# Intermolecular Forces

## Vapor Pressure & Phase Diagrams

# Equilibrium Vapor Pressure

- The pressure of the vapor present at equilibrium.
- Determined principally by the size of the intermolecular forces in the liquid.
- Increases significantly with temperature.
- Volatile liquids have high vapor pressures.
- B.P. T at which vapor pressure = atmospheric pressure

# Vapor Pressure

- The pressure exerted by the vapor when it is in dynamic equilibrium with its liquid is called the vapor pressure.
  - Remember using Dalton's Law of Partial Pressures to account for the pressure of the water vapor when collecting gases by water displacement?
- The weaker the attractive forces between the molecules, the more molecules will be in the vapor.
- Therefore, the weaker the attractive forces, the higher the vapor pressure.
  - The higher the vapor pressure, the more volatile the liquid.

# Vapor–Liquid Dynamic Equilibrium

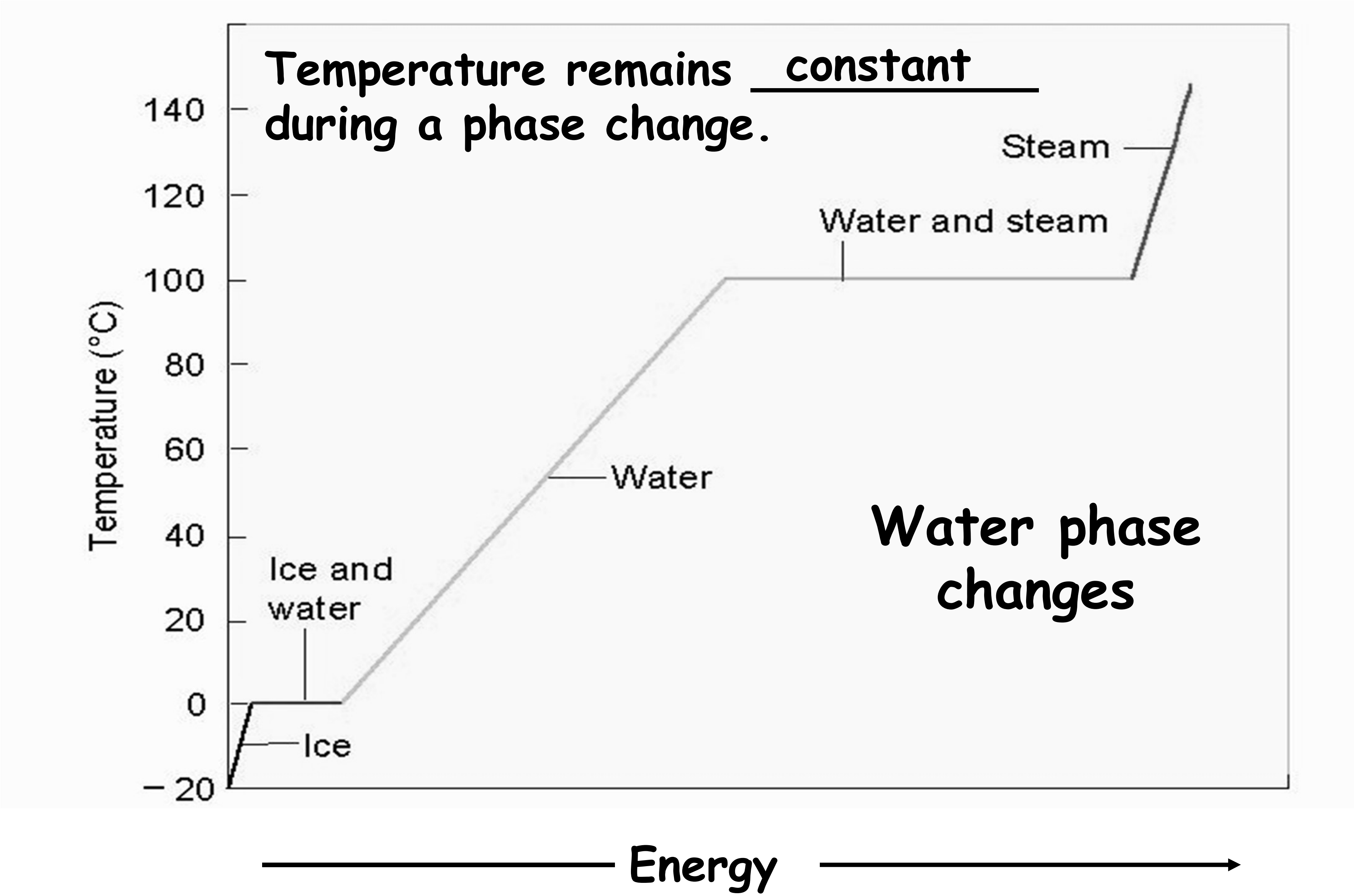
- If the volume of the chamber is increased, it will decrease the pressure of the vapor inside the chamber.
  - At that point, there are fewer vapor molecules in a given volume, causing the rate of condensation to slow.
- Therefore, for a period of time, the rate of vaporization will be faster than the rate of condensation, and the amount of vapor will increase.

# Vapor–Liquid Dynamic Equilibrium

- Eventually, enough vapor accumulates so that the rate of the condensation increases to the point where it is once again as fast as evaporation.
  - Equilibrium is reestablished.
- At this point, the vapor pressure will be the same as it was before.

## Water phase changes

Temperature remains constant during a phase change.



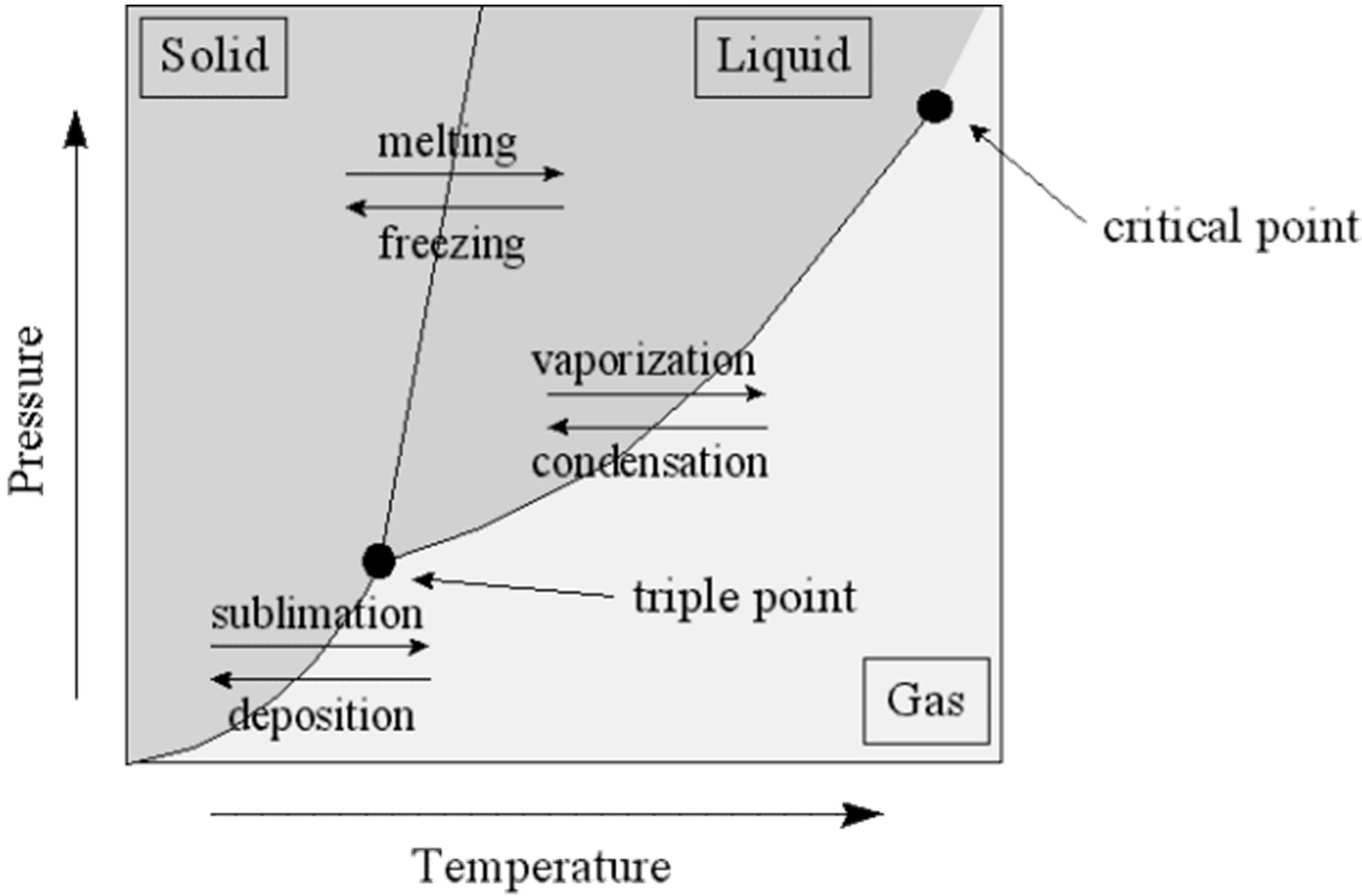
# Phase Diagram

- Represents phases as a function of temperature and pressure.
- Critical temperature: temperature above which the vapor can not be liquefied.

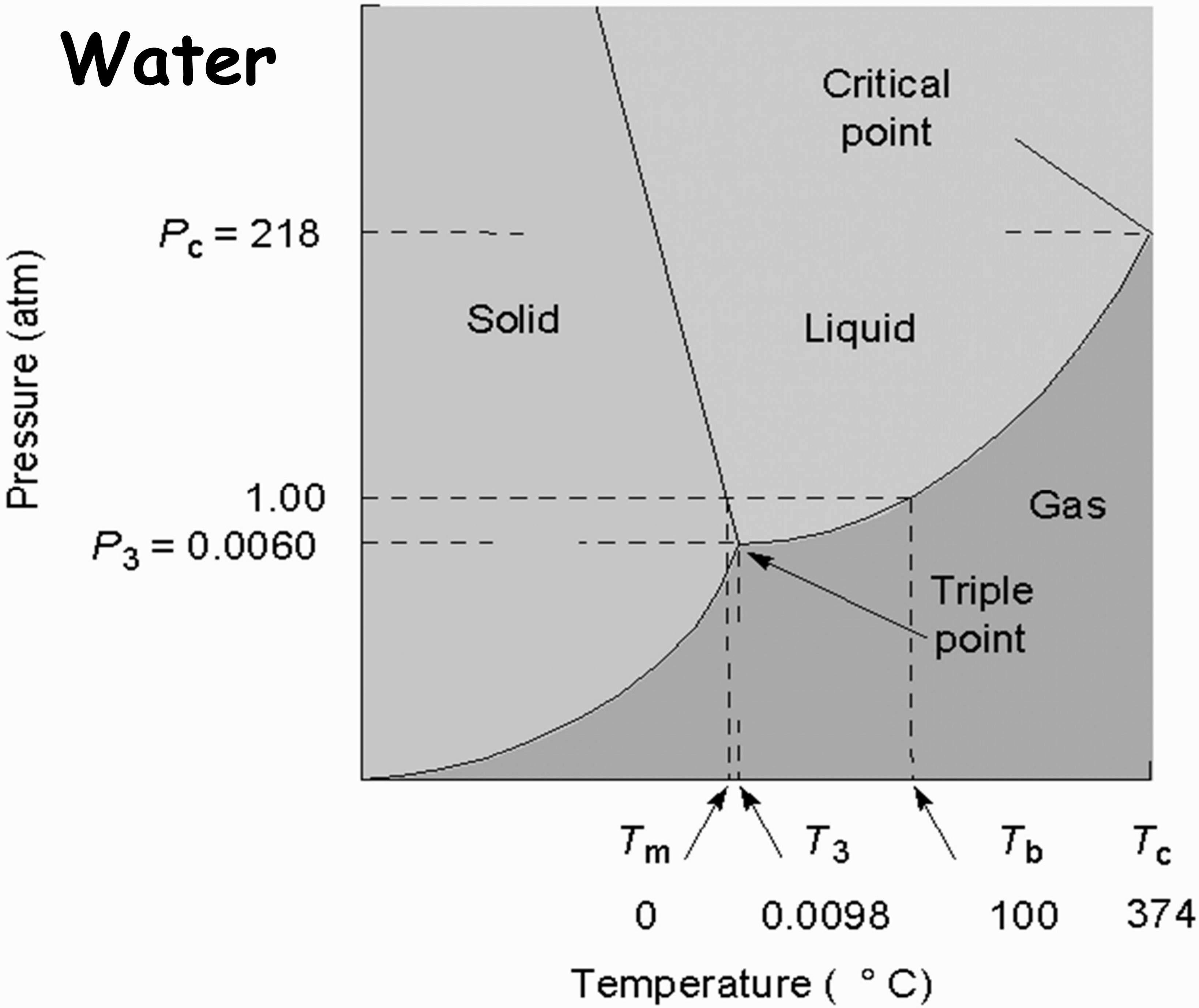
# Phase Diagram

- Critical pressure: pressure required to liquefy AT the critical temperature.
- Critical point: critical temperature and pressure (for water, $T_c$ = 374°C and 218 atm).

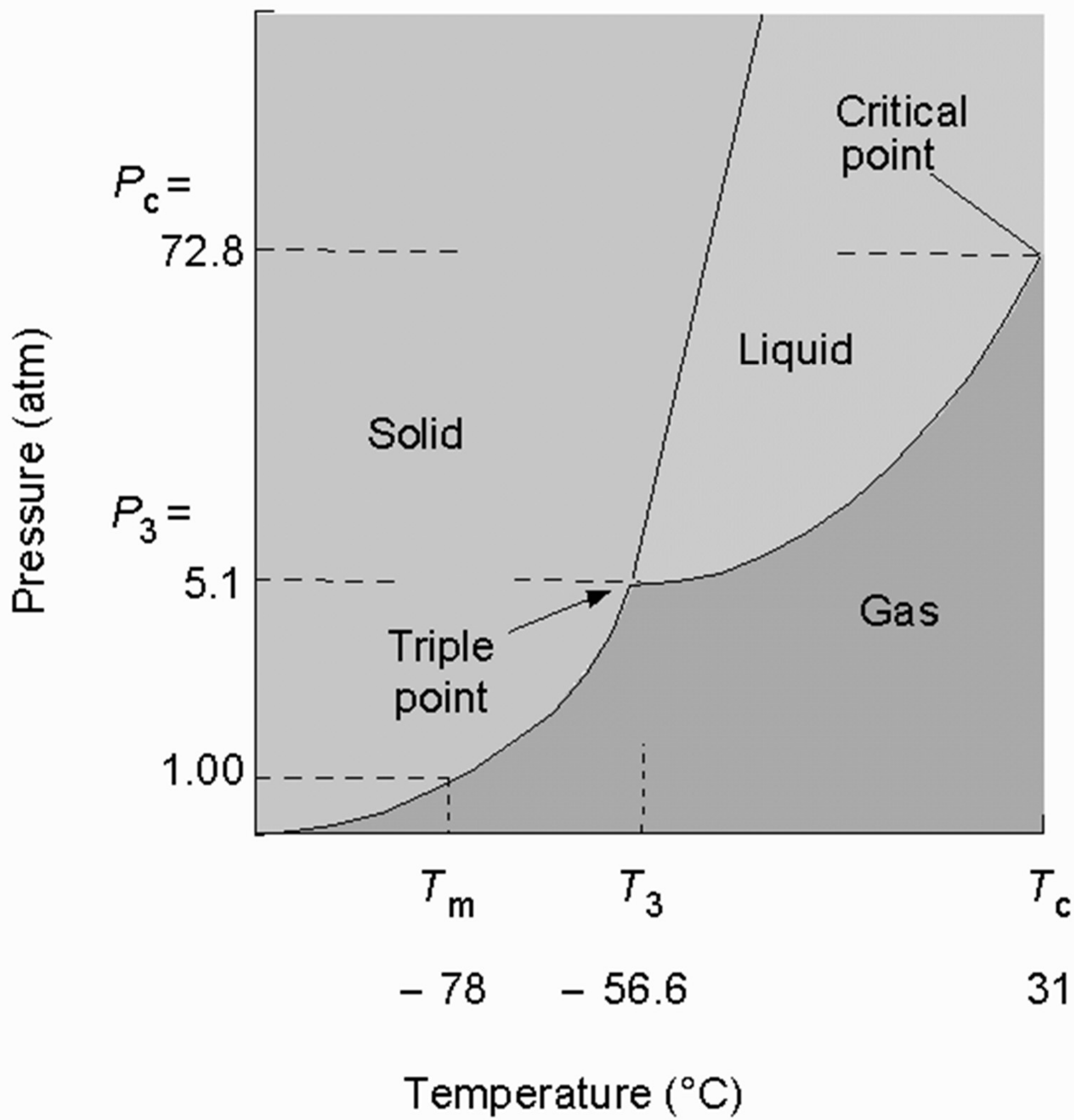
# Phase changes by Name



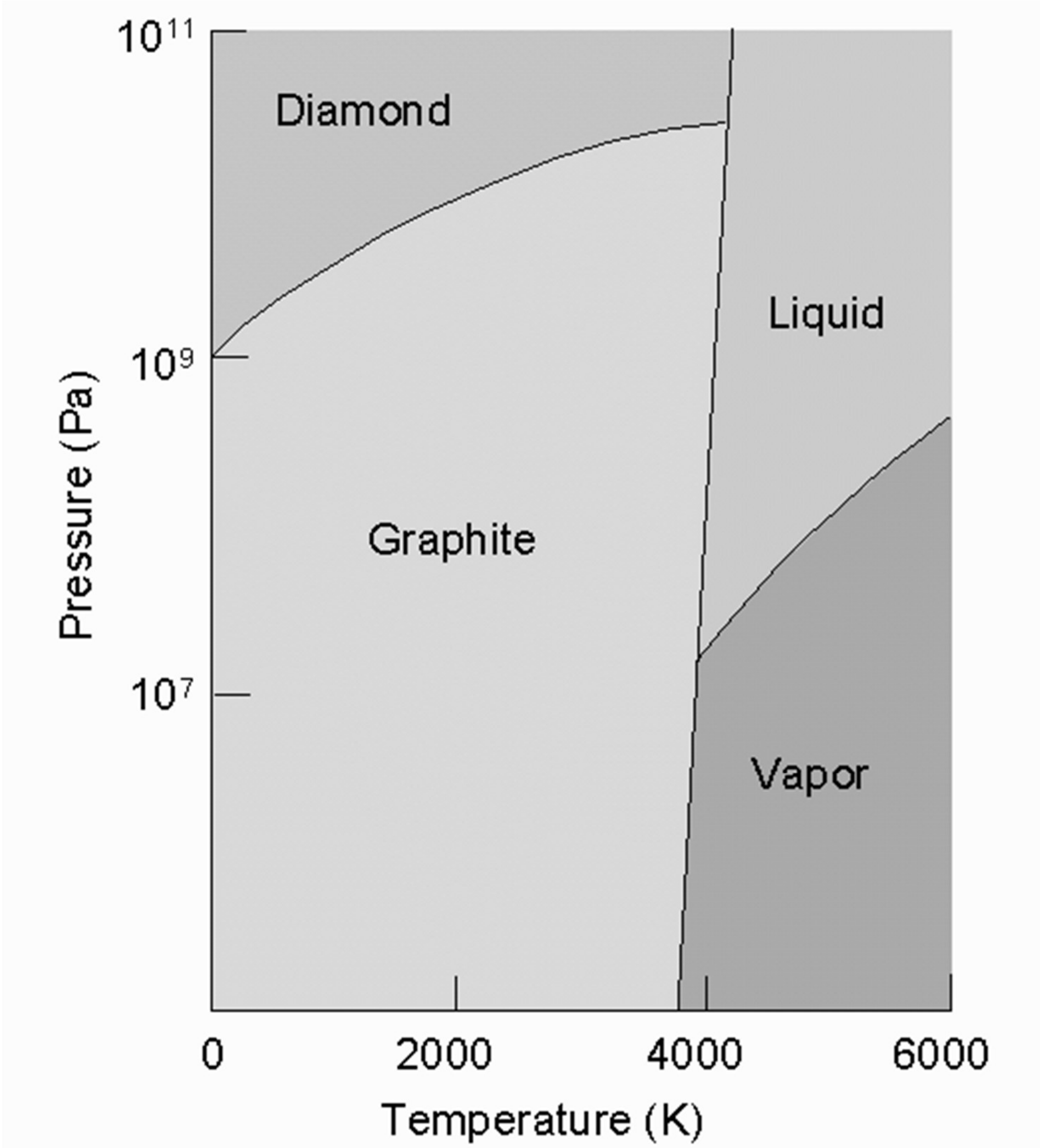
# Water



Critical point
Solid
Liquid
Gas
Triple point
Pressure (atm)
$P_c$ = 218
1.00
$P_3$ = 0.0060
$T_m$
$T_3$
$T_b$
$T_c$
0
0.0098
100
374
Temperature ( °C)

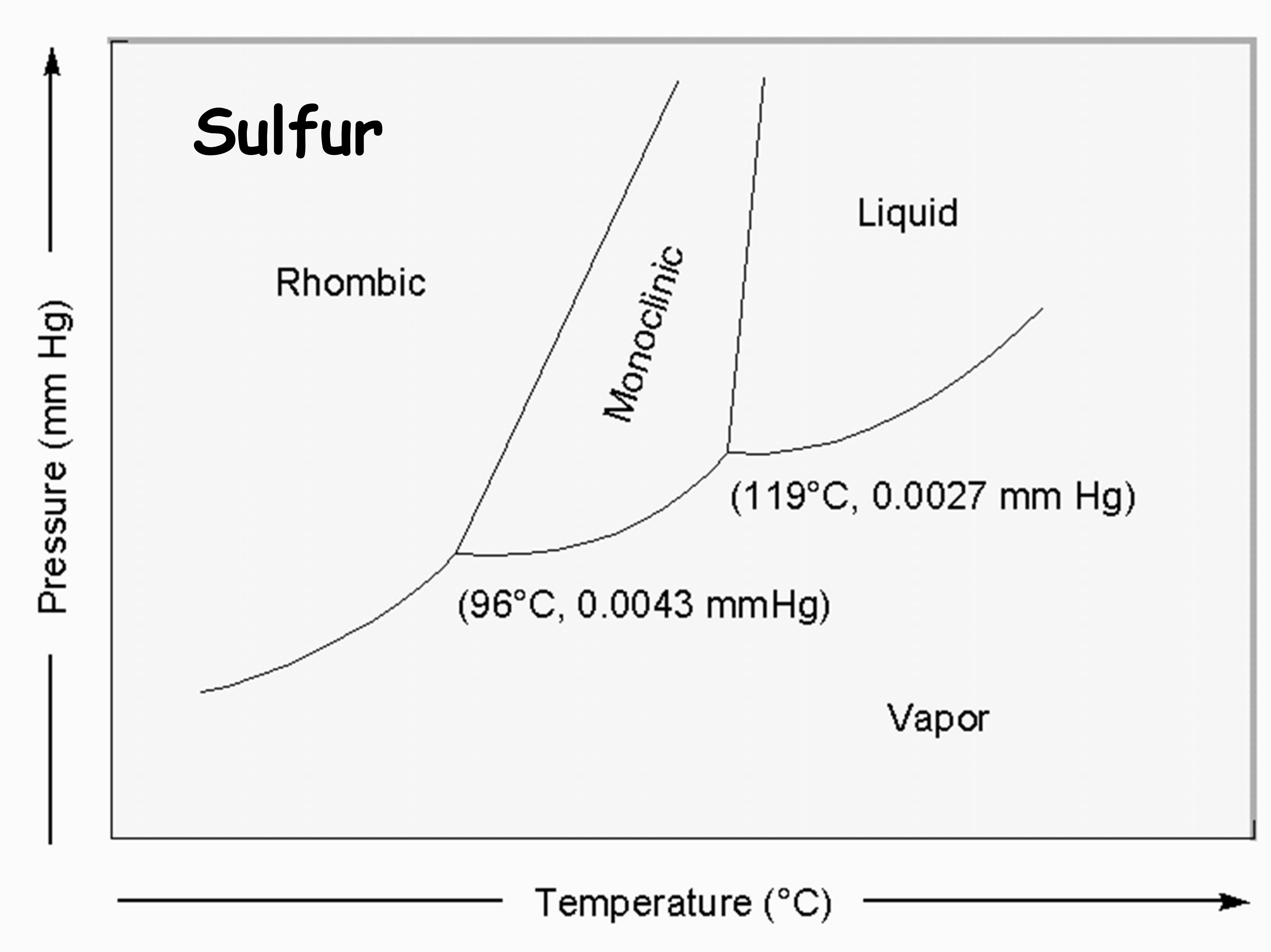



# Carbon dioxide



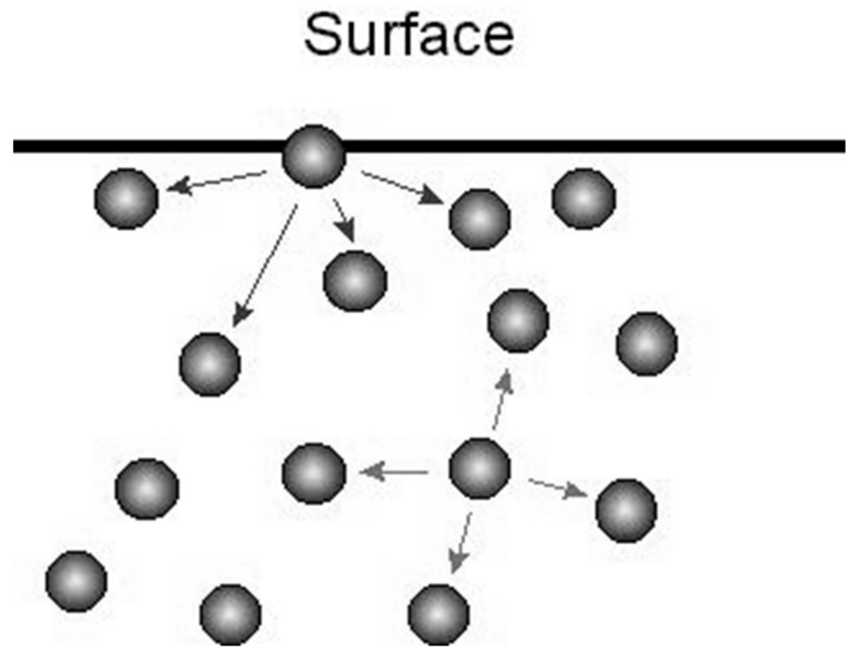
$10^{11}$
Diamond
Liquid
$10^9$
Pressure (Pa)
Graphite
$10^7$
Vapor
0
2000
4000
6000
Temperature (K)


# Carbon

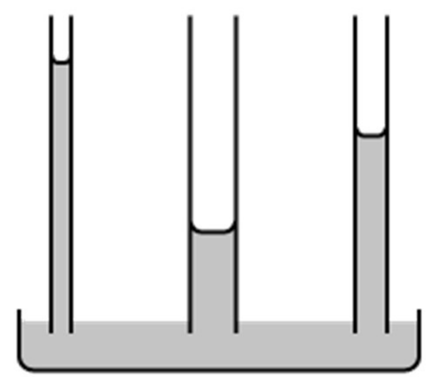

Sulfur
Liquid
Rhombic
Monoclinic
(119°C, 0.0027 mm Hg)
(96°C, 0.0043 mmHg)
Vapor
Pressure (mm Hg)
Temperature (°C)

# Stop

# Some Properties of a Liquid




- **Surface Tension:**
  The resistance to an increase in its surface area (polar molecules, liquid metals).



- **Capillary Action:**
  Spontaneous rising of a liquid in a narrow tube.

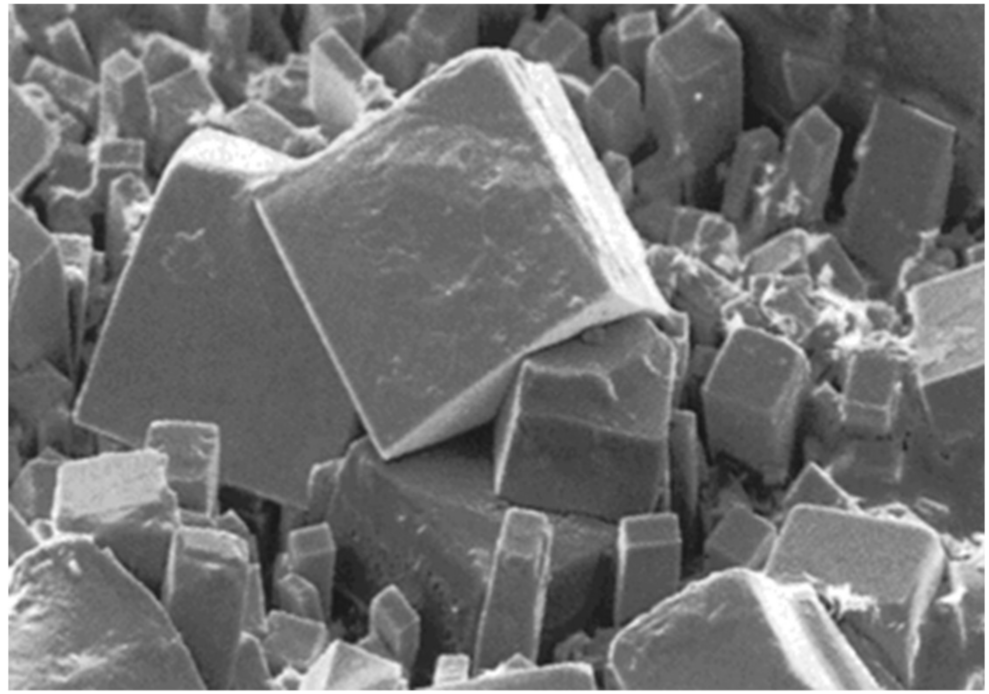
# Some Properties of a Liquid

- Viscosity: Resistance to flow

- High viscosity is an indication of strong intermolecular forces

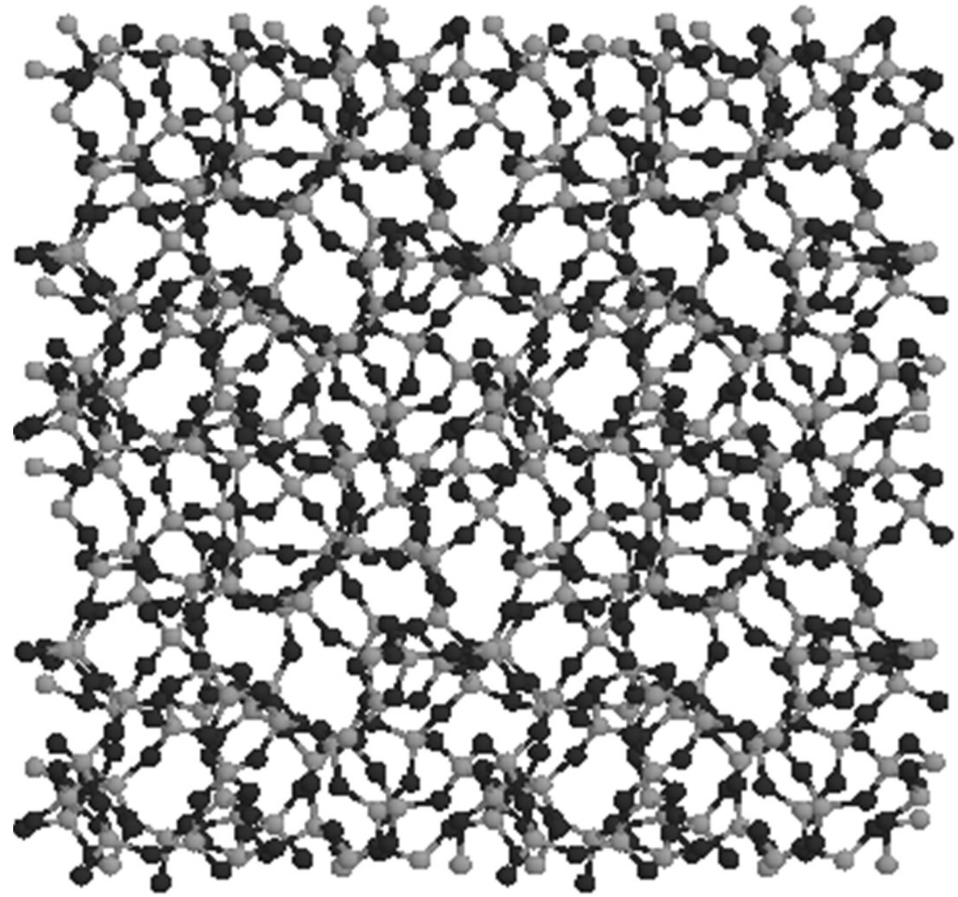
# Types of Solids

- Crystalline Solids: highly regular arrangement of their components



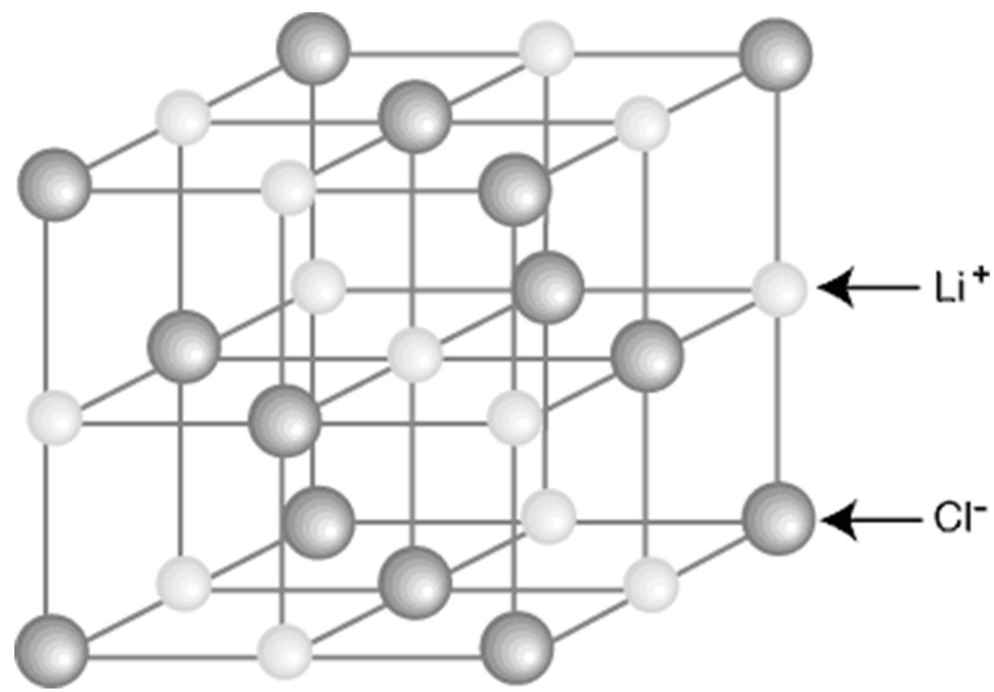
# Types of Solids

- Amorphous solids: considerable disorder in their structures (glass).

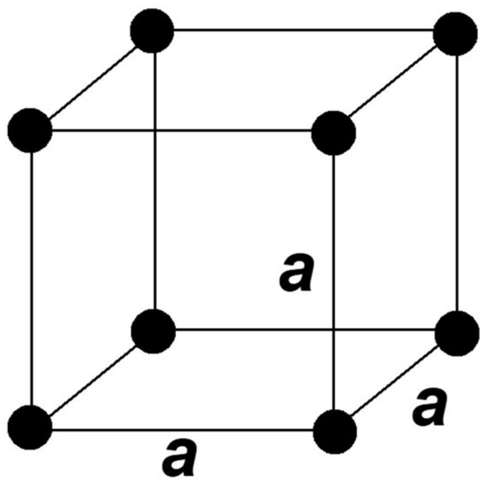


# Representation of Components in a Crystalline Solid

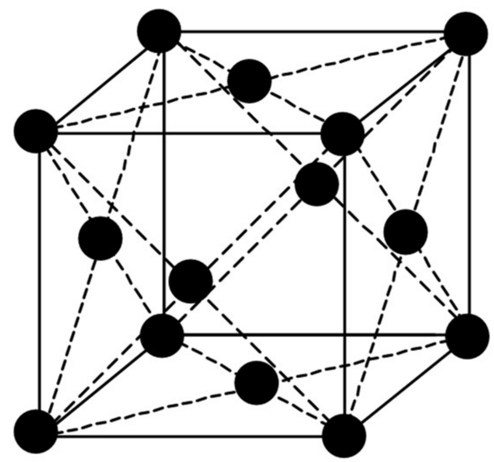
Lattice: A 3-dimensional system of points designating the centers of components (atoms, ions, or molecules) that make up the substance.



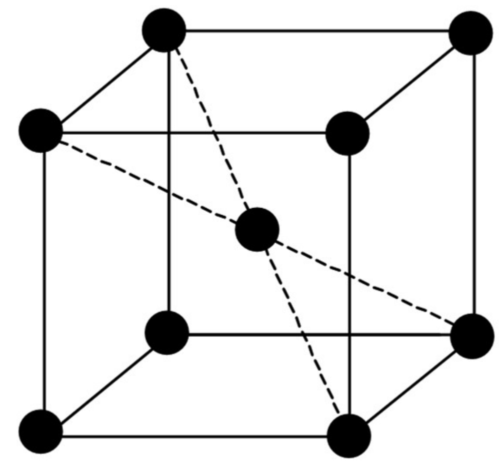
# Crystal Structures - Cubic




*Simple*

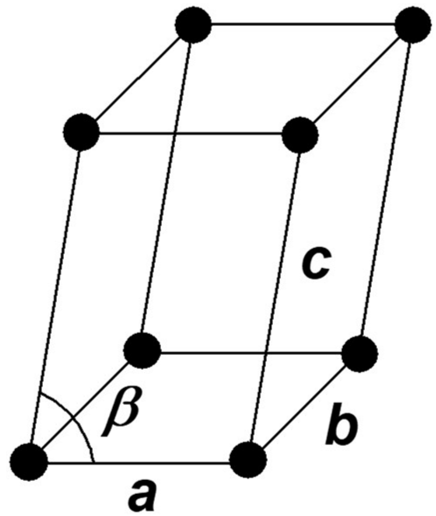


*Face-Centered*

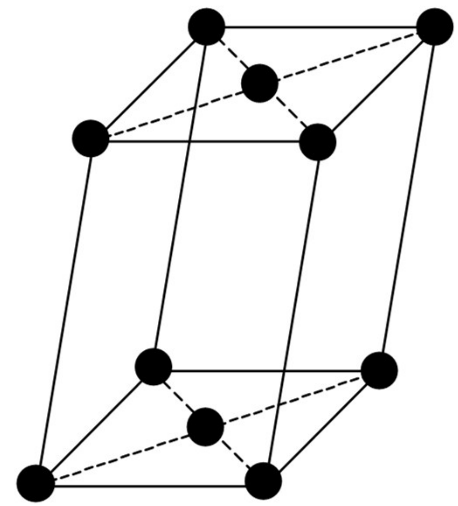


*Body-Centered*

# Crystal Structures - <u>Monoclinic</u>

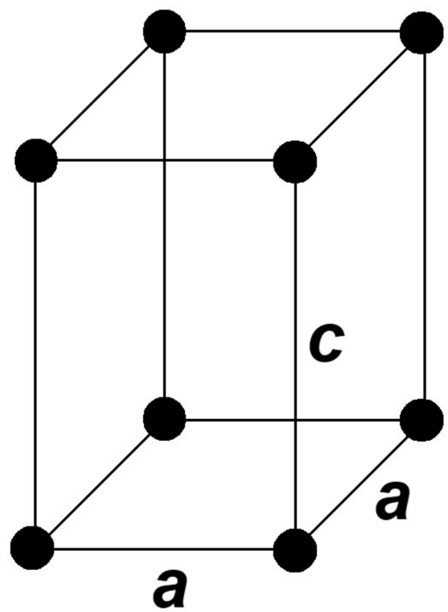


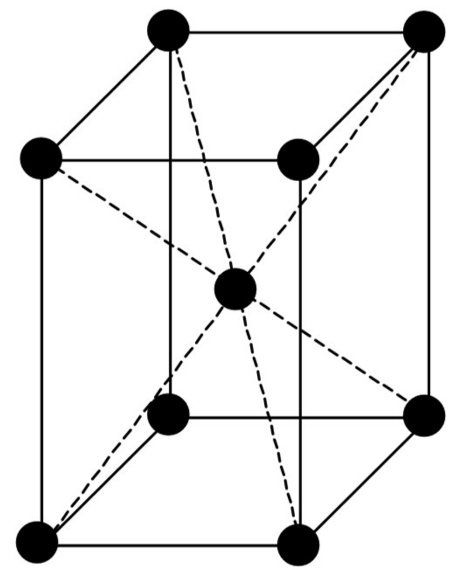

*Simple*



*End Face-Centered*

# Crystal Structures - <u>Tetragonal</u>

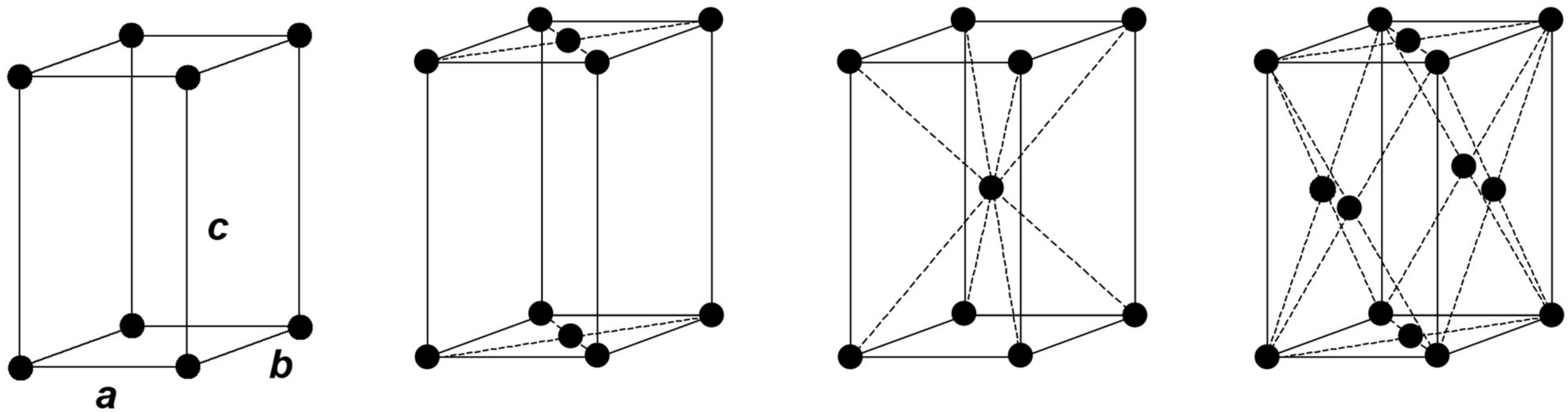


*Simple*

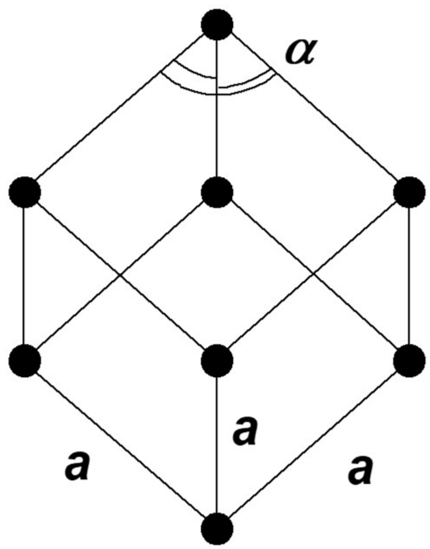
*Body-Centered*

# Crystal Structures - Orthorhombic

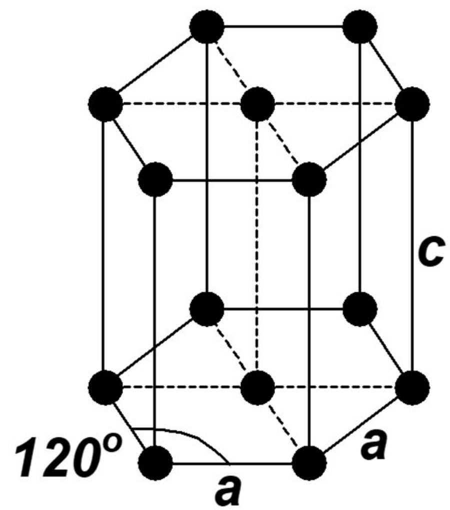



*Simple* | *End Face-Centered* | *Body Centered* | *Face Centered*

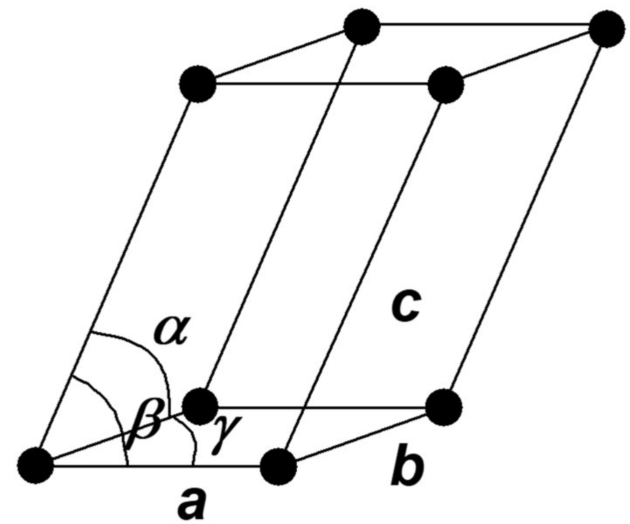
# Crystal Structures – <u>Other Shapes</u>




Rhombohedral

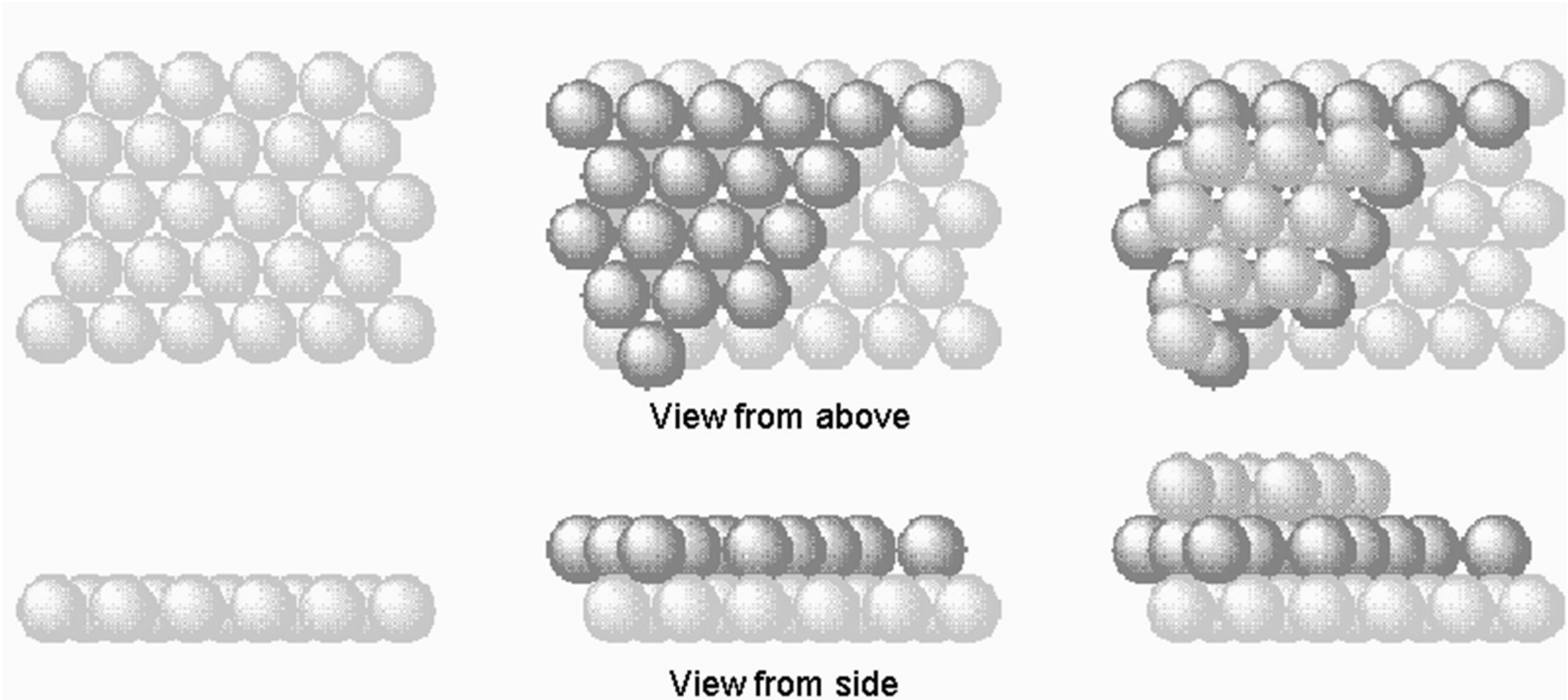



Hexagonal



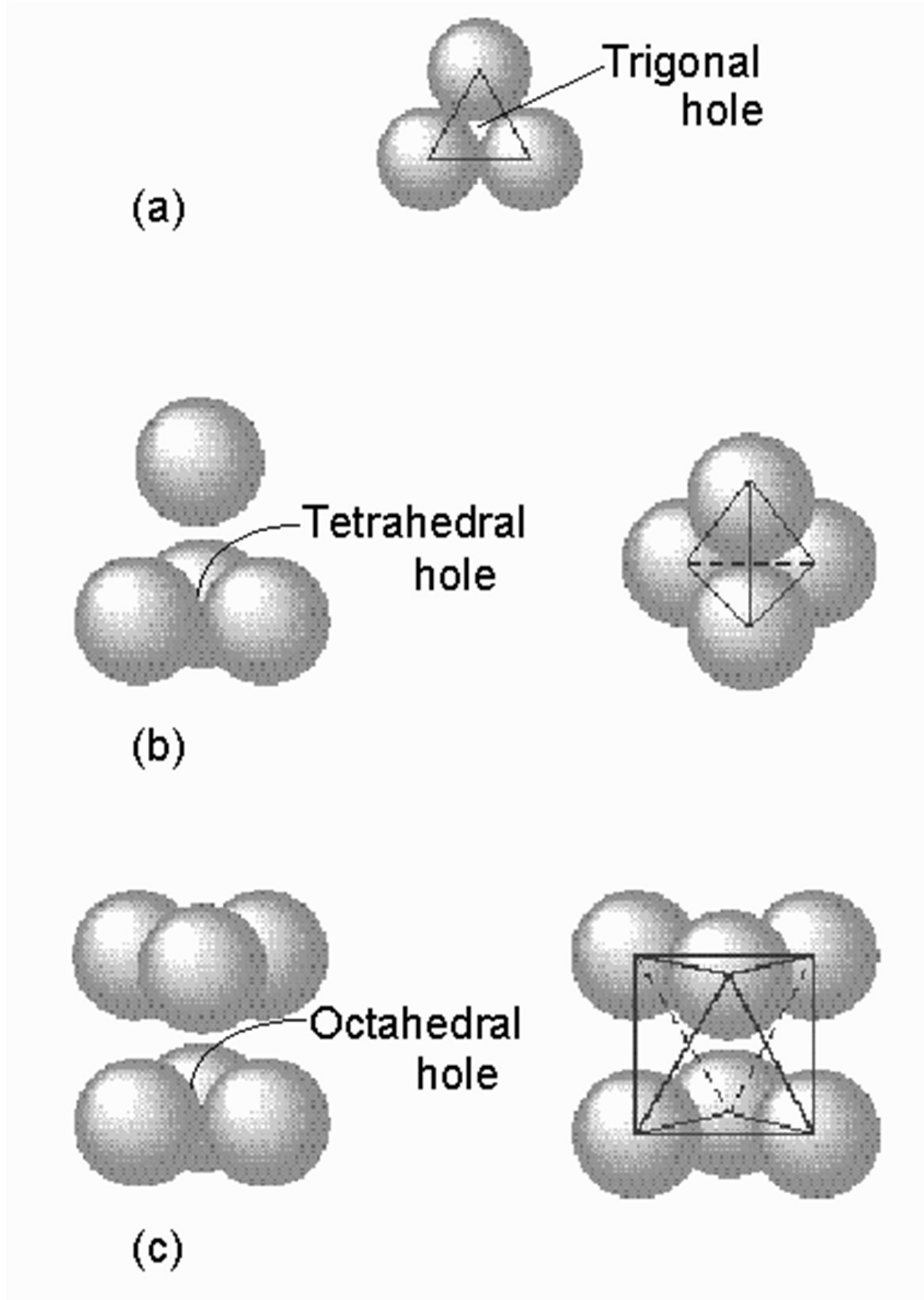

Triclinic

# Packing in Metals



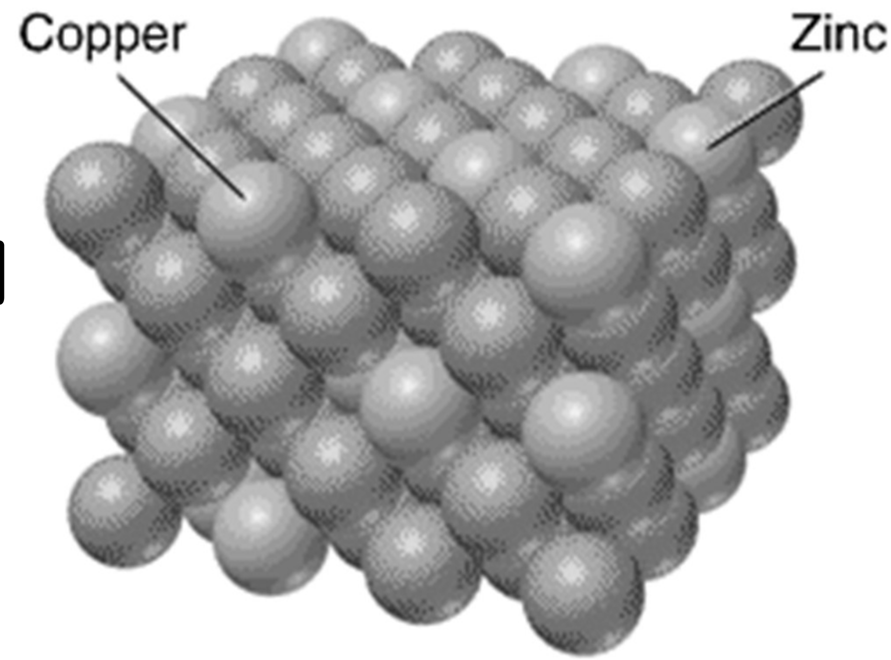

**Model: Packing uniform, hard spheres to best use available space. This is called closest packing. Each atom has 12 nearest neighbors.**

# Closest Packing Holes



# Metal Alloys

- Substitutional Alloy: some metal atoms replaced by others of similar size.
  - brass = Cu/Zn
  - Bronze = Sn/Cu

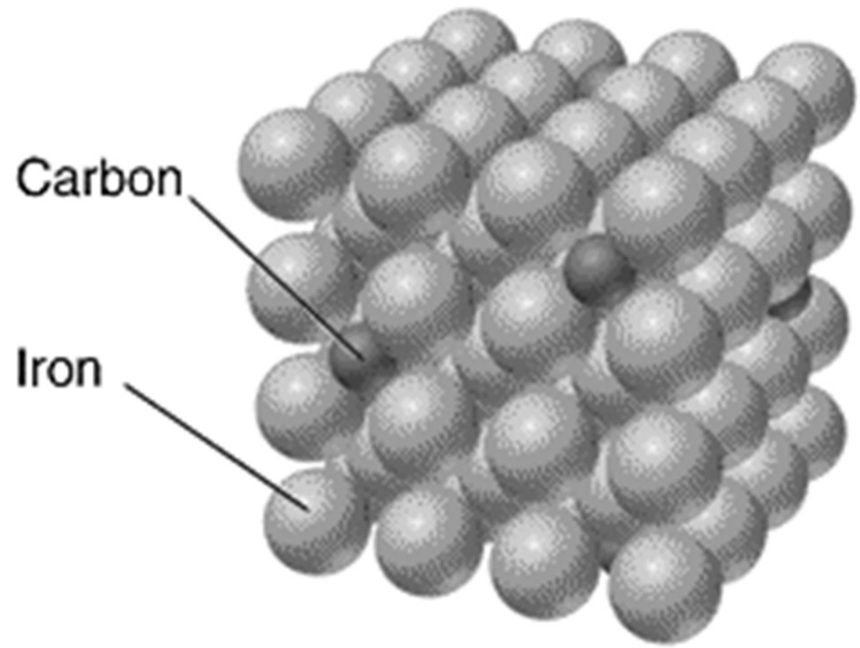



**A** Brass, a substitutional alloy

# Metal Alloys

(continued)

- **Interstitial Alloy:** Interstices (holes) in closest packed metal structure are occupied by small atoms.
  - steel = iron + carbon




**B** Carbon steel, an interstitial alloy