ACTIVITY 29 – ACIDS AND BASES

Timer: _____Manager: _____
Recorder/Presenter: _____Reader: _____
Reflector/Quality Control: _____ Other: _____

11 minutes to next solid line

INFORMATION

Acids are compounds that contain H in their formula and produce H^+ when dissolved in water. The naming of acids involves simple changes from the element or polyatomic anion from which they are derived. You will only name neutral acids.

Model 1: Naming acids

Acids formed from hydrogen and one other element.

Formula of acid	**Name of acid**
HCl	Hydrochloric acid
HBr	Hydrobromic acid
H_2S	Hydrosulfuric acid

Key Questions:

1. The name preceding the "acid" has two parts; one part indicates the hydrogen and the other part indicates the other element.
    a. How is the hydrogen indicated in the *name* of a binary acid?

    Does it change when there is more than one hydrogen? _____
    b. How is the elemental name of the other element changed in the name of the acid?

Acids formed from adding hydrogen ions to a polyatomic anion.

Polyatomic ion (formula)	**Name of polyatomic ion**	**Acid from polyatomic ion (formula)**	**Name of acid**
$C_2H_3O_2^-$	Acetate	$HC_2H_3O_2$	Acetic acid
CrO_4^{2-}	Chromate	H_2CrO_4	Chromic acid
NO_2^-	Nitrite	HNO_2	Nitrous acid
ClO_2^-	Chlorite	$HClO_2$	Chlorous acid

2. What is the difference between the *formula* of the polyatomic ion and the *formula* of the acid derived from the polyatomic ion?

3. How does the number of H's on the acid correlate with the charge on the polyatomic ion?

4. What is the change in the name when going from the polyatomic ion to the acid? Be sure to examine all the acids.

5. Is "hydro" included when forming an acid from a polyatomic anion? _____

Exercises:

1. Name the following acids:
    a. HI _____
    b. H_2CO_3 _____
    c. HNO_2 _____
2. What would be the chemical formula of the acid formed from phosphate, PO_4^{3-}?

15 minutes to next solid line

Model 2: Arrhenius acids and bases

Acids	**Bases**
$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$	$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$
$HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$	$LiOH(aq) \rightarrow Li^+(aq) + OH^-(aq)$

Key Questions:

1. Acids and bases can be characterized by what they do in aqueous solution. Let's examine the acids first.
    a. What do all the acids have in common in their molecular formula (left-hand side of the chemical equation)?
    b. As evidenced by the chemical reaction, what is always produced from an acid in aqueous solution?
2. Now, let's examine the bases.
    a. What do all the bases in the table have in common in their molecular formula?
    b. As evidenced by the chemical reaction, what is always produced from a base in aqueous solution?

This model illustrates the Arrhenius concept of an acid and a base. An acid produces H^+ ions in solution and a base produces OH^- ions in solution. The H^+ ion in water is very unstable and

combines with a water molecule to produce the hydronium ion, $H_3O^+(aq)$. $H^+(aq)$ and $H_3O^+(aq)$ are often used interchangeably, and both refer to the hydronium ion.

Group Participation: **Timer,** report the time remaining. Is your group moving forward at an appropriate pace?

INFORMATION

The Arrhenius definition of acids and bases is limited to aqueous solutions. A more general (and usually better) description of acids and bases examines specifically what happens to the H^+ ion (or proton) during the reaction. In the definition studied below, an acid and a base always occur in the same chemical equation.

Model 3: The moving proton definition.

$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$ (reaction 1)

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ (reaction 2)

Key Questions:

1. What are the names of the two reactants in reaction 1?

2. Examine reaction 1 from the viewpoint of what happens to the H^+ ion. Often, you can tell what happens to a reactant by examining the products.
    a. With reference to H^+, what specifically occurs to HCl during the course of the reaction (reactant to product)?

    b. With reference to H^+, what specifically occurs to H_2O during the course of the reaction (reactant to product)?

According to the Brønsted-Lowry definition, an acid is a proton (H^+) donor and a base is a proton (H^+) acceptor.

3. In reaction 1, the reactant that is acting as the proton donor is _____, and the reactant acting as the proton acceptor is _____.
4. According to this definition, an acid-base reaction is simply a proton (H^+) transfer. Describe how this is true for the reaction between $HCl(aq)$ and $H_2O(l)$.

5. Examine reaction 2 using the Brønsted-Lowry definition. The reactant that is the acid (or proton donor) is _____, and the reactant that is the base (or proton acceptor) is _____.
6. Examine the $H_2O(l)$ in both acid-base reactions (reaction 1 and reaction 2). What is interesting about $H_2O(l)$ in terms of acid-base behavior?

Substances that can act as acids or bases are termed as amphoteric. This is not unique to water.

The double arrows are present in reaction 2 because it is reversible, the forward and reverse reactions occur. Eventually, the rates become equal, and chemical equilibrium exists.

7. Think about the reverse reaction for reaction 2 ($OH^-(aq)$ and $NH_4^+(aq)$ reacting to form $H_2O(l)$ and $NH_3(aq)$). An acid and base can also be identified on the product side.
    a. Which product, $NH_4^+(aq)$ or $OH^-(aq)$, would be the acid? _____ Which product would be the base?_____

Notice that the acid on the reactant side became a base on the product side and the base on the reactant side became an acid on the product side. The reactant and product that have this relationship and differ by only one proton are called a conjugate acid-base pair. The acid on the product side of the reaction is called a conjugate acid and the base is called the conjugate base.

    b. Identify the conjugate acid-base pairs in reaction 2 (there are two pairs).

Exercises:

15 minutes to next solid line

1. Examine the acid-base reaction below.

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$$

    a. Which reactant is the acid _____ and which reactant is the base? _____ (this would be the forward reaction)
    b. Which product is the conjugate acid _____ and which product is the conjugate base? _____
    c. Write down the conjugate acid-base pairs?

Group Participation: **Reflector,** is the group moving at an appropriate pace for all group members?

A common type of acid-base reaction is a neutralization reaction. It is generally called a neutralization reaction because all the acid *and* base are neutralized. These types of reactions form water and a salt (or an ionic compound). The salt contains the cation from the base and the anion from the acid. See the reaction below.

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow 2H_2O(l) + Na_2SO_4(aq)$$

The stoichiometry in the reaction depends on the number of H^+ ions in the acid and the number of OH^- ions in the base. For the above reaction, NaOH has one OH^- ion and H_2SO_4 has two H^+

ions. Being the case, a coefficient of "2" is required for NaOH (one H^+ and one OH^- is required to produce one H_2O).

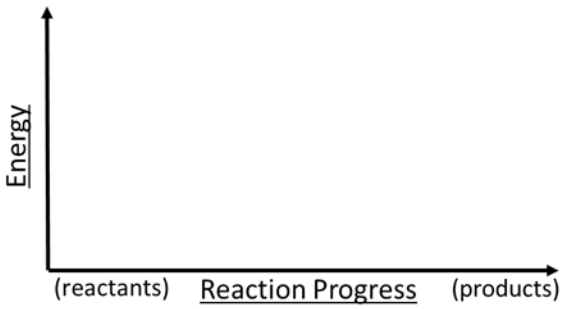
You should also notice that whenever OH^- (or a base containing OH^-) reacts with an acid the products are water and a salt (or an ionic compound).

2. Write the balanced chemical equation for the neutralization reaction between hydrochloric acid (HCl) and magnesium hydroxide ($Mg(OH)_2$).

Review:

1. For the reaction above (question #2), ΔH is -108 kJ. The activation energy, E_a, is small.
   a. Is this reaction endothermic or exothermic? _____
   b. Write the thermochemical equation for this reaction.

   c. Draw the energy diagram for this reaction. In the diagram, indicate ΔH and the activation energy, E_a.



2. Consider the reversible chemical reaction shown below.
   $H_2O(l) + HCN(aq) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$ $K_{eq} = 6.2 \times 10^{-10}$
   a. Write the equilibrium constant expression.

   b. Is this reaction product-favored or reactant-favored? _____ How do you know?

End of activity

The Recorder needs to submit (turn in) the activity, and the Reflector needs to submit the survey.