# Common Ions and Separating Ions

## The Effect of Common Ions on Solubility

An example of Le Chatelier's Principle, the common ion effect states that equilibrium in solution can be shifted by dissolving any compound that contains ions already present, or any compound that reacts with one of the ions present in solution.

**Example:**

$$BaSO_{4\,(s)} \rightleftharpoons Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$$

Let's add $BaCl_{2\,(s)}$ to this solution: $BaCl_{2(s)} \rightleftharpoons Ba^{+2}_{(aq)} + 2Cl^-_{(aq)}$

So in reality we are adding: $Ba^{+2}$ as $Cl^-$ is simply a spectator

This shifts equilibrium left (due to ↑ $Ba^{+2}_{(aq)}$) resulting in more solids

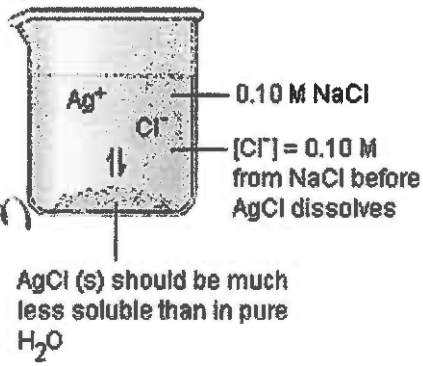
* meaning common ions reduce solubility *

**Example:** Would you expect solid silver chloride to be more soluble in water or in a solution of sodium chloride?

$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

adding $NaCl_{(aq)} \rightleftharpoons Na^+_{(aq)} + Cl^-_{(aq)}$

really adds $Cl^-$ thereby shifting equilibrium left and decreasing AgCl solubility




**Example:** In last unit's lab we added $NaOH_{(aq)}$ to a solution of potassium chromate. Neither sodium nor hydroxide are common ions yet we observed equilibrium shifting. Explain.

$$CrO_4^{-2}{}_{(aq)} + 2H^+_{(aq)} \rightleftharpoons Cr_2O_7^{-2}{}_{(aq)} + H_2O_{(l)}$$

chromate yellow — dichromate orange

adding $NaOH_{(aq)} \rightleftharpoons Na^+_{(aq)} + OH^-_{(aq)}$ adds $OH^-$ which combines with $H^+_{(aq)}$ to make more $H_2O_{(l)}$ thereby ↓ $H^+$ and shifting eqm left

## Separating Ions Out of Solution via Selective Precipitation

Ions can be separated from each other based on their solubilities.

Consider a solution containing both $Ag^+$ and $Cu^{2+}$. If $HCl_{(aq)}$ is added to the solution:

$HCl_{(aq)} \rightleftharpoons H^+_{(aq)} + Cl^-_{(aq)}$ $H^+$ is a spectator but $Cl^-$ will bond

$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$ $Cu^{+2}_{(aq)} + Cl^-_{(aq)} \rightarrow CuCl_{2(aq)}$

↑ from table now only $Cu^{+2}$ left in soln

Separation of ions in an aqueous solution by using a reagent that forms a precipitate with one or a few of the ions is called selective precipitation.

Example: A solution contains $Ag^+$, $Cu^{+2}$, and $Mg^{+2}$ ions mixed together. What reagents can be added to separate the ions?

1. Determine which cation is most insoluble.
   - $Ag^+$ is insoluble with $CH_3COO^-$, halides ($Cl^-$, $Br^-$, $I^-$), $SO_4^{-2}$, $S^{-2}$, $OH^-$ ...
   - $Cu^{+2}$ is insoluble with $S^{-2}$, $OH^-$, $CrO_4^{-2}$ ...
   - $Mg^{+2}$ is insoluble with $OH^-$, $CrO_4^{-2}$ ...

2. Find a reagent cation to bond with the anions.
   - Recall that a reagent must have a cation and an anion. Since alkali cations are soluble, they will act as spectator ions (example: sodium, $Na^+$).

3. Select the order.
   - First add NaCl to remove $Ag^+$.

     $NaCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$ $Na^+$ spectator

     $Cl^-_{(aq)} + Ag^+_{(aq)} \rightarrow AgCl_{(s)}$

     now only $Cu^{+2}$ + $Mg^{+2}$ left in soln
   - Now as $Na_2S$ to remove $Cu^{+2}$.

     $Cu^{+2}_{(aq)} + S^{-2}_{(aq)} \rightarrow CuS_{(s)}$

     now only $Mg^{+2}$ is left; can leave as is or
   - Finally, add NaOH to remove $Mg^{+2}$.

     $Mg^{+2}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$

**Example:** Describe how to separate the following positive ions present in a solution with nitrate ions.

$Ca^{2+}$; $Ag^{+}$; $Zn^{2+}$

$Ca^{+2}$ insoluble with $SO_4^{-2}$, $OH^-$, $CrO_4^{-2}$

$Ag^+$ halides, $SO_4^{-2}$, $S^{-2}$ ...

$Zn^{+2}$ $SO_4^{-2}$, $S^{-2}$, $OH^-$ ...

① add $KCl_{(aq)} \rightarrow K^+_{(aq)} + Cl^-_{(aq)}$

$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

now only $Ca^{+2}$ and $Zn^{+2}$ remain in sol'n

② add $K_2S_{(aq)} \rightarrow 2K^+_{(aq)} + S^{-2}_{(aq)}$

$Zn^{+2}_{(aq)} + S^{-2}_{(aq)} \rightarrow ZnS_{(s)}$

now only $Ca^{+2}$ is left in solution

③ Leave as is or add $KOH_{(aq)} \rightarrow K^+_{(aq)} + OH^-_{(aq)}$

$Ca^{+2}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$