<u>Liquids and Solids</u>

Relative Magnitudes of Forces

The types of bonding forces vary in their strength as measured by average bond energy.

Strongest

Weakest

Covalent bonds (400 kcal/mol)

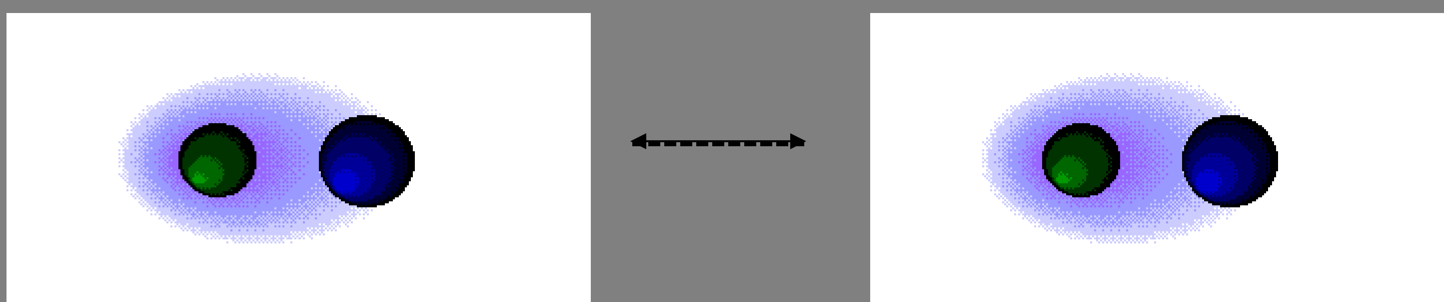
Hydrogen bonding (12-16 kcal/mol)

Dipole-dipole interactions (2-0.5 kcal/mol)

London forces (less than 1 kcal/mol)

Dipole-Dipole Forces

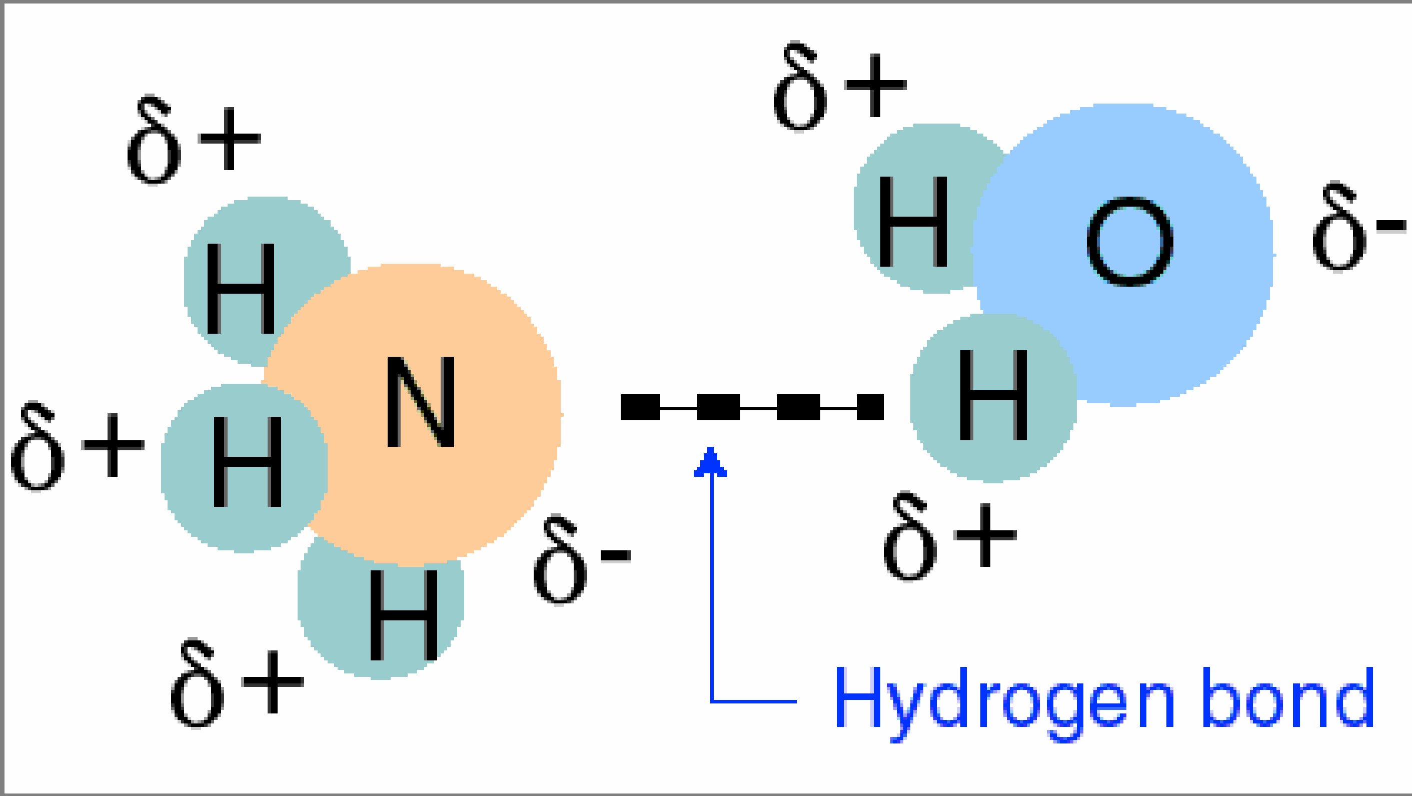
Attraction between the positive end of one molecule and the negative end of another. Strong attractions, but not as strong as hydrogen bonding. These are only found in polar molecules.



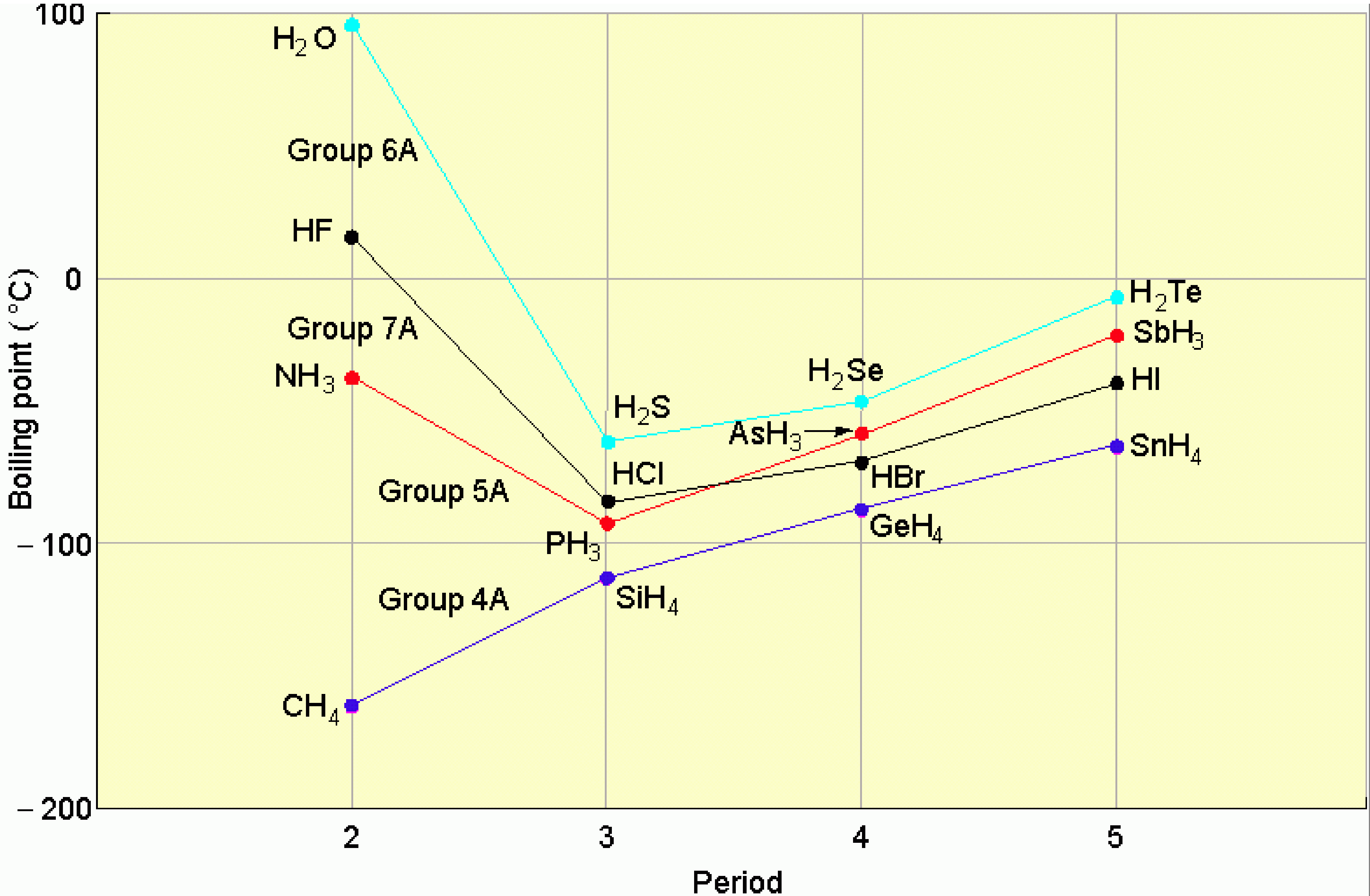
δ- charge δ+ charge δ- charge δ+ charge

Hydrogen Bonding

Bonding between hydrogen and more electronegative neighboring atoms such as oxygen and nitrogen



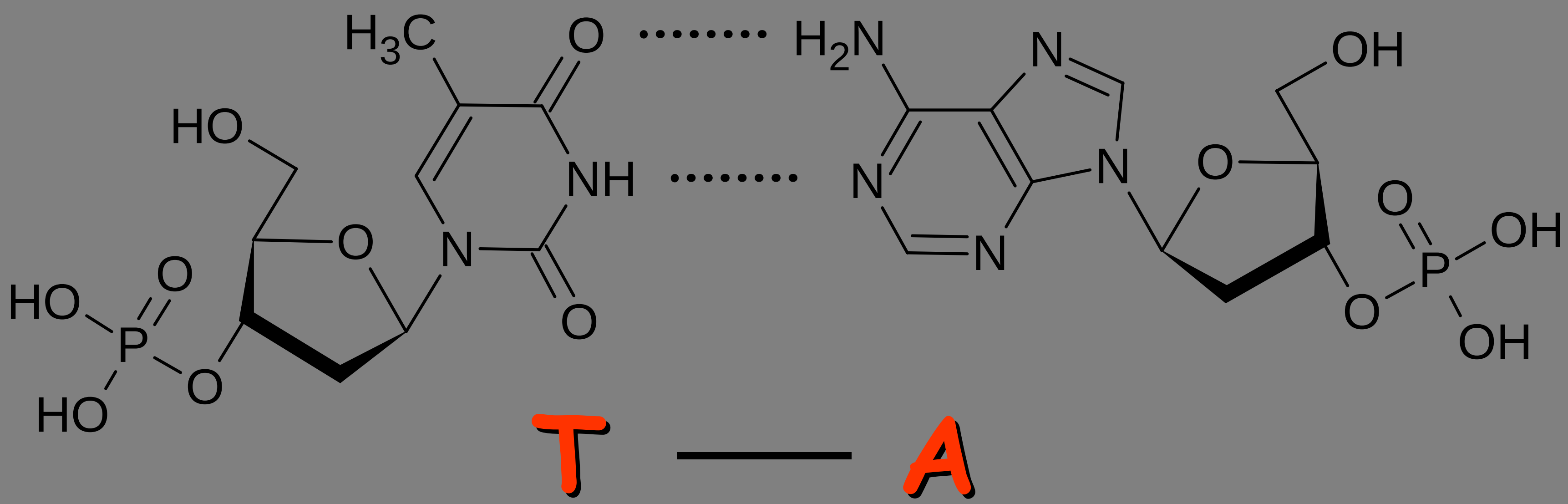
Hydrogen bonding between ammonia and water



Boiling point as a measure of intermolecular attractive forces

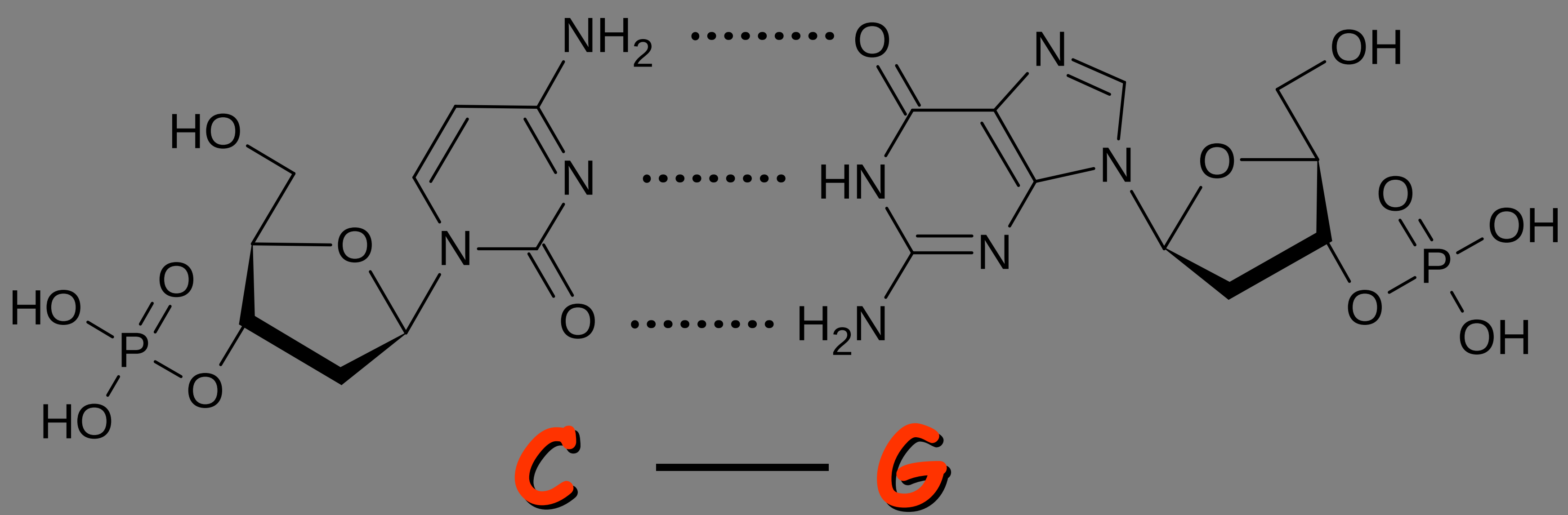
Hydrogen Bonding in DNA

Thymine hydrogen bonds to Adenine



Hydrogen Bonding in DNA

Cytosine hydrogen bonds to Guanine



Factors making Hydrogen Bonding

Special strong dipole-dipole attraction

1. The small size of the elements F,N,O
2. The relatively high electronegativity of them.

- This allows for the creation of strong dipole forces of attraction between the molecules. The effect of which can be seen on the boiling point of substances that contain hydrogen bonding.

London Dispersion Forces

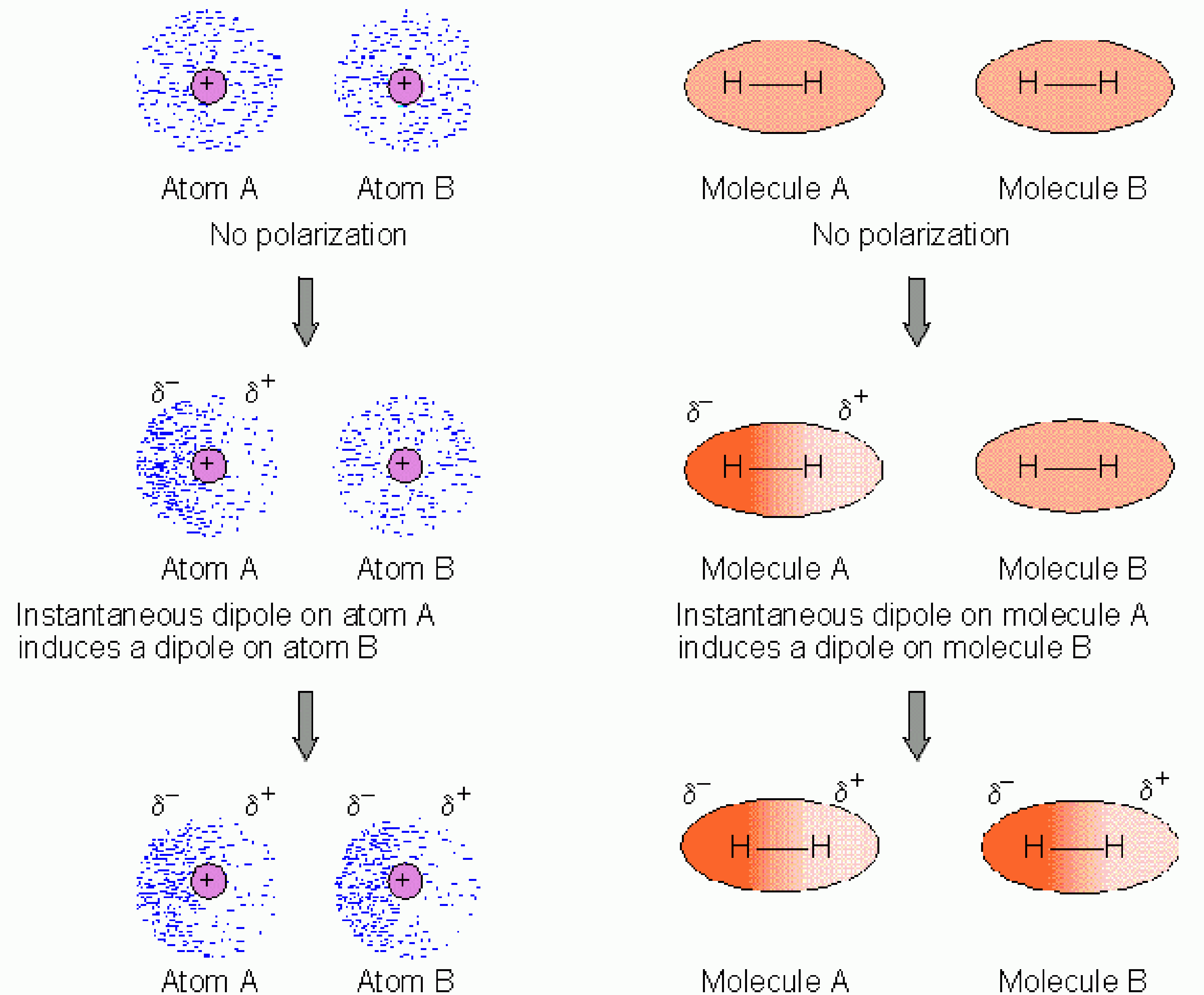
Fritz London
1900-1954

The temporary separations of charge that lead to the London force attractions are what attract one nonpolar molecule to its neighbors.

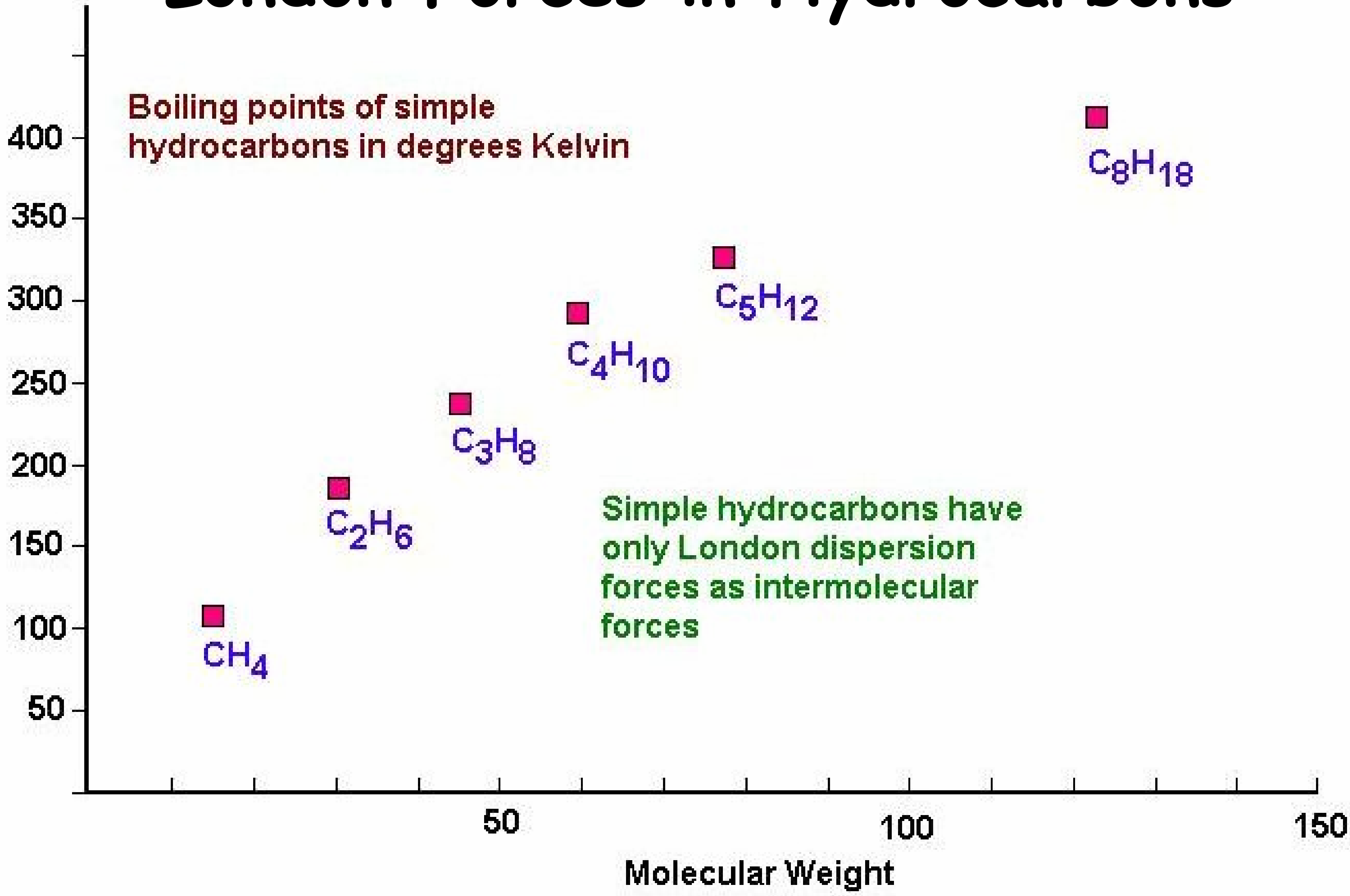
London forces increase with the size of the molecules.

C —— G

London Dispersion Forces



London Forces in Hydrocarbons

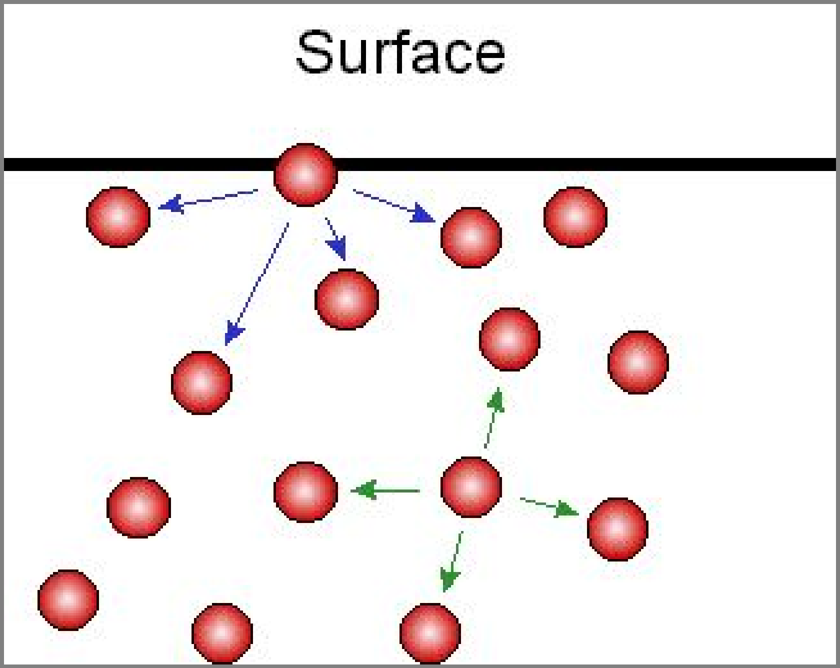


Summary of intermolecular forces

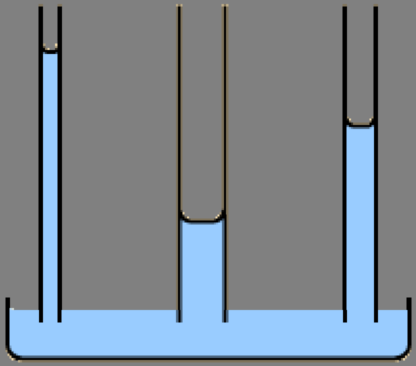
Hydrogen bonding	Dipole-dipole	LDF (London Dispersion Forces)	
Occurs between molecules that are **polar and have H-F, H-O or H-N** bonds.	Occurs in **polar molecules that do not have hydrogen bonding.** Weaker than H-bond	Occurs in **non-polar molecules**. The weakest interaction.	
Caused by attraction of highly electronegative and small F,O,N with hydrogen.	Caused by attraction of oppositely charged poles of molecules	Caused by attraction of atoms when their electrons are unequally distributed around the molecule for an instant of time.	
Strongest	strong	Weak- gets stronger with more electrons. ex. He-weak Ar-Stronger	

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.



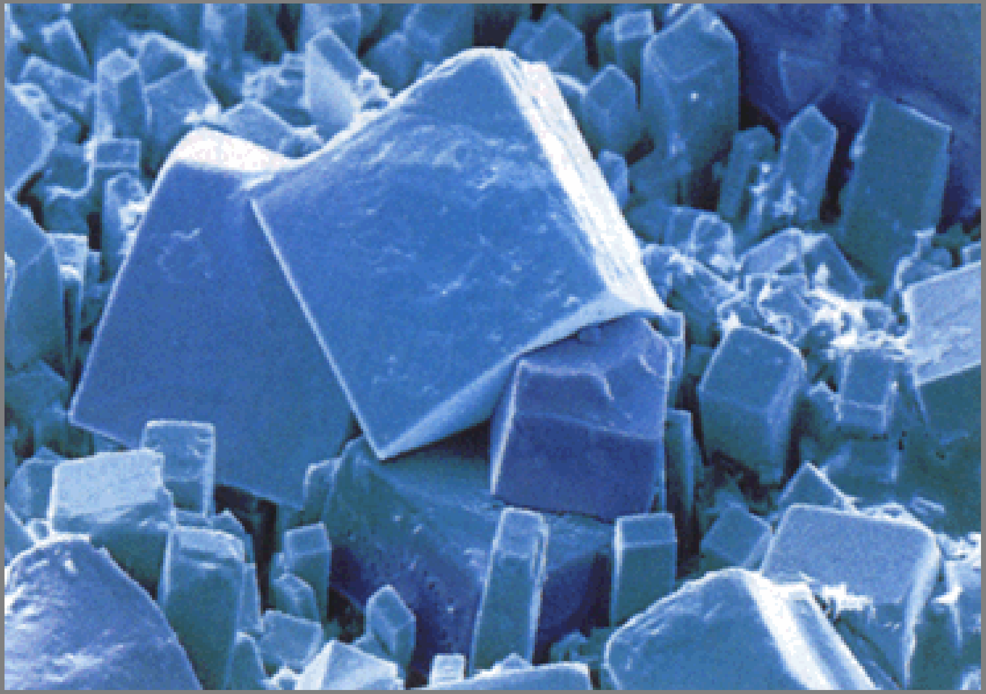
Some Properties of a Liquid

- **Viscosity**: Resistance to flow

- **High viscosity** is an indication of strong intermolecular forces

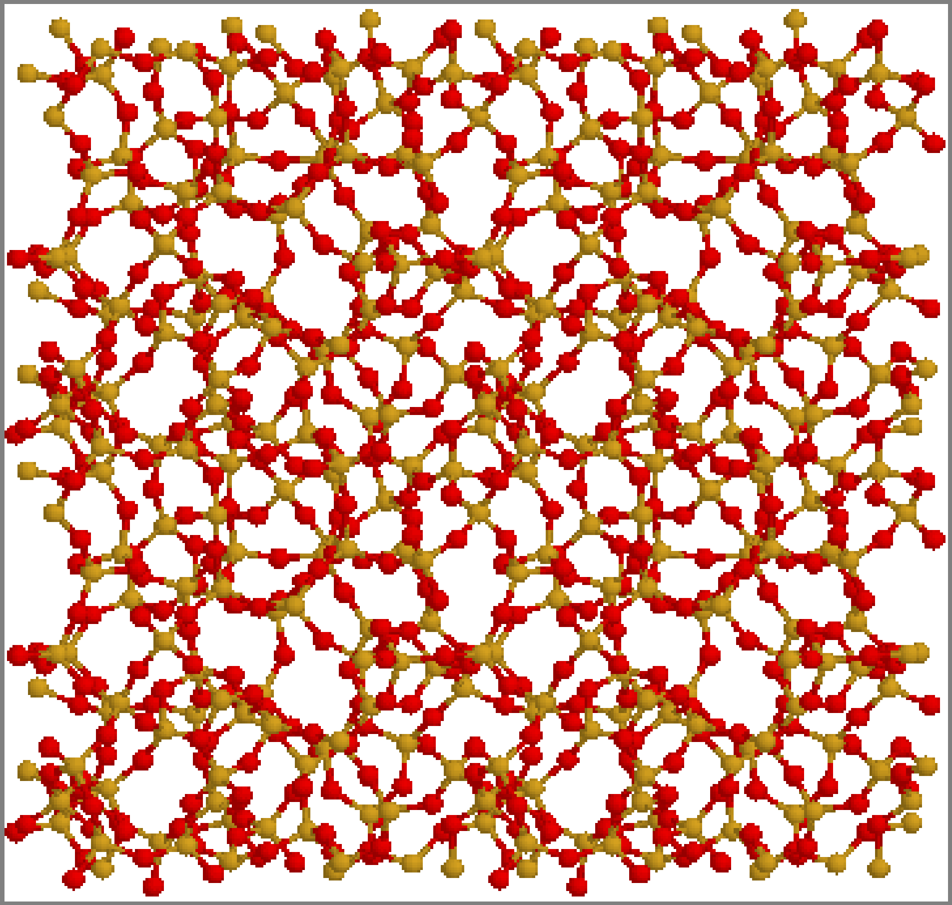
Types of Solids

- Crystalline Solids: highly regular arrangement of their components



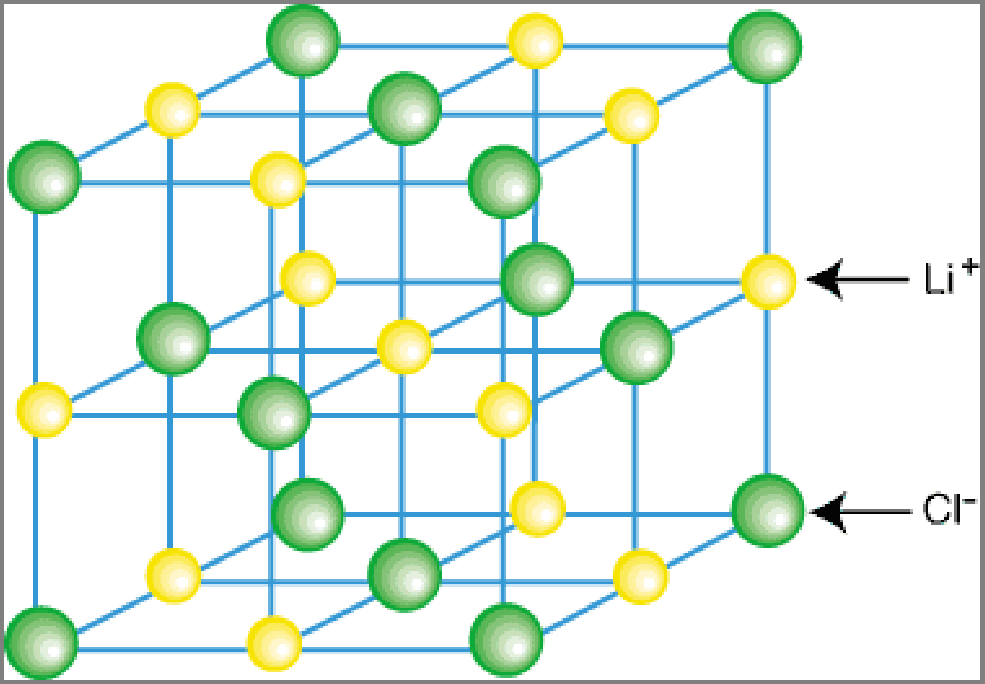
Types of Solids

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

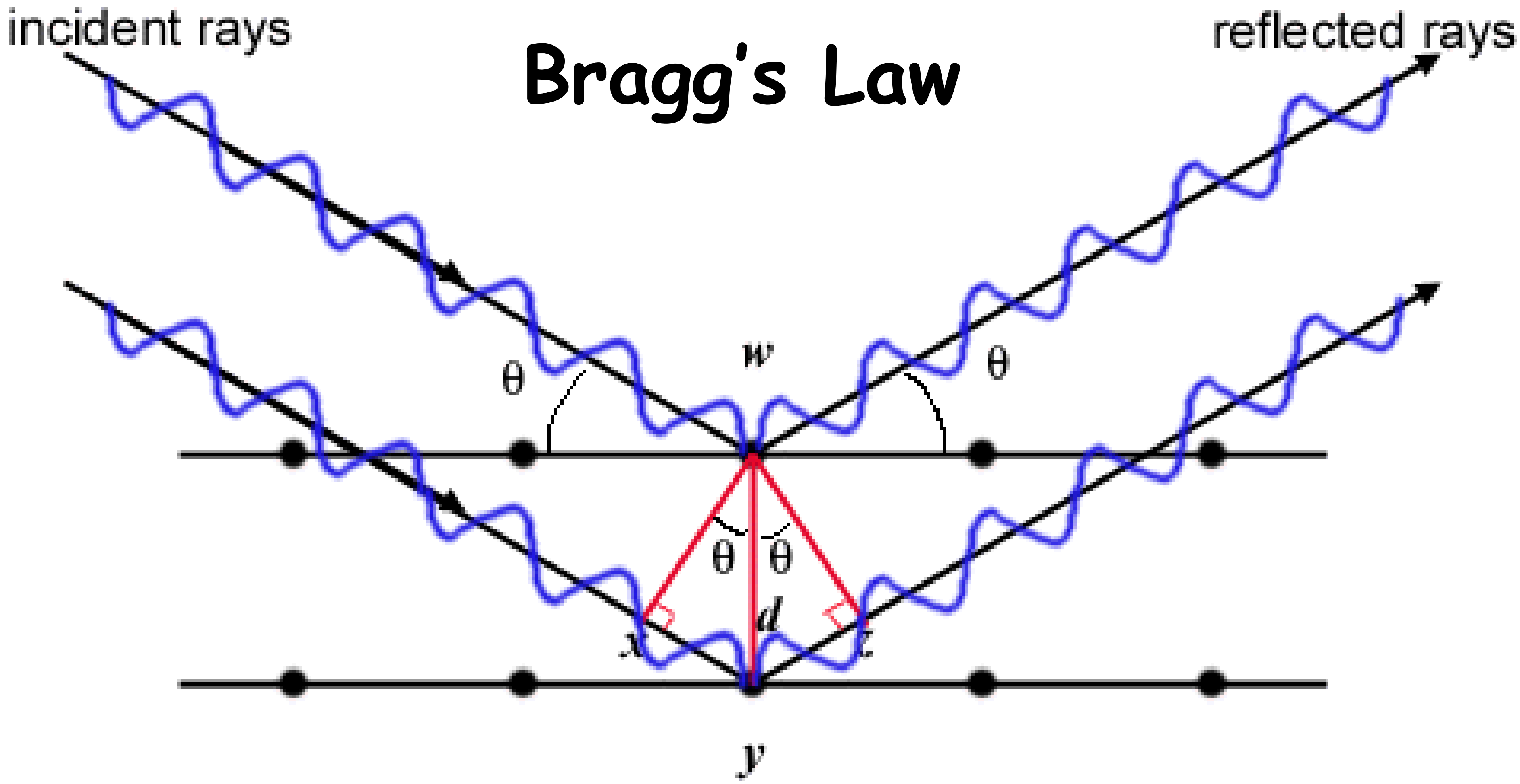


Representation of Components in a Crystalline Solid

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



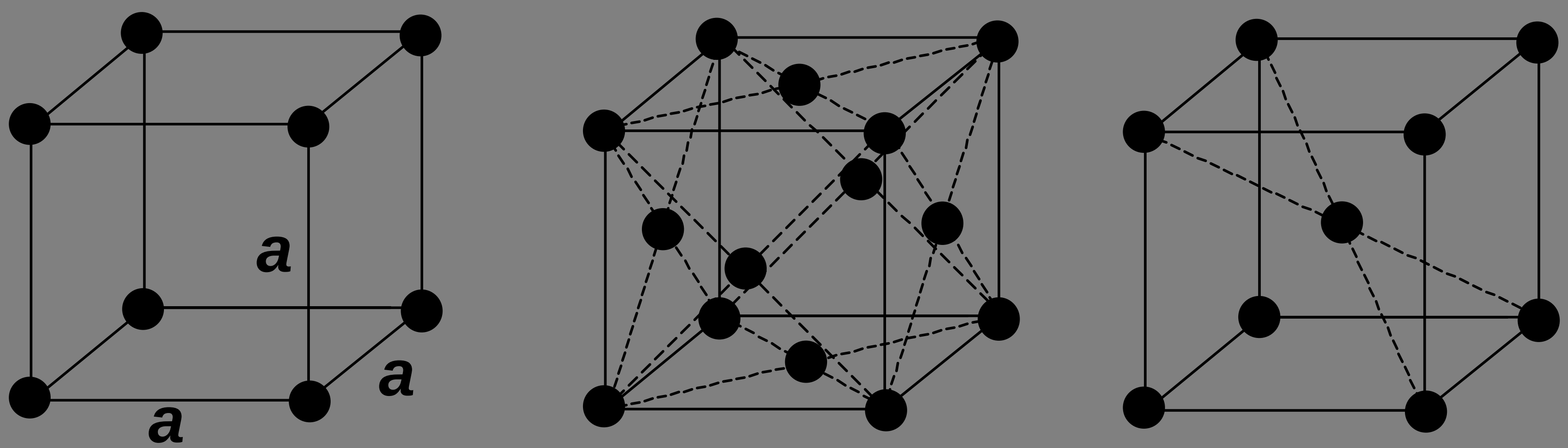
Bragg's Law



$xy + yz = n\lambda$ and $xy + yz = 2d \sin\theta$

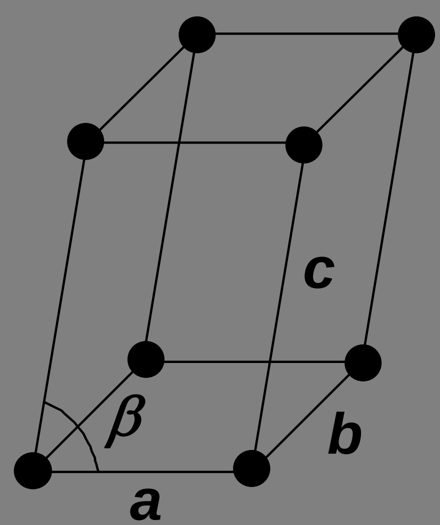
$\therefore \quad n\lambda = 2d \sin \theta$

Crystal Structures - Cubic

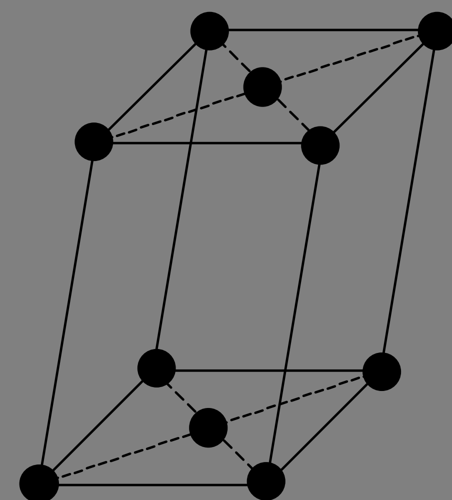


Simple *Face-Centered* *Body-Centered*

Crystal Structures - Monoclinic

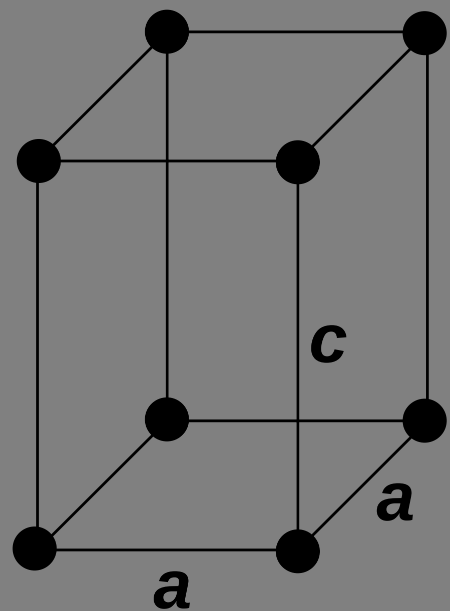


Simple

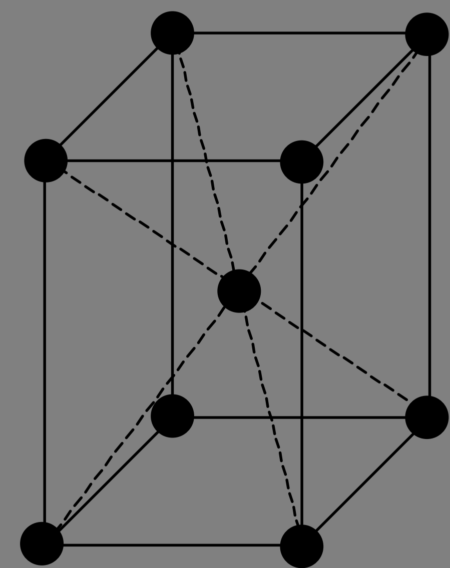


End Face-Centered

Crystal Structures - Tetragonal

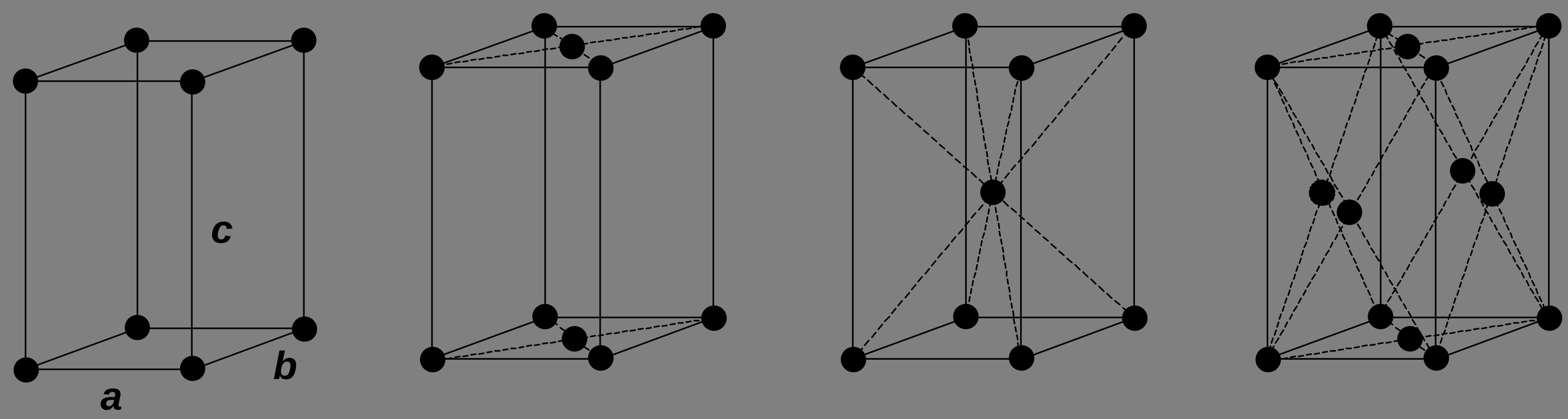


Simple



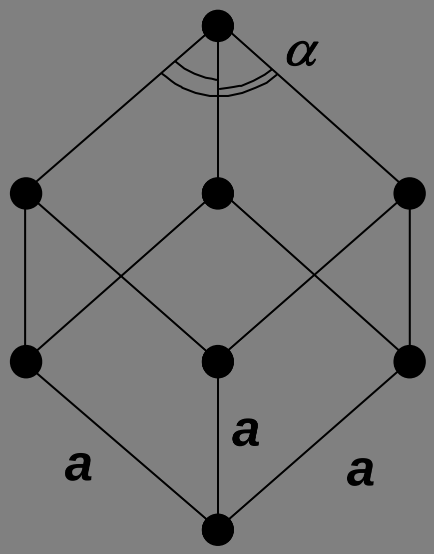
Body-Centered

Crystal Structures - Orthorhombic

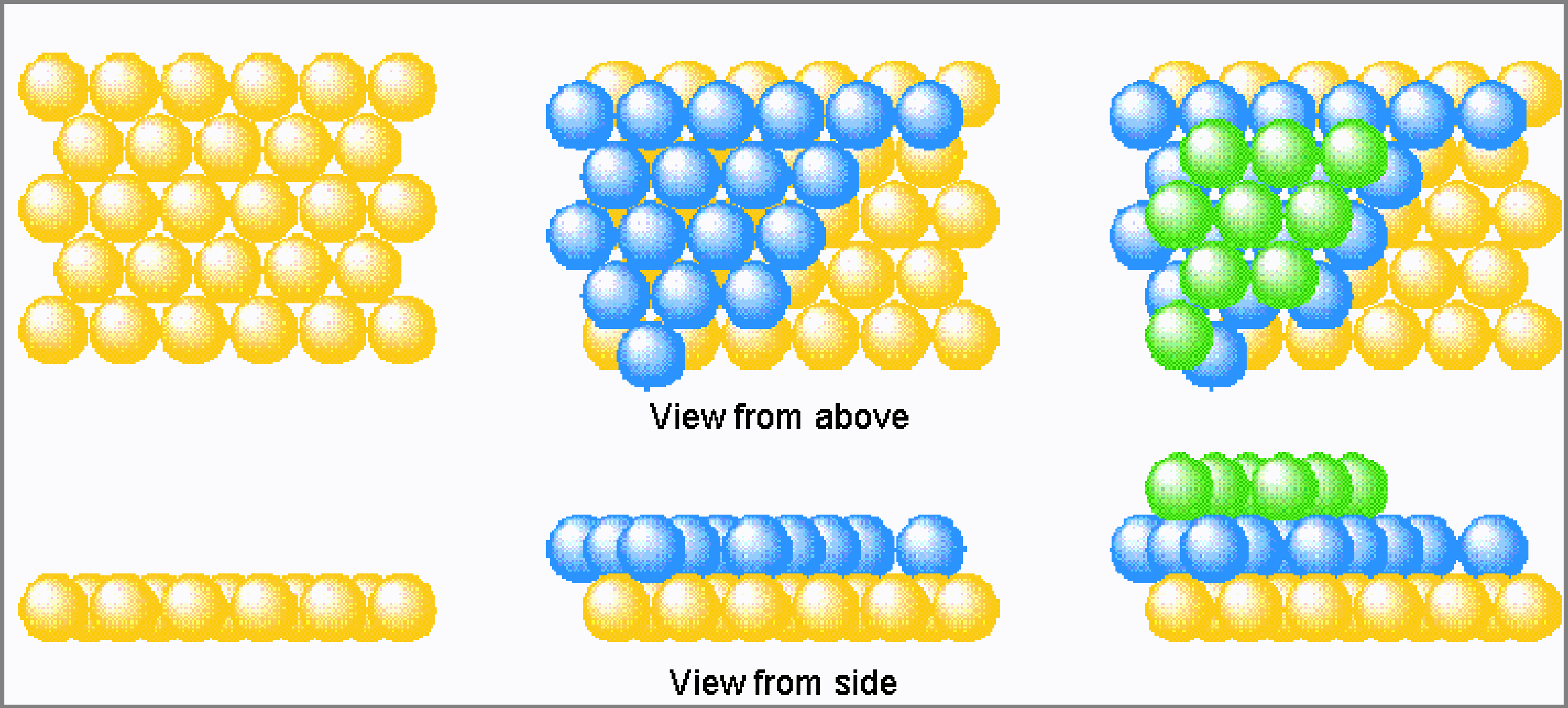


Simple	End Face-Centered	Body Centered	Face Centered

Crystal Structures – Other Shapes

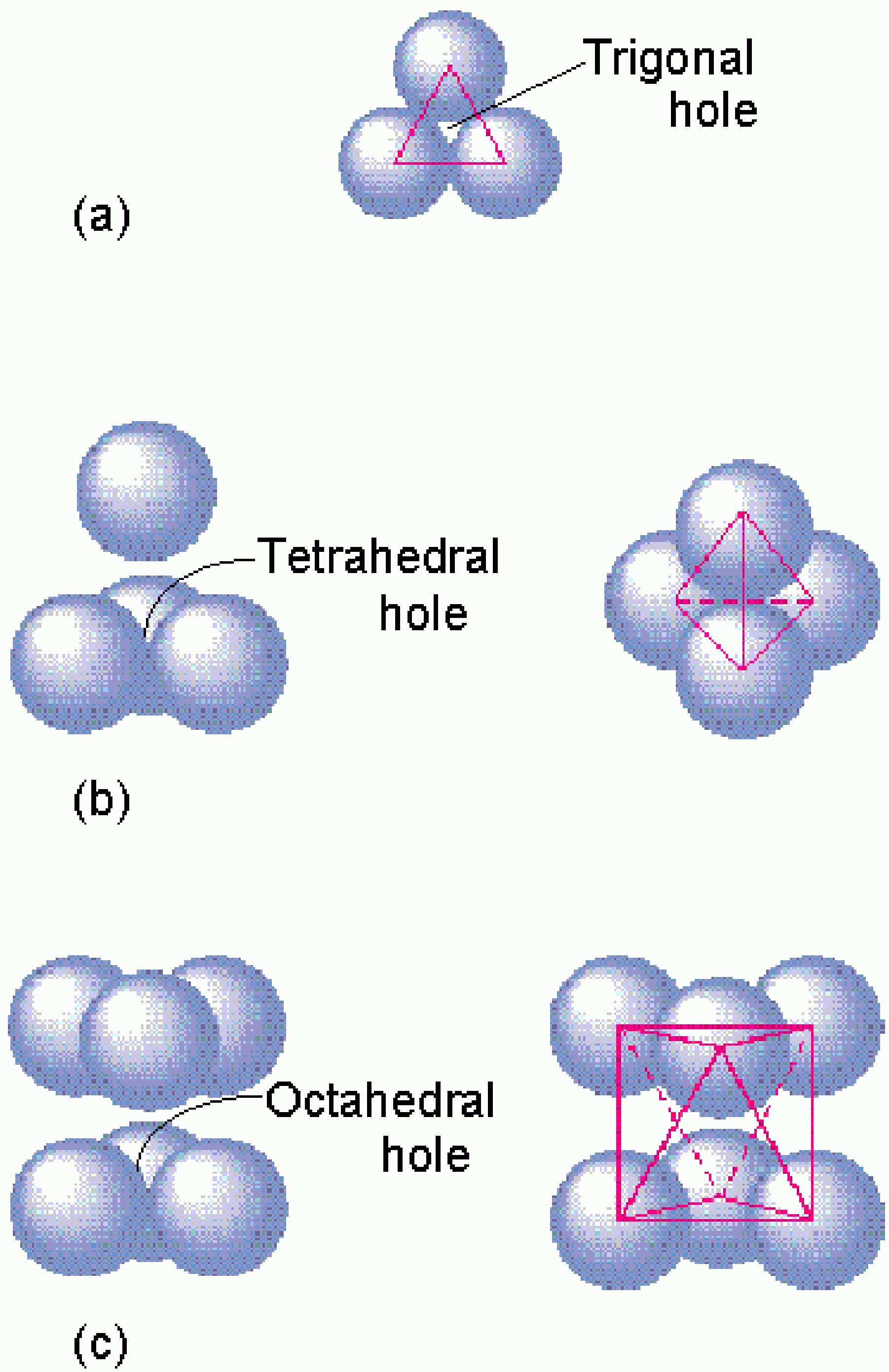


Packing in Metals



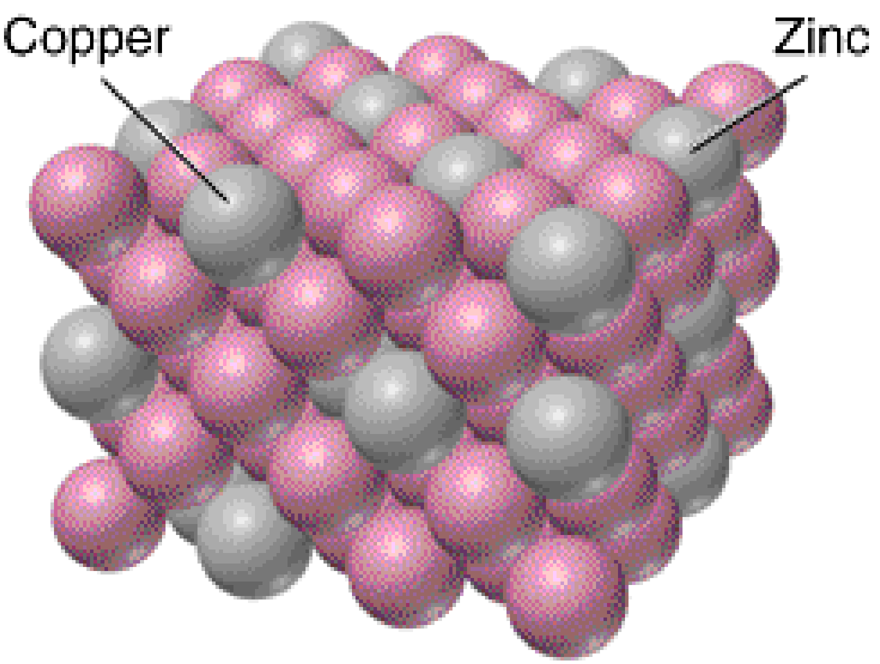
Model: Packing uniform, hard spheres to best use available space. This is called **closest packing**. Each atom has 12 nearest neighbors.

Closest Packing Holes



Metal Alloys

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

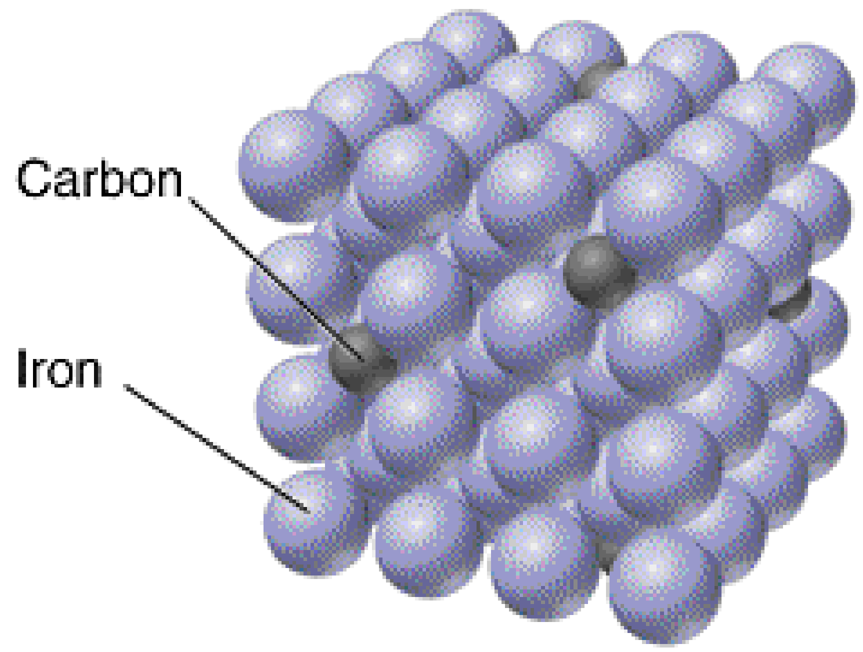


A Brass, a substitutional alloy

Metal Alloys
(continued)

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

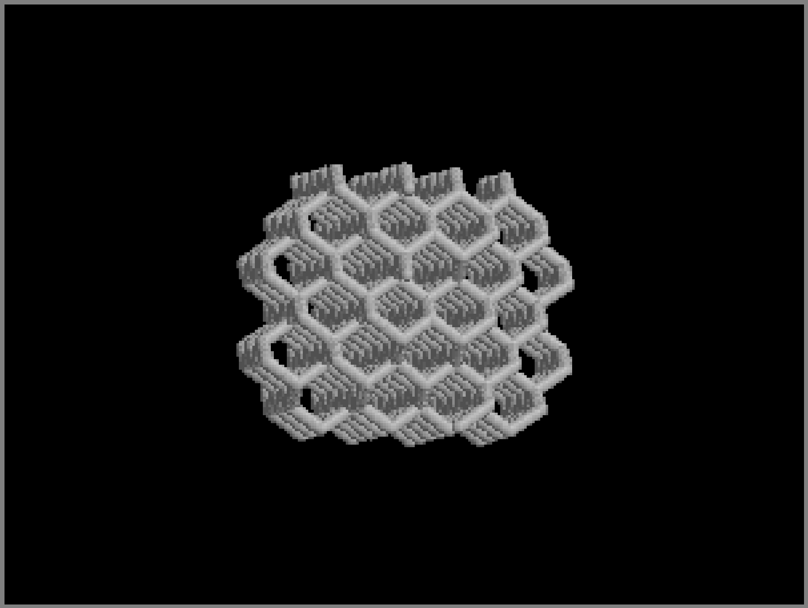
  - steel = iron + carbon



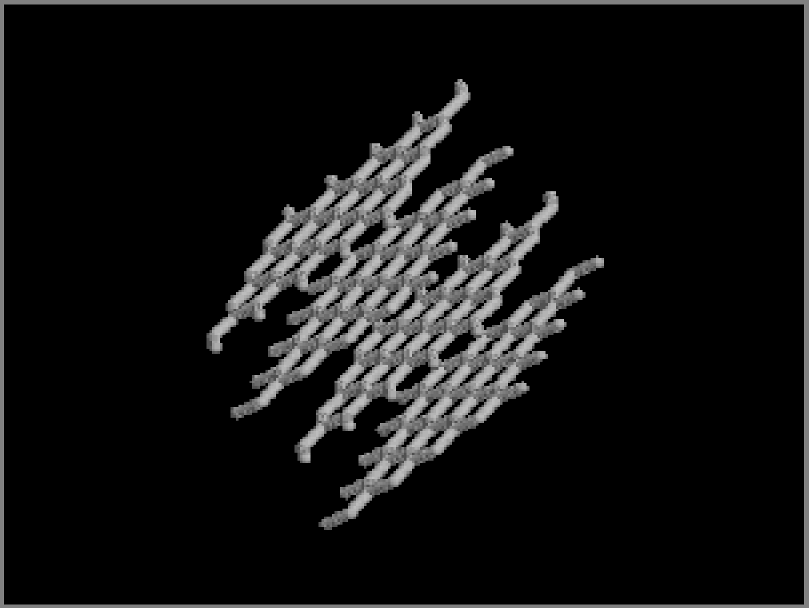
B Carbon steel, an interstitial alloy

Network Atomic Solids

Some covalently bonded substances DO NOT form discrete molecules.



Diamond, a network of covalently bonded carbon atoms

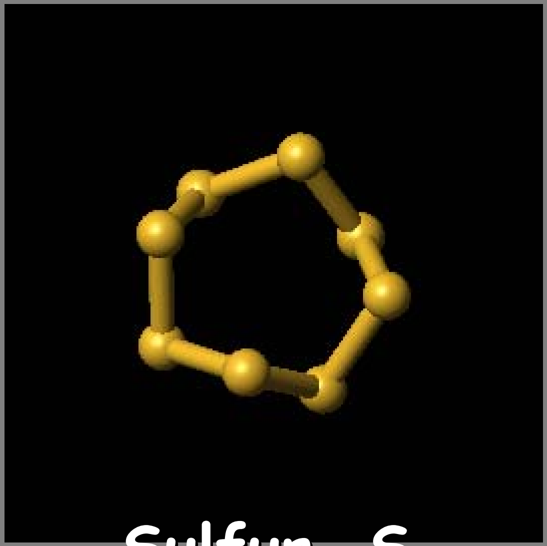


Graphite, a network of covalently bonded carbon atoms

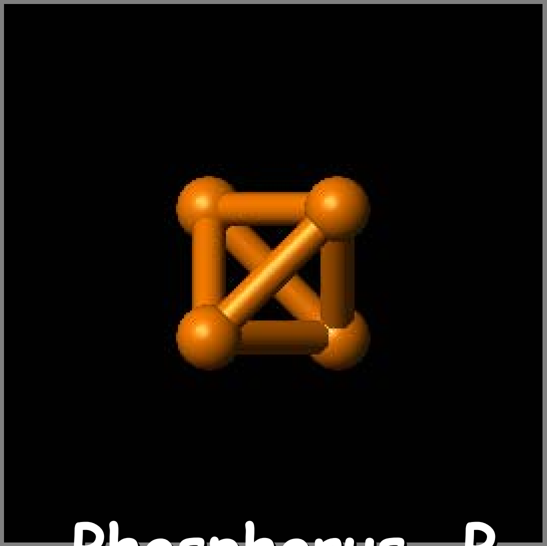
Molecular Solids

Strong covalent forces within molecules

Weak covalent forces between molecules



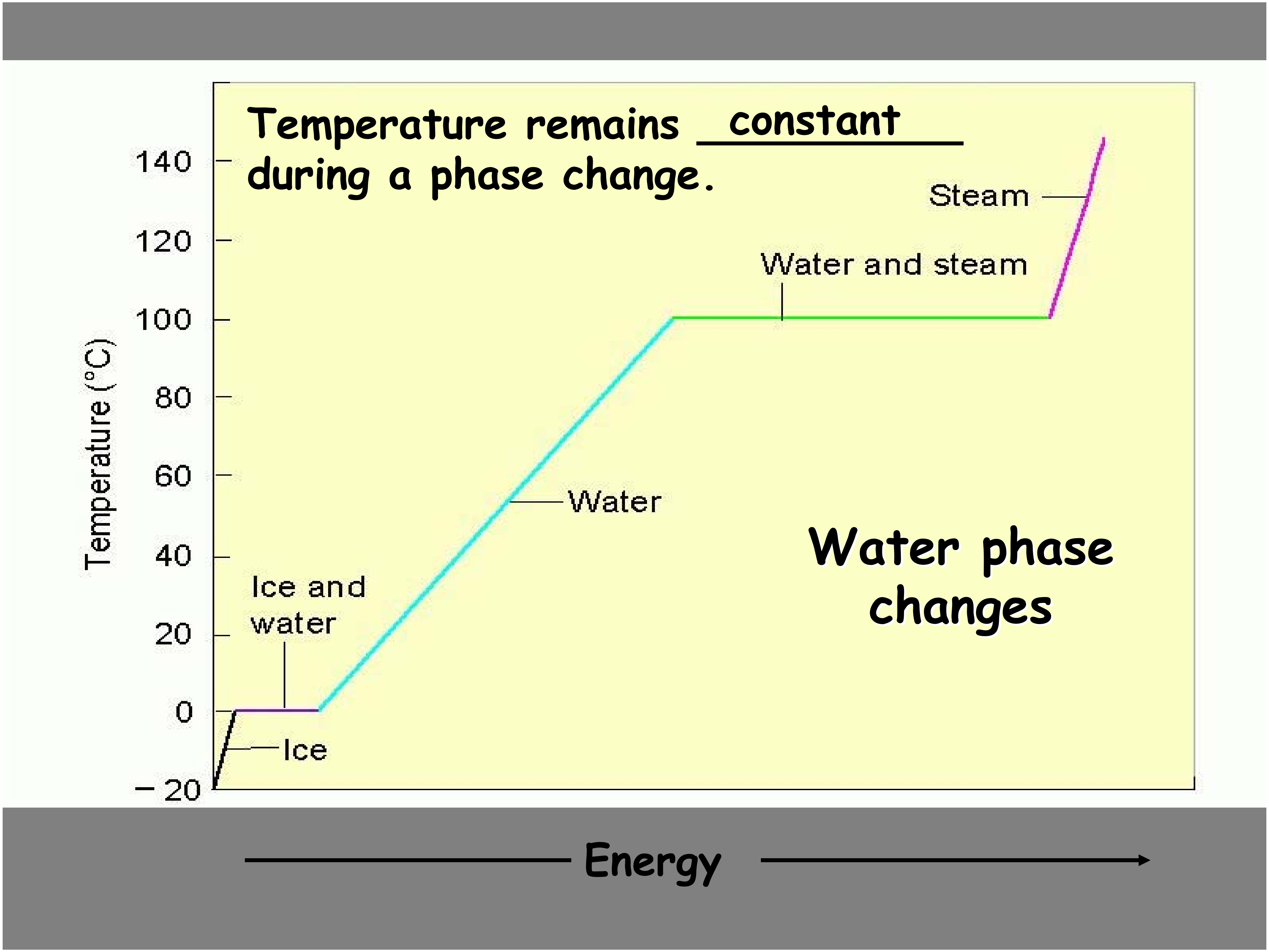
Sulfur, S_8



Phosphorus, P_4

Equilibrium Vapor Pressure

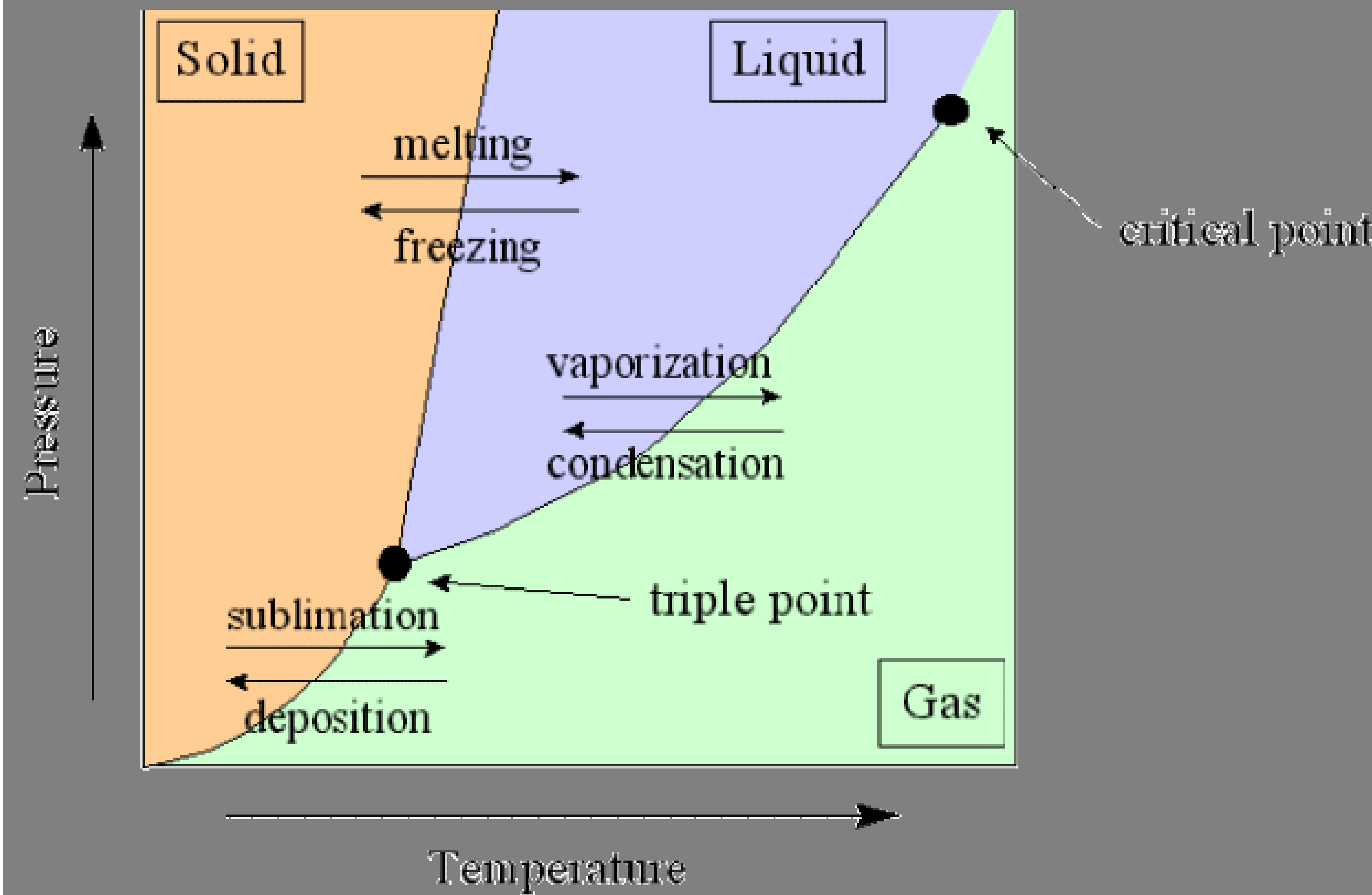
- The pressure of the vapor present at equilibrium.
- Determined principally by the size of the intermolecular forces in the liquid.
- Increases significantly with temperature.
- Volatile liquids have high vapor pressures.


Temperature remains constant
during a phase change.
Water phase changes
Temperature (°C)
140
120
100
80
60
40
20
0
− 20
Steam
Water and steam
Water
Ice and water
Ice
Energy

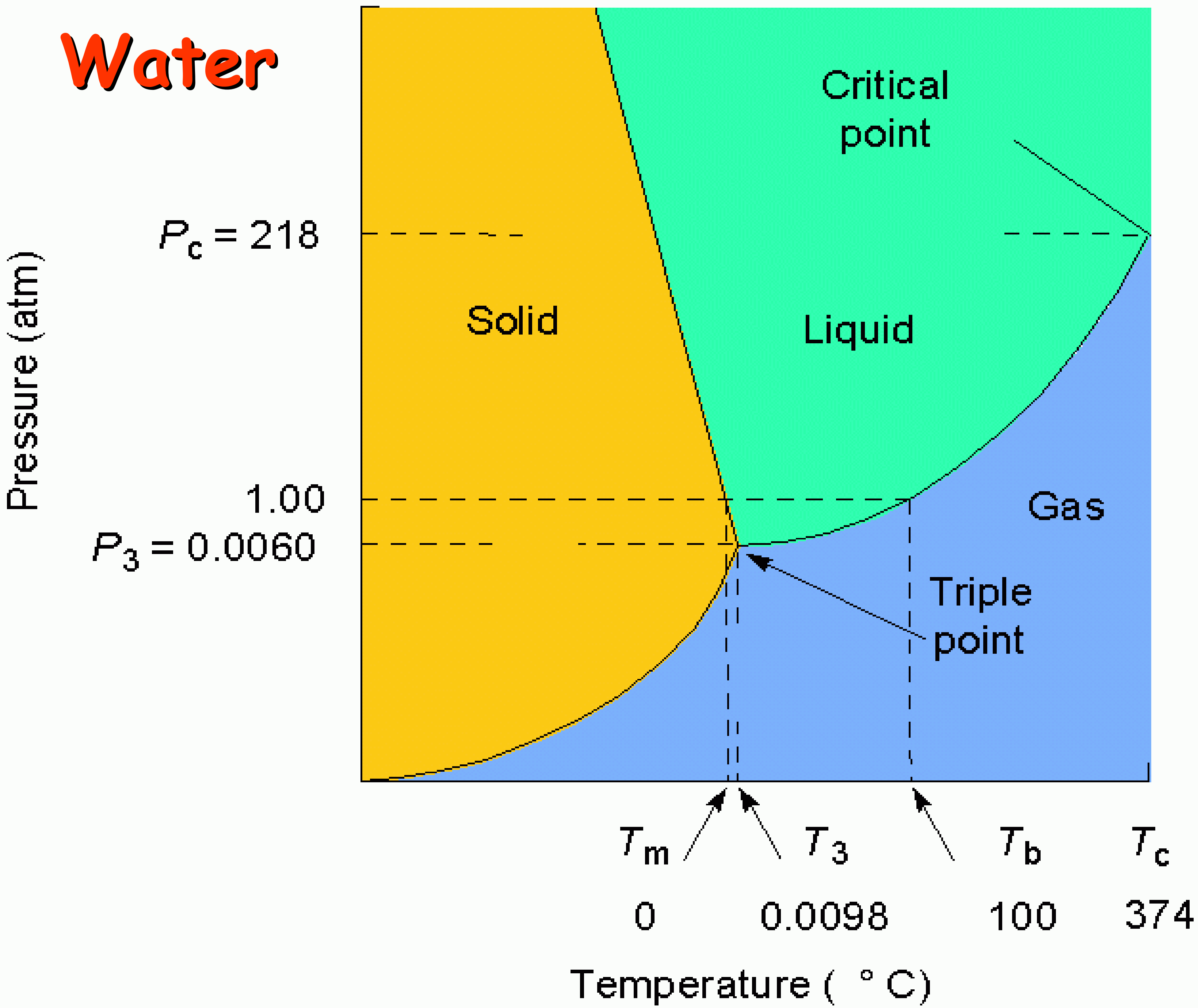
Phase Diagram

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

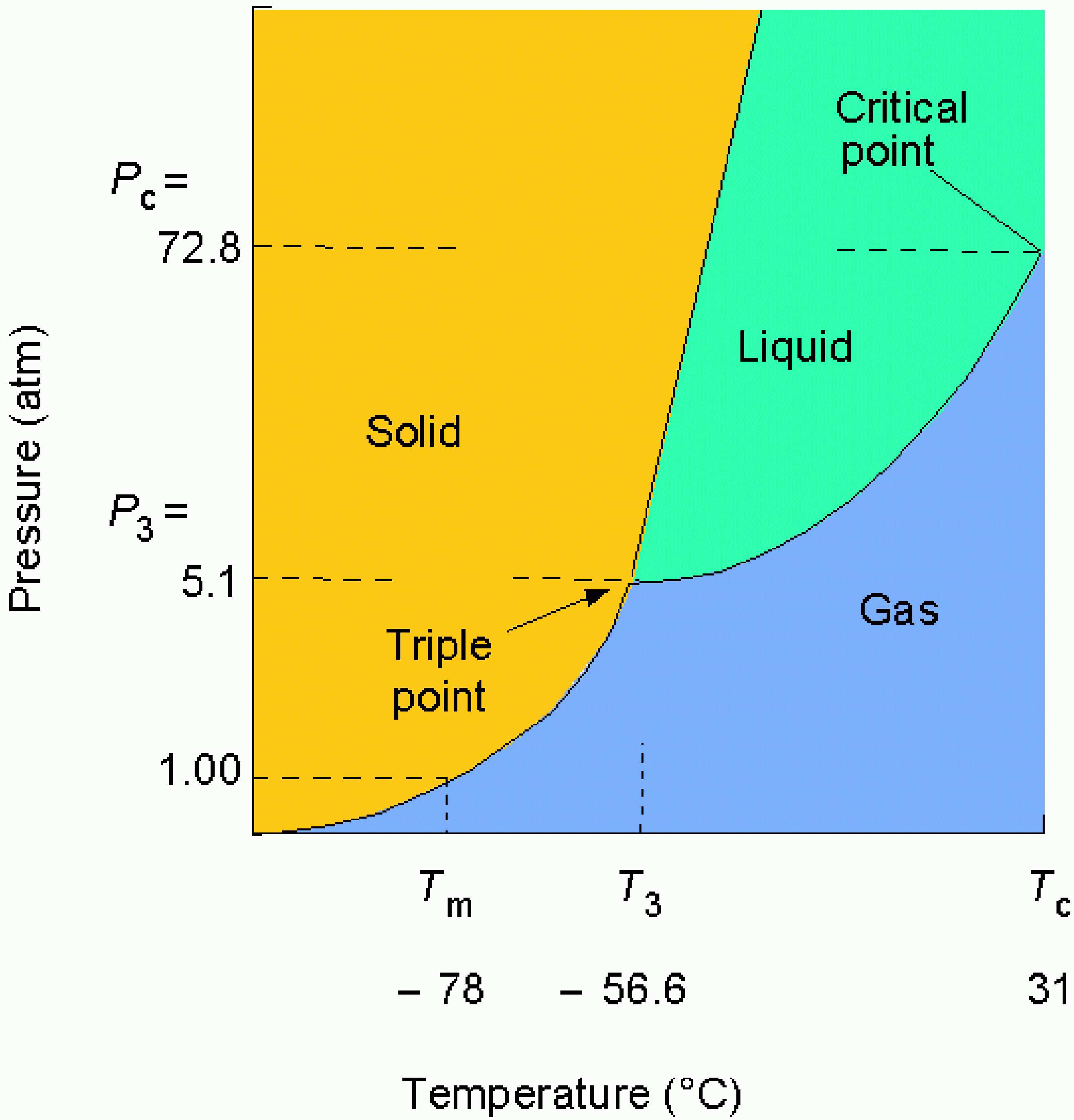
Phase changes by Name



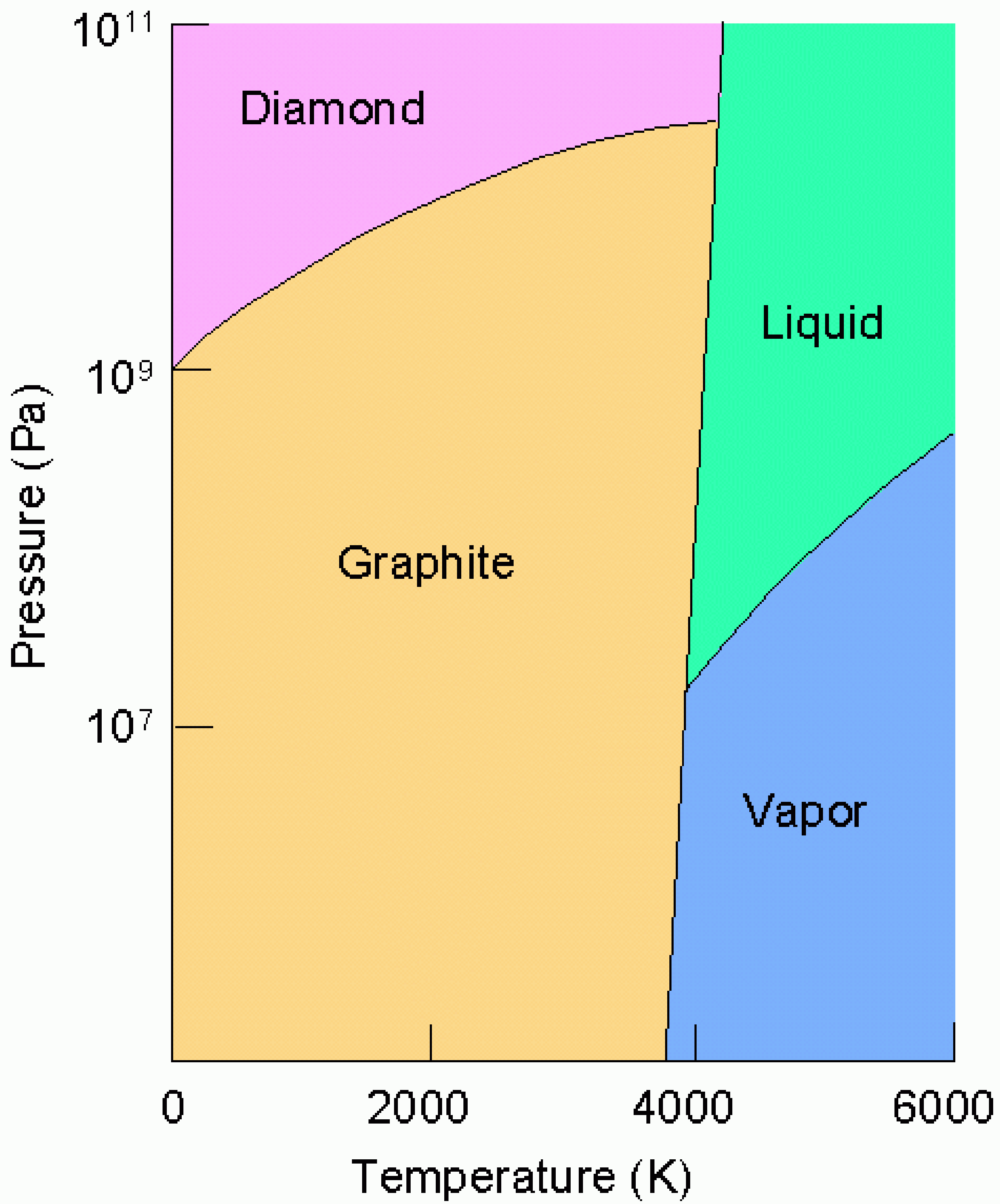
Water


Critical point
Pc = 218
Solid
Liquid
Pressure (atm)
1.00
P3 = 0.0060
Gas
Triple point
Tm
T3
Tb
Tc
0
0.0098
100
374
Temperature (°C)

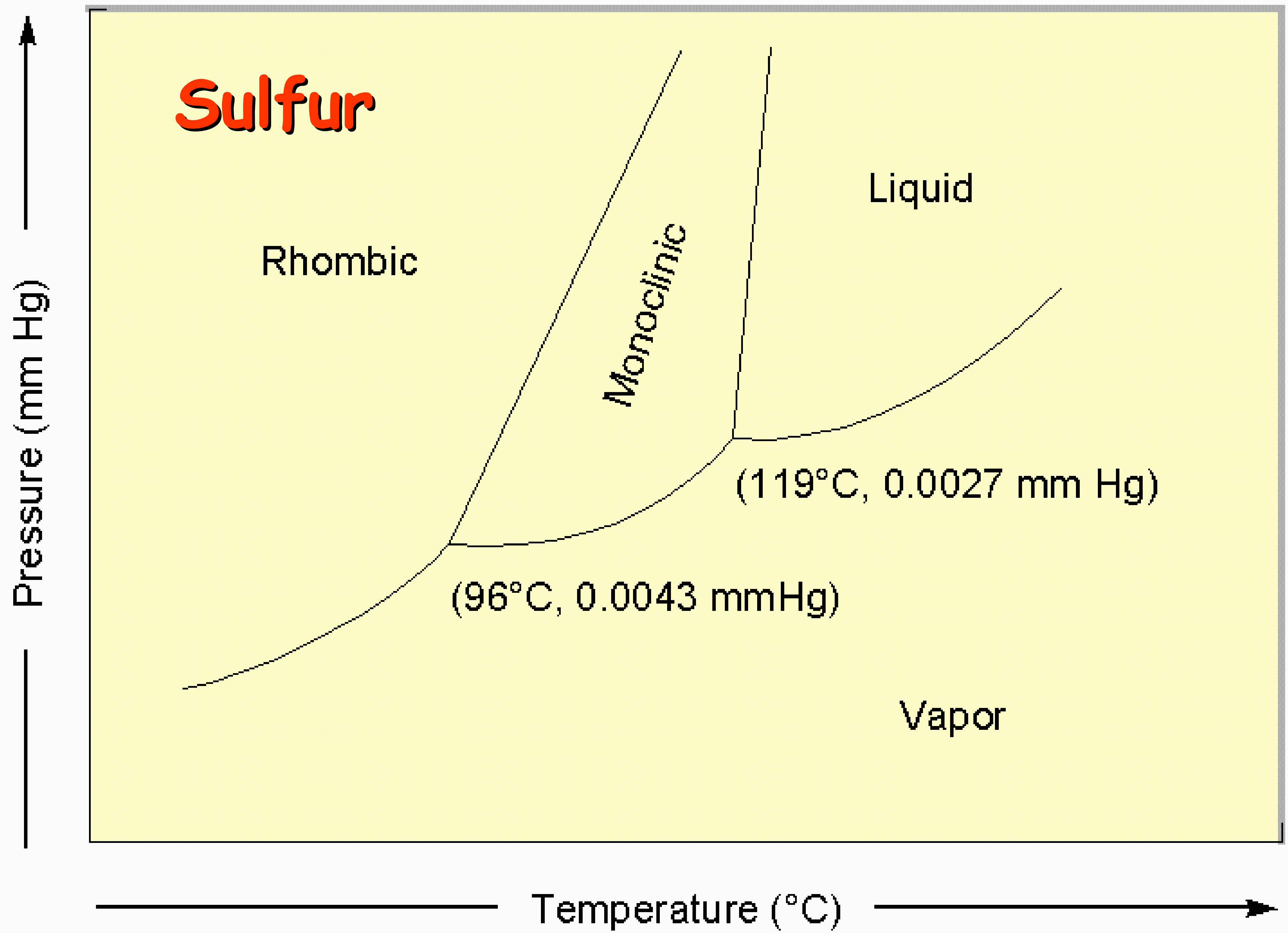
Carbon dioxide



Carbon



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



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