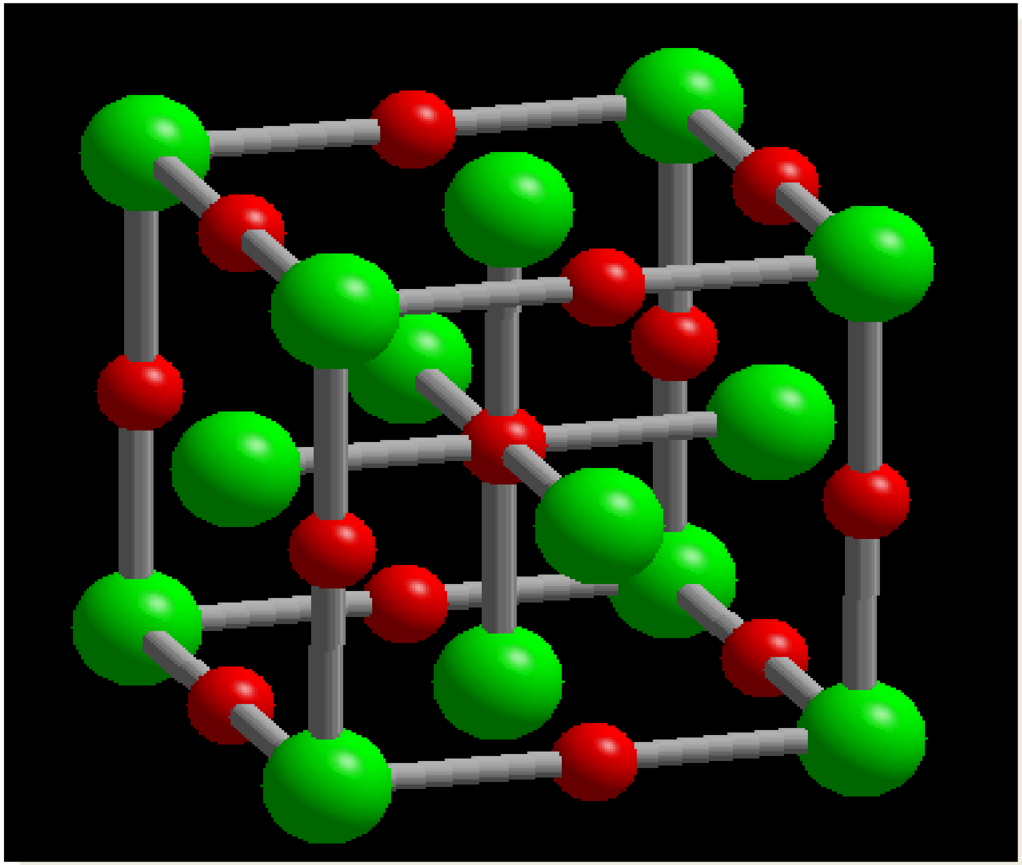
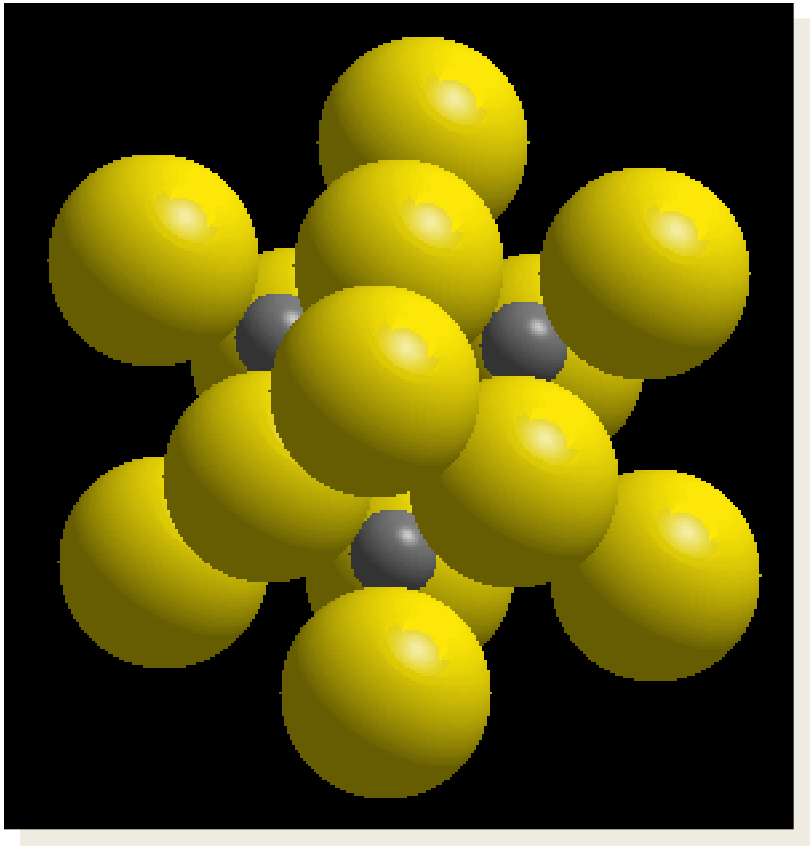
Solids



Adapted from a presentation by Dr. Schroeder, Wayne State University

Properties of Solids

- Definite shape, definite volume
- Particles are CLOSE together, so…
- Attractive forces (bonds or IMF's) are strong
- Often highly ordered,
- Rigid, incompressible



ZnS, zinc sulfide

SOLIDS can be arranged into two categories:

- **Crystalline Solids:** have a regular structure in which particles pack in a repeating pattern from one edge of the solid to another.

- **Amorphous Solids:** "solids without form" have random structure and little long-range order. Includes glass and many plastics.

CRYSTALLINE SOLIDS

- There are four types of crystalline solids
- Classified on a basis of the bonding or attractive force holding them together

1. Molecular solids ⇒ IMF's
2. Covalent solids ⇒ covalent bonds
3. Ionic solids ⇒ ionic bonds
4. Metallic solids ⇒ metallic bonds

1. Molecular Solids

- **Composed of atoms or molecules held together by IMF's**
- **Relatively soft, low mp's, bp's, etc.**
- Water, carbon dioxide, NH_3, Iodine (I_2), sugar ($C_{12}H_{22}O_{11}$), and polyethylene are typical examples.

<u>Example</u>: Dry ice (CO_2) sublimes at -78°C.

Strong *intra*molecular (covalent) bonds

O=C=O

Weak intermolecular forces → London forces

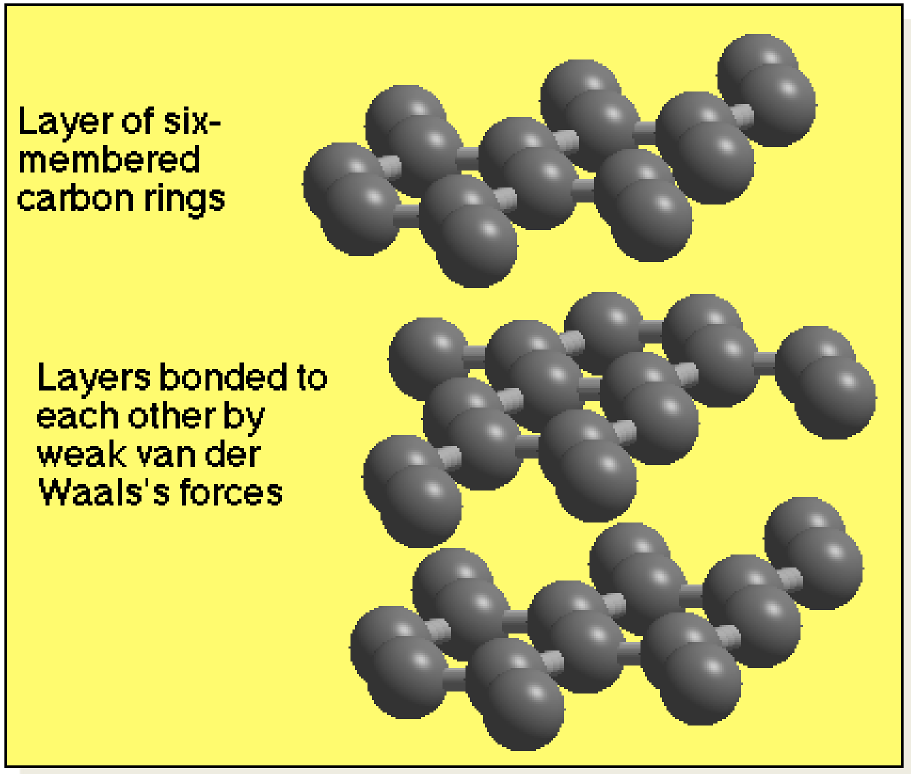
O=C=O

δ- δ+ δ -

Symmetric molecule, nonpolar

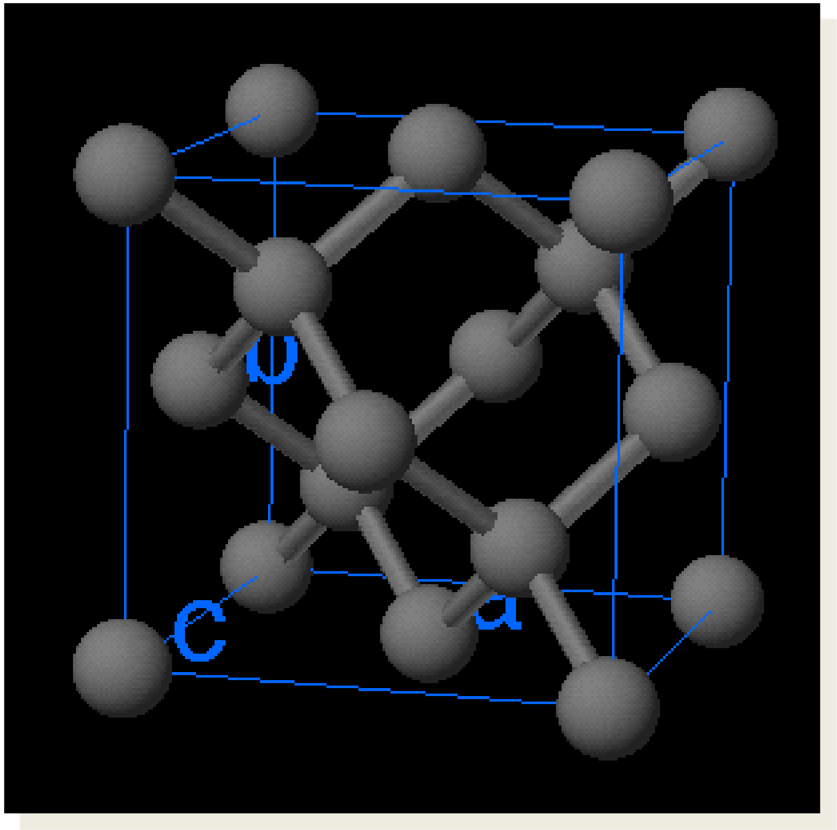
2. COVALENT SOLIDS

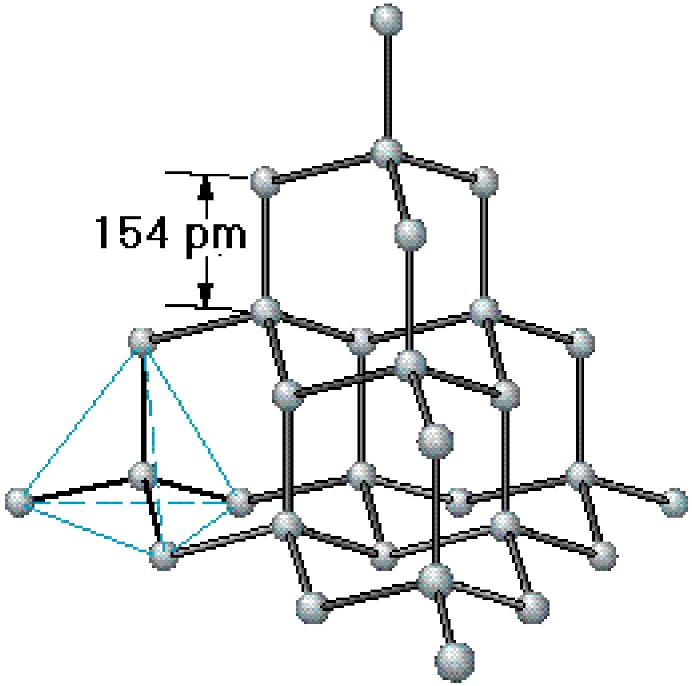
- *aka "covalent network solids"*
- Form crystals that can be viewed as a single "giant" molecule held together by an endless number of covalent bonds.
- Diamond is an example of a covalent solid. Diamond is hard and difficult to melt (mp = 3,550^{o}C) because all bonds are equally strong. Also graphite, quartz, and asbestos.



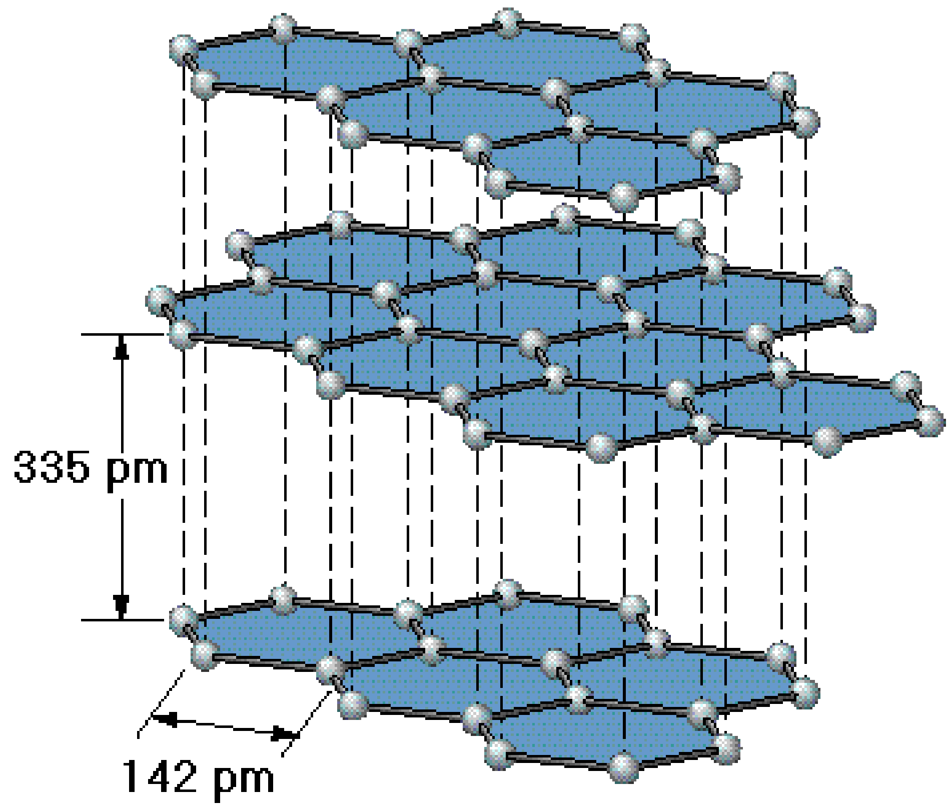
Graphite

Diamond





Diamond



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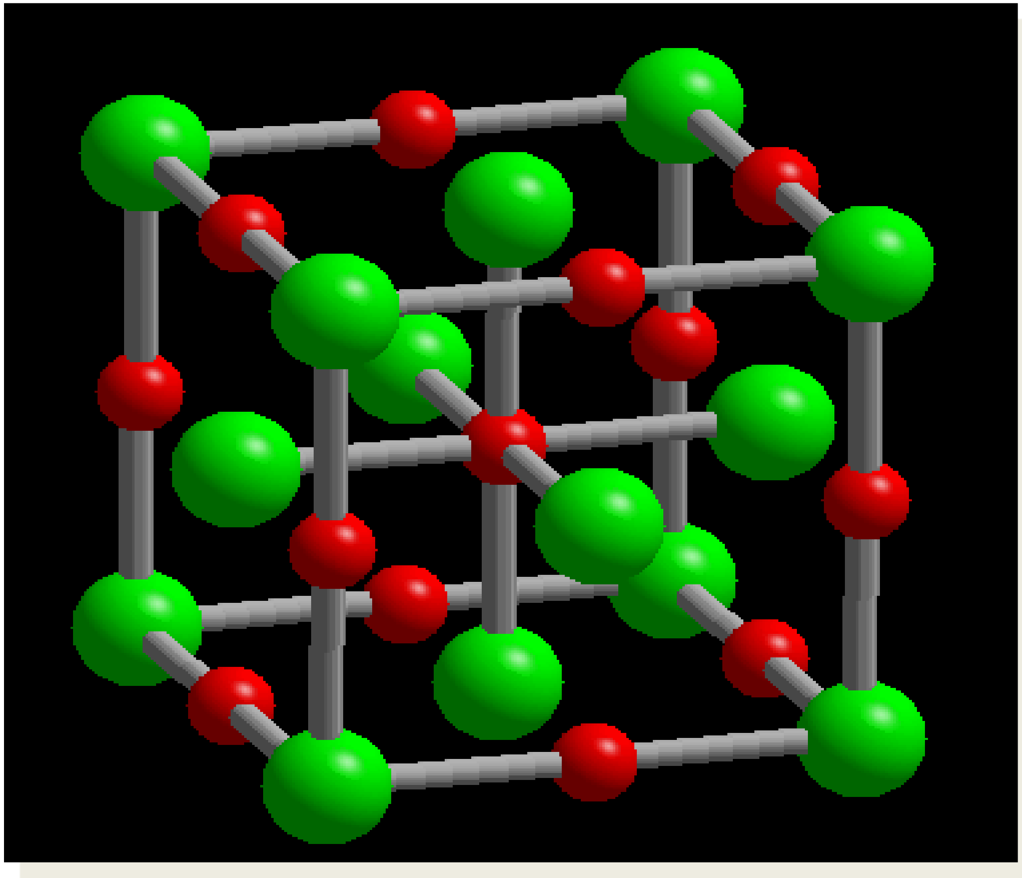
Solids



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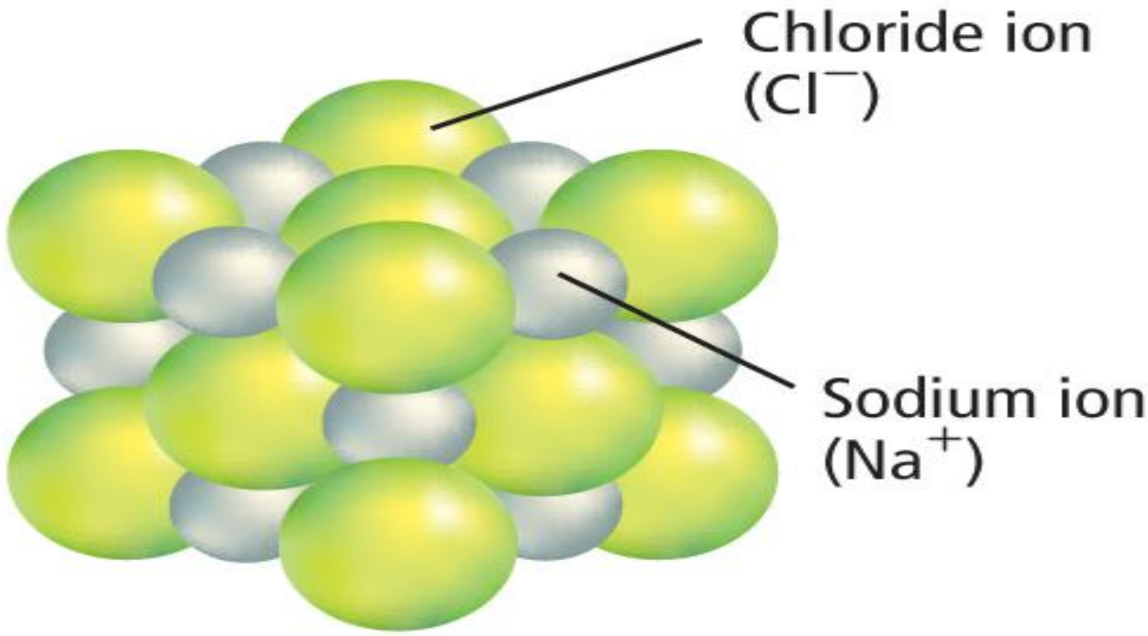
3. IONIC SOLIDS

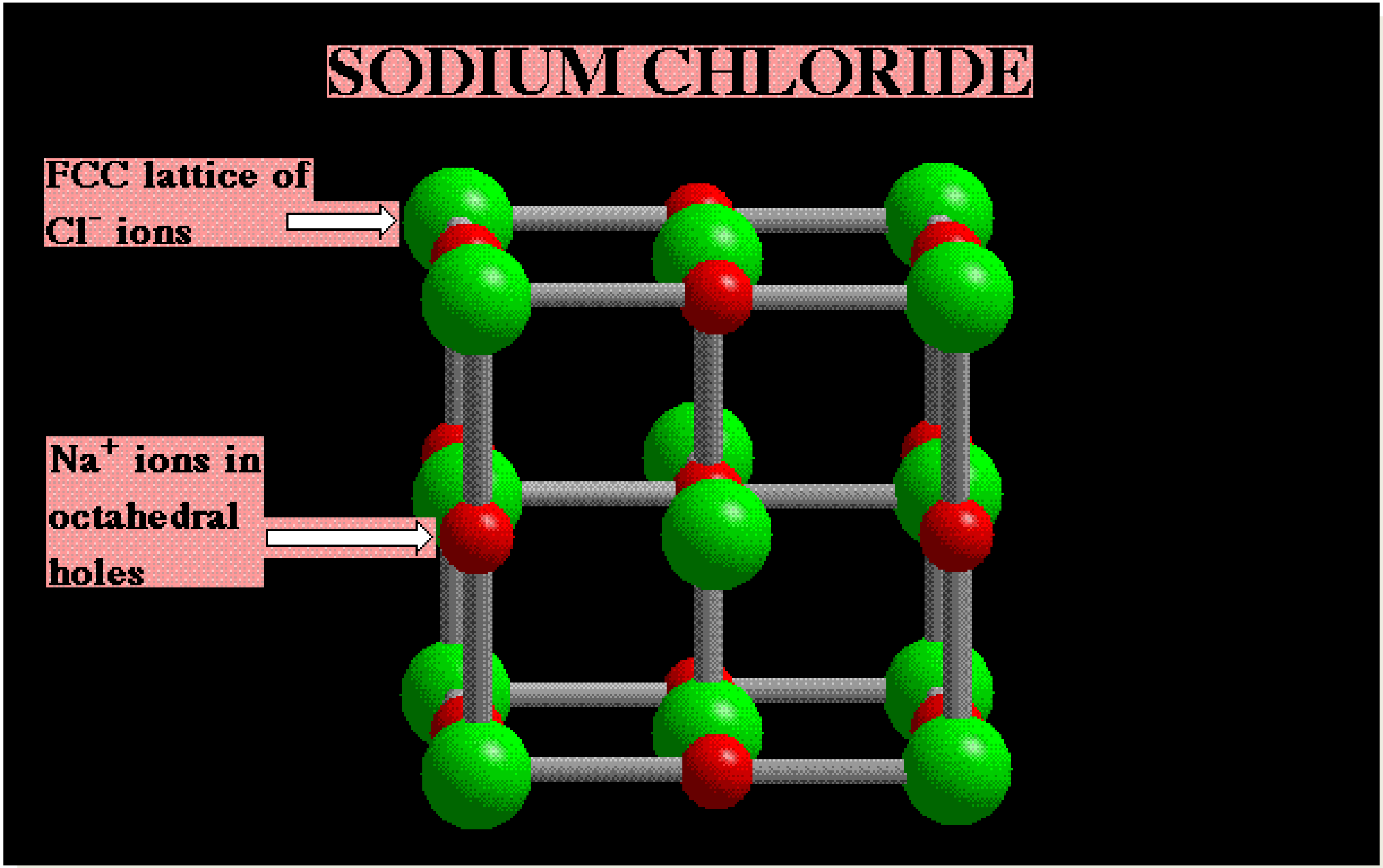
- Are held together primarily by the strong force of attraction between oppositely charged ions (ionic bonds)
- Are typically hard, brittle, and insulators
- Will conduct as liquids or in aqueous solutions
- High mp’s and bp’s
- **NaCl** and **CsF** are typical examples.

Ionic Compounds

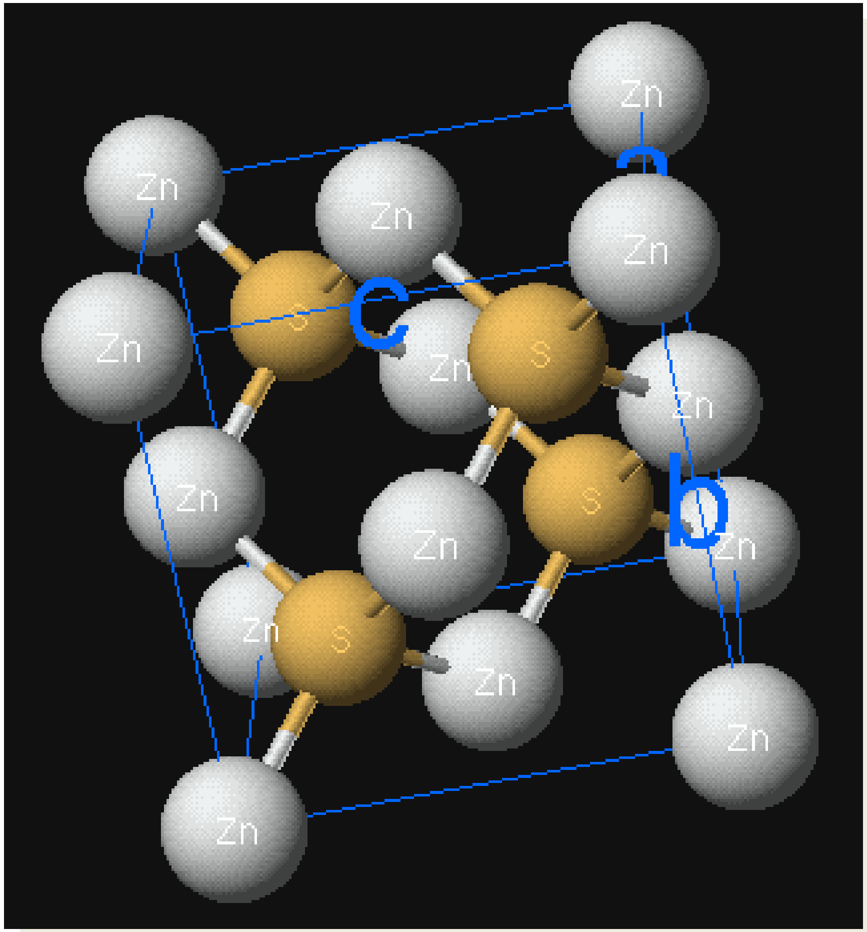
- As solids, exist in a 3-D repeating pattern called a crystal "lattice"



Sodium chloride crystal

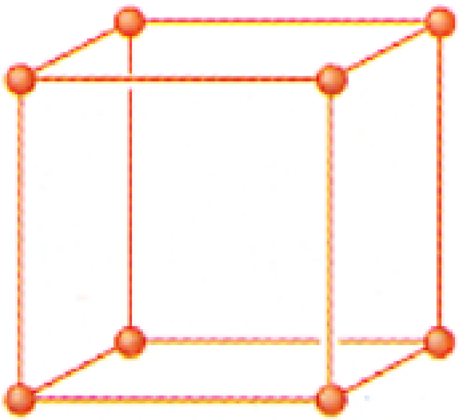

SODIUM CHLORIDE
FCC lattice of
Cl⁻ ions
Na⁺ ions in
octahedral
holes

Common Ionic Solids

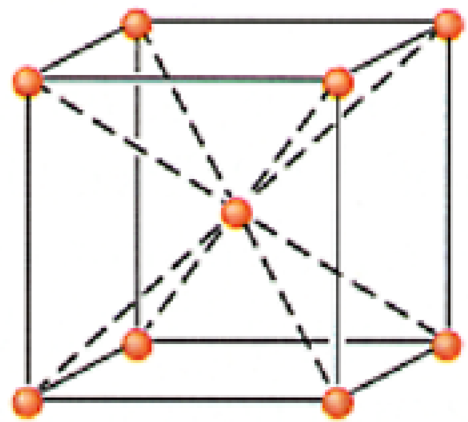


- Zinc sulfide, ZnS
- The S^{2-} ions are in **TETRAHEDRAL** holes in the Zn^{2+} FCC lattice.
- This gives 4 net Zn^{2+} ions and 4 net S^{2-} ions.

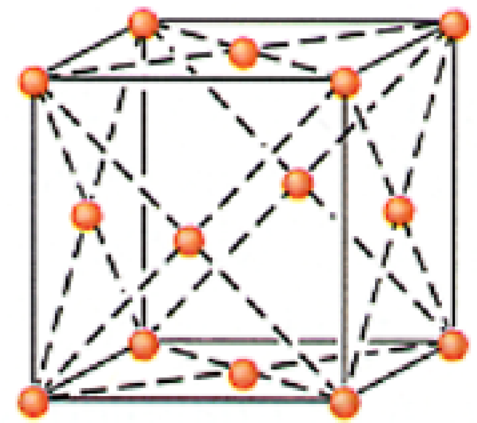
Crystal Systems



Simple cubic



Body-centered cubic



Face-centered cubic

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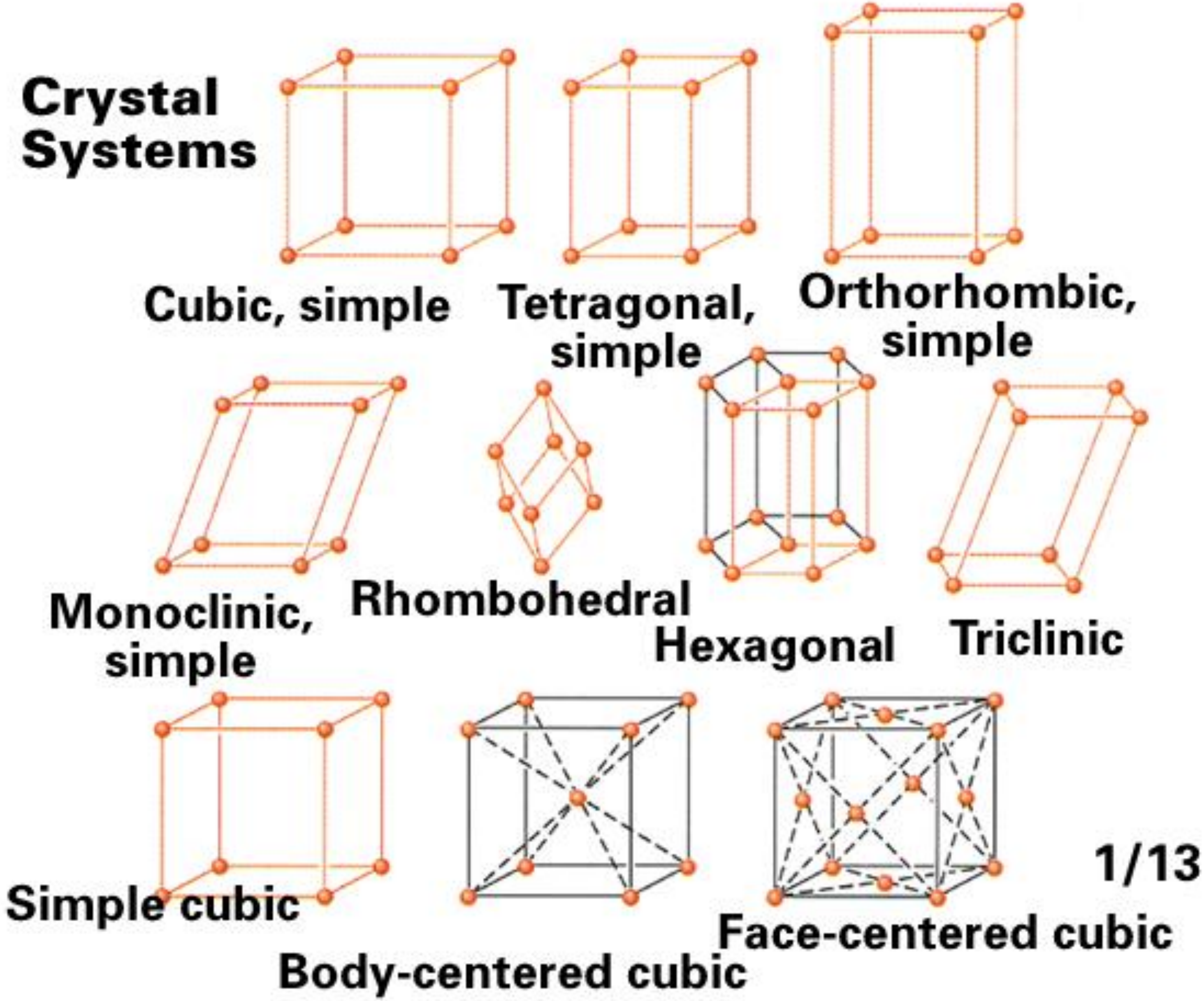

Crystal
Systems
Cubic, simple
Tetragonal,
simple
Orthorhombic,
simple
Monoclinic,
simple
Rhombohedral
Hexagonal
Triclinic
Simple cubic
Body-centered cubic
Face-centered cubic
1/13

Ion dissociation

- Many ionic compounds will dissolve in water if it results in lower E (more stability) than in the solid ionic compound
- the ions "dissociate" from each other
- Ex: $CaCl_{2(s)} + H_2O \rightarrow Ca^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$

Ionic Bond Strength:

A measure of the attractive force between the ions

Ionic bonds are generally stronger when there are:

1. Larger charge magnitude
2. smaller ions
3. smaller atom ratio

- evidence: melting points

$$F = \frac{kQ_1Q_2}{r^2}$$

Compare the melting points:

- KCl : 776^{o}C
- KI : 723^{o}C

- Cl is smaller than I
- smaller ions result in stronger ionic bonds

Compare the melting points:

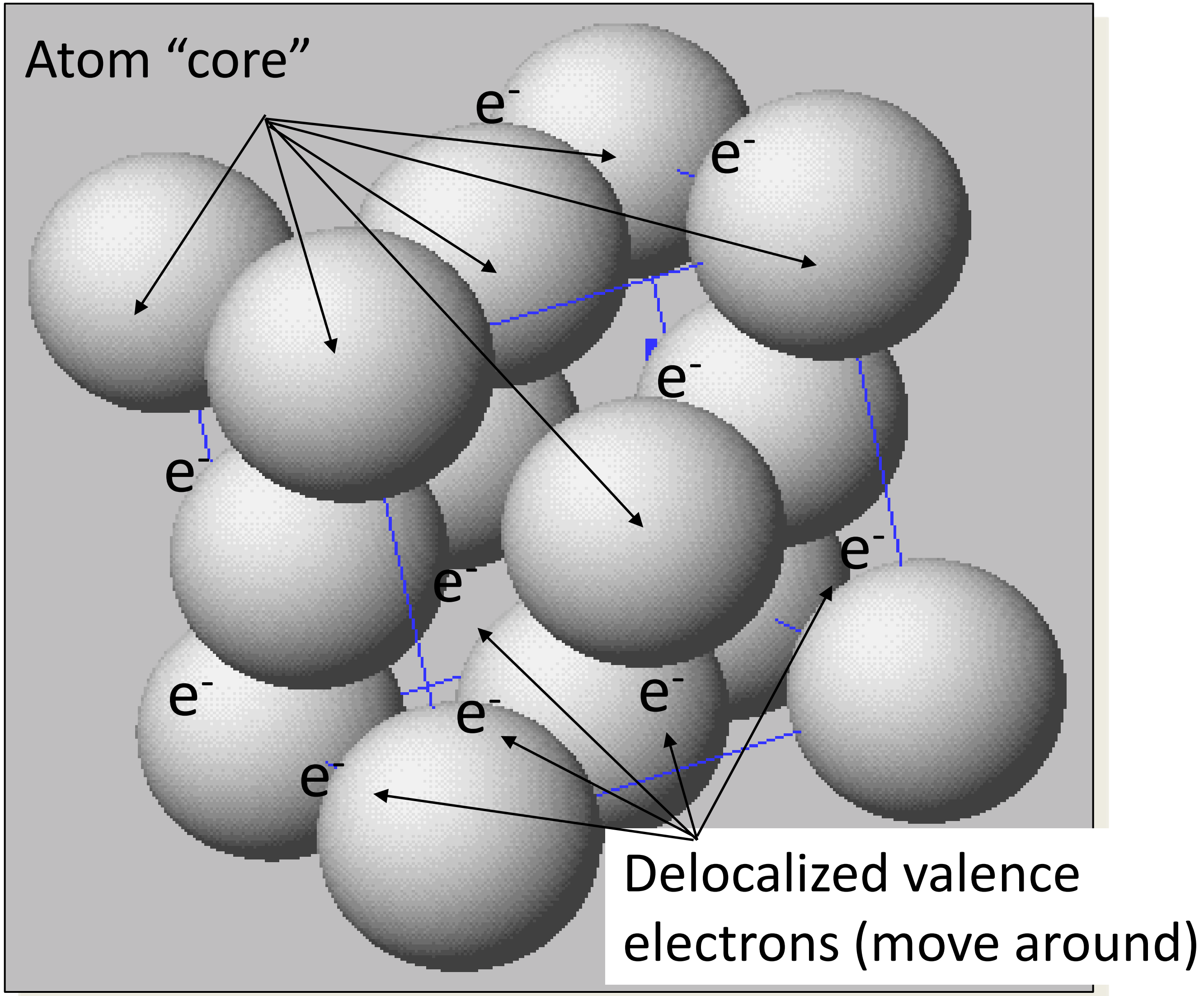
- $FeCl_3$: 306°C
- $FeCl_2$: 677°C

➢ fewer atoms (smaller subscript ratio) result in stronger ionic bonds

4. METALLIC SOLIDS

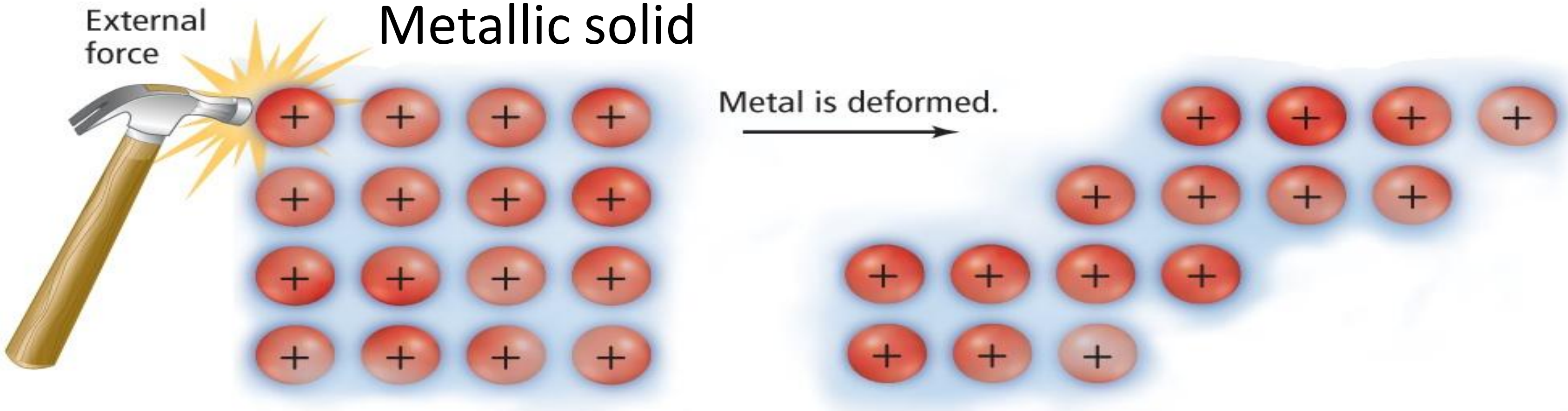
- Malleable and ductile
- Held together by "metallic bonds"
  - Have their valence electrons *delocalized* over many metal atoms.
  - For this reason most metals are good conductors.
  - "sea of electrons" model
  - Jello with fruit
- Includes Au, Fe, Al, etc.

4. METALLIC SOLIDS

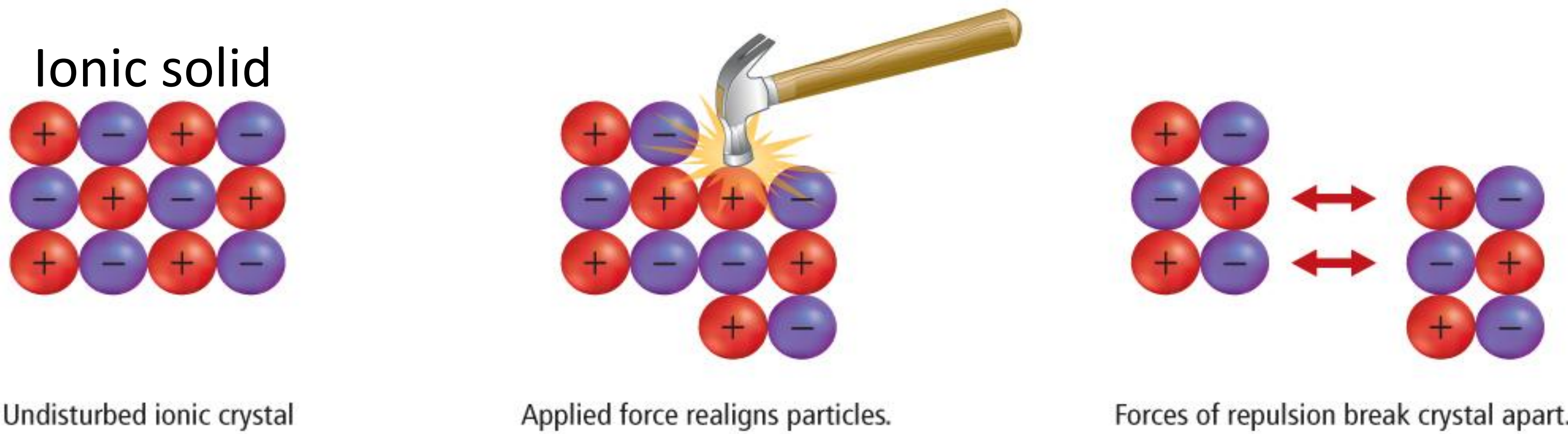


Why are metal solids malleable while ionic solids are brittle?

Metallic solid



Ionic solid



Types of Crystalline Solids

Type	Attractive forces	examples
Molecular	IMF's	Ice, dry ice, sugar
Covalent network	Covalent bonds	Diamond, graphite, gemstones
Ionic	Ionic bonds	NaCl, CaF_2, ZnS
Metallic	Metallic bonds	Na, Fe, Zn, Au

What kind of solid would this be?

$SO_2(s)$

- Properties: low melting point, crumbly, nonconducting solid or liquid when melted
- 2 nonmetals
- Molecular solid
- Exists as independent molecules
- Held together by IMF’s
- Polar molecule, so principle IMF = dipole/dipole
- Weak attractive force

What kind of solid would this be?

$SiO_2(s)$

- Properties: high melting point, hard, nonconducting solid
- Covalent network solid
- A semimetallic with a nonmetal
- NO independent molecules
- Held together by covalent bonds
- Strong attractive force

What kind of solid would this be?

$SnO_2(s)$

- Properties: high melting point, brittle, hard, nonconducting solid, but conducting as aqueous solution
- A metal with a nonmetal
- Ionic solid
- NO independent molecules
- Held together by ionic bonds
- Strong attractive force
- SnO would have a higher melting point

What kind of solid would this be?

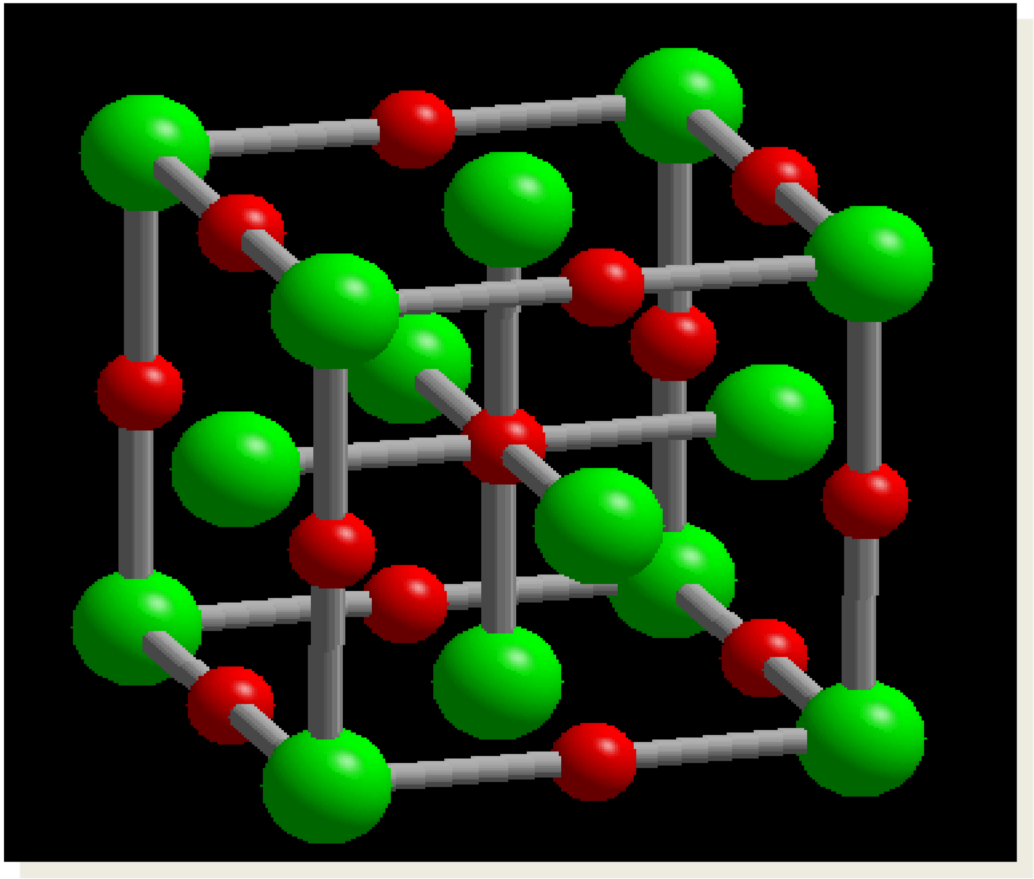
Sn(s)

- Properties: high melting point, malleable, ductile, shiney, conducting solid
- metallic solid
- Metal atoms only
- NO independent molecules
- Held together by metallic bonds
- Strong attractive force

Amorphous Solids

- No regular geometric pattern
- More “jumbled up”
- Typically long chains of molecules that get tangled up together
- Held together by IMF’s
- Classified on a basis of the strength of the IMF holding them together
- Examples: waxes, asphalt, many plastics

Solids



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