RARE EARTHS

Extraction Preparation and Applications

Edited by R.G. Bautista and M.M. Wong

TG146.4-53
R221
1989

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Proceedings of a symposium on Rare Earths, Extraction, Preparation and Applications sponsored by the TMS Reactive Metals Committee, held at the TMS Annual Meeting in Las Vegas, Nevada, February 27-March 2, 1989.

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昆明理工大学
图书馆藏书

A Publication of
TMS
Minerals • Metals • Materials

E9063561

A Publication of The Minerals, Metals & Materials Society
420 Commonwealth Drive
Warrendale, Pennsylvania 15086
(412) 776-9024

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Printed in the United States of America
Library of Congress Catalog Number 88-42986
ISBN Number 0-87339-047-4

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PREFACE

In years past, research papers on various aspects of rare earths and related elements have always been included in the technical sessions of the TMS Annual Meetings. Current intense interest in the use of rare earths and related elements for new materials gives renewed impetus to all phases of rare-earth research, from supply of materials to finished products. Therefore, a symposium devoted exclusively to rare earths and related elements has been organized by the Reactive Metals Committee and will be held during the TMS Annual Meeting in Las Vegas, Nevada, February 27-March 1, 1989.

The symposium includes papers covering research and developments in mineral processing; extraction; reaction chemistry; high-purity separation; preparation of metals and alloys; physical properties of alloy; applications in superconductors, magnets, catalysts, phosphors, etc.; and economics and marketing. The international nature of the interest is demonstrated by the contribution of papers from six countries.

The editors are grateful to all authors whose papers provided the substance for this symposium, to the session chairmen and the Reactive Metals Committee members for their valuable support and to the TMS staff, who made this symposium volume a reality. Our thanks are also extended to Jane Pilotte, University of Nevada-Reno, and to Sharon Savord, Unocal, for their extensive secretarial assistance.

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October 1, 1988

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NONCOMMUNIST WORLD MARKETS FOR

RARE EARTH MINERALS

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Introduction

Rare earths markets by definition usually include not only the rare earth elements, but also yttrium. They can be subdivided into a very large light rare earth fraction (about 95 percent by weight of all rare earths consumed), consisting mainly of cerium and lanthanum and a smaller fraction (with much higher unit value) consisting of selected high-purity oxides or elements such as yttrium, europium, samarium, or neodymium.

CRA estimates that the noncommunist world market for all rare earths and yttrium was on the order of US$750 million in 1986.

The main focus of this paper is on the principal uses for rare earths, some CRA-developed proprietary data on their consumption by region, and the selective nature of business opportunities in the rare earth markets. We also provide forecasts on the future trends in these markets.

Consumption of Rare Earths: Publicly Available Data

Published historical data on consumption are limited and often either incorrect or not very useful.

As an example, Table I gives the U.S. Bureau of Mines data for 1979 through 1986, segmented according to four broad use categories. As shown, the broad categories of end uses for these data make it difficult to understand clearly the underlying uses and the nature of the forces driving these markets.

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The Minerals, Metals & Materials Society, 1988

Table I. HISTORICAL DATA ON RARE EARTHS CONSUMPTION (Tonnes Oxide)

U.S. Market Segment	1979	1980	1981	1982	1983	1984E	1985	1986
Petroleum Catalysts	6,900	9,013	9,100	9,400	12,740	14,087	5,900	4,400
Metallurgical	5,700	7,446	7,200	5,100	3,920	4,334	4,000	3,650
Glass/Ceramics	2,300	3,004	4,400	2,200	2,352	2,601	2,300	3,400
Electronic/Magnetic	500	653	400	400	342	378	500	350
Total United States	16,000	18,900	20,100	17,100	19,354	21,400	12,700	11,800

SOURCE: Charles River Associates, 1988, based on U.S. Bureau of Mines Minerals Yearbook, various years.

Some excellent comprehensive reviews on rare earths have been published. See, for instance, "Rare Earths Industry Profile and Market Review," Industrial Minerals March 1979 and "Rare Earths -- Attracting Increasing Attention," Industrial Minerals April 1984. Reviews of selected market segments are also available in the literature, for instance, Sauvion, G.N. and Ducros, P., "Catalysts: A Growing Market for Rare Earths," Journal of the Less Common Metals 111, p. 23-25, 1985.

The information reported in these and other publications as well as in proprietary reports is, in general, fragmentary. Therefore, Charles River Associates undertook the major task of establishing a detailed proprietary database of the rare earth consumption patterns in world markets.

Consumption of Rare Earths, 1986: CRA Proprietary Database

Noncommunist world consumption of

- Yttrium,
- Europium,
- Neodymium,
- Samarium,
- Gadolinium, and
- Light Rare Earths

segmented into

- The United States,
- Japan,
- Western Europe, and
- The rest of the noncommunist world (RONCW)

for 1986, is summarized in Table II. As shown in Table II:

- Estimated consumption of light rare earths (about 21,200 tonnes) accounts for 93 percent of all consumption of rare earth oxides (about 22,600 tonnes).

- The next largest consumption is that of yttrium, samarium, and neodymium.

- The United States accounts for about 45 percent of the total consumption of combined rare earths, Western Europe for 27 percent, Japan for 20 percent, and the rest of the noncommunist world for 8 percent.

- Estimated consumption of light rare earths in the United States, Western Europe, and the rest of the noncommunist world is well over 90 percent of the total consumption of all combined rare earths; however, in Japan, light rare earths account for around 81 percent of total combined rare earths consumption.

- Japan accounts for major portions of the consumption of heavy rare earths, at about 55 percent of yttrium, 65 percent of europium, 73 percent of samarium, and 65 percent of gadolinium.

- The United States and Japan are roughly equal consumers of neodymium.

Table II. CRA ESTIMATED DEMAND FOR RARE EARTHS BY TYPE AND GEOGRAPHICAL REGION: 1986 (Tonnes of Oxide Equivalent)

Element	United States	Japan	Western Europe	RONCW	NCW
Yttrium	109	238	68	17	432
Europium	6	29	9	1	44
Neodymium	201	193	10	0	404
Samarium	88	346	37	5	476
Gadolinium	15	46	10	0	71
Light Rare Earths	9,661	3,781	6,006	1,799	21,247
Total	10,080	4,663	6,139	1,822	22,674

Note: Numbers are rounded and may not add up to totals.

SOURCE: Charles River Associates estimates, 1988.

Details of estimated CRA demand by use are discussed later. Because Table II was constructed by trial and error based on many sources of fragmented information, the **error margin** in our estimates is large. We believe that our estimates for consumption of light rare earths are likely to be within the 20 percent range, and that our estimates for heavy rare earths fall in the 30 percent range. Note also that in general, for consumption estimates of light rare earths as shown, the total across the noncommunist world is likely to be more reliable than the breakdown by region.

In order to understand the size of these markets, we have shown, in Table III, the dollar values for each of these rare earth oxide markets. As shown:

- The noncommunist world market for all rare earths (oxides and metals) is approximately $760 million.

- Even though the U.S. market for all combined rare earths is the largest in terms of quantity (as discussed before), **the Japanese market is the largest by our estimates in terms of dollar size,** at around $346 million, followed by the U.S. market, at about

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$235 million. The reason is that higher-value heavy rare earths consumption is greater in Japan and the United States than elsewhere.

- Samarium and europium are the two most important heavy rare earths in terms of their dollar market size. Samarium and neodymium market values are based on a portion of the demand being for **metal**, whereas all the other rare earth market sizes are based on oxide values only.

Table III. CRA ESTIMATED MARKET SIZES IN 1986 U.S. DOLLARS BASED ON FORM AND PURITY OF RARE EARTH USED: 1986 (Million 1986 U.S. Dollars)

Element	United States	Japan	Western Europe	RONCW	NCW
Yttrium	12	26	7	2	47
Europium	11	55	16	2	83
Neodymium	19	20	1	0	40
Samarium	35	114	15	2	165
Gadolinium	2	6	1	0	10
Light Rare Earths	157	125	108	23	414
Total	235	345	149	29	759

Note: Numbers are rounded and may not add up to totals.

SOURCE: Charles River Associates estimates, 1988.

The underlying **value** of each of the oxides and metals (in 1986 U.S. dollars per kilogram), in CRA estimates, is as follows:

	Metal	Oxide
Yttrium	110	
Europium	1900	
Neodymium	80	260
Samarium	130	395
Gadolinium	140	
Mixed lights	10	
Cerium	40	
Lanthanum	20	

The detailed segmentation of each rare earth's consumption by end use **and** region is summarized in Tables IV through IX. The actual CRA estimates for consumption by use and region are proprietary data and are not discussed; however, we have shown the approximate consumption in each use and region.

Table IV. CRA ESTIMATED SEGMENTATION OF YTTRIUM CONSUMPTION BY END USE AND REGION: 1986

	United States	Japan	Western Europe	RONCW
Color TV Phosphors	A	B	A	A
Other CRTs	D	C	D	D
Tricolor Lamps	D	C	C	N
X-ray Screens	D	N	N	N
Oxygen Sensors				
Auto	D	D	D	D
Nonauto	D	D	N	N
Other Ceramics				
Sialon	D	D	D	N
Zirconia	N	C	N	N
Lasers	D	D	N	N
High-temperature Coatings				
MCrAlY	D	N	N	N
ODS	N	N	N	N
Thermal Barriers	N	N	N	N
Superconductors	D	D	D	D

Note: A: 60 percent or more of total consumption in a region
B: 30 percent to 59 percent of total consumption in a region
C: 10 percent to 29 percent of total consumption in a region
D: less than 10 percent of total consumption in a region
N: no significant demand

SOURCE: Charles River Associates estimates, 1988.

Table V. CRA ESTIMATED SEGMENTATION OF EUROPIUM CONSUMPTION BY END USE AND REGION: 1986

	United States	Japan	Western Europe	RONCW
Color TV Phosphors	A	C	B	A
Other CRTs	D	C	D	D
Tricolor Lamps	B	A	A	N

Note: A: 60 percent or more of total consumption in a region
B: 30 percent to 59 percent of total consumption in a region
C: 10 percent to 29 percent of total consumption in a region
D: less than 10 percent of total consumption in a region
N: no significant demand

SOURCE: Charles River Associates estimates, 1988.

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