

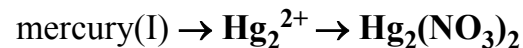
## 4.3 Precipitation Reactions

- Formation of an insoluble product (**precipitate**) after mixing of two electrolyte solutions
  - The driving force of precipitation reactions is the elimination of ions from the solution by formation of an insoluble product

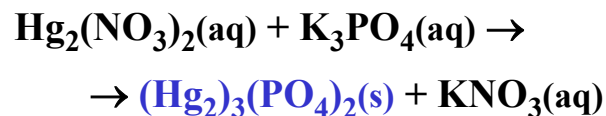


### Example:

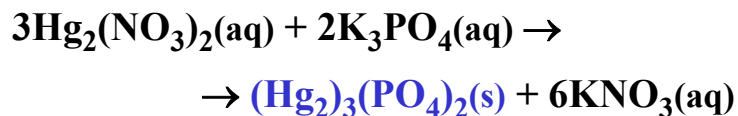
When mercury(I) nitrate and potassium phosphate solutions are mixed, mercury(I) phosphate **precipitates**. Write the net ionic equation.



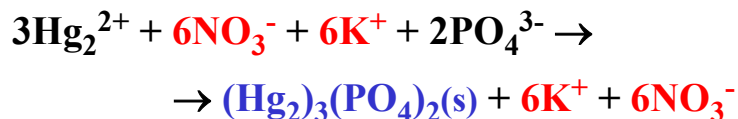
⇒ Skeletal eq:



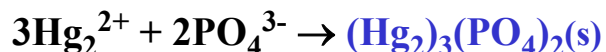
⇒ Overall balanced eq:



⇒ Complete ionic eq:



⇒ Net ionic eq:



## Predicting the outcome of precipitation

- Precipitation reactions are classified as **double replacement** (metathesis) reactions – exchange of ions leads to an insoluble combination of ions

Table 4.1 Solubility Rules for Ionic Compounds in Water

Soluble Ionic Compounds	Insoluble Ionic Compounds
1. All common compounds of Group 1A(1) ions ( $\text{Li}^+$ , $\text{Na}^+$ , $\text{K}^+$ , etc.) and ammonium ion ( $\text{NH}_4^+$ ) are soluble.	1. All common metal hydroxides are insoluble, <i>except</i> those of Group 1A(1) and the larger members of Group 2A(2) (beginning with $\text{Ca}^{2+}$ ).
2. All common nitrates ( $\text{NO}_3^-$ ), acetates ( $\text{CH}_3\text{COO}^-$ or $\text{C}_2\text{H}_3\text{O}_2^-$ ), and most perchlorates ( $\text{ClO}_4^-$ ) are soluble.	2. All common carbonates ( $\text{CO}_3^{2-}$ ) and phosphates ( $\text{PO}_4^{3-}$ ) are insoluble, <i>except</i> those of Group 1A(1) and $\text{NH}_4^+$ .
3. All common chlorides ( $\text{Cl}^-$ ), bromides ( $\text{Br}^-$ ), and iodides ( $\text{I}^-$ ) are soluble, <i>except</i> those of $\text{Ag}^+$ , $\text{Pb}^{2+}$ , $\text{Cu}^+$ , and $\text{Hg}_2^{2+}$ .	3. All common sulfides are insoluble <i>except</i> those of Group 1A(1), Group 2A(2), and $\text{NH}_4^+$ .
4. All common sulfates ( $\text{SO}_4^{2-}$ ) are soluble, <i>except</i> those of $\text{Ca}^{2+}$ , $\text{Sr}^{2+}$ , $\text{Ba}^{2+}$ , $\text{Ag}^+$ , $\text{Pb}^{2+}$ , and $\text{Hg}_2^{2+}$ .	

### Example:

Predict the outcome of the mixing of silver nitrate and potassium carbonate solutions.

⇒ Ions present in the solution:



⇒ consider all possible combinations of ions to find if an insoluble product can form:



⇒ Net ionic eq:  $2\text{Ag}^+ + \text{CO}_3^{2-} \rightarrow \text{Ag}_2\text{CO}_3(\text{s})$

**Note:** The net ionic equation can be predicted directly from the formula of the precipitate.

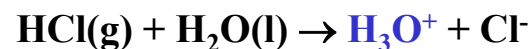
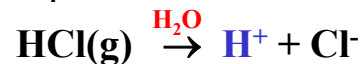
## 4.4 Acid-Base Reactions

– Acids - sharp, sour taste; Bases - soapy, bitter taste

- **Arrhenius acids** – release hydrogen ions,  $\text{H}^+(\text{aq})$  [or  $\text{H}_3\text{O}^+(\text{aq})$ ], in water solutions
- Acidic hydrogen atoms in molecules
  - can be released as  $\text{H}^+$  ions
  - formulas normally begin with the acidic Hs

### Examples:

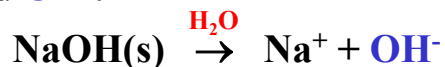
⇒  $\text{HCl}, \text{H}_2\text{SO}_4, \text{HCN}, \dots$



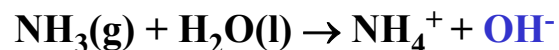
- **Arrhenius bases** – release hydroxide ions,  $\text{OH}^-$ , in water solutions

### Examples:

⇒  $\text{NaOH}$  dissolves in water and dissociates to  $\text{Na}^+$  and  $\text{OH}^-$ .



⇒ Ammonia gas,  $\text{NH}_3$ , dissolves in water and produces  $\text{NH}_4^+$  and  $\text{OH}^-$ .

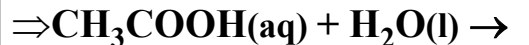


- **Strong acids** – almost completely ionized in aqueous solutions



(~100% ionized)

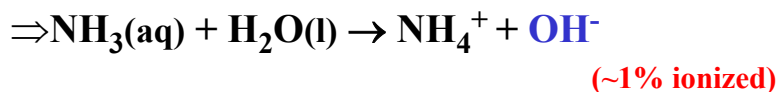
- The strong acids in aqueous solution are:  $\text{HCl}(\text{aq})$ ,  $\text{HBr}(\text{aq})$ ,  $\text{HI}(\text{aq})$ ,  $\text{HNO}_3$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{HClO}_4$ , and  $\text{HClO}_3$
- **Weak acids** – only partially ionized in aqueous solutions ( $\text{HF}$ ,  $\text{H}_2\text{S}$ , organic acids ... )



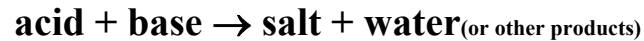
- **Strong bases** – almost completely ionized in aqueous solutions (oxides and hydroxides of alkali and alkaline earth metals)



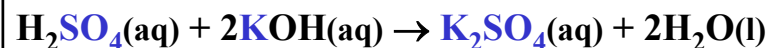
- The strong bases in aqueous solution are:  
Group I hydroxides,  $\text{Ca(OH)}_2$ ,  $\text{Sr(OH)}_2$ , and  $\text{Ba(OH)}_2$
- **Weak bases** – only partially ionized in aqueous solutions (ammonia, amines, ...)



## Neutralization

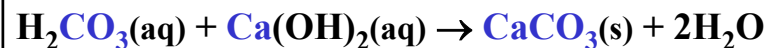


- **Salt** – an ionic compound with a cation from the base and an anion from the acid



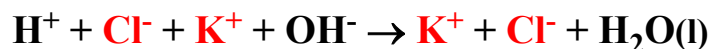
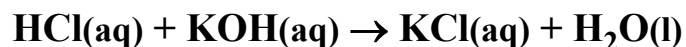
- Neutralization reactions are also viewed as **double replacement** (metathesis) reactions – exchange of ions leads to a salt and water

**Example:** Predict the products of the reaction between carbonic acid and calcium hydroxide.



## Proton Transfer

- Net ionic equations for reactions between strong acids and bases



–  $\text{H}^+$  is present in the form of  $\text{H}_3\text{O}^+$

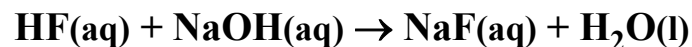


Net ionic equation for all strong acid/strong base reactions (transfer of a proton from  $\text{H}_3\text{O}^+$  to  $\text{OH}^-$ )

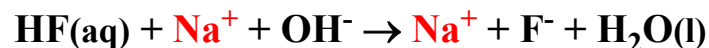
– The driving force of strong acid-base reactions is the elimination of ions ( $\text{H}^+$  and  $\text{OH}^-$ ) from the solution by formation of water

- Net ionic equations for reactions between weak acids and strong bases

**Example:**



$\text{HF(aq)} \rightarrow$  weak acid (only partially ionized)



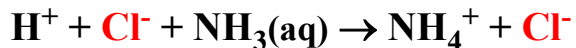
$\Rightarrow$  transfer of a proton from HF to  $\text{OH}^-$

- Net ionic equations for reactions between strong acids and weak bases

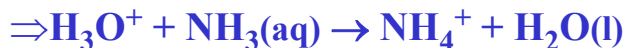
### Example:



$\text{NH}_3(\text{aq}) \rightarrow$  weak base (only partially ionized)



–  $\text{H}^+$  is present in the form of  $\text{H}_3\text{O}^+$

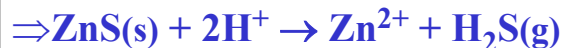
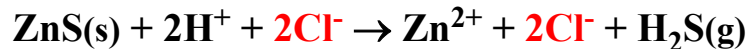
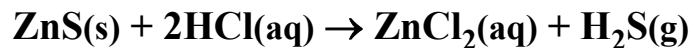


$\Rightarrow$  transfer of a proton from  $\text{H}_3\text{O}^+$  to  $\text{NH}_3$

### Gas Formation Reactions

- Reactions of salts of weak or volatile acids with strong acids

### Example:



–  $\text{H}^+$  is present in the form of  $\text{H}_3\text{O}^+$



$\Rightarrow$  transfer of a proton from  $\text{H}_3\text{O}^+$  to  $\text{S}^{2-}$