edited by
MARY VIRGINIA ORNA, O.S.U
College of New Rochelle
New Rochelle, NY 10801

Metalloids

Robert H. Goldsmith
St. Mary's College of Maryland
St. Mary's City, MD 20686

The use of the term *metalloid* to designate certain element groupings has a curious history. A survey of about 170 chemistry textbooks, monographs, and dictionaries spanning almost two centuries of publication dates indicates a rather checkered history for the term.

Of the 40 elements known before 1800, those described as metals—i.e., iron, lead, gold, and silver—had fairly high densities. Sir Humphry Davy's discovery of sodium and potassium in 1807 posed a dilemma since these elements possessed many of the physical properties of the known metals but had low densities. To resolve this difficulty, Erman and Simon, in 1808, proposed that sodium and potassium be termed *metalloids* (meaning "metal likeness") to indicate that they resembled metals only somewhat.[1] This suggestion was ignored by the chemical community, and the concern disappeared.

In 1811, Berzelius began to use the term *metalloid* to designate nonmetallic elementary substances. In one of his more significant papers, he referred to metalloids as a group of elements which included sulfur, carbon, and oxygen and which was distinct from metals such as tin, cobalt, and copper.[2] *Metalloids* was clearly used as a synonym for nonmetals. Bernelius' idea of metalloids was to become the dominant viewpoint for the rest of the century.

Over the next 70 years, interest focused on the physical nature of metals and their metallic properties. It was observed that metals, for the most part, were opaque solids. They exhibited unusual luster, malleability, ductility, elasticity, and resistance to destructive forces like tearing. Metals had crystalline structures and were able to conduct heat and electricity. Chemical properties were not emphasized during this period. Nevertheless, grouping elements as metals, metalloids, or nonmetals based on the data presented problems. One author in 1849 held that the nonmetals were not a distinctive group. He subdivided them into the colorless gases, halogens, and metalloids, defining the latter as "bodies that resemble the metals in their chemical reactions." [3] Included in this group were boron, carbon, silicon, sulfur, selenium, arsenic, antimony, tellurium, and phosphorus.

During the next 40 years, others joined the debate over the classification of elements as metals or nonmetals. Richter and Mendeleef maintained that it was impossible to draw a sharp line between the metals and the metalloids (or nonmetals).[4] Other authors writing at the end of the century shared this view. A belief that there were intermediate elements such as arsenic between metals and nonmetals was held by several chemists, including Mendeleef. Perhaps the search for this new reclassification of the elements was best expressed by G. S. Newth in 1898. He noted that the two groups of elements gradually merge into each other and that a given element, depending upon its physical or chemical properties, could be placed into either group. Therefore, elements like arsenic which resemble metals physically but nonmetals chemically are true intermediate elements best described by the term *metalloid*.[5] It was in this period that the idea of an intermediate group of elements was born, but the term *metalloid* was still being used in diverse ways.

During the period from 1920 to 1940, the situation was in great flux. The older classification scheme of elements as only metals and nonmetals *or* metalloids was often used. At other times, authors recognized a group of intermediate elements described as metalloids. The application of Arrhenius' acid-base theory of 1884 helped in understanding the chemical behavior of the elements. Metals were viewed as base-forming elements and their oxides as basic anhydrides, and nonmetals were viewed as acid-forming elements and their oxides as acid anhydrides. Those elements having both acidic and basic properties were termed amphoteric, and some authors equated metalloids with the amphoteric elements. In dividing the periodic table into acid-formers and base-formers, metalloids became the intermediate group, although amphoteric behavior was present in most, but not all, of the metalloids. Consensus regarding the metalloids as intermediate or borderline elements did not occur until the period between 1940 and 1960. Since the mid-fifties, there has been greater emphasis on the place of metalloids in the periodic table.

Current textbooks use one or more of three approaches to metalloids today. The most general approach is to categorize metalloids as intermediate elements having both metallic and nonmetallic characteristics. The second approach is to view the metalloids as the elements lying along the diagonal zigzag line that separates the metals from the nonmetals in the periodic table. The newest approach is to emphasize aspects of their physical and/or chemical nature such as electronegativity, crystallinity, overall electronic nature and the role of certain metalloids as semiconductors.

Teachers should be aware that there is currently no agreement on an exact definition of metalloid, nor has there been any agreement about which elements should be identified as metalloids. The elements boron, silicon, arsenic, germanium, antimony, and tellurium have been mentioned most frequently, but polonium and astatine are sometimes included in this list. Beryllium, aluminum, carbon, tin, selenium, and bismuth are mentioned only rarely as metalloids or are classified as metalloids only under special circumstances.

Another interesting fact is that the use of the term *metalloid* has increased dramatically in recent years despite the fact that the IUPAC Commission on Inorganic Nomenclature recommended in 1970 that the term *metalloid* be abandoned and that elements be classified as metals, semimetals, and nonmetals.[6] Indeed, while only 20% of the textbooks used before 1970 mention metalloids, a majority of the texts used in the past ten years refer to them. Describing the intermediate elements as metalloids is clearly in fashion today.

Presented at the 15th Middle Atlantic Regional Meeting of the American Chemical Society, Washington, D.C., January 7–9, 1981.

[1] Erman, P. and Simon, P. L., *Gilbert's Annalen*, **28**, 131 (1808).

[2] Berzelius, J. J., *Annals of Philosophy*, **3**, 51 (1814).

[3] Parley, P., "A Glance at the Sciences," Rand and Mann, Boston, **1849**, pp. 264–5.

[4] Mendeleef, D., "Principles of Chemistry," 5th Ed., Vol. I, Longmans, Green & Co., London, **1891**, p. 23; Richter, V., "A Textbook of Inorganic Chemistry," P. Blackiston, Son & Co., Philadelphia, **1885**, p. 20.

[5] Newth, G. S., "Inorganic Chemistry," 6th Ed., Longmans, Green & Co., London, **1898**, p. 8.

[6] International Union of Pure and Applied Chemistry, "Nomenclature of Inorganic Chemistry," 2nd Ed., Definitive Rules, 1970, Butterworths, 1970, Rule 1.22, p. 11.

In summary, this study has pointed out the different ways in which the term *metalloid* has been used. The increase in the known number of elements and our understanding of their nature has pointed out the challenge of classification, but in all of this, it has become increasingly clear that increased conceptual understanding has definitely preceded terminology.