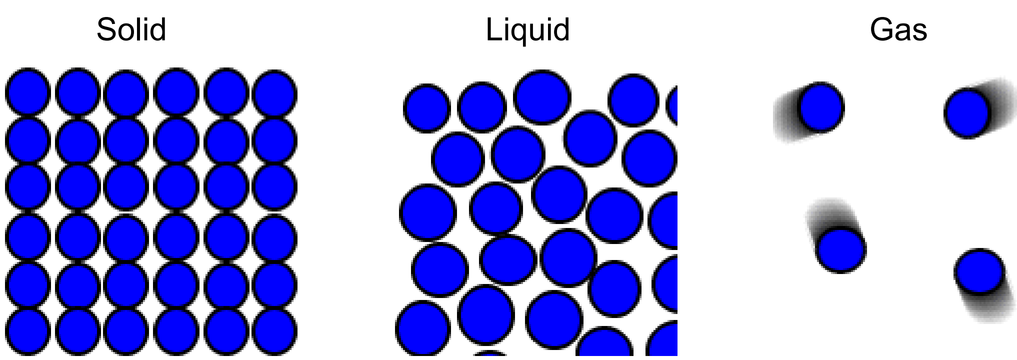
Unit 6 – Solids, Liquids and Solutions

12-1 Liquids

I. Properties of Liquids and the Kinetic Molecular Theory
- A. Fluids
  - 1. Substances that can flow and therefore take the shape of their container
- B. Relative High Density
  - 1. 10% less dense than solids (average)
    - a. Water is an exception
  - 2. 1000x more dense than gases
- C. Relative Incompressibility
  - 1. The volume of liquids doesn't change appreciably when pressure is applied
- D. Ability to Diffuse
  - 1. Liquids diffuse and mix with other liquids
  - 2. Rate of diffusion increases with temperature (↑ average Kinetic Energy)
- E. Surface Tension
  - 1. Surface Tension
    - a. A force that tends to pull adjacent parts of a liquid's surface together, thereby decreasing surface area to the smallest possible size
    - b. Hydrogen bonding in water creates stronger than normal surface tension
  - 2. Capillary Action
    - a. The attraction of the surface of a liquid to the surface of a solid
- F. Evaporation and Boiling
  - 1. Vaporization
    - a. The process by which a liquid of solid changes to a gas
  - 2. Evaporation
    - a. The process by which particles escape from the surface of a nonboiling liquid enter the gas state
    - b. Evaporation is a form of vaporization
  - 3. Boiling
    - a. The change of a liquid to bubbles of vapor that appear throughout the liquid
- G. Formation of Solids
  - 1. Freezing (or Solidification)
    - a. The physical change of a liquid to a solid by removal of heat



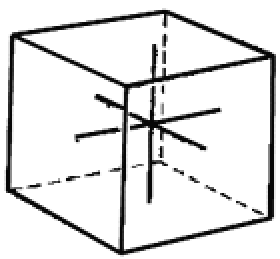
12-2 Solids

I. Properties of Solids and the Kinetic Molecular Theory

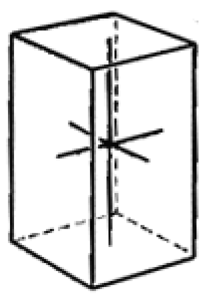
- A. Types of Solids
    - 1. Crystalline Solids - substances in which the particles are arranged in an orderly, geometric, repeating pattern
    - 2. Amorphous Solids - substances in which the particles are arranged randomly
- B. Definite Shape and Volume
- C. Definite Melting Point
    - 1. Melting is the physical change of a solid to a liquid by the addition of heat
    - 2. Melting point is the temperature at which a solid becomes a liquid
        - a. Crystalline solids have definite melting points
        - b. Amorphous solids do not have definite melting points
- D. High Density and Incompressibility
- E. Low Rate of Diffusion
    - 1. Two solids in contact will experience VERY SLOW rates of diffusion

II. Crystalline Solids

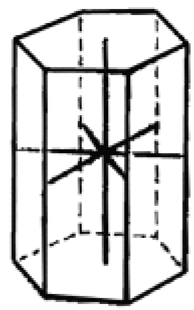
- A. Crystal Structure
    - 1. The total three dimensional arrangement of particles of a crystal
- B. Unit Cell
    - 1. The smallest portion of a crystal lattice that shows the three-dimensional pattern of the entire lattice



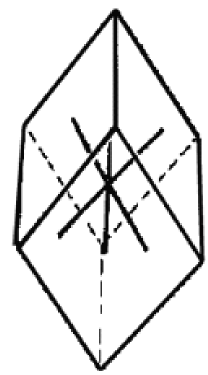
Isometric or cubic



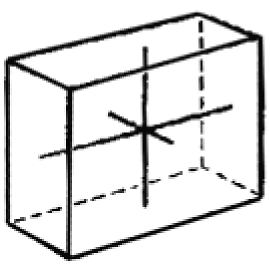
Tetragonal



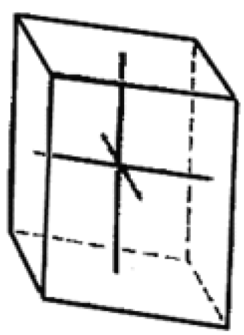
Hexagonal



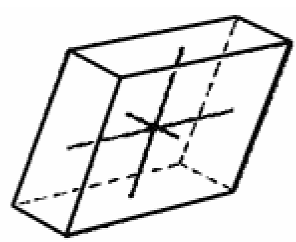
Trigonal



Orthorhombic



Triclinic



Monoclinic

III. Amorphous Solids

- A. "Amorphous"
    - 1. Greek for "without shape"
- B. Formation of amorphous solids
    - 1. Rapid cooling of molten materials can prevent the formation of crystals
        - a. Glass
        - b. Obsidian

12.3 Phase Changes

I. Boiling and Condensation

A. Boiling

1. The conversion of a liquid to a vapor within the liquid as well as at its surface. It occurs when the equilibrium vapor pressure of the liquid equals the atmospheric pressure

B. Boiling Point

1. The temperature at which the equilibrium vapor pressure of the liquid equals the atmospheric pressure
   a. Water boils at 100 °C at 1 atm pressure
   b. Water boils above 100 °C at higher pressures
   c. Water boils below 100 °C at lower pressures

C. Condensation

1. The conversion of a gas to a liquid by the removal of energy

II. Freezing and Melting

A. Freezing Point

1. The temperature at which the solid and liquid are in equilibrium at 1 atm
2. For pure crystalline solids, the melting point and freezing point are the same
3. Temperature remains constant during a phase change

B. Molar Heat of Fusion

1. The amount of heat energy required to melt one mole of solid at its melting point

C. Sublimation and Deposition

1. Sublimation is the change of state from a solid directly to a gas
   a. Dry ice → Gaseous CO_2
2. Deposition is the change of state from a gas directly to a solid

III. Phase Diagrams

A. Phase Diagram

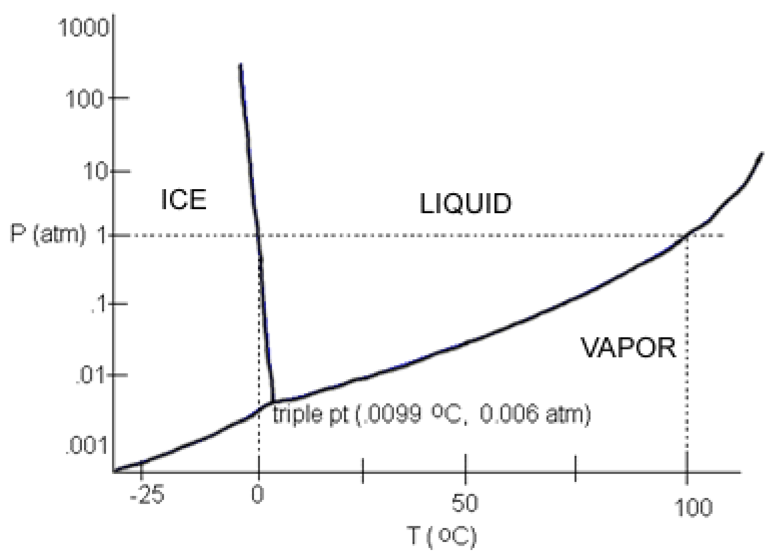
1. A graph of pressure versus temperature that shows the conditions under which the phases of a substance exist (notice that pressure is on a logarithmic scale)

B. Triple Point

1. The temperature and pressure conditions at which the solid, liquid, and vapor of the substance can coexist at equilibrium

C. Critical Temperature

1. The temperature at above which the substance cannot exist in the liquid state, regardless of pressure
   a. For water, the critical temperature is 373.99 °C



D. Critical Pressure

1. The lowest pressure at which the substance can exist as a liquid at the critical temperature
   a. For water, the critical pressure is 217.75 atm

E. Critical Point

1. The point on the graph describing simultaneously the critical temperature and the critical pressure

P = 217.75 atm Temperature = 373.99 °C

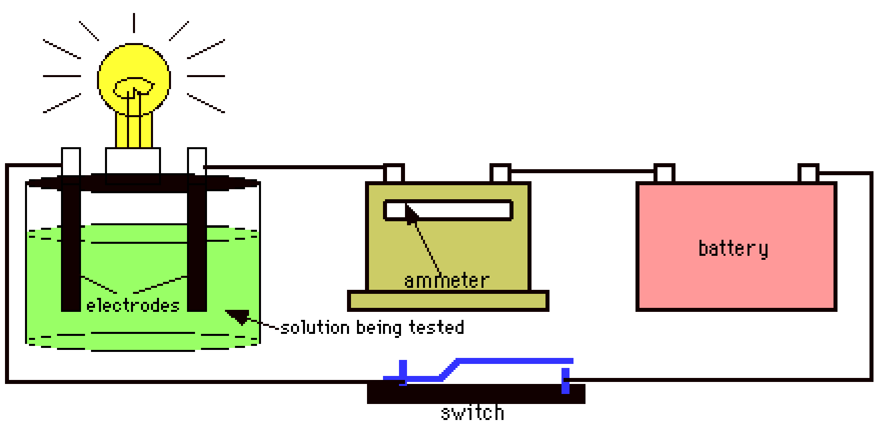
12-4 Water

Bond Type	Polar		Density of ice (0 °C)	0.917 g/cm^3
Bond angle	105°		Density of water (0 °C)	0.999 g/cm^3
Boiling point	100 °		Point of maximum density	3.98 °C
Melting Point	0 °C		Molar heat of fusion	6.009 kJ/mole
			Molar heat of vaporization	40.79 kJ/mole

13-1 Properties of Solutions

I. Solutions
- A. Soluble
  1. Capable of being dissolved
- B. Solution
  1. A homogeneous mixture of two or more substances in a single phase
- C. Solvent
  1. The dissolving medium in a solution
- D. Solute
  1. The dissolved substance in a solution
- E. Types of solutions
  1. Gaseous mixtures
     - a. Air is a solution
  2. Solid solutions
     - a. Metal alloys
  3. Liquid solutions
     - a. Liquid dissolved in a liquid (alcohol in water)
     - b. Solid dissolved in a liquid (salt water)

II. Solutes: Electrolytes vs. Nonelectrolytes
- A. Electrolyte
  1. A substance that dissolves in water to give a solution that conducts electric current
  2. Solutions of acids, bases and salts are electrolytes
- B. Nonelectrolyte
  1. A substance that dissolves in water to give a solution that does not conduct an electric current
- C. Measuring Conductivity



  1. Good conductors
     - a. Lamp glows brightly, ammeter registers a substantial current
  2. Moderate conductors
     - a. Lamp is dull, ammeter registers a small current
  3. Nonconductors
     - a. Lamp does not glow, ammeter may not register a current at all

13-2 The Solution Process

I. Factors Affecting the Rate of Dissolution
   A. Increasing the Surface Area of the Solute
      1. Finely divided substances dissolve more rapidly
   B. Agitating a Solution
      1. Stirring or shaking brings solvent into contact with more solute particles
      2. Added energy temporarily increases solubility
   C. Heating
      1. Heating always increasing the rate of dissolution of solids in liquids

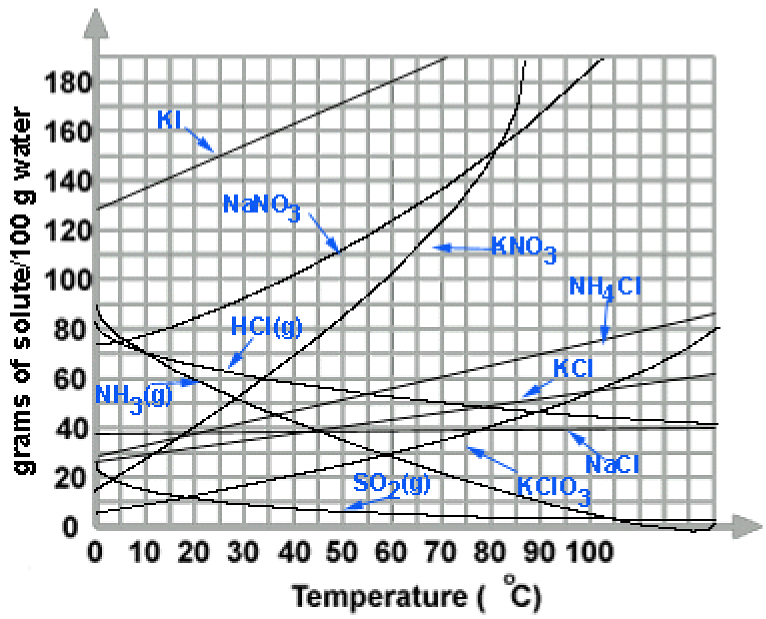
II. Solubility
   A. Solution Equilibrium
      1. The physical state in which the opposing processes of dissolution and crystallization of a solute occur at equal rates
   B. Saturation Levels
      1. Saturated solution
         a. A solution that contains the maximum amount of dissolved solute
      2. Unsaturated solutions
         a. A solution that contains less solute than a saturated solution under the existing conditions
      3. Supersaturated Solutions
         a. A solution that contains more dissolved solute than a saturated solution contains under the same conditions
   C. Solubility Values
      1. The solubility of a substance is the amount of that substance required to form a saturated solution with a specific amount of solvent at a specified temperature
      2. The rate at which a substance dissolves does not alter the substances solubility

III. Solute-Solvent Interactions
   A. "Like dissolves like"
      1. Polar substances dissolve in polar solvents
      2. Nonpolar substances dissolve in nonpolar solvents
   B. Dissolving Ionic Compounds in Aqueous Solutions
      1. Electropositive hydrogen of the water molecule is attracted to negatively charged ions
      2. Electronegative oxygen of the water molecule is attracted to positively charged ions
      3. Hydration
         1. The solution process with water as the solvent
      4. Hydrates
         1. Ionic substances that incorporate water molecules into their structure during the recrystallization process

$$CuSO_4 \bullet 5H_2O$$

            a. the " •" means that the water is loosely attached
   C. Nonpolar Solvents
      1. Polar and ionic compounds are not soluble in nonpolar solvents
      2. Fats, oils and many petroleum products are soluble in nonpolar solvents
      3. Nonpolar solvents include CCl4 and toluene (methyl benzene), $C_6H_5CH_3$
   D. Liquid Solutes and Solvents
      1. Immiscible - Liquid solutes and solvents that are not soluble in each other
         a. Oil and water
      2. Miscible - Liquids that dissolve freely in one another in any proportion
         a. Benzene and carbon tetrachloride (both nonpolar)
         b. Water and ethanol (both polar)
   E. Effects of Pressure on Solubility
      1. Pressure has no real effect on the solubilities of liquids and solids in liquid solvents
      2. Increasing pressure increases the solubility of gases in liquids

F. Effects of Temperature on Solubility
   1. Solubility of solids (generally) increases with temperature
   2. Solubility of gases decreases with temperature



13-3 Concentration of Solutions
Concentration - A measure of the amount of solute in a given amount of solvent or solution

Grams per liter represent the mass of solute divided by the volume of solution, in liters. This measure of concentration is most often used when discussing the solubility of a solid in solution.

Molarity describes the concentration of a solution in moles of solute divided by liters of solution. Masses of solute must first be converted to moles using the molar mass of the solute. This is the most widely used unit for concentration when preparing solutions in chemistry and biology. The units of molarity, mol/L, are usually represented by a scripted capital "*M*".

Parts per million (ppm), is a ratio of parts of solute to one million parts of solution, and is usually applied to very dilute solutions. It is often found in reports of concentration of water contaminants. To calculate parts per million, divide the mass of the solute by the total mass of the solution. This number is then multiplied by 10^6 and expressed as parts per million (ppm). In dilute water solutions, we can assume that 1 mL of water-based solution has a mass of 1 gram, so 1 liter of solution has a mass of 1000 grams.

Percent composition is the ratio of one part of solute to one hundred parts of solution and is expressed as a percent. Determine the mass of solute and solution and then divide the mass of the solute by the total mass of the solution. This number is then multiplied by 100 and expressed as a percent. In dilute water solutions, we can assume that 1 mL of water-based solution has a mass of 1 gram, so 1 liter of solution has a mass of 1000 grams.

15-1 Properties of Acids and Bases

I. Acids

A. Properties of Acids

1. Aqueous solutions have a sour taste
2. Acids change the color of acid-base indicators
3. Acids react with carbonates to produce water, a salt, and carbon dioxide

$$Na_2CO_3(s) + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

4. Some acids react with active metals to release hydrogen

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

5. Acids react with bases to produce salts and water

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

6. Acids conduct electric current

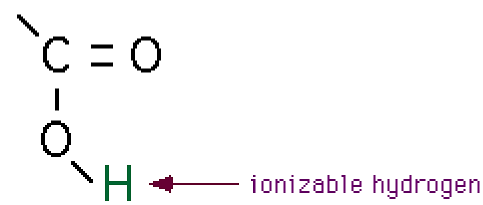
B. Strength of Acids

1. Strong acids ionize completely in solution
2. Weak acids ionize only slightly and are weak electrolytes

Strong acids	*Weak acids*
H_2SO_4	H_3PO_4
$HClO_4$	HF
HCl	$HC_2H_3O_2$
HNO_3	H_2CO_3
HBr	H_2S
HI	HCN

C. Organic Acids

1. Covalent molecular substances containing a carboxyl group
   a. (-COOH)
2. Weak acids (only slightly ionize)
3. Examples
   a. Butyric acid - in rancid butter
   b. Lactic acid - in sour milk
   c. Citric acid - in citrus fruit
   d. Acetic acid - in vinegar



II. Bases

A. Properties of Bases

1. Aqueous solutions of bases have a bitter taste
2. Bases change the color of acid-base indicators
3. Dilute aqueous solutions of bases feel slippery
4. Bases react with acids to produce salts and water
5. Bases conduct electric current

B. Aqueous Solutions of Bases

1. Ionic bases dissociate to some extent when placed in water

$$NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$$

2. Basic solutions are referred to as "alkaline"
3. Molecular bases produce hydroxide ions through a reaction with water

$$NH_3(g) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$$

C. Strength of Bases

1. Strength of ionic bases is linked to solubility
   a. High solubility = strong base
   b. Low solubility = weak base
2. Molecular bases tend to be weak regardless of solubility