# Net Ionic Equations Roadmap

- Being able to classify the reaction type is the key to writing the net ionic equation.
- Reaction Types (Watch for this):
  - Precipitation (ions and solubility)
  - Acid-Base (ions and water* forms)
  - Gas Forming (gas forms)
  - Redox (oxidation numbers change)
- Net ionic equations show key chemistry



# Soluble Salts Form Ions when they dissolve in water

water + salt → aqueous solution



$CuCl_2$ (s) → $Cu^{2+}$(aq) + $2Cl^-$(aq)

soluble salt

* ions form in water solution



# Ions Conduct Electricity

Solutions with ions are called ELECTROLYTES

HCl, NaOH, $CuCl_2$, and NaCl are strong electrolytes. They dissociate completely (or nearly so) into ions.

* Ions form in solution

# Strong Electrolytes Are:

1) Ionic compounds, **strong acids** or **strong bases** (not molecular compounds, weak acids or weak bases)

2) Soluble in water (not insoluble or slightly soluble)



# Weak Electrolytes Form Few Ions

Acetic acid is a weak electrolyte.

$CH_3CO_2H(aq) \rightleftharpoons CH_3CO_2^-(aq) + H^+(aq)$

* Mostly molecules in solution, not ions



# Nonelectrolytes Form No Ions

Some compounds dissolve in water

Examples include:
- sugar
- ethanol
- ethylene glycol

Some compounds don't dissolve much in water

Examples include:
- $CaCO_3$
- AgCl
- $Hg_2SO_4$

## Determine Water Solubility of Ionic Compounds



*Soluble Ionic Compounds*

1. All compounds of the alkali metals (Group IA) are soluble.
2. All salts containing $NH_4^+$, $NO_3^-$, $ClO_4^-$, and $C_2H_3O_2^-$ are soluble.
3. All chlorides ($Cl^-$), bromides ($Br^-$), and iodides ($I^-$) are soluble, *except* those of $Ag^+$, $Pb^{2+}$, and $Hg_2^{2+}$ (note the subscript "2").
4. All sulfates are soluble, *except* those of $Pb^{2+}$, $Ca^{2+}$, $Sr^{2+}$, $Hg_2^{2+}$, and $Ba^{2+}$.

*Insoluble Ionic Compounds*

5. All hydroxides ($OH^-$) and metal oxides (containing $O^{2-}$) are insoluble, *except* those of Group IA and $Ca^{2+}$, $Sr^{2+}$, and $Ba^{2+}$. When metal oxides do dissolve, they give hydroxides (their solutions do not contain $O^{2-}$ ions). For example,

$$Na_2O(s) + H_2O \rightarrow 2\,NaOH(aq)$$

6. All compounds that contain $PO_4^{3-}$, $CO_3^{2-}$, $SO_3^{2-}$, and $S^{2-}$ are insoluble, *except* those of Group IA and $NH_4^+$

- **Soluble ionic compounds form ions in solution and are electrolytes**
- **Insoluble ionic compounds form no ions in solution and are nonelectrolytes**

**Solubility rules are given**

Practice: $Mg(OH)_2$

## Acids Form $H_3O^+$ in Water



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

$$HCl(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

HCl is a strong acid

**Write formulas of acids with H at the beginning or at the end**

## Memorize the 6 Strong Acids



| | |
|---|---|
| HCl | hydrochloric acid |
| HBr | hydrobromic acid |
| HI | hydroiodic acid |
| $H_2SO_4$ | sulfuric acid |
| $HClO_4$ | perchloric acid |
| $HNO_3$ | nitric acid |

# All Other Acids Are Weak

$CH_3CO_2H$ acetic acid, vinegar
($CH_3COOH$, HOAc, $HC_2H_3O_2$)
$H_2CO_3$ carbonic acid
$H_3PO_4$ phosphoric acid
HF hydrofluoric acid
And many more…

* Weak acids form primarily molecules (not ions) in solution so they are weak electrolytes or nonelectrolytes



# Nonmetal Oxides Can Be Acids

- Burning fuel containing C

$CO_2(aq) + H_2O(\ell) \rightarrow H_2CO_3(aq)$

- Burning fuel containing S

$SO_3(aq) + H_2O(\ell) \rightarrow H_2SO_4(aq)$

Are these acids strong or weak?



# Bases form $OH^-$ in Water

$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$

NaOH is a strong base

Write formulas of bases that contain OH with the OH at the end

## Memorize the 4 Strong Bases

| | |
|---|---|
| LiOH | Lithium hydroxide |
| NaOH | Sodium hydroxide |
| KOH | Potassium hydroxide |
| $Ba(OH)_2$ | Barium hydroxide |

## Other bases are:

- Weak — $NH_3$
- Not very soluble — $Ca(OH)_2$
- Not common — CsOH



## Ammonia, $NH_3$, *A Weak Base*

$$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

* $NH_3$ exists as mostly molecules in solution



## Most Metal Oxides are Bases

$$CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(aq)$$

Because they produce hydroxides

# Writing Net Ionic Equations

- Write the total ionic equation by dissociating species that form ions (Keep solids, gases, weak acids, and weak bases together as molecules)
- Cancel ions (spectator ions) if they are the same on both sides of a reaction to give the net ionic equation.



# Example Net Ionic Equation

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

Step 1) Dissociate into ions (total ionic equation)

$Mg(s) + 2H^+(aq) + 2Cl^-(aq) \rightarrow H_2(g) + Mg^{2+}(aq) + 2Cl^-(aq)$

Step 2) Cancel spectator ions (net ionic equation)

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

$Cl^-$ ions are SPECTATOR IONS
Could have used another anion, $NO_3^-$.



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## Recognizing Precipitation Reactions

$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow 2KNO_3(aq) + PbI_2(s)$

- Driving force is forming a precipitate

**Net ionic equation**

$Pb^{2+}(aq) + 2I^-(aq) \dashrightarrow PbI_2(s)$



## Recognizing Acid-Base Reactions

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

Driving force is forming water

**Net ionic equation**

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

This net ionic equation applies to STRONG acids and STRONG bases because weak acids and weak bases stay as molecules.



## Recognizing Acid-Base Reactions

- Also called **Neutralizations**
- Other product of Acid-Base reaction is a Salt, MX.

$HX + MOH \dashrightarrow MX + H_2O$

$M^{n+}$ comes from base & $X^{n-}$ comes from acid

This is one way to make compounds!

# Recognizing Gas-Forming Reactions

$CaCO_3(s) + H_2SO_4(aq) \rightarrow 2CaSO_4(s) + H_2CO_3(aq)$

Carbonic acid is unstable and forms $CO_2$ (g) & $H_2O$ ($\ell$)

$H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(\ell)$



# Terminology for Solutions

- **SOLVENT** - component whose physical state is preserved when solution forms.
- **SOLUTE** - the other solution component.



## Molarity Is A Unit of Concentration

$$\text{Molarity (M)} = \frac{\text{moles solute}}{\text{1 liter of solution}}$$

The solution includes the solute and the solvent

## Units of Molarity Are

2.0 M HCl = $\frac{\text{2.0 moles HCl}}{\text{1 L HCl solution}}$

**[HCl] = 2.0M**

6.0 M HCl = $\frac{\text{6.0 moles HCl}}{\text{1 L HCl solution}}$

**[HCl] = 6.0M**



**PROBLEM:** Dissolve 5.00 g of $NiCl_2 \cdot 6\ H_2O$ in enough water to make 250 mL of solution.

**Step 1:** Calculate moles of $NiCl_2 \cdot 6H_2O$

$$5.00\ g \cdot \frac{1\ mol}{237.7\ g} = 0.0210\ mol$$

**Step 2:** Calculate molarity

$$\frac{0.0210\ mol}{0.250\ L} = 0.0841\ M$$

$[NiCl_2 \cdot 6\ H_2O] = 0.0841\ M$



## Determine Concentrations of Ions in a 0.30M $CuCl_2$ Solution

$CuCl_2(aq) \rightarrow Cu^{2+}(aq) + 2\ Cl^-(aq)$

If $[CuCl_2] = 0.30$ M, then

$[Cu^{2+}] = 0.30$ M

$[Cl^-] = 2 \times 0.30$ M

**Problem:** What mass of oxalic acid, $H_2C_2O_4$, is required to make 250. mL of a 0.0500 M solution?

M = moles/V
So moles = M * V



**Problem:** What mass of oxalic acid, $H_2C_2O_4$, is required to make 250. mL of a 0.0500 M solution?

**Step 1:** Calculate moles of acid.
(0.0500 mol/L)(0.250 L) = 0.0125 mol

**Step 2:** Calculate mass of acid.
(0.0125 mol )(90.00 g/mol) = 1.13 g



## Preparing a Solution by

Use this equation:
$M_{conc}V_{conc}=M_{dilute}V_{dilute}$

PROBLEM: You have 50.0 mL of 3.0 M NaOH and you want 0.50 M NaOH. What do you do?

Add water to the 3.0 M solution to lower its concentration to 0.50 M

**Dilute the solution!**



PROBLEM: You have 50.0 mL of 3.0 M NaOH and you want 0.50 M NaOH. What do you do?

$M_{conc} = 3.0M$ $M_{dilute} = 0.50M$

$V_{conc} = 0.0500L$ $V_{dilute} = ?$

$M_{conc} * V_{conc} = C_{dilute} * V_{dilute}$

$3.0M * 0.0500L = 0.50M * V_{dilute}$

$V_{dilute} = 0.3\ L,$

To the 0.050L NaOH, add 0.250L of water