Three Definitions of Acids and Bases

• **Arrhenius**
  - An acid is a substance that generates $\text{H}_3\text{O}^+$ in water
  - A base is a substance that generates $\text{OH}^-$ in water

• **Brønsted-Lowry**

• **Lewis**
Arrhenius Acid-Base Reactions?

$\text{NH}_3(aq) + \text{HF}(aq) \rightleftharpoons \text{NH}_4^+(aq) + \text{F}^-(aq)$

base              acid

$\text{H}_2\text{O}(l) + \text{HF}(aq) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{F}^-(aq)$

neutral          acid

$\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)$

base            neutral
Acid and Base Definitions

• **Acid**
  – Arrhenius: a substance that generates $\text{H}_3\text{O}^+$ in water
  – Brønsted-Lowry: a proton, $\text{H}^+$, donor

• **Base**
  – Arrhenius: a substance that generates $\text{OH}^-$ in water
  – Brønsted-Lowry: a proton, $\text{H}^+$, acceptor

• **Acid-Base Reaction**
  – Arrhenius: between an Arrhenius acid and base
  – Brønsted-Lowry: a proton ($\text{H}^+$) transfer
Brønsted-Lowry Acids and Bases

\[
\text{NH}_3(aq) + \text{HF}(aq) \rightleftharpoons \text{NH}_4^+(aq) + \text{F}^-(aq)
\]
base \quad \text{acid}

\[
\text{H}_2\text{O}(l) + \text{HF}(aq) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{F}^-(aq)
\]
base \quad \text{acid}

\[
\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)
\]
base \quad \text{acid}
Why Two Definitions for Acids and Bases? (1)

• Positive Aspects of Arrhenius Definitions
  – All isolated substances can be classified as acids (generate $\text{H}_3\text{O}^+$ in water), bases (generate $\text{OH}^-$ in water), or neither.
  – Allows predictions, including (1) whether substances will react with a base or acid, (2) whether the pH of a solution of the substance will be less than 7 or greater than 7, and (3) whether a solution of the substance will be sour or bitter.

• Negative Aspects of Arrhenius Definitions
  – Does not include similar reactions ($\text{H}^+$ transfer reactions) as acid-base reactions.
Why Two Definitions for Acids and Bases? (2)

• Positive aspects of Brønsted-Lowry model
  – Includes similar reactions (H\(^+\) transfer reactions) as acid-base reactions.

• Negative aspects of Brønsted-Lowry model
  – Cannot classify isolated substances as acids, bases, or neither. The same substance can sometimes be an acid and sometimes a base.
  – Does not allow predictions of (1) whether substances will react with another substance, (2) whether the pH of a solution of the substance will be less than 7 or greater than 7, and (3) whether a solution will be sour or bitter.
Conjugate Acid-Base Pairs

\[
\text{NH}_3(aq) + \text{HF}(aq) \rightleftharpoons \text{NH}_4^+(aq) + \text{F}^-(aq)
\]

base          acid          acid          base
Brønsted-Lowry Acids and Bases

\[ H_2PO_4^- (aq) + HF(aq) \rightleftharpoons H_3PO_4(aq) + F^-(aq) \]

- \( H_2PO_4^- \) is the conjugate acid of \( H_2PO_4^- \).
- \( H_2PO_4^- \) is the conjugate base of \( H_3PO_4 \).
- \( H_3PO_4 \) and \( H_2PO_4^- \) are a conjugate acid-base pair.
- \( F^- \) is the conjugate base of the acid \( HF \).
- \( HF \) is the conjugate acid of the acid \( F^- \).
- \( HF \) and \( F^- \) are a conjugate acid-base pair.
Can be a Brønsted-Lowry acid in one reaction and a Brønsted-Lowry base in another?

\[
\text{HCO}_3^-(aq) + \text{HF}(aq) \rightleftharpoons \text{CO}_2(g) + \text{H}_2\text{O}(l) + \text{F}^-(aq)
\]

base \hspace{1cm} acid

\[
\text{HCO}_3^-(aq) + \text{OH}^-(aq) \rightleftharpoons \text{CO}_3^{2-}(aq) + \text{H}_2\text{O}(l)
\]

acid \hspace{1cm} base

\[
\text{H}_2\text{PO}_4^-(aq) + \text{HF}(aq) \rightleftharpoons \text{H}_3\text{PO}_4(aq) + \text{F}^-(aq)
\]

base \hspace{1cm} acid

\[
\text{H}_2\text{PO}_4^-(aq) + 2\text{OH}^-(aq) \rightarrow \text{PO}_4^{3-}(aq) + 2\text{H}_2\text{O}(l)
\]

acid \hspace{1cm} base