THE OCCURRENCE AND HARDNESS OF INDIUM

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ABSTRACT

Microscopical and spectrographic studies made on a large number of ore deposits from this and other continents, revealed that the indium content of primary ores occurs predominantly in the lead sulfide..

Present data indicate that indium is the softest of all the metals. It is considerably softer than talc. Some of the physical and chemical properties of indium are discussed.

OCCURRENCE

Indium occurs in nature predominantly in association with lead minerals. A survey of sulfide ores from a large number of widely scattered localities showed the indium to occur largely in apparent solution in the lead sulfide. The various ore minerals were crushed to 60–100 mesh and optically pure mineral particles were hand picked under the microscope. Their indium content was determined with the spectrograph.

Pure In_2S_3 is an amber-colored strongly pleochroic substance possessing extremely high indices of refraction, birefringence and dispersion. It should therefore lend itself to detection, even when present in very minute quantities, in indium-bearing galena. The failure to detect this compound in any of the indium-bearing specimens examined indicates an appreciable solid solubility of In_2S_3 in galena.

Moderate concentrations of indium were found in some oxidized zinc minerals such as hemimorphite and smithsonite. In many other instances little concentration of indium was seen in the oxidized zinc minerals.

In the course of treatment at the smelters and refineries the indium tends to concentrate with the zinc and cadmium and this, no doubt, has given rise to the erroneous observation that indium occurs in nature largely in association with zinc minerals. Indium is frequently observed in relatively large quantities in primary zinc sulfide ores but its actual occurrence in them is typically in the galena associated with these zinc and cadmium minerals. Only moderate amounts of indium were observed in any of the hand picked particles of sphalerite.

Powder photographic data from x-ray studies of indium are said to indicate an arrangement of its atoms at the points of a face-centered tetragonal lattice of axial ratio $c:a=1.06$. The lengths of the edges of this unit tetragonal prism are $a=4.58$Å, $c=4.86$Å.[1]

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[1] Hull, A. W., *X*-ray crystal analysis of thirteen common metals: *Phys. Rev.*, **17,** 571 (1921).

The specific gravity of extruded or hammered indium is 7.32. It melts at 155°C. According to measurements made by the writer, and based on the relative time required to volatilize a given quantity of the pure metal in the carbon arc, the boiling point of indium is 2610°C. The interval between the melting point and the boiling point of indium is larger than that of any other metal in this temperature range.

Indium imparts a deep blue coloration to the gas flame. Its compounds yield a blue flame tinged with colors produced by the various elements involved. In the carbon arc the color of the blue flame from metallic indium or its compounds is considerably lighter in shade than that in the much lower temperature of the gas flame.

In the carbon arc surrounded by air, metallic cadmium, zinc, aluminum and all other more electropositive elements are rapidly converted to oxides. Those portions of the oxides in contact with the hot carbon are gradually reduced to metal which volatilizes together with lesser amounts of oxide vapors.

Metallic indium, however, behaves like tin or lead in the carbon arc and remains as a metallic globule until completely volatilized. Indium oxide is reduced to metallic indium in the open carbon arc.

When heated with the blowpipe flame, indium is oxidized with difficulty. Before the blowpipe on charcoal a yellowish-gray coating is ultimately formed near the assay.

When pure indium is burned in the carbon arc, a coating of In_2O_3 forms on the upper electrode. At higher temperatures (but below a red heat) this coating is brown or tan-colored. On further cooling it changes to brownish yellow and later to bright canary yellow. When cold its color is pale yellow or yellowish white. Indium oxide yields colorless bead tests.

Metallic indium dissolves quietly and rapidly in nitric acid. Only slightly less rapid is the action of hydrochloric acid on indium. This causes considerable boiling and effervescence due to the liberation of hydrogen. Indium dissolves slowly in dilute sulfuric acid.

Indium is a silvery-white metal of the aluminum family. Its color is lighter than that of tin and when freshly rolled it possesses a color tone resembling but considerably lighter than aluminum.

Metallic indium is resistant to chemical corrosion and its surfaces are practically unaffected by air or water. The metal is very malleable and ductile.

Hardness

Metallic indium is softer than any other known metal or alloy. Some of the alkali metals, if equally pure and free from oxidation products, might possibly be as soft or even softer than indium. When cut with a knife, indium tends to adhere to the blade. Pieces of indium can be welded at room temperature by pressing them together with the fingers.

The scratch hardness of high purity indium was compared with that of pure transparent foliated talc. The purity of this talc was checked by the spectrograph and by index of refraction measurements with the petrographic microscope.

The talc proved to be considerably harder than the indium. Slender bundles of talc folia readily scratched the indium. The surfaces of the talc folia could not be scratched by the indium. The hardness of indium is therefore less than unity on Mohs' scale.

The hardness of minerals has been discussed in an excellent paper by Talmage.[2]

Due principally to the different degrees of plastic flowage exhibited by extremely soft minerals, the precise comparison of their hardness is a difficult problem.

An attempt was made to obtain a quantitative relationship between the hardness of talc and indium. Sclerometer measurements using a Spencer microcharacter quickly demonstrated the futility of securing precision values for hardness when comparing a soft malleable substance with a soft partly brittle foliated one.

The microcharacter produced a clean V-shaped groove in the malleable indium but made an exceedingly irregular one as it crossed the distorted torn and upturned folia of the talc.

The scratch hardness of pure lead is only slightly lower than that of selenite. When compared with the microcharacter, the hardness of lead and selenite are so close that errors of determination may cause the values to merge with each other. The hardness of indium is so much lower than that of talc that even the sclerometer tests easily show which is harder.

Since it is possible to duplicate the hardness determinations on malleable metals with the microcharacter with satisfactory fidelity, these measurements were made on high purity lead and indium. The difference between the hardness of lead and indium is somewhat greater than the difference between the hardness of selenite and talc.

The high purity indium used in these experiments[3] contained about 0.001% lead and 0.0008% iron. Copper, silver and aluminum were present in amounts less than 0.0001%. The spectrograph showed no traces of cadmium, arsenic, thallium, tin or any other element. The hardness

[2] Talmage, S. B., Quantitative standards for hardness of the ore minerals: *Econ. Geology*, **20,** 531–553 (1925).

[3] Prepared at this laboratory by C. Zischkau.

value obtained from this indium can be regarded as identical with that of pure indium.

The lead used in the hardness comparison with indium was prepared by the writer. It contained approximately 0.00001% bismuth and 0.00005% copper. No other impurities were detected with the spectrograph.

Brinell hardness values on these metals were as follows:

	Brinell Hardness Number
High purity lead	4.0
High purity indium	0.75 (Approximate)

The microcharacter (using a 3 gram weight) produced a clean V-shaped mark as it traversed the metal specimens. On the mineral specimens it made a jagged, irregular mark bounded by torn and bent and up-turned folia. The widths of the grooves were as follows:

	mm.
Indium	0.089
Talc	0.083–0.086
Lead	0.037
Selenite	0.035–0.037

The microcharacter tests were made on metal surfaces prepared with the microtome. The widths of the grooves were measured by projecting their images on the photographic screen of the large metallographic microscope and comparing with that of the projected micrometer scale.

Microcharacter readings on high purity lead varied somewhat depending on the nature of the surface tested. Exterior chilled surfaces gave readings as low as 0.029 mm. However, surfaces of lead from the interior of a casting, prepared with the microtome, gave consistent groove widths of 0.037 mm.

Microcharacter tests on indium were consistent regardless of the flat surface selected for study. Specimens of metallic indium containing about 0.01–0.02% each of cadmium, lead, thallium, and tin gave the same hardness values as the purified specimen.