses domestic and imported celestite to supply its plants. Since Chinese reserves of celestite are lower and are of lower quality, it remains to be seen if the Chinese producers can keep up with demand (7). Quimica del Estronico, S. A. operated a 35,000 t/yr strontium carbonate and 6,000 t/yr strontium nitrate plant in Cartegena. Unusual technology is used for strontium carbonate production; strontium nitrate is produced in an intermediate step (9).

No strontium minerals have been produced in the United States since 1959. Imports and exports of strontium compounds were expected to decrease in 2004 from 2003. See Table 3 for important United States statistics (2). Table 4 gives data on the distribution of primary strontium compounds by end use in the United States (7).

According to the United States Census Bureau, the average unit customs value of imported strontium carbonate in 2004 was \$0.35/kg. This represents a drop from the 2003 price of \$0.48. Strontium nitrate's value was \$1.52/kg, a decrease of the 2003 price of \$2.95/kg.

Shifts have been made in sales of television and computer monitors in the United States. Many televisions sold still contain CRTs, but flat-panel technology is gaining in the marketplace. Flat-panel TVs require little or no strontium. Production of faceplate glass for smaller televisions has shifted to Asia and Mexico. Production of TV glass production has declined in Europe also leading to a decrease in strontium demand. Demand for use in Asia and Mexico is expected to be strong, but newer television technology may affect growth in these markets.

Ferrite magnets markets are expected to stay strong. Growth in other markets will probably continue at a slower rate.

2.3. Health and Safety Factors. The strontium ion has a low order or toxicity, and strontium compounds are remarkably free of toxic hazards. Chemically, strontium is similar to calcium, and strontium salts, like calcium sales, are not easily absorbed by the intestinal tract. Strontium carbonate has no commonly recognized hazardous properties. Strontium nitrate is regulated as an oxidizer that promotes rapid burning of combustible materials, and it should not be stored in areas of potential fire hazards.

2.4. Uses. In 2004, 80% of all strontium used in the United States was consumed in ceramics and glass manufacture. In the U.S., 75% of strontium carbonate was used in television cathode ray tubes (CRTs). The other principal application for strontium compounds is in ferrite ceramic magnets, which represented 9% of U.S. use. Other applications for strontium compounds include pyrotechnics, 9%, and others, 7% (2).

2.5. Strontium Acetate. Strontium acetate [543-94-2], $Sr(CH_3CO_2)_2$, is a white crystalline salt with a specific gravity of 2.1, and it is soluble to the extent of 36.4 g in 100 mL of water at 97°C. It crystallizes as the tetrahydrate or as the pentahydrate below 9.5°C. When heated, strontium acetate decomposes.

2.6. Strontium Carbonate. Strontium carbonate, $SrCO_3$, occurs naturally as strontianite in orthorhombic crystals and as isomorphs with aragonite, $CaCO_3$, and witherite, $BaCO_3$. There are deposits in the United States in

Schoharie County, New York; in Westphalia, Germany; and smaller deposits in many other areas. None is economically workable. Strontianite has a specific gravity of 3.7, a Mohs' hardness of 3.5, and it is colorless, gray, or reddish in color.

Strontium carbonate is a colorless or white crystalline solid having a rhombic structure below 926°C and a hexagonal structure above this temperature. It has a specific gravity of 3.70, a melting point of 1497°C at 6 MPa (60 atm), and it decomposes to the oxide on heating at 1340°C. It is insoluble in water but reacts with acids, and is soluble in solutions of ammonium salts.

Production. In the commercial production of strontium carbonate, celestite ore is crushed, ground, and stored in bins before it is fed to rotary kilns. As the ground ore is being conveyed to the kilns, it is mixed with ground coke. In the kilns, the celestite is reduced to strontium sulfide [1314-96-1], known as black ash, according to the reaction:

$$\mathrm{SrSO_4(s) + 2C(s) \longrightarrow SrS(s) + 2\,CO_2(s)}$$

The product stream from the kilns is collected in storage bins. Black ash from the bins is fine-ground in a ball mill and fed to a leacher circuit, which is a system of stirred tanks, where it is dissolved in water and the muds are separated by countercurrent decantation. The solution from the decantation is passed through filter presses; the muds are washed, centrifuged, and discarded. The filtered product, a saturated solution containing 12–13 wt % strontium sulfide, is sent to an agitation tank where soda ash is added to cause precipitation of strontium carbonate crystals:

$$\mathrm{SrS(l) + Na_2CO_3(s) \longrightarrow SrCO_3(s) + Na_2S\,(l)}$$

After precipitation is complete, the slurry is pumped to vacuum drum filters where a nearly complete liquid–solids separation is accomplished. The liquid is dilute sodium sulfide solution, which is concentrated by evaporation to a flaked 60 wt % sodium sulfide product. The filter cake is a 60 wt % strontium carbonate solid which is fed to a carbonate dryer. After drying, the strontium carbonate product is cooled, ground, and screened for packaging.

Strontium carbonate also precipitates from strontium sulfide solution with carbon dioxide. Hydrogen sulfide is generated as a by-product of this reaction and reacts with sodium hydroxide to produce sodium hydrosulfide, which is sold as by-product. The ability of the black ash process to produce a product exceeding 95% strontium carbonate, from ores containing ≤ 85% strontium sulfate, has led to its predominance.

In another process, strontium sulfate can be converted to strontium carbonate directly by a metathesis reaction wherein strontium sulfate is added to a solution of sodium carbonate to produce strontium carbonate and leave sodium sulfate in solution (10). Prior to this reaction, the finely ground ore is mixed with hydrochloric acid to convert the calcium carbonates and iron oxides to water-soluble chlorides.

Uses. The largest use of strontium carbonate is in the manufacture of glass faceplates for color-television tubes. It is present in glass at ca 12–14 wt % on a strontium oxide basis and functions as an x-ray absorber. Strontium carbonate is an effective x-ray barrier because strontium has a large atomic radius, and its presence is required in the relatively high voltage television sets used in the United States and Japan. The lower voltage Western European television faceplates contain the less expensive barium carbonate as an x-ray absorber. Strontium carbonate, when added to special glasses, glass frits, and ceramic glazes, increases the firing range, lowers acid solubility, and reduces pin-holing; strontium carbonate also has low toxicity. It is used in the production of high purity, low lead electrolytic zinc by a process patented by ASARCO, Inc. (11) and it is used in Australia, South Africa, the United States, and Japan. At a use level of 4.4–7.7 kg of strontium carbonate per ton of metal produced, it removes lead from the cathode zinc.

2.7. Strontium Chromate.

Strontium chromate [7789-06-2], $SrCrO_4$, is made by precipitation of a water-soluble chromate solution using a strontium salt or of chromic acid using a strontium hydroxide solution. It has a specific gravity of 3.84 and is used as a low toxicity, yellow pigment and as an anticorrosive primer for zinc, magnesium, aluminum, and alloys used in aircraft manufacture (12) (see CORROSION AND CORROSION CONTROL).

2.8. Strontium Hexaferrite.

Strontium hexaferrite [12023-91-5], $SrO\cdot 6Fe_2O_3$, is made by combining powdered ferric oxide, Fe_2O_3, and strontium carbonate, $SrCO_3$, and calcining the mixture at ca 1000°C in a rotary kiln (13). The material is crushed, mixed with a binder, and pressed or extruded into finished shapes and sintered at ca 1200°C. The sintered ferrite shapes are used as magnets in small electric motors, particularly in fractional horsepower motors for automobile windshield wipers and window risers. Flexible magnets for use as refrigerator door gaskets are made by blending ferrite powder with a polymer, melting the polymer, and extruding the mixture into the required shape.

2.9. Strontium Halides.

Strontium halides are made by the reactions of strontium carbonate with the appropriate mineral acids. They are used primarily in medicines as replacements for other bromides and iodides.

Strontium bromide [10476-81-0], $SrBr_2$, forms white, needle-like crystals, which are very soluble in water (222.5 g in 100 mL water at 100°C) and soluble in alcohol. The anhydrous salt has a specific gravity of 4.216 and a melting point of 643°C.

Strontium chloride [10476-85-4], $SrCl_2$, is similar to calcium chloride but is less soluble in water (100.8 g in 100 mL water at 100°C). The anhydrous salt forms colorless cubic crystals with a specific gravity of 3.052 and a melting point of 873°C. Strontium chloride is used in toothpaste formulations (see DENTIFRICES).

Strontium fluoride [7783-48-4], SrF_2, forms colorless cubic crystals or a white powder with a specific gravity of 4.24 and a melting point of 1190°C. It is insoluble in water but is soluble in hot hydrochloric acid.

Strontium iodide [10476-86-5], SrI_2, forms colorless crystals which decompose in moist air. It is very soluble in water (383 g in 100 mL water at 100°C) and the anhydrous salt has a specific gravity of 4.549 and a melting point of 402°C.

2.10. Strontium Nitrate.

Strontium nitrate, $Sr(NO_3)_2$, in the anhydrous form is a colorless crystalline powder with a melting point of 570–645°C and a specific gravity of 2.986. It also exists as a tetrahydrate [13470-05-8] which has a density of 2.2 and a melting point of 100°C. The anhydrous salt is the commercially produced product. Strontium nitrate is made by the reaction of milled strontium carbonate with nitric acid. The nitrate slurry is filtered, crystallized, and centrifuged before it undergoes drying in a rotary dryer. The final product is screened and bagged for shipment. Strontium nitrate is classified as an oxidizer by the U.S. Department of Transportation and may react rapidly enough with easily oxidizable substances to cause ignition. The anhydrous material is normally stable but starts to decompose at ca 500°C with the evolution of nitrogen oxides.

The principal use of strontium nitrate is in the manufacture of pyrotechnics (qv) as it imparts a characteristic, brilliant crimson color to a flame. Railroad fusees and distress or rescue signaling devices are the main uses for strontium nitrate. It is also used to make red tracer bullets for the military.

2.11. Strontium Oxide, Hydroxide, and Peroxide.

Strontium oxide, SrO, is a white powder that has a specific gravity of 4.7 and a melting point of 2430°C. It is made by heating strontium carbonate with carbon in an electric furnace, or by heating celestite with carbon and treating the sulfide formed with caustic soda and then calcining the product (14). It reacts with water to form strontium hydroxide [18480-07-4] and is used as the source of strontium peroxide [1314-18-7].

Strontium hydroxide, $Sr(OH)_2$, resembles slaked lime but is more soluble in water (21.83 g per 100 g of water at 100°C). It is a white deliquescent solid with a specific gravity of 3.62 and a melting point of 375°C. Strontium soaps are made by combining strontium hydroxide with soap stocks, eg, lard, tallow, or peanut oil. The strontium soaps are used to make strontium greases, which are lubricants that adhere to metallic surfaces at high loads and are water-resistant, chemically and physically stable, and resistant to thermal breakdown over a wide temperature range (15).

Strontium peroxide, SrO_2, is a white powder with a specific gravity of 4.56 that decomposes in water. It is made by the reaction of hydrogen peroxide with strontium oxide and is used primarily in pyrotechnics and medicines.

2.12. Strontium Sulfate.

Strontium sulfate, $SrSO_4$, occurs as celestite deposits in beds or veins in sediments or sedimentary rocks. Celestite has a specific gravity of ca 3.97, a Mohs' hardness of 3.0–3.5, and is colorless-to-yellow and often pale blue. Strontium sulfate forms colorless or white rhombic crystals with a specific gravity of 3.96 and an index of refraction of 1.622–1.631. It decomposes at 1580°C and has a solubility of 0.0113 g per 100 mL of water at 0°C.

2.13. Strontium Titanate.

Strontium titanate [12060-59-2], $SrTiO_3$, is a ceramic dielectric material that is insoluble in water and has a specific gravity of 4.81. It is made from strontium carbonate and is used in the form of 0.5-mm thick disks as electrical capacitors in television sets, radios, and computers.

BIBLIOGRAPHY

"Strontium" under "Alkaline Earth Metals," in *ECT* 1st ed., Vol. 1, p. 463, by C. L. Mantell, Consulting Chemical Engineer; "Strontium Compounds" in *ECT* 1st ed., Vol. 13, pp. 113–118, by L. Preisman, Barium Reduction Corp., and D. M. C. Reilly, Food Machinery and Chemical Corp.; "Strontium" in *ECT* 2nd ed., Vol. 19, pp. 48–49, by L. M. Pidgeon, University of Toronto; "Strontium Compounds" in *ECT* 2nd ed., Vol. 19, pp. 50–54, by L. Preisman, Pittsburgh Plate Glass Co.; in *ECT* 3rd ed., Vol. 21, pp. 762–769, by A. F. Zeller, FMC Corp.; "Strontium and Strontium Compounds" in *ECT* 4th ed., Vol. 22, pp. 947–955, by S. G. Hibbins, of Timminco Metals; "Strontium and Strontium Componds" in *ECT* (online), posting date: December 4, 2000, by S. G. Hibbins, Timminco Metals.

CITED PUBLICATIONS

1. J. W. Mellor, *A Comprehensive Treatise on Inorganic and Theoretical Chemistry*, Vol. III, John Wiley & Sons, Inc., New York, 1922.
2. J. A. Ober, "Strontium," *Mineral Commodity Summaries*, United States Geological Survey, Reston, Va., 2005.
3. *Metals Handbook*, 9th ed., Vol. 2, American Society for Metals, Metals Park, Ohio, 1979.
4. *Gmelins Handbuch der Anorganischen Chemie*, System Number 29, Verlag Chemie, Weinheim/Bergstr., Germany, 1964.
5. *Celestite*, Mineral Dossier No. 6, Mineral Resources Consultative Committee, HMSO, London, 1973.
6. M. Guntz and M. Galliot, *Compt. Rend.* **151**, 813 (1910).
7. J. A. Ober, "Strontium," *Minerals Yearbook*, United States Geological Survey, Reston, Va., 2004.
8. M. Reguiero, *Industrial Minerals*, (441), 28–41 (June 2004).
9. Quimica del Estrontio, S. A. "An Initiative for the Future," www.qsrestroncio.com/pages/English/0.1html, 2004.
10. D. L. Stein, in T. J. Gray, ed., *Conference on Strontium Containing Compounds*, Nova Scotia Technical College, Halifax, Nova Scotia, Canada, 1973, 1–9.
11. U.S. Pat. 2,539,681 (Jan. 30, 1951), R. P. Yeck and Y. E. Lebedeff (to American Smelting and Refining Co.).
12. T. J. Gray and R. J. Rontil, "Strontium-Based Pigments and Glazes," in Ref. 10.
13. T. J. Gray and R. J. Routil, "Strontium Hexaferrite," in Ref. 10.
14. G. D. Parkes, ed., *Mellor's Modern Inorganic Chemistry*, John Wiley & Sons, Inc., New York, 1967.
15. T. J. Gray and T. Betancourt, "Strontium Soaps and Greases" in Ref. 10, pp. 137–148.

STEPHEN G. HIBBINS
Timminco Metals

Table 1. **World Strontium Mine Production, Reserves, and Reserve Base, t**[a]

	Mine production			
	2003	2004[b]	Reserves	Reserve base
United States	—	—	—	1,400,000
Argentina	3,320	3,300	All other:	All other:
China	100,000	150,000	6,800,000	11,000,000
Iran	2,000	2,000		
Mexico	127,000	130,000		
Morocco	2,700	3,000		
Pakistan	2,000	2,000		
Spain	160,000	150,000		
Tajikistan	NA[c]	NA[c]		
Turkey	70,000	70,000		
World total (rounded)	*470,000*	*510,000*	*6,800,000*	*12,000,000*

[a] Ref. 2.

[b] Estimated.

[a] Not available.

Table 2. **Physical Properties of Strontium**[a]

Property	Value
atomic weight	87.62
melting range, °C	768–791
boiling range, °C	1350–1387
density, g/cm^3	2.6
crystal system	face-centered cubic
lattice constant, pm	605
latent heat of fusion, kJ/kg[b]	104.7
electrical resistivity, μΩ/cm	22.76
stable isotopes, % abundance	
^{84}Sr [15758-49-3]	0.56
^{86}Sr [13982-14-4]	9.86
^{87}Sr [13982-64-4]	7.02
^{88}Sr [14119-10-9]	82.56

[a] Refs. 1, 3, 4.

[b] To convert J to cal, divide by 4.184.

Table 3. **United States Statistics for Strontium, 2000–2004**[a]

Category	2000	2001	2002	2003	2004[b]
production	—	—	—	—	—
imports for consumption:					
strontium minerals	7,460	5,640	1,150	1,010	2,500
strontium compounds	29,900	26,500	25,400	23,300	16,000
exports, compounds	4,520	929	340	693	310
shipments from Government stockpile excesses	—	—	—	—	—
consumption, apparent, celestite and compounds	32,800	31,200	26,500	23,600	18,000
price, average value of mineral imports at port of exportation, dollars per ton	62	63	60	58	54
net import reliance[c] as a percentage of apparent consumption	100	100	100	100	100

[a] Ref. 2.

[b] Estimated.

[c] Imports−exports + adjustments for Government and industry stock changes.

Table 4. **U. S. Estimated Distribution of Primary Strontium Compounds, by End Use, %**[a]

End use	2003	2004
electrolytic production of zinc	2	2
ferrite ceramic magnets	10	11
pigments and fillers	2	2
pyrotechnics and signals	10	14
television picture tubes	73	68
other	3	3
Total	*100*	*100*

[a] Ref. 7.