Minor Metals

By Staff, Division of Nonferrous Metals

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ARSENIC [1]

Domestic Production.—Arsenic trioxide was produced in the United States as a byproduct of base-metal ores, primarily copper ore, at the Tacoma, Wash., plant of the American Smelting and Refining Company. Production figures cannot be published. Production in 1972, however, rose substantially over that in 1971 which had been curtailed by the strike at copper facilities. Shipments were less than production and yearend stocks continued the upward trend begun in 1968.

Consumption and Uses.—Apparent consumption of arsenic, essentially all as white arsenic (As_2O_3), decreased slightly from that in 1971. Calcium and lead arsenate chemicals were the major end products. Minor quantities of arsenic were used in sodium arsenate and other chemical compounds.

Production of calcium arsenate has trended downward since 1968 when nearly 1,700 tons was produced. Less than 600 tons was produced in 1969 and in 1970, and only 470 tons was produced in 1971. Lead arsenate, on the other hand, rose to nearly 3,100 tons in 1971 from 2,100 tons in 1970.

Arsenic is primarily used for its toxic qualities in the agricultural industry for insecticides, selective plant killers, defoliants, and for parasitic control in chicken feed; arsenic compounds continued to be used as wood preservatives. Consumption of Wolman Salts, the principal arsenic preservative, totaled 1,085 tons in 1971 compared with 806 tons in 1970.

About 3% of the arsenic consumed is used as metal for alloying with lead and copper. Small quantities of high-purity arsenic are used in the electronics industry.

Prices.—The price of refined white arsenic, 99.5%, at New York docks, in barrels, small lots, has been unchanged at 6-1/4 to 6-3/4 cents per pound since July 6, 1968. Refined white arsenic in bulk carload lots at Laredo, Tex., was $120 per ton, and crude white arsenic was quoted at $94 per ton at Tacoma, Wash. Lead arsenate in 50-pound bags was quoted at 26 to 29 cents per pound throughout 1972.

Arsenic metal was quoted in London at £600 nominal per long ton (64.3 cents per pound) until mid-May when it rose to £650 (69.5 cents). In July the price rose to £690 per metric ton (75.1 cents per pound) where it remained through yearend.

Foreign Trade.—No exports of arsenic metal or white arsenic have been reported since 1945.

Imports of white arsenic declined 21% in 1972 to 13,600 tons, the lowest level since 1960. Sweden, the principal supplier of white arsenic, furnished 60%, followed by Mexico with 26%, and France with 11%.

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[1] Prepared by Gertrude N. Greenspoon, mineral specialist.

Receipts of arsenic metal were 665 tons, 24% more than in 1971. Sweden supplied 659 tons, Canada 5 tons, and Japan 1 ton. Small quantities were received from Belgium-Luxembourg, West Germany, the Netherlands, and the United Kingdom.

Tariff.—Under the General Agreement on Tariffs and Trade (GATT), the duty on arsenic metal was reduced from 1.5 to 1.2 cents per pound, effective January 1, 1972. Arsenic oxide (white arsenic) enters duty free.

Table 1.—U.S. imports for consumption of white arsenic, (As_2O_3) content, by country

Country	1970		1971		1972	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
Belgium-Luxembourg	--	--	25	$9	1	$7
France	2,650	$274	1,425	180	1,556	184
Germany, West	--	--	(1)	(1)	11	4
Mexico	7,750	867	8,316	980	3,552	462
Peru	110	65	68	27	24	27
South Africa, Republic of	111	13	196	23	285	44
Sweden	8,142	870	r 7,276	968	8,184	1,228
Total	18,763	2,089	r 17,306	2,187	13,613	1,956

r Revised.
1 Less than ½ unit.

Table 2.—U.S. imports for consumption of arsenicals, by class
(Thousand pounds and thousand dollars)

Class	1970		1971		1972	
	Quantity	Value	Quantity	Value	Quantity	Value
White arsenic (As_2O_3)	37,525	2,089	r 34,612	2,187	27,226	1,956
Metallic arsenic	912	1,876	1,072	1,260	1,331	1,790
Sulfide	17	5	--	--	2	(1)
Sodium arsenate	186	23	248	35	479	69
Lead arsenate	--	--	4	1	--	--
Arsenic compounds, n.e.c	42	50	1	26	(1)	19

r Revised.
1 Less than ½ unit.

World Review.—*Brazil.*—All white arsenic produced in Brazil is recovered as a byproduct from the treatment of gold ore produced at the Morro Velho mine near Belo Horizonte. The mine is operated by Mineração Morro Velho, S.A. Peak output was attained in 1951 when 1,500 tons was produced. Thereafter, production trended downward to 181 tons in 1972.

France.—Two processing plants, one each in the Aude and Bouches du Rhône Departments, account for all white arsenic produced in France. About half of the output is derived from arsenical pyrite produced in Aude and the remainder comes from the treatment of imported ores.

Sweden.—The Boliden Co. will build a new plant for the production of arsenic metal.[2] The plant located at the company Rönnskär works will have an initial capacity of 1,500 tons annually and is estimated to cost $2 million. A new process developed by Boliden, which will be utilized, is said to be virtually continuous, will provide a good working environment, and will create no pollution. All production units will be equipped with closed ventilation systems. Ventilation air and process gases will be treated in wet scrubbers and the scrub water will be highly purified before disposal.

Technology.—In a study[3] conducted on methods for removing arsenic from gold extraction plant effluents, the chemical precipitation process was considered to be effective and the most attractive from an economic standpoint. Two other methods—ion exchange resins and activated charcoal adsorption, and reverse osmosis—were alternative choices also investigated.

[2] Mining Journal (London). New Process for Arsenic Plant. V. 280, No. 7171, Jan. 26, 1973, p. 73.
[3] Rosehart, R., and J. Lee. Effective Methods of Arsenic Removal From Gold Mine Wastes. Canadian Min. J., v. 93, No. 6, June 1972, pp. 53–57.

Table 3.—White arsenic (arsenic trioxide) [1]: World production, by country

(Short tons)

Country [2]	1970	1971	1972 [p]
Brazil	328	163	181
Canada	71	50	30
France	11,236	[e] 11,000	[e] 11,000
Germany, West	408	40	[e] 550
Japan	974	1,054	471
Mexico	10,075	12,658	6,523
Peru	851	723	1,123
Portugal	209	205	[e] 210
South-West Africa, Territory of [3]	4,478	4,080	[e] 4,400
Spain	19	--	--
Sweden	18,078	[e] 17,600	[e] 17,600
U.S.S.R.[e]	7,880	7,880	7,940
United States	W	W	W
Total	[r] 54,607	55,453	50,028

[e] Estimate. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing individual company confidential data.

[1] Including calculated trioxide equivalent for output reported as elemental arsenic and arsenic compounds other than trioxide.

[2] In addition to the countries listed Argentina, Austria, Belgium, the People's Republic of China, Czechoslovakia, East Germany, Finland, Hungary, Southern Rhodesia, the United Kingdom and Yugoslavia have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to ascertain whether such production has continued, and if so at what levels.

[3] Output of Tsumeb Corp. Ltd. for year ending June 30 of that stated; data given are white arsenic equivalent of reported black arsenic oxide production.

Background data for the study disclosed that the arsenic dissolved in the final plant effluent discharged to the lake constituted only 0.3% of the arsenic contained in the mill feed. Distribution of the remainder of the mine arsenic balance was 14.8% in solids discharged to the lake, 2.6% in mine backfill, 1.8% in roaster flue dust, and 80.5% (by difference) in roaster stack losses.

CESIUM AND RUBIDIUM [4]

Domestic Production.—No cesium or rubidium ores were produced in the United States in 1972. Imported pollucite and *ALKARB,* a residue from past lithium compound production, were the raw material sources for all domestic production of cesium and rubidium products.

The total production of the chemical compounds of cesium declined in 1972 while the production of rubidium compounds increased. Compounds were produced by Cooper Chemical Co., Long Valley, N.J.; Kawecki Berylco Industries, Inc. (KBI), Revere, Pa.; Kerr-McGee Corp., Trona, Calif.; and Rocky Mountain Research, Inc., Golden Colo. No rubidium metal and only a few pounds of cesium metal were produced during the year. KBI and MSA Research Corp., Evans City, Pa., shipped both metals from inventories.

Consumption and Uses.—Statistics on the consumption and uses of cesium and rubidium metal and compounds were not available. The largest use was probably in research and development of new power generating systems, the biological sciences, and other technical fields. Commercial applications for cesium and rubidium included their use in pharmaceuticals, scintillation counters, photomultiplier tubes, photoelectric cells, ultracentrifuges, and ionic propellant engines for space-flight applications. Cesium and rubidium and their compounds can be substituted for each other in some uses.

The development of commercial-scale magnetohydrodynamic (MHD) electric power generators and thermionic converters appeared to offer the greatest potential for large usage of cesium and rubidium. Research on MHD received increased funding both privately and through the Office of Coal Research, U.S. Department of the Interior. If successfully developed, MHD was expected to provide cheaper electricity and major increases in power generating efficiency. Investigations have indicated that a mixed potassium-cesium seeding is

[4] Prepared by Horace F. Kurtz, industry economist.

Table 4.—Prices of selected cesium and rubidium compounds

Item	Base price per pound [1]	
	Technical grade	High-purity grade
Cesium bromide	$28	$65
Cesium carbonate	29	67
Cesium chloride	30	68
Cesium fluoride	35	75
Cesium hydroxide	35	75
Rubidium carbonate	45	75
Rubidium chloride	46	76
Rubidium fluoride	51	83
Rubidium hydroxide	51	83

[1] Excludes packaging cost, 50 to 100 pound quantities, f.o.b. Revere, Pa.

Source: Kawecki Berylco Industries, Inc.

desirable for open-cycle MHD coal-burning power plants.[5]

Prices.—American Metal Market quoted a nominal price for pollucite (about 20% Cs) over 10 tons, delivered entry point, at $300 per short ton. Metal Bulletin quoted a nominal price for pollucite concentrates, minimum 24% Cs_2O, f.o.b. source, at $12.40 (using 1£ = $2.60) per metric ton unit (22.046 pounds) of Cs_2O. The American Metal Market quotation on cesium metal 99+% was unchanged at $100 to $375 per pound. The quotation on rubidium metal, 99.5+%, was also unchanged at $300 per pound.

Foreign Trade.—Pollucite was imported from Canada during 1972, but data on quantities and values of imports of cesium and rubidium raw materials were not published. Imports of cesium compounds increased to over 12,000 pounds nearly three times the quantity in 1971. Rubidium metal was not imported during 1972. No other data were available on imports and exports of cesium and rubidium products.

Table 5.—U.S. imports for consumption of cesium compounds, by country

Country	Cesium chloride		Cesium compounds, n.s.p.f.	
	Pounds	Value	Pounds	Value
Germany, West	1,661	$56,934	8,358	$252,328
Netherlands	--	--	1,974	20,078
United Kingdom	--	--	55	1,351
Total	1,661	56,934	10,387	273,757

World Review.—In 1971, Tantalum Mining Corp. of Canada, Ltd., produced about 400 tons of pollucite at its mine at Bernic Lake, Manitoba. The company did not mine pollucite in 1972, but shipments were made from stocks.

GERMANIUM [6]

The short supply situation reversed itself in mid-1970 when semiconductor demand dropped by an estimated 50% resulting in excessive consumer stocks and an oversupply of germanium for a brief period of 1 to 1½ years. Demand has increased since the 1970 slump with a slow and steady growth in both the semiconductor and optical industry. Estimated production of germanium from primary and secondary sources for 1972 was the same when compared to 1971.

Legislation and Government Programs.—Information was received on August 21, 1972, that germanium point contact diodes from Japan were being sold at less than fair value within the meaning of the Antidumping Act, 1921, as amended. This information was the subject of an "Antidumping Proceeding Notice" which was published in the Federal Register, September 23, 1972, page 20046. The notice indicated that there was evidence on record concerning injury to or prevention of establishment of an industry in the United States.

Domestic Production.—Production of primary germanium from domestic raw material sources was estimated at 27,000

[5] Bergman, P. D., and D. Bienstock. Economics of Mixed Potassium-Cesium Seeding of an MHD Combustion Plasma. BuMines RI 7717, 1972, 12 pp.

[6] Prepared by Herbert R. Babitzke, physical scientist.

pounds in 1972, with an additional estimated 10,000 pounds recovered from germanium-containing zinc concentrates imported from other countries. Most of the primary germanium was obtained from treating smelter residues resulting from the processing of roasted zinc concentrates. No mines are operated solely for recovery of germanium. This metal is a minor byproduct of ores mined for zinc with the supply of germanium being a function of the zinc production rate. Although at present no new residues are derived from treating ores of the Kansas-Missouri-Oklahoma region or from Kentucky and Illinois, a significant supply of residues has been stockpiled. Primary production was supplemented with recycled waste or new scrap. Waste recycle returns from 65% to 80% of the metal as scrap from cutting shapes used in the manufacture of semiconductors. Eagle-Picher Industries, Inc. of Miami, Okla., was the only producer of primary germanium from domestic sources. The above company and others listed below produced germanium from secondary sources and imports: GTE Sylvania, Towanda, Pa.; Kawecki Berylco Industries, Inc., Revere, Pa.; and Atomergic Chemetals Co., Long Island, N.Y.

Consumption and Uses.—The principal form in which germanium is used for semiconductors is as high-purity single crystal metal while for optical applications the material must be of high purity but may be polycrystalline. Semiconductor devices account for a large portion of the domestic demand. Electronic components account for 55% of the current use of germanium, and the remaining 45% is consumed in the manufacture of specialized optical glass, infrared equipment, and other minor applications. Germanium and silicon transistors, diodes, and rectifiers have replaced vacuum or electron tubes in many applications where cost-performance ratios have been competitive and where miniaturization is necessary in solid state devices. A market for germanium will continue to exist in those semiconductor applications where it is more reliable than silicon, specifically in some high-frequency and high-power requirements.

Germanium has numerous miscellaneous applications including nuclear radiation detectors, in solder and brazing alloys, as an alloying constituent to improve the mechanical properties of copper, aluminum, and magnesium alloys, in thermistors, photoconductors, and superconductors. Germanium has a high refractive index and is transparent to infrared light. To take advantage of this unique property, germanium windows, prisms, or lenses are employed in various optical systems.

Research is continuing in a number of areas which employ germanium. A large part of the research was to establish more of the physical constants of germanium and various germanium alloys and compounds.

A significant contribution was made to the petroleum refining industry when a new series of petroleum catalysts were developed. In the bimetallic cat-cracking catalysts platinum is one of the components and the second metals considered were gold, gallium, germanium, indium, and iridium.[7] A patent was issued to Universal Oil Products Co., Des Plaines, Ill., concerning a novel catalytic composite.[8] The catalyst comprised a combination of a platinum-group component, a germanium component, and a halogen component with a porous carrier material to result in a composite containing 0.01 to 2.0 weight-percent platinum, 0.01 to 5.0 weight-percent germanium, and 0.5 to 3.5 weight-percent halogen. The principal use of the composite was in the conversion of hydrocarbons, particularly in the reforming of a gasoline fraction. This catalyst had exceptional activity, selectivity, and resistance to deactivation when employed in a hydrocarbon conversion process that requires a catalyst having both a hydrogenation-dehydrogenation function and an acid function.

Highly refined germanium is one of the keys to making an X-ray spectrometer used for measuring the lead content of ordinary steels. The lead content is a gage of machinability. The spectrometer, the first of its kind in industry was placed in operation in a steel plant in September 1972. The instrument operates through X-ray fluorescence analysis, using cobalt as the radioactive source. When the steel sample is exposed to the high-energy X-rays from

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[7] Burke, Donald P. A Comprehensive Look at a $168-million/year Business Headed for Spectacular Growth. Part 1: Petroleum Catalysts. Chem. Week, v. 111, No. 18, Nov. 1, 1972, pp. 23–33.

[8] Hayes, John C. Hydrocarbon Conversion Process and Platinum-Germanium Catalytic Composite for Use Therein. U.S. Pat. 3,578,584, May 11, 1971.

the radioisotope, the lead particles become fluoresced or energized. The fluoresced lead X-rays are then counted by the unit's germanium transducer, and digital electronics provides the necessary energy analysis.

Prices.—The price of domestic zone-refined (intrinsic) germanium was $293 per kilogram and germanium dioxide was $167.50 per kilogram. These prices have been in effect since June 8, 1970. At the beginning of the year, imported germanium and germanium dioxide was $207 and $108.50 per kilogram, respectively, effective since January 1, 1971, but on April 1, 1972, the prices of imported germanium and germanium dioxide were increased to $229 and $120 per kilogram, where they remained through the end of the year.

Foreign Trade.—U.S. imports of germanium metal (unwrought, and waste and scrap) was 5,506 pounds valued at $724,331, a decrease from the previous year of 17% in quantity and 30% in value. The U.S.S.R. supplied 54% of the germanium imports. Belgium-Luxembourg supplied only 10% of the germanium but this represented 63% of the total value.

World Review.—World production of primary germanium was estimated at 160,000 pounds for 1972 which was 7% more than in 1971. Production in Japan was 49,395 pounds of germanium and 27,192 pounds of germanium dioxide. Japan also imported 593 pounds of germanium metal and 44,536 pounds of germanium dioxide. All African production of germanium was from the Shaba and Kivu Provinces of Zaire. In 1971, 117,000 pounds of germanium was produced by La Générale des Carrierès et des Mines du Zaire (Gécamines), a Zairian government company under contract with the Société Gènérale des Minerais of Belgium. Refining was done in Belgium.

Table 6.—U.S. imports for consumption of germanium, by country

Country	Quantity	Value
	Unwrought, and waste and scrap	
Belgium-Luxembourg	544	$455,401
Czechoslovakia	932	46,950
Denmark	220	15,705
Germany, West	336	25,292
Netherlands	254	13,196
Switzerland	165	10,819
U.S.S.R.	2,966	150,425
United Kingdom	89	6,543
Total	5,506	724,331
	Wrought	
Belgium-Luxembourg	13	3,134
Denmark	102	10,000
Switzerland	289	20,442
Total	404	33,576

INDIUM [9]

Domestic Production.—The American Smelting and Refining Company was the only domestic producer of indium during the year. Refining plants were situated in Denver, Colo., and Perth Amboy, N.J. Indium was recovered from flue dusts and residues in which indium source materials were concentrated during the processing of zinc ores and concentrates.

Uses.—The chief use of indium was in various applications in the manufacture of electronic devices. It was used as a component of solder for connecting lead wires to germanium in transistors and as a property-modifying agent in intermetallic germanium semiconductors. Indium compounds (arsenides, antimonides, and phosphides) were used in various electronic applications; indium halides were used as a color correctant in mercury vapor lamps. Indium-containing alloys were used in glass-sealing, and in dentistry.

Stocks.—Despite increased imports, stocks were estimated to have decreased.

Prices.—Producer prices of indium during the year were unchanged at $2.50 per troy ounce for sticks in lots of less than 100 ounces; ingots of 100 ounces brought $2.05 per ounce and lots of 10,000 ounces were priced at $1.75 per ounce. Probably very little metal moved at $1.75 as the dealer's price was in the range of $1.20 to $1.40 per ounce in ingot lots. Metals Week started quoting ingots at $1.75 effective December 14, 1972, and ceased quoting sticks.

Foreign Trade.—Imports of indium rose 62% over 1971 imports to 628,887 ounces. The lower world price of the material accounted for the growth of imports, because foreign metal could be traded by dealers for more than $1.00 per ounce less than

[9] Prepared by Burton E. Ashley, physical scientist.

the domestic producer price. The chief sources of imports were: Canada, 33%; U.S.S.R., 27%; Peru, 15%; United Kingdom, 14%; and others, 11%.

In accordance with decisions made under the General Agreement on Tariffs and Trade, the import duty on unwrought, waste and scrap metal was 5% ad valorem for 1972; however, such duties were temporarily suspended until June 30, 1973, under Public Law 92–44 which was effective June 30, 1971. Wrought metal was dutiable at a rate of 9% ad valorem and indium compounds at 5% ad valorem. The statutory rate on unwrought, waste and scrap metal, and on compounds, remained at 25% ad valorem from Communist-bloc countries; the duty on wrought metal was 45% from Communist-bloc countries, with Yugoslavia excepted in both cases.

Table 7.—U.S. imports for consumption of indium, by country

Country	Quantity (troy ounces)	Value
	Unwrought, waste and scrap	
Canada	209,928	$216,731
Germany, West	44,440	51,599
Japan	18,452	92,606
Netherlands	5,449	10,165
Peru	94,104	144,461
U.S.S.R	170,242	281,850
United Kingdom	85,185	113,473
Total	627,800	910,885
	Wrought	
Netherlands	1,087	1,373

RADIUM [10]

During 1972, radium was used primarily in therapeutic treatment of cancer. There were fewer industrial applications as substitution by cheaper and less hazardous radioisotopes continued.

Legislation and Government Program.—During 1972, there were no specific Federal programs related to radium only. Radium was not held in Governmental stockpiles. Imports of radium and its compounds were free of tariff.

Domestic Production.—Radium has not been produced in the United States for many years. The small domestic requirements were met by imports or withdrawal from dealers' stocks. The Belgian company, Union Minière S.A., remained the principal source of imported radium during 1972. Radium Chemical Co., Inc., New York, was the main radium dealer in the United States during 1972.

Uses.—Radium, in small quantities expressed in milligrams, was used in treatment of cancer and in luminous compounds, static eliminators, and neutron sources. Based on manufacturers' sales data, about 1,300 to 1,600 curies [11] of radium have been sold in the United States to date. Approximately 330 to 360 curies of radium, contained in 50,000 to 60,000 sources, were used in medical applications. Nonmedical uses accounted for 250 curies, and the rest was involved in luminous compounds and other uses.[12]

Up to 40 curies are added annually to the totals of radium in use in the United States. The after-effects of gamma radiation in medical applications and the price of radium have lead to substitution by other radioisotopes. This trend was also apparent in other uses of radium.

Prices.—Radium prices, per milligram, were quoted by Radium Chemical Co., as follows: Less than 100 milligrams, $24; 200 to 499 milligrams, $20; 500 milligrams to 4.99 grams, $18; over 5 grams, $17.

World Review.—Information on radium in world markets is not readily available, mainly because of the small quantities involved in production and trade. Small amounts of radium and its compounds are produced in Belgium, Canada, the United Kingdom, and the U.S.S.R. Trade in radium was not published as such; in most cases, radium is included with other items in trade statistics.

Technology.—The Federal Bureau of Mines continued a study to develop techniques for recovering radium from uranium ores, tailings, and processing solu-

[10] Prepared by Roman V. Sondermayer, physical scientist.
[11] One curie is equivalent to radioactivity of 1 gram of pure radium, or 3.7 × 10 disintegrations per second.
[12] Data on uses are estimates based on partial sales reports.

tions to eliminate this radioactive contaminant. Leaching of uranium ores with hydrochloric acid resulted in extraction of 20% to 90% of contained radium. During 1972, samples of domestic uranium ores and uranium mill tailings were examined. Results confirmed fair recovery of radium. In case of increased future demand, this method could become a new source of radium.

SCANDIUM[13]

Production of scandium metal, measured in grams, increased slightly compared with that of 1971. Scandium was used mostly in reasearch and in production of high-intensity lamps. The main potential raw material source for scandium was waste products from uranium mills although none was recovered in 1972. The bulk of domestic demand apparently was met by imports. Trade in scandium was not reported as such, but was included with other items in trade statistics.

Domestic Production.—Research Chemicals, a division of Nucor Corp., Phoenix, Ariz., was the only domestic producer of scandium during 1972. Supply was adequate for the small demand. The limited consumption and high production costs were expected to maintain high prices for marketable scandium products. Extraction of scandium from other sources, such as phosphate rock and tungsten concentrate, was not considered profitable.

Uses.—In addition to uses in research and development, scandium had two commercial applications. High purity scandium metal was used in the manufacture of high-intensity mercury lamps. These lamps were particularly useful for illumination of events televised in color because their illuminating efficiency and color range approached the qualities of sunlight. Radioisotope scandium-46 was used in tracing fluid flows in oil well reservoir studies and in evaluation of quality of casing cementations.

Prices.—The price of scandium oxide, 99.9%, as quoted by Research Chemicals, remained unchanged during the year at $2.80 per gram in lots of 100 to 453 grams; that of scandium metal in ingots and distilled forms was $8 and $15 per gram, respectively, while that of powder and chips remained unchanged at $10.35 per gram. Prices for scandium sheet foil were $17.85 to $105 per square inch for 51 to 100 square inch lots, ranging from 0.001 to 0.1 inch in thickness. Larger quantities were available for most items at lower prices.

Technology.—Most research remained aimed at a better understanding of properties and behavior of scandium in different environments. A limited number of projects were related to production of scandium metal and compounds. A process for recovering scandium from uranium waste liquors was developed using a three-phase system of an ion exchange resin, H_2SO_4 solution, and kerosene solution of bis (2-ethyl-hexyl) phosphate. Distribution of scandium in the system was tabulated. Selective scandium desorption is possible using this method.[14]

SELENIUM[15]

Domestic selenium production was 769,000 pounds, an increase of 17% from 1971. Shipments by domestic producers increased 19% to 791,000 pounds with the difference supplied from stocks which stood at 161,000 pounds at yearend. World production increased 5% to 2,642,000 pounds.

On August 11, 1971, Congress authorized disposal of the 474,774 pounds of selenium held in the national stockpile. No disposals were made during the remainder of 1971. During 1972 a total of 16,090 pounds of selenium was sold or exchanged for strategic commodities needed for the national stockpile.

Domestic Production.—Primary selenium was produced at four plants operated by the following major electrolytic copper refiners: American Metal Climax, Inc., Car-

[13] Prepared by Roman V. Sondermayer, physical scientist.
[14] Csovari, M., B. Szegedi, and I.A. Kuzin. Application of Three-Phase Systems in Chemical Technology. Pro. of 2d Conf. on Applied Phys. Chem., Budapest, Hungary, V.1, 1971, pp. 145–152.
[15] Prepared by Lyman Moore, mining engineer.

Table 8.—Salient selenium statistics

(Thousand pounds of contained selenium)

	1968	1969	1970	1971	1972
United States:					
Production	633	1,247	1,005	657	[1] 769
Shipments to consumers	941	1,429	1,056	663	[1] 791
Imports for consumption	583	546	454	395	430
Stocks, Dec. 31, producers	428	240	189	182	161
Producers price per pound, commercial and high-purity grades	$4.50–$6	$7–$8.50	$9–$10.50	$9–$11.50	$9–$11.50
World: Production	1,946	2,834	2,883	2,527	2,642

[1] Includes an estimated 30,000 pounds of selenium refined from secondary sources.

teret, N.J.; American Smelting and Refining Company, Baltimore, Md.; The Anaconda Company, Perth Amboy, N.J.; and Kennecott Copper Corp., Garfield, Utah. Crude materials containing primary selenium were transferred to these plants from copper refineries operated by Inspiration Consolidated Copper Co., Magma Copper Co., and Phelps Dodge Corp. An estimated 30,000 pounds of selenium was recovered by domestic secondary refineries from purchased electronic scrap. Considerable selenium home scrap was reused by manufacturers after outside reprocessing under toll contracts. Some domestic selenium-containing material was shipped to foreign plants for refining. High-purity selenium and various selenium compounds were produced by primary and other processors from commerical grade metal.

Consumption and Uses.—Apparent selenium consumption increased about 10% from 1971. Estimated usage in glass manufacturing, which consumed over one-third of the total metal used, increased over 15%. Small proportions of selenium compounds are added to glass melts to neutralize the green coloration caused by iron. Larger proportions are used to produce gray and bronze tinted window glass that reduces glare and heat transmission and to produce red- and amber-colored glass for signals and decorative uses. Consumption of selenium in xerography increased slightly during 1972 and this use now consumes about one-fourth of the primary metal shipped. More efficient use of selenium in xerographic copying machines and reclaiming of home scrap have restrained the consumption of primary selenium in xerography despite increasing use of copying machines. However, new applications in this field promise a larger future demand. Selenium consumption for rectifiers, photoelectric cells, and other electronic applications remained steady despite industry expansion, because of more efficient usage of selenium. Electronic uses consumed about one-fifth of the selenium marketed. Demand for selenium in pigments and steel alloys increased significantly. Other chemical, pharmaceutical, and miscellaneous uses were little changed from 1971.

Prices.—The producers' price for commercial and high-purity-grade selenium remained at $9 and $11.50 per pound, respectively, throughout the year, but there were periods of spot shortages and surpluses of metal. The merchant price for commercial grade was $9 to $9.30 during early 1972, slumped to below $8 in August and recovered to about $8.40 in November, and was $9 at yearend.

Foreign Trade.—Selenium exports rebounded from 1971 shipments which were unusually low because of the copper industry strike. The largest shipments were made to West Germany, the United Kingdom, and the Netherlands.

Selenium imports for consumption increased 9% and the value of imports increased 4%. Canada continued to be the principal supplier. Imports by country are shown in table 9.

World Review. The United States was the leading selenium producer, Japan was second, and Canada was third. These three countries accounted for 82% of world production (excluding the U.S.S.R.).

Technology.—The Selenium-Tellurium Development Association, Inc. continued sponsorship of research programs designed to increase selenium utilization.

United States animal feed processors have applied to the Food and Drug Administration for approval to add selenium to feed for poultry and swine. Research on animal nutrition has shown that, although food containing more than 3 parts per

Table 9.—U.S. imports for consumption of selenium, by country

(Thousand pounds and thousand dollars)

Country	Quantity	Value
	Unwrought, waste and scrap	
Australia	2	18
Canada	342	3,558
Germany, West	(1)	(1)
Japan	26	195
Mexico	28	176
Peru	1	10
Sweden	(1)	(1)
United Kingdom	5	54
Yugoslavia	4	28
Total	408	4,039
	Oxide (selenium content)	
Canada	18	183
Germany, West	(1)	1
United Kingdom	4	41
Total	22	225

[1] Less than ½ unit.

million (ppm) of selenium can be poisonous to swine and poultry, concentrations of up to 0.1 ppm are beneficial to swine and chickens and up to 0.2 ppm are beneficial to turkeys. Farm and laboratory animals whose diets are deficient in selenium are susceptible to serious disorders including muscular dystrophy and necrosis of the liver, kidneys, and pancreas. Selenium deficiency also makes animals highly vulnerable to poisoning from heavy metals such as mercury and lead. Selenium feed additions have long been used with good effect in Australia and New Zealand where the soil is notably lacking in selenium. The selenium content of U.S. soil varies considerably, ranging from dangerously high to inadequate. Studies are also in progress to determine optimum human selenium consumption and the present intake from food, air, and water.

Table 10.—Selenium: World refinery production by country [1]

(Thousand pounds)

Country [2]	1970	1971	1972 [p]
Australia [e]	[r] 7	7	7
Belgium-Luxembourg [3]	68	120	147
Canada	[r] 854	886	[4] 655
Finland	15	14	[e] 16
Japan	467	524	738
Mexico [5]	278	115	97
Peru	15	16	18
Sweden	139	[e] 134	[e] 140
United States	1,005	657	769
Yugoslavia	35	54	55
Total	[r] 2,883	2,527	2,642

[e] Estimate. [p] Preliminary. [r] Revised.
[1] Insofar as possible, data relate to refinery output of elemental selenium only; thus countries that produce selenium in copper ores and concentrates, blister copper, and/or refinery residues, but do not recover elemental selenium have been excluded to avoid double counting.
[2] In addition to the countries listed, West Germany and the U.S.S.R. are known to produce refined selenium and Zaire and Zambia may produce refined selenium, but available information is inadequate to make reliable estimates of output levels.
[3] Exports.
[4] Recoverable selenium content of blister copper treated at domestic refineries plus refined selenium from domestic raw materials, but excludes other unspecified materials that provide a portion of total refined selenium output. Corresponding figures for previous years in thousand pounds are: 1970—663; 1971—719.
[5] Figures represent mine output only, not refinery production.

TELLURIUM [16]

Domestic tellurium production of 257,000 pounds was the highest since 1962 and was 57% above the strike-reduced output of 1971. Domestic shipments of 271,000 pounds was a new record. Imports increased five times from those of 1971.

Domestic Production.—Production of tellurium was reported by the following major electrolytic copper or lead refiners: American Metal Climax, Inc., Carteret, N.J.; American Smelting and Refining Company, Baltimore, Md.; The Anaconda Company, Perth Amboy, N.J.; and United States Smelting Lead Refinery, Inc., East Chicago, Ind., division of UV Industries, Inc. Electrolytic refinery sludges containing primary tellurium were also produced at refineries operated by Inspiration Consolidated Copper Co., Kennecott Copper Corp., Magma Copper Co., and Phelps

[16] Prepared by Lyman Moore, mining engineer.

Dodge Corp. High-purity tellurium, tellurium master alloys, and tellurium compounds were produced by primary and intermediate processors from commercial-grade metal and tellurium dioxide.

Consumption and Uses.—Tellurium shipments for use as a free-machining agent in carbon and stainless steel and as a chilling agent in cast iron increased from the previous year and were about 60% of the total consumption. Reductions in consumer inventories that held down shipments in 1971 were completed and steel makers and machinery manufacturers increased purchases especially in the later part of the year. Consumption of tellurium in free-machining copper increased and was about 20% of consumption. About 11% was used in rubber manufacture, 6% in chemicals, and 3% in electronic and other uses.

Prices.—The producer price for commercial-grade powder and slab continued at $6 per pound throughout 1972, unchanged since 1962. Some discounting by merchants was reported during the first part of the year. Prices for high-purity grades of tellurium ranged from $10 to $32 per pound.

Table 11.—Salient tellurium statistics

(Thousand pounds of contained tellurium)

	1968	1969	1970	1971	1972
United States:					
Production, primary and secondary	121	234	158	164	257
Shipments to consumers	201	182	209	163	271
Stocks, Dec. 31, producers	157	177	128	r 116	102
Imports	71	112	64	30	146
Price per pound, commercial grade	$6	$6	$6	$6	$6
World: Production	258	395	367	340	422

r Revised.

Table 12.—U.S. imports for consumption of tellurium, by country

(Thousand pounds and thousand dollars)

Country	Quantity	Value
Canada	15	100
India	(1)	2
Peru	131	713
Total	146	815

1 Less than ½ unit.

Foreign Trade.—Imports in 1972 were 146,000 pounds compared with 30,000 pounds in 1971. Large shipments were received from Peru early in the year. The imported metal was nearly all of commercial grade and had an average value of $5.58 per pound. In accordance with the General Agreement on Tariffs and Trade, the effective import duty was reduced January 1, 1972, from 4.5% ad valorem on metal and 6.0% ad valorem on compounds to 4% and 5%, respectively.

World Review.—The United States continued to lead the world in tellurium output; Japan was second and Canada third.

Table 13.—Tellurium: World refinery production by country [1]

(Thousand pounds)

Country [2]	1970	1971	1972 p
Canada	r 65	44	[3] 48
Japan	78	79	77
Peru	r 66	53	e 40
United States	158	164	257
Total	r 367	340	422

e Estimate. p Preliminary. r Revised.

1 Insofar as possible, data related to refinery output only, thus countries that produce tellurium in copper ores and concentrates, blister copper, and/or refinery residues, but do not recover refined tellurium are excluded to avoid double counting.

2 In addition to the countries listed, Australia, Belgium, West Germany and the U.S.S.R. are known to produce refined tellurium, and other countries such as Zaire and Zambia may produce refined tellurium, but available information is inadequate to make reliable estimates of output levels.

3 Includes recoverable tellurium content of blister copper treated at domestic refineries plus refined tellurium from domestic raw materials but excludes other unspecfied materials that provide a portion of total refined tellurium output. Corresponding figures for previous years in thousand pounds are: 1970—59; 1971—24.

THALLIUM [17]

Thallium and thallium compounds are limited as to both size of market and number of uses. Federal restrictions regarding use of some compounds deter the use of this rare metal.

Domestic Production.—The American Smelting and Refining Company, Denver, Colo., was the only domestic producer of thallium and thallium compounds. Metal production was up slightly over 1971, but shipments were down.

Uses.—Distribution of thallium consumption was about 40% for electronics, 30% for low-melting alloys, 10% for optical glass, 7% for agriculture, 3% for medicine, 5% for academic purposes and development research, and other uses about 5%.

Curtailment of thallium as a rodenticide by Government action is continuing with increasing controls resulting from an accidental killing of wildlife in 1971 in the West. On February 8, 1972, the President issued Executive Order 11643 which offers environmental safeguards on activities for animal damage control on Federal Lands. The policy of the order is to restrict the use of chemical toxicants for killing predatory mammals, birds, or reptiles, which may cause secondary poisoning of such animals on Federal Land, and the use of such toxicants in any Federal program of mammal or bird damage control.

Thallium has a significant use in the electronics industry for production of thallium-activated sodium iodide crystals and for the production of "thallofide" cells which contain thallium sulfide and are sensitive to infrared radiation. Some thallium compounds are extremely photosensitive especially to light of low intensity. Thallium is also used in low-melting alloys for switches, thermometers, and other instruments for protection against extreme Arctic temperatures. Further use of thallium is likely for reaction intermediates in a variety of syntheses where the oxidizing power of thallium (III) and the stability of thallium (I) derivatives are exploited.[18]

Prices.—The price of thallium in 25-pound lots has been $7.50 per pound since December 1957.

Foreign Trade.—U.S. imports for consumption in 1972 were 1,449 pounds of unwrought, and waste and scrap thallium valued at $3,940. The amount was about twice that imported in 1971. Thallium compounds imported were 936 pounds valued at $7,144.

[17] Prepared by Herbert R. Babitzke, physical scientist.

[18] Lee, A. G. The Chemistry of Thallium. Elservier Publishing Co., Ltd., Barking, Essex, England, Monograph 14, 1971, 336 pp.

Table 14.—U.S. imports for consumption of thallium in 1972, by country

Country of origin	Compounds (gross weight)		Unwrought, and waste and scrap	
	Pounds	Value	Pounds	Value
Belgium-Luxembourg	425	$1,468	1,000	$2,910
Canada	--	--	3	259
Germany, West	246	2,567	--	--
U.S.S.R.	--	--	446	771
United Kingdom	265	3,109	--	--
Total	936	7,144	1,449	3,940