RHENIUM

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In the past decade, the two most important uses of rhenium have been in platinum-rhenium catalysts and high-temperature superalloys. Platinum-rhenium catalysts are used to produce lead-free, high-octane gasoline. Superalloys are used for turbine engine components. Other applications of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, are more diverse; these included thermocouples, heating elements, temperature controls, flashbulbs, vacuum tubes, x-ray tubes and targets, metallic coatings, and electrical contact points. Research by industry continued on the recovery of rhenium from ore and concentrate and the development of new catalysts and alloys.

In the United States, rhenium is a byproduct of molybdenite recovered as a byproduct of porphyry copper ore from five operating porphyry copper-molybdenum-rhenium mines in the Western States. Domestic mine production data for rhenium (table 1) were derived by the U.S. Geological Survey from reported molybdenum production at the mines. Domestic demand for rhenium metal and other rhenium products was met principally by imports, but also from domestic recovery and stocks.

Compared with that of 2000, 2001 rhenium consumption increased by about 1.5%; imports of metal for consumption increased by 88.7% and imports of ammonium perrhenate decreased by 38.8% (table 1). The average values for metal powder and ammonium perrhenate were $906 and $789 per kilogram, respectively.

Consumption

Rhenium is used in petroleum-reforming catalysts for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Bimetallic platinum-rhenium catalysts have replaced many of the monometallic catalysts. Rhenium catalysts tolerate greater amounts of carbon formation in making gasoline and make it possible to operate the production process at lower pressures and higher temperatures, which leads to improved yields (production per unit of catalyst used) and higher octane ratings. In 2001, catalytic uses comprised about 20% of rhenium consumption reported in table 1. Platinum-rhenium catalysts also were used in the production of benzene, toluene, and xylenes, although this use was small compared with that of gasoline production.

A significant property of rhenium is its ability to alloy with molybdenum and tungsten. Molybdenum alloys containing about 50-weight-percent rhenium have greater ductility and can be fabricated by either warm or cold working. Unlike other molybdenum alloys, this type of alloy is ductile at temperatures above 196° C and can be welded. Alloys of tungsten with 24-weight-percent rhenium have improved ductility and have lower ductile-to-brittle transition temperatures than pure tungsten. Rhenium improves the strength properties of nickel alloys at high temperatures (1,000° C). In 2001, metallurgical uses comprised about 75% of rhenium consumption. Other uses for these alloys, which collectively represented only 5% of total consumption, were in thermocouples, temperature controls, heating elements, ionization gauges, mass spectrographs, electron tubes and targets, electrical contacts, metallic coatings, vacuum tubes, crucibles, electromagnets, and semiconductors.

Foreign Trade

Imports for consumption of rhenium metal are listed in tables 1 and 2, and those of ammonium perrhenate are listed in tables 1 and 3. World supply of rhenium in ore was estimated to be 25.5 metric tons (t); the quantity of rhenium recovered is estimated to have been about 22 t, because not all concentrates were processed to recover the rhenium values. Rhenium was recovered from some byproduct molybdenite concentrates from porphyry copper deposits in Canada, Chile, China, Iran, Kazakhstan, Peru, Russia, and the United States. Rhenium metal and compounds were produced in Chile, France, Germany, Russia, the United Kingdom, and the United States.

World Review

World reserves of rhenium are contained primarily in molybdenite in porphyry copper deposits. U.S. reserves of rhenium are concentrated in Arizona, New Mexico, and Utah. Chilean reserves are found primarily at four large porphyry copper mines and in lesser deposits in the northern one-half of the country. In Peru, reserves are concentrated primarily in the Toquepala open pit porphyry copper mine and in about 12 other deposits in the rest of the country.

Other world reserves are in several porphyry copper deposits and sedimentary copper deposits in Armenia, northwestern China, Russia, and Uzbekistan and in sedimentary copper-cobalt deposits in the Congo (Kinshasa).

Technology Development

Rhenium recovery by solvent extraction from the leach liquors resulting from the processing of molybdenum and tungsten ores exceeded 99% (Gerhardt and others, 2001). Researchers found that the solvent tested selectively extracted refractory metals (molybdenum, tungsten, and rhenium), and that co-extraction of other metals was small.

Outlook

In the next 5 years, demand for rhenium metal was expected to follow the demand for turbine engines and petroleum. For the long term (10 to 20 years), recycling of rhenium-bearing waste and scrap was expected to increase. Identified U.S. resources are estimated to be about 7,000 t, and identified rest-of-world resources are estimated to be about 10,000 t.

Reference Cited

Gerhardt, N.I., Palant, A.A., Petrova, V.A., and Tagirov, R.K., 2001, Solvent extraction of molybdenum (VI), tungsten (VI) and rhenium (VII) by diisododecylamine from leach liquors: Hydrometallurgy, v. 60, no. 1, p. 1-5.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Rhenium. Ch. in Mineral Commodity Summaries, annual.
Rhenium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Rhenium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT U.S. RHENIUM STATISTICS 1/

(Gross weight, kilograms)

	1997	1998	1999	2000	2001
Supply 2/	15,400	14,000	12,000	12,400 r/	11,800
Consumption e/	17,900	28,600	32,500	32,000	32,500
Imports (metal)	8,510	14,200	12,800	10,700	20,200
Imports (ammonium perrhenate)	6,560	11,000	2,750	7,450	4,560

e/ Estimated. r/ Revised.

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

2/ Rhenium contained in molybdenite concentrates, based on calculations by the U.S. Geological Survey.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF RHENIUM METAL, BY COUNTRY 1/

	2000		2001	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Austria	23	$24	--	--
Chile	9,850	10,100	16,500	$16,500
Estonia	40	32	43	30
France	--	--	149	77
Germany	300	260	229	204
Kazakhstan	--	--	685	462
Mexico	--	--	1,970	364
Romania	22	13	412	254
Russia	136	83	--	--
Switzerland	36	38	--	--
United Kingdom	291	259	291	426
Total	10,700	10,800	20,200	18,300

-- Zero.

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

Source: U.S. Census Bureau, with adjustments by the U.S. Geological Survey.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY 1/

Country	2000		2001	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Estonia	151	$61	--	--
France	--	--	206	$197
Germany	183	129	399	338
Kazakhstan	6,100	2,970	3,640	2,930
Sweden	--	--	316	144
United Kingdom	1,010	671	--	--
Total	7,450	3,830	4,560	3,600

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

Source: U.S. Census Bureau, with adjustments by the U.S. Geological Survey.

TABLE 4
RHENIUM: ESTIMATED WORLD SUPPLY, BY COUNTRY 1/ 2/

(Kilograms)

Country	1997	1998	1999	2000	2001
Armenia	NA	1,000	700	700	750
Canada	--	2,200	1,600	1,600	1,700
Chile	2,500	2,500	2,400	2,200	2,000
Kazakhstan	1,800	2,400	2,400	2,400	2,500
Peru	2,000	2,300	4,800	4,800	5,000
Russia	NA	900	1,100	1,100	1,200
United States 3/	15,400	14,000	12,000	12,400 r/	11,800
Uzbekistan	NA	NA	NA	NA	NA
Other	5,000	3,200	3,000	3,000	590
Total	26,700	28,500	28,000	28,200 r/	25,500

r/ Revised. NA Not available. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through June 13, 2002.
3/ Calculated rhenium contained in MoS_2 concentrates. Recovered quantities are considerably less and are withheld.