Metallic and Ionic Solids

**Section 13.4**

**Types of Solids**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>EXAMPLE</th>
<th>FORCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic</td>
<td>NaCl, CaF₂, ZnS</td>
<td>Ion-ion</td>
</tr>
<tr>
<td>Metallic</td>
<td>Na, Fe</td>
<td>Metallic</td>
</tr>
<tr>
<td>Molecular</td>
<td>Ice, I₂</td>
<td>Dipole</td>
</tr>
<tr>
<td>Network</td>
<td>Diamond, Graphite</td>
<td>Extended covalent</td>
</tr>
</tbody>
</table>

**Network Solids**

A comparison of diamond (pure carbon) with silicon.

**Properties of Solids**

1. Molecules, atoms or ions locked into a CRYSTAL LATTICE
2. Particles are CLOSE together
3. STRONG IM forces
4. Highly ordered, rigid, incompressible

**Crystal Lattices**

Regular 3-D arrangements of equivalent LATTICE POINTS in space.

The lattice points define UNIT CELLS, the smallest repeating internal unit that has the symmetry characteristic of the solid.

There are 7 basic crystal systems, but we are only concerned with CUBIC.
Cubic Unit Cells

- All angles are 90 degrees
- All sides equal length

Cubic Unit Cells of Metals

- Simple cubic (SC)
- Body-centered cubic (BCC)
- Face-centered cubic (FCC)

Simple Cubic Unit Cell

- Simple cubic unit cell.
- Note that each atom is at a corner of a unit cell and is shared among 8 unit cells.

Body-Centered Cubic Unit Cell

- Atom at each cube corner plus atom in each cube face.

Face Centered Cubic Unit Cell

Crystal Lattices—Packing of Atoms or Ions

- Assume atoms are hard spheres and that crystals are built by PACKING of these spheres as efficiently as possible.
- FCC is more efficient than either BC or SC.

See Closer Look, pp. 622-623
Crystal Lattices—Packaging of Atoms or Ions

Packing of $C_60$ molecules. They are arranged at the lattice points of a FCC lattice.

Crystal Lattices—Packing of Atoms or Ions

Crystal Lattices—Packing of Atoms or Ions

Number of Atoms per Unit Cell

<table>
<thead>
<tr>
<th>Unit Cell Type</th>
<th>Net Number Atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC</td>
<td>1</td>
</tr>
<tr>
<td>BCC</td>
<td>2</td>
</tr>
<tr>
<td>FCC</td>
<td>4</td>
</tr>
</tbody>
</table>

Simple Ionic Compounds

Lattices of many simple ionic solids are built by taking a SC or FCC lattice of ions of one type and placing ions of opposite charge in the holes in the lattice.

**EXAMPLE:** CsCl has a SC lattice of Cs$^+$ ions with Cl$^-$ in the center.

Simple Ionic Compounds

Salts with formula MX can have SC structure — but not salts with formula MX$_2$ or M$_2$X

Simple Ionic Compounds

Construction of NaCl

We begin with a cube of Cl$^-$ ions. Add more Cl$^-$ ions in the cube faces, and then add Na$^+$ ion in the octahedral holes.
The Sodium Chloride Lattice

Na⁺ ions are in OCTAHEDRAL holes in a face-centered cubic lattice of Cl⁻ ions.

Many common salts have FCC arrangements of anions with cations in OCTAHEDRAL HOLES — e.g., salts such as Ca = NaCl
- FCC lattice of anions \( \rightarrow \) 4 A/ unit cell
- C⁺ in octahedral holes \( \rightarrow \) 1 C⁺ at center
  - \( + [12 \text{ edges} \cdot 1/4 \text{ C⁺ per edge}] \)
  - \( = 4 \text{ C⁺ per unit cell} \)

Comparing NaCl and CsCl

- Even though their formulas have one cation and one anion, the lattices of CsCl and NaCl are different.
- The different lattices arise from the fact that a Cs⁺ ion is much larger than a Na⁺ ion.

Common Ionic Solids

Titanium dioxide,
TiO₂
- There are 2 net Ti⁺⁺ ions and 4 net O²⁻ ions per unit cell.

Common Ionic Solids

Zinc sulfide, ZnS
- The S²⁻ ions are in TETRAHEDRAL holes in the Zn⁺⁺ FCC lattice.
- This gives 4 net Zn⁺⁺ ions and 4 net S²⁻ ions.
Common Ionic Solids

- Fluorite or CaF$_2$
- FCC lattice of Ca$^{2+}$ ions
- This gives 4 net Ca$^{2+}$ ions.
- F$^{-}$ ions in all 8 tetrahedral holes.
- This gives 8 net F$^{-}$ ions.