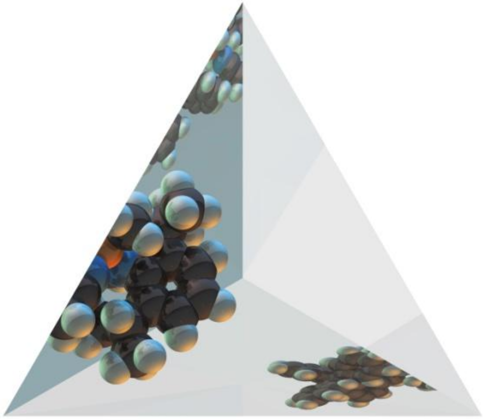


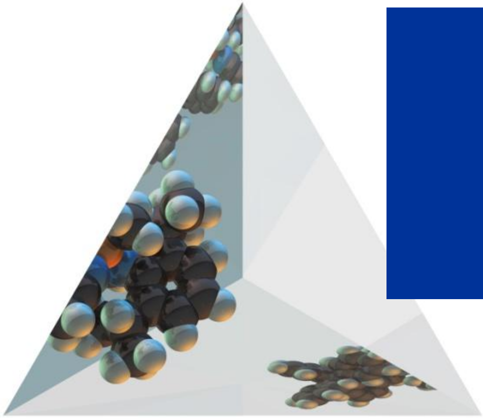
CHEMISTRY

The Central Science

8th Edition

Chapter 4
Aqueous Reactions and Solution Stoichiometry

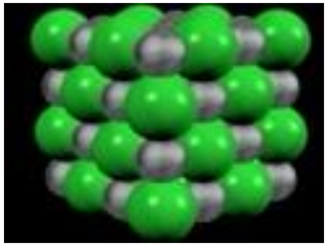
Dr. Kozet YAPSAKLI

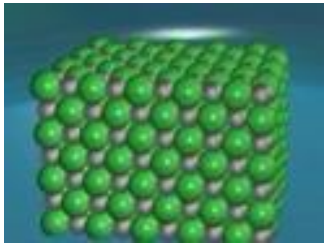


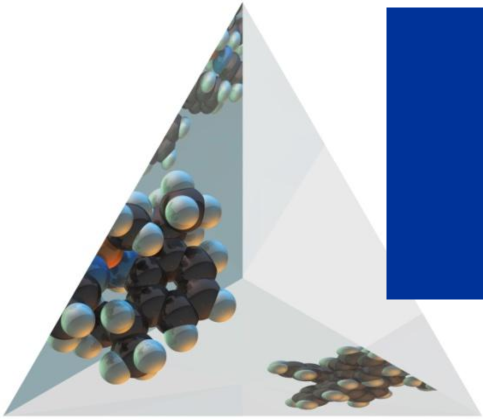
General Properties of Aqueous Solutions

Electrolytic Properties

- Aqueous solutions, have the potential to conduct electricity.
- The ability of the solution to conduct depends on the number of ions in solution.
- There are three types of solution:
  - Strong electrolytes.
  - Weak electrolytes.
  - Nonelectrolytes.



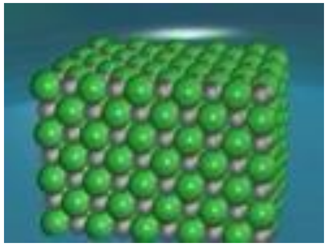


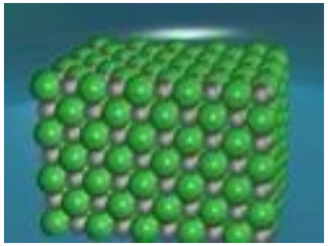


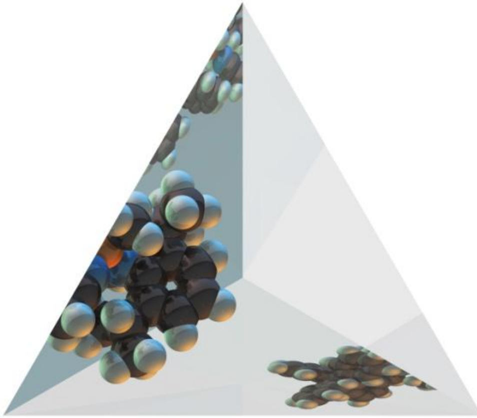
General Properties of Aqueous Solutions

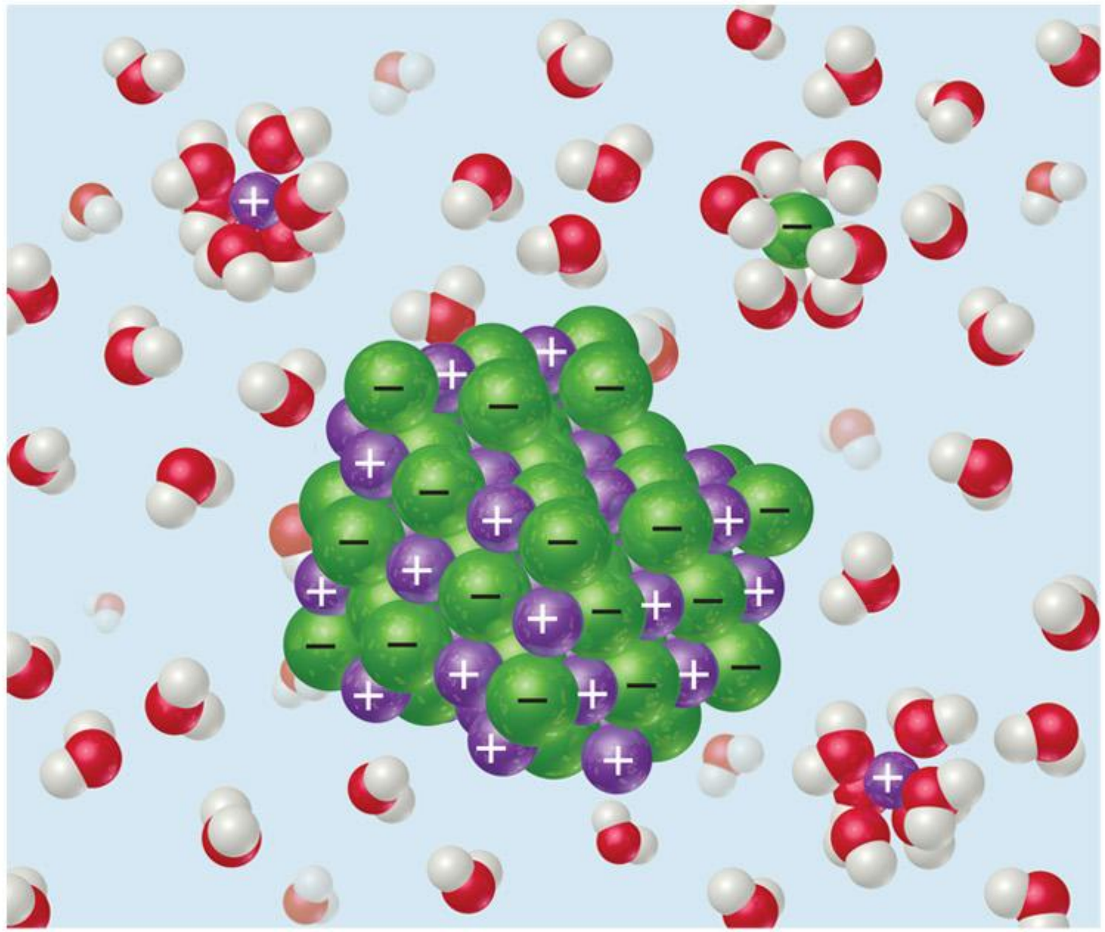
Electrolytic Properties

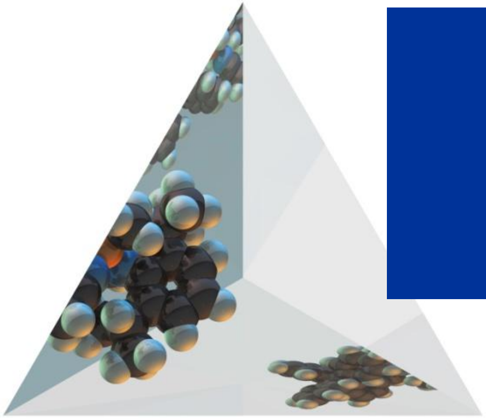
- When an ionic substance dissolves in water, the solvent pulls the individual ions from the crystal and solvates them.
- This process is called dissociation.
- Substances dissociate into ions when dissolved in water.
- Transport of ions through solution causes flow of current.











General Properties of Aqueous Solutions

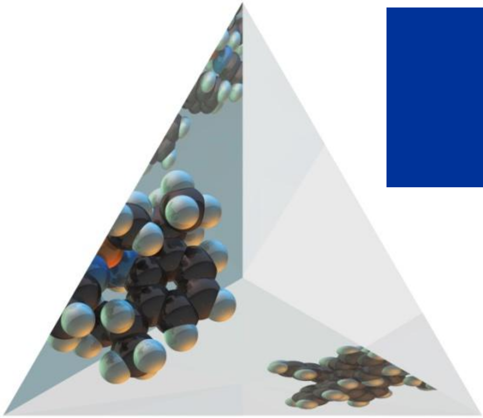
Strong and Weak Electrolytes

- Strong electrolytes: completely dissociate in solution.

$$HCl(\mathit{aq}) \longrightarrow H^{+}(\mathit{aq}) + Cl^{-}(\mathit{aq})$$

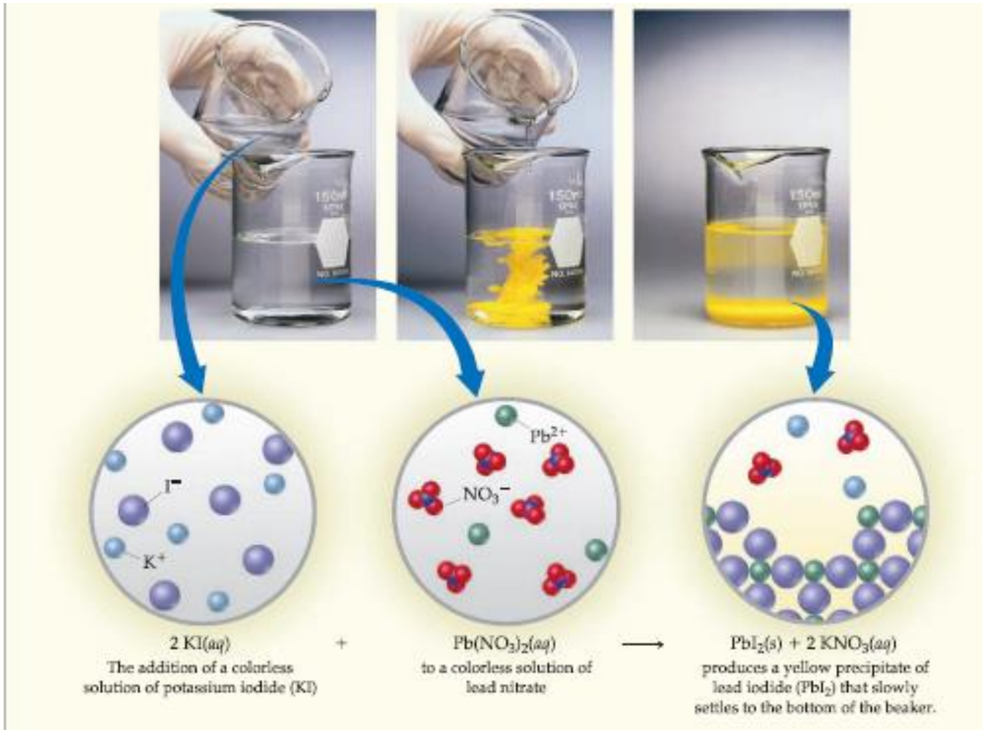
- Weak electrolytes: produce a small concentration of ions.
- These ions exist in *equilibrium* with the unionized substance.

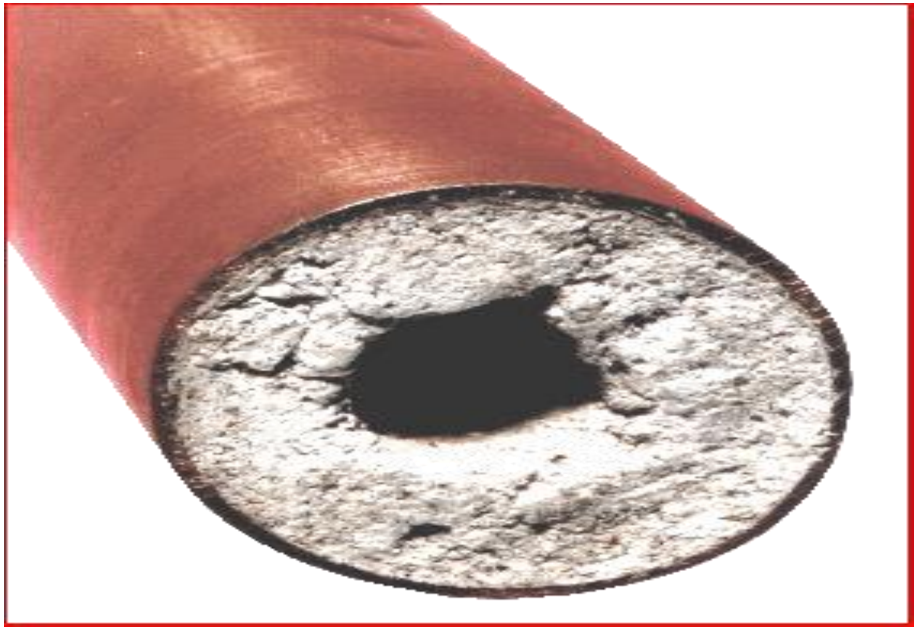
$$HC_2H_3O_2(\mathit{aq}) \rightleftharpoons H^{+}(\mathit{aq}) + C_2H_3O_2^{-}(\mathit{aq})$$

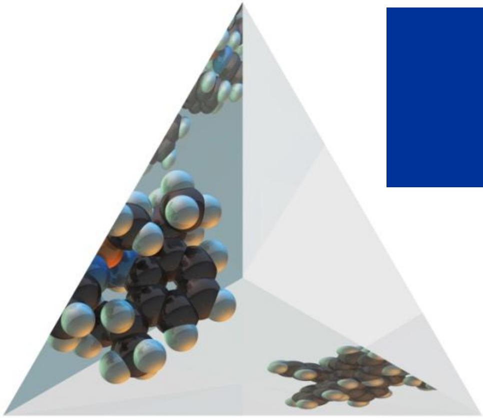


Precipitation

- When two solutions are mixed and a solid is formed, the solid is called a *precipitate*.







Precipitation Reactions

Exchange (Metathesis) Reactions

- Metathesis reactions involve swapping ions in solution:

$$AX + BY \rightarrow AY + BX.$$

- Metathesis reactions will lead to a change in solution if one of three things occurs:
  - an insoluble solid is formed (precipitate),
  - weak or nonelectrolytes are formed or an insoluble gas is formed.

$$\mathbf{AgNO_{3\,(\mathit{aq})} + KCl_{\,(\mathit{aq})} \longrightarrow AgCl_{\,(\mathit{s})} + KNO_{3\,(\mathit{aq})}}$$

TABLE 4.1 Solubility Guidelines for Common Ionic Compounds in Water

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	$C_2H_3O_2^-$	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}

Insoluble Ionic Compounds		Important Exceptions
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and NH_4^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

(a) Predict the identity of the precipitate that forms when solutions of $BaCl_2$ and K_2SO_4 are mixed.

(b) Write the balanced chemical equation for the reaction.

Solution

Plan: We need to write down the ions present in the reactants and to exchange the anions between the two cations. Once we have written the chemical formulas for these products, we can use Table 4.1 to determine which is insoluble in water. Knowing the products also allows us to write the equation.

Solve: **(a)** The reactants contain Ba^{2+}, Cl^-, K^+, and SO_4^{2-} ions. If we exchange the anions, we will have $BaSO_4$ and KCl. According to Table 4.1, most compounds of SO_4^{2-} are soluble but those of Ba^{2+} are not. Thus, $BaSO_4$ is insoluble and will precipitate from solution. KCl, on the other hand, is soluble.

(b) From part (a) we know the chemical formulas of the products, $BaSO_4$ and KCl. The balanced equation with phase labels shown is

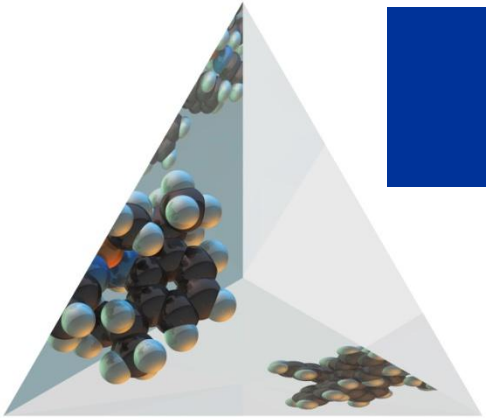
$$BaCl_2(aq) + K_2SO_4(aq) \longrightarrow BaSO_4(s) + 2\,KCl(aq)$$

Acid-Base Reactions

Acids

- Substances that increase the concentration of H^+ when dissolved in water. (e.g. HCl, HNO_3, CH_3CO_2H, lemon, vitamin C).

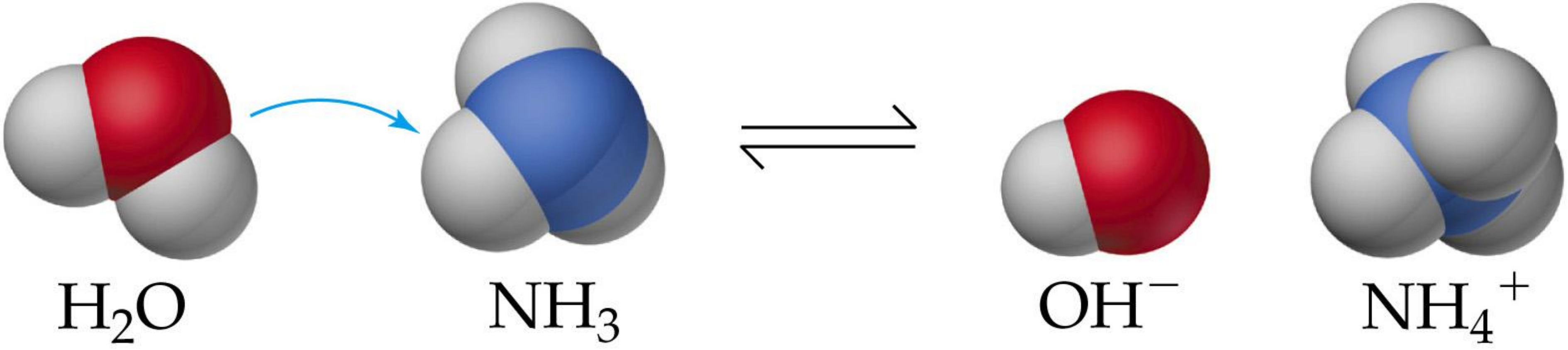
- Acids with *one* acidic proton are called *mono*protic (e.g., HCl).
- Acids with *two* acidic protons are called *di*protic (e.g., H_2SO_4).
- Acids with *many* acidic protons are called *poly*protic.

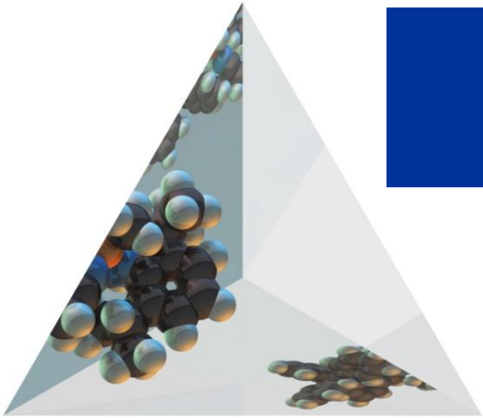


Acid-Base Reactions

Bases

- Substances that increase the concentration of OH^- when dissolved in water. (e.g. NH_3, Milk).



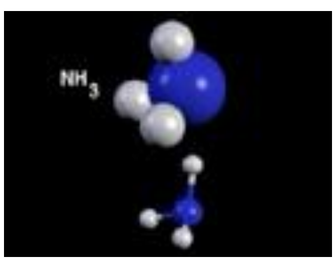


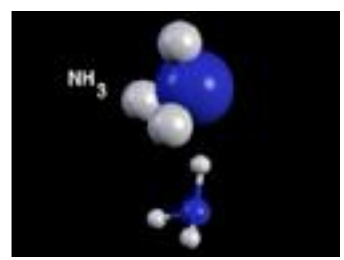
Acid-Base Reactions

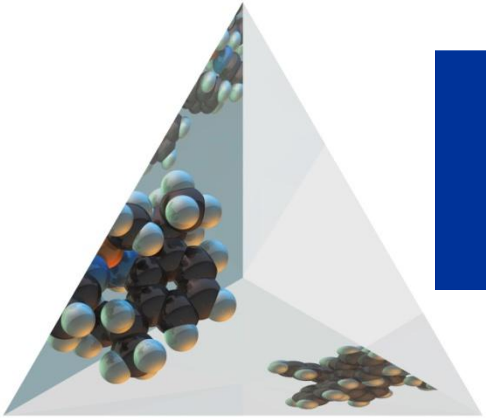
Strong and Weak Acids and Bases

- Strong acids and bases are strong electrolytes.
  - They are completely ionized in solution.

- Weak acids and bases are weak electrolytes.
  - They are partially ionized in solution.







Strong Acids and Bases

- Common Strong Acids
  - HCl -$HClO_3$
  - HBr -$HClO_4$
  - HI
  - HNO_3
  - H_2SO_4
- Common Strong Bases
  - LiOH
  - NaOH
  - KOH

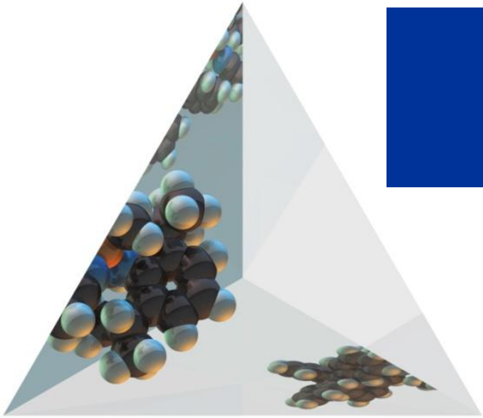
Acid-Base Reactions

Identifying Strong and Weak Electrolytes

- Water soluble and ionic = strong electrolyte (probably).
- Water soluble and not ionic, but is a strong acid (or base) = strong electrolyte.
- Water soluble and not ionic, and is a weak acid or base = weak electrolyte.
- Otherwise, the compound is probably a nonelectrolyte.

TABLE 4.3 Summary of the Electrolytic Behavior of Common Soluble Ionic and Molecular Compounds

	Strong Electrolyte	Weak Electrolyte	Nonelectrolyte
Ionic	All	None	None
Molecular	Strong acids (see Table 4.2)	Weak acids (H . . .) Weak bases (NH_3)	All other compounds



Acid-Base Reactions

Neutralization Reactions and Salts

- Neutralization occurs when a solution of an acid and a base are mixed:

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

- Notice we form a salt (NaCl) and water.
- Salt = ionic compound whose cation comes from a base and anion from an acid.
- Neutralization between acid and metal hydroxide produces water and a salt.

Acid-Base Reactions

Acid-Base Reactions with Gas Formation

- Sulfide and carbonate ions can react with H^+ in a similar way to OH^-.

$$2HCl(aq) + Na_2S(aq) \rightarrow H_2S(g) + 2NaCl(aq)$$

$$2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$$

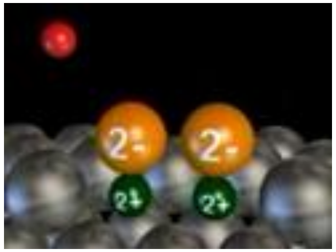
$$HCl(aq) + NaHCO_3(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

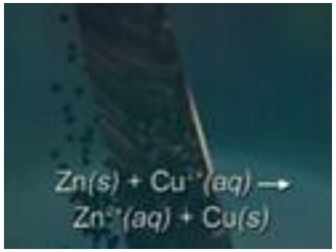
- The expected product decomposes to give a gaseous product (CO_2 or SO_2).

Oxidation-Reduction Reactions

Oxidation and Reduction

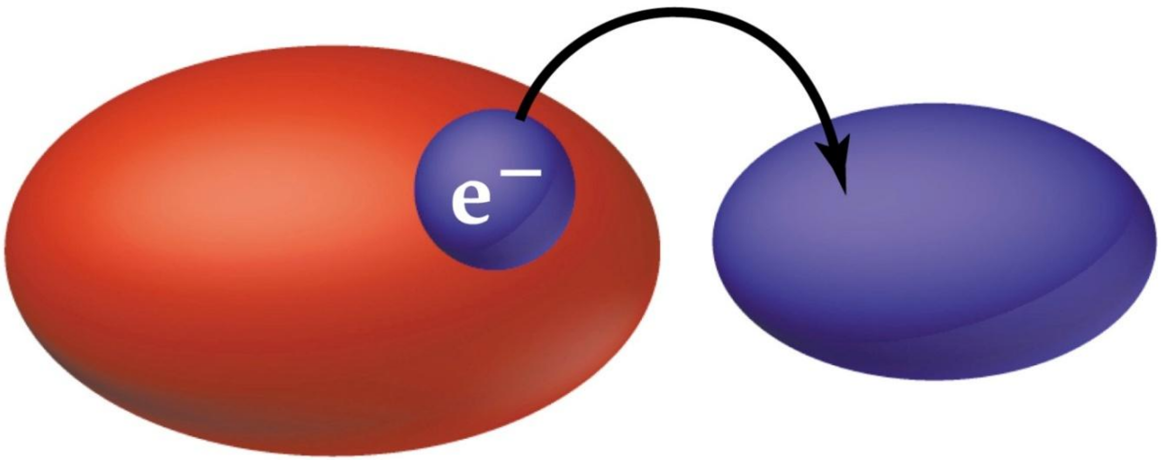
- Oxidized: atom, molecule, or ion becomes more positively charged.
  - Oxidation is the loss of electrons.
- Reduced: atom, molecule, or ion becomes less positively charged.
  - Reduction is the gain of electrons.





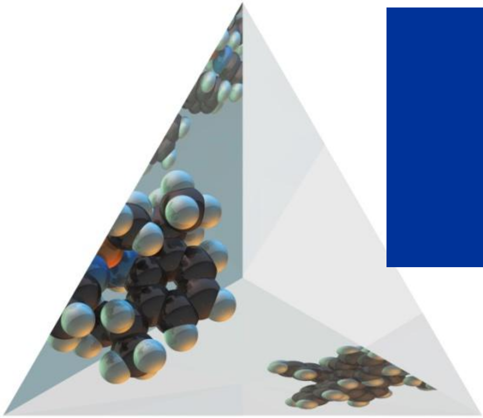
Oxidation-Reduction Reactions

Oxidation and Reduction



Substance **oxidized** (loses electron)

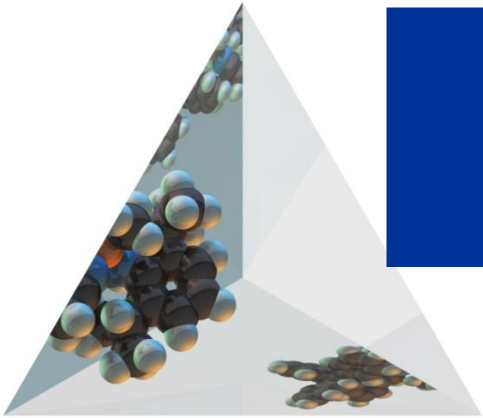
Substance **reduced** (gains electron)



Oxidation-Reduction Reactions

Oxidation Numbers

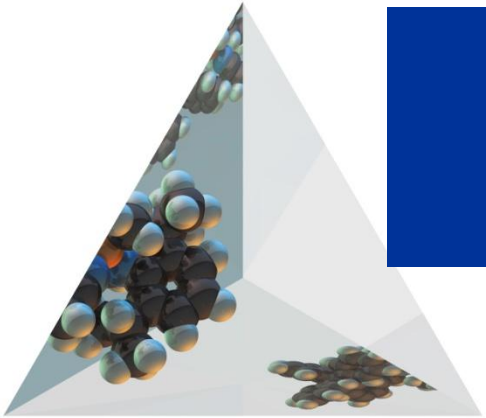
- **Oxidation number for an ion**: the charge on the ion.
- **Oxidation number for an atom**: the hypothetical charge that atom would have if it was an ion.
- Oxidation numbers are assigned by a series of rules:
  1. If the atom is in its elemental form, the oxidation number is zero. E.g., Cl_2, H_2, P_4.
  2. For a monoatomic ion, the charge on the ion is the oxidation state.



Oxidation-Reduction Reactions

Oxidation Numbers

3. Nonmetal *usually* have negative oxidation numbers:
   a) Oxidation number of O is usually –2.
   b) Oxidation number of H is +1 when bonded to nonmetals and –1 when bonded to metals (e.g. NaH).
   c) The oxidation number of F is –1.
4. The sum of the oxidation numbers for the atom is the charge on the molecule (zero for a neutral molecule).



Oxidation-Reduction Reactions

Oxidation of Metals by Acids and Salts

- Metals are oxidized by acids to form salts:

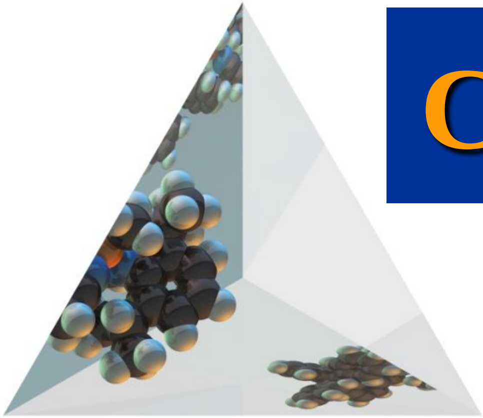
$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

- During the reaction, $2H^+(aq)$ is reduced to $H_2(g)$.

- Metals can also be oxidized by other salts:

$$Fe(s) + Ni^{2+}(aq) \rightarrow Fe^{2+}(aq) + Ni(s)$$

- Notice that the Fe is oxidized to Fe^{2+} and the Ni^{2+} is reduced to Ni.



Concentrations of Solutions

Molarity

- Solution: solute dissolved in solvent.
- Solute: present in smallest amount.
- Water as solvent = aqueous solutions.
- Change concentration by using different amounts of solute and solvent.

Molarity: Moles of solute per liter of solution.

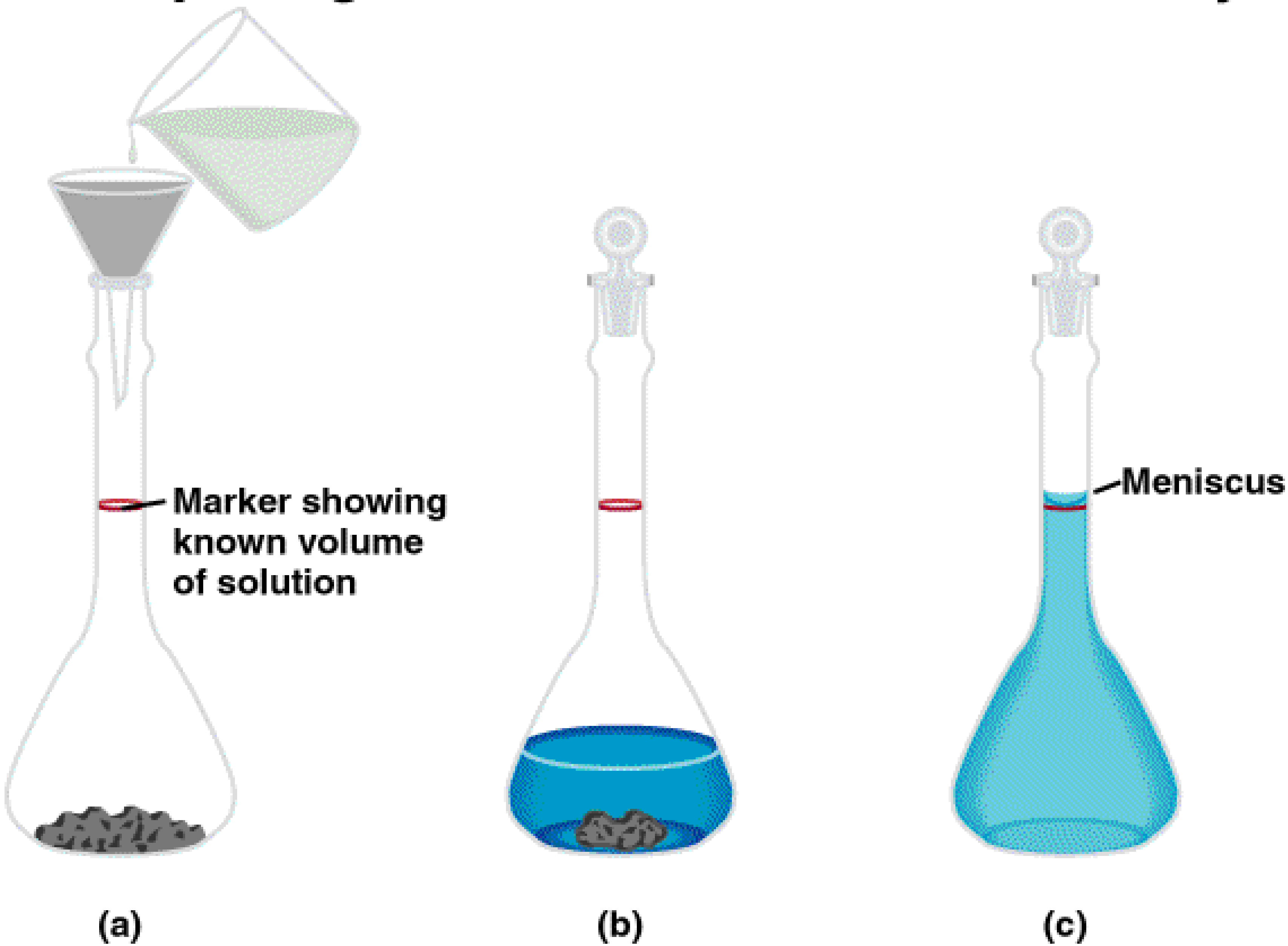
Concentrations of Solutions

Molarity

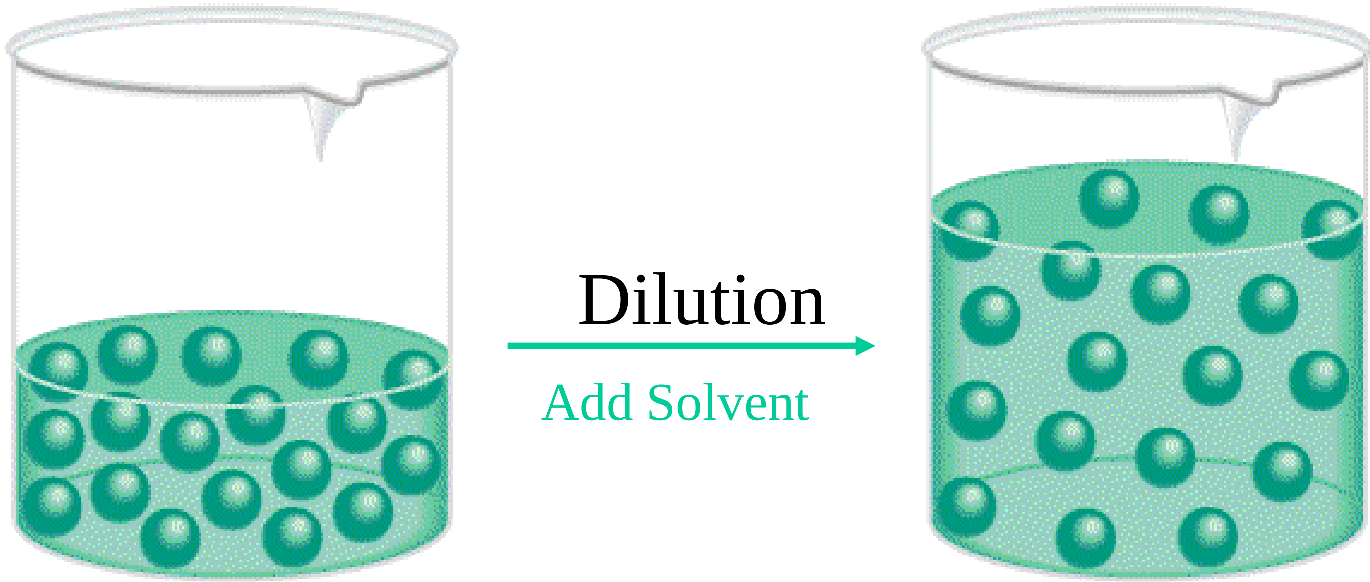
$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$

- If I have 23 g of NaCl in a 500 mL solution what is the molarity (M) of that solution?
  - 23 g of NaCl = 0.397 mols NaCl
  - 0.397 mols NaCl / 0.500 L = 0.79 M solution of NaCl

Preparing a Solution of Known Molarity



Dilution is the procedure for preparing a less concentrated solution from a more concentrated solution.



Moles of solute before dilution (i) = Moles of solute after dilution (f)

$$M_i V_i = M_f V_f$$

Concentrations of Solutions

Dilution

- We recognize that the number of moles are the same in dilute and concentrated solutions.
- So:

$$M_{\text{dilute}}V_{\text{dilute}} = \text{moles} = M_{\text{concentrated}}V_{\text{concentrated}}$$

Dilution