# *Aqueous Reactions and Solution Stoichiometry*

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*Chapter 4*

## *Properties of Solutes in Aqueous Solution*

### Ionic Compounds in Water

Ions dissociate in water.

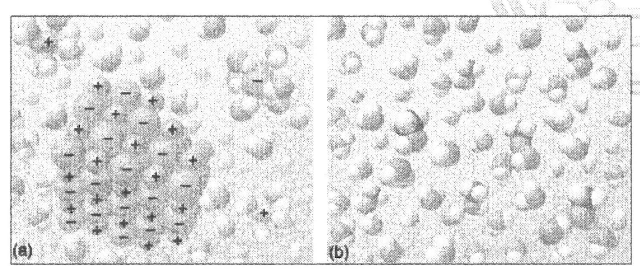
In solution, each ion is surrounded by water molecules.

Transport of ions through solution causes flow of current.



## *Properties of Solutes in Aqueous Solution*

### Ionic Compounds in Water






## *Properties of Solutes in Aqueous Solution*

### Molecular Compounds in Water

Molecular compounds in water (e.g., $CH_3OH$): no ions are formed.

If there are no ions in solution, there is nothing to transport electric charge.



## *Properties of Solutes in Aqueous Solution*

### Strong and Weak Electrolytes

Strong electrolytes: completely dissociate in solution.

For example:

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

Weak electrolytes: produce a small concentration of ions when they dissolve.

These ions exist in equilibrium with the unionized substance.

For example:

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

## *Ionic Equations*

Used to highlight reaction between ions.

Molecular equation: all species listed in their molecular forms:

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

Complete ionic equation: lists <u>all</u> ions:

$$H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)$$

Net ionic equation: lists only <u>unique</u> ions:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Note that only strong electrolytes are written in ionic form.



## *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.



## *Metathesis Reactions*

### Solubility Guidelines for Ionic Compounds

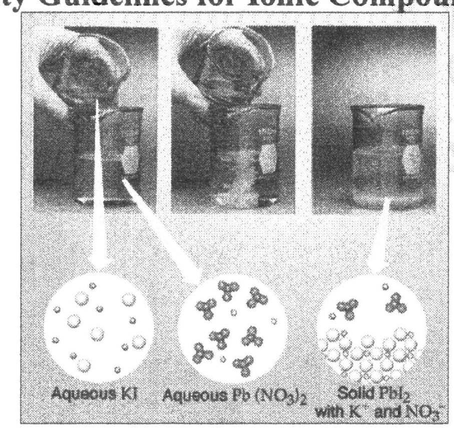
**Solubility Guidelines for Common Ionic Compounds in Water**

| Soluble Compounds | Important Exceptions |
|---|---|
| Compounds containing $NO_3^-$ | None |
| $C_2H_3O_2^-$ | None |
| $Cl^-$ | Salts of $Ag^+$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| $Br^-$ | Salts of $Ag^+$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| $I^-$ | Salts of $Ag^+$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| $SO_4^{2-}$ | Salts of $Ca^{2+}$, $Sr^{2+}$, $Ba^{2+}$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| **Insoluble Compounds** | **Important Exceptions** |
| Compounds containing $S^{2-}$ | Salts of $NH_4^+$, the alkali metal cations, and $Ca^{2+}$, $Sr^{2+}$, and $Ba^{2+}$ |
| $CO_3^{2-}$ | Salts of $NH_4^+$ and the alkali metal cations |
| $PO_4^{3-}$ | Salts of $NH_4^+$ and the alkali metal cations |
| $OH^-$ | Compounds of the alkali metal cations, $Ca^{2+}$, $Sr^{2+}$, and $Ba^{2+}$ |

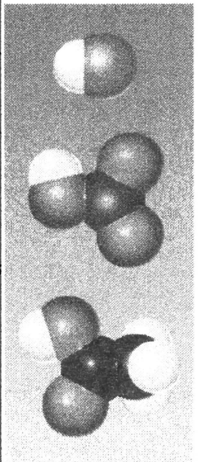


## *Metathesis Reactions*

### Solubility Guidelines for Ionic Compounds



## *Acids, Bases, and Salts*



### Acids

Dissociation = pre-formed ions in solid move apart in solution.

Ionization = neutral substance forms ions in solution.

Acid = substances that ionizes to form $H^+$ in solution (e.g. HCl, $HNO_3$, $CH_3CO_2H$, lemon, lime, vitamin C).

Bases = substances that react with the $H^+$ ions formed by acids (e.g. $NH_3$, Drano™, Milk of Magnesia™).




## *Acids, Bases, and Salts*

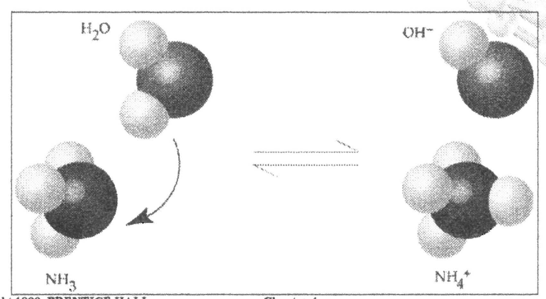
### Strong and Weak Acids and Bases

**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.







## *Acids, Bases, and Salts*

### Strong and Weak Acids and Bases

Water soluble and ionic = strong electrolyte (probably).

Water soluble and not ionic, but is a strong acid (or base) = strong electrolyte.

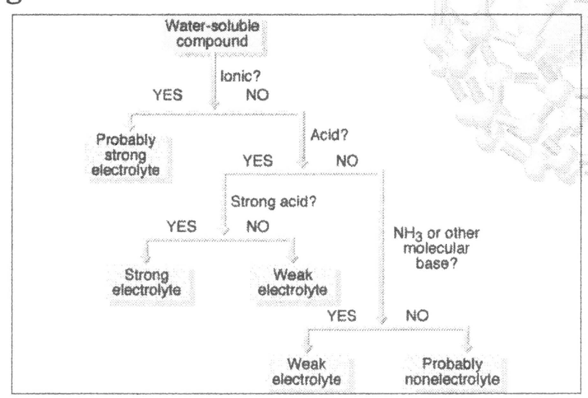
Water soluble and not ionic, and is a weak acid or base = weak electrolyte.

Otherwise, the compound is probably a nonelectrolyte.




## *Acids, Bases, and Salts*

### Strong and Weak Acids and Bases



## *Acids, Bases, and Salts*

### 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.

## *Introduction to Oxidation-Reduction Reactions*

### Oxidation and Reduction

- When a metal undergoes corrosion it loses electrons to form cations:

$$Ca(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2(g)$$

- 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.

## *Introduction to 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.

## *Introduction to Oxidation-Reduction Reactions*

### The Activity Series

Some metals are easily oxidized whereas others are not.

Activity series: a list of metals arranged in decreasing ease of oxidation.

The higher the metal on the activity series, the more active that metal.

Any metal can be oxidized by the ions of elements below it.

## *Solution Composition*

### 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.

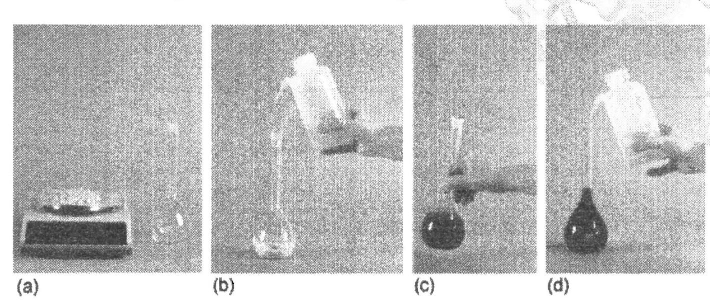
  Molarity: Moles of solute per liter of solution.
- If we know: molarity and liters of solution, we can calculate moles (and mass) of solute.



## *Solution Composition*

### Molarity

Molarity: Moles of solute per liter of solution.






## *Solution Composition*

### Dilution

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

So:

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



## *Solution Stoichiometry and Chemical Analysis*

There are two different types of units:

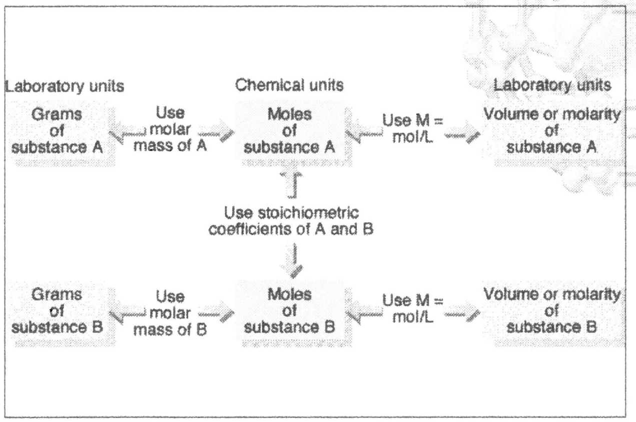
- •laboratory units (macroscopic units: measure in lab);
- •chemical units (microscopic units: relate to moles).

Always convert the laboratory units into chemical units first.

- •Grams are converted to moles using molar mass.
- •Volume or molarity are converted into moles using $M$ = mol/L.

Use the stoichiometric coefficients to move between reactants and product.

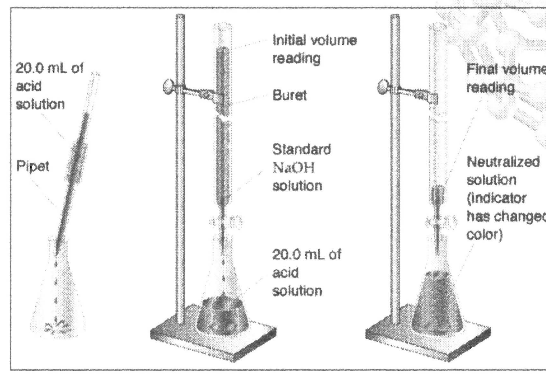
## *Solution Stoichiometry and Chemical Analysis*






## *Solution Stoichiometry and Chemical Analysis*

### Titrations






## *Solution Stoichiometry and Chemical Analysis*

### Titrations

***Suppose we know the molarity of a NaOH solution and we want to find the molarity of an HCl solution.***

**We know:**

**molarity of NaOH, volume of HCl.**

**What do we want?**

**Molarity of HCl.**

**What do we do?**

**Take a known volume of the HCl solution, measure the mL of NaOH required to react completely with the HCl.**



## *Solution Stoichiometry and Chemical Analysis*

### Titrations

**What do we get?**

**Volume of NaOH. We know molarity of the NaOH, we can calculate moles of NaOH.**

**Next step?**

**We also know $HCl + NaOH \rightarrow NaCl + H_2O$. Therefore, we know moles of HCl.**

**Can we finish?**

**Knowing mol(HCl) and volume of HCl (20.0 mL above), we can calculate the molarity.**