

### IMPORTANT TRENDS AND ANOMALOUS PROPERTIES OF BORON

The tri-chlorides, bromides, and iodides of these elements are covalent compounds and undergo hydrolysis when placed in water. In an aqueous environment, species such as tetrahedral  $[M(OH)_4]^-$  and octahedral  $[M(H_2O)_6]^{3+}$  exist, with the exception of boron. This deviation is due to the absence of d orbitals, limiting boron's maximum covalence to 4. In contrast, elements like aluminum and others possess d orbitals, allowing for the potential of covalence's exceeding 4.

#### Occurrence

Element	Abundance	Source
B (Boron)	9 ppm (Rare element)	<ul style="list-style-type: none"> <li>➤ Borax: <math>Na_2[B_4O_5(OH)_4] \cdot 8H_2O</math></li> <li>➤ Colemanite: <math>Ca_2B_6O_{11} \cdot 5H_2O</math></li> <li>➤ Kernite: <math>Na_2[B_4O_5(OH)_4] \cdot 2H_2O</math></li> <li>➤ Boric acid: <math>H_3BO_3</math></li> </ul>
Al (Aluminum)	83000 ppm (Most abundant metal, 3 <sup>rd</sup> most Abundant element)	<ul style="list-style-type: none"> <li>➤ Bauxite: <math>Al_2O_3 \cdot H_2O - Al_2O_3 \cdot 3H_2O</math></li> <li>➤ Aluminosilicate rocks (feldspars, mica)</li> <li>➤ Cryolite: <math>Na_3AlF_6</math></li> </ul>
Ga (Gallium)	19 ppm	➤ Ores of Al, Zn, Ge
In (Indium)	0.24 ppm	➤ ZnS & PbS ores
Tl (Thallium)	0.5 ppm	➤ ZnS & PbS ores

#### Allotropy

Elements	Allotropes
B	5 crystalline forms: $\beta$ -rhombohedral
	2 amorphous forms
Al	No allotrope
Ga	No allotrope
In	No allotrope
Tl	$\alpha$ -Thallium
	$\beta$ -Thallium

#### Atomic & Physical Properties

Boron is characterized as a non-metal. It presents itself as a solid with exceptional hardness and a black color. Boron exhibits multiple allotropic forms. Its remarkably high melting point is attributed to its strong crystalline lattice. In contrast, the remaining members of the group are soft metals with low melting points and high electrical conductivity. Gallium, for instance, has a low melting point (303 K) to the extent that it can be in a liquid state during the summer. Its high boiling point (2676 K) renders it useful for measuring elevated temperatures. Aluminum displays excellent heat and electricity conductivity and possesses malleable and ductile properties. As we move down the group from boron to thallium, the density of these elements increases.

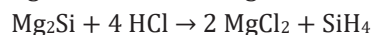
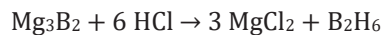
**Boron family**

1. Borax is represented chemically as  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$  or alternatively as  $\text{Na}_2[\text{B}_4\text{O}_5(\text{OH})_4] \cdot 8\text{H}_2\text{O}$ .
2. Colemanite has the chemical formula  $\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 5\text{H}_2\text{O}$ .
3. Boric acid is denoted by the chemical formula  $\text{H}_3\text{BO}_3$ .

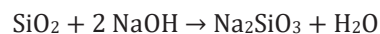
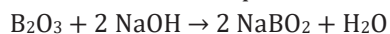
Property		B		Al	Ga	In	Tl
Character		Metalloid		Metallic	Metallic	Metallic	Metallic
Atomic Number		5		13	31	49	81
Atomic Mass/g mol <sup>-1</sup>		10.81		26.98	69.72	114.82	204.38
Electronic configuration General electronic configuration = (ns <sup>2</sup> np <sup>1</sup> )		[He] 2s <sup>2</sup> 2p <sup>1</sup>		[Ne] 3s <sup>2</sup> 3p <sup>1</sup>	[Ar] 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>1</sup>	[Kr] 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>1</sup>	[Xe] 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 6p <sup>1</sup>
Covalent Radius / pm (B < Ga < Al < In < Tl)		85		143	135	167	170
		In Ga, poor shielding of 10 d-electrons					
Ionic Radius X <sup>-</sup> / pm (B < Al < Ga < In < Tl)		27		53.5	62	80	88.5
Ionization enthalpy (kJ mol <sup>-1</sup> ) (B > Al < Ga > In < Tl)	$\Delta_i H_1$	I	801	577	579	558	589
	$\Delta_i H_2$	II	2427	1816	1979	1820	1971
	$\Delta_i H_3$	III	3659	2744	2962	2704	2877
		Poor shielding of d-orbital and f-orbital in Ga & Tl respectively					
Electronegativity (B > Al < Ga < In < Tl)		2.0			1.5	1.6	1.7
		Marginal increase after Al					
Melting point / K		2453			933	303	430
Boiling point / K (B > Al > Ga > In > Tl)		3923			2740	2676	2353
Density/[g cm <sup>-3</sup> (at 293 K)] (B < Al < Ga < In < Tl)		2.35			2.70	5.90	7.31
Oxidation State		+3			+3	+3, +1	+3, +1
		+1 oxidation state arises due to inert pair effect.					
		Stability of Oxidation state: +1: Ga < In < Tl +3: Al > Ga > In > Tl					

**Diagonal Relationship Between Boron and Silicon**

1. Neither of these elements is naturally found in a free state; instead, they are encountered as oxo compounds, such as borates and silicates.
2. Both elements share similar physical properties, existing in both amorphous and crystalline forms.
3. The stability of both B–O and Si–O bonds is comparable.
4. Both elements have the capacity to form hydrides from their magnesium salts. This is evident in reactions such as:



5. Boron (III) oxide and silicon dioxide exhibit solid states with macromolecular structures, dissolving exclusively in alkaline solutions. This phenomenon is exemplified by reactions like:



6. The acids of both elements can generate volatile esters when heated with alcohol in the presence of concentrated  $\text{H}_2\text{SO}_4$ . This is demonstrated through reactions such as:

