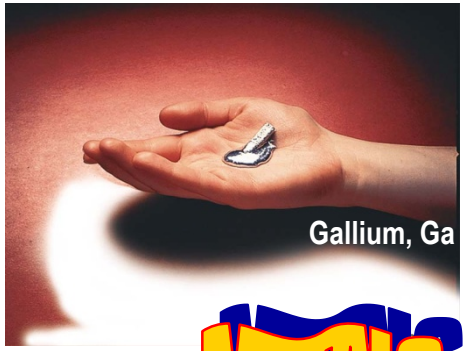
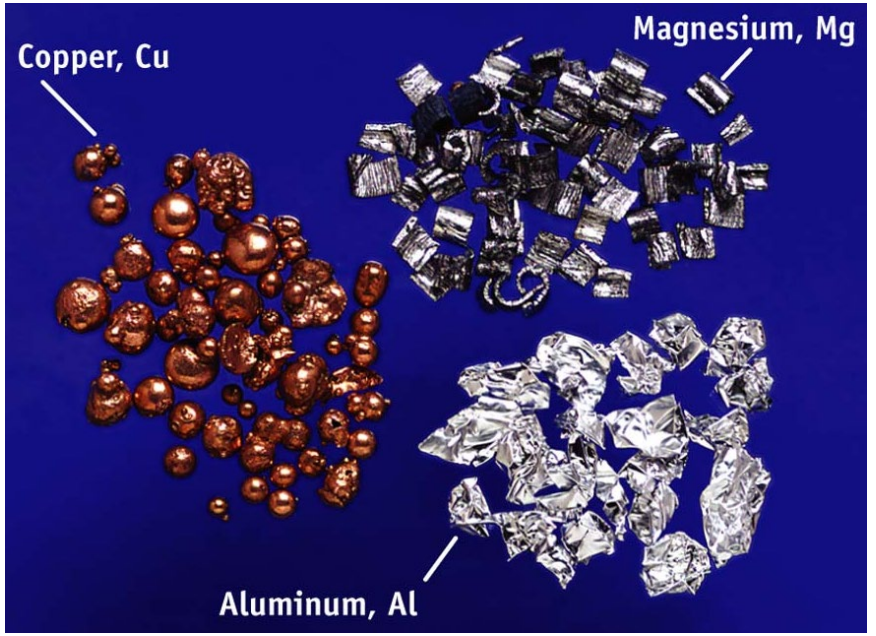


METALS



CHEMISTRY 1000

Topic #2: The Chemical Alphabet

Fall 2020

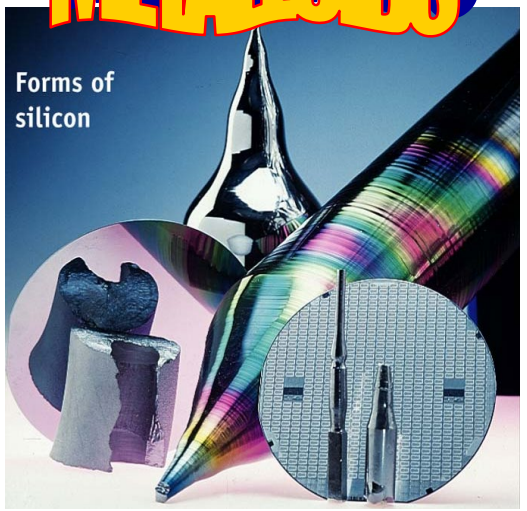
Dr. Susan Findlay

See Exercises 11.1 to 11.4

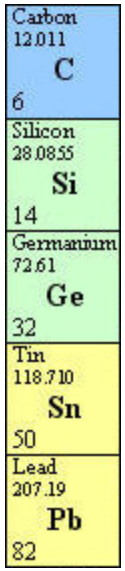
NONMETALS

Forms of Carbon

METALLOIDS

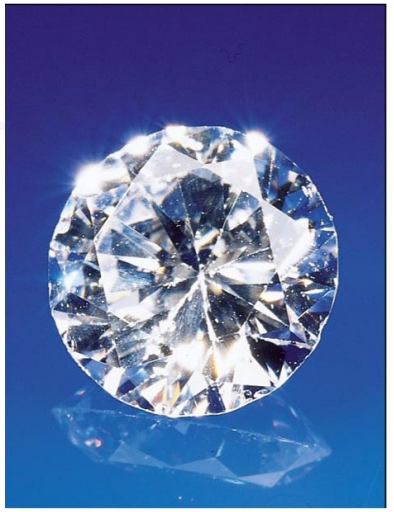


The Group 14 Elements



- What do we know about the Group 14 elements?
  - Nonmetal (C), metalloid (Si, Ge) or metal (Sn, Pb)
  - Carbon has multiple allotropes
  - They can take on multiple oxidation states, but don't tend to form ions (except Sn and Pb which can be +2 or +4; C^{4-} is rare and highly reactive)
  - They have four valence electrons (valence electron configuration $[N.G.]ns^2np^2$)

	Melting Point	**Boiling Point**	**Density** (at 20 °C)
Carbon (graphite)	>3500 °C	3370 °C	2.26 g/cm^3
Silicon	1410 °C	2477 °C	2.329 g/cm^3
Germanium	937 °C	2830 °C	5.323 g/cm^3
Tin (grey)	232 °C	2623 °C	5.77 g/cm^3
Lead	327 °C	1751 °C	11.34 g/cm^3

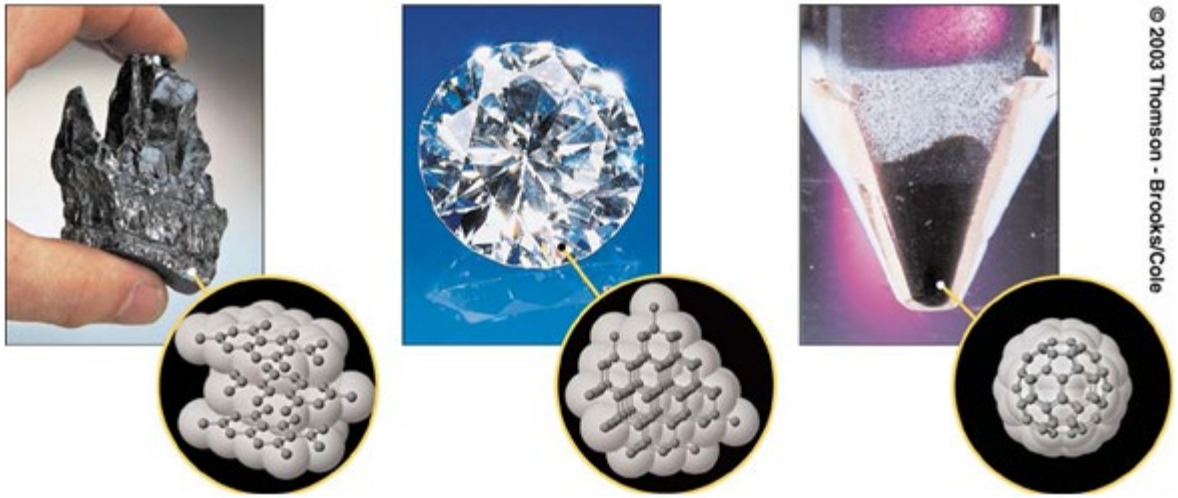


Carbon

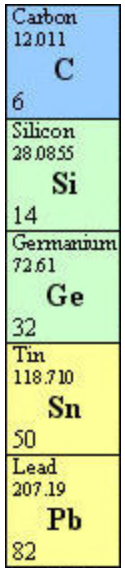
Carbon
12.011
C
6
Silicon
28.0855
Si
14
Germanium
72.61
Ge
32
Tin
118.710
Sn
50
Lead
207.19
Pb
82

- With the possible exception of hydrogen, more compounds contain carbon than any other element. The chemistry of carbon compounds is so diverse that an entire field of chemistry is devoted to it – organic chemistry *(seen in CHEM 2000).*

- There are three main allotropes of carbon:
  - Graphite, a network solid
  - Diamond, a network solid
  - Fullerenes, most commonly C_{60} (buckminsterfullerene – the "bucky ball")

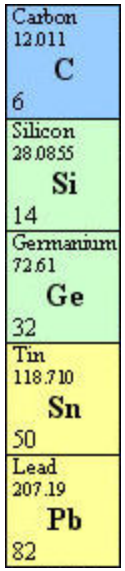


Carbon



- Graphite has many uses:
  - It's used as a lubricant because, while the atoms within a layer are tightly bonded, the layers themselves are held together loosely.
  - For the same reason, it's also used as the "lead" in pencils.
  - Unlike most nonmetals, it can conduct electricity and is used to make electrodes in batteries and for electrolysis.
  - The extremely high temperatures at which it remains solid mean that it is also useful in many high temperature environments (e.g. furnaces).
- While graphite is relatively soft and flaky, the three-dimensional network of diamond makes it the hardest substance known. It's therefore useful to make drill bits and abrasives.
- Fullerenes are hollow molecules made up of 5- and 6-carbon rings (similar to a soccer ball).

Carbon



- You already know the two major oxides of carbon:
  - Like the oxides of the other nonmetals, they are acidic:

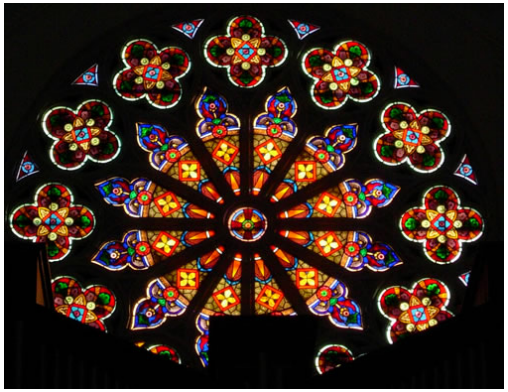
  - Draw the Lewis structure of carbon monoxide. What is unusual about it?

    For this reason, carbon monoxide is an excellent Lewis base – so much so that it can bond to iron cations in hemoglobin, preventing oxygen transport:

Silicon

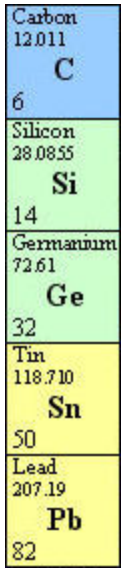
Carbon 12.011 C 6
Silicon 28.0855 Si 14
Germanium 72.61 Ge 32
Tin 118.710 Sn 50
Lead 207.19 Pb 82

- Silicon is the second most abundant element in the Earth's crust (after oxygen) and is primarily found in oxoanions (silicates). Its neutral oxide (silica) has the chemical formula SiO_2 but, unlike CO_2, does not exist as discrete molecules.
  - If silica does not exist as discrete molecules, what must its structure be like?



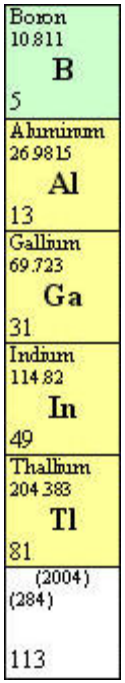
  - Silica is a very common and useful compound
    - Sand and quartz are both forms of silica.
    - Silica that has been melted and resolidified without being allowed to crystallize is glass (an **amorphous solid**).
  - Silica is weakly acidic, slowly dissolving in strong bases:

Tin and Lead



- As the two metals in Group 14, tin and lead have significantly lower melting points than carbon, silicon and germanium.
- Tin and lead can both form cations. What are the electron configurations of the two tin cations? Why is Sn^{3+} not feasible?
- Many compounds of tin and lead are highly toxic; however, while elemental lead is toxic, elemental tin is not. In fact, tin is an essential element (in the right form).

A Few Words About Boron (Group 13)

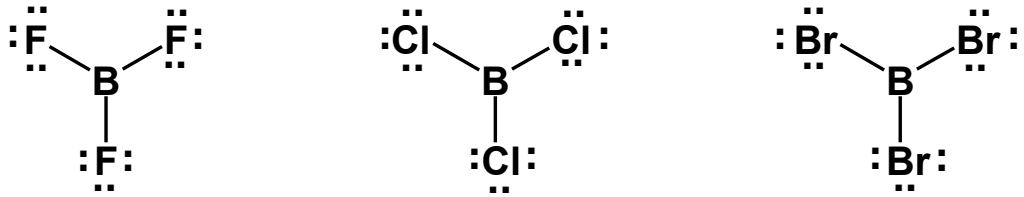


- Boron is the only element in Group 13 that is not a metal. *(Some introductory texts call it a nonmetal; others a metalloid. Because it is a semi-conductor, we will classify it as a metalloid.)*
- Boron does not react with oxygen, water, acids or bases (though some boron-containing compounds will react with these substances).
- In crystalline form, boron is one of the hardest substances on Earth. Scoring 9.3 on the Mohs scale of hardness, crystalline boron can scratch most substances other than diamond (which scores a perfect 10).

A Few Words About Boron (Group 13)

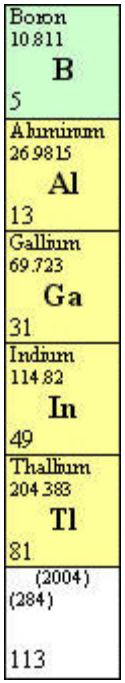
Boron
10.811
B
5
Aluminum
26.9815
Al
13
Gallium
69.723
Ga
31
Indium
114.82
In
49
Thallium
204.383
Tl
81
(2004)
(284)
113

- We have already seen a few boron-containing compounds in CHEM 1000:



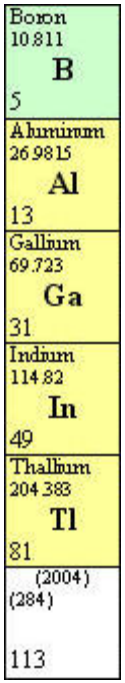
- Each of these compounds is an excellent Lewis acid. Why?

A Few Words About Boron (Group 13)



- Pure borane (BH_3) has never been isolated. It is presumably a good Lewis acid because if borane is made in a solvent that is a good Lewis base, a Lewis acid-base complex forms:

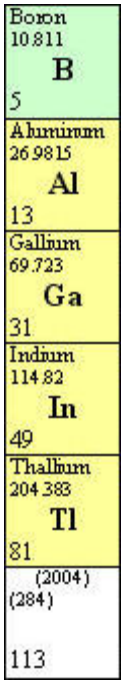
A Few Words About Boron (Group 13)



- If borane is made without another Lewis base present, it undergoes a Lewis acid-base reaction with itself. The simplest example of this reaction gives diborane (B_2H_6):

- B_2H_6 contains two bonds in which three atoms share one pair of electrons. The two central hydrogen atoms are each part of a **three-atom two-electron bond** with both boron atoms.

A Few Words About Boron (Group 13)



- Given the limitations of some drawing software, you may sometimes see B_2H_6 drawn like this:

- It is important to understand that the picture above is not a true Lewis diagram. There are only 12 valence electrons in B_2H_6, but this picture looks like it's showing 8 bonds (16 electrons).

- Why is it more favourable to have one B_2H_6 molecue rather than two BH_3 molecules?

A Few Words About Boron (Group 13)

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

- Diborane is just one of many boranes that form. Many larger boranes form in a similar fashion:

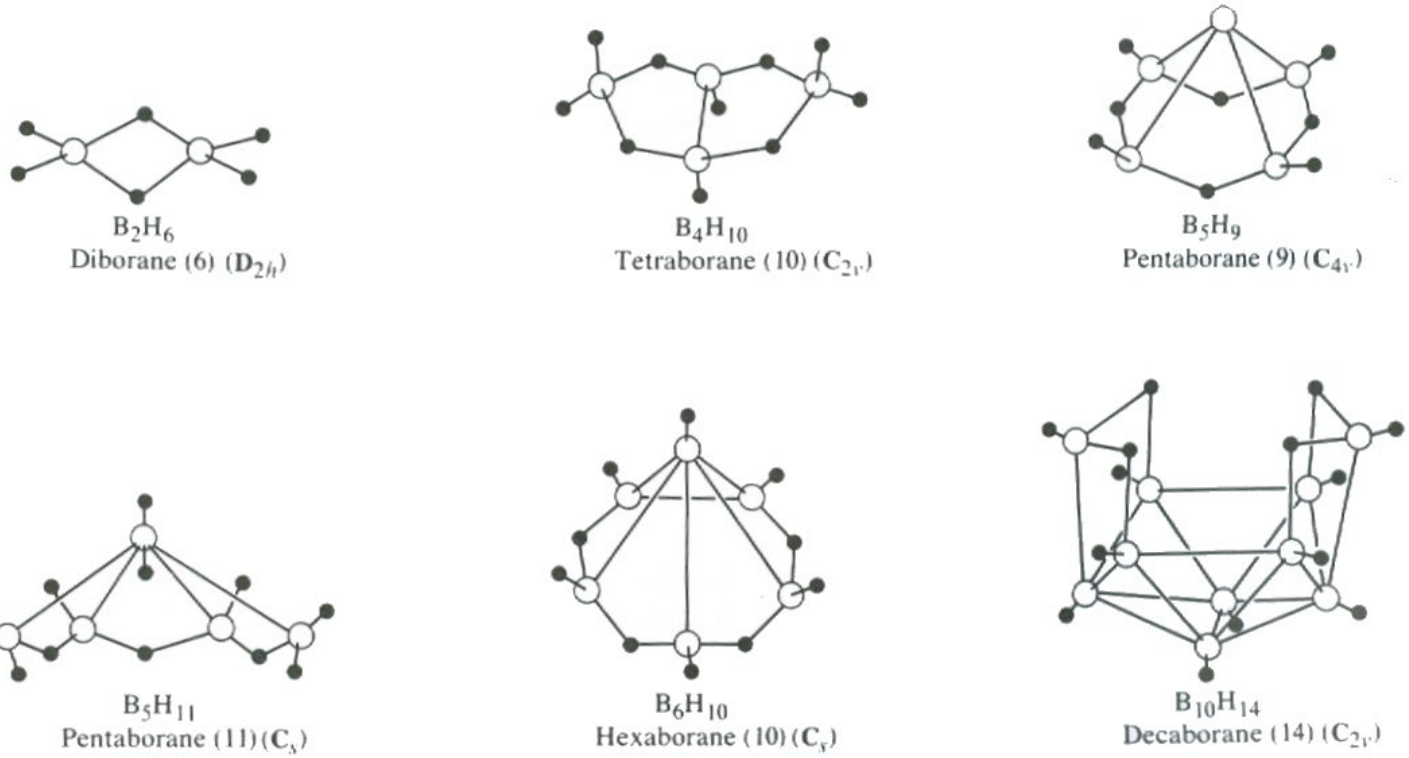


Figure 17.1 Structures of Stock's boron hydrides. (From S. G. Shore in *Boron Hydride Chemistry*, E. L. Muetterties, Ed., Academic Press, New York, 1975.)