Boron is the fifth element of the periodic table (Z=5), located in Group 13. It is classified as a metalloid due to its properties that reflect a combination of both metals and nonmetals.

Introduction

The name Boron comes from the Arabic and Persian words for borax, its principal ore. Although compounds of boron were known in ancient times, it was first isolated in 1808 by Gay-Lussac and Thénard and independently by Sir Humphry Davy (who has a lot of elements to his credit!).

Boron exists in the earth’s crust to the extent of only about 10 ppm (about the same abundance as lead). The pure element is shiny and black. It is very hard and in extremely pure form is nearly as hard as diamond, but much too brittle for practical use. At high temperatures it is a good conductor but at room temperature and below is an insulator. This behavior as well as many of its other properties earn it the classification of a metalloid. In addition to the crystalline form of boron there is also an amorphous dark brown powder (as shown above).

The element can be prepared by the reduction of borax (\(\text{Na}_2\text{B}_4\text{O}_7\)) with carbon. High-purity boron can be produced by electrolysis of molten potassium fluoroborate. Common compounds of boron include borax and boric acid (\(\text{H}_3\text{BO}_3\)).

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic Mass</td>
<td>10.811 g/mol</td>
</tr>
<tr>
<td>Electronic Configuration</td>
<td>([\text{He}]2s^2\ 2p^1)</td>
</tr>
<tr>
<td>Melting Point</td>
<td>2349 K</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>4200 K</td>
</tr>
<tr>
<td>Heat of Fusion</td>
<td>50.2 kJ/mol</td>
</tr>
<tr>
<td>Heat of Vaporization</td>
<td>480 kJ/mol</td>
</tr>
<tr>
<td>Specific Heat Capacity</td>
<td>11.087 J/mol·K</td>
</tr>
<tr>
<td>Oxidation States</td>
<td>+4, +3, +2, +1</td>
</tr>
<tr>
<td>Magnetic Ordering</td>
<td>diamagnetic</td>
</tr>
<tr>
<td>Electronegativity</td>
<td>2.04</td>
</tr>
<tr>
<td>Atomic Radius</td>
<td>90 pm</td>
</tr>
<tr>
<td>Stable Isotopes</td>
<td>(^{10}\text{B}, ^{11}\text{B})</td>
</tr>
</tbody>
</table>

Boron is the only element in group 3 that is not a metal. It has properties that lie between metals and non-metals (semimetals). For example Boron is a semiconductor unlike the rest of the group 13 elements. Chemically, it is closer to
aluminum than any of the other group 13 elements.

History

Boron was first discovered by Joseph-Louis Gay-Lussac and Louis-Jaques Thenard, and independently by Humphry Davy in the year 1808. These chemists isolated Boron by combining boric acid with potassium. Today, there are many ways of obtaining Boron but the most common way is by heating borax (a compound of sodium and boron) with calcium.

Boron and its Compounds

Many boron compounds are electron-deficient, meaning that they lack an octet of electrons around the central boron atom. This deficiency is what accounts for boron being a strong Lewis acid, in that it can accept protons (H\(^+\) ions) in solution. Boron-hydrogen compounds are referred to as boron hydrides, or boranes.

Boranes

In the molecule BH\(_3\), each of the 3 hydrogen atoms is bonded to the central boron atom. The boron atom has only six electrons in its outer shell, leading to an electron deficiency.

Diborane:

\[
\begin{array}{c}
\text{H} & \text{H} \\
\text{I} & \text{I} \\
\text{H} - \text{B} & \text{B} - \text{H} \\
\text{I} & \text{I} \\
\text{H} & \text{H}
\end{array}
\]

This molecule has 12 valence shell electrons; 3 each from the B atoms, and 1 each from the six H atoms. To make this structure follow the rules required to draw any lewis structure model, then it must have 14 valence shell electrons; however it does not. According to this figure, the two B atoms and four H atoms lie in the same plane (sp\(^3\)- perpendicular to the plane of the page). In these four bonds 8 electrons are involved. Four electrons bond the remaining H atoms to the two B atoms and the B atoms together. This is done when the two H atoms simultaneously bond to the two B atoms. This creates what is called an atom "bridge" because there are two electrons shared among three atoms. These bonds are also called three-center two-electron bonds. The bond between the H and the B atoms can be rationalized using molecular orbital theory.

Other Boron Compounds

Although boron compounds are widely distributed in Earth's crust, a few concentrated ores are located in Italy, Russia,
Tibet, Turkey, and California. Borax is the most common ore found, and it can be turned into a variety of boron compounds. When a solution of borax and hydrogen peroxide is crystallized, sodium perborate (NaBO$_3$ * 4 H$_2$O) is formed. Sodium perborate is used in color-safe bleaches. The key to the bleaching ability of this compound is the presence of its two peroxo groups that bridge the boron atoms together. Another compound that other boron compounds can be synthesized from is boric acid (B(OH)$_3$). When mixed with water, the weakly acidic and electron deficient boric acid accepts an OH$^-$ ion from water and forms the complex ion [B(OH)$_4$]$^-$. Borate salts produce basic solutions that are used in cleaning agents. Boric acid is also used as an insecticide to kill roaches, and as an antiseptic in eyewash solutions. Other boron compounds are used in a variety of things, for example: adhesives, cement, disinfectants, fertilizers, fire retardants, glass, herbicides, metallurgical fluxes, and textile bleaches and dye.

References


Problems

1. What is the electronic configuration of boron?
2. What accounts for the formation of boron hydrides?
3. What are some uses of boron compounds?
4. Draw B$_4$H$_{10}$.
5. What is the molecular orbital theory and how is it used to rationalize the bonds in boron hydrides?

Answers

1. [He]2s$^2$ 2p$^1$
2. Boron is highly electronegative, and wants to form compounds with hydrogen atoms.
3. Adhesives, cement, disinfectants, fertilizers, etc.
4. The molecular orbital theory treats compounds not as having individual bonds between atoms, but as sharing electrons with multiple atoms through their orbitals. In this way, hydrogen atoms are "bonded" between 2 other atoms at a time, in that a pair of electrons is shared between 3 atoms at once.

Contributors

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