Solids, Liquids, and Gases

Intermolecular Forces (IMFs)

Intermolecular Forces are the forces between molecules that determine how they interact with each other. Among other properties, these forces are important in determining the matter phase of a substance. The 3 main phases of matter are **solids, liquids, and gases**.

All of the forces between neutral molecules are **van der Waals forces**. These have to do with the instantaneous localization of electronic density in a molecule that allows different parts of a molecule to experience a **partial charge** or dipole.

Dispersion forces are the result of temporary dipoles in molecules that arise from the instantaneous changes in instantaneous electron density in a molecule. These changes induce a dipole and as such are refered to as **indiced dipole** forces.

Dipole-Dipole forces occur when formal dipoles are present in polar molecules, which occurs when there is a partial charge difference in a molecule such that one portion of a molecule is more electronegative than another. The partial charges that arise from formal dipoles allow for attraction of the oppositely partial charged portion of other polar molecules.

Hydrogen Bonding occurs in the special case of a particularly strong dipole that is created when a hydrogen is attached to a strongly electronegative atom.

Properties of liquids

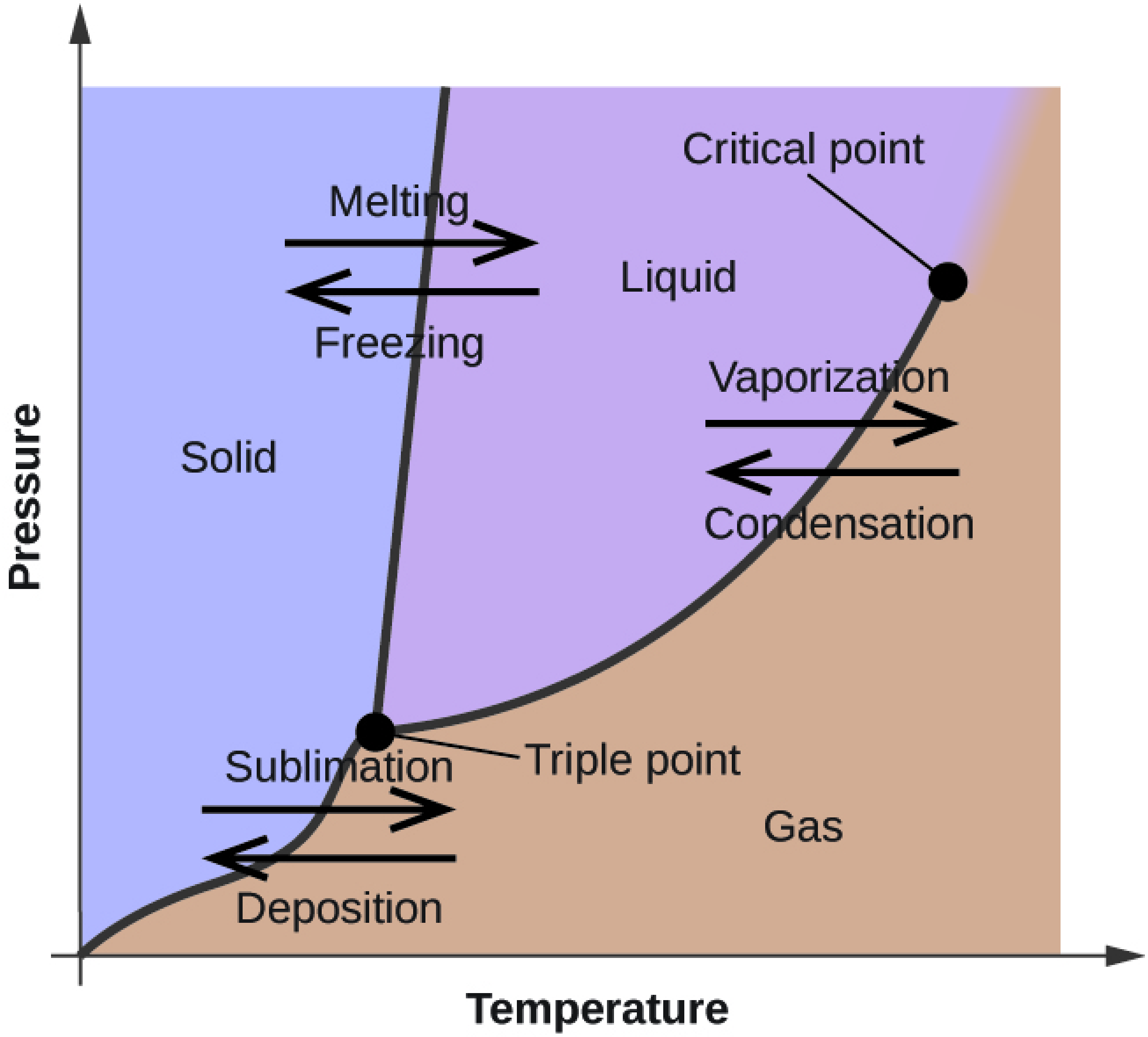
Viscosity is a liquids resistance to flow. It comes about through a combination of intermolecular forces, molecular size, shape, and temperature.

IMFs in liquids are examples of **cohesive forces**, because the force molcule is surrounded equally on all sides by other like molecules and is equally attracted in all directions. Molecules on the surface only experience half of these forces, however, liquids assume a droplet shape to minimize the number of molecules on the surface. **Surface tension** is the energy required to increase the surface area of a droplet.

Adhesive forces are the attractive IMFs between different molecules. **Capillary action** is a phenomena that happens when liquids come into contact with porous materials. The attractive IMFs between the material and other liquid molecules allows the liquid to "climb" up the material.

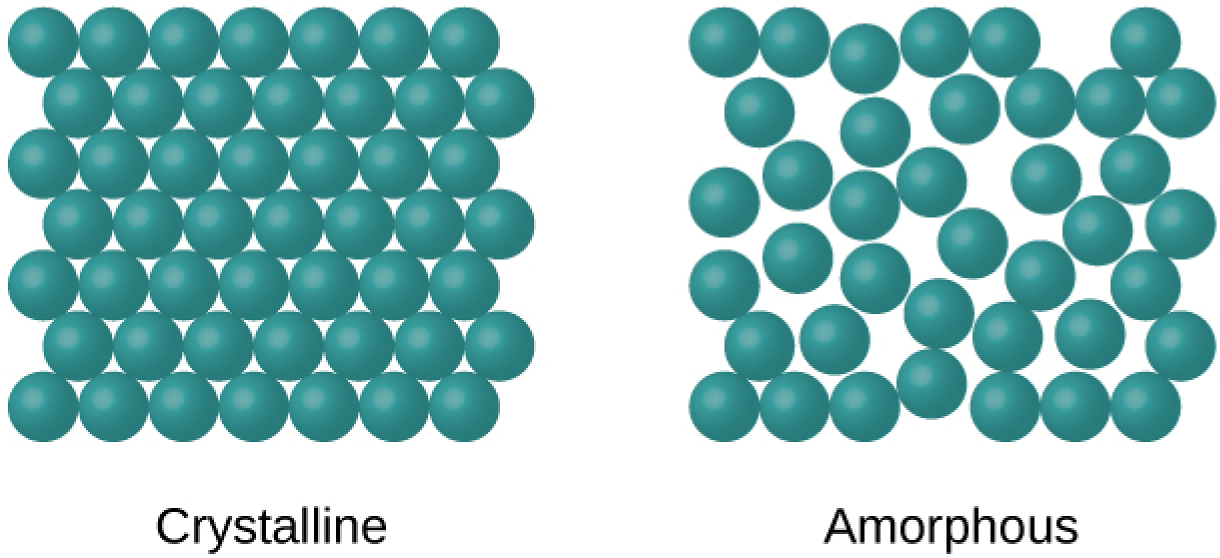
Phase Diagrams

A **Phase diagram** is a temperature, pressure plot that delineates between the phase of a material. The **triple point** is a temperature-pressure combinatin at which the material can exist in all 3 phases of matter simultaneously. There is also a temperature-pressure combination at which the material is present as an intermediate between liquid and gas, known as a **supercritical fluid**, the point after which the supercritical fluid exists is the **critical point**.



Solids

Solids can be found in **crystalline** form, molecules, atoms, or ions in repeating, ordered arrangements, or in **amorphous** form, the particles in these forms lack an ordered structure.

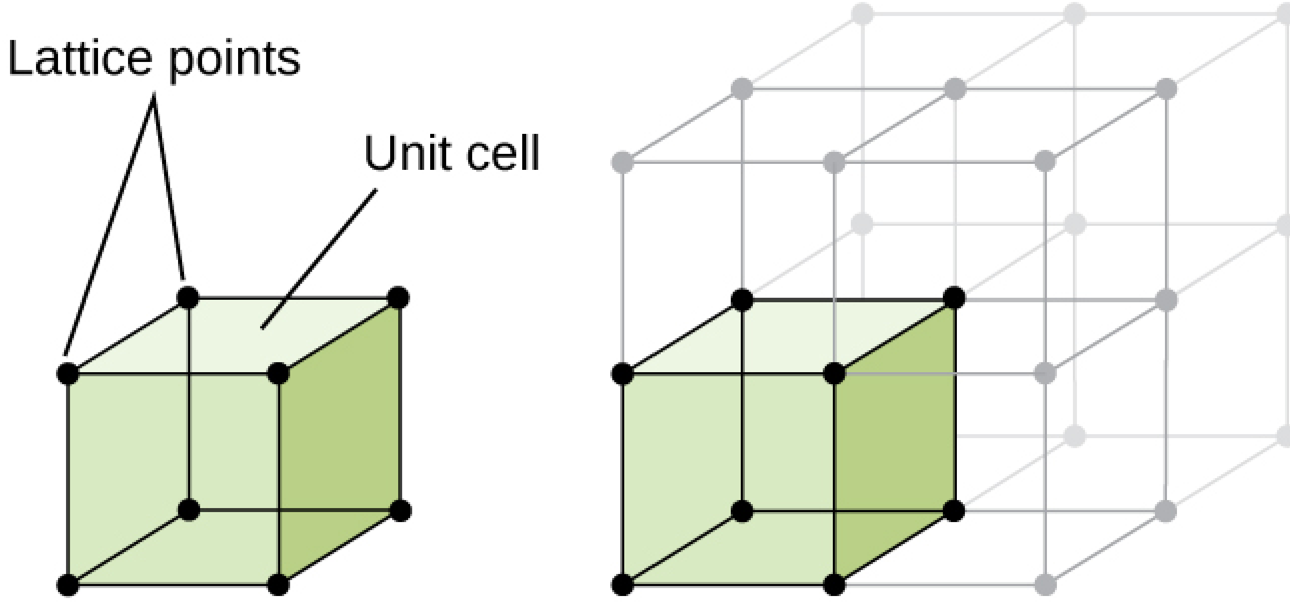


Types of Crystalline Solids and Their Properties				
Type of Solid	**Type of Particles**	**Type of Attractions**	**Properties**	**Examples**
ionic	ions	ionic bonds	hard, brittle, conducts electricity as a liquid but not as a solid, high to very high melting points	NaCl, Al_2O_3
metallic	atoms of electropositive 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, $C_{12}H_{22}O_{11}$

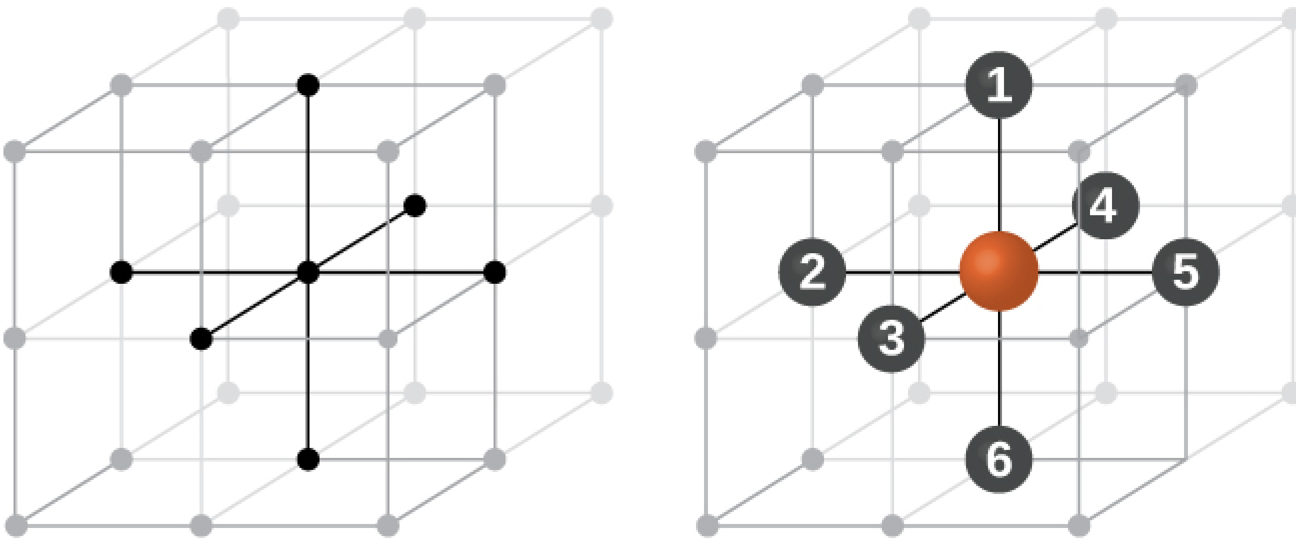
Vacancies are positions in the crystal lattice that typically contain a particle, but they are not present. **Intersticial sites** are located between normal atom positions and can be occupied by impurities.

Structure of Solids

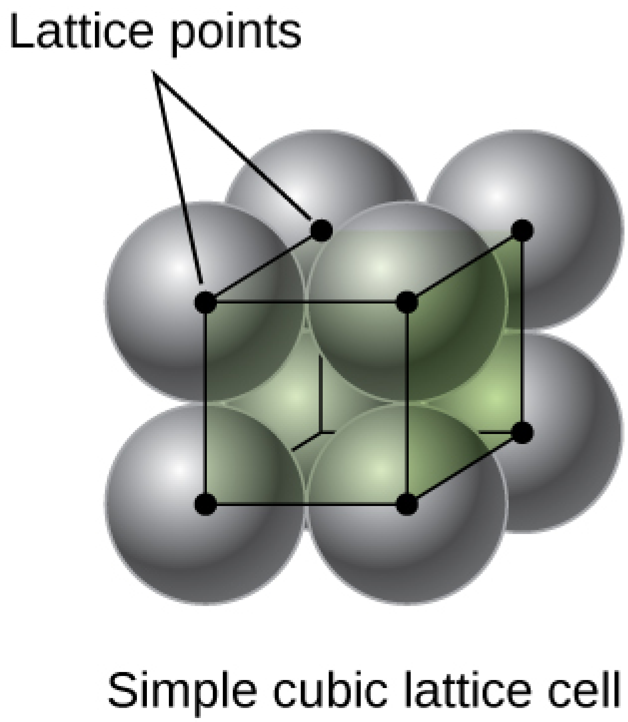
The **unit cell** is the simplest repeating unit of a crystal solid.

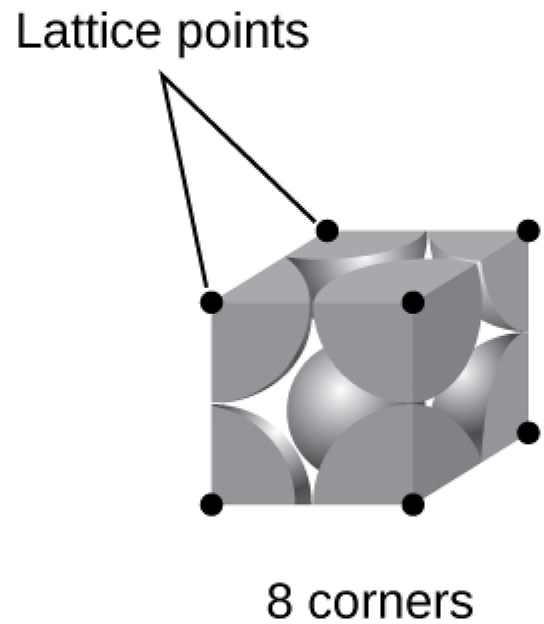


The number of particles that an atom is in contact with in a crystal is its **coordination number**

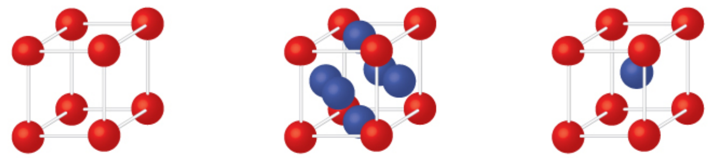
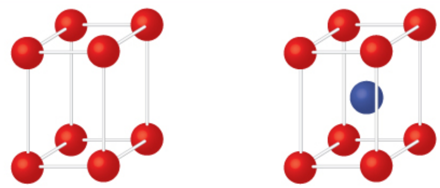
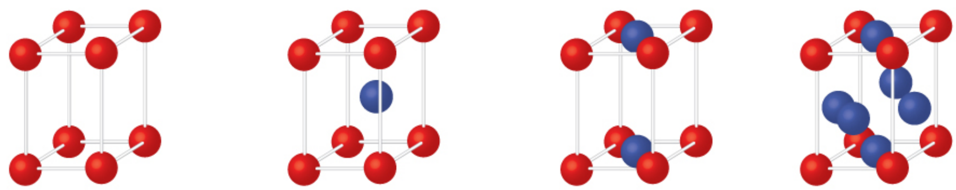
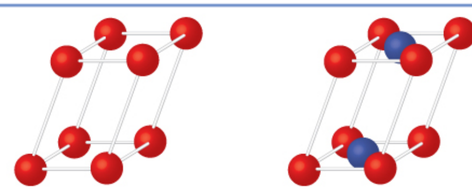
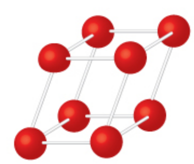
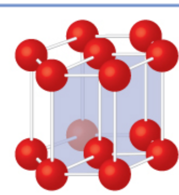
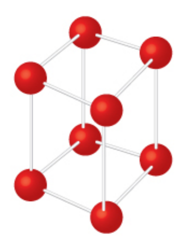


In a cubic unit cell, one can count the number of atoms within the unit cell by recognizing that there are 8 1/8ths of an atom in the unit cell, or 1 total atom.

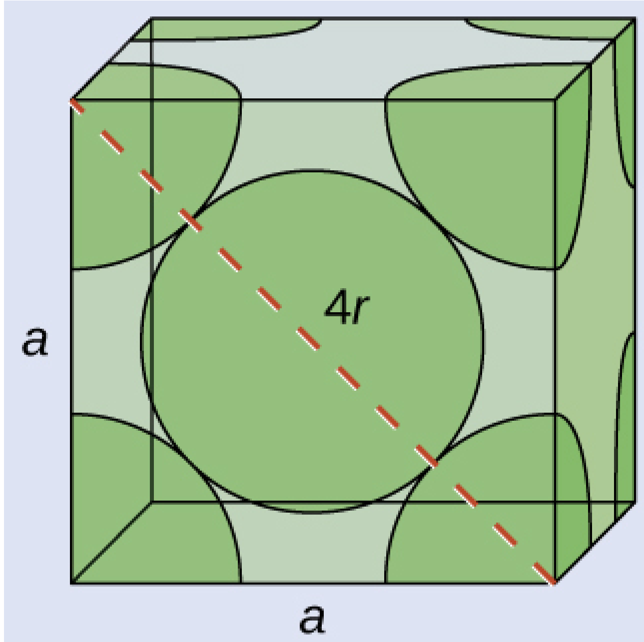




There are several types of unit cells.

System/Axes/Angles	Unit Cells
Cubic $a = b = c$ $\alpha = \beta = \gamma = 90^\circ$	 Simple Face-centered Body-centered
Tetragonal $a = b \neq c$ $\alpha = \beta = \gamma = 90^\circ$	 Simple Body-centered
Orthorhombic $a \neq b \neq c$ $\alpha = \beta = \gamma = 90^\circ$	 Simple Body-centered Base-centered Face-centered
Monoclinic $a \neq b \neq c$ $\alpha = \gamma = 90^\circ; \beta \neq 90^\circ$	 Simple Base-centered
Triclinic $a \neq b \neq c$ $\alpha \neq \beta \neq \gamma \neq 90^\circ$	
Hexagonal $a = b \neq c$ $\alpha = \beta = 90^\circ; \gamma = 120^\circ$	
Rhombohedral $a = b = c$ $\alpha = \beta = \gamma \neq 90^\circ$	

For any unit cell, one can use pythagorean theorem to calulate the diagonal of a unit cell, exemplified for the face-centered cube below.



$$a^2 + a^2 = d^2 = (4r)^2$$

Gases

Pressure, Volume, Temp. relations

$$\frac{P_2}{T_2} = \frac{P_1}{T_1}$$

$$\frac{V_2}{T_2} = \frac{V_1}{T_1}$$

$$P_1V_1 = P_2V_2$$

Ideal Gas Law

$$PV = nRT$$