# 4. Bronsted – Lowry Theory of Acids and Bases – Demo in: HCl NaOH NaCl $Na_2CO_3$ PHTH + methyl orange

• ***takes equilibrium reactions into account!***

## a) Acids

i) Proton donors – gives $H^+$ to another substance

ii) $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$

- $HCl$ donated *one* proton to $H_2O$, so it is an acid.
- $HCl$ is a "Monoprotic Acid" (donates *one* proton).

iii) $H_2SO_4 + H_2O \rightleftharpoons H_3O^+ + HSO_4^-$

- $H_2SO_4$ donated a proton to $H_2O$
- $HSO_4^-$ can also donate a proton!

$$HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{-2}$$

- $H_2SO_4$ is a "Diprotic Acid" (can donate *two* protons total).

iii) $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$

- $H_2PO_4^-$ can still donate 2 protons.
- $H_3PO_4$ is a "Triprotic Acid" (can donate *three* protons total).

## b) Bases

i) Proton acceptors – receives an $H^+$ from a substance.

ii) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

- $NH_3$ receives an $H^+$ to form $NH_4^+$ so it is a base.

## c) Amphiprotic Species

i) Substances that act as both an acid or a base (depends on the situation).

ii) Water is a common amphiprotic substance

iii) Example:

$$HCl + \underset{\textit{base}}{H_2O} \rightleftharpoons H_3O^+ + Cl^-$$

$$NH_3 + \underset{\textit{acid}}{H_2O} \rightleftharpoons NH_4^+ + OH^-$$

iv) Diprotic and Triprotic Acids that have already lost a proton are also amphiprotic.

v) Example:

$$\underset{\textit{acid}}{HSO_3^-} + NH_3 \rightleftharpoons NH_4^+ + SO_3^{-2}$$

$$\underset{\textit{base}}{HSO_3^-} + HCl \rightleftharpoons H_2SO_3 + Cl^-$$

## d) Bronsted – Lowry Reactions

i) all BL reactions have an acid and a base on both sides of the equilibrium!

ii) Example:

$$\underset{\text{base}}{NH_3} + \underset{\text{acid}}{H_2O} \rightleftharpoons NH_4^+ + OH^-$$

$$NH_3 + H_2O \rightleftharpoons \underset{\text{acid}}{NH_4^+} + \underset{\text{base}}{OH^-}$$

**e) Identify the Acid and Base on the Reactant Side of Equilibrium**

i) $H_2PO_4^- + CO_3^{-2} \rightleftharpoons HPO_4^{-2} + HCO_3^-$

ii) $SCN^- + H_2O \rightleftharpoons HSCN + OH^-$

iii) $NH_3 + HSO_4^- \rightleftharpoons NH_4^+ + SO_4^{-2}$

iv) $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

v) $NH_2^- + HPO_4^{-2} \rightleftharpoons NH_3 + PO_4^{-3}$

**f) Identify the Acid and Base on Both Sides of Equilibrium**

i) $H_2S + HCO_3^- \rightleftharpoons HS^- + H_2CO_3$

ii) $NO_3^- + H_3O^+ \rightleftharpoons HNO_3 + H_2O$

## g) Conjugate Pairs

i) A conjugate pair is the two similar species on either sides of the equilibrium that differ by only one proton.

ii) Identify the conjugate pairs:

$$H_3PO_4 + NH_3 \rightleftharpoons H_2PO_4^{-2} + NH_4^+$$

$$HBr + HCO_3^- \rightleftharpoons H_2CO_3 + Br^-$$

$$H_2O + HSO_3^- \rightleftharpoons H_3O^+ + SO_3^{-2}$$

## h) Conjugate Acids and Bases

i) In each conjugate pair, one is the ***conjugate acid*** and one is the ***conjugate base***

ii) Conjugate acid (CA) – the one species of the pair that has the extra proton

iii) Conjugate base (CB) – the one species of the pair that has one less proton.

iv) Identify the CA's and CB's for each equilibrium:

$$H_3PO_4 + NH_3 \rightleftharpoons H_2PO_4^{-2} + NH_4^+$$

CA CB CB CA

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

CB CA CA CB

$$H_2O + HCO_3^- \rightleftharpoons H_3O^+ + CO_3^{-2}$$

CB CA CA CB

$$CH_3CH_2NH_2 + H_3O^+ \rightleftharpoons CH_3CH_2NH_3 + H_2O$$

CB CA CA CB

v) What is the conjugate base of the following species?

$HNO_2$ __$NO_2^-$____ $OH^-$ ____$O^{-2}$____.

$H_2SO_4$ ___$HSO_4^-$___.

vi) What is the conjugate acid of the following species?

$Br^-$ ______HBr________ $CH_3COO^-$ __$CH_3COOH$___.

$HCO_3^-$___$H_2CO_3$______

## i) Summary

i) All Bronsted-Lowry reactions have a CA and a CB on each side of the equilibrium.

$$CA_1 + CB_2 \rightleftharpoons CA_2 + CB_1$$

$CA_1$ and $CB_1$ are conjugate pairs

$CB_2$ and $CA_2$ are conjugate pairs

ii) Complete the following reactions and identify the CA and CB on both sides of the equilibrium:

$HF + H_2O \rightleftharpoons F^- + H_3O^+$
CA CB CB CA

$CO_3^{-2} + HPO_4^{-2} \rightleftharpoons HCO_3^{-2} + PO_4^{-3}$
CB CA CA CB

$HS^- + NH_4^+ \rightleftharpoons NH_3 + H_2S$
CB CA CB CA

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