Chapter 12

Acids and Bases

Opening Essay

Formerly there were rather campy science-fiction television shows in which the hero was always being threatened with death by being plunged into a vat of boiling acid: “Mwa ha ha, Buck Rogers [or whatever the hero’s name was], prepare to meet your doom by being dropped into a vat of boiling acid!” (The hero always escapes, of course.) This may have been interesting drama but not very good chemistry. If the villain knew his/her/its science, the hero would have been dropped into a vat of boiling base.

Recall that the active component of a classic acid is the H^+ ion, while the active part of a classic base is the OH^- ion. Both ions are related to water in that all H^+ion needs to become a water molecule is an OH^- ion, while all an OH^- ion needs to become water is an H^+ ion. Consider the relative masses involved: an ion of mass 1 needs an ion of mass 17 to make water, while an ion of mass 17 needs an ion of mass 1 to make water. Which process do you think will be easier?

In fact, bases are more potentially dangerous than acids because it is much easier for an OH^- ion to rip off an H^+ ion from surrounding matter than it is for an H^+ion to rip off an OH^- ion. Certain household chemicals, such as some brands of cleanser, can be very concentrated bases, which makes them among the most potentially hazardous substances found around the home; if spilled on the skin, the strong caustic compound can immediately remove H^+ ions from the flesh, resulting in chemical burns. Compare that to the fact that we occasionally purposefully ingest substances such as citrus fruits, vinegar, and wine—all of which contain acids. (Of course, some parts of the body, such as the eyes, are extremely sensitive to acids as well as

bases.) It seems that our bodies are more capable of dealing with acids than with bases.

So a note to all the villains out there: get your chemistry right if you want to be successful!

Acids and bases are important classes of chemical compounds. They are part of the foods and beverages we ingest, they are present in medicines and other consumer products, and they are prevalent in the world around us. In this chapter, we will focus on acids and bases and their chemistry.

12.1 Arrhenius Acids and Bases

LEARNING OBJECTIVES

1. Identify an Arrhenius acid and an Arrhenius base.
2. Write the chemical reaction between an Arrhenius acid and an Arrhenius base.

Historically, the first chemical definition of an acid and a base was put forward by Svante Arrhenius, a Swedish chemist, in 1884. An **Arrhenius acid** is a compound that increases the H^+ ion concentration in aqueous solution. The H^+ ion is just a bare proton, and it is rather clear that bare protons are not floating around in an aqueous solution. Instead, chemistry has defined the **hydronium ion** (H_3O^+) as the actual chemical species that represents an H^+ ion. H^+ ions and H_3O^+ ions are often considered interchangeable when writing chemical equations (although a properly balanced chemical equation should also include the additional H_2O). Classic Arrhenius acids can be considered ionic compounds in which H^+ is the cation. http://catalog.flatworldknowledge.com/bookhub/reader/2273 - ball-ch12_s01_t01lists some Arrhenius acids and their names.

Table 12.1 Some Arrhenius Acids

Formula	Name
$HC_2H_3O_2$ (also written CH_3COOH)	acetic acid
$HClO_3$	chloric acid
HCl	hydrochloric acid
HBr	hydrobromic acid
HI	hydriodic acid
HF	hydrofluoric acid
HNO_3	nitric acid
$H_2C_2O_4$	oxalic acid
$HClO_4$	perchloric acid
H_3PO_4	phosphoric acid
H_2SO_4	sulfuric acid
H_2SO_3	sulfurous acid

An Arrhenius base is a compound that increases the OH^- ion concentration in aqueous solution. Ionic compounds of the OH^- ion are classic Arrhenius bases.

EXAMPLE 1

Identify each compound as an Arrhenius acid, an Arrhenius base, or neither.

1. HNO_3
2. CH_3OH

3. $Mg(OH)_2$

Solution

1. This compound is an ionic compound between H^+ ions and NO_3^- ions, so it is an Arrhenius acid.
2. Although this formula has an OH in it, we do not recognize the remaining part of the molecule as a cation. It is neither an acid nor a base. (In fact, it is the formula for methanol, an organic compound.)
3. This formula also has an OH in it, but this time we recognize that the magnesium is present as Mg^{2+} cations. As such, this is an ionic compound of the OH^- ion and is an Arrhenius base.

Test Yourself

Identify each compound as an Arrhenius acid, an Arrhenius base, or neither.

1. KOH
2. H_2SO_4
3. C_2H_6

Answer

1. Arrhenius base
2. Arrhenius acid
3. neither

Acids have some properties in common. They turn litmus, a plant extract, red. They react with some metals to give off H_2 gas. They react with carbonate and hydrogen carbonate salts to give off CO_2 gas. Acids that are ingested typically have a sour, sharp taste. (The name *acid* comes from the Latin word *acidus*, meaning "sour.") Bases also have some properties in common. They are slippery to the touch, turn litmus blue, and have a bitter flavor if ingested.

Acids and bases have another property: they react with each other to make water and an ionic compound called a salt. A **salt**, in chemistry, is any ionic compound made by combining an acid with a base. A reaction between an acid and a base is called a **neutralization reaction** and can be represented as follows:

acid + base → H_2O + salt

The stoichiometry of the balanced chemical equation depends on the number of H^+ ions in the acid and the number of OH^- ions in the base.

EXAMPLE 2

Write the balanced chemical equation for the neutralization reaction between H_2SO_4 and KOH. What is the name of the salt that is formed?

Solution

The general reaction is as follows:

$H_2SO_4 + KOH \rightarrow H_2O + \text{salt}$

Because the acid has two H^+ ions in its formula, we need two OH^- ions to react with it, making two H_2O molecules as product. The remaining ions, K^+ and SO_4^{2-}, make the salt potassium sulfate (K_2SO_4). The balanced chemical reaction is as follows:

$H_2SO_4 + 2KOH \rightarrow 2H_2O + K_2SO_4$

Test Yourself

Write the balanced chemical equation for the neutralization reaction between HCl and $Mg(OH)_2$. What is the name of the salt that is formed?

Answer

$2HCl + Mg(OH)_2 \rightarrow 2H_2O + MgCl_2$; magnesium chloride

KEY TAKEAWAYS

- An Arrhenius acid is a compound that increases the H^+ ion concentration in aqueous solution.
- An Arrhenius base is a compound that increases the OH^- ion concentration in aqueous solution.
- The reaction between an Arrhenius acid and an Arrhenius base is called neutralization and results in the formation of water and a salt.

EXERCISES

1. Define *Arrhenius acid*.

2. Define *Arrhenius base*.

3. What are some general properties of Arrhenius acids?

4. What are some general properties of Arrhenius bases?

5. Identify each substance as an Arrhenius acid, an Arrhenius base, or neither.
   a. NaOH
   b. C_2H_5OH
   c. H_3PO_4

6. Identify each substance as an Arrhenius acid, an Arrhenius base, or neither.

   a. $C_6H_{12}O_6$
   b. HNO_2
   c. $Ba(OH)_2$

7. Write the balanced chemical equation for the neutralization reaction between KOH and $H_2C_2O_4$. What is the salt?

8. Write the balanced chemical equation for the neutralization reaction between $Sr(OH)_2$and H_3PO_4. What is the salt?

9. Write the balanced chemical equation for the neutralization reaction between HCl and $Fe(OH)_3$. What is the salt?

10. Write the balanced chemical equation for the neutralization reaction between $H_2SO_4$and $Cr(OH)_3$. What is the salt?

11. $CaCl_2$ would be the product of the reaction of what acid and what base?

12. $Zn(NO_3)_2$ would be product of the reaction of what acid and what base?

13. $BaSO_4$ would be product of the reaction of what acid and what base?

14. Na_3PO_4 would be product of the reaction of what acid and what base?

ANSWERS

1. a compound that increases the H^+ concentration in water

3. sour taste, react with metals, and turn litmus red

3. a. Arrhenius base
   b. neither
   c. Arrhenius acid

5. $2KOH + H_2C_2O_4 \rightarrow 2H_2O + K_2C_2O_4$; $K_2C_2O_4$

7. $3HCl + Fe(OH)_3 \rightarrow 3H_2O + FeCl_3$; $FeCl_3$

9. HCl and $Ca(OH)_2$

11. H_2SO_4 and $Ba(OH)_2$