Unit 14: Acid-Base Equilibria

Bronsted-Lowry Acids and Bases

This worksheet will cover Bronsted-Lowry acids and bases, conjugate acids and bases, and water in relation to these concepts. It will discuss the definition and application of those terms, as well as the weak and strong nature of acids. As you progress through the worksheet, you will develop the skills to identify acids/bases/conjugate acids/conjugate bases and apply K_a to acid strength.

1. Provide a brief description of each of the following terms.

Bronsted-Lowry Acid	
Bronsted-Lowry Base	
Conjugate Acid	
Conjugate Base	

2. Define the term "amphiprotic" and how it relates to water (H_2O).

3. Complete the reactions, then label the Bronsted-Lowry acids and bases, as well as conjugate acids/bases.

a. $H_2O + HC_2H_3O_2 \leftrightarrow$

b. $HOCl + NH_3 \leftrightarrow$

c. $NH_4^+ + OH^- \leftrightarrow$

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4. Differentiate between a “weak” and a “strong” acid. Provide an example of each.

5. Define $K_{a,}$ and write its generalized equation. Explain what a large and small K_a indicates.

6. List the following acids in increasing acid strength and determine the strongest conjugate base. Explain your choices.

$HC_2H_3O_2$	$K_a = 1.8 \times 10^{-5}$
HF	$K_a = 6.7 \times 10^{-4}$
HCN	$K_a = 7.2 \times 10^{-16}$

7. Define the term “autoionization” and its relation to H_2O and K_w.

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Bronsted-Lowry Acids and Bases
ANSWER KEY

1. Provide a brief description of each of the following terms.

Bronsted-Lowry Acid	Proton (H^+) donor; species is protonated as a reactant
Bronsted-Lowry Base	Proton (H^+) acceptor; species is deprotonated as a reactant
Conjugate Acid	Species formed from gaining a proton
Conjugate Base	Species formed from losing a proton

2. Define the term "amphiprotic" and how it relates to water (H_2O).

"Amphiprotic" refers to a substance that can act as both an acid and a base by either donating or accepting a proton. Water is an example of an amphiprotic molecule. H_2O is capable of liberating its proton upon dissociating, forming the conjugate base of OH^-. It is also capable of accepting a proton to form the hydronium ion, H_3O^+, its conjugate acid.

3. Complete the reactions, then label the Bronsted-Lowry acids and bases, as well as conjugate acids/bases.

B = base A = acid CA = conjugate acid CB = conjugate base

a. $H_2O + HC_2H_3O_2 \leftrightarrow H_3O^+ + C_2H_3O_2^-$
B A CA CB

$HC_2H_3O_2$ is a common example of an acid, as it is protonated with an H^+ that can be donated. Here, $HC_2H_3O_2$ is donating its H^+ to the amphiprotic H_2O, forming the conjugate acid, the hydronium ion, and the conjugate base, acetic acid ($C_2H_3O_2^-$).

b. $HOCl + NH_3 \leftrightarrow OCl^- + NH_4^+$
A B CB CA

HOCl has an acidic proton that can be donated to NH_3, the base. Once HOCl is deprotonated, its conjugate base, OCl^-, forms. NH_4^+ is the conjugate acid since it is now protonated.

c. $NH_4^+ + OH^- \leftrightarrow NH_3 + H_2O$
A B CB CA

NH_4^+ is protonated, indicated by the positive charge on the molecule, and can thus act as an acid and donate its proton. OH^- will accept the proton and form its conjugate acid, H_2O. NH_3 forms as the conjugate base, as this species may accept a proton in the reverse reaction.

4. Differentiate between a “weak” and a “strong” acid. Provide an example of each.

Weak and strong acids differ in their degree of dissociation in water. A weak acid only partially dissociates into ions when dissolved in water, establishing an equilibrium. A strong acid completely dissociates into ions when dissolved in water, so it does not establish an equilibrium and the reaction proceeds to completion. An example of a weak acid is acetic acid ($HC_2H_3O_2$), and an example of a strong acid is hydrochloric acid (HCl).

5. Define K_a, and write its generalized equation. Explain what a large and small K_a indicates.

K_a is the acid dissociation constant, and it measures the strength of an acid in solution, quantifying the extent to which an acid dissociates/ionizes in water.

$$K_a = \frac{[H+][A-]}{[HA]}$$

Where:
$[H^+]$ represents the concentration of hydrogen ions in the solution.
$[A^-]$ represents the concentration of the conjugate base of the acid.
[HA] represents the concentration of the undissociated acid.

A large K_a value indicates a strong acid. This means that the acid dissociates almost completely in solution, resulting in a high concentration of hydrogen ions ($[H^+]$) and the conjugate base ($[A^-]$). Strong acids have large K_a values because their dissociation reactions proceed almost to completion.

Conversely, a small K_a value indicates a weak acid. Weak acids only partially dissociate in solution, resulting in relatively low concentrations of hydrogen ions ($[H^+]$) and the conjugate base ($[A^-]$). Weak acids have small K_a values because their dissociation reactions proceed to a much lesser extent compared to strong acids.

6. List the following acids in increasing acid strength and determine the strongest conjugate base. Explain your choices.

$HC_2H_3O_2$	$K_a = 1.8 \times 10^{-5}$
HF	$K_a = 6.7 \times 10^{-4}$
HCN	$K_a = 7.2 \times 10^{-16}$

The smaller the K_a value, the weaker the acid and the less the species dissociates. Thus, the acid with the smallest K_a is the weakest acid — HCN. $HC_2H_3O_2$ has a medium strength, and HF is the strongest acid of the three with the highest K_a value. In addition, since HCN is the weakest acid, CN^- is the strongest conjugate base, as this species is more inclined to be protonated than lose its H^+.

7. Define the term “autoionization” and its relation to H_2O and K_w.

Autoionization is the process in which water reacts with itself to produce hydronium ions (H_3O^+) and hydroxide ions (OH^-). Its equilibrium equation is $2\ H_2O \leftrightarrow H_3O^+ + OH^-$. K_w is the equilibrium constant for this reaction, known as the ion product of water; K_w is $[H_3O^+]$ times $[OH^-]$, which equals 10^{-14} at 25°C.