RARE EARTHS

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The principal economic sources of rare earths are the minerals bastnasite, monazite, loparite, and the lateritic ion-adsorption clays (table 2). The rare earths are a moderately abundant group of 17 elements composed of scandium, yttrium, and the 15 lanthanides. The elements range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements in the Earth's crust at 60 parts per million, to thulium and lutetium, the least abundant rare-earth elements at about 0.5 part per million. In rock-forming minerals, the rare earths typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates.

Scandium, atomic number 21, is the lightest rare-earth element. It is the 31st most abundant element in the Earth's crust with an average crustal abundance of 22 parts per million. Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. It is represented by the chemical symbol Sc and has one naturally occurring isotope. Although its occurrence in crustal rocks is greater than 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, is chemically similar to the lanthanides and often occurs in the same minerals as a result of its similar ionic radius. It is represented by the chemical symbol Y and has one naturally occurring isotope. Yttrium's average concentration in the Earth's crust is 33 parts per million and is the second most abundant rare earth in the Earth's crust. Yttrium is a bright silvery metal that is soft and malleable, similar in density to titanium.

The lanthanides comprise a group of 15 elements with atomic numbers 57 through 71 that includes the following: 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). Cerium, the most abundant of the group at 60 parts per million, is more abundant than copper at 50 parts per million, followed next in decreasing crustal abundance by yttrium at 33 parts per million, lanthanum at 30 parts per million, and neodymium at 28 parts per million. Thulium and lutetium, the least abundant of the lanthanides at 0.5 part per million, occur in the Earth's crust in higher concentrations than antimony, bismuth, cadmium, and thallium.

The rare earths were discovered in 1787 by Swedish Army Lieutenant Karl Axel Arrhenius when he collected the black mineral ytterbite (later renamed gadolinite) from a feldspar and quartz mine near the village of Ytterby, Sweden (Weeks and Leicester, 1968, p. 667). Because they have similar chemical structures, the rare-earth elements proved difficult to separate. It was not until 1794 that the first element, an impure yttrium oxide, was isolated from ytterbite by Finnish chemist Johann Gadolin (Weeks and Leicester, 1968, p. 671).

The elemental forms of rare earths are iron gray to silvery lustrous metals that are typically soft, malleable, and ductile and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798° C for cerium to 1,663° C for lutetium. The rare earths' unique properties are used in a wide variety of applications.

In 1999, consumption was estimated to have increased as imports of individual rare-earth compounds increased. Production of bastnasite continued in the United States as production of cerium concentrates resumed on a limited scale. As a result, imports of cerium compounds decreased (table 1). Since March 1998, refinery production at the Mountain Pass, CA, site of Molycorp, Inc., was suspended reportedly because of low rare-earth prices on world markets and unresolved regulatory and permitting requirements for a wastewater system (Unocal, 1999, p. 15).

Demand decreased for rare earths used in petroleum fluid cracking catalysts and in rare-earth phosphors for television, X-ray intensifying, and fluorescent and incandescent lighting. Yttrium was used primarily in lamp and cathode-ray tube phosphors, structural ceramics, and oxygen sensors.

The domestic use of scandium increased in 1999, but overall consumption remained small. Commercial demand increased as recently developed applications entered the market. Most metal, alloys, and compounds were used in sporting goods equipment, metallurgical research, and analytical standards. Minor amounts were used in specialty lighting and semiconductors.

Production

In 1999, one mining operation in California accounted for all domestic mine production of rare earths. Molycorp, a wholly owned subsidiary of Unocal Corporation, mined bastnasite, a rare-earth fluorocarbonate mineral, by open pit methods at Mountain Pass, CA. Mine production was estimated at 5,000 metric tons of rare-earth oxide (REO) in concentrates.

Refined lanthanides were processed by two companies in 1999. Molycorp ceased production of refined compounds from bastnasite at its separation plant at Mountain Pass in 1998 as a result of a blocked wastewater pipe that underlies land administered by several Federal and State Government jurisdictions. Molycorp applied for permits to process wastewater at the mine site.

Rhodia Inc. agreed to sell its Rhodia Rare Earths Inc. operations in Phoenix, AZ, to Santuko Metal Industry Company of Japan. As part of the agreement, Rhodia will double its holdings in its 1993 Japanese joint venture with Santoku, Anan Kasei K.K. Anan Kasei processes intermediate rare-earth concentrates to produce rare-earth compounds including high-purity oxides (Industrial Minerals, 1999g).

Rhodia Inc. also announced the closure of its rare-earth separation plant in Freeport, TX, in conjunction with its plan to build a new separation plant in China. The new plant will be in Baotou, Inner Mongolia, China, about 90 kilometers south of China's principal rare-earth mine at Bayan Obo. It will operate other parts of the Freeport plant to upgrade and produce finished rare-earth products (Industrial Minerals, 1999f).

Grace Davison, a division of W.R. Grace & Co., refined rare earths from rare-earth chlorides and other rare-earth compounds for petroleum fluid cracking catalysts at Chattanooga, TN.

Essentially all purified yttrium was derived from imported compounds. The minor amounts of yttrium contained in bastnasite from Mountain Pass, CA, are not recovered as a separate product.

Three scandium processors operated in 1999. High-purity products were available in various grades with scandium oxide produced up to 99.999% purity. Sausville Chemical Co. refined scandium at its facilities in Knoxville, TN. The company expected to produce high-purity scandium compounds, including oxide, fluoride, nitrate, chloride, and acetate. Boulder Scientific Co. processed scandium at its Mead, CO, operations. It refined scandium primarily from imported oxides to produce high-purity scandium compounds, including diboride, carbide, chloride, fluoride, hydride, nitride, oxalate, and tungstate.

Scandium was also purified and processed from imported oxides at Aldrich-APL in Urbana, IL, to produce high-purity scandium compounds, including oxide, fluoride, and hydrous and anhydrous chloride. The company also produced high-purity scandium metal.

Principal domestic producers of neodymium-iron-boron magnet alloys were Magnequench International, Inc., Anderson, IN; Neomet Corp., Edinburg, PA; and Rhodia, Phoenix, AZ. Leading U.S. producers of rare-earth magnets were Magnequench International Inc., Hitachi Magnetics Corp., Edmore, MI; Crumax Magnetics, Inc., Elizabethtown, KY; and Ugimag Inc., Valparaiso, IN.

Consumption

Statistics on domestic rare-earth consumption were developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing U.S. Government stockpile shipments. Domestic apparent consumption of rare earths increased in 1999 compared with that of 1998. Domestic consumption of rare-earth metals and alloys also increased in 1999, especially for those used in permanent magnets. Consumption of rare earths increased in most applications, except those using cerium compounds and mixed rare-earth chlorides.

Based on information supplied by U.S. rare-earth refiners, selected consumers, and analysis of import data, the approximate distribution of rare earths by use was as follows: automotive catalytic converters, 60%; glass polishing and ceramics, 11%; permanent magnets, 8%; petroleum refining catalysts, 7%; metallurgical additives and alloys, 6%; rare-earth phosphors for lighting, televisions, computer monitors, radar, and X-ray intensifying film, 2%; and miscellaneous, 6%.

In 1999, yttrium consumption was estimated to be 428 metric tons, a decrease from 516 tons in 1998. Yttrium compounds and metal were imported from several sources in 1999. Yttrium was imported from China, 68.1%; Hong Kong, 15.2%; France, 11.6%; the United Kingdom, 2.6%; Germany, 2.0%; and Japan, 0.5%. The estimated use of yttrium, based on imports, was primarily in lamp and cathode-ray tube (CRT) phosphors, 70.4%; structural ceramics and abrasives, 8.5%; alloys, 4.6%; and oxygen sensors, lasers, electronics, and miscellaneous, 16.5%.

Tariffs

U.S. tariff rates in 1999, specific to the rare earths, including scandium and yttrium, were unchanged from 1998 except for the lowering of the tariff for cerium compounds (U.S. International Trade Commission, 1999). Selected rare-earth tariff rates for countries with "Normal trade relations" and "Non-normal trade relations" status, respectively, were as follows: HS 2805.30.0000 rare-earth metals, including scandium and yttrium, whether intermixed or interalloyed, 5.0% ad valorem, 31.3% ad valorem; HS 2846.10.0000 cerium compounds, 5.5% ad valorem, 35% ad valorem; HS 2846.90.2010 mixtures of rare-earth oxides except cerium oxide, Free, 25% ad valorem; HS 2846.90.2050 mixtures of rare-earth chlorides, Free, 25% ad valorem; HS 2846.90.4000 yttrium-bearing materials and compounds containing by weight greater than 19% but less than 85% yttrium oxide equivalent, Free, 25% ad valorem; HS 2846.90.8000 individual rare-earth compounds, including oxides, nitrates, hydroxides, and chlorides (excludes cerium compounds, mixtures of REO, and mixtures of rare-earth chlorides) 3.7% ad valorem, 25% ad valorem; HS 3606.90.3000 ferrocerium and other pyrophoric alloys, 5.9% ad valorem, 56.7% ad valorem; HS 7202.99.5040 ferroalloys, other (including rare-earth silicide), 5.0% ad valorem, 25% ad valorem; and HS 7601.20.9090 aluminum alloys, other (including scandium-aluminum alloys), Free, 10.5% ad valorem.

Special rare-earth tariffs for Canada and Mexico were the result of Presidential Proclamation 6641, implementing the North American Free Trade Agreement, effective January 1, 1994. Under the agreement, tariff rates for most rare-earth products from Canada and Mexico were granted "Free" status and those that were scheduled for staged reductions have achieved "Free" status. Tariff rates for most other foreign countries were negotiated under the Generalized Agreement on Tariffs and Trade Uruguay Round of Multilateral Trade Negotiation.

Stocks

All U.S. Government stocks of rare earths in the National Defense Stockpile (NDS), were shipped in 1998. Periodic assessments of the national defense material requirements may necessitate the inclusion of rare earths in the NDS at a future date.

Prices

Rare-earth prices were essentially unchanged in 1999. The following prices were estimated by the author based on the basis of trade data from various sources. All rare-earth prices remained nominal and subject to change without notice. The competitive pricing policies in effect in the industry caused most rare-earth products to be quoted on a daily basis. The average price of imported rare-earth chloride was $2.09 per kilogram in 1999, a decrease from $2.43 per kilogram in 1998. In 1999, imported rare-earth metal prices averaged $12.44 per kilogram, a decrease from $17.64 per kilogram in 1998. Mischmetal and specialty mischmetals comprised most rare-earth metal imports. (Mischmetal is a natural mixture of rare-earth metals typically produced by metallothermic reduction of a mixed rare-earth chloride.) The price range of mischmetal was $5.00 to $7.00 per kilogram (in metric ton quantities) at yearend 1999, a decrease from the $6.00 to $8.00 per kilogram in 1998 (Elements—Rare Earths, Specialty Metals and Applied Technology, 1999). The average annual price for imported cerium compounds, excluding cerium chloride, increased to $4.43 per kilogram from $3.10 per kilogram in 1998. The primary cerium compound imported was cerium carbonate.

The estimated market price for bastnasite concentrate was $3.91 per kilogram. The price of monazite concentrate, typically sold with a minimum 55% rare-earth oxide, including thorium oxide content, free-on-board (f.o.b.) as quoted in U.S. dollars and based on the last U.S. import data, was unchanged at $400.00 per metric ton. In 1999, no monazite was imported into the United States. Prices for monazite remained depressed because several principal international rare-earth processors continued to process only thorium-free feed materials.

The nominal price for basic neodymium-iron-boron alloy, calculated by the author from data supplied by several U.S. producers, was $13.23 per kilogram ($6.00 per pound), f.o.b. shipping point, 1,000-pound minimum. Most alloy was sold with additions of cobalt (up to 15%, typically 4% to 6%) or dysprosium (up to 3%). The cost of the additions was based on pricing before shipping and alloying fees; with the average cobalt price decreasing to $37.52 per kilogram ($17.02 per pound) in 1999, the cost would be about $0.38 for each percent addition per kilogram ($0.17 for each percent addition per pound).

Rhodia quoted rare-earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, in effect at yearend 1999, as listed in table 3.

No published prices for scandium oxide in kilogram quantities were available. Yearend 1999 nominal prices for scandium oxide per kilogram were compiled by the author from information provided by several domestic suppliers and processors. Prices decreased from those of the previous year for most grades and were listed as follows: 99% purity, $900; 99.9% purity, $1,400; 99.99% purity, $2,100; and 99.999% purity, $4,000.

Scandium metal prices for 1999 were slightly higher from those of 1998, except for powder, which was significantly lower (Alfa Aesar, 1999)—99.99% REO purity, lump, sublimed dendritic, ampouled under argon, $175 per gram; 99.9% REO purity, less than 250-micron powder, ampouled under argon, $395 per 2 grams; and 99.9% purity, lump, sublimed dendritic, ampouled under argon, $267 per 2 grams; 99.9% REO purity, foil, 0.025-millimeter thick, ampouled under argon, 25 millimeters by 25 millimeters, $98.80 per item.

Scandium compound prices as listed by Aldrich Chemical Co. (Aldrich Chemical Co., 1998, p. 1478-1479) were as follows: scandium acetate hydrate 99.9% purity, $57.45 per gram; scandium chloride hydrate 99.99% purity, $62.00 per gram; scandium nitrate hydrate 99.9% purity, $59.30 per gram; and scandium sulfate pentahydrate 99.9% purity, $60.05 per gram. Prices for standard solutions for calibrating analytical equipment were $22.70 per 100 milliliters of scandium atomic absorption standard solution and $338.15 per 100 milliliters of scandium plasma standard solution.

Prices for kilogram quantities of scandium metal in ingot form have historically averaged about twice the cost of the oxide, and higher purity distilled scandium metal have averaged about five times the cost.

Foreign Trade

U.S. exports of rare earths were essentially unchanged as imports increased significantly in 1999. U.S. exports totaled 9,645 tons valued at $53 million, about the same quantity and a 24% decrease in value compared with those of 1998 (table 4). Imports totaled 27, 507 tons gross weight valued at $144 million, a 41% increase in quantity and a 4% increase in value compared with those of 1998 (table 5).

In 1999, U.S. exports of rare earths were mixed with cerium compounds, and ferrocerium and pyrophoric alloys decreasing, and exports of rare-earth compounds and rare-earth metals increasing. The United States exported 1,340,000 kilograms of rare-earth metals, a 121% increase compared with that of 1998, valued at more than $5 million. Principal destinations, in descending order of quantity, were Japan, France, the Republic of Korea, and Germany. Exports of cerium compounds, primarily for glass polishing and automotive catalytic converters, decreased by 15%, to 3,960,000 kilograms valued at $18.4 million. Major destinations, in descending order of quantity, were the Republic of Korea, Germany, the United Kingdom, and Malaysia.

Exports of inorganic and organic rare-earth compounds increased to 1,690,000 kilograms in 1999 from 1,630,000 kilograms in 1998, and the value of the shipments increased by almost 18% to $19.6 million. Shipments, in descending order of quantity, were to China, Taiwan, Canada, and India.

U.S. exports of ferrocerium and other pyrophoric alloys decreased to 2,660,000 kilograms valued at $10.7 million from 2,760,000 kilograms valued at $10.6 million in 1998. Principal destinations, in descending order of quantity, were Canada, the United Arab Emirates, Japan, and Hong Kong.

In 1999, U.S. imports of compounds and alloys increased for five out of seven categories, as listed in table 5. China and France dominated the import market, especially for mixed and individual rare-earth compounds.

Imports of cerium compounds totaled 5,970,000 kilograms valued at $26.5 million. After an increase in imports in 1998, the quantity of cerium compounds imported decreased by 19%, the result of decreased demand for automotive exhaust catalysts and increased production from the major domestic producer. China was the major supplier for the fifth year in a row, followed by France.

Imports of yttrium compounds containing between 19 and 85 weight-percent oxide equivalent (yttrium concentrate) increased by 149% in 1999. China was the leading supplier of yttrium compounds, followed by France, Japan, and the United Kingdom.

Imports of individual rare-earth compounds, traditionally the major share of rare-earth imports, increased by 109% compared with those of 1998. Rare-earth compound imports increased to 10,300,000 kilograms valued at $71.6 million. The major sources of individual rare-earth compounds were China, France, and Japan. Imports of mixtures of rare-earth oxides, other than cerium oxide, increased by almost 136% to 5,980,000 kilograms valued at $15.5 million. The principal source of the mixed rare-earth oxides was China, with smaller quantities from Austria and Japan. Imports of rare-earth metals and alloys into the United States totaled 1,480,000 kilograms in 1999, an 87% increase compared with those of 1998, valued at $18.5 million. The principal rare-earth metal sources, in descending order of quantity, were China and Japan. Metal imports increased as demand for mischmetal for steel additives and specialty mischmetals for rechargeable batteries increased.

In 1999, imports of rare-earth chlorides decreased by 9% to 3,330,000 kilograms valued at $6.96 million. Supplies of rare-earth chloride, in descending order of quantity, came from China, followed distantly by India, Japan, and the United Kingdom. Rare-earth chloride was used mainly as feed material for manufacturing fluid cracking catalysts. Imports of ferrocerium and pyrophoric alloys increased by 3.2% to 136,000 kilograms valued at $1.92 million. Principal suppliers, in descending order, were France, Austria, and Brazil.

World Review

China, France, and India were major import sources of rare-earth chlorides, nitrates, and other concentrates and compounds (table 5). Thorium-free intermediate compounds as refinery feed were still in demand because industrial consumers expressed concerns with radioactive thorium's potential liabilities, the costs of complying with environmental monitoring and regulations, and costs at approved waste disposal sites. Demand for rare earths increased in the United States as the rate of economic growth increased. In 1999, estimated world production of rare earths increased slightly to 75,400 tons of REO (table 6). Production of monazite concentrate production was estimated at 7,800 tons (table 7).

World reserves of rare earths were estimated by the USGS to be 100 million metric tons of contained REO in 1999. China, with 43%, had the largest share of those world reserves.

Australia.—Australia remained one of the world's major potential sources of rare-earth elements from its heavy-mineral sands and rare-earth laterite deposits. Monazite is a constituent in essentially all of Australia's heavy-mineral sands deposits. It is normally recovered and separated during processing but was returned to tailings because of a lack of demand. In 1999, major producers of heavy-mineral sands and concentrates were Iluka Resources Limited (formerly RGC Ltd. and Westralian Sands Ltd. (WSL)), Tiwest Joint Venture, Cable Sands Ltd., and Consolidated Rutile Ltd. RGC and WSL merged their heavy-mineral sands operations in December 1998. The newly merged corporation's U.S. operations were renamed Iluka Resources Inc.

Alkane Exploration NL announced the completion of an initial feasibility study of the Dubbo zirconium-bearing deposit in New South Wales by DEMA Pty. Ltd. The multimineral deposit is based on the Toongi alkaline intrusive that contains hafnium, lanthanides, niobium, tantalum, yttrium, and zirconium. Based on a planned 200,000-ton-per-year sulfuric acid leach process, annual capacities at the plant were expected to produce 3,650 tons zirconium oxide and hafnium oxide, 1,130 tons of yttrium-lanthanide concentrate, and 875 tons of tantalum-niobium pentoxide concentrate (Industrial Minerals, 1999a).

Broken Hill Proprietary Company Limited (BHP) lifted its *force majeure* at its Beenup heavy-mineral sands mine in January. BHP's *force majeure* had been in effect since May 1998 when the company experienced problems with the dredge and high slime-content in the tailings (Industrial Minerals, 1999b). By the end of the first quarter, however, production problems could not be resolved and the Beenup operation was closed (Industrial Minerals, 1999c).

The Mount Weld deposit in Western Australia, which was discovered in 1968, has been under recent review for its rare earth, phosphate (fertilizer), and tantalum potential. New process technologies developed by the Commonwealth Scientific and Industrial Research Organisation, commonly known as CSIRO, have improved the prospects for its future development (Industrial Minerals, 1999e). Mount Weld is a world-class rare-earth deposit that has been explored extensively. Its large reserves of light rare-earth elements, especially cerium, represent a significant potential as an alternative source of rare earths.

China.—The Government of China announced it has stopped issuing new permits for rare-earth mining. The decision is reportedly the result of an oversupply of rare earths that has created low prices. China produced most of the world's supply of rare earths in 1999. The ban also includes limits on foreign investment in rare-earth processing plants and metallurgical operations (Industrial Minerals, 1999d). Foreign ownership of Chinese rare-earth mines was not allowed prior to these new restrictions.

Outlook

Global use of rare earths, especially in automotive pollution catalysts, permanent magnets, and rechargeable batteries, is expected to continue to increase in the future as demand for automobiles, electronics, computers, and portable equipment grows. Rare-earth markets are expected to require greater amounts of higher purity mixed and separated products. Strong demand is expected to continue into the next decade for cerium and neodymium for use in automotive catalytic converters and permanent magnets. Future growth is forecast for rare earths in magnetic refrigeration, rechargeable nickel hydride batteries, fiber optics, and medical applications, including magnetic resonance imaging (MRI) contrast agents and dental and surgical lasers.

World reserves are sufficient to meet forecast world demand well into the 21st century. Several world class rare-earth deposits in Australia and China have yet to be developed because world demand is currently (1999) being satisfied by existing production (Singer, 1995). World resources should be adequate to fulfill demand for the foreseeable future.

Domestic companies have shifted away from using naturally occurring radioactive rare-earth ores. This trend has had a negative impact on monazite-producing mineral sands operations worldwide. Future long-term demand for monazite, however, is expected to increase because of its abundant supply and recovery as a low-cost byproduct. The cost and space to dispose of radioactive waste products in the United States are expected to continue to increase, severely limiting domestic use of low-cost monazite and other thorium-bearing rare-earth ores. World markets are expected to continue to be very competitive based on lower wages and fewer environmental and permitting requirements. China is expected to remain the world's principal rare-earth supplier. Economic growth in several developing countries will provide new and potentially large markets in Southeast Asia and Eastern Europe.

The long-term outlook is for an increasingly competitive and diverse group of rare-earth suppliers. As research and technology continue to advance the knowledge of rare earths and their interactions with other elements, the economic base of the rare-earth industry is expected to continue to grow. New applications are expected to continue to be discovered and developed.

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

TABLE 1
SALIENT U.S. RARE EARTH STATISTICS 1/

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

	1995	1996	1997	1998	1999
Production of rare-earth concentrates 2/	22,200	20,400	10,000 e/	5,000 e/	5,000 e/
Exports:					
Cerium compounds	5,120	6,100	5,890	4,640	3,960
Rare-earth metals, scandium, yttrium	444	250	991	724	1,600
Ores and concentrates	--	2	--	--	--
Rare-earth compounds, organic or inorganic	1,550	2,210	1,660	1,630	1,710
Ferrocerium and pyrophoric alloys	3,470	4,410	3,830	2,460	2,360
Imports for consumption: e/					
Monazite	22	56	11	--	--
Cerium compounds	--	3,180	1,820	4,940	3,990
Ferrocerium and pyrophoric alloys	78	107	121	117	120
Metals, alloys, oxides, other compounds	14,100	14,000	10,000	8,950	17,200
Stocks, producers and processors, yearend	NA	NA	NA	NA	NA
Consumption, apparent	NA	NA	NA	NA	NA
Prices, yearend, per kilogram:					
Bastnasite concentrate, REO basis	$2.87	$2.87	$2.87 e/	$2.87 e/	$2.87 e/
Monazite concentrate, REO basis	$0.44	$0.48	$0.73	$0.73	$0.73 e/
Mischmetal, metal basis	$9.50	$8.75 3/	$8.45 3/	$16.00 3/	$16.00 3/
Employment, mine and mill	NA	NA	NA	NA	NA
Net import reliance as a percentage of apparent consumption 4/	(5/)	(5/)	(5/)	(5/)	(5/)

e/ Estimated. NA Not available. -- Zero.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Comprises only the rare earths derived from bastnasite as obtained from Molycorp, Inc., company representative.

3/ Source: Elements--Rare Earths, Specialty Metals and Applied Technology, TradeTech, Denver, CO.

4/ Imports minus exports plus adjustments for Government and industry stock changes.

5/ Net importer.

TABLE 2

RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS 1/

(Percent of total rare-earth oxide)

Rare earth	Bastnasite, Mountain Pass, CA, USA 2/	Bastnasite, Bayan Obo, Inner Mongolia, China 3/	Monazite, North Capel, Western Australia 4/	Monazite, North Stradbroke Island, Queensland, Australia 5/	Monazite, Green Cove Springs, FL, USA 6/	Monazite, Nangang, Guangdong, China 7/
Yttrium	0.10	trace	2.40	2.50	3.20	2.40
Lanthanum	33.20	23.00	23.90	21.50	17.50	23.00
Cerium	49.10	50.00	46.00	45.80	43.70	42.70
Praseodymium	4.34	6.20	5.00	5.30	5.00	4.10
Neodymium	12.00	18.50	17.40	18.60	17.50	17.00
Samarium	.8000	.8000	2.53	3.10	4.90	3.00
Europium	.1000	.2000	.0530	.8000	.1600	.1000
Gadolinium	.2000	.7000	1.49	1.80	6.60	2.00
Terbium	trace	.1000	.0350	.3000	2600	.7000
Dysprosium	trace	.1000	.7000	.6000	.9000	.8000
Holmium	trace	trace	.0530	.1000	.1100	.1200
Erbium	trace	trace	.2000	.2000	trace	.3000
Thulium	trace	trace	trace	trace	trace	trace
Ytterbium	trace	trace	.1000	.1000	.2100	2.40
Lutetium	trace	trace	trace	.0100	trace	.1400
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000

Rare earth	Monazite, East coast, Brazil 8/	Monazite, Mount Weild, Australia 9/	Xenotime, Lahat, Perak, Malaysia 2/	Xenotime, southeast, Guangdong, China 10/	Rare earth laterite Xunwu, Jiangxi Province, China 11/	Rare earth laterite Longnan, Jiangxi Province, China 11/
Yttrium	1.40	trace	61.00	59.30	8.00	65.00
Lanthanum	24.00	26.00	1.24	1.20	43.40	1.82
Cerium	47.00	51.00	3.13	3.00	2.40	.4000
Praseodymium	4.50	4.00	.5000	.6000	9.00	.7000
Neodymium	18.50	15.00	1.60	3.50	31.70	3.00
Samarium	3.00	1.80	1.10	2.20	3.90	2.80
Europium	.1000	.4000	trace	.2000	.5000	0.10
Gadolinium	1.00	1.00	3.50	5.00	3.00	6.90
Terbium	.1000	.1000	.9000	1.20	trace	1.30
Dysprosium	.4000	.2000	8.30	9.10	trace	6.70
Holmium	trace	.1000	2.00	2.60	trace	1.60
Erbium	.1000	.2000	6.40	5.60	trace	4.90
Thulium	trace	trace	1.10	1.30	trace	.7000
Ytterbium	.0200	.1000	6.80	6.00	.3000	2.50
Lutetium	not determined	trace	1.00	1.80	.1000	.4000
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000

1/ Data are rounded to no more than three significant digits: may not add to totals shown.

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5/ Analysis from Consolidated Rutile Ltd.

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TABLE 3
RHODIA RARE EARTH OXIDE PRICES IN 1999

Product (oxide)	Percentage purity	Standard package quantity (kilograms)	Price per kilogram
Cerium	95.00	25	$19.00
Cerium	99.50	25	23.00
Dysprosium	95.00	20	65.00
Erbium	96.00	20	150.00
Europium	99.99	10	700.00
Gadolinium	99.99	50	115.00
Holmium	99.90	10	485.00
Lanthanum	99.99	25	23.00
Lutetium	99.99	2	4,500.00
Neodymium	95.00	20	22.00
Praseodymium	96.00	20	32.00
Samarium	96.00	25	75.00
Terbium	99.90	5	685.00
Thulium	99.90	5	3,600.00
Ytterbium	99.00	10	230.00
Yttrium	99.99	50	85.00

TABLE 4
U.S. EXPORTS OF RARE EARTHS, BY COUNTRY 1/

	1998		1999	
Category and country 2/	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Cerium compounds: (2846.10.0000)				
Australia	13,300	$123,000	8,060	$42,200
Belgium	73,400	413,000	111,000	1,540,000
Brazil	92,000	565,000	51,900	486,000
Canada	179,000	1,580,000	96,200	684,000
France	150,000	925,000	135,000	807,000
Germany	747,000	14,600,000	828,000	1,870,000
Hong Kong	57,100	430,000	31,000	193,000
India	5,740	178,000	5,190	38,900
Japan	326,000	3,770,000	150,000	1,320,000
Korea, Republic of	1,250,000	5,520,000	1,230,000	5,340,000
Malaysia	280,000	1,750,000	320,000	1,710,000
Mexico	160,000	1,600,000	75,700	548,000
Netherlands	147,000	443,000	38,600	231,000
Singapore	18,800	19,000	24,800	85,200
South Africa	103,000	3,520,000	43,800	579,000
Taiwan	205,000	1,030,000	237,000	1,060,000
United Kingdom	595,000	2,120,000	480,000	1,170,000
Other	234,000	1,040,000	93,800	650,000
Total	4,640,000	39,600,000	3,960,000	18,400,000
Total estimated equivalent REO content.	4,640,000	39,600,000	3,960,000	18,400,000

See footnotes at end of table.

TABLE 4--Continued
U.S. EXPORTS OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1998 Gross weight (kilograms)	1998 Value	1999 Gross weight (kilograms)	1999 Value
Rare-earth compounds: (2846.90.0000)				
Austria	17,800	$435,000	16,700	$566,000
Brazil	6,060	89,000	78,400	168,000
Canada	216,000	2,340,000	151,000	1,860,000
China	181,000	726,000	515,000	1,040,000
Colombia	232,000	125,000	18,600	44,600
Finland	9,200	371,000	73,100	2,120,000
France	94,300	314,000	365	57,900
Germany	77,200	642,000	11,300	578,000
India	60,900	452,000	152,000	652,000
Japan	406,000	6,170,000	73,400	2,730,000
Korea, Republic of	48,500	400,000	150,000	974,000
Mexico	37,900	321,000	8,160	95,500
Taiwan	109,000	2,610,000	192,000	4,900,000
United Kingdom	58,600	327,000	20,100	1,140,000
Other	71,500	1,320,000	233,000	2,700,000
Total	1,630,000	16,600,000	1,690,000	19,600,000
Total estimated equivalent REO content.	1,630,000	16,600,000	1,690,000	19,600,000
Rare-earth metals, including scandium and yttrium: (2805.30.0000)				
China	21,400	519,000	6,450	530,000
France	122	25,900	563,000	1,120,000
Germany	4,030	61,200	6,710	177,000
Japan	514,000	1,340,000	657,000	1,720,000
Korea, Republic of	3,510	179,000	9,450	276,000
Taiwan	5,670	261,000	2,160	39,400
United Kingdom	7,550	476,000	2,170	212,000
Other	47,300	893,000	89,400	1,200,000
Total	603,000	3,750,000	1,340,000	5,280,000
Total estimated equivalent REO content.	724,000	4,500,000	1,600,000	6,340,000
Ferrocerium and other pyrophoric alloys: (3606.90.0000)				
Argentina	34,900	186,000	42,100	72,900
Australia	34,600	385,000	3,260	24,300
Brazil	2,640	39,100	21,200	76,100
Canada	950,000	1,760,000	1,060,000	1,810,000
Chile	29,600	68,700	13,900	27,700
Colombia	23,500	109,000	3,020	11,700
Costa Rica	185	6,180	--	--
El Salvador	319,000	1,150,000	--	--
France	53,000	304,000	4,310	164,000
Germany	66,200	705,000	19,400	63,500
Greece	13,300	16,000	28,600	121,000
Hong Kong	105,000	982,000	172,000	449,000
Ireland	2,370	165,000	--	--
Italy	16,400	150,000	998	128,000
Japan	133,000	1,280,000	175,000	1,570,000
Korea, Republic of	5,980	67,200	10,100	7,380
Kuwait	64,100	136,000	37,800	51,500
Mexico	60,200	215,000	27,300	401,000
Netherlands	72,300	479,000	87,500	511,000
New Zealand	53,800	120,000	24,900	53,900
Saudi Arabia	188,000	334,000	136,000	2,910,000
Singapore	108,000	226,000	41,200	133,000
South Africa	28,200	69,800	16,100	28,300
Spain	19,500	42,200	457	11,000
Taiwan	3,420	83,200	132,000	221,000
United Arab Emirates	85,700	115,000	283,000	431,000
United Kingdom	16,100	291,000	37,000	225,000
Other	275,000	1,090,000	285,000	1,190,000
Total	2,760,000	10,600,000	2,660,000	10,700,000
Total estimated equivalent REO content.	2,460,000	9,390,000	2,360,000	9,490,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ U.S. and International Trade Commission of harmonized code tariff category number.

Source: U.S. Census Bureau.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1998 Gross weight (kilograms)	1998 Value	1999 Gross weight (kilograms)	1999 Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, oxalates: (2846.10.0000)				
Austria	31,400	$358,000	36,700	$396,000
China	7,000,000	16,100,000	3,570,000	13,400,000
France	287,000	4,850,000	2,160,000	7,640,000
Japan	43,700	1,270,000	188,000	4,360,000
Other	19,000	259,000	22,000	373,000
Total	7,380,000	22,800,000	5,970,000	26,200,000
Total estimated equivalent REO content	4,940,000	15,300,000	3,990,000	17,500,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent: (2846.90.4000)				
China	75,300	1,580,000	231,000	2,640,000
France	4,960	272,000	36,000	505,000
Germany	2,730	48,700	--	--
Hong Kong	17,000	232,000	--	--
Japan	7,150	133,000	612	50,800
United Kingdom	42	178,000	1	4,010
Other	81	16,500	--	--
Total	107,000	2,460,000	268,000	3,200,000
Total estimated equivalent REO content	64,400	1,480,000	161,000	1,980,000
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides: (2846.90.8000)				
Austria	7,690	309,000	27,500	928,000
China	3,160,000	20,100,000	7,000,000	19,500,000
Estonia	48,900	80,400	16,000	21,900
France	1,150,000	15,200,000	2,720,000	13,800,000
Germany	19,900	321,000	1,100	242,000
Hong Kong	17,000	247,000	1,000	10,700
Hungary	18,400	217,000	--	--
Japan	401,000	13,100,000	468,000	10,900,000
Malaysia	2,210	252,000	5,040	569,000
Norway	11,400	11,700,000	35,600	18,500,000
Russia	3,020	189,000	101	90,600
Taiwan	34,100	543,000	19,000	152,000
United Kingdom	53,500	6,730,000	53,300	6,720,000
Other	35,600	122,000	1,220	136,000
Total	4,960,000	69,100,000	10,300,000	71,600,000
Total estimated equivalent REO content	3,720,000	51,800,000	7,760,000	53,700,000
Mixtures of rare-earth oxides except cerium oxide: (2846.90.2010)				
Austria	19,100	1,140,000	29,400	1,800,000
China	2,370,000	9,080,000	5,910,000	9,690,000
France	18,200	769,000	1,920	31,400
Germany	10,200	2,080,000	4,350	280,000
Japan	37,800	5,510,000	21,300	3,610,000
Russia	--	--	21	6,480
Thailand	58,300	180,000	--	--
United Kingdom	350	5,420	3,540	73,800
Other	15,000	202,000	1,230	46,400
Total	2,530,000	19,000,000	5,980,000	15,500,000
Total estimated equivalent REO content	2,530,000	19,000,000	5,980,000	15,500,000

See footnotes at end of table.

TABLE 5 --Continued

U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1998 Gross weight (kilograms)	1998 Value	1999 Gross weight (kilograms)	1999 Value
Rare-earth metals, whether intermixed or alloyed: (2805.30.0000)				
China	344,000	$4,530,000	963,000	$9,090,000
Hong Kong	73	3,370	30,100	541,000
Japan	439,000	9,030,000	439,000	7,840,000
Russia	2,490	195,000	872	203,000
United Kingdom	6,580	136,000	26,800	442,000
Other	2,320	136,000	25,500	357,000
Total	794,000	14,000,000	1,480,000	18,500,000
Total estimated equivalent REO content	953,000	16,800,000	178,000	22,200,000
Mixtures of rare-earth chlorides, except cerium chloride: (2846.90.2050)				
China	3,050,000	5,470,000	3,150,000	3,950,000
France	14,500	774,000	114	5,980
India	479,000	602,000	81,900	106,000
Japan	38,600	1,180,000	79,700	2,730,000
Taiwan	20,100	318,000	--	--
United Kingdom	42,100	264,000	12,100	65,000
Other	6,120	251,000	3,410	94,000
Total	3,650,000	8,860,000	3,330,000	6,960,000
Total estimated equivalent REO content	1,680,000	4,080,000	1,530,000	3,200,000
Ferrocerium and other pyrophoric alloys: (3606.90.3000)				
Austria	6,670	154,000	9,020	207,000
Brazil	4,500	86,500	3,000	56,100
France	111,000	1,500,000	120,000	1,580,000
Other	8,850	138,000	3,780	78,100
Total	131,000	1,870,000	136,000	1,920,000
Total estimated equivalent REO content	117,000	1,660,000	120,000	1,710,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ U.S. and International Trade Commission of harmonized code tariff category number.

Source: U.S. Census Bureau.

TABLE 6

RARE EARTHS: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of rare earth oxide equivalent)

Country 3/	1995	1996	1997	1998	1999 e/
Australia e/	110	--	--	--	--
Brazil	103	--	--	--	--
China e/	48,000	55,000	53,000	60,000	70,000
India e/	2,700	2,700	2,700	2,700	2,700
Malaysia	448	340	418 r/	350 e/	625 4/
Sri Lanka e/	120	120	120	120	120
Thailand	--	--	12	--	--
U.S.S.R. e/ 5/	2,000	2,000	2,000	2,000	2,000
United States 6/	22,200	20,400	10,000 e/	5,000 e/	5,000
Total	75,700	80,600	68,300 r/	70,200	80,400

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 16, 2000.

3/ In adddition to the countries listed, rare-earth minerals are believed to be produced in Indonesia, Mozambique, North Korea, and Vietnam, but information is inadequate to formulate reliable estimates.

4/ Reported figure.

5/ Dissolved in December 1991; information, however, is inadequate to formulate reliable estimates of rare-earths mine production for Kazakhstan, Kyrgyzstan, Russia, Ukraine, and Uzbekistan.

6/ Comprises only the rare earths derived from bastnasite as reported from company sources.

TABLE 7

MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1995	1996	1997	1998	1999
Australia e/	200	--	--	--	--
Brazil e/	1,400	1,400	1,400	1,400	1,400
India e/	5,000	5,000	5,000	5,000	5,000
Malaysia	822	618	767 r/	700 r/	1,200 e/
Sri Lanka e/	200	200	200	200	200
Thailand	--	--	12	-- e/	--
Total	7,620	7,220	7,380	7,300	7,800

e/ Estimated. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 20, 2000.

3/ In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and the former U.S.S.R. may produce monazite;