VANADIUM

(Data in metric tons, vanadium content, unless otherwise specified)

Domestic Production and Use: Vanadium production in Utah from the mining of uraniferous sandstones on the Colorado Plateau ceased in early 2020 and was not restarted in 2023. Secondary vanadium production continued in Arkansas, Ohio, and Pennsylvania where processed waste materials (petroleum residues, spent catalysts, utility ash) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, and vanadium pentoxide. Estimated U.S. apparent consumption of vanadium in 2023 increased by 27% from that in 2022. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2023. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production from primary ore and concentrate	460	17	—	—	—
Production from ash, residues, and spent catalysts[e]	3,000	2,900	3,200	4,400	5,700
Imports for consumption:					
Aluminum-vanadium master alloy	222	101	35	104	300
Ash and residues[1, 2]	2,120	1,550	1,680	2,240	3,100
Ferrovanadium	2,280	1,360	2,170	2,650	2,400
Oxides and hydroxides, other	105	67	69	222	100
Vanadium chemicals[3]	734	382	846	804	900
Vanadium metal[4]	45	([5])	([5])	18	35
Vanadium ores and concentrates[1]	108	2	4	492	500
Vanadium pentoxide	3,620	1,670	1,710	1,980	2,100
Exports:					
Aluminum-vanadium master alloy	29	14	72	28	30
Ash and residues[1]	1,280	503	930	1,130	1,000
Ferrovanadium	295	210	173	172	200
Oxides and hydroxides, other	750	51	235	309	200
Vanadium metal[4]	27	1	4	8	100
Vanadium ores and concentrates[1]	95	92	81	185	10
Vanadium pentoxide	423	50	17	143	5
Consumption:					
Apparent[6]	9,790	7,110	8,200	11,000	14,000
Reported	9,900	7,920	8,030	7,510	8,000
Price, average, vanadium pentoxide,[7] dollars per pound	12.17	6.68	8.17	9.25	9.25
Stocks, yearend[8]	257	269	271	248	250
Net import reliance[9] as a percentage of apparent consumption	65	59	61	60	58

Recycling: Recycling of vanadium is mainly associated with reprocessing vanadium catalysts into new catalysts. The range in vanadium content in spent catalysts varies depending on the crude oil feedstock and the uncertainty associated with the quantity of vanadium recycled from spent chemical process catalysts was significant.

Import Sources (2019–22): Ferrovanadium: Canada, 46%; Austria, 33%; Russia, 8%; and other, 13%. Vanadium pentoxide: Brazil, 49%; South Africa, 36%; Germany, 4%; and other, 11%. Total: Canada, 28%; Brazil, 15%; Austria, 10%; Russia, 8%; and other, 39%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Vanadium ores and concentrates	2615.90.6090	Free.
Vanadium-bearing ash and residues	2620.40.0030	Free.
Vanadium-bearing ash and residues, other	2620.99.1000	Free.
Vanadium pentoxide, anhydride	2825.30.0010	5.5% ad valorem.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad valorem.
Ferrovanadium	7202.92.0000	4.2% ad valorem.
Vanadium metal	8112.92.7000	2% ad valorem.
Vanadium and articles thereof[10]	8112.99.2000	2% ad valorem.
Vanadium chemicals	([3])	5.5% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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VANADIUM

Events, Trends, and Issues: The estimated average Chinese vanadium pentoxide price in both 2022 and 2023 was $9.25 per pound. The estimated United States ferrovanadium price decreased by 25% to $17.89 per pound in 2023 compared with that in 2022. The World Steel Association forecast global steel consumption to increase by 2.3% in 2023 and by 1.7% in 2024. Total world steel production was unchanged during the first 8 months of 2023 compared with that in the same period in 2022. Like most ferroalloys, vanadium is largely dependent on the market characteristics of steel and specifically the Chinese steel industry. In 2023, China continued to be the world's top vanadium producer, producing most of its vanadium from vanadiferous iron ore processed for steel production.

Vanadium redox flow battery (VRFB) technology continued to be an increasingly important part of large-scale energy storage as it allows for high-safety, large-scale, environmentally friendly, medium- and long-term energy storage. Installations of VRFB projects continued to increase worldwide as energy companies looked to support renewable energy projects as many countries attempt to lower their carbon emissions. Project Blue and other analysts projected that the VRFB market would account for approximately 17% of vanadium consumption in 2033 compared with only 3% in 2021. The new supply of high-purity vanadium pentoxide needed to support the VRFB market was expected to come from either existing producers or from projects which are, for the vast majority, still in their very early phases of development. Despite the anticipated growth of VRFBs, there will be continued competition from a variety of alternative battery technologies looking to capture a portion of the energy storage market share.

World Mine Production and Reserves: Reserves for Australia, China, and South Africa were revised based on company and Government reports.

	Mine production		Reserves[11]
	2022	2023[e]	(thousand metric tons)
United States	—	—	45
Australia	—	—	[12]8,500
Brazil	5,840	6,400	120
China	66,900	68,000	4,400
Russia	[e]20,000	20,000	5,000
South Africa	8,870	9,100	750
World total (rounded)	102,000	100,000	19,000

World Resources:[11] World resources of vanadium exceed 63 million tons. Vanadium occurs in deposits of phosphate rock, titaniferous magnetite, and uraniferous sandstone and siltstone, in which it constitutes less than 2% of the host rock. Significant quantities are also present in bauxite and carboniferous materials, such as coal, crude oil, oil shale, and tar sands. Because vanadium is typically recovered as a byproduct or coproduct, demonstrated world resources of the element are not fully indicative of available supplies.

Substitutes: Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. Currently, no acceptable substitute for vanadium is available for use in aerospace titanium alloys.

[e]Estimated. — Zero.

[1]Reported by the U.S. Census Bureau as kilograms of vanadium pentoxide. To convert vanadium pentoxide content to vanadium content, multiply by 0.56.

[2]Includes estimates for data suppressed by the U.S. Census Bureau in the years 2020 through 2023.

[3]Includes Harmonized Tariff Schedule of the United States codes for chloride oxides and hydroxides of vanadium (2827.49.1000), hydrides and nitrides of vanadium (2850.00.2000), vanadates (2841.90.1000), vanadium chlorides (2827.39.1000), and vanadium sulfates (2833.29.3000).

[4]Includes waste and scrap.

[5]Less than ½ unit.

[6]Defined as primary production + secondary production + imports – exports ± adjustments for industry stock changes.

[7]Chinese annual average vanadium pentoxide prices. Source: CRU Group.

[8]Includes ferrovanadium, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.

[9]Defined as imports – exports ± adjustments for industry stock changes.

[10]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium and is the main master alloy for the vanadium industry. Unwrought aluminum-vanadium master alloy (Harmonized Tariff Schedule of the United States code 7601.20.9030) was not included.

[11]See Appendix C for resource and reserve definitions and information concerning data sources.

[12]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 3 million tons.