Section 10.5
The Solid State of Matter

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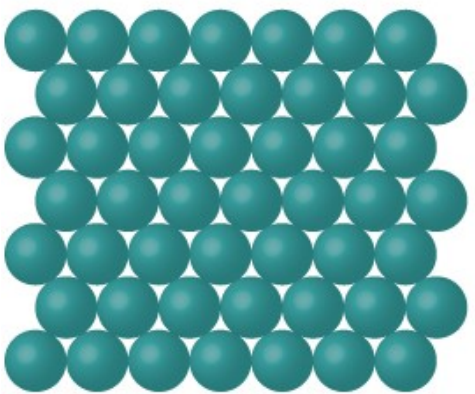
Learning Objectives

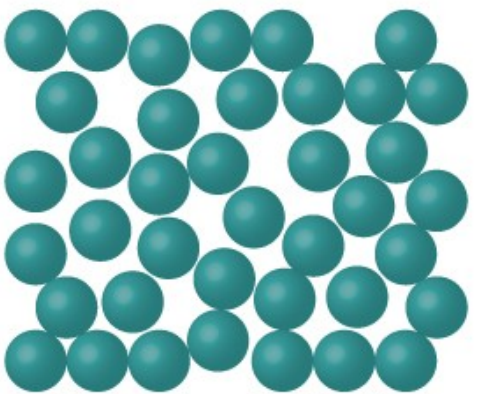
- Define and describe the bonding and properties of ionic, molecular, metallic, and covalent network crystalline solids
- Describe the main types of crystalline solids: ionic solids, metallic solids, covalent network solids, and molecular solids
- Explain the ways in which crystal defects can occur in a solid

Crystalline vs. Amorphous

- **Crystalline Solids** have atoms, ions, or molecules that are arranged in a definite repeating pattern.
- **Amorphous Solids (noncrystalline solids or glasses)** have particles that lack an ordered internal structure and are randomly arranged.



Crystalline



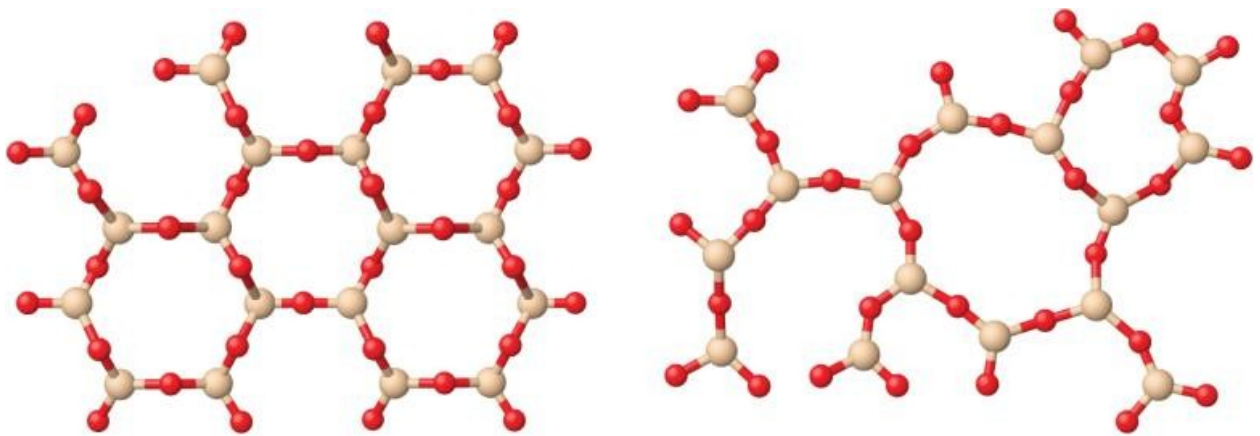
Amorphous

Why One over Another?

- Metals and ionic compounds typically form ordered, crystalline solids.
- Substances that consist of large molecules, or a mixture of molecules whose movements are more restricted, often form amorphous solids.
- Sometimes it depends on the conditions under which the solid formed.

Silicon Dioxide

- (a) Silicon dioxide, SiO_2, is abundant in nature as one of several crystalline forms of the mineral quartz.
- (b) Rapid cooling of molten SiO_2 yields an amorphous solid known as “fused silica”.



Ionic Solids

- **Ionic Solids** are composed of positive and negative ions that are held together by electrostatic attractions.
- Ionic Interactions are often strong than covalent interactions.
  - Ionic solids will have higher melting points than molecular solids.
- They are hard and brittle.
- Ionic solids do not conduct electricity but molten ionic liquids do.

Ionic Solids

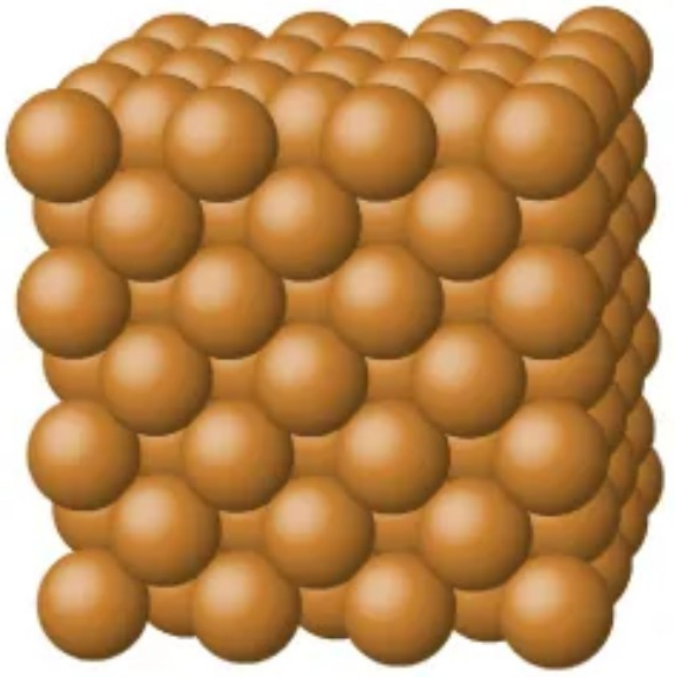
- These solids are usually formed from the the reaction of a metal with a nonmetal.
- Sodium chloride is an ionic solid.

Metallic Solids

- **Metallic Solids** are crystalline structures formed from metal atoms.
- Atoms are held together by a unique force known as **metallic bonding** that gives rise to many useful and varied bulk properties.
- They exhibit high thermal conductivity, electrical conductivity, metallic luster, malleability, and ductility.
- They typically have lower melting points than ionic solids

Metallic Solids

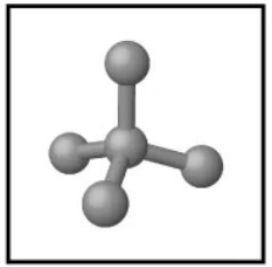
- Metallic crystals are often described as a uniform distribution of atomic nuclei within a “sea” of delocalized electrons.
- Copper is a metallic solid.

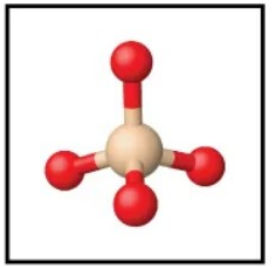


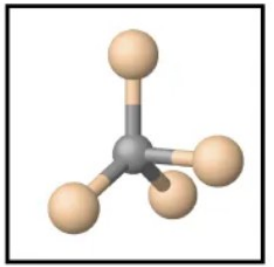
Covalent Network Solid

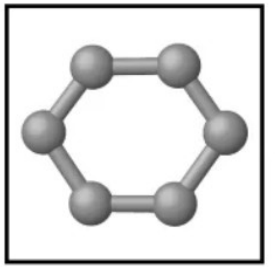
- **Covalent network solids** are held together by interconnecting network of covalent bonds.
- To break or to melt a covalent network solid, covalent bonds must be broken.
- They are typically hard and strong materials with high melting points.
- Diamond is one of the hardest substances known and melts above 3500 °C.

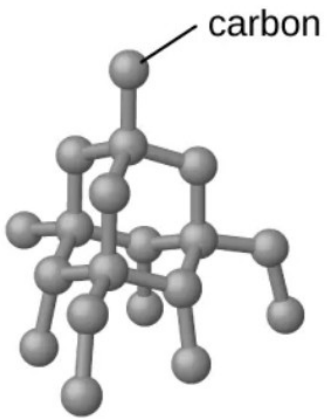
Covalent Network Solids

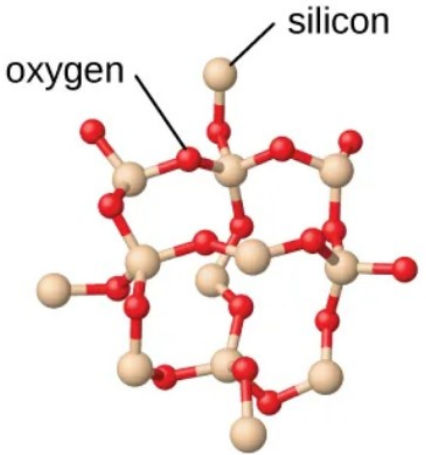


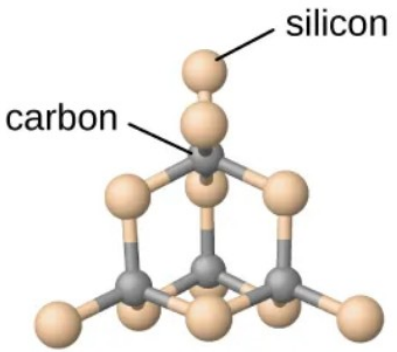


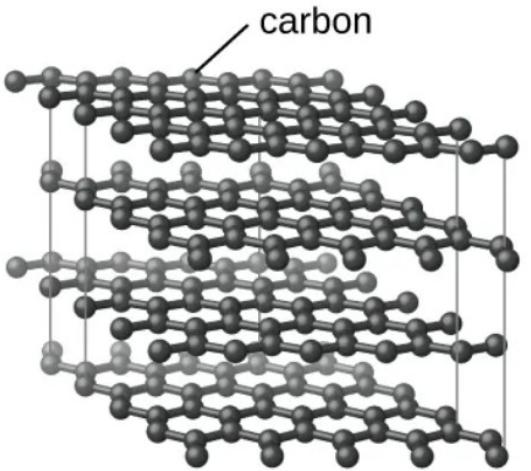










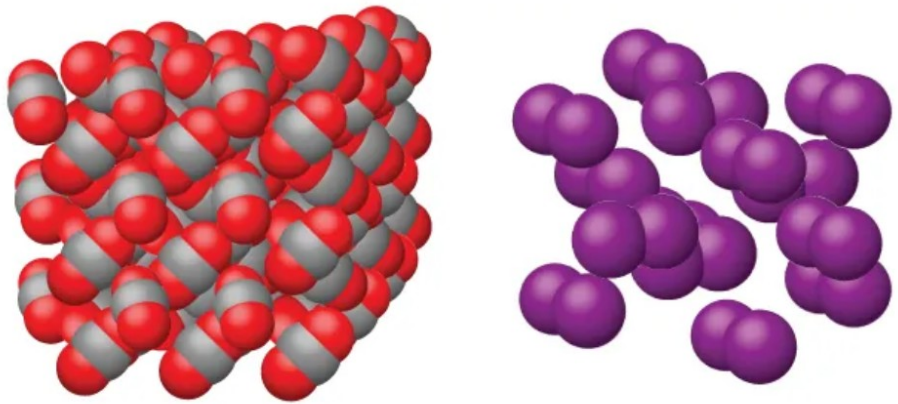


Molecular Solids

- **Molecular solids** are composed of neutral molecules.
- The strengths of the attractive forces between the units present in different crystals vary widely, as indicated by the melting points of the crystals.
- As the IMFs of the molecules increase in the strength the melting points rise.
  - Small molecule dispersive < Large Molecule Dispersive < Dipole-Dipole

Molecular Solids

- Carbon dioxide (CO_2) consists of small, nonpolar molecules and forms a molecular solid with a melting point of −78 °C. Iodine (I_2) consists of larger, nonpolar molecules and forms a molecular solid that melts at 114 °C.



carbon dioxide iodine

Properties of Solids

Type of Solid	Type of Particles	Type of Attractions	Properties	Examples
ionic	ions	ionic bonds	hard, brittle, conducts electricity as a liquid but not as a solid, high to very high melting points	NaCl, Al_2O_3
metallic	atoms of electropositive elements	metallic bonds	shiny, malleable, ductile, conducts heat and electricity well, variable hardness and melting temperature	Cu, Fe, Ti, Pb, U
covalent network	atoms of electronegative elements	covalent bonds	very hard, not conductive, very high melting points	C (diamond), SiO_2, SiC
molecular	molecules (or atoms)	IMFs	variable hardness, variable brittleness, not conductive, low melting points	H_2O, CO_2, I_2, $C_{12}H_{22}O_{11}$

Crystal Defects

- Occasional defects may occur in the pattern of a crystalline solid.
- **Vacancies** are defects that occur when positions that should contain atoms or ions are vacant.
- Sometimes atoms may occupy “out of place” locations called **interstitial sites**.
- Sometimes impurities are trapped in the crystal lattice.
- The practice of intentionally including impurities to produce desired properties is called **doping**.

Crystal Defects

- Types of crystal defects include vacancies, interstitial atoms, and substitutions impurities.