ZIRCONIUM AND HAFNIUM

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The principal economic source of zirconium is the zirconium silicate mineral, zircon ($ZrSiO_4$). The mineral baddeleyite, a natural form of zirconia (ZrO_2), is secondary to zircon in its economic significance. Zircon is the primary source of all hafnium. Zirconium and hafnium are contained in zircon at a ratio of about 50 to 1. Zircon is a coproduct or byproduct of the mining and processing of heavy-mineral sands for the titanium minerals, ilmenite and rutile, or tin minerals. The major end uses of zircon are refractories, foundry sands (including investment casting), and ceramic opacification. Zircon is also marketed as a natural gemstone, and its oxide processed to produce the diamond simulant, cubic zirconia. Zirconium is used in nuclear fuel cladding, chemical piping in corrosive environments, heat exchangers, and various specialty alloys. The major end uses of hafnium are in nuclear control rods, nickel-based superalloys, nozzles for plasma arc metal cutting, and high-temperature ceramics.

Zirconium is a grayish-white, heavy, lustrous metallic element with a high melting point and five naturally occurring isotopes. It is represented by the chemical symbol Zr. Zirconium is the 18th most abundant element in the Earth's crust with an average crustal abundance of 165 parts per million. The element was discovered in 1789 in Germany by Martin Heinrich Klaproth, who analyzed zircon, although the mineral and gemstone had been known since ancient times (Weeks and Leicester, 1968 p. 517-520). Jöns Jakob Berzelius produced the first impure zirconium metal in 1824. Commercial metal production is by reduction of zirconium tetrachloride with magnesium by using the Kroll process. Zirconia has the fifth highest melting point of the binary oxides.

Hafnium is a bright silver, ductile, lustrous metallic element with a very high melting point and six naturally occurring isotopes. It is represented by the chemical symbol Hf. Hafnium is the 45th most abundant element in the Earth's crust with an average crustal abundance of 3 parts per million. The element was discovered by Dirk Coster and George Charles von Hevesey by separating it from zirconium in 1923 (Weeks and Leicester, 1968 p. 517-520). Hafnium metal was first produced by passing hafnium tetrachloride over a tungsten filament in 1925 (van Arkel and de Boer, 1925). Commercial metal is produced by reduction of hafnium tetrachloride with magnesium by using the Kroll process. Hafnium oxide, also called hafnia, has the second highest melting point of the binary oxides.

World production of zirconium mineral concentrates was estimated to have decreased slightly in 1998. Data on U.S. production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Domestic production of zircon increased as a new mine in Virginia came online. Production of milled zircon was essentially unchanged from that of 1997. According to U.S. Customs trade statistics, the United States was a net importer of zirconium ore and concentrates. In 1998, however, the United States was more import reliant than in 1997. Imports of zirconium ore and concentrates increased significantly as U.S. exports of zirconium ore and concentrates declined by 7%.

With the exception of prices, all data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers.

Production

Data for zirconium and hafnium materials are developed by the U.S. Geological Survey from one voluntary survey of domestic operations. Of the 49 operations surveyed, 33 responded. Data for nonrespondents were estimated on the basis of prior-year levels. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Milled zircon production was unchanged from 1997, and zirconium dioxide production increased by 1,400 metric tons (table 1).

Zircon is normally produced as a byproduct of the mining and processing of heavy-mineral sands for the titanium minerals rutile and ilmenite. In 1998, U.S. mine producers of zircon were RGC (USA) Mineral Sands, Inc., and E.I. du Pont de Nemours and Co. (DuPont). DuPont produced zircon from its heavy-mineral sands deposits near Starke, FL. RGC (USA) produced zircon from its operations at Green Cove Springs, FL, and Stony Creek, VA. U.S. producers of zirconium and hafnium metal were Oremet-Wah Chang, Albany, OR, and Western Zirconium, Ogden, UT. Primary zirconium chemicals were produced by Oremet-Wah Chang and Magnesium Elektron Inc., Flemington, NJ. Secondary zirconium chemicals were produced by about 10 companies, and zirconia was produced from zircon sand at plants in Alabama, New Hampshire, New York, Ohio, and Oregon.

RGC (USA), which completed construction of zircon production facilities at Stony Creek, VA, in October 1997, began production in 1998. The $49 million mine and facilities was expected to have a mine life of 17 years. When fully operational, RGC (USA) expected the mine to produce up to 30,000 tons per year of zircon (Mineral Sands Report, 1997).

Altair International Inc. announced that it had nearly doubled its estimate of the resources at its Camden, TN, heavy-mineral sands deposit. The western extension of the deposit,

known as the Little Benton, was estimated to contain an additional 209 million tons of sand grading 3.5% heavy minerals, including zircon. The Camden deposit was previously estimated to contain 272 million tons of sand grading 4% heavy minerals (Altair International Inc., Altair's titanium deposit doubled, accessed January 25, 1999, at URL http://biz.yahoo.com/ prnews/990119/wy_altair_1.html).

Consumption

Approximately 95% of all zirconium consumed is in the form of zircon, zirconium oxide, or other zirconium chemicals. The remainder is consumed as zirconium metal and zirconium-containing alloys.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon is used in refractory paints for coating the surfaces of molds. Zircon in the form of refractory bricks and blocks is used in furnaces and hearths for containing molten metals. Glass tank furnaces use fused cast and bonded alumina-zirconia-silica-base refractories. Baddeleyite is used principally in the manufacture of alumina-zirconia abrasives, as well as in ceramic colors and refractories.

Stabilized zirconium oxide exhibits high light reflectivity and good thermal stability and is primarily used as an opacifier and pigment in glazes and colors for pottery and other ceramic products. Yttria-stabilized zirconia (YSZ) is used in the manufacture of oxygen sensors that control combustion in furnaces and automobile engines. YSZ is also used in the manufacture of a diverse array of products including high-temperature high-strength structural ceramics, coatings for the hot sections of jet engines, and cubic zirconia, a gemstone simulant.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium is used as cladding for nuclear fuel rods. Commercial-grade zirconium, unlike nuclear grade, contains hafnium and is used in the chemical process industries because of its excellent corrosion resistance.

Hafnium is used in nuclear control rods because of its high thermal neutron absorption cross section. However, the largest end use for hafnium metal is as an alloy addition in superalloys.

Prices

In 1998, the availability of zirconium-based concentrates caused prices to decrease. The average value of imported ore and concentrates decreased from $446 per ton in 1997 to $355 per ton in 1998, a decrease of 20%. Domestic prices of standard- and premium-grade zircon declined as a result of excess supply. Published prices for imported grades of zircon were lower than those of 1997. Published prices for zirconium, hafnium, and zirconium oxide products were unchanged (table 2).

Foreign Trade

According to the Bureau of the Census trade statistics, the United States was a net importer of zirconium ore and concentrates in 1998. U.S. imports of zirconium ore and concentrates were 89,500 tons, an increase of 27,100 tons from those in 1997 (table 4). Australia and South Africa supplied about 97% of the imports of ores and concentrates. U.S. exports of zirconium ore and concentrates were 41,000 tons, a 7% decrease from the previous year (table 3).

The United States was a net importer of zirconium and hafnium metal in 1998. Imports of unwrought zirconium metal and waste and scrap were 894 tons, a 30% increase compared with those of 1997 (table 4). The leading import sources of unwrought zirconium, were in descending order of quantity, France, Germany, and the United Kingdom.

Domestic imports of ferrozirconium alloys were 60.5 tons in 1998. Imports originated primarily from Brazil, with a small amount shipped from France.

U.S. imports of unwrought hafnium metal and waste and scrap were 10 tons, a 44% increase compared with those of 1997.

U.S. exports of unwrought zirconium metal and waste, and scrap were 161 tons, a 16% increase in tonnage compared with those of 1997 (table 3). U.S. exports classified as other zirconium metal, waste, and scrap were 988 tons.

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 1998 is estimated to be 814,000 tons, a decrease of 2% compared with that of 1997 (table 5). Australia and South Africa supplied about 83% of all production outside the United States. World reserves of zircon are estimated to be 36 million tons of ZrO_2, while identified world resources of zircon were 65 million tons of ZrO_2. During 1998, the zirconium industry continued to be active in the exploration and development of mineral deposits on a global basis, particularly in Australia, Kenya, Mozambique, and South Africa.

Australia.—Australia was the largest producer of zircon concentrates in the world (table 5). In 1998, major producers of zircon concentrates were RGC Ltd., Westralian Sands Ltd. (WSL), Tiwest Joint Venture, Cable Sands Ltd. (CSL), and Consolidated Rutile Ltd. (CRL).

RGC and Westralian Sands merged their heavy-mineral sands operations in December 1998. Production numbers for 1998, however, were reported separately. RGC's production of zircon decreased by 9% (included production from U.S. mines) to 192,000 tons (Mineral Sands Report, 1999f). Lower production was attributed to decreased market demand and stockpiling of lower quality materials by RGC Ltd. RGC Ltd.'s U.S. subsidiary, RGC (USA), began zircon production at its new mine in Stony Creek, VA, in 1998.

RGC was extensively exploring for heavy-mineral sands in Australia. The company reportedly had 55,000 square kilometers of exploration rights in the Murray Basin, which covers parts of New South Wales, South Australia, and Victoria. The company was conducting a prefeasibility study for a mine at either Kulwin or Woornack, Victoria (Industrial Minerals, 1998e).

RGC's announced exploration work at its Eneabba deposit

had identified additional reserves. These reserves will extend mine life from 1998 out 12 years to 2010. The company planned to produce 2 million tons of zircon during that time. During 1998, the dry mill was moved to a site 10 kilometers south of its former location. The dredge was expected to be moved at yearend 1999 from the Eneabba West location to the extended reserves at Pharaoh's Flat on the northern edge of the Eneabba deposit (Industrial Minerals, 1998f).

WSL announced the closure of its Yoganup North mine in Western Australia in October 1998. Yoganup's processing plant was transferred to WSL's North Capel mine. WSL's zircon production increased to 44,000 tons in 1998, a 15% increase from 38,000 tons in 1997. The increased zircon production was expected, the result of a February 1998 startup of a new plant at the North Capel Mine (Mineral Sands Report, 1999g).

CRL's zircon production increased to 62,000 tons in 1998, a 13% increase from 55,000 tons in 1997. Both CRL dredges operated at full capacity during the year. Last year, CRL upgraded and moved the dredge and floating concentrator from its exhausted Bayside deposit to its Ibis-Alpha heavy-mineral deposit on North Stradbroke Island, Queensland. In 1999, CRL planned to move the dredge from its Gordon mine site to its Yarraman ore body on North Stradbroke Island. The Yarraman deposit was expected to begin production by yearend. The Yarraman ore body had an expected mine life of 13.5 years at a 3,000-ton-per-hour mining rate (Industrial Minerals, 1998a). Zircon production was estimated to average 21,000 tons per year over the life of the mine. As a result of CRL's move, zircon production is expected to decrease in 1999 (Mineral Sands Report, 1999a).

In 1998, CSL started production from its new mine at Sandalwood and continued operations at its two other mines in Western Australia at Jangardup, its largest operation, and at Yarloop, 55 kilometers northeast of Bunbury. Zircon production was estimated to have increased by 13%, to 41,000 tons (Mineral Sands Report, 1999d).

In May 1998, Broken Hill Proprietary Company Limited (BHP) declared force majeure at its Beenup, Western Australia, deposit. BHP noted that the deposit, which began production in January 1996, was having difficulty producing at capacity. Problems have included excessive wear on the dredge and concentrator and tailings consolidation problems (Broken Hill Proprietary Company Limited, May 26, 1998, Titanium minerals project update, press release, accessed January 12, 1999, at URL http://www.bhp.com.au/press/bhp_press/data/19980526a.html). The deposit was expected to produce up to 3,500 tons per hour of ore with a zircon capacity of 20,000 tons per year. Shipments of heavy-mineral concentrates began in 1997 (Broken Hill Proprietary Company Limited, 1997). The Beenup Mine reportedly operated significantly below capacity levels in 1997 as a result of startup problems. Zircon production from the mine was negligible (Minerals Sands Report, 1998).

Tiwest Joint Venture, an Australian collaboration of Kerr-McGee Corp. (USA) and Minproc Holdings, operated a heavy-mineral sands mine at Cooljarloo, Western Australia. Reserves at the deposit were 177 million tons of sands grading 3.7% heavy minerals. In 1998, production was 418,000 tons of heavy-mineral concentrates. Zircon production was reportedly 64,000 tons, a 3% increase from that of 1997 (Mineral Sands Report, 1999e).

BHP Titanium Minerals Pty. Ltd. (previously Mineral Deposits Pty. Ltd.) sold its Viney Creek and Fullerton, New South Wales, heavy-mineral sands operations to Nimbus Resources N.L. in October 1998 (Mineral Sands Report, 1999f). As part of the acquisition, Nimbus acquired the rights to the established corporate name, "Mineral Deposits" (MDL). Subsequently, Nimbus and its associated mining group, Dreadnought Mining N.L. joined under the acquired corporate name, MDL (Mineral Deposits Limited, 1998, Welcome to Mineral Deposits Limited, accessed May 4, 1999, at URL http://www.mineraldeposits.com.au/index.html). Wet mill concentrate from the two mines was trucked to the dry mill at Hawks Nest for separation. MDL's production of zircon in the last 2 months of 1998 was 1,376 tons (Mineral Sands Report, 1999c).

RZM Pty. Ltd. operated a heavy-mineral sands mine near Newcastle and dry mill at Tomago, New South Wales. RZM and Western Metals Limited (previously Aberfoyle Limited) have reportedly identified a high-grade rutile and zircon mineral sands deposit at Wemen, New South Wales, and were proceeding with development (Western Metals Limited, accessed May 4, 1999, at URL http://www.reflections.com.au/MiningandExploration/Companies/Archives.html).

France.—U.S.-based Millennium Inorganic Chemicals purchased a line of specialty chemical products, including zirconia, from Rhône-Poulenc SA of France. Zirconia will be produced at Millennium's manufacturing facility at Thann, France (Industrial Minerals, 1998b).

Kenya.—Tiomin Resources Inc. (Canada) completed its prefeasibility assessment of its Kwale heavy-mineral sands deposit. Resources of 200 million tons of ore containing 600,000 tons of zircon were estimated to provide a 15-year mine life. Tiomin acquired an 80% interest in the licensed mineral rights, and partner Pangea Goldfields Inc. retained the remaining 20%. Tiomin has arranged financing for the project with Aur Resources Inc. and was expected to complete a bankable feasibility report during 1999 (Tiomin—Tiomin arranges funding with Aur Resources to proceed to feasibility at Kwale Project, news release, accessed January 12, 1999, at URL http://www.tiomin.com/s/NewsReleases.asp?ReportID=3032).

Norway.—The zirconia producer, Nako AS, a 1997 joint venture of TAM Ceramics Inc. (USA), BM Trading (Norway), and Kovdor Mining (Russia), was declared bankrupt. The operation was to have produced about 3,000 tons per year of fused zirconia from baddeleyite from Kovdor's mining operations in Russia (Industrial Minerals, 1998c).

South Africa.—South Africa was the second largest source of zirconium minerals production in the world (table 5). Zirconium minerals were produced from three sources. Heavy-mineral sands mining operations were operated by Namakwa Sands Ltd. and Richards Bay Minerals (RBM) to yield zircon concentrates, and baddeleyite was produced at Palabora as a byproduct of open-pit copper and phosphate mining.

RBM announced that it would upgrade its mineral sands wet mill facilities on the coast in KwaZulu-Natal Province. The investment was to include a new floating dredge and gravity concentrators. The new dredge and equipment were to be located north of RBM's Zulti North mining lease with startup scheduled for yearend 1999 (Industrial Minerals, 1998d). In 1998, RBM's zircon production was estimated at 250,000 tons by TZ Minerals International Pty. Ltd. of Australia (TZMI) (Mineral Sands Report, 1999e).

Namakwa Sands, a subsidiary of Anglo American Corp., produced an estimated 49,000 tons of zircon in 1999, according to TZMI. The $240 million Phase 2 expansion of the mining and processing operations, commissioned in 1998, resulted in an increase in zircon capacity to 140,000 tons per year (African Mining, 1997). Namakwa Sands recovered zircon at its mine in Brand-se-Baai, Western Cape Province, and had a dry separation plant 60 kilometers south at Koekenaap. Reserves at Namakwa are 500 million tons of ore with an estimated mine life of 35 years. Revenues from the sale of zircon were estimated to be lower in 1998 because of lower prices (Mineral Sands Report, 1999b).

Rhino Minerals (Pty) Ltd., a subsidiary of Avmin Limited, increased the milling capacity of its Nyala Minerals (Pty.) Ltd. operations, near Richards Bay, KwaZulu-Natal Province. Nyala Minerals was a 50-50 joint venture between Rhino Minerals and the Holland-based Eggerding & Co. Group. Capacity to mill zircon was increased with the installation of two additional ceramic-lined air-swept mills (Rhino Minerals—Nyala Minerals (Pty.) Ltd., accessed June 3, 1999, at URL http://www.rhino.co. za/ overview.htm). Avmin was reorganized on January 1, 1999, as Anglovaal Mining Limited (Anglovaal Mining Limited, Avmin—Who we are, accessed June 3, 1999, at URL http:// www.avmin.co.za/splash.htm).

Iscor Mining has deferred development of the Iscor Heavy Minerals project in KwaZulu-Natal Province until the last half of 1999. The primary reasons for the delay were the high-interest rates in South Africa and global economic uncertainty. Planned zircon capacity at the Iscor Heavy Mineral project is 35,000 tons per year (Iscor Mining, Information release, January 10, 1998, accessed June 3, 1999, at URL http://www.iscorltd.co.za/ihm/ press_articles/98100101.htm).

Ukraine.—Zircon was mined from the Mayshev mineral sands deposits at Vilnohirsk, in the central region of Ukraine. The Vilnohirsk deposit was mined by the Vilnohirsk State Mining & Metallurgical Plant (VSMMP). Located about 75 kilometers west of Dnipropetrovsk, the alluvial sand deposit contains mostly quartz (49% to 90%), with lesser amounts of clay (5% to 50%), and heavy minerals (8% to 12%). The heavy-mineral assemblage at Vilnohirsk includes chromite, ilmenite, kyanite, leucoxene, rutile, sillimanite, staurolite, tourmaline, and zircon. VSMMP expected to produce 26,000 tons of zircon in 1998 (Industrial Minerals, 1998g, p. 21-41).

Outlook

The average global demand for zirconium materials is expected to increase by 3% per year during the next few years. The tight supply of zircon in 1996 and 1997 ended in 1998, resulting in a decrease in prices. During the next few years, however, the supply and demand of zircon is expected to be in closer balance as new deposits and plant expansions come online. Expansions in supply are expected in Mozambique and South Africa, and further exploration and development efforts are underway in Australia, Canada, India, Kenya, South Africa, Ukraine, and the United States. Production of zircon in the United States is expected to increase during the next decade.

References Cited

African Mining, 1997, Early growth for Anglo American's debut titanium project: African Mining, November-December, v. 2, no. 6, p. 41-43.

Broken Hill Proprietary Company Limited, 1997, Annual report 1997: Melbourne, Victoria, Broken Hill Proprietary Company Limited, Australia, 48 p.

Industrial Minerals, 1998a, CRL mine sands operation on the move: Industrial Minerals, no. 371, August, p. 9.

———1998b, Millennium restructures and concludes Tibras buy: Industrial Minerals, no. 372, September, p. 27.

———1998c, Nako fused ZrO_2 declared bankrupt: Industrial Minerals, no. 374, November, p. 13.

———1998d, RBM minsands plant investment: Industrial Minerals, no. 364, January, p. 15.

———1998e, RGC focuses on minsands: Industrial Minerals, no. 367, April, p. 142.

———1998f, RGC increases Eneabba reserves: Industrial Minerals, no. 370, July, p. 82.

———1998g, Ukraine's minerals: Industrial Minerals, no. 373, October, p. 21-41.

Mineral Sands Report, 1997, New titanium mineral sands project: Mineral Sands Report, no. 34, p. 11-12.

———1998, CRL and BHP production: Mineral Sands Report, no. 39, February, p. 11.

———1999a, CRL and BHP production: Mineral Sands Report, no. 45, February, p. 10.

———1999b, Namakwa sands production and revenue: Mineral Sands Report, no. 45, February, p. 15.

———1999c, New South Wales producers: Mineral Sands Report, no. 45, February, p. 12.

———1999d, Other Australian producers: Mineral Sands Report, no. 45, February, p. 12.

———1999e, RBM production and revenue: Mineral Sands Report, no. 45, February, p. 14.

———1999f, RGC production and revenue: Mineral Sands Report, no. 45, February, p. 8.

——— 1999g, WSL production and revenue: Mineral Sands Report, no. 45, February, p. 9.

van Arkel, A.E., and deBoer, J.H., 1925, Preparation of pure titanium, zirconium, hafnium, and thorium metal: Zeitschrift für Anorganishe Chemie, v. 148, 345 p.

Weeks, M.E., and Leicester, H.M., 1968, Discovery of the elements (7th ed.): Easton, PA, Journal of Chemical Education, 7th ed., 896 p.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

International Strategic Minerals Inventory summary report—Zirconium: U.S. Geological Survey Circular 930-L, 1992.

Zirconium and hafnium. Ch. in Mineral Commodity Summaries, annual.[1]

Zirconium. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Other

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

American Metal Market, daily.
Chemical Engineering, biweekly.
Chemical Week, weekly.
Engineering and Mining Journal, monthly.
International Titanium Association.
Industrial Minerals [London], monthly.
Metal Bulletin [London], semiweekly.
Mineral Sands Report, bimonthly.
Mining Engineering, monthly.
Mining Magazine and Mining Journal [London], monthly and weekly.
Roskill Information Services Ltd. [London].
U.S. Department of Commerce, U.S. Census Bureau, monthly trade statistics.
Zirconium and hafnium. Ch. In Mineral facts and problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT U.S. ZIRCONIUM STATISTICS 1/

(Metric tons)

	1994	1995	1996	1997	1998
Zircon:					
Production:					
Concentrates	W	W	W	W	W
Milled zircon	53,300	56,000	55,300	55,700	55,700
Exports	32,000	40,300	35,000	44,300	41,000
Imports for consumption 2/	82,000	93,600	92,500	62,400	89,500
Consumption, apparent 2/	W	W	W	W	W
Stocks, December 31: Dealers and consumers 3/	30,100	33,400	34,300	29,300 r/	32,000
Zirconium oxide:					
Production 4/	12,100	14,200	15,000	15,900	17,300
Exports 5/	1,220	1,680	1,480	1,970	1,540
Imports for consumption 5/	2,400	4,370	5,240	4,220	3,900
Consumption, apparent	W	W	W	W	W
Stocks, December 31: Producer 4/	W	W	822	982 r/	985

r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.
2/ Includes insignificant amounts of baddeleyite.
3/ Excludes foundries.
4/ Excludes intermediate oxides associated with metal production.
5/ Includes germanium oxides and zirconium dioxides.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM AND HAFNIUM MATERIALS

Specification of material	1997	1998
Zircon:		
Domestic, standard-grade, bulk, per short ton 1/	$419.00	$320.00
Domestic, 75% minimum quantity zircon and aluminum silicates, bulk, per short ton 1/	381.00	280.00
Domestic, premium-grade zircon, bulk, per short ton 1/	489.00	390.00
Imported sand, ceramic application, f.o.b., bulk, per metric ton 2/	$420.00 - 470.00	$360.00 - 410.00
Imported sand, refractory application, f.o.b., bulk, per metric ton 2/	390.00 - 425.00	360.00 - 395.00
Imported sand, foundry sand application, f.o.b., bulk, per metric ton 2/	380.00 - 420.00	330.00 - 375.00
Baddeleyite, imported concentrate: 3/		
98% to 99% ZrO2, minus 100-mesh, c.i.f. Atlantic ports, per pound	.98	1.00
Over 99% ZrO2, minus 100-mesh, c.i.f. Atlantic ports, per pound	1.43	1.45
Zirconium oxide: 4/		
Powder, commercial-grade, drums, 2,000-pound minimum, per pound	3.00 - 6.60	3.00 - 6.60
Electronic, same basis, per pound	3.50 - 8.00	3.50 - 8.00
Insulating, stabilized, 325° F, same basis, per pound	3.35 - 4.00	3.35 - 4.00
Insulating, unstabilized, 325° F, same basis, per pound	3.35 - 4.00	3.35 - 4.00
Dense, stabilized, 300° F, same basis, per pound	3.60	3.60
Zirconium: 5/		
Powder, per pound	75.00 - 150.00	75.00 - 150.00
Sponge, per pound	9.00 - 12.00	9.00 - 12.00
Sheets, strip, bars, per pound	20.00 - 50.00	20.00 - 50.00
Hafnium, sponge, per pound 5/	75.00 - 95.00	75.00 - 95.00

1/ Domestic average price.
2/ Industrial Minerals (London), no. 363, December 1997, p. 79; and no. 375, December 1998, p. 79.
3/ American Vermiculite Corp. baddeleyite price lists.
4/ Chemical Market Reporter, v. 252, no. 26, December 29, 1997, p. 25; and v. 254, no. 26, December 28, 1998, p. 29.
5/ American Metal Market, v. 105, no. 250, December 30, 1997, p. 7; and v. 106, no. 247, December 28, 1998, p. 16.

TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY 1/

Class and country	1997 Quantity (metric tons)	1997 Value (thousands)	1998 Quantity (metric tons)	1998 Value (thousands)
Ore and concentrates:				
Argentina	487	$91	449	$333
Belgium	356	200	450	231
Brazil	3,620	1,850	2,590	1,340
Canada	5,530	3,010	7,060	3,300
China	3,320	2,450	3,120	1,550
Colombia	2,200	2,130	2,320	1,890
Dominican Republic	198	235	278	263
Ecuador	119	101	194	147
France	1,060	844	899	649
Germany	2,980	2,100	1,440	1,300
Hong Kong	702	626	48	33
Indonesia	487	376	39	28
Ireland	123	144	129	140
Italy	100	70	6,400	2,560
Japan	1,180	424	1,210	298
Korea, Republic of	181	128	243	71
Malaysia	390	303	78	60
Mexico	4,150	2,020	6,700	3,210
Netherlands	3,640	582	--	--
Pakistan	312	257	273	216
Philippines	331	281	234	173
Spain	3,080	410	2,270	761
Sweden	53	26	59	35
Taiwan	448	286	68	68
United Kingdom	7,680	2,970	2,880	2,110
Venezuela	1,010	798	1,200	941
Other	594	452	341	375
Total	44,300	23,200	41,000	22,100
Unwrought zirconium and waste and scrap:				
Japan	63	781	51	1,040
United Kingdom	30	860	50	1,170
Other	46	1,200	60	1,250
Total	139	2,840	161	3,460

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY 1/

Class and country	1997 Quantity (metric tons)	1997 Value (thousands)	1998 Quantity (metric tons)	1998 Value (thousands)
Zirconium ore and concentrates:				
Australia	26,400	$10,400	29,900	$11,700
Italy	200	188	1,570	$1,180
South Africa	35,000	14,700	57,300	18,100
Other	757 r/	2,460 r/	734	780
Total	62,400	27,800	89,500	31,800
Zirconium, unwrought and waste and scrap:				
Austria	60	302	--	--
Canada	26	1,830	15	1,460
China	49	443	35	412
France	384	13,400	566	28,000
Germany	66	11,600	151	14,000
Japan	40	1,690	23	1,030
United Kingdom	(2/)	10	58	1,050
Other	63 r/	1,490 r/	46	1,910
Total	688	30,700	894	47,900
Hafnium, unwrought and waste and scrap:				
France	6	1,020	9	1,500
Germany	(2/)	270	1	265
United Kingdom	(2/)	3	1	96
Total	7	1,290	10	1,860

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 5
ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1994	1995	1996	1997	1998 e/
Australia	511,000	518,000	502,000	424,000	404,000 3/
Brazil 4/	17,064	16,343	15,560 r/	16,000 r/	16,000
China e/	15,000	15,000	15,000	15,000	15,000
India e/	18,000	18,000	19,000	19,000	19,000
Indonesia e/	2,500	2,000	2,000	2,000 e/	2,000
Malaysia	1,656	3,790	4,511	4,050 r/	4,000
Russia 5/	2,622 r/	2,652 r/	5,080 r/	5,745 r/	6,293 3/
Sierra Leone e/	1,300	--	--	--	--
South Africa e/ 6/	240,000 r/	260,000 r/	260,000 r/	265,300 r/ 3/	270,000
Sri Lanka	22,310	21,971	15,863	12,450 r/	12,500
Thailand	326	--	5 r/	--	--
Ukraine e/	65,000	60,000	55,000	65,000	65,000
United States	W	W	W	W	W
Total	897,000 r/	918,000 r/	894,000 r/	829,000 r/	814,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Includes data available through June 8, 1999.
3/ Reported figure.
4/ Includes production of baddeleyite-caldasite.
5/ Production of baddeleyite concentrate averaging 98% ZrO_2.
6/ Includes production of byproduct zircon from titanium sands mining and 10,000 to 15,000 tons per year of baddeleyite from Palabora Mining Co. Ltd.