

## 2.5: Acids and Bases

### Learning Objectives

- To identify and name some common acids and bases.

For our purposes at this point in the text, we can define an **acid** as a substance with at least one hydrogen atom that can dissociate to form an anion and an  $H^+$  ion (a proton) in aqueous solution, thereby forming an *acidic solution*. We can define **bases** as compounds that produce hydroxide ions ( $OH^-$ ) and a For cation when dissolved in water, thus forming a *basic solution*. Solutions that are neither basic nor acidic are *neutral*. We will discuss the chemistry of acids and bases in more detail in [Chapter 4](#), [Chapter 8](#), and [Chapter 16](#), but in this section we describe the nomenclature of common acids and identify some important bases so that you can recognize them in future discussions. Pure acids and bases and their concentrated aqueous solutions are commonly encountered in the laboratory. They are usually highly corrosive, so they must be handled with care.

### Acids

The names of acids differentiate between (1) acids in which the  $H^+$  ion is attached to an oxygen atom of a polyatomic anion (these are called **oxoacids**, or occasionally **oxyacids**) and (2) acids in which the  $H^+$  ion is attached to some other element. In the latter case, the name of the acid begins with *hydro-* and ends in *-ic*, with the root of the name of the other element or ion in between. Recall that the name of the anion derived from this kind of acid always ends in *-ide*. Thus hydrogen chloride ( $HCl$ ) gas dissolves in water to form hydrochloric acid (which contains  $H^+$  and  $Cl^-$  ions), hydrogen cyanide ( $HCN$ ) gas forms hydrocyanic acid (which contains  $H^+$  and  $CN^-$  ions), and so forth (Table 2.5.1 ). Examples of this kind of acid are commonly encountered and very important. For instance, your stomach contains a dilute solution of hydrochloric acid to help digest food. When the mechanisms that prevent the stomach from digesting itself malfunction, the acid destroys the lining of the stomach and an ulcer forms.

#### Note the Pattern

Acids are distinguished by whether the  $H^+$  ion is attached to an oxygen atom of a polyatomic anion or some other element.

Table 2.5.1 Some Common Acids That Do Not Contain Oxygen

Formula	Name in Aqueous Solution	Name of Gaseous Species
HF	hydrofluoric acid	hydrogen fluoride
HCl	hydrochloric acid	hydrogen chloride
HBr	hydrobromic acid	hydrogen bromide
HI	hydroiodic acid	hydrogen iodide
HCN	hydrocyanic acid	hydrogen cyanide
$H_2S$	hydrosulfuric acid	hydrogen sulfide

If an acid contains one or more  $H^+$  ions attached to oxygen, it is a derivative of one of the common oxoanions, such as sulfate ( $SO_4^{2-}$ ) or nitrate ( $NO_3^-$ ). These acids contain as many  $H^+$  ions as are necessary to balance the negative charge on the anion, resulting in a neutral species such as  $H_2SO_4$  and  $HNO_3$ .

The names of acids are derived from the names of anions according to the following rules:

- If the name of the anion ends in *-ate*, then the name of the acid ends in *-ic*.** For example, because  $NO_3^-$  is the nitrate ion,  $HNO_3$  is nitric acid. Similarly,  $ClO_4^-$  is the perchlorate ion, so  $HClO_4$  is perchloric acid. Two important acids are sulfuric acid ( $H_2SO_4$ ) from the sulfate ion ( $SO_4^{2-}$ ) and phosphoric acid ( $H_3PO_4$ ) from the phosphate ion ( $PO_4^{3-}$ ). These two names use a slight variant of the root of the anion name: *sulfate* becomes *sulfuric* and *phosphate* becomes *phosphoric*.
- If the name of the anion ends in *-ite*, then the name of the acid ends in *-ous*.** For example,  $OCl^-$  is the hypochlorite ion, and  $HOCl$  is hypochlorous acid;  $NO_2^-$  is the nitrite ion, and  $HNO_2$  is nitrous acid; and  $SO_3^{2-}$  is the sulfite ion, and  $H_2SO_3$  is sulfurous acid. The same roots are used whether the acid name ends in *-ic* or *-ous*; thus, *sulfite* becomes *sulfurous*.

The relationship between the names of the oxoacids and the parent oxoanions is illustrated in Figure 2.5.1, and some common oxoacids are in Table 2.5.2.

Figure 2.5.1 *The Relationship between the Names of the Oxoacids and the Names of the Parent Oxoanions*

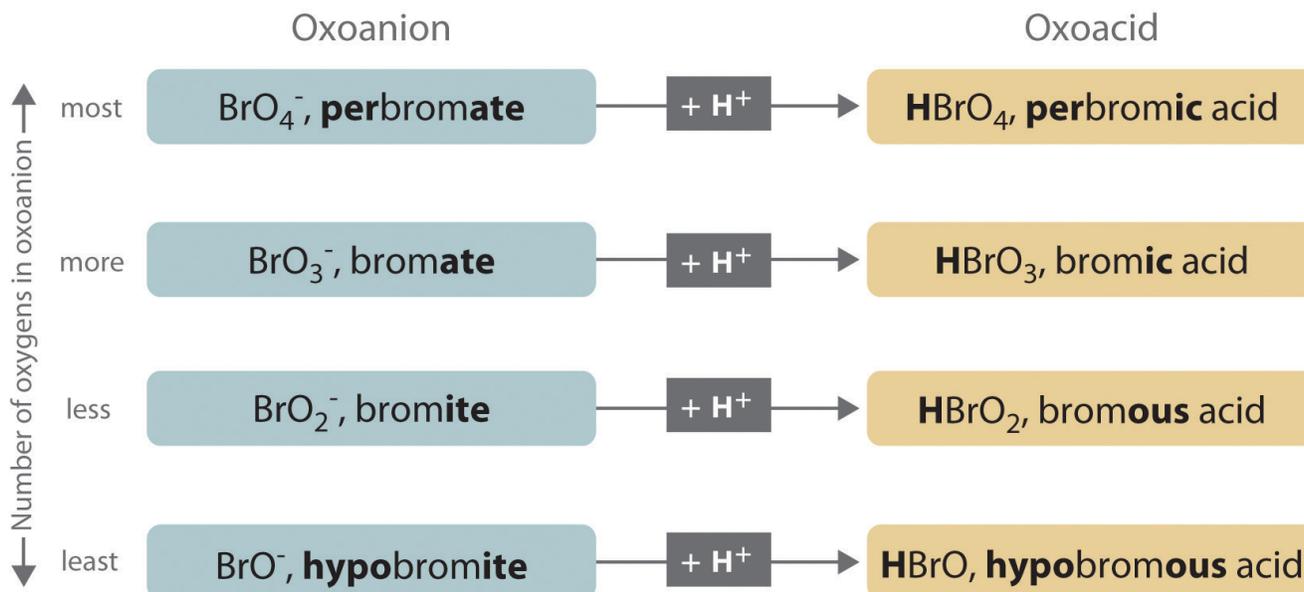


Table 2.5.2 Some Common Oxoacids

Formula	Name
$\text{HNO}_2$	nitrous acid
$\text{HNO}_3$	nitric acid
$\text{H}_2\text{SO}_3$	sulfurous acid
$\text{H}_2\text{SO}_4$	sulfuric acid
$\text{H}_3\text{PO}_4$	phosphoric acid
$\text{H}_2\text{CO}_3$	carbonic acid
$\text{HClO}$	hypochlorous acid
$\text{HClO}_2$	chlorous acid
$\text{HClO}_3$	chloric acid
$\text{HClO}_4$	perchloric acid

#### ✓ Example 2.5.1

Name and give the formula for each acid.

1. the acid formed by adding a proton to the hypobromite ion ( $\text{OBr}^-$ )
2. the acid formed by adding two protons to the selenate ion ( $\text{SeO}_4^{2-}$ )

**Given:** anion

**Asked for:** parent acid

**Strategy:**

Refer to Table 2.5.1 and Table 2.5.2 to find the name of the acid. If the acid is not listed, use the guidelines given previously.

### Solution

Neither species is listed in Table 2.5.1 or Table 2.5.2, so we must use the information given previously to derive the name of the acid from the name of the polyatomic anion.

1. The anion name, *hypobromite*, ends in *-ite*, so the name of the parent acid ends in *-ous*. The acid is therefore hypobromous acid (HOBr).
2. *Selenate* ends in *-ate*, so the name of the parent acid ends in *-ic*. The acid is therefore selenic acid (H<sub>2</sub>SeO<sub>4</sub>).

### ? Exercise 2.5.1

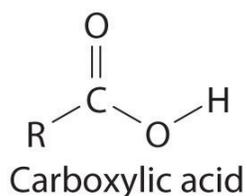
Name and give the formula for each acid.

1. the acid formed by adding a proton to the perbromate ion (BrO<sub>4</sub><sup>-</sup>)
2. the acid formed by adding three protons to the arsenite ion (AsO<sub>3</sub><sup>3-</sup>)

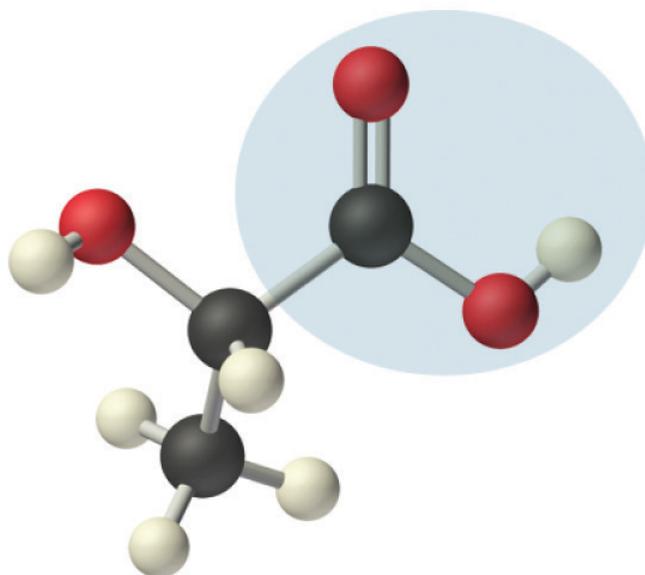
### Answer

1. perbromic acid; HBrO<sub>4</sub>
2. arsenous acid; H<sub>3</sub>AsO<sub>3</sub>

Many organic compounds contain the **carbonyl group**, in which there is a carbon–oxygen double bond. In **carboxylic acids**, an –OH group is covalently bonded to the carbon atom of the carbonyl group. Their general formula is RCO<sub>2</sub>H, sometimes written as RCOOH:

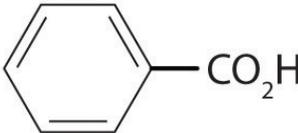


where R can be an alkyl group, an aryl group, or a hydrogen atom. The simplest example, HCO<sub>2</sub>H, is *formic acid*, so called because it is found in the secretions of stinging ants (from the Latin *formica*, meaning “ant”). Another example is *acetic acid* (CH<sub>3</sub>CO<sub>2</sub>H), which is found in vinegar. Like many acids, carboxylic acids tend to have sharp odors. For example, butyric acid (CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CO<sub>2</sub>H), is responsible for the smell of rancid butter, and the characteristic odor of sour milk and vomit is due to lactic acid [CH<sub>3</sub>CH(OH)CO<sub>2</sub>H]. Some common carboxylic acids are shown in Figure 2.5.2.



Lactic acid,  $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$

Figure 2.5.2 Some Common Carboxylic Acids

Formula (Structure)	Name	Uses
$\text{HCO}_2\text{H}$	formic acid	tanning, dyeing
$\text{CH}_3\text{CO}_2\text{H}$	acetic acid	vinegar, food preservative
$\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$	propionic acid	food preservative
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$	butyric acid	varnishes
$\text{C}_6\text{H}_5\text{CO}_2\text{H}$ 	benzoic acid	food preservative, dyeing

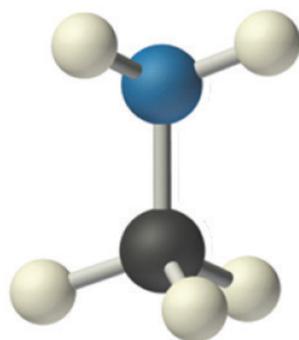
Although carboxylic acids are covalent compounds, when they dissolve in water, they dissociate to produce  $H^+$  ions (just like any other acid) and  $RCO_2^-$  ions. Note that *only the hydrogen attached to the oxygen atom of the  $CO_2$  group dissociates to form an  $H^+$  ion*. In contrast, the hydrogen atom attached to the oxygen atom of an alcohol does *not* dissociate to form an  $H^+$  ion when an alcohol is dissolved in water. The reasons for the difference in behavior between carboxylic acids and alcohols will be discussed in [Chapter 8](#).

### Note the Pattern

Only the hydrogen attached to the oxygen atom of the  $CO_2$  group dissociates to form an  $H^+$  ion.

## Bases

We will present more comprehensive definitions of bases in later chapters, but virtually every base you encounter in the meantime will be an ionic compound, such as sodium hydroxide ( $NaOH$ ) and barium hydroxide [ $Ba(OH)_2$ ], that contain the hydroxide ion and a metal cation. These have the general formula  $M(OH)_n$ . It is important to recognize that alcohols, with the general formula  $ROH$ , are covalent compounds, not ionic compounds; consequently, they do *not* dissociate in water to form a basic solution (containing  $OH^-$  ions). When a base reacts with any of the acids we have discussed, it accepts a proton ( $H^+$ ). For example, the hydroxide ion ( $OH^-$ ) accepts a proton to form  $H_2O$ . Thus bases are also referred to as *proton acceptors*.



Methylamine

Concentrated aqueous solutions of ammonia ( $NH_3$ ) contain significant amounts of the hydroxide ion, even though the dissolved substance is *not* primarily ammonium hydroxide ( $NH_4OH$ ) as is often stated on the label. Thus aqueous ammonia solution is also a common base. Replacing a hydrogen atom of  $NH_3$  with an alkyl group results in an **amine** ( $RNH_2$ ), which is also a base. Amines have pungent odors—for example, methylamine ( $CH_3NH_2$ ) is one of the compounds responsible for the foul odor associated with spoiled fish. The physiological importance of amines is suggested in the word *vitamin*, which is derived from the phrase *vital amines*. The word was coined to describe dietary substances that were effective at preventing scurvy, rickets, and other diseases because these substances were assumed to be amines. Subsequently, some vitamins have indeed been confirmed to be amines.

### Note the Pattern

Metal hydroxides ( $MOH$ ) yield  $OH^-$  ions and are bases, alcohols ( $ROH$ ) do not yield  $OH^-$  or  $H^+$  ions and are neutral, and carboxylic acids ( $RCO_2H$ ) yield  $H^+$  ions and are acids.

### Summary

Common **acids** and the polyatomic anions derived from them have their own names and rules for nomenclature. The nomenclature of acids differentiates between **oxoacids**, in which the  $H^+$  ion is attached to an oxygen atom of a polyatomic ion, and acids in which the  $H^+$  ion is attached to another element. **Carboxylic acids** are an important class of organic acids. Ammonia is an important **base**, as are its organic derivatives, the **amines**.

### KEY TAKEAWAY

- Common acids and polyatomic anions derived from them have their own names and rules for nomenclature.

## CONCEPTUAL PROBLEMS

1. Name each acid.

1. HCl
2. HBrO<sub>3</sub>
3. HNO<sub>3</sub>
4. H<sub>2</sub>SO<sub>4</sub>
5. HIO<sub>3</sub>

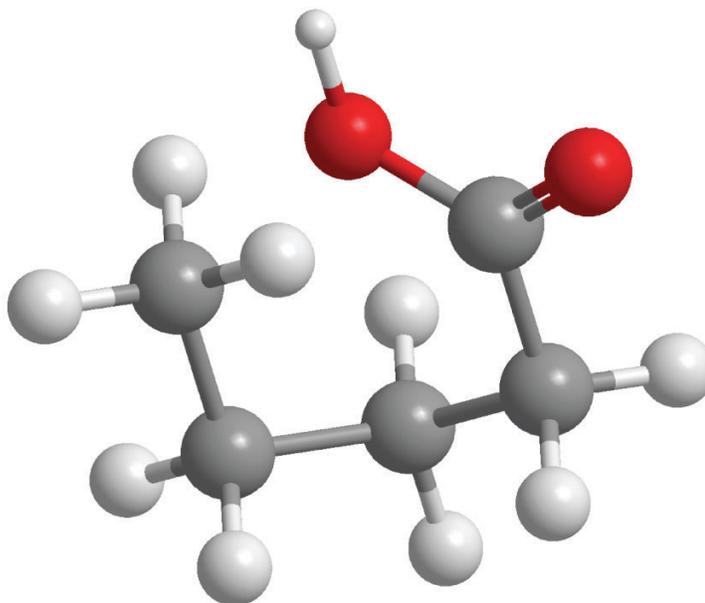
2. Name each acid.

1. HBr
2. H<sub>2</sub>SO<sub>3</sub>
3. HClO<sub>3</sub>
4. HCN
5. H<sub>3</sub>PO<sub>4</sub>

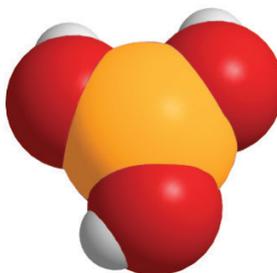
3. Name the aqueous acid that corresponds to each gaseous species.

1. hydrogen bromide
2. hydrogen cyanide
3. hydrogen iodide

4. For each structural formula, write the condensed formula and the name of the compound.

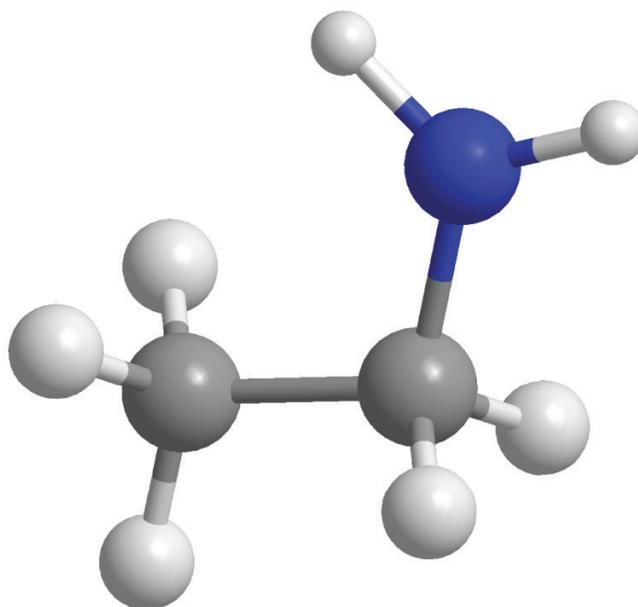


1.

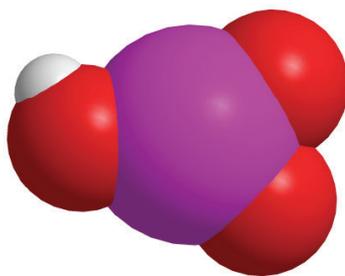


2.

5. For each structural formula, write the condensed formula and the name of the compound.



1.



2.

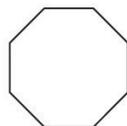
6. When each compound is added to water, is the resulting solution acidic, neutral, or basic?

1.  $\text{CH}_3\text{CH}_2\text{OH}$
2.  $\text{Mg}(\text{OH})_2$
3.  $\text{C}_6\text{H}_5\text{CO}_2\text{H}$
4.  $\text{LiOH}$
5.  $\text{C}_3\text{H}_7\text{CO}_2\text{H}$
6.  $\text{H}_2\text{SO}_4$

7. Draw the structure of the simplest example of each type of compound.

1. alkane
2. alkene
3. alkyne
4. aromatic hydrocarbon
5. alcohol
6. carboxylic acid
7. amine
8. cycloalkane

8. Identify the class of organic compound represented by each compound.



- 1.
2.  $\text{CH}_3\text{CH}_2\text{OH}$
3.  $\text{HC}\equiv\text{CH}$

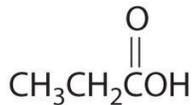
- 4.
5.  $C_3H_7NH_2$
6.  $CH_3CH=CHCH_2CH_3$



7.



8.

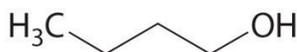


9. Identify the class of organic compound represented by each compound.

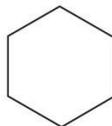
1.



2.



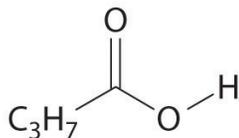
3.



4.

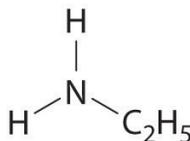


5.

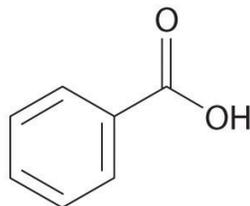


6.  $CH_3C\equiv CH$

7.



8.



### NUMERICAL PROBLEMS

1. Write the formula for each compound.

1. hypochlorous acid
2. perbromic acid
3. hydrobromic acid

4. sulfurous acid
  5. sodium perbromate
2. Write the formula for each compound.
1. hydroiodic acid
  2. hydrogen sulfide
  3. phosphorous acid
  4. perchloric acid
  5. calcium hypobromite
3. Name each compound.
1. HBr
  2.  $\text{H}_2\text{SO}_3$
  3. HCN
  4.  $\text{HClO}_4$
  5.  $\text{NaHSO}_4$
4. Name each compound.
1.  $\text{H}_2\text{SO}_4$
  2.  $\text{HNO}_2$
  3.  $\text{K}_2\text{HPO}_4$
  4.  $\text{H}_3\text{PO}_3$
  5.  $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$

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