

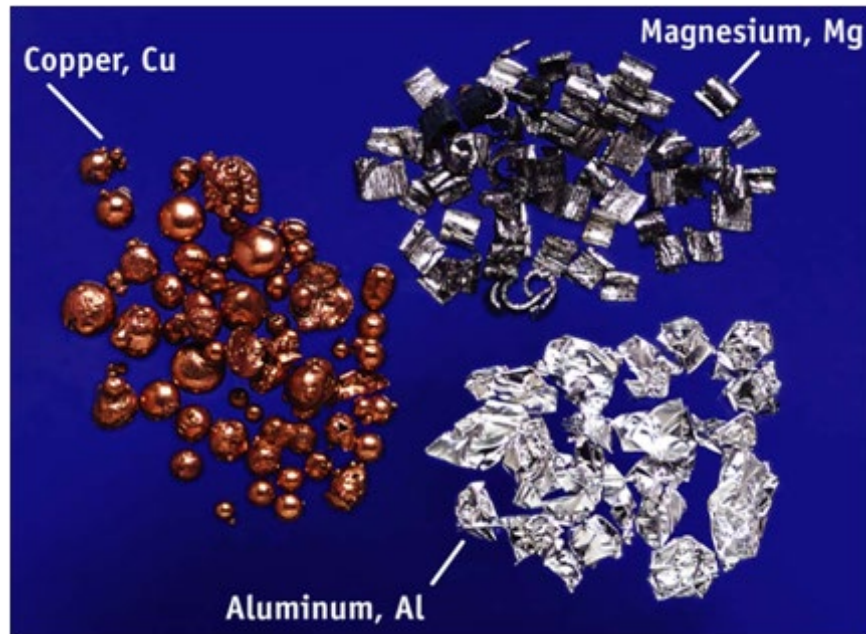


Gallium, Ga

# METALS



Sodium, Na



Copper, Cu

Magnesium, Mg

Aluminum, Al

## CHEMISTRY 1000

### Topic #2: The Chemical Alphabet

Fall 2020

Dr. Susan Findlay

See Exercises 7.3 to 7.5

# NONMETALS



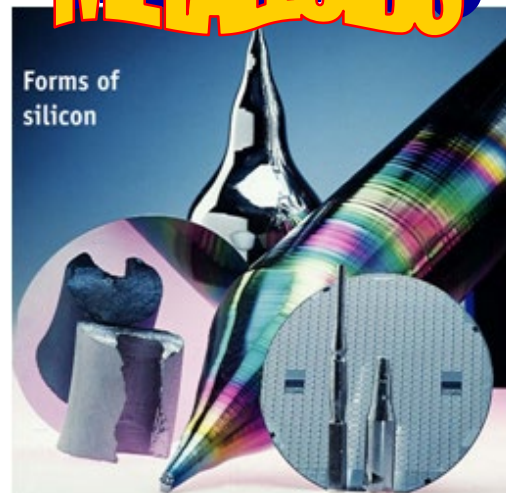
Bromine, Br<sub>2</sub>

Iodine, I<sub>2</sub>



Forms of Carbon

# METALLOIDS



Forms of silicon

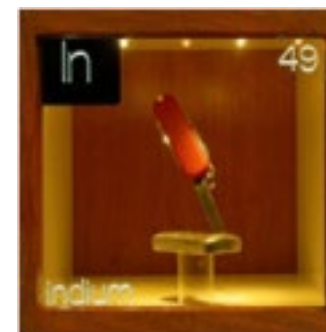
© 2003 THOMSON - BROADVIEW

# The Metals of Group 13 (Aluminium *et al*)

Boron 10811 B 5
Aluminium 269815 Al 13
Gallium 69.723 Ga 31
Indium 114.82 In 49
Thallium 204.383 Tl 81
(2004) (284)
113

- How do the group 13 elements differ?
  - Boron is a metalloid (i.e. a semiconductor). It is much harder than the other elements in group 13 (*crystalline boron falls between corundum (9) and diamond (10) on the Mohs scale; aluminium has a hardness of 2.75 – slightly harder than fingernails*) and has much higher melting and boiling points.
  - The other elements in group 13 are metals.

	<b>Melting Point</b>	<b>Boiling Point</b>	<b>Density (at 20 °C)</b>
Boron	2075 °C	4000 °C	2.34 g/cm <sup>3</sup>
Aluminium	660.37 °C	2467 °C	2.698 g/cm <sup>3</sup>
Gallium	29.78 °C	2403 °C	5.907 g/cm <sup>3</sup>
Indium	156.17 °C	2080 °C	7.310 g/cm <sup>3</sup>
Thallium	303.55 °C	1457 °C	11.85 g/cm <sup>3</sup>



# The Metals of Group 13 (Aluminium *et al*)

Boron 10811 B 5
Aluminium 269815 Al 13
Gallium 69723 Ga 31
Indium 11482 In 49
Thallium 204383 Tl 81
(2004) (284) 113

- What else do we know about the group 13 metals?
  - Three valence electrons (*Al* is  $[Ne]3s^23p^1$ ; *Ga* is  $[Ar]4s^23d^{10}4p^1$ )
  - They can all form +3 cations. Indium and thallium can also form +1 cations (thallium is most commonly +1):
    - Aluminium is an excellent **reducing agent** with a standard reduction potential of -1.676 V (and, therefore, a standard oxidation potential of +1.676 V):
    - Thallium is \*highly\* toxic (the maximum allowable concentration is 0.1 ng/L) and has been used as a poison in both fiction and reality. Even exposure to a few mg will cause hair loss, nerve damage, etc.

# The Metals of Group 13 (Aluminium *et al*)

Boron 10.811 B 5
Aluminium 26.9815 Al 13
Gallium 69.723 Ga 31
Indium 114.82 In 49
Thallium 204.388 Tl 81
(2004) (284) 113

- What sort of reactions do the group 13 metals undergo?
  - Reaction with oxygen? The group 13 metals react with oxygen in the air to give the corresponding oxide:

Thallium is so reactive with the oxygen in air that it's actually stored under (oxygen-free) water!

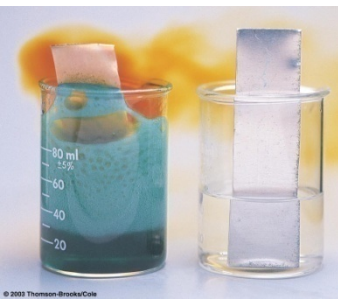
For the other group 13 metals, this oxidation is quite useful. The thin layer of oxide that forms on the surface of the metal protects it from rusting. For aluminium, this layer can be thickened (up to 0.02 mm) by an electrolytic process called **anodic oxidation**. Anodized aluminium is harder than regular aluminium.

- Reaction with water? Not at room temperature. The thin oxide layer on the metal's surface protects it. This is protective coating is known as a **passivation** layer.

# The Metals of Group 13 (Aluminium *et al*)

Boron 10811 B 5
Aluminium 269815 Al 13
Gallium 69723 Ga 31
Indium 11482 In 49
Thallium 204383 Tl 81
(2004) (284)
113

- Reaction with acid? Depends on the acid:
  - Oxidizing acids (e.g.  $HNO_3^*$ ) do not react with group 13 metals because the surface metal is already oxidized into a protective coating.
  - Strong non-oxidizing acids (e.g.  $HCl$ ) dissolve group 13 metals, producing hydrogen gas:
- Reaction with base? Group 13 metals react with aqueous base to produce a complex ion and hydrogen gas:

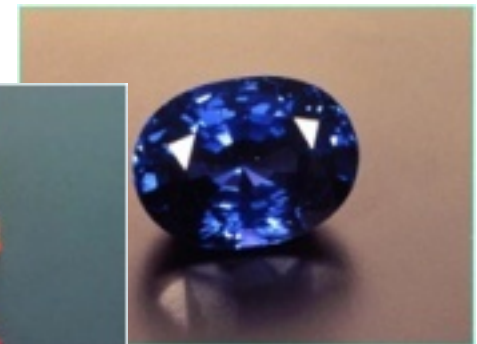


\* *What is an oxidizing acid? Think back to the Copper Cycle lab. What happened when you dissolved copper in nitric acid (an oxidizing acid)?*

# The Metals of Group 13 (Aluminium *et al*)

Boron 10.811 B 5
Aluminium 26.9815 Al 13
Gallium 69.723 Ga 31
Indium 114.82 In 49
Thallium 204.388 Tl 81
(2004) (284)
113

- Aluminium oxide is not just a protective layer.
  - One of its forms is extremely hard and therefore useful as an abrasive and polishing material.
  - Another ("corundum") is the main component of rubies (*when contaminated with chromium(III)*) and sapphires (*when contaminated with iron(III) and titanium(IV)*).
  - In the lab, a finely powdered form of aluminium oxide ("activated alumina") can be used to separate compounds in a technique called chromatography. This form of aluminium oxide is synthetic, prepared by heating aluminium hydroxide to dehydrate it:



# The Metals of Group 13 (Aluminium *et al*)

Boron 10.811 B 5
Aluminium 26.9815 Al 13
Gallium 69.723 Ga 31
Indium 114.82 In 49
Thallium 204.383 Tl 81
(2004) (284) 113

- Aluminium hydroxide is unusual in that it is amphoteric. In other words, it can act as either an acid or a base.  
(*A hydroxide as an acid? Yes, really. ☺*)
  - Aluminium hydroxide is insoluble in water. Why is that?
  - It reacts with aqueous base, though, to give a soluble anion:
  - It also reacts with aqueous acid to give a solvated cation:

# The Metals of Group 13 (Aluminium *et al*)

- How is aluminium made?

- Like the alkali metals and alkaline earth metals, aluminium is not found in pure form in nature. It reacts with oxygen too readily, so naturally occurring aluminium is always part of a salt or mineral.
- Again, we turn to electrolysis as a method for isolating the metal.
- The starting material of choice, bauxite, is an ore containing mostly  $Al(OH)_3$  (gibbsite) and/or  $AlO(OH)$  (diaspore or boehmite); however, it also contains iron(III) oxide ( $Fe_2O_3$ ) which must be removed before electrolysis. How can this be accomplished?

Boron 10.811 B 5
Aluminium 26.9815 Al 13
Gallium 69.723 Ga 31
Indium 114.82 In 49
Thallium 204.383 Tl 81
(2004) (284)
113





# The Metals of Group 13 (Aluminium *et al*)

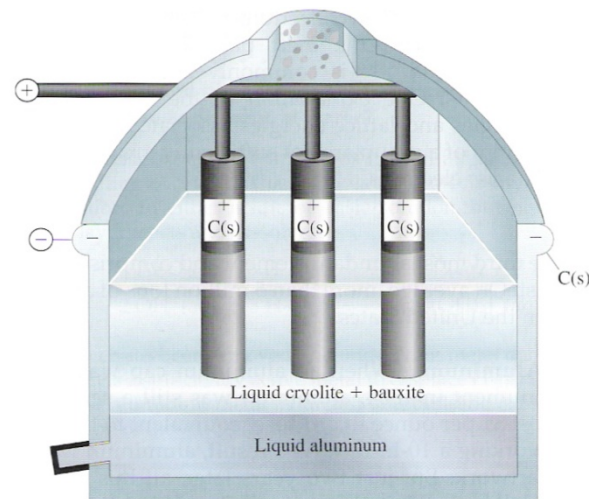
Boron 10.811 <b>B</b> 5
Aluminium 26.9815 <b>Al</b> 13
Gallium 69.723 <b>Ga</b> 31
Indium 114.82 <b>In</b> 49
Thallium 204.383 <b>Tl</b> 81
(2004) (284) 113

- It's a three-step process, taking advantage of the amphoteric nature of aluminium salts:

# The Metals of Group 13 (Aluminium *et al*)

Boron 10.811 B 5
Aluminium 26.9815 Al 13
Gallium 69.723 Ga 31
Indium 114.82 In 49
Thallium 204.383 Tl 81
(2004) (284)
113

- Once the aluminium oxide has been purified, it can theoretically be melted and electrolyzed. The next problem is its high melting point (2020 °C!) Aluminium went from being considered a precious metal to an everyday material after it was discovered that aluminium oxide could be dissolved in the molten mineral **cryolite** ( $Na_3AlF_6$ ) at only 1000 °C. Cryolite conducts electricity well, so it is a good solvent for electrochemistry:



- Interestingly, it actually costs \*twenty times\* as much to produce aluminium from bauxite than it does to make it by recycling! This is primarily due to the large amount of energy needed for the electrolysis. The take-home message: recycle those pop cans!