5.9: Acids

A spot test for gold has been in use for decades. The sample is first treated with nitric acid. Other metals may react or dissolve in this acid, but gold will not. Then the sample is added to a mixture of nitric acid and hydrochloric acid. Gold will only dissolve in this mixture. The term "acid test" arose from the California gold rush in the late 1840's when this combination was used to test for the presence of real gold. It has since come to mean "tested and approved" in a number of fields.

Acids

An **acid** can be defined in several ways. The most straightforward definition is that an acid is a molecular compound that contains one or more hydrogen atoms and produces hydrogen ions (H^+) when dissolved in water.


Figure 5.9.1: (A) Vinegar comes in a variety of types, but all contain acetic acid. (B) Citrus fruits like grapefruit contain citric and ascorbic acids.

This is a different type of compound than the others we have seen thus far. Acids are molecular, which means that in their pure state they are individual molecules and do not adopt the extended three-dimensional structures of ionic compounds like NaCl. However, when these molecules are dissolved in water, the chemical bond between the hydrogen atom and the rest of the molecule breaks, leaving a positively-charged hydrogen ion and an anion. This can be symbolized in a chemical equation:

$$HCl \rightarrow H^+ + Cl^- \tag{5.9.1}$$

Since acids produce H^+ cations upon dissolving in water, the H of an acid is written first in the formula. The remainder of the acid (other than the H) is the anion after the acid dissolves.

Binary Acids

The name of an acid is based on the other elements with which it is combined. A **binary acid** is an acid that consists of hydrogen combined with one other element. The most common binary acids contain a halogen. The convention for naming binary acids is

hydro- + root name of the other element + *-ic acid*

In other words, the acid name begins with the prefix *hydro-*, followed immediately by the root name of the other element, which is then followed by the suffix *-ic acid*. It should also be noted that binary acids are only assigned their acid name when they are dissolved in water, which we designate with a phase label of (*aq*), which stands for aqueous (pronounced AY-quee-us).

Therefore, the name of HCl (*aq*) is hydrochloric acid, since the root name of chlorine is *chlor-* and we are showing that the HCl is dissolved in water. As a gas, HCl (*g*) is called hydrogen chloride. While this distinction is important, the phase label is usually left off and the correct name is usually based on the context in which it is used. In the absence of a phase label, one is usually safe to assume that a binary acid is named as an acid, in which the *hydro-* prefix and *-ic acid* suffix are used.

When writing the formula of an acid, the formula of a hydrogen ion, H^+, is combined with the formula and charge of the nonmetal anion in the acid. To write the formula of hydroiodic acid, H^+ would be combined with I^-, since iodine is located in Group VIIA of the periodic table (see Figure 5.5.1). The charges H^+ and I^- are already balanced, so the formula of hydroiodic acid is HI (*aq*). The formula could also be simply written as HI, since we know the context in which it was used (as an acid, according to its name).

✅ Example 5.9.1: Binary Acids

If the chemical formula is provided, write the name. If the name is provided, write the formula.

A. HF (*aq*)
B. hydrosulfuric acid

Solution

A. Since there are just two elements and the first element in the formula is H, this a binary acid. Binary acids have a *hydro-* prefix and an *-ic acid* suffix. The root name of fluorine is *fluor-*. HF (*aq*) is hydrofluoric acid.

B. The name has a *hydro-* prefix and an *-ic acid* suffix, making it a binary acid. H^+ would be combined with S^{2-}. The charge on sulfide is 2– based on its position (Group VIA) on the periodic table. Charge is balanced with two H^+ for every one S^{2-}. Hydrosulfuric acid is H_2S (*aq*) or simply H_2S.

Oxyacids

An acid always contains the element hydrogen and the H is always written at the front of the chemical formula. An **oxyacid** is an acid that also contains the element oxygen, along with a third (and occasionally fourth) element. The third element is almost always a nonmetal. Oxyacids may also be thought of as a compound where H^+ has combined with an oxyanion. As we recall, the most common oxyanions end with an *-ate* suffix, while other oxyanions end with an *-ite* suffix.

The convention for naming oxyacids:

- Identify and name the oxyanion present in the acid.
- If the oxyanion name ends with *-ate*, drop the *-ate* suffix from the anion name and replace with an *-ic acid* suffix.
- If the oxyanion name ends with *-ite*, drop the *-ite* suffix from the anion name and replace with an *-ous acid* suffix.

✅ Example 5.9.2: Naming Oxyacids

Write the name for each acid.

A. HNO_3
B. HNO_2

Solution

HNO_3	HNO_2

	HNO_3	HNO_2
1. Identify the oxyanion present in the acid.	NO_3^-	NO_2^-

	HNO_3	HNO_2
2. Name the oxyanion.	nitrate	nitrite
3. Drop *-ate* or *-ite* from the anion name.	nitr-	nitr-

	HNO_3	HNO_2
4. Replace *-ate* with *-ic acid*. Replace *-ite* with *-ous acid*.	nitric acid	nitrous acid

✅ Example 5.9.3: Writing Formulas for Oxyacids

Write the chemical formula for each acid.

A. chlorous acid
B. chloric acid

Solution

The process of arriving at a name now needs to be reversed.

	chlorous acid	chloric acid
1. Identify suffix as *-ic acid* or *-ous acid*.	chlorous acid	chloric acid
2. Replac	chlorite	chlorate

	chlorous acid	chloric acid
e - *i* *c* *a* *c* *i* *d* w i t h - *a* *t* *e* . R e p l a c e - *o* *u* *s* *a* *c* *i* *d* w i t h - *i* *t* *e* .		
3. S i n c	H^+ with ClO_2^-	H^+ with ClO_3^-

chlorous acid	chloric acid
either is an acid, combine H^+ with the formula of the oxyanion.	

	chlorous acid	chloric acid
4. Balance charges.	one H^+ balances one ClO_2^-	one H^+ balances one ClO_3^-

chlorous acid	chloric acid
5. Write the final formula. Charges are left off.	$HClO_2$	$HClO_3$

⚡ Sulfur and Phosphorus

When sulfur or phosphorus are present in acids, their root names are different than when they are present in anions. Everything else about naming acids that contain sulfur or phosphorus remains the same.

Element	Root Name in Anions	Root Name in Acids

sulfur	sulf-	sulfur-
phosphorus	phosph-	phosphor-

✅ Example 5.9.4: Naming Oxyacids

Write the name for H_2SO_4.

Solution

	H_2SO_4
1. Identify the oxyanion present in the acid.	SO_4^{2-}
2. Name the oxyanion.	sulfate
3. Drop *-ate* or *-ite* from the anion name.	sulf-
4. Replace *-ate* with *-ic acid*. Replace *-ite* with *-ous acid*. Sulfur has a root name of sulfur- in acids.	sulfuric acid

✏️ Exercise 5.9.1

If the chemical formula is provided, write the name. If the name is provided, write the formula.

A. sulfurous acid
B. HBr (*aq*)
C. acetic acid
D. H_2CO_3

Answer A

H_2SO_3

Answer B

hydrobromic acid

Answer C

$HC_2H_3O_2$

Answer D

carbonic acid

Summary

- Acids are molecular compounds that release hydrogen ions when dissolved in water.
- A binary acid consists of hydrogen and one other element.
- Oxyacids contain hydrogen, oxygen, and at least one other element.
- The name of the acid is based on the anion attached to the hydrogen.