Unit 14: Acid-Base Equilibria

Terminology

Arrhenius, Bronsted-Lowry, Lewis Acids and Bases

This worksheet will cover the terminology used in acid-base equilibria. Specifically, it will discuss the **Arrhenius, Bronsted-Lowry,** and **Lewis** definitions of acids and bases as well as the Bronsted-Lowry definitions of **conjugate acids** and **conjugate bases**.

1. Fill in the table:

Model	Definition of Acid	Definition of Base
Arrhenius		
Bronsted-Lowry		
Lewis		

2. For each reaction, identify the Lewis acid and base:

   a. $Ni^{2+}(aq) + 6NH_3(aq) \rightarrow Ni(NH_3)_6^{2+}(aq)$

   b. $H^+(aq) + H_2O(aq) \rightleftharpoons H_3O^+(aq)$

3. Using the following equation for the dissociation of an acid (HA) as a guide, write the dissociation equation for the following acids and label the base, conjugate acid, and conjugate base.

$$HA(aq) + H_20(l) \rightleftharpoons H_30^+(aq) + A^-(aq)$$

   a. Acetic acid ($HC_2H_3O_2$):

   b. Ammonium ion (NH_4^+):

4. Looking at the following equations, label the reactants as acids and bases according to the three definitions of acids and bases. (Hint: some may be defined as acids or bases by multiple definitions)
    a. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$
    b. $NH_{3(aq)} + H_2O_{(l)} \rightarrow OH^-_{(aq)} + NH_4^+{}_{(aq)}$
    c. $F^-_{(aq)} + BF_3 \rightarrow BF_4^-{}_{(aq)}$

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ANSWER KEY

1. Fill in the table

Solution:
Arrhenius Acids are defined as compounds that produce H^+ when dissolved in water and Arrhenius bases are defined as compounds that produce OH^- when dissolved in water.

Bronsted-Lowry acids are defined as compounds that donate H^+ ion(s) in solution and Bronsted-Lowry bases are defined as compounds that accept H^+ ion(s) in solution. The Bronsted-Lowry definition of acids and bases is what is most commonly used when discussing acids and bases.

Lewis acids are defined as compounds that accept an electron pair in solution and Lewis bases are defined as compounds that donate an electron pair in solution.

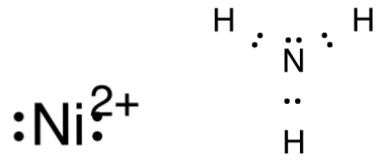
Model	Definition of Acid	Definition of Base
Arrhenius	H^+ producer	OH^- producer
Bronsted-Lowry	H^+ donor	H^+ acceptor
Lewis	Electron-pair acceptor	Electron-pair donor

2. For each reaction, identify the Lewis acid and base:
   a. $Ni^{2+}(aq) + 6NH_3(aq) \rightarrow Ni(NH_3)_6^{2+}(aq)$

   b. $H^+(aq) + H_2O(aq) \rightleftharpoons H_3O^+(aq)$

Solution:
A helpful way to start this problem is to draw the Lewis structures for both reactants. This can help identify if either have lone pairs that could be donated to another atom or molecule while maintaining stability.

a. The Lewis structures for Ni^{2+} and NH_3 are shown below:



Though Ni^{2+} has two electron pairs, it is already electron deficient given its positive charge. Thus, it is unlikely that Ni will donate electrons. On the other hand, NH_3 has a lone electron pair that it can donate while still remaining stable.
Therefore,

Ni^{2+} is a Lewis Acid (accepts electron pair)
NH_3 is a Lewis Base (donates electron pair)

b. The Lewis structures for H_2O and H^+ are shown below:

As shown by the Lewis structure, H^+ has no electrons to donate, thus it is impossible for it to be a Lewis base. On the other hand, H_2O has two lone pairs and can donate one while remaining stable.
Therefore,

H^+ is a Lewis Acid (accepts electron pair)
H_2O is a Lewis Base (donates electron pair)

3. Using the following equation for the dissociation of an acid (HA) as a guide, write the dissociation equation for the following acids and label the base, conjugate acid, and conjugate base.

$$HA\,(aq) + H_20(l) \rightleftharpoons H_30^+(aq) + A^-(aq)$$

a. Acetic acid ($HC_2H_3O_2$):

b. Ammonium ion (NH_4^+):

Solution:

This question addresses writing dissociation equations as well as defining molecules as acids, bases, conjugate acids, and conjugate bases based on the Bronsted-Lowry definition. A conjugate acid is defined as the atom or molecule in the products that has gained a proton, and a conjugate base is defined as the atom or molecule in the products that has lost a proton. If the equation were reversed, the conjugate acid would act as the acid and the conjugate base would act as the base.

a. $HC_2H_3O_2$ (aq) + H_2O (l) ⇌ H_3O^+ (aq) + $C_2H_3O_2^-$ (aq)

   $[HC_2H_3O_2]$ = acid
   $[H_2O]$ = base
   $[H_3O^+]$ = conjugate acid
   $[C_2H_3O_2^-]$ = conjugate base

b. NH_4^+ (aq) + H_2O (l) ⇌ H_3O^+ (aq) + NH_3 (aq)

   $[NH_4^+]$ = acid
   $[H_2O]$ = base
   $[H_3O^+]$ = conjugate acid
   $[NH_3]$ = conjugate base

4. Looking at the following equations, label the reactants as acids and bases according to all three definitions of acids and bases. (Hint: some may be defined as acids or bases by multiple definitions)
   a. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$
   b. $NH_{3(aq)} + H_2O_{(l)} \rightarrow OH^-_{(aq)} + NH_4^+{}_{(aq)}$
   c. $F^-_{(aq)} + BF_3 \rightarrow BF_4^-{}_{(aq)}$

Solution:

a. HCl is defined as a Bronsted-Lowry acid (proton donor) and NaOH is defined as a Bronsted-Lowry base (proton acceptor).
b. NH_3 is defined as a Bronsted-Lowry base (proton acceptor) and Arrhenius base (OH^- producer). H_2O is defined as a Bronsted-Lowry acid (proton donor).
c. F^- is a Lewis base (lone pair donor) and BF_3 is a Lewis acid (lone pair acceptor).