Introduction to Acids and Bases

Why?

Is water an acid, a base, neither, or both? There are three different ways to define a substance as an acid or base. One definition is based on the ions found in a compound (Arrhenius), another is based on how a compound behaves when added to water (Bronsted-Lowry), and a third is based on how a molecule reacts with other molecules (Lewis). These definitions address different behaviors of compounds and explain how seemingly different compounds can be classified as behaving like an acid or a base.

Success Criteria

- Define an acid according to the Arrhenius definition and the Bronsted-Lowry definition.
- Define a base according to the Arrhenius definition and the Bronsted-Lowry definition.
- Identify acids and bases that illustrate the Arrhenius definition and Bronsted-Lowry definition.
- Explain the acid-base properties of amphiprotic substances.

Information

Acid –

- a compound that yields hydronium ions, $H_3O^+_{(aq)}$, as positive ions in aqueous solution (Arrhenius definition).
- a compound that donates a hydrogen ion (H^+) to another species (Bronsted-Lowry definition).

Base –

- a compound that yields hydroxide ions, $OH^-_{(aq)}$, as negative ions in aqueous solution (Arrhenius definition).
- a compound that accepts a hydrogen ion, (H^+), from another species (Bronsted-Lowry definition).

Neutral solution –

- contains hydrogen ions and hydroxide ions in equal concentrations.

Note: In the context of acid-base chemistry, the hydrogen ion usually is referred to as a proton because an atom of hydrogen contains one proton and one electron - when it loses the electron during ion formation all that is left is the nucleus, which is one proton.

Authored by Josephine Parlagreco and Robert Dayton
Edited by Linda Padwa and David Hanson, Stony Brook University

Model

1. $NaOH(s) + H_2O(l) \rightarrow Na^+(aq) + OH^-(aq)$

2. $HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

3. $NH_3(g) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

4. $H_2CO_3(g) + H_2O(l) \rightarrow H_3O^+(aq) + HCO_3^-(aq)$

5. $HCl(aq) + NH_3(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$

Key Questions

1. In equation 1, is NaOH(s) an acid or a base? Explain.

2. In equation 2, is HCl(aq) an acid or a base? Explain.

3. In equation 3, is NH_3(g) an acid or a base? Explain.

4. In equation 3, is H_2O(l) and acid or a base? Explain.

5. In equation 4, is H_2O(l) and acid or a base? Explain.

6. Is H_2CO_3(g) in equation 4 an acid or a base? Explain.

7. Compare the behavior of NH_3 in equations 3 and 5. Identify any similarities and differences. Explain.

8. Identify the substances in the Model that behave as both an acid and a base? Explain how this duplicity in behavior can or cannot occur.

Authored by Josephine Parlagreco and Robert Dayton
Edited by Linda Padwa and David Hanson, Stony Brook University

Exercises

1. In the reaction below identify which of the reactants is an acid and which is a base:

$$HC_2H_3O_2(aq) + H_2O(l) \rightarrow C_2H_3O_2^-(aq) + H_3O^+(aq)$$

2. Consider the atomic structure of the H^+ ion. Complete the table below indicating the correct number of each subatomic particle.

Composition of the H^+ ion ($_1^1H^+$)

Subatomic particle	Number of subatomic particles
Protons	
Electrons	
Neutrons	

3. In some textbooks, when explaining the Brønsted – Lowry definition, acids and bases are described as proton donors and proton acceptors. Based on your response to Exercise 2, explain why these are correct terms.

4. A definition of the prefix *amphi* is; "both or of both kinds." Define the term "amphiprotic" and based on the insight you gained from examining the model, explain why the term is used to describe water.

Authored by Josephine Parlagreco and Robert Dayton
Edited by Linda Padwa and David Hanson, Stony Brook University

Applications

1. Ammonium chloride is one component of ordinary dry cell batteries. Ammonia gas can react with hydrogen chloride gas to form the solid salt ammonium chloride. Write the balanced equation for this reaction including the phases of each substance.

2. Label the acid and the base in the reactants of your equation in Application 1.

3. Your blood contains an acid-base buffer system. A buffer system is a chemical system that resists changes in pH when small amounts of either acid or base are added to the system. It is important that our blood pH does not change suddenly. A pH balance ensures that chemical reactions in the body take place correctly. If the pH drops below 6.8 or rises above 7.8, death can occur. The buffer in blood is the bicarbonate ion, $HCO_3^-(aq)$. Two equations that illustrate bicarbonate's buffering action are shown in these equations:

$HCO_3^-(aq) + H^+(aq) \rightarrow H_2CO_3(aq)$

$HCO_3^-(aq) + OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$

Label the acid and the base in each of these equations.

4. Explain why bicarbonate ions are said to be amphiprotic.

5. When we exercise, CO_2 builds up in our blood and the following reactions occur.
$CO_2 + H_2O(l) \rightarrow H_2CO_3(aq)$
$H_2CO_3(aq) \rightarrow H^+(aq) + HCO_3^-(aq)$
How does the buffer system in our blood respond to this reaction in order to keep the pH within the acceptable range?

Got It?

Is water an acid, a base, neither, or both? Explain.

Authored by Josephine Parlagreco and Robert Dayton
Edited by Linda Padwa and David Hanson, Stony Brook University