



2018 Minerals Yearbook

ZIRCONIUM AND HAFNIUM [ADVANCE RELEASE]

ZIRCONIUM AND HAFNIUM

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In 2018, production of zirconium mineral concentrates in the United States increased, and estimated production of milled zircon decreased slightly from that in 2017. U.S. imports of zircon and other zirconium ore and mineral concentrates increased by 9%, and exports increased almost threefold compared with those in 2017 (table 1). World production of zirconium mineral concentrates in 2018 was 1.53 million metric tons (Mt), a slight decrease from the revised 2017 production total (table 5).

The primary source of zirconium was the mineral zircon ($ZrSiO_4$), principally found in heavy-mineral sands. A relatively small quantity of zirconium was derived from the mineral baddeleyite, a natural form of zirconia [zirconium oxide (ZrO_2)] recovered from a single source in Kovdor, Russia. In 2018, the leading producers of zircon were Australia and South Africa. Zircon was also the primary source of hafnium; zirconium and hafnium are contained in zircon at a ratio of about 34:1 (Jones and others, 2017, p. V5). Zirconium and hafnium metals were produced in China, France, India, Russia, and the United States.

Production

Zircon is a coproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile. In 2018, the U.S. producers of zircon were The Chemours Co. (Wilmington, DE), Southern Ionics Inc. (West Point, MS), and Twin Pines Minerals, LLC (Starke, FL). Chemours produced zirconium mineral concentrates from its operation near Starke, FL, and Southern Ionics produced zirconium mineral concentrates from its operation in Nahunta, GA. In February, Twin Pines Minerals processed existing Chemours mine tailings for zircon in Starke, FL. Iluka Resources, Inc. (a wholly owned subsidiary of Iluka Resources Ltd., Perth, Western Australia, Australia), had terminated its mining operations near Stony Creek, VA, at the end of 2015 but continued processing material. Iluka Resources, Inc. reported 9,300 metric tons (t) of zircon production in 2018 (Iluka Resources Ltd., 2018).

U.S. producers of zirconium and hafnium metal were ATI Wah Chang LLC (an Allegheny Technologies, Inc. business unit) in Albany, OR, and Western Zirconium Inc. (a subsidiary of Westinghouse Electric Co.) in Ogden, UT.

Data for zirconium and hafnium manufactured materials were collected from a voluntary survey of domestic operations. Of the 38 operations surveyed, 10 responded, and data for nonrespondents were estimated based on data from prior years. Domestic production of milled zircon was 49,200 t in 2018. Data on domestic production and consumption of zirconium mineral concentrates were rounded to one significant digit to avoid disclosing company proprietary data. Insufficient data were available to determine stocks of zirconium mineral concentrates as well as production of zirconium chemicals and zirconium metal (table 1).

Consumption

Globally, the leading end uses for zircon were, in descending order by tonnage, ceramics, zirconium-base chemicals, refractories, and foundry and casting applications (Blackwell, 2018, p. 21). Zircon sand was preferred in casting applications where high-quality finishes and tight tolerances were required owing to its lower expansion coefficient and greater stability at high temperatures compared with other materials. Zircon recovered from hard-rock mining was valued as a natural gemstone. Zirconia powder in minor quantities was processed to produce cubic zirconia, a synthetic gemstone and diamond simulant.

Zirconium metal was used in corrosive environments, nuclear fuel cladding, and various specialty alloys. The principal uses of hafnium were in high-temperature ceramics, nickel-base superalloys, nozzles for plasma arc metal cutting, and nuclear control rods.

Zirconia exhibits high light reflectivity and good thermal stability and was primarily used as an opacifier and pigment in glazes and colors used for pottery and other ceramic products. Yttria-stabilized zirconia (YSZ) was used in the manufacture of oxygen sensors that control combustion in automobile engines and furnaces. YSZ was also used in the manufacture of a diverse array of products, including cubic zirconia, fiber optic connector components, refractory coatings, and engineering and structural ceramics. YSZ was used in biomedical applications, such as dental bridges, crowns, and inlays, because it has double to triple the fracture resistance and 1.4 times the strength of alternative alumina products.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon was used in refractory paints for coating the surfaces of molds. Refractory bricks and blocks containing zircon were used in furnaces and hearths for containing molten metals. Fused-cast and bonded alumina-zirconia-silica-base refractories were used in glass-tank furnaces.

Baddeleyite was used principally in the manufacture of alumina-zirconia abrasives and in ceramic colors and refractories. Ammonium- and potassium-zirconium carbonates were used as antiperspirants, paper and board coatings, and in printing and paper manufacturing. Zirconium chemicals were also used in inks to promote adhesion to metals and plastics.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal was used as cladding for nuclear fuel rod tubes. Hafnium was used in nuclear control rods because of its high thermal neutron absorption cross section. Commercial-grade zirconium, unlike nuclear-grade, contains hafnium and was used in chemical process industries because of its excellent corrosion resistance. Hafnium metal also was used as an additive in superalloys.

Prices

In 2018, the reporting of prices for domestic standard-grade bulk zircon concentrate and Australian standard-grade, free on board bulk zircon concentrate were discontinued (table 2). The average range of 2018 published prices for China standard-grade bulk zircon concentrate was \$1,400 to \$1,550 per metric ton. The average unit value of imported zirconium ore and concentrates in 2018 was \$1,380 per metric ton, a 36% increase from that in 2017 (table 4). The published yearend price range of abrasive and refractory zirconia was \$6,150 to \$7,150 per metric ton, unchanged from that of the previous year (table 2).

In 2018, the average duty-paid unit value of imported unwrought zirconium (including sponge and powder) from China, the leading source of United States zirconium imports, increased to almost \$13 per kilogram from \$12 per kilogram in 2017, but the value in 2017 decreased by almost two-thirds from that in 2016. The average duty-paid unit value of other zirconium metal under the Harmonized Tariff Schedule of the United States (HTS) code 8109.90.0000 from France, a major producer of nuclear-grade zirconium, was \$147 per kilogram, a decrease of 5% from \$155 per kilogram in 2017. The average value of unwrought hafnium was \$747 per kilogram in 2018 (table 4).

Foreign Trade

In 2018, U.S. exports of zirconium ore and concentrates were 119,000 t, an almost threefold increase from 48,400 t in 2017 (table 3). Imports of zirconium ore and concentrates totaled 40,600 t, a 9% increase from those in 2017. South Africa, Senegal, and Australia supplied most of the zirconium ore and concentrates (55%, 33%, and 8%, respectively) imported into the United States (table 4).

Most zirconium metal, excluding ferrozirconium, was exported in wrought products classified within "Other zirconium and articles thereof" under the Harmonized System export classification system (Schedule B) code 8109.90.0000 (table 3). Exports of other zirconium including mostly wrought products totaled 1,145 t in 2018, an 18% increase from those in 2017 (table 3). Most zirconium metal was imported as unwrought zirconium or zirconium metal powder under the HTS code 8109.20.0000. The United States imported 1,670 t of unwrought zirconium in 2018, more than double those in 2017 (table 4). Imports of hafnium metal, HTS code 8112.92.2000, totaled 42 t, about only one-third of imports in 2017 and the lowest level since 2014 (tables 1, 4). Imports of ferrozirconium alloys were 191 t in 2018, an increase of 19% from those in 2017 (table 4).

World Review

Global zircon inventories were reported to have contracted. Owing to depleted supplies, shortages of zircon resulted in increased prices (Iluka Resources Ltd., 2018, p. 6).

Australia.—Iluka produced 328,000 t of zircon from its operations in Australia, an increase of 12% from that in 2017. The majority of the Cataby project in Western Australia was constructed in 2018 and was expected to begin production in the first half of 2019. With a projected mine life of 8.5 years, zircon production was anticipated to average about 50,000 metric

tons per year. Iluka completed the feasibility study for moving mining from the Jacinth deposit to the adjacent Ambrosia deposit and the decision was made to proceed with the move sooner than originally planned. By the end of 2018, work was initiated on the Ambrosia deposit (Iluka Resources Ltd., 2018, p. 30–33, 38).

Tronox Holdings plc produced 34,000 t of zircon from its Cooljarloo Mine in Western Australia, unchanged from that in 2017 (Tronox Holdings plc, 2019, p. 10-K/A 37).

Sheffield Resources Ltd. obtained offtake agreements to account for almost all zircon and zircon concentrate production during the first 4-year phase of its Thunderbird project. Production of zircon in the first year of production was expected to be about 80,000 t, increasing to 110,000 t in the fourth year of production. Contingent on financing, Sheffield was expecting to commence production at Thunderbird in 2020 (Sheffield Resources Ltd., 2018, p. 9, 15, 19).

China.—As the leading consumer of zirconium mineral concentrates, China imported 1.05 Mt in 2018, an increase of 3% from 1.02 Mt imported in the previous year (Zen Innovations AG, 2020).

Kenya.—Base Resources Ltd. produced 38,600 t of zircon from its Kwale operation in the reporting year ending June 30, 2018, a decrease of 13% from that in the previous year. During the year, the Kwale Phase 2 mine project was ongoing. This work involved shutting down the mine and wet concentrator plant for the month of March to complete equipment installation and start a second hydraulic unit (Base Resources Ltd., 2018, p. 8).

Madagascar.—Base Resources acquired an 85% interest in the Toliara project in January and worked throughout the year to develop a labor plan and training programs in consultation with the Government and local communities. A prefeasibility study was expected to be completed in the first quarter of 2019, and the company projected production would begin in late 2021 (Base Resources Ltd., 2018, p. 16).

Mozambique.—Kenmare Resources plc produced 74,700 t of primary and secondary zircon at the Moma Mine in 2018. Increased production resulted from projects to increase recovery rates and capacity enhancement of the zircon recovery circuits. The company announced plans to expand capacity to increase ilmenite coproduct production by 20% by 2021 (Kenmare Resources plc, 2019, p. 16, 23).

Senegal.—In July, Eramet Group acquired full ownership of the Grande Côte mineral sands operation operated by TiZir Ltd. Eramet reported zircon sales of 65,000 t (Eramet Group, 2019, p. 25).

South Africa.—Tronox produced 119,000 t of zircon from its Namakwa Sands operation and 53,000 t of zircon from its KZN Sands operation in South Africa, for a total of 172,000 t, an increase of 3% from that in 2017 (Tronox Holdings plc, 2019, p. 10-K/A 37).

In 2018, Mineral Commodities Ltd. produced 17,000 t of zircon-rutile concentrate, containing 68% zircon and 17% rutile, at its Tormin Mine in Western Cape Province. Although the amount of ore processed was greater than that in 2017, the zircon and rutile ore grades decreased from those in 2017 (Mineral Commodities Ltd., 2019, p. 9).

Tanzania.—Strandline Resources Ltd. continued to wait for mining licenses and seek funding for its Fungoni heavy-mineral-sands project. According to a definitive feasibility study completed in 2017, ore reserves were 12.3 Mt containing 3.9% heavy minerals (Strandline Resources Ltd., 2017; East, 2018).

Outlook

Owing to price increases in 2018 and expected continued price increases in 2019, several suppliers are looking at expansions in zircon production to supply the market. In the near term, the United States is expected to be a net exporter of zirconium ores and concentrates, while remaining a net importer of zirconium metal.

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TABLE 1
SALIENT U.S. ZIRCONIUM AND HAFNIUM STATISTICS¹

(Metric tons, gross weight)

	2014	2015	2016	2017	2018
Zircon:					
Production:					
Concentrates	W	80,000 ²	W	100,000 ^{r,2}	100,000 ²
Milled zircon ^c	43,300	46,000	49,000	49,900	49,200
Exports	7,460	4,920	5,050	48,400	119,000
Imports for consumption ³	50,400	32,000	38,400	37,300	40,600
Consumption, apparent ⁴	W	100,000 ²	W	100,000 ^{r,2}	100,000 ²
Zirconium oxide: ⁵					
Production	NA	NA	NA	NA	NA
Exports	7,380	5,700	5,420	5,110 ^r	4,070
Imports for consumption	4,240	4,140	2,620	3,380	2,690
Zirconium, metal, including waste and scrap:					
Production	NA	NA	NA	NA	NA
Exports	1,450	1,530	1,150	1,600	1,700
Imports for consumption	1,100	1,330 ^r	1,240	1,180	2,160
Ferrozirconium:					
Production	NA	NA	NA	NA	NA
Exports	1,620	973	476	62	424
Imports for consumption	131	158	59	161	191
Hafnium, unwrought, including powder, imports for consumption	21	72	180	113	42

^cEstimated. ^rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data.

¹Table includes data available through September 10, 2020. Data are rounded to no more than three significant digits.

²Data are rounded to one significant digit to avoid disclosing company proprietary data.

³Includes insignificant amounts of baddeleyite.

⁴Defined as production plus imports for consumption minus exports plus or minus Government shipments.

⁵Includes germanium oxides and zirconium dioxides.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM MATERIALS¹

(Dollars per metric ton)

Material	2017	2018
Zircon:		
Domestic, standard-grade, bulk	950–1,100	NA
Australian, standard-grade, free on board, bulk	950–1,000	NA
China, standard-grade, cost insurance and freight, bulk ²	1,050–1,150	1,400–1,550
Zirconium ores and concentrates ³	1,010	1,290
Zirconia, fused, monoclinic, refractory and abrasive ²	6,150–7,150	6,150–7,150

NA Not available.

¹Table includes data available through September 10, 2020. Data are rounded to no more than three significant digits.

²Source: Industrial Minerals.

³Source: U.S. Census Bureau. Unit value based on landed-duty-paid United States imports for consumption from Australia, Senegal, and South Africa.

TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY OR LOCALITY¹

Class and country or locality	HTS ² code	2017		2018	
		Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Ore and concentrates:	2615.10.0000				
Belgium		911	\$2,130	595	\$1,520
Canada		1,460	2,910	1,920	4,310
Chile		233	408	283	479
China		39,200	29,600	104,000	61,900
France		957	1,740	5,850	9,010
India		215	417	2,970	4,530
Japan		692	3,080	876	3,470
Mexico		2,180	3,200	1,390	2,330
South Africa		1,440	1,060	--	--
United Kingdom		695	1,690	552	1,640
Other		444 ^r	1,160 ^r	595	1,480
Total		48,400	47,400	119,000	90,700
Ferrozirconium:	7202.99.1000				
Israel		--	--	52	74
Mexico		59	124	362	756
Other		4	31 ^r	11	31
Total		62	155^r	424	861
Unwrought zirconium, including powder:	8109.20.0000				
Germany		69	1,850	69	1,980
Japan		4	119	--	--
Netherlands		17	402	--	--
Russia		104	4,890	26	1,740
Sweden		49	2,560	47	2,600
United Kingdom		91	3,030	62	2,760
Other		59	2,870	64	2,240
Total		393	15,700	268	11,300
Zirconium waste and scrap:	8109.30.0000				
Belgium		95	869	50	584
Canada		49	2,270	34	1,580
Italy		(3)	3	12	208
Japan		2	71	12	399
United Kingdom		26	423	48	786
Other		61	1,010	132	1,510
Total		234	4,650	288	5,070
Other zirconium:	8109.90.0000				
Argentina		35	3,280	22	2,080
Canada		364	35,300	365	38,000
China		45	4,090	156	13,200
France		62	5,930	164	18,900
Germany		7	746	9	1,100
Japan		60	4,480	45	5,180
Korea, Republic of		199	28,200	180	27,100
Sweden		64	7,840	69	7,760
United Arab Emirates		55	6,210	(3)	13
United Kingdom		66	2,700	32	1,510
Other		15	2,430	105	6,650
Total		972	101,000	1,150	121,000

^rRevised. -- Zero.

¹Table includes data available through September 10, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States.

³Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY OR LOCALITY¹

Class and country or locality	HTS ² code	2017		2018	
		Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Zirconium ore and concentrates:	2615.10.0000				
Australia		7,620	\$7,110 ^r	3,440	\$5,090
China		265	1,270 ^r	449	1,420
Russia		458	2,100	624	3,100
Senegal		9,020	10,300	13,300	19,100
South Africa		19,600	15,800	22,500	26,500
Other		354	1,210	293	762
Total		37,300	37,800	40,600	55,900
Ferrozirconium:	7202.99.1000				
Canada		12	42	76	358
China		149	559	115	323
Total		161	601	191	682
Unwrought zirconium, including powder:	8109.20.0000				
China		432	5,220	1,480	18,800
France		15	657	--	--
Germany		151	5,710 ^r	127	5,150
Japan		58	324 ^r	16	77
Korea, Republic of		--	--	14	172
Other		(3)	23	33	130
Total		656	11,900 ^r	1,670	24,300
Zirconium waste and scrap:	8109.30.0000				
Australia		116	133	--	--
Canada		19	33	33	59
France		17	107	30	454
Germany		10	40	68	417
Japan		46	227	51	299
Korea, Republic of		20	229	18	273
Other		15	377	11	151
Total		243	1,150	210	1,650
Other zirconium:	8109.90.0000				
Canada		7	759	16	1,190
France		167	24,900	181	25,600
Germany		59	5,680	47	5,420
Other		48	5,220	39	5,150
Total		282	36,500	284	37,300
Unwrought hafnium, including powder:	8112.92.2000				
China		25	11,100	18	13,100
France		30	8,660	12	9,990
Germany		55	21,500	9	6,060
Other		3	785	3	2,170
Total		113	42,100	42	31,400

^rRevised. -- Zero.

¹Table includes data available through September 10, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States.

³Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY OR LOCALITY¹

(Metric tons, gross weight)

Country or locality ²	2014	2015	2016	2017	2018
Australia	798,000	601,000	600,000 ^r	505,300	560,000 ^e
Brazil	23,659	22,647 ^r	23,000 ^{r,e}	23,000 ^{r,e}	21,000 ^e
China	150,000	150,000	140,000 ^e	140,000 ^e	140,000 ^e
India	20,626	18,891	18,437	30,351 ^r	13,951
Indonesia ^e	21,000	30,900	34,800	30,400 ^r	30,000
Kenya	15,004	25,951	39,687	42,217 ^r	45,487
Madagascar	27,300 ^{r,3}	11,879	12,300 ^{r,3}	26,000 ^{r,3}	18,700
Malaysia	677	826	653 ^r	1,595 ^r	1,000 ^e
Mozambique	63,100	57,900 ^e	215,222 ^r	124,022 ^r	105,000
Nigeria	1,030 ^{r,3}	960 ^e	891 ³	4,090 ^{r,3}	9,000 ^e
Russia ⁴	7,900 ^r	8,180 ^r	7,704 ^r	7,200 ^r	8,000 ^e
Senegal	9,040	45,248	52,627	81,749	64,278
Sierra Leone	2,357	1,326	1,500 ^e	3,000	11,400
South Africa	398,101	377,767 ^r	377,430 ^r	380,000 ^{r,e}	350,000 ^e
Sri Lanka	1,830 ^{r,5}	38,135	24,700 ^{r,5}	24,000 ⁵	24,000 ^e
Turkey	1,100	1,500	500 ^r	1,200 ^r	1,000 ^e
Ukraine	27,000 ^e	25,000	22,200	26,500 ^r	25,000 ^e
United States	W	80,000	W	100,000 ^r	100,000
Vietnam ⁶	10,000 ^r	4,300 ^r	9,500 ^r	5,240 ^{r,3}	6,900
Total	1,580,000	1,500,000 ^r	1,580,000 ^r	1,560,000 ^r	1,530,000

^eEstimated. ^rRevised. W Withheld to avoid disclosing company proprietary data.

¹Table includes data available through May 30, 2020. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²In addition to the countries and (or) localities listed, various countries and (or) localities may have produced small amounts of zirconium mineral concentrates, but available information was inadequate to make reliable estimates of output.

³Estimated figures based on exports of zirconium ore to China.

⁴Production of baddeleyite concentrate averaging 98% ZrO₂.

⁵Estimated figures based on exports of zirconium ore to China and Malaysia.

⁶Estimated figures based on Vietnam inferred exports of zirconium ore to China.