Group 14: The Carbon Family

- Electron configuration is $ns^2np^2$ ($n$ is the period number)
- The half filled orbital allows this group to straddle the line between metal and non-metal
- The elements show increasing metallic character as you go down a group
- The heavier elements of the group are more likely to keep their s electrons and can have oxidation numbers of +2 or +4
Group 14: The Carbon Family

Elements (Carbon)

- Central element to life and natural intelligences
- Carbon has nonmetallic properties
- Forms Covalent bonds with nonmetals and ionic bonds with metals
- Small radium allows for the wide occurrence of C=C and C=O bonds in compounds
- Carbon is the only member of group 14 that commonly forms multiple bonds with itself
Group 14: The Carbon Family

Elements (Silicon)

- Central element to electronic technology and artificial intelligences.
- Larger atomic size than C which results in relatively few compounds that have Si=Si and Si=O bonds.
- Si compounds can act as Lewis acids where as C compounds typically cannot.
- Si compounds can expand its valence shell by using its d electrons thereby allowing for the accommodation of lone pair electrons of an Lewis base.
Two most common phases of carbon are graphite and diamond.
Group 14: The Carbon Family

Elements (Forms of Carbon)

**Diamond**

- $sp^3$ Hybridized carbon (tetrahedral)
- Only C-C $\sigma$ bonds

**Properties:**
- Rigid
- Transparent
- Electrically insulating
- Solid
- Good conductor of heat

**Uses In:**
- Abrasives
Graphite

- $sp^2$ hybridized carbon in a hexagonal network
- Electrons are free to move from one carbon to another through $\pi$ network formed by the overlap of unhybridized $p$-orbitals on each of the carbon atoms

**Properties:**
- Black
- Lustrous
- Electrically conductive
- Slippery

**Uses In:**
- Electrical conductors in industry
- Electrodes in electrochemical cells
- Lubricants
- Lead in pencils
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Elements (Forms of Carbon)

Soot and Carbon Black
Contains very small crystals of graphite

Made:
Heating gaseous hydrocarbons near 1000°C in the absence of air

Uses In:
Reinforcing rubber, pigment, and printing ink

Activated Carbon (Activated Charcoal)
Contains granules of microcrystalline carbon

Made:
Heating waste organic matter in the absence of air and then processing it to increase the porosity, producing a very high specific surface area.

Uses In:
Air purifiers, gas masks, aquarium water filters, water purification plants (remove organic compounds from drinking water)
Fullerenes

- Soccer ball shaped carbon molecules
- Different numbers of carbon atoms
- Scientists are investigating whether they would be able to hold an atom of another element

10 Buckminsterfullerene, $C_{60}$
Group 14: The Carbon Family

Elements (Silicon)

- Second most abundant atom in the earth’s crust
- Occurs widely in rocks as silicates (compounds containing the silicate ion, $\text{SiO}_3^{2-}$)
- Pure silicon is obtained by reduction of quartzite (a granular form of quartz) with high purity carbon in an electric arc furnace

$$\text{SiO}_2(s) + 2\text{C}(s) \xrightarrow{\Delta} \text{Si}(s) + 2\text{CO}(g) \quad \text{(crude is exposed to Cl}_2 \text{ (g))}$$

$$\text{SiCl}_4(l) + 2\text{H}_2(g) \rightarrow \text{Si}(s) + 4\text{HCl}(g) \quad \text{(purer form of element)}$$

- Further purification is necessary before silicon can be used in the semiconductor industry
Group 14: The Carbon Family

Elements (Germanium and Tin)

- Germanium is recovered from the flue dust of industrial plants processing zinc ores (it occurs as an impurity in zinc).
- Germanium is mainly used in the semiconductor industry.
- Tin is easily obtained from its ore (cassiterite (SnO$_2$)) by reduction with carbon.

\[
\text{SnO}_2(s) + C(s) \xrightarrow{1200^\circ C} \text{Sn}(l) + \text{CO}_2(g)
\]

- Tin is expensive and not very strong but it is resistant to corrosion. Its main use is in tin plating and used in alloys such as bronze.
Group 14: The Carbon Family

Elements (Lead)

- Lead is also easily obtained from its ore (galena (PbS)) and converted to its oxide and then reduced with coke (form of carbon)

\[
2\text{PbS(s)} + 3\text{O}_2(g) \xrightarrow{\Delta} 2\text{PbO(s)} + 2\text{SO}_2(g)
\]

\[
\text{PbO(s)} + \text{C(s)} \rightarrow \text{Pb(s)} + \text{CO(g)}
\]

- Lead is durable and malleable which makes it useful in the construction industry

- In addition, lead is very dense which makes it ideal as radiation shields from x rays

- Lead is also used as electrodes for rechargeable batteries
CO₂ (Carbon dioxide)

- Formed when organic matter burns in the air and when animals exhale.
- CO₂ is always present in air but the burning of fossil fuels is increasing the amount of CO₂ in the air which is then leading to global warming.
- CO₂ is an acid anhydride of carbonic acid.
  \[ \text{CO}_2(g) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_2\text{CO}_3(aq) \]
- Carbonated beverages have high partial pressures of CO₂ to drive the equilibrium to H₂CO₃ when the beverage is opened the equilibrium shifts to produce CO₂.
**Group 14: The Carbon Family**

**Compounds (Oxides of Carbon)**

**CO (Carbon monoxide)**

- Formed when carbon burns in the a limited source of air
- This happens in cigarettes and badly tuned automobile engines
- CO is the formula anhydride to formic acid (HCOOH)
- CO can be produced in the laboratory by the dehydration of formic acid with hot, concentrated sulfuric acid

\[
\text{HCOOH}(l) \xrightarrow{150^\circ C, H_2SO_4} \text{CO}(g) + \text{H}_2\text{O}(l)
\]

- CO is a reducing agent and is used in the production of a number of metals, most notably iron in blast furnaces

**Properties:**
- Colorless
- Odorless
- Flammable
- Almost Insoluble
- Toxic Gas
SiO$_2$ (Silica)

- Occurs naturally in quartz,
- Sand is usually small fragments of quartz. The golden brown color is caused by iron oxide impurities
- Silica gets its strength from its covalent bonding network structure.

Properties:
- Hard
- Rigid network solid
- Insoluble in water

Red = Silicon
Purple = Oxygen
Silicates can be viewed as various arrangements of tetrahedral oxoanions (an anion of an acid that contains oxygen) of silicon in which each Si-O bond has considerable covalent character.

Differences in the internal structure of these highly regular network solids lead to a wide array of materials, ranging from gemstones to fibers.
ZnSiO$_4$ (Zircon)

- Used as a substitute for diamonds in costume jewelry

Ca$_2$Mg$_5$(Si$_4$O$_{11}$)$_2$(OH)$_2$ (Tremolite or Asbestos)

- Fibrous material which can withstand extreme heat (once widely used for insulation in buildings) however fibers can lodge in lung tissue where fibrous scar tissue forms leading to lung cancer
Silicones

- Synthetic materials that consist of long -O-Si-O-Si- chains with the remaining silicon bonding positions occupied by organic groups such as the methyl group (-CH₃)

- Silicones are used to waterproof fabric because their oxygen atoms attach to the fabric, leaving the hydrophobic methyl groups like tiny inside out umbrellas sticking out of the fabrics surface
Carbides: Form when a carbon atom bonds with a less electronegative element (In other words carbon acts as an anion)

Carbon is the only group 14 element that will form an anion

Three types of carbides: saline carbides, covalent carbides, and interstitial carbides
Saline Carbides are formed when metals of group 1 and 2, aluminum, and a few other metals form ionic bonds with carbon.

The s-block metals form saline carbides when their oxides are heated with carbon.

The anions present in saline carbides are either $C_2^{2-}$ or $C_4^{-}$.

$C_4^{-}$ carbides are called methides because they produce methane and the corresponding hydroxide in water:

\[
\text{Example:} \quad \text{Al}_4\text{C}_3(s) + 12\text{H}_2\text{O}(g) \rightarrow 4\text{Al(OH)}_3(s) + 3\text{CH}_4(g)
\]

The methide ions are very strong Bronstead bases.
The species $C_2^{2-}$ is the acetylide ion and the carbides are commonly called acetylides.

Acetylide ions are very strong Bronsted bases.

Acetylides react with water to produce ethyne ($C_2H_2$) and the corresponding hydroxide.

CaC$_2$ (calcium carbide) is the most common saline carbide.
Group 14: The Carbon Family

Compounds (Covalent Carbides)

- When carbon reacts with an atom that is only slightly less electronegative than itself and is about the same size, a covalent carbide is formed.
- The most common well known covalent carbide is silicon carbide (SiC)
Group 14: The Carbon Family

Compounds (Interstitial Carbides)

- Interstitial carbides are the compounds formed by the direct reaction of a $d$-block metal and carbon at temperature above 2000°C
- In these compounds the C atoms occupy the gaps between the metal atoms pinning the metal atoms together into a rigid structure
- The materials are very hard and often have melting points well above 3000°C
Group 14: The Carbon Family

Common Reactions

**Reaction with Halogens**
\[ M + 2X_2 \rightarrow MX_4 \]
\( X_2 = \) any group 17 molecule,
\( M = \) Ge or Sn; Pb gives PbX₂

**Reactions with O**
\[ M + O_2 \rightarrow MO_2 \]

**Reactions with the ions**
\[ M + 2H^+ \rightarrow M^{2+} + H_2 \]
\( M = \) Sn or Pb