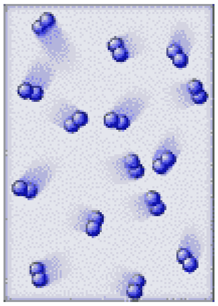
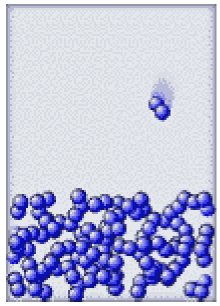
4 States of Matter: Liquids, Solids, Gases, and Plasma

Gas



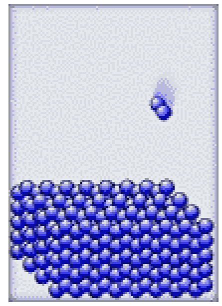
low density
easy to expand/compress
fills container

Liquid



high density
hard to expand/compress
takes shape of container

Solid



high density
hard to expand/compress
rigid shape

The forces involved in the three states of matter (from weakest to strongest)

1. Intermolecular forces
2. Covalent bonding
3. Ionic bonding
4. Network covalent bonding

The change in phases is caused by the change of forces **among** the molecules.

TYPES OF INTERMOLECULAR FORCES (from weakest to strongest)

- ***London dispersion forces***- forces between non-polar and noble gas molecules. The molecules involved have zero dipole moment. Generally, more electrons means greater Dispersion forces
- ***Dipole-dipole attractions***-forces between polar molecules. The positive pole of the molecule attracts the negative pole of another molecule. This force is only 1% as strong as a covalent or ionic bond. The strength of the force is inversely proportional to the distance between the two molecules.
- ***Hydrogen Bonding***-the strongest intermolecular force. Its strength is largely due to the small size of the hydrogen atom and the large polarity in the resulting molecule.
- The atoms that form hydrogen bonding are the following: Fluorine (F), Nitrogen (N), and Oxygen (O).

Exothermic: heat released, products have less energy content than reactants, PE → KE
Endothermic: heat absorbed, products have more energy content than reactants,
KE → PE

Liquid State:

- Low compressibility
- High density compared to gas
- Lack of rigidity
- Viscosity-measure of resistance to flow (stronger intermolecular forces = greater viscosity)
- Surface tension-resistance of liquid to increase its surface area (stronger intermolecular forces = greater surface tension)
- Capillary action-the sudden rise in level of liquid in tight space

Cohesive forces-intermolecular forces between the molecules in the liquid
Adhesive forces-intermolecular forces between the liquid and the container
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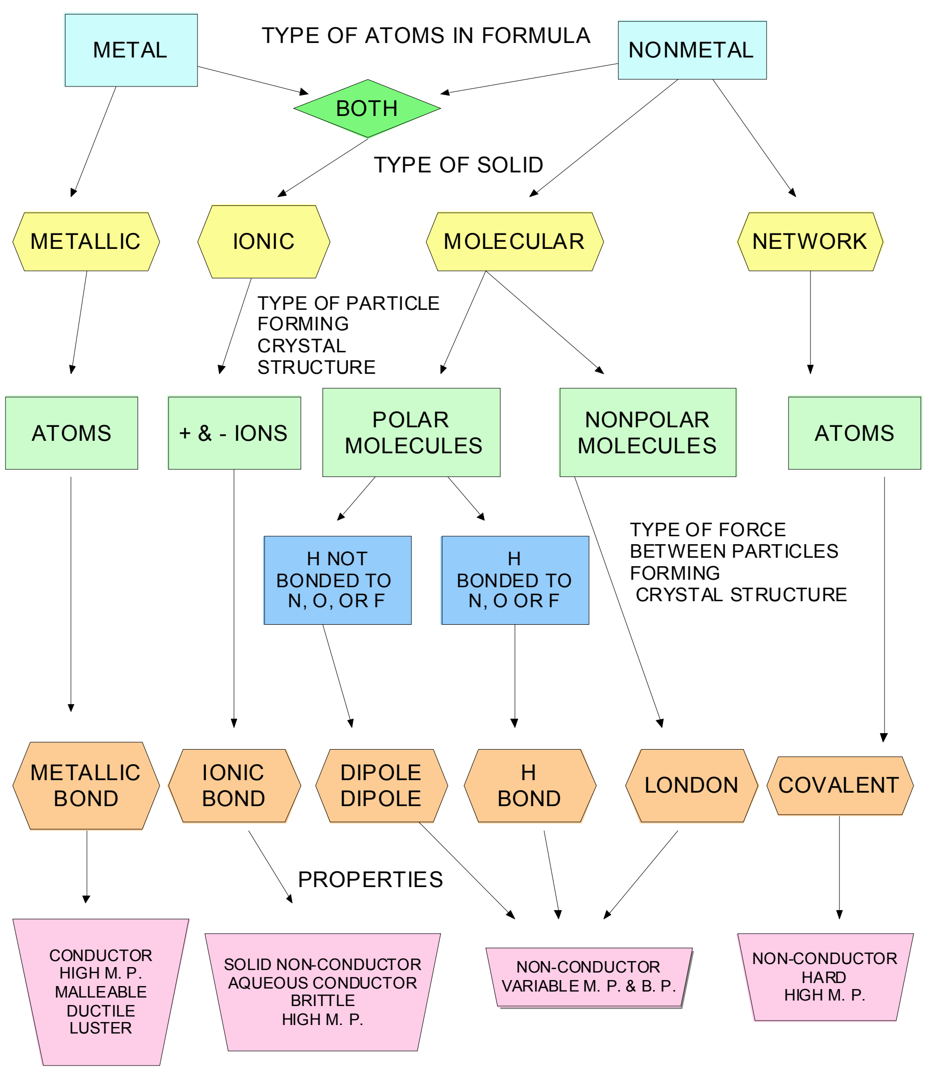
Solids: **Types**

1. Crystalline solids**-** organized structures of its components
2. Amorphous solids**-** disorganized arrangement of its components

TYPES OF SOLIDS



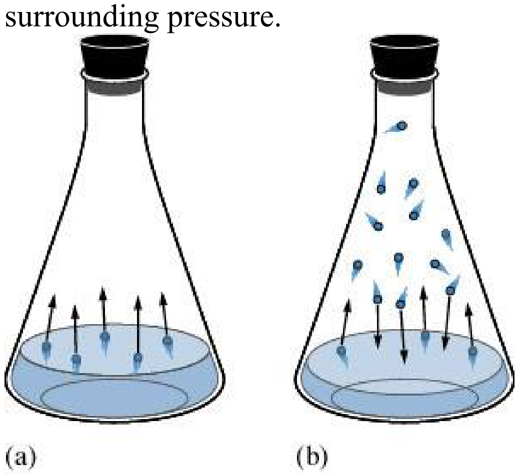
Driving Forces: In order for a process to occur the particles under going the change have to accomplished one or both of the following:

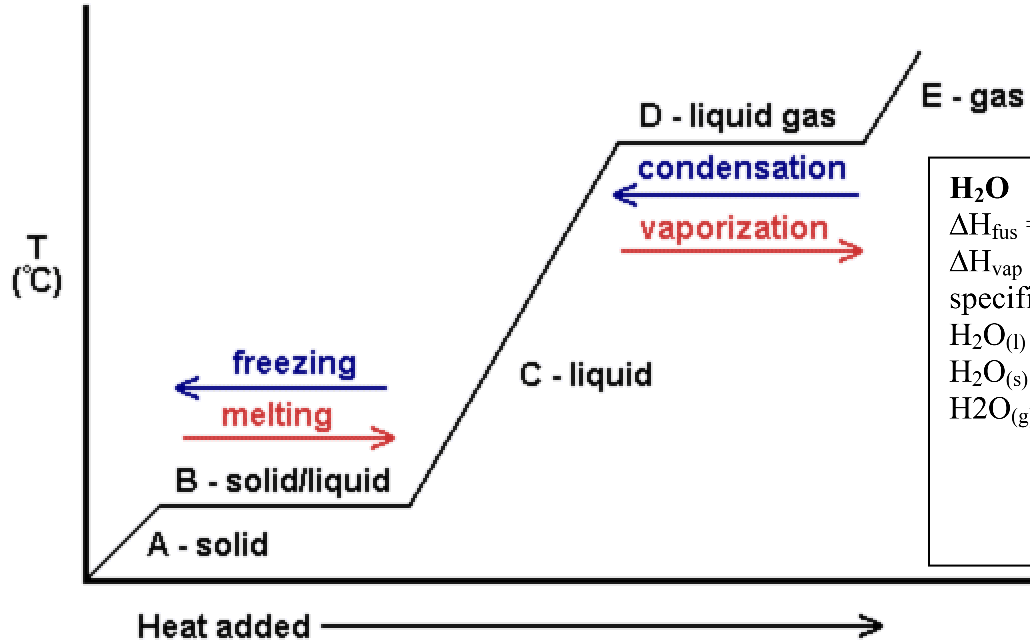
1. Minimum enthalpy: (enthalpy= energy content) products have less energy content than reactants = exothermic
2. Maximum Entropy: products more disordered than reactants
   gas > solutions > liquids > solids, more particles more disorder

Transitions between the 3 states of matter:

Fusion (melting): Heat + Solid←→ Liquid Freezing: Liquid ← → Solid + Heat
Heat of fusion, ΔH_{fus}, heat required to change a given amount of a substance from a solid to a liquid or released when the substance changes from a liquid to a solid
Melting/freezing point: temperature and pressure at which the solid and liquid phase are in equilibrium
Sublimation: heat +Solid←→ Gas Deposition: Gas ←→ Solid + Heat
Evaporation: Heat + Liquid← → Gas Condensation: Gas ← → Liquid + Heat
Also known as vaporization , ΔH_{vap}, heat required to change a given amount of a substance from a liquid to a gas or released when the substance changes from a gas to a liquid

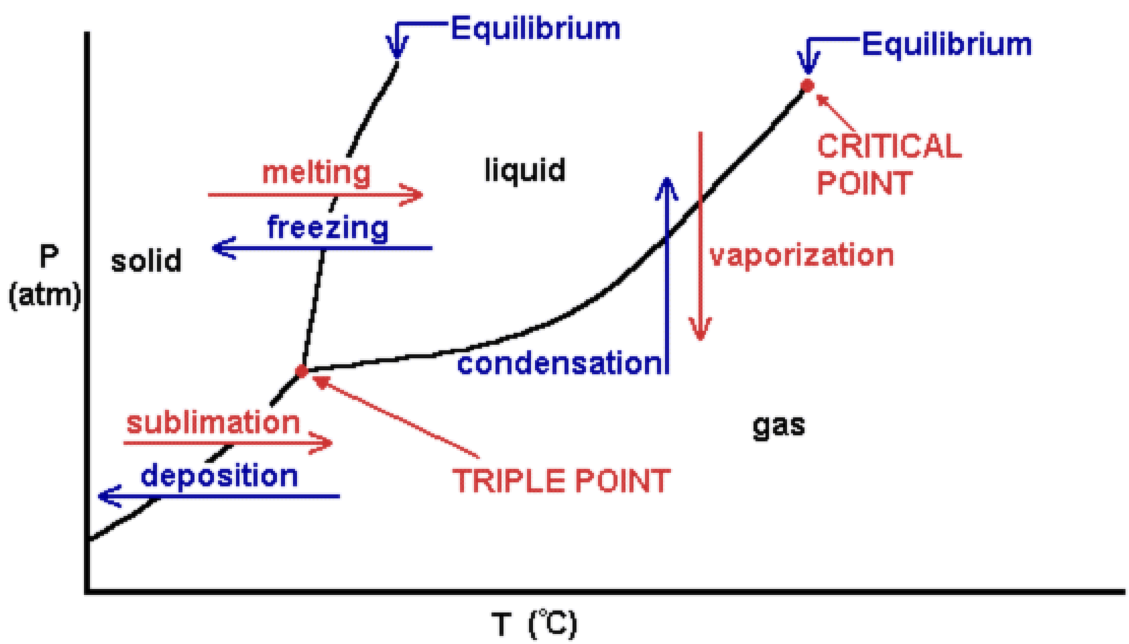
When a liquid is sealed in a closed container, the liquid evaporates, but at the same time the gas condenses back to the liquid state. Equilibrium is reached when the rate of condensation equals the rate of evaporation. The equilibrium vapor pressure is also the vapor pressure of the liquid. **Equilibrium** is the state in which two opposing processes are equal. **Vapor pressure** is the pressure exerted by a liquids vapor in equilibrium with the liquid at a specified temperature.
Boiling Point: temperature at which the vapor pressure of the liquid is equal to the surrounding pressure.





H_2O
ΔH_{fus} = 80cal/g
ΔH_{vap} = 540 cal/g
specific heats:
$H_2O_{(l)}$ = 1cal/g^{o}c
$H_2O_{(s)}$ = .5cal/g^{o}c
$H2O_{(g)}$ = .5cal/g^{o}c

Heating Curve for water:
change in temperature: $q = (m)(sh)(\Delta t)$ change in state: $q = (m)(\Delta H_{fus}$ or $\Delta H_{vap})$



- **Sublimation** is the phase change as a substance changes from a solid to a gas without passing through the intermediate state of a liquid.
- **Deposition** is the phase change as a substance changes from a gas to a solid without passing through the intermediate state of a liquid.
- **<u>TRIPLE POINT</u>** - The temperature and pressure at which the solid, liquid, and gas phases exist simultaneously.
- **<u>CRITICAL POINT</u>** - The temperature above which a substance will always be a gas regardless of the pressure.
- **NOTE:**
    - The solid phase is more dense than the liquid phase.
    - The line between the solid and liquid phases is a curve of all the freezing/melting points of the substance.
    - The line between the liquid and gas phases is a curve of all the boiling points of the substance.
- **<u>Freezing Point</u>** - The temperature at which the solid and liquid phases of a substance are in equilibrium at atmospheric pressure.
- **<u>Boiling Point</u>** - The temperature at which the vapor pressure of a liquid is equal to the pressure on the liquid.
- **<u>Normal (Standard) Boiling Point</u>** - The temperature at which the vapor pressure of a liquid is equal to standard pressure (1.00 atm = 760 mmHg = 760 torr = 101.325 kPa)