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2021 Minerals Yearbook

ZIRCONIUM AND HAFNIUM [ADVANCE RELEASE]

U.S. Department of the Interior
U.S. Geological Survey

March 2025

U.S. Geological Survey, Reston, Virginia: 2025

Zirconium and Hafnium

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In 2021, production of zirconium mineral concentrates in the United States was less than 100,000 metric tons (t), and production of milled zircon was an estimated 50,000 t (table 1). U.S. imports of zirconium ore and mineral concentrates increased by 19%, and exports decreased by 18% compared with those in 2020 (tables 1, 3, 4). Excluding the United States, world production of zirconium mineral concentrates in 2021 was 1.35 million metric tons (Mt), a 13% increase from the 2020 revised production total. Global and domestic consumption of mineral concentrates were influenced by a resurgence in manufacturing following the global coronavirus disease 2019 (COVID-19) pandemic and related shutdowns (table 5).

The primary source of zirconium is the mineral zircon ($ZrSiO_4$), principally found in heavy-mineral sands. A relatively small quantity of zirconium is derived from the mineral baddeleyite, a natural form of zirconia [zirconium oxide (ZrO_2)] recovered from a single source in Kovdor, Russia. In 2021, 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 to 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 2021, The Chemours Co. (Wilmington, DE) produced separated zircon concentrates. Twin Pines Minerals, LLC (Birmingham, AL) produced mineral concentrates containing zircon and other heavy minerals.

Hyperion Metals Ltd. (Charlotte, NC) completed a resource estimate for its Titan project in western Tennessee. Total mineral resources were 431 Mt containing 2.2% heavy minerals (9.5 Mt). Using a 0.4% heavy-minerals cutoff grade, 241 Mt was classified as indicated resources. If developed, the company expected the project would produce titanium, rare earths, silica sand, and zirconium mineral concentrates (IperionX Ltd., 2022).

U.S. producers of zirconium and hafnium metal were Allegheny Technologies, Inc. near 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, 5 responded, and data for nonrespondents were estimated on the basis of prior-year levels. Domestic production of milled zircon was an estimated 50,000 t in 2021. 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, ceramics, refractories and foundry, and zirconium-base chemicals (Iluka Resources Ltd., 2022, p. 2). 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. In the gemstone industry, zircon recovered from hard-rock mining was valued as a natural gemstone, and 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 used primarily 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 also was 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 two to three times the fracture resistance and 1.4 times the strength of alternative products based on alumina.

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 also were 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 2021, the annual average price for China standard-grade bulk zircon concentrate was $1,440 per metric ton, an increase from $1,370 per metric ton in 2020. The annual average unit value of imported zirconium ore and concentrates from the leading import sources (Australia, Senegal, and South Africa) in 2021 was $1,450 per metric ton, a 4% increase from that in 2020 (table 4). The average price of fused zirconia ex-works China was $5,270 per metric ton, a 47% increase from $3,580 per metric ton in 2020 (table 2).

In 2021, the annual average unit value of imported unwrought zirconium (including sponge and powder) from China, the leading source of United States unwrought zirconium imports, increased to $6.85 per kilogram from $5.95 per kilogram in 2020. The annual average unit value of other zirconium metal imported from France, a major producer of nuclear-grade zirconium, was $167 per kilogram, an 18% increase from $141 per kilogram in 2020. The annual average unit value of imported unwrought hafnium was $623 per kilogram in 2021, 3% lower than that in 2020 (table 4).

Foreign Trade

In 2021, exports of zirconium ore and concentrates totaled 15,400 t, a 18% decrease from those in 2020 (table 3). Imports of zirconium ore and concentrates totaled 28,500 t, a 19% increase from those in 2020. South Africa, Australia, and Senegal supplied most of the zirconium ore and concentrates (39%, 33%, and 26%, respectively) into the United States (table 4).

Most zirconium metal, excluding ferrozirconium, was exported in wrought products classified as "Other zirconium and articles thereof" under the Harmonized-System-based Schedule B number 8109.90.0000 (table 3). Exports of zirconium wrought products totaled 966 t in 2021, a 15% increase from those in 2020 (table 3). Unlike exports, most zirconium metal was imported as unwrought zirconium or zirconium metal powder under Harmonized Tariff Schedule of the United States (HTS) code 8109.20.0000. The United States imported 557 t of unwrought zirconium in 2021, 69% less than that in 2020 (table 4). Imports of hafnium metal, HTS code 8112.92.2000, totaled 23 t, a 44% increase from those in 2020, reversing a 4-year decline in imports (tables 1, 4). Imports of ferrozirconium were 98 t in 2021, a decrease of 47% compared with those in 2020 (table 4).

World Review

Owing to the global economic conditions, global zircon production and consumption increased in 2021. The easing of restrictions put in place to limit the spread of the COVID-19 disease and increased sales of downstream products contributed to increased demand.

Australia.—As of February, Astron Corp. Ltd. updated reserves for its Donald mineral sands project in the State of Victoria. The Donald Project reserves were 602 Mt with a grade of 4.8% (29 Mt) heavy minerals; zircon accounted for 19% (5.5 Mt) of the heavy-mineral content. Using a cutoff grade of 1% heavy minerals, mineral resources were 2.4 billion metric tons (Gt) and contained 19% (22 Mt) zircon. A definitive feasibility study for the project was expected to be completed in 2022. In 2021, Astron was considering a demerger of its upstream operations in Australia from its downstream operations in China (Astron Corp. Ltd., 2021, p. 11, 124, 126).

In 2021, Iluka Resources Ltd. produced 320,000 t of zircon from its mining and concentrating operations in Australia, a substantial increase from 174,000 t in 2020. At Iluka's Eneabba mineral sands operations in the State of Western Australia, a project to recover monazite and zircon in a mixed concentrate from stockpiled mine tailings entered production. Sales of monazite-zircon mixed concentrate in 2021 were reported to be 62,000 t, and the second phase of the project to upgrade the material to a higher grade was under construction (Iluka Resources Ltd., 2022, p. 14, 26, 27).

Image Resources NL reported production in 2021 of 295,000 t of mineral concentrate with a grade of 93.5% heavy minerals. The mixed heavy-mineral concentrate contained 19.2% (53,000 t) of ZrO_2. As of December 2020, the company's reserves from the Atlas and Booanarring deposits totaled 15.6 Mt with an 8.0% (1.2 Mt) heavy-minerals grade and contained 16% (150,000 t) zircon (Image Resources NL, 2022, p. 4, 21).

In the State of New South Wales, Tronox Holdings plc was developing its Atlas-Campaspe mining project that was expected to replace feedstock supply from its existing Snapper and Ginkgo Mines which were nearing end of life. Production from the new mines was expected to begin in 2022. At yearend, the company's reserves in Australia were 520 Mt containing 15 Mt of heavy minerals including 1.7 Mt of zircon (Tronox Holdings plc, 2022, p. 2, 3, 36).

Following the completion of a definitive feasibility study in 2019, Strandline Resources Ltd. was proceeding with construction of the Coburn Mineral Sands project in Western Australia. The company planned to begin production of heavy-mineral concentrates by the end of 2022. As well as rutile and ilmenite, production capacity plans included 88,000 metric tons per year (t/yr) of premium zircon and zircon concentrates. Using a 0.8% heavy-minerals cutoff grade, Coburn's total resources were 1.6 Gt with 1.2% (19.6 Mt) heavy minerals containing 22% (4.3 Mt) zircon. Reserves were 523 Mt with 1.1% (5.8 Mt) heavy minerals (Strandline Resources Ltd., 2021, p. 13, 21).

China.—As the leading consumer of zirconium mineral concentrates, China imported 1.28 Mt in 2021, an increase compared with 1.09 Mt in 2020. China's leading import sources of zirconium ore and mineral concentrates were Australia (56%) and South Africa (15%) (Zen Innovations AG, 2023).

In Shandong Province, Linyi Huazhu New Materials Co., Ltd. was preparing to commission a mineral separation plant with 300,000 t/yr of capacity to process heavy-mineral concentrates. The company planned to source mixed heavy-mineral concentrates from Mozambique and elsewhere and produce titanium mineral and zirconium mineral concentrates (Xun, 2021).

In Maoming City, Guangdong Province, Maoming Ruihai New Material Technology Co. was commissioning a mineral separation plant to process up to 200,000 t/yr of heavy-mineral concentrates. Production was expected to include 130,000 t/yr of titanium mineral concentrates and 30,000 t/yr of zircon

concentrates produced from imported heavy-mineral concentrates (ECHEMI Technology Co., Ltd., 2021).

Kenya.—Base Resources Ltd. produced about 27,000 t of zircon from its Kwale operation in 2021. A prefeasibility study for mining the Bumamani deposit and higher grade subsets of the Kwale North Dune deposit concluded that it was viable to mine and extend the mine life of the Kwale operations to 2024 (Base Resources Ltd., 2022). As of June, the total resource estimate for the Kwale North, Kwale South, and Bumamani deposits was 254 Mt containing about 270,000 t of zircon (Base Resources Ltd., 2021a, p. 1).

Madagascar.—In 2019, following a request by the Government of Madagascar, Base Resources suspended on-the-ground activities for the Toliara mining project. Work on the project was reported to be ongoing in 2021 and in September an updated definitive feasibility study was released. The updated study increased the scale of the project to produce about 1 million metric tons per year (Mt/yr) of heavy-mineral concentrates with an expected mine life of 38 years. The Ranobe reserves supporting the project were updated to 940 Mt containing about 6.1% heavy minerals. Measured and indicated resources were 1,390 Mt with 71 Mt of heavy minerals containing 4.2 Mt of zircon (Base Resources Ltd., 2021b).

Mozambique.—At Kenmare Resources plc's Moma mining and processing operations, production of zircon products increased to 100,000 t compared with 78,100 t in 2020. The Moma operations produced what the company described as standard zircon, secondary zircon concentrates, special zircon, and zircon included in concentrates. Primary zircon production increased by 30% in 2021 to 56,300 t. During the year, Kenmare was working to complete a prefeasibility study on the Nakata deposit, where mining was scheduled to commence in 2025. At yearend, the total reserves from the Namalope, Pilivili, and Nataka deposits were 1.53 Gt with a 3.2% (41 Mt) heavy-minerals grade and contained 2.7 Mt of zircon (Kenmare Resources plc, 2022, p. 32, 33, 37).

Senegal.—Eramet Group reported zircon production of 64,000 t in 2021 from the Grande Côte mining operations that were jointly owned by Eramet (90%) and the Senegal Government (10%). Increased production of mineral concentrates compared with that in 2020 was attributed to improved operational performance and higher ore grades (Eramet Group, 2022).

South Africa.—Tronox reported active heavy-mineral-sands mining operations including the Namakwa Sands mine in the Western Cape Province and KZN Sands mine in the KwaZulu-Natal Province. In the first quarter of 2021, Exxaro Resources Ltd. sold its interest in Tronox. Consequently, Tronox ownership in its South African operations increased to 100%. At yearend, the combined proven and probable reserves at Namakwa Sands and KZN Sands were 920 Mt containing 5.4 Mt of zircon (Tronox Holdings plc, 2022, p. 33, 36).

In 2021, Mineral Commodities Ltd. (MCL) produced 13,700 t of mixed heavy-mineral concentrate, containing primarily zircon (72%) and rutile (19%), at its Tormin mining operations in Western Cape Province. The Tormin operations included mining several placer beach and inland heavy-mineral-sands deposits. Tormin's beach deposits were periodically replenished with heavy minerals through storm surges and wave activity. As of December, MCL's total mineral resource in South Africa was 562 Mt with a 6.6% (37 Mt) heavy-minerals grade (Mineral Commodities Ltd., 2022, p. 18, 127).

Production of heavy minerals from the Richards Bay mining operations was suspended temporarily for a portion of the year because of safety and security concerns surrounding the mine. In addition to the interrupted production, the company continued a 2019 suspension of work on the Zulti South Mine expansion project that would have supported the Richards Bay operations. Rio Tinto plc owned a 74% controlling interest in Richards Bay Minerals (Rio Tinto plc, 2021, 2022).

Outlook

Global production and consumption of zircon increased in 2021 primarily owing to easing restrictions related to the global COVID-19 pandemic. Despite numerous heavy-mineral-sands projects in various stages of development, some existing operations were reaching the end of their mine life and experiencing declining ore grades. Short- and long-term supply deficits are expected if increasing demand is not matched with sufficient additional mine production. If recent import and export trends continue, the United States is expected to become increasingly reliant on imports of zirconium ore and concentrates and remain a net importer of zirconium metal. China is expected to increase its imports of mixed and separated heavy-mineral concentrates.

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TABLE 1
SALIENT U.S. ZIRCONIUM AND HAFNIUM STATISTICS[1]

(Metric tons, gross weight)

	2017	2018	2019	2020	2021
Zircon:					
Production:					
Concentrates	100,000 [2]	100,000 [2]	100,000 [2]	<100,000 [r, 3]	<100,000 [3]
Milled zircon[e]	49,900	49,200	48,500	47,400 [r]	50,000
Exports	48,400	119,000	62,200	18,700	15,400
Imports for consumption[4]	37,300	40,600	34,800	24,000	28,500
Consumption, apparent[5]	100,000 [2]	100,000 [2]	100,000 [2]	100,000 [2]	100,000 [2]
Zirconium oxide:					
Production	NA	NA	NA	NA	NA
Exports[6]	5,110	4,070	3,420	4,710	4,050
Imports for consumption[6]	3,380	2,690	2,790	3,560	3,350
Zirconium, metal, including waste and scrap:					
Production	NA	NA	NA	NA	NA
Exports	1,600	1,700	1,710	1,500	1,560
Imports for consumption	1,180	2,160	2,110	2,340	1,010
Ferrozirconium:					
Production	NA	NA	NA	NA	NA
Exports	62	424	359	63	107
Imports for consumption	161	191	170	184	98
Hafnium, unwrought, including powder, imports for consumption	113	42	32	16	23

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through January 24, 2023. Data are rounded to no more than three significant digits.
[2]Data are rounded to the nearest 100,000 metric tons (t) to avoid disclosing company proprietary data.
[3]Reported as less than 100,000 t to avoid disclosing company proprietary data.
[4]Includes insignificant amounts of baddeleyite.
[5]Defined as production plus imports for consumption minus exports plus or minus Government shipments.
[6]Includes germanium oxides and zirconium dioxides.

TABLE 2
AVERAGE PRICES OF ZIRCONIUM MATERIALS[1]

(Dollars per metric ton)

Material	2020	2021
Zircon:		
China, standard grade, cost insurance and freight, bulk[2]	1,370	1,440
Zirconium ores and concentrates:		
Australia, exports, bags, drums, and similar containers, unit value[3]	1,290	1,340
Domestic, imports, unit value[4]	1,400	1,450
Zirconia, fused, ex-works China[5]	3,580	5,270

[1]Table includes data available through January 24, 2023. Data are rounded to no more than three significant digits.
[2]Source: Fastmarkets IM.
[3]Source: Global Trade Tracker.
[4]Source: U.S. Census Bureau. Unit value based on landed-duty-paid United States imports for consumption from Australia, Senegal, and South Africa.
[5]Source: Argus Media group—Argus Metals International.

TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY OR LOCALITY[1]

Class and country or locality	Schedule B number	2020 Gross weight (metric tons)	2020 Value (thousands)	2021 Gross weight (metric tons)	2021 Value (thousands)
Ore and concentrates:	2615.10.0000				
Belgium		315	$915	728	$1,970
Canada		1,280	2,910 r	721	1,670
China		2,870	4,360	6,850	7,650
France		561	1,560	730	1,860
India		5,670	7,200 r	2,720	3,330
Japan		643	2,600	498	1,270
Malaysia		1,980	1,440	--	--
Mexico		3,760	6,470	1,670	3,870
Other		1,650 r	3,630 r	1,480	3,790
Total		18,700	31,100	15,400	25,400
Ferrozirconium:	7202.99.1000				
Mexico		59	114	74	133
Taiwan		3	4	18	25
Other		1	8	15	21
Total		63	126	107	179
Unwrought zirconium, including powder:	8109.20.0000				
China		13	412	12	386
France		98	7,050	39	2,600
Germany		73	1,430	74	1,360
Russia		79	3,820	38	2,840
Sweden		73	4,350	81	4,320
United Kingdom		101	4,030	65	2,170
Other		35 r	1,010 r	15	378
Total		473	22,100	323	14,000
Zirconium waste and scrap:	8109.30.0000				
Australia		3	108	8	212
Belgium		80	986	112	1,300
Estonia		14	468	17	587
Italy		14	191	24	357
Japan		43	1,190	58	1,110
Spain		5	164	17	593
United Kingdom		10	209	6	169
Other		23 r	392 r	24	649
Total		191	3,710	266	4,980
Other zirconium:	8109.90.0000				
Argentina		50	5,150	37	4,130
Canada		430	44,900	386	42,400
China		20	2,210	5	646
France		47	4,080	127	4,580
Japan		57	4,120	44	2,900
Korea, Republic of		138	22,300	255	38,500
Russia		--	--	33	1,500
United Kingdom		32	2,590	25	4,270
Other		65 r	7,340 r	55	6,880
Total		838	92,700	966	106,000

rRevised. -- Zero.
[1]Table includes data available through January 4, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY OR LOCALITY[1]

Class and country or locality	HTS[2] code	2020 Gross weight (metric tons)	2020 Value (thousands)	2021 Gross weight (metric tons)	2021 Value (thousands)
Zirconium ore and concentrates:	2615.10.0000				
Australia		8,640	$13,000	9,260	$14,100
Senegal		5,460	8,100	7,380	11,300
South Africa		9,240	11,100	11,100	14,500
Other		622	3,490	740	4,590
Total		24,000	35,700	28,500	44,400
Ferrozirconium:	7202.99.1000				
Brazil		36	70	--	--
Canada		20	70	6	30
China		90	202	86	371
Hong Kong		38	95	--	--
Sweden		--	--	6	25
Total		184	437 r	98	426
Unwrought zirconium, including powder:	8109.20.0000				
China		1,710	10,200	516	3,530
France		5	261	7	201
Germany		61	3,000	24	2,200
Other		6 r	144 r	10	294
Total		1,780	13,600	557	6,220
Zirconium waste and scrap:	8109.30.0000				
Canada		63	197	59	532
France		14	705	49	5,140
Germany		109	973	49	676
Japan		57	494	2	150
Other		11 r	91 r	30	601
Total		255	2,460	189	7,100
Other zirconium:	8109.90.0000				
Belgium		14	314	27	1,350
China		25	2,620	8	595
France		193	27,200	144	24,000
Germany		45	5,230	73	5,840
Other		26	4,790	13	2,050
Total		302	40,200	265	33,800
Unwrought hafnium, including powder:	8112.92.2000				
China		1	435	5	3,120
France		8	5,470	4	2,830
Germany		6	3,840 r	10	6,490
Other		1	579	3	1,900
Total		16	10,300	23	14,300

rRevised. -- Zero.
[1]Table includes data available through January 4, 2023. Data are rounded to no more than three significant digits; may not add to totals
[2]Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 5
ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons, gross weight)

Country or locality[2]	2017	2018	2019	2020	2021
Australia	505,300	530,000	470,000	400,000	500,000 e
Brazil	21,000 e	21,000 e	11,695	7,225	10,000 e
China[e]	140,000	140,000	140,000	133,000	140,000
India	30,351	13,951	18,000 e	18,000 e	16,000 e
Indonesia[e, 3]	29,000	54,000	73,000	64,000	55,000
Kenya	42,217	36,387	30,350	31,730	27,000
Madagascar	26,040	22,757	29,473	26,029	22,000 e, 4
Malaysia	1,595	509	449	157	170 e
Mozambique	124,022	202,022	121,768	104,076	123,011
Nigeria	1,799	120	8,161	700	3,030 e, 3
Russia[5]	7,200	7,400	6,300	2,400 e	5,200 e
Senegal	81,749	64,278	65,000 e	60,200	64,000
Sierra Leone	3,000	11,400	9,000 e	6,600	4,100
South Africa	361,813	341,308	324,000	310,000 e	320,000 e
Sri Lanka	1,061	1,500 e	2,089	1,600 e, 4	3,100 e, 4
Turkey	1,200	1,950	1,900 e	--	800 e
Ukraine	26,500	21,614	17,000 e, 6	16,000 e, 6	29,000 e, 6
United States	100,000 7	100,000 7	100,000 7	<100,000 8	<100,000 8
Vietnam[e, 3]	5,400	11,000	6,200	11,000	30,000
Total	1,510,000	1,580,000	1,430,000	1,190,000 9	1,350,000 9

[e]Estimated. [r]Revised. -- Zero.

[1]Table includes data available through June 20, 2023. All data are reported unless otherwise noted; totals may include estimated data. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

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

[3]Estimated based on China imports of zirconium ores and concentrates.

[4]Estimated based on global imports of zirconium ores and concentrates from the source country.

[5]Production of baddeleyite concentrate averaging 98% zirconium oxide.

[6]Based on exports of zirconium ores and concentrates.

[7]Rounded to the nearest 100,000 metric tons (t) to avoid disclosing company proprietary data.

[8]Reported as less than 100,000 t to avoid disclosing company proprietary data.

[9]Excludes the United States.