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RARE EARTHS [ADVANCE RELEASE]

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Rare Earths

By Daniel J. Cordier

Domestic survey data and tables were prepared by Annie C. Hwang, statistical assistant.

In 2020, primary mining operations in Mountain Pass, CA, combined with byproduct production in Offerman, GA, produced a total of 39,000 metric tons (t) of rare-earth-oxide (REO) equivalent in mineral concentrates (table 1). About 530 t of byproduct monazite production from heavy-mineral-sands processing in Offerman, GA, were exported. The quantity of U.S. exports of rare-earth materials in REO equivalent included compounds (38,400 t), ferrocerium (625 t), and metals (24.7 t) valued at over $128 million (tables 4, 5). Imports of rare-earth materials in REO equivalent included compounds (6,560 t), ferrocerium (273 t), and metals (636 t), valued at $109 million (tables 6, 7).

In 2020, world rare-earth mine production was 243,000 t of REO equivalent (tables 1, 8). China continued to dominate global production and consumption of rare-earth mineral concentrates, compounds, and metals.

The rare earths are a group of moderately abundant elements comprising the 15 lanthanides, scandium (Sc), and yttrium (Y). The lanthanides are the elements with atomic numbers 57 through 71, in order of atomic number: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). In rock-forming minerals, rare earths typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates (Mason and Moore, 1982, p. 46). The principal economic rare-earth minerals are bastnaesite, loparite, monazite, xenotime, and the lateritic ion-adsorption clays. The percentage distribution of REOs in mineral concentrates varies significantly on the basis of mineral source and location (table 2).

Excluding scandium, a rare-earth element (REE) can be classified as either a light rare-earth element (LREE) or a heavy rare-earth element (HREE). The LREEs include the lanthanide elements from atomic number 57 (La) through atomic number 64 (Gd), and the HREEs include the lanthanide elements from atomic number 65 (Tb) through atomic number 71 (Lu). The division is based on the LREEs having unpaired electrons in the 4f electron shell and HREEs having paired electrons in the 4f electron shell.

Scandium (atomic number 21), a transition metal, is the lightest REE, but is classified neither as an LREE nor as an HREE. Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. Although its occurrence in crustal rocks is greater than that of lead, mercury, and the precious metals, scandium rarely occurs in concentrated quantities because it does not selectively combine with the common ore-forming anions.

Yttrium (atomic number 39), a transition metal, is chemically similar to the lanthanides and commonly occurs in the same minerals as a result of its similar ionic radius. Yttrium is included as an HREE even though it is not part of the lanthanide series.

The elemental forms of rare earths are iron-gray to silvery lustrous metals that are typically soft, malleable, ductile, and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798 degrees Celsius (°C) for cerium to 1,663 °C for lutetium.

Government Actions and Legislation

In February 2020, the U.S. Geological Survey (USGS) published a new methodology to evaluate the global supply of and U.S. demand for 52 mineral commodities for the years 2007 through 2016. The USGS identified 23 mineral commodities, including aluminum, antimony, bismuth, cobalt, gallium, germanium, indium, niobium, platinum group metals, REEs, tantalum, titanium, and tungsten, as posing the greatest supply risk for the U.S. manufacturing sector (Nassar and others, 2020).

In October 2020, the U.S. Department of Defense (DOD), Defense Logistics Agency Strategic Materials (DLA Strategic Materials) announced the fiscal year 2020 (October 1, 2020, through September 30, 2021) Annual Materials Plan (AMP) for the National Defense Stockpile (NDS). The AMP includes potential acquisitions of new NDS stocks. In fiscal year 2021, the potential acquisitions list included 500 t of cerium (unspecified form), 20 t of dysprosium (unspecified form), 1,300 t of lanthanum (unspecified form), 600 t of neodymium (unspecified form), 70 t of praseodymium (unspecified form), 100 t of rare-earth magnet block, and 600 t of yttrium (unspecified form) (Defense Logistics Agency Strategic Materials, 2020).

The U.S. Department of Energy (DOE) continued to fund research in pursuit of methods to separate rare earths from coal and coal byproducts. The DOE announced plans to make available $122 million in Federal funding for cost-shared research and development under the funding opportunity announcement (U.S. Department of Energy, 2020). The National Energy Technology Laboratory (NETL) announced a funding opportunity for projects to realize the full potential of carbon ores and critical minerals within U.S. basins (National Energy Technology Laboratory, 2020a; 2020b, p. 8, 54–57). The NETL announced the selection of Texas Mineral Resources to lead a consortium for an award of up to $1 million targeting the production of rare earths in Pennsylvania (Mining.com, 2020).

In November 2020, the DOD announced awards to REE producers made under the authority of title III of the Defense Production Act (DPA). In a technology investment agreement with MP Materials Corp., the DOD would contribute $9.6 million to MP Materials' effort to add downstream processing and separation capabilities to its Mountain Pass operations for LREEs (U.S. Department of Defense, 2020).

The DOD also signed DPA title III agreements with TDA Magnetics, LLC of Rancho Dominguez, CA, and Urban Mining Company of San Marcos, TX, for REE magnet supply chain

studies and inventory demonstrations for $2.3 million and $0.86 million, respectively. The DOD awarded MP Materials and Lynas USA LLC $660,000 and $650,000, respectively, to support the technical development of HREE separation capabilities in the United States. Urban Mining Co. was awarded $28.8 million by the DOD to maintain capabilities during the disruption caused by the coronavirus disease 2019 (COVID-19) pandemic while strengthening the domestic supply chain of rare-earth materials. In September, the DLA Strategic Materials increased the scope of a Rapid Innovation Fund project awarded to Rare Earth Salts Separations & Refining, LLC that was expected to scale Rare Earth Salts' production capacity up to 20 metric tons per year (t/yr) of neodymium and praseodymium at its facility in Beatrice, NE (U.S. Department of Defense, 2020).

Production

The USGS developed domestic mine production data for rare-earth minerals from a voluntary canvass of U.S. mining operations and information gathered from publicly available reports. In 2020, rare-earth mineral concentrates were produced domestically by MP Mine Operations LLC doing business as MP Materials and by The Chemours Co. Bastnaesite mineral concentrates were produced as a primary product by MP Materials at mining and processing operations in Mountain Pass, CA. The Mountain Pass operations produced mineral concentrates in 2020; however, much of the downstream cracking and solvent extraction production capacity at Mountain Pass were idle. Monazite concentrates were recovered as a byproduct of processing heavy-mineral sands by Chemours from operations near Offerman, GA, and were exported.

Leading producers of rare-earth-bearing catalysts and chemical intermediates in the United States included Albemarle Corp. (Baton Rouge, LA), BASF Corp. (Florham Park, NJ), Solvay Chemicals, Inc. (Houston, TX), and W.R. Grace & Co. (Columbia, MD). Globe Metallurgical Inc. (Beverly, OH), a subsidiary of Ferroglobe PLC and CC Metals and Alloys, LLC (Calvert City, KY), produced specialty ferroalloys containing rare-earth metals. U.S. producers of rare-earth alloys or magnets included Electron Energy Corp. (Landisville, PA), Eutectix LLC (Troy, MI, and Tolleson, AZ), and TdVib, LLC (Boone, IA). Rare Earth Salts (Beatrice, NE) was working to commercialize a proprietary process to produce separated rare-earth compounds. Energy Fuels Inc. (Blanding, UT) produced a mixed REE carbonate on a pilot scale at its White Mesa mill, located near Blanding, UT, using monazite from a North American source (Energy Fuels Inc., 2020).

In addition to MP Materials and Chemours, companies with plans to develop domestic mine production of rare earths included NioCorp Developments Ltd. at its Elk Creek project in Nebraska, Rare Element Resources Ltd. at its Bear Lodge project in Wyoming, Texas Mineral Resources Corp. (TMRC) at its Round Top project in Texas, Ucore Rare Metals Inc. at its Bokan Mountain project in Alaska, and American Rare Earths Ltd. at its La Paz rare earths and scandium project in Arizona. In addition to the lanthanides and yttrium, several companies were considering scandium recovery in their project plans (Scheyder, 2020).

Rare Element Resources conducted pilot-plant testing to upgrade sample material to 92% to 97% rare-earth concentrate. In the final stage of processing at the pilot plant at the Bear Lodge project in northeastern Wyoming, a 99.5%, commercial-grade neodymium-praseodymium oxide was produced, along with other REOs (Rare Element Resources Ltd., 2020).

Consumption

Owing to limited data, industry estimates of global consumption of rare earths varied significantly. Based on global mine production, consumption was estimated to be about 243,000 t. The leading end uses of rare earths globally were, in descending order of quantity, magnets, catalysts, polishing, and metallurgical applications. Other end uses included ceramics, glass, phosphors, pigments, and miscellaneous other uses. Based on trade data and excluding stock changes, U.S. apparent consumption of rare earths of compounds and metals was estimated to be about 5,400 t of REO equivalent in 2020.

The estimated domestic uses of rare earths in 2020 were primarily in catalysts, with the remainder, in descending order of quantity, in ceramics and glass, other uses, polishing, and metallurgical and alloy applications.

The United States primarily consumed LREEs. Because the United States had limited capabilities to produce battery alloys, magnet alloys, and phosphors, most LREE consumption was in the form of cerium and lanthanum compounds used to produce catalysts, ceramics, glass, and polishing compounds; ferrocerium and rare-earth metals were used for alloys and other metallurgical applications. Most HREE consumption was in the form of yttrium compounds.

The amount of specific REEs used varied significantly by market sector and application. In the catalysts sector, the primary REEs consumed were lanthanum and cerium, with lesser amounts of neodymium. Consumption in the magnet sector varied by the type of permanent magnet. Neodymium-iron-boron magnets primarily used neodymium and praseodymium with lesser amounts of dysprosium, gadolinium, and terbium; samarium-cobalt magnets used samarium and lesser amounts of gadolinium. Lanthanum had limited use in certain ferrite magnets. Polishing compounds primarily used cerium with lesser amounts of lanthanum. Batteries primarily used lanthanum and lesser amounts of cerium and other REEs. Ceramics were dominated by yttrium consumption with lesser amounts of cerium and other REEs. Metallurgical applications varied by element. Europium, terbium, and yttrium were the three REEs commonly associated with the phosphors sector, but other REEs also were used by that sector. The glass sector used lanthanum, cerium, and erbium, in descending order of consumption, as well as other REEs. The HREEs were often used in high-unit-value applications. For example, laser crystals commonly were based on neodymium and yttrium and were doped with the HREEs (particularly dysprosium, erbium, thulium, and ytterbium). Among its other uses, lutetium was used in positron emission tomography.

Global consumption of scandium was estimated to be 15 to 25 t/yr. Although not quantified, the domestic end uses of scandium were primarily for fuel cells and as an additive in aluminum alloys; however, scandium for these applications

was estimated by the USGS to be imported in the form of value-added intermediate products. Globally, the leading end uses for scandium were aluminum-scandium alloys, fuel cells, and lasers.

Prices

Prices for rare-earth products were influenced by the overall production of REOs and demand for specific elements in a wide variety of end uses. In 2020, REO prices for cerium and lanthanum primarily used in catalyst applications were relatively unchanged compared with those in 2019. In magnet end uses, prices for neodymium oxide increased by 9% and dysprosium and terbium oxides increased by 9% and 32%, respectively; however, the praseodymium oxide price decreased by 13%. The price for samarium oxide was unchanged. In phosphor end uses, the europium oxide price decreased by 11%. The price for yttrium oxide used in ceramic and a variety of other end uses was unchanged. The domestic price for scandium oxide quoted by a domestic supplier decreased by 3% compared with that in 2019 (table 3).

Prices for REOs used predominately in catalyst, ceramic, polishing, and glass applications were relatively unchanged compared with those in 2019.

Based on information collected by the U.S. Census Bureau on imports, the estimated unit value of REO in rare-earth compounds was about $15 per kilogram compared with $12 per kilogram in 2019 (table 6). Variations in the purity or mix of specific compounds imported from year to year affected the unit value of imports.

Foreign Trade

Owing primarily to the resumption of production and export of rare-earth mineral concentrates from Mountain Pass, total exports of rare-earth compounds and metals increased substantially to 39,000 t of REO equivalent, a 36% increase compared with those in 2019. Exports of monazite were 530 t of REO equivalent. Exports of rare-earth metals, including unalloyed and alloyed metals but excluding ferrocerium, were 25 t of REO equivalent, a decrease compared with 83 t of REO equivalent in 2019. The leading export destinations for rare-earth metals (excluding ferrocerium) were Austria, Brazil, and China. In 2020, exports of ferrocerium and other pyrophoric alloys were 625 t of REO equivalent, a substantial decrease compared with those in 2019 (tables 1, 4, 5).

U.S. imports of rare-earth compounds and metals totaled 7,200 t of REO equivalent in 2020, a 46% decrease compared with those in 2019 (table 1). About 91% of rare-earth REO-equivalent imports were in the compound form, and 9% were metals (tables 6, 7). China continued to be the largest supplier of rare earths to the United States in most import categories. Cerium compounds and lanthanum compounds were the leading categories for specific rare earths, but the leading categories were unspecified Harmonized Tariff Schedule of the United States categories.

Imports of rare-earth metals, including unalloyed and alloyed metals but excluding ferrocerium, were 362 t of REO equivalent, whereas imports of ferrocerium and pyrophoric alloys were 274 t of REO equivalent. Imports of unalloyed REE metals were 211 t of REO equivalent and were primarily cerium or lanthanum. Imports of other rare-earth alloys were 152 t of REO equivalent (table 7).

World Review

Australia.—Geoscience Australia's national assessment of reserves compliant with the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves [the Joint Ore Reserve Committee (JORC)] were 3.02 million metric tons (Mt) of REO equivalent. Geoscience Australia's estimate of economic demonstrated resources (EDR) was 4.03 Mt of REO equivalent as of the end of December 2019. Australia's EDR included reserves and measured and indicated resources but excluded 27 Mt of inferred resources. The EDR for scandium was assessed separately and determined to be 27,000 t of scandium. Reserves for scandium were an estimated 13,000 t (Geoscience Australia, 2021, p. 6).

Australia was an active geographic region for mineral exploration and development. Publicly listed companies developing projects with JORC-compliant rare-earth reserves in Australia included Australian Strategic Materials Ltd. (2020) [demerged from Alkane Resources Ltd. (Dubbo Zirconia, New South Wales)], Arafura Resources Ltd. (Nolans Bore, Northern Territory), Australian Mines Ltd. (Sconi, Queensland), Clean TeQ Holdings Ltd. (Sunrise, New South Wales), Hastings Technology Metals Ltd. (Yangibana, Western Australia), Lynas Corp. Ltd. (Mt Weld, Western Australia), Northern Minerals Ltd. (Browns Range, Western Australia), Platina Resources Ltd. (Owendale, New South Wales), and Scandium International Mining Corp. (Nyngan, New South Wales) (Geoscience Australia, 2021, p. 72–73).

Heavy-mineral-sands producer Iluka Resources Ltd. was proceeding with its Eneabba Mineral Sands Recovery Project. Iluka planned to process a stockpile of historical tailings to produce byproducts including rare-earth, titanium, and zirconium mineral concentrates. The measured and indicated resources of the stockpile were estimated to be 1 Mt grading 83% heavy minerals. Monazite and xenotime made up about 20% and 1.2%, respectively, of the heavy-minerals fraction (Iluka Resources Ltd., 2019, p. 2).

In 2020, Iluka produced and exported 44,000 t of mixed monazite-zircon concentrates. In future years, Iluka planned to produce a 90% monazite concentrate and construct downstream capabilities to refine rare earths (Iluka Resources Ltd., 2021, p. 2).

Lynas, a leading producer of rare-earth mineral concentrates outside of China in 2020, continued to operate its Mt Weld mining operations in Western Australia to support its processing operations in Malaysia. In 2020, Lynas announced plans for expansion and relocating its crack and leach plant to Kalgoorlie, Western Australia, from Malaysia (Lynas Rare Earths Ltd., 2020, p. 1). Lynas announced signing a contract with the DOD for phase I work on a U.S.-based HREE facility. This phase I funding provided by the DOD would allow Lynas and its U.S. partner Blue Line to complete a detailed market and strategy study plus detailed planning and design work for the construction of a HREE separation facility (Lynas Corp. Ltd., 2020a, b, c). In December, Lynas Corp. Ltd. changed the

company name to "Lynas Rare Earths Ltd." (Lynas Rare Earths Ltd., 2020, p. 2).

Pilot-plant-scale operations were ongoing at Northern Minerals Browns Range project in Western Australia. The project's total resources in Western Australia and the Northern Territory were estimated at 9.3 Mt containing 0.67% (62,000 t) REO distributed in seven deposits (Area 5, Banshee, Cyclops, Dazzler, Gambit, Gambit West, and Wolverine) plus the mined pilot-plant stockpiles as of June 30, 2020. Shipments totaling 157 t of rare-earth carbonate were sold to Thyssenkrupp Materials Trading GmbH during the fiscal year ending in June 2020 (Northern Minerals Ltd., 2020a, p. 37; 2020b).

Brazil.—In 2020, 600 t of monazite was produced in Brazil and sold to the international market. Brazilian reserves were estimated to be 22 Mt of REO equivalent (Calaes and others, 2020).

Burundi.—Rainbow Rare Earths Ltd. released a technical report on the Gakara REE project that updated the exploration targets and established an exploration program to convert the exploration targets to inferred mineral resources (Rainbow Rare Earths Ltd., 2020, p. 1).

Canada.—In 2020, there were numerous companies with rare-earth projects under development in Canada. In 2020, publicly listed companies with projects known to have measured or indicated resources included Appia Energy Corp. (Elliot Lake, Ontario), Avalon Advanced Materials Inc. (Nechalacho, Northwest Territories), Commerce Resources Corp. (Ashram, Quebec), Defense Metals Corp (Wicheeda, British Columbia), Geomega Resources Inc. (Montviel, Quebec), Torngate Metals Ltd. (Strange Lake, Quebec), IAMGOLD Corp. (St-Honore, Quebec), Quebec Precious Metals Corp (Kipawa-Zeus, Quebec), and Search Minerals Inc. (Deep Fox, Newfoundland and Labrador).

China.—China dominated global production of rare-earth minerals, separated compounds, and metals. Based on China's production quota, China accounted for 58% of global mine production in 2020 (table 8). Nearly all mine, smelting, and separation quotas were allocated to state-owned enterprises.

India.—India's producers of rare-earth-bearing heavy-mineral concentrates included Indian Rare Earths Ltd. (IREL) and Kerala Metals & Minerals Ltd. IREL had capacity at its Aluva facilities to produce 5,000 t/yr of mixed rare-earth chlorides and separated compounds from monazite concentrates. At Chatrapur, in the State of Odisha, IREL was operating a processing plant that used monazite as a feedstock to produce up to 11,200 t/yr of mixed rare-earth chlorides. In fiscal year 2019 (April 1, 2018, through March 31, 2019), rare-earth-chloride production was reported to be 4,220 t. No data were available for 2020 (Indian Bureau of Mines, 2020, p. 24–3—24–10).

Madagascar.—In 2020, QIT Madagascar Minerals (QMM) produced and exported monazite-bearing concentrates as a byproduct of processing heavy-mineral sands to produce ilmenite and zircon-sillimanite concentrates. QMM was owned by the Government of Madagascar (20%) and Rio Tinto plc (80%) (Rio Tinto plc, undated). In 2020, China imported 25,000 t (gross weight) of monazite-bearing concentrates from Madagascar (Zen Innovations AG, 2021).

Malaysia.—Lynas continued production of rare-earth compounds at its Lynas Advanced Material Plant (LAMP) near the Port of Kuantan in the State of Pahang. The production of neodymium-praseodymium compounds decreased significantly, and the overall production of REOs in compounds from the LAMP operations in 2020 was about 14,600 t, a 17% decrease compared with production in 2019. The overall decrease in the production of compounds was caused in part by restrictions owing to the COVID-19 pandemic (Lynas Corp. Ltd., 2020d, 2021).

A license for 3 years was approved by the Malaysian Government to continue processing rare earths at LAMP (Ashok and Burton, 2020). Lynas was proposing to open a rare-earth-processing facility as Lynas Kalgoorlie Pty Ltd to process rare-earth concentrate from the Mt Weld Mine to produce a rare-earth carbonate for export (Western Australia Environmental Protection Agency, undated).

Philippines.—Japan's Sumitomo Metal Mining Co., Ltd. (SMM) continued commercial-scale production of a scandium intermediate product at its subsidiary Taganito HPAL Nickel Corp. on Palawan Island. The plant was expected to recover up to 7.5 t/yr of scandium oxide equivalent from a process stream following the leaching of nickel laterite (nickel oxide ore) for nickel-cobalt sulfide. Processing of the intermediate product into scandium oxide began in 2019 and was performed at SMM's Harima operation in Japan (Sumitomo Metal Mining Co., Ltd., 2020, p. 83).

Russia.—Imports of rare-earth compounds [Harmonized System (HS) code 2846] into Russia were 992 t in 2020, and exports were 6,530 t. Rare-earth-metal (HS code 2805.30) imports and exports were 113 t and 1.2 t, respectively. China and Estonia were Russia's leading import sources, and Estonia, China, and India, in descending order, were the leading export destinations of rare-earth compounds (Zen Innovations AG, 2021).

South Africa.—Steenkampskraal Holdings Ltd. continued plans to reopen the Steenkampskraal (SKK) monazite mine that was active from 1952 to 1963. The company planned to produce up to 2,700 t/yr of REO equivalent in mixed carbonates. In 2019, the company reported that it had received the water license it needed to fully permit construction and mining. Using a 1%-REO cutoff grade, SKK's measured and indicated resources were reported to be 605,000 t containing 14.4% (86,900 t) of REO equivalent (Steenkampskraal Monazite Mine (Pty) Ltd., 2019).

Sweden.—In June, owing to actions taken by the Government related to the COVID-19 pandemic, the exploration license for Leading Edge Materials Corp.'s Norra Karr mining project was extended to be valid until August 2025. Probable reserves for the project were reported previously to be 23.6 Mt containing 0.592% (140,000 t) REO equivalent. Using a 0.4%-REO cutoff grade, indicated resources were 31.1 Mt containing 0.61% (190,000 t) REO equivalent. The predominate REE mineralization was eudialyte. A prefeasibility study was based on a production of about 5,000 t/yr of mixed REOs and a 20-year mine life, using a 0.4%-REO cutoff grade (Tasman Metals Ltd., 2015, p. 42–43, 45; Leading Edge Materials Corp., 2021, p. 4).

Tanzania.—Peak Resources Ltd. continued the development of its Ngualla project with plans for mining operations in southwestern Tanzania. Reserves were reported to be 18.5 Mt containing 4.8% (887,000 t) of REO equivalent using a 1%-REO cutoff grade. Resources were reported to be 210 Mt

containing 2.2% (4.6 Mt) REO equivalent and 93% of the resources were classified as measured and indicated. Peak Resources expected the Ngualla operations to produce up to 32,700 t/yr of mineral concentrate containing 45% REO. At yearend, a special mining license was under review by Tanzania's Ministry of Minerals (Peak Resources Ltd., 2020).

United Kingdom.—In 2019, Peak Resources continued plans to construct its Teesside extraction and separation operations located in the Wilton industrial area near Middleborough. The company expected that the Teesside operation would process up to 32,700 t/yr of concentrates from its Ngualla, Tanzania, mining operations and produce mixed and separated REO compounds (Peak Resources Ltd., 2020).

Outlook

The annual average growth rate of REE consumption is expected to range from 5% to 10% through 2025. The leading end uses of rare earths are expected to be magnets, catalysts, and polishing compounds, in descending order of quantity. The magnet materials sector is expected to have higher average growth, and the catalysts, ceramics, and phosphors sectors are expected to have lower average growth. As the leading producer and consumer of rare-earth minerals and most downstream products, China is expected to continue to shape the global markets for rare-earth compounds and metal alloys. China's imports of mineral concentrates are expected to continue to significantly increase.

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TABLE 1
SALIENT RARE-EARTH STATISTICS[1]

(Metric tons)

	2016	2017	2018	2019	2020
United States:					
Production of rare-earth concentrates, rare-earth-oxide (REO) equivalent[e, 2, 3]	--	--	14,000	28,000	39,000
Exports, REO equivalent:[e]					
Rare-earth concentrates, monazite	--	--	260	840	530
Compounds:					
Cerium compounds	309	1,140	304	208	337
Other rare-earth compounds	281	598	17,300	27,100	38,000
Metals:					
Ferrocerium and pyrophoric alloys	943	982	1,250	1,290	625
Rare-earth metals, scandium, yttrium	103	55	28	83	25
Imports for consumption, REO equivalent:[e]					
Compounds:					
Cerium compounds	1,830	2,390	2,940	2,500 [r]	2,140
Other rare-earth compounds	9,650	8,600	7,890	9,800	4,420
Metals:					
Ferrocerium and pyrophoric alloys	268	309	298	330 [r]	274
Rare-earth metals, scandium, yttrium	404	524	526	627	362
World production, REO equivalent	133,000	147,000	190,000	219,000	243,000
Prices, annual average:					
Monazite concentrate, gross basis[e]	2.57	2.70	2.40	2.60	2.80
Mischmetal, 65% cerium, 35% lanthanum, metal basis[4]	5.17	5.51	6.16	5.82	5.03

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

[1]Table includes data available through July 8, 2021. Data are rounded to no more than three significant digits.

[2]Includes only the rare earths derived from bastnaesite.

[3]Sources: MP Materials Corp., 2020, Prospectus: U.S. Securities and Exchange Commission, 149 p.; MP Materials Corp., 2021, Form 10—For the fiscal year ending December 31, 2020: MP Materials Corp.

[4]Source: Argus Media group – Argus Metals International.

TABLE 2
RARE-EARTH COMPOSITION OF SELECTED SOURCE MINERALS[1, 2]

(Percentage of total rare-earth oxide)

			Rare-earth-element symbol														
Primary source	Country	Location	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
Bastnaesite	China	Bayan Obo, Nei Mongol Autonomous Region[3]	23.00	50.00	6.20	18.50	0.80	0.20	0.70	0.10	0.10	NA	NA	NA	NA	NA	NA
Do.	do.	Dechang, Sichuan Province[4]	35.63	43.81	4.73	13.06	1.22	0.23	0.52	0.06	0.09	0.05	0.04	0.01	0.06	NA	0.40
Do.	do.	Maoniuping, Sichuan Province[4]	29.49	47.56	4.42	15.18	1.24	0.23	0.65	0.12	0.21	0.05	0.06	0.04	0.05	0.01	0.70
Do.	do.	Weishan, Shandong Province[4]	35.46	47.76	3.95	10.90	0.79	0.13	0.53	0.14	NA	NA	NA	NA	0.03	NA	0.76
Do.	United States	Mountain Pass, CA[5]	34.00	48.80	4.20	11.70	0.79	0.13	0.21	NA	NA	NA	NA	NA	NA	NA	0.12
Loparite	Russia	Revda, Murmansk Oblast[6]	25.00	50.50	5.00	15.00	0.70	0.09	0.60	NA	0.60	0.70	0.80	0.10	0.20	0.15	1.30
Monazite	Australia	Mt Weld Central Lanthanide, Western Australia[7]	23.88	47.55	5.16	18.13	2.44	0.53	1.09	0.09	0.25	0.03	0.06	0.01	0.03	NA	0.76
Do.	China	Nangang, Guangdong Province[4]	23.00	42.70	4.10	17.00	3.00	0.10	2.00	0.70	0.80	0.12	0.30	NA	2.40	0.14	2.40
Do.	India	Manavalakurichi, Tamil Nadu[8]	22.00	46.00	5.50	20.00	2.50	0.02	1.20	0.06	0.18	0.02	0.01	0.00	0.00	0.00	0.45
Rare-earth laterite	China	Xunwu, Jiangxi Province[4]	38.00	3.50	7.41	30.18	5.32	0.51	4.21	0.46	1.77	0.27	0.88	0.13	0.62	0.13	10.07
Do.	do.	Xinfeng, Jiangxi Province[4]	27.26	3.23	5.62	17.55	4.54	0.93	5.96	0.68	3.71	0.74	2.48	0.27	1.13	0.21	24.26
Do.	do.	Longnan, Jiangxi Province[4]	2.18	<1.09	1.08	3.47	2.34	<0.37	5.69	1.13	7.48	1.60	4.26	0.60	3.34	0.47	64.90
Xenotime	do.	Guangdong Province[9]	1.20	3.00	0.60	3.50	2.20	0.20	5.00	1.20	9.10	2.60	5.60	1.30	6.00	1.80	59.30

Do., do. Ditto. NA Not available.

[1]Table includes data available through July 8, 2021. Rows may not add to 100 percent.

[2]Rare earths are listed in order of atomic number except yttrium, which is listed after the last of the heavy rare-earth lanthanide elements.

[3]Source: Zang, Zhang Bao, Lu, Ke Yi, King, Kue Chu, Wei, Wei Cheng, and Wang, Wen Cheng, 1982, Rare-earth industry in China: Hydrometallurgy, v. 9, no. 2, p. 205–210.

[4]Source: Zhi Li, Ling, and Yang, Xiaosheng, 2014, China's rare earth ore deposits and beneficiation techniques: ERES 2014—1st European Rare Earth Resources Conference, Milos, Greece, April 4–7, 11 p.

[5]Source: Molycorp, Inc., 2015, Form 10–K—2014: Greenwood Village, CO, Molycorp, Inc., 145 p. (Accessed June 30, 2016, at http://www.molycorp.com/investors.)

[6]Source: Hedrick, J.B., Sinha, S.P., and Kosynkin, V.D., 1997, Loparite, a rare-earth ore: Journal of Alloys and Compounds, v. 250, p. 467–470.

[7]Source: Lynas Corp., Ltd., 2012, Increase in Mt Weld resource estimate for the Central Lanthanide deposit and Duncan deposit: Sydney, New South Wales, Australia, Lynas Corp., Ltd. press release, January 18.

[8]Source: Patra, R.N., 2014, Latest scenario in rare earth and atomic minerals in India: PDAC Convention 2014, Toronto, Ontario, Canada, March 2–4, presentation, 42 p.

[9]Source: Nakamura, Shigeo, 1988, China and rare metals—Rare earth: Industrial Rare Metals, no. 94, May, p. 23–28.

TABLE 3
RARE-EARTH-OXIDE PRICES[1]

Product (oxide)	Purity (percent)	Price (dollars per kilogram) 2019	2020
Scandium[2, 3]	99.990	3,900	3,800
Yttrium[4]	99.999	3	3
Lanthanum[4]	99.500	2	2
Cerium[4]	99.500	2	2
Praseodymium[4]	99.500	54	47
Neodymium[4]	99.500	45	49
Samarium[4]	99.500	2	2
Europium[4]	99.990	35	31
Gadolinium[4]	99.999	46	43
Terbium[4]	99.990	507	670
Dysprosium[4]	99.500	239	261

[1]Products are listed in order of atomic number.
[2]Source: Stanford Metals Corp.
[3]Five-kilogram lot size.
[4]Source: Argus Media group – Argus Metals International.

TABLE 4

U.S. EXPORTS OF RARE-EARTH COMPOUNDS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	Schedule B number	2019 Gross weight (kilograms)	2019 Value	2020 Gross weight (kilograms)	2020 Value
Cerium compounds:	2846.10.0000				
Austria		10,300	$135,000	9,760	$130,000
Canada		23,900	362,000	75,300	603,000
China		20,100	1,170,000	21,600	1,250,000
Germany		38,000	1,030,000	53,300	1,030,000
Japan		21,500	322,000	12,500	188,000
Korea, Republic of		26,700	283,000	36,100	411,000
South Africa		12,100	152,000	5,470	68,500
Taiwan		104,000	554,000	106,000	550,000
United Kingdom		1,390	151,000	152,000	328,000
Other		52,600 r	668,000 r	32,500	1,130,000
Total		311,000	4,820,000	504,000	5,680,000
Total estimated rare-earth-oxide (REO) equivalent content		208,000	XX	337,000	XX
Other rare-earth compounds:					
Oxides:					
Scandium or yttrium oxides:	2846.90.2015				
Germany		4,990	168,000	750	130,000
Spain		521	4,170	--	--
Other		265 r	126,000 r	416	221,000
Total		5,770	298,000	1,170	351,000
Total estimated REO equivalent content		5,770	XX	1,170	XX
Other oxides:	2846.90.2040				
China		173	232,000	3,310	36,400
Japan		60,900	458,000	8,980	80,800
Switzerland		2,260	1,670,000	2,400	1,860,000
Other		4,540 r	378,000 r	3,230	200,000
Total		67,800	2,730,000	17,900	2,180,000
Total estimated REO equivalent content		67,800	XX	17,900	XX
Chlorides:	2846.90.2060				
China		3,190	61,400	156	3,900
Mexico		310	14,100	--	--
Sweden		--	--	1,150	225,000
Other		135 r	400,000 r	401	185,000
Total		3,640	476,000	1,710	414,000
Total estimated REO equivalent content		1,670	XX	785	XX
Unspecified rare-earth compounds:	2846.90.9000				
China		45,600,000	65,200,000	62,100,000	96,700,000
Other		331,000	9,540,000	1,180,000	12,600,000
Total		45,900,000	74,700,000	63,300,000	109,000,000
Total estimated REO equivalent content		27,000,000	XX	38,000,000	XX
Grand total		46,300,000	83,100,000	63,900,000	118,000,000
Grand total estimated REO equivalent content		27,300,000	XX	38,400,000	XX

rRevised. XX Not applicable. -- Zero.

[1]Table includes data available through June 22, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 5
U.S. EXPORTS OF RARE-EARTH METALS AND ALLOYS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	Schedule B number	2019 Gross weight (kilograms)	2019 Value	2020 Gross weight (kilograms)	2020 Value
Ferrocerium and other pyrophoric alloys:	3606.90.0000				
Aruba		27,400	$42,300	6,240	$19,300
Australia		26,000	3,000,000	3,330	905,000
Bahamas, The		24,100	55,400	5,990	25,700
Barbados		26,000	82,600	11,900	39,800
Belgium		2,860	25,300	71,900	134,000
Canada		298,000	1,240,000	306,000	1,340,000
China		43,800	1,970,000	34,300	1,360,000
Costa Rica		56,000	150,000	893	27,900
Dominican Republic		35,000	54,700	--	--
Haiti		19,300	31,600	6,340	11,200
Honduras		356,000	417,000	1,150	4,180
Israel		38,900	41,100	--	--
Italy		438	18,100	31,100	190,000
Jamaica		64,200	114,000	34,600	57,500
Japan		20,300	1,200,000	13,500	1,620,000
Mexico		23,100	109,000	60,200	176,000
Panama		71,700	147,000	15,700	23,900
Thailand		36,300	12,900	226	2,980
Trinidad and Tobago		71,300	124,000	9,220	16,800
United Kingdom		91,100	557,000	8,270	124,000
Other		121,000 r	2,150,000 r	83,700	2,070,000
Total		1,450,000	11,500,000	704,000	8,140,000
Total estimated rare-earth-oxide (REO) equivalent content		1,290,000	XX	625,000	XX
Rare-earth metals and alloys:	2805.30.0000				
Austria		1,680	84,600	13,400	791,000
Brazil		15,200	30,700	358	82,900
China		19,900	232,000	319	64,100
Japan		3,080	156,000	241	38,800
United Kingdom		22,300	402,000	59	35,800
Other		3,060	714,000	5,050	1,310,000
Total		65,200	1,620,000	19,400	2,320,000
Total estimated REO equivalent content		82,800	XX	24,700	XX

rRevised. XX Not applicable. -- Zero.
[1]Table includes data available through June 22, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF RARE-EARTH COMPOUNDS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	HTS[2] code	2019 Gross weight (kilograms)	2019 Value	2020 Gross weight (kilograms)	2020 Value
Cerium oxides:	2846.10.0010				
China		225,000	$1,430,000	163,000	$1,260,000
Japan		530,000	23,600,000	505,000	21,400,000
Other		15,000	566,000	16,300	605,000
Total		770,000	25,600,000	684,000	23,300,000
Total estimated rare-earth-oxide (REO) equivalent content		770,000	XX	684,000	XX
Cerium compounds, other than cerium oxide:	2846.10.0050				
China		1,860,000 r	6,150,000 r	1,730,000	5,960,000
Estonia		646,000	1,460,000	402,000	813,000
Other		82,300	878,000	47,800	847,000
Total		2,580,000 r	8,490,000 r	2,180,000	7,620,000
Total estimated REO equivalent content		1,730,000 r	XX	1,460,000	XX
Other rare-earth compounds:					
Carbonates:					
Lanthanum carbonates mixtures:	2846.90.8070				
China		323,000	1,180,000	18,300	221,000
Other		1,020	22,300	3,050	32,600
Total		324,000	1,200,000	21,300	254,000
Total estimated REO equivalent content		222,000	XX	14,600	XX
Other rare-earth carbonates mixtures:	2846.90.8075				
China		5,100	372,000	175	2,160
Malaysia		--	--	19,700	19,500
Other		--	--	185	54,700
Total		5,100	372,000	20,000	76,300
Total estimated REO equivalent content		2,810	XX	11,000	XX
Chlorides:					
Unspecified mixtures of oxides or chlorides:	2846.90.2084				
China		1,120,000	2,630,000	552,000	2,060,000
Other		36,900	1,400,000	35,000	1,060,000
Total		1,150,000	4,030,000	587,000	3,110,000
Total estimated REO equivalent content		634,000	XX	323,000	XX
Oxides:					
Lanthanum oxides:	2846.90.2005				
China		759,000	1,910,000	85,900	289,000
Malaysia		67,700	427,000	5,970	35,800
Other		53,600 r	2,070,000 r	21,000	1,970,000
Total		881,000	4,410,000	113,000	2,300,000
Total estimated REO equivalent content		881,000	XX	113,000	XX
Scandium or yttrium oxides:	2846.90.2015				
China		18,800	389,000	772	184,000
Japan		1,270	362,000	2,280	1,300,000
Korea, Republic of		3,330	729,000	3,320	738,000
Other		2,050	226,000	1,390	187,000
Total		25,400	1,700,000	7,750	2,410,000
Total estimated REO equivalent content		25,400	XX	7,750	XX
Other oxides:	2846.90.2040				
China		98,900	5,440,000	80,600	3,370,000
Russia		59,900	187,000	19,800	51,400
Other		9,340	596,000	485	114,000
Total		168,000	6,220,000	101,000	3,540,000
Total estimated REO equivalent content		168,000	XX	101,000	XX

See footnotes at end of table.

TABLE 6—Continued
U.S. IMPORTS FOR CONSUMPTION OF RARE-EARTH COMPOUNDS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	HTS[2] code	2019 Gross weight (kilograms)	2019 Value	2020 Gross weight (kilograms)	2020 Value
Other rare-earth compounds or mixtures:					
Unspecified compounds or mixtures:	2846.90.8090				
China		11,000,000	63,500,000	4,450,000	29,000,000
Malaysia		1,850,000	4,100,000	972,000	2,050,000
Other		1,130,000	23,300,000	510,000	18,600,000
Total		14,000,000	90,900,000	5,940,000	49,600,000
Total estimated REO equivalent content		7,680,000	XX	3,270,000	XX
Yttrium materials and compounds content by weight greater than 19% but less than 85% oxide equivalent:	2846.90.4000				
China		305,000	759,000	978,000	2,230,000
Other		4,640	1,940,000	1,050	1,510,000
Total		310,000	2,700,000	979,000	3,740,000
Total estimated REO equivalent content		186,000	XX	587,000	XX

[r]Revised. XX Not applicable. -- Zero.
[1]Table includes data available through June 22, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF RARE-EARTH METALS AND ALLOYS, BY COUNTRY OR LOCALITY[1]

Category and country or locality	HTS[2] code	2019 Gross weight (kilograms)	2019 Value	2020 Gross weight (kilograms)	2020 Value
Ferrocerium and other pyrophoric alloys:	3606.90.3010 and 3606.90.3090				
Austria		36,900	$423,000	40,600	$406,000
China		160,000 r	1,710,000 r	140,000	1,420,000
Netherlands		4,390	25,400	18,000	108,000
Spain		139,000	2,440,000	90,400	1,580,000
Other		31,000 r	284,000 r	19,100	153,000
Total		372,000 r	4,890,000 r	308,000	3,670,000
Total estimated rare-earth-oxide (REO) equivalent content		330,000 r	XX	274,000	XX
Rare-earth metals and alloys:					
Cerium, unalloyed:	2805.30.0010				
China		100,000	843,000	34,000	259,000
Hong Kong		180,000	936,000	--	--
Other		--	--	2,820	44,700
Total		280,000	1,780,000	36,800	304,000
Total estimated REO equivalent content		344,000	XX	45,200	XX
Lanthanum, unalloyed:	2805.30.0005				
China		105,000	1,500,000	77,300	1,430,000
Other		167	13,300	3	2,900
Total		105,000	1,520,000	77,300	1,430,000
Total estimated REO equivalent content		123,000	XX	90,700	XX
Neodymium, unalloyed:	2805.30.0020				
China		2,480	361,000	1,900	272,000
Japan		83	7,000	--	--
Total		2,560	368,000	1,900	272,000
Total estimated REO equivalent content		2,990	XX	2,220	XX
Other rare-earth metals, unalloyed:	2805.30.0050				
China		29,200	1,150,000	38,100	2,750,000
Russia		10,100	808,000	21,700	1,740,000
Other		55	16,300	563	89,400
Total		39,300	1,970,000	60,300	4,570,000
Total estimated REO equivalent content		47,200	XX	72,400	XX
Other rare-earth metals, alloys:	2805.30.0090				
China		81,200	1,710,000	123,000	1,890,000
Other		10,100	848,000	4,070	408,000
Total		91,300	2,560,000	127,000	2,300,000
Total estimated REO equivalent content		110,000	XX	152,000	XX
Grand total		890,000 r	13,100,000	611,000	12,600,000
Grand total estimated REO equivalent content		957,000 r	XX	636,000	XX

rRevised. XX Not applicable. -- Zero.

[1]Table includes data available through June 22, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 8
RARE EARTHS: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons, rare-earth-oxide equivalent)

Country or locality[2]	2016	2017	2018	2019	2020
Australia[e]	15,000	19,000	21,000	20,000	17,000
Brazil[e]	2,700	1,700	1,200	710	600
Burma[e]	3,500	15,000	23,000	25,000	31,000
Burundi	--	40 [e]	620 [e]	200 [e]	300 [e]
China[3]	105,000	105,000	120,000	132,000	140,000
India[e, 4]	1,500	1,800	2,900	2,900	2,900
Madagascar[e]	--	--	2,000	4,000	5,000
Malaysia[e]	1,100	180	990	66	100
Russia	2,700	2,700	2,700	2,700 [e]	2,700
Thailand[e, 5]	1,600	1,300	1,000	1,900	3,600
United States[e]	--	--	14,000	28,000	39,000
Vietnam[e, 5]	240	220	920	1,300	700
Total	133,000	147,000	190,000	219,000	243,000

[e]Estimated. -- Zero.

[1]Table includes data available through August 16, 2021. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

[2]In addition to the countries and (or) localities listed, Indonesia, North Korea, Nigeria, and some Commonwealth of Independent States countries may have produced rare-earth minerals, but available information was inadequate to make reliable estimates of output.

[3]Official production quota. Illegal production could not be quantified.

[4]India's Department of Atomic Energy did not disclose monazite production data.

[5]Rare-earth-oxide content of exports.