10.1 Properties of Acids and Bases

Canadians' teeth have never been healthier. Advances in dental care during the twentieth century have greatly reduced the incidence of dental decay. One remaining concern, however, is the number of Canadians whose teeth are wearing out faster than expected. The cause? Acid erosion (**Figure 1**). Our modern diet is rich in acidic foods. These include natural, nutritious foods such as citrus fruits, pure fruit juices, and tomatoes. But they also include processed foods such as sour candy and pop. Citric acid occurs naturally in oranges and limes. The tart taste of cola is caused by a combination of phosphoric and carbonic acids. In fact, pop would taste almost as sour as vinegar if not for its sweeteners. Acids prematurely wear away teeth, which can make teeth more sensitive. A simple way to solve this problem is to consume fewer acidic foods and drinks, especially those of little nutritional value like pop. Otherwise, you might need extensive dental work to the repair the damage.

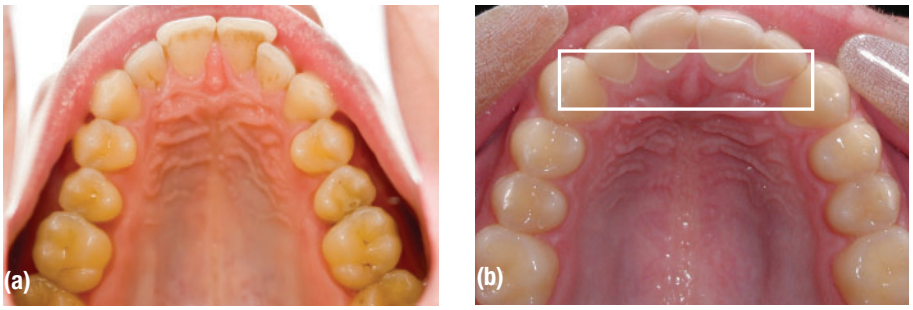

Figure 1 Compare (a) a teenager's healthy teeth and (b) a teenager's teeth damaged by acid erosion. The frame highlights where the enamel has worn away on the incisors.

CAREER LINK

Dentists and dental hygienists can advise you on how to care for your teeth. To find out more about these careers,

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LEARNING TIP

"Alkali" in the Periodic Table

The elements in Group 1 are sometimes called "alkali metals." Recall that the oxides of these metals form basic solutions. Similarly, Group 2 elements are the alkaline earth metals. They, too, react to form basic solutions. Basic = alkali.

To understand why acidic foods can be so damaging, we can examine the properties and structure of tooth enamel. Tooth enamel is the hard material on the outer surface of a tooth. Much of tooth enamel consists of the mineral calcium hydroxylapatite, $Ca_{10}(PO_4)_6(OH)_2(s)$. Hydrogen ions in acidic fluids can break down or demineralize this compound:

$$Ca_{10}(PO_4)_6(OH)_2(s) + 8\ H^+(aq) \rightarrow 10\ Ca^{2+}(aq) + 6\ HPO_4^{2-}(aq) + 2\ H_2O(l)$$

This reaction is similar to the reaction that occurs when vinegar is used to remove the mineral buildup in a clogged shower head. Demineralization softens teeth, making them more easily worn away. That is why brushing your teeth immediately after drinking cola (pH 3) may not be wise. This is when tooth enamel is softest.

Acids have a number of properties in common. Reactivity with certain minerals and low pH are two characteristic properties of acids.

Acids and Bases in History

We have known about acids and bases for centuries. Ancient winemakers, for example, knew that exposure to air makes wine sour. Today we know that wine sours because oxygen reacts with ethanol in the wine to produce ethanoic acid (acetic acid). Recall that vinegar is a dilute solution of ethanoic acid. In fact, the word "acid" comes from the Latin word *acidus,* meaning sour.

The use of bases (also known as alkalis) also has a long history. The word "alkali" comes from the Arabic term *al-qilwi*, meaning "basic." Many ancient civilizations discovered that the ashes from a wood fire produced a corrosive mixture when dissolved in water. They also discovered that cooking wood ashes with animal fats or vegetable oils produced an effective cleaner.

Wood ashes are rich in potassium carbonate, K_2CO_3. You will soon learn how potassium carbonate dissolves in water to produce a basic solution. Soap is still produced today using essentially the same ingredients (a base and fat) in a process called saponification (**Figure 2**).

Figure 2 Soap can be made by cooking vegetable oils in a concentrated solution of sodium hydroxide.

People in many cultures developed a practical or empirical understanding of acids and bases, founded on their properties, long before we knew their chemical structures. **Table 1** compares some of the properties of acids and bases.

Table 1 Properties of Acids and Bases

Property		Acid	Base
pH		less than 7	greater than 7
electrical conductivity		conductivity varies	conductivity varies (**Figure 3**)
taste (Never taste chemicals in the lab.)		sour	bitter
feel (Never touch chemicals that are labelled "corrosive.")		no special feel	slippery
colour with acid–base indicator	bromothymol blue		
	phenolphthalein		
	methyl orange		
	litmus		
neutralization reactions		acids neutralize bases	bases neutralize acids

Figure 3 The fluid paste in an alkaline cell must be a good conductor of electricity in order for the cell to generate electricity. These cells are called "alkaline" because they contain the base potassium hydroxide, KOH.

Reactions of Acids

We can also distinguish acids from other substances by their characteristic reactions. In Chapter 4, you learned that acids react with metals above hydrogen on the activity series to produce hydrogen gas. For example, **Figure 4** shows a typical acid, hydrochloric acid, in two different reactions. With magnesium metal, hydrochloric acid reacts to release visible bubbles of hydrogen:

$$Mg(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

Hydrochloric acid also reacts with carbonate compounds to produce carbon dioxide:

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Figure 4 Acids react with (a) reactive metals (such as magnesium) to produce hydrogen gas and (b) carbonate compounds (such as calcium carbonate in chalk) to produce carbon dioxide gas.

Figure 5 When carbon dioxide bubbles through a straw into a solution of calcium hydroxide (limewater), a precipitate turns the liquid cloudy. This reaction is used in the familiar limewater test for carbon dioxide.

Reactions of Bases

Bases also undergo some characteristic reactions: they react with carbon dioxide to form carbonates. For example, blowing carbon dioxide into a calcium hydroxide solution (limewater) produces a calcium carbonate precipitate (**Figure 5**):

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

Bases also react with oils and fats to produce soap. If a base comes in contact with your skin it feels slippery because it is reacting with oils on your skin to form a soap-like mixture.

Nomenclature of Acids and Bases

Many traditional names have been used to identify acids and bases. Today, a few of these names remain in everyday use. For example, early chemists of the sixteenth century learned to make a highly corrosive fluid called "muriatic acid." Today, pool chemical suppliers sell muriatic acid (hydrochloric acid) to lower the pH of pool water. Similarly, caustic soda and lye are two common names for the same base: sodium hydroxide. Sodium hydroxide is the active ingredient in some drain cleaners.

Today, there are far too many acids and bases for the use of common names to be either safe or practical. Fortunately, chemists have developed a more systematic method of naming these compounds.

Naming Acids

You can usually tell that a compound is an acid if its chemical formula starts with one or more hydrogen atoms. (Water is an exception to this rule.) Acids are sometimes represented by the general formula HA(aq). "H" represents hydrogen and "A" represents the rest of the acid's formula. We add the state symbol (aq) because most acids show their acidic properties only when they are dissolved in water.

Chemists use two different systems to name acids, depending on whether or not the compounds contain oxygen.

ACIDS WITHOUT OXYGEN

The names of acids without oxygen start with the prefix *hydro-* and end with *-ic acid*. The stem of the acid name comes from the element or group following hydrogen in the formula. For example, HCl(aq) is called hydrochloric acid because it contains chlorine. *Chlor*, from "chlorine," is the stem of the acid's name. Halogens have similar properties and similar electron arrangements. You would therefore expect halogens to form acids with similar chemical formulas (**Table 2**). These include hydrofluoric acid, HF(aq), hydrochloric acid, HCl(aq), and hydroiodic acid, HI(aq).

Table 2 Acids without Oxygen

Acid name	Chemical formula
hydrofluoric acid	HF(aq)
hydrochloric acid	HCl(aq)
hydrobromic acid	HBr(aq)
hydroiodic acid	HI(aq)
hydrosulfuric acid	H_2S(aq)
hydrocyanic acid	HCN(aq)

oxyacid an acid that includes oxygen in its formula

ACIDS WITH OXYGEN

The name of an acid that contains oxygen is based on the name of its oxyanion. These acids are called **oxyacids**. **Table 3** lists some oxyacids. Note that their names do not start with the prefix *hydro-*. Recall from Section 2.4 that a negatively charged polyatomic ion that contains oxygen is called an oxyanion.

If the oxyanion name ends in *-ate*, the acid name ends in *-ic acid*. For example,

ion	**acid**
NO_3^-	HNO_3(aq)
nitrate ion	nitric acid

If the oxyanion name ends in *-ite*, the acid name ends in *-ous acid*. For example,

ion	**acid**
NO_2^-	HNO_2(aq)
nitrite ion	nitrous acid

Similarly, the hypochlorite ion is related to hypochlorous acid. **Table 4** lists the oxyanions that contain the same elements as the chlorate ion, ClO_3^-. Note that all the halogens follow this pattern for the names and formulas of their oxyanions.

Table 3 Acids with Oxygen (Oxyacids)

Acid name	Chemical formula	Parent oxyanion
nitric acid	$HNO_3(aq)$	nitrate, NO_3^-
chloric acid	$HClO_3(aq)$	chlorate, ClO_3^-
carbonic acid	$H_2CO_3(aq)$	carbonate, CO_3^{2-}
sulfuric acid	$H_2SO_4(aq)$	sulfate, SO_4^{2-}
phosphoric acid	$H_3PO_4(aq)$	phosphate, PO_4^{3-}

Table 4 Oxyanions of Chlorine

Anion	Formula of anion
perchlorate	ClO_4^-
chlorate	ClO_3^-
chlorite	ClO_2^-
hypochlorite	ClO^-

LEARNING TIP

Oxyanion Review

Recall that *per, ite,* and *hypo___ite* are used to indicate the number of oxygen atoms in the oxyanion as compared to the *−ate* anion:
per means 1 more oxygen atom.
ite means 1 less oxygen atom.
hypo + *ite* means 2 less oxygen atoms. You can apply the pattern of oxyanion names in Table 4 to any of the parent oxyanions in Table 3. This allows you to write ions such as the nitrite ion, NO_2^-. With practice you will become familiar with the oxyanions, the number of oxygen atoms in each, their charges, and their related oxyacids.

Tutorial 1 Naming Acids

Figure 6 summarizes a procedure that you can follow when naming acids. This procedure assumes that you already know that the compound is an acid: HA(aq). You will also need to refer to Tables 3 and 4 when naming acids that include oxygen in their formulas.

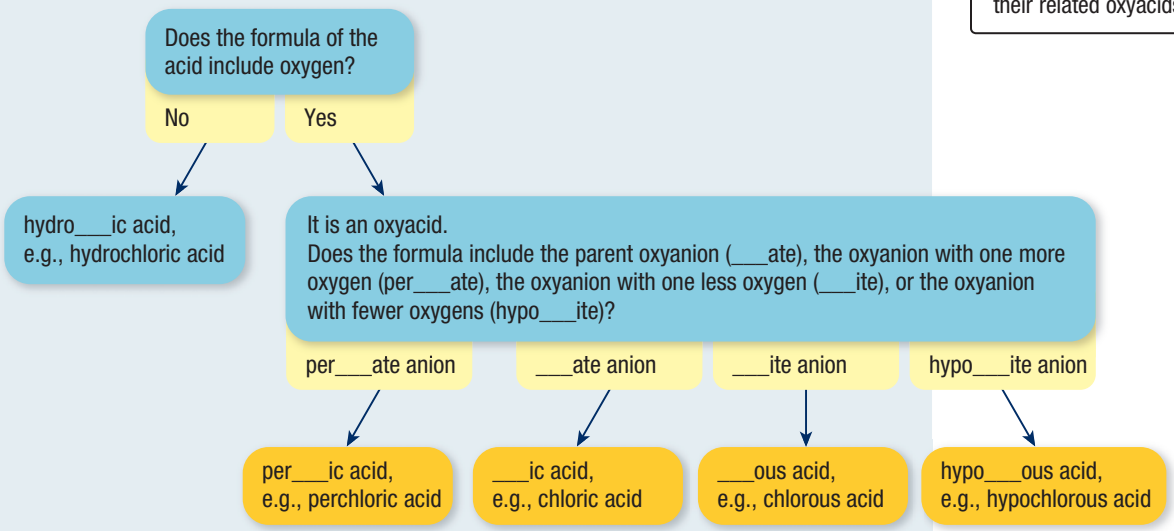

Figure 6 A summary of how to name acids

Sample Problem 1: Naming an Acid That Includes Oxygen

Write the name of the acid with formula $H_2SO_3(aq)$.

Step 1. Start at the top of the flow chart in Figure 6. Establish whether oxygen is present.

Oxygen is present, so it is an oxyacid. It is related to an oxyanion.

Step 2. Identify the oxyanion.

The oxyanion is SO_3^{2-}, sulfite ion.

Step 3. Establish the name of the acid from the name of the oxyanion.

The acid with formula $H_2SO_3(aq)$ is sulfurous acid.

Sample Problem 2: Writing the Formula of an Oxyacid

Write the chemical formula of bromic acid.

Step 1. Use the name to identify the type of acid.

Since the prefix *hydro-* is not present, bromic acid is an oxyacid.

Step 2. Use the stem of the acid's name and any prefixes or suffixes in the name to determine the oxyanion in the acid's formula.

Since the stem of the acid's name is *brom-* and the suffix is *-ic*, the oxyanion is the bromate ion, BrO_3^-.

LEARNING TIP

Non-Oxygen Name

The name of the acid comes from the non-oxygen element in the anion. For example, the acid related to the sulfite ion (which contains sulfur and oxygen) is called "sulfurous acid." Notice that the stem of the acid name changes from *sulf-* to *sulfur-*.

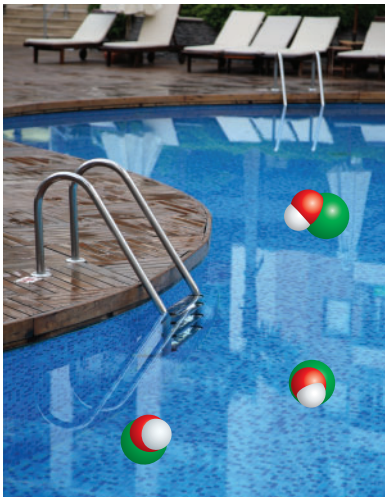

Figure 7 Hypochlorous acid forms in pool water from the chemicals used to disinfect the pool. This acid kills bacteria by passing through the cell membrane and bleaching the cell's interior.

Step 3. Use the zero-sum rule to determine the number of hydrogen ions that are required to produce a neutral acid molecule.

Since the charge of the bromate ion is –1, only one H^+ ion is required to produce a neutral acid molecule.

Step 4. Combine the correct number of H^+ ions with the oxyanion to write the formula for the acid.

The formula of bromic acid is $HBrO_3(aq)$.

Practice

1. Name the following acids: K/U
   (a) HBr(aq)
   (b) $H_3PO_3(aq)$
   (c) $H_2S(aq)$
   (d) $H_2SO_3(aq)$
   (e) $HIO_4(aq)$
   (f) HFO(aq)
2. Write the chemical formula for each of the following acids: K/U
   (a) hydrofluoric acid
   (b) sulfurous acid
   (c) hypochlorous acid (**Figure 7**)
   (d) perbromic acid

Naming Bases

A number of substances produce basic solutions when dissolved in water. However, for this course you only have to learn how to name bases that are ionic hydroxides, such as sodium hydroxide, NaOH(aq), and calcium hydroxide, $Ca(OH)_2(aq)$. (You will encounter other bases in future chemistry courses.) Note that the name of the base is the same as the name of the ionic hydroxide.

Hydroxide bases only show their basic properties when they are in solution. Because of this, we always use the symbol (aq) in the chemical formula of a base.

10.1 Summary

- Acids taste sour, have a pH less than 7, conduct electricity (to varying degrees), change the colours of acid-base indicators, and neutralize bases.
- Acids react with metals above hydrogen on the activity series.
- Acids react with carbonate compounds.
- Bases taste bitter, feel slippery, have a pH greater than 7, conduct electricity to some degree, change the colours of acid-base indicators, and neutralize acids.
- Acids that do not have oxygen in the formula are named hydro____ic acid.
- The names of acids with oxygen are based on the name of their oxyanion (Figure 6).
- The names of bases that are ionic hydroxides are simply the names of the ionic hydroxides.

10.1 Questions

1. Chewy sour candies sometimes remain stuck to teeth for several minutes. Why is this a problem? K/U A
2. The reaction of sodium hydrogen carbonate (baking soda), $NaHCO_3$, and vinegar is a safe and effective method of opening a clogged drain (**Figure 8**). C A
   (a) Write the chemical equation for this reaction.
   (b) Explain why using sodium hydrogen carbonate and vinegar may be a greener alternative to using household drain openers, many of which contain sodium hydroxide.

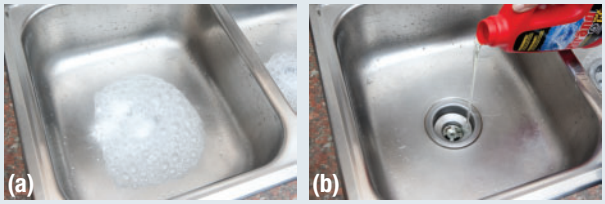

Figure 8 You can open a clogged drain using (a) baking soda and vinegar or (b) a household product that may contain sodium hydroxide.

3. Sulfuric acid is dripped onto samples of three metals: silver, zinc, and aluminum. K/U T/I C
   (a) Use the activity series to determine whether a reaction will occur with each metal.
   (b) Write a chemical equation for each reaction that occurs.
4. Name the following acids: T/I
   (a) $H_2CO_3(aq)$ (in carbonated beverages)
   (b) HI(aq) (used to make organic iodine compounds)
   (c) $H_2S(aq)$ (rotten-egg smell)
   (d) $H_3PO_4(aq)$ (rust remover)
   (e) $HNO_3(aq)$ (used to make fertilizers)
   (f) HF(aq) (used to etch glass)
   (g) $HNO_2(aq)$
   (h) $H_2SO_3(aq)$
   (i) $H_3PO_3(aq)$
   (j) $HIO_4(aq)$
   (k) HClO(aq)
5. What information in the chemical formula indicates that a compound is likely to be an acid? K/U
6. Write the chemical formula for each of the following acids: T/I C
   (a) hydrobromic acid
   (b) perchloric acid
   (c) chlorous acid
   (d) hydroiodic acid
7. Name the following bases: T/I
   (a) $Mg(OH)_2(aq)$ (b) KOH(aq)
8. How are the chemical formulas of chloric acid and hydrochloric acid similar? How do they differ? K/U T/I
9. Given that the elements chlorine and iodine are in the same chemical family, you would expect them to form compounds with similar chemical formulas. T/I C
   (a) Predict the chemical formula of iodic acid.
   (b) Use your answer from (a) to predict the chemical formulas of iodous acid and hypoiodous acid.
10. The stomach secretes a corrosive mixture of digestive juices that includes hydrochloric acid. Research why the stomach does not digest itself. A
11. Despite its name, the medical condition known as "heartburn" has nothing to do with the heart. Research the cause of heartburn and what can be done to soothe its symptoms. T/I A
12. Research the role of carbon dioxide in the formation of caves in limestone deposits (**Figure 9**). T/I A

Figure 9 Carlsbad Caverns in New Mexico

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