

# Acids and Bases

How do acids and bases behave in water?

## Why?

Acids and bases play an important role in our lives. Numerous biological processes, industrial applications, and even environmental problems are a function of the acidity or basicity (alkalinity) of aqueous solutions. It is therefore important to understand what makes a substance behave as an acid or a base when dissolved in water. In this activity, we will explore the physical and chemical properties of acids and bases.

## Model 1 – Arrhenius Acids and Bases

Common Name for Aqueous Solution	Chemical Formula	Found in...	Tastes...	Turns Litmus Paper...	Conducts Electricity?	Acid or Base
Acetic acid	$\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$	Vinegar	Sour	Red	Yes	Acid
Benzoic acid	$\text{HC}_7\text{H}_5\text{O}_2(\text{aq})$	Food preservative	Sour	Red	Yes	Acid
Phosphoric acid	$\text{H}_3\text{PO}_4(\text{aq})$	Soda pop	Sour	Red	Yes	Acid
Hydrochloric acid	$\text{HCl}(\text{aq})$	Stomach acid	Sour	Red	Yes	Acid
Citric acid	$\text{H}_3\text{C}_6\text{H}_5\text{O}_7(\text{aq})$	Citrus fruits	Sour	Red	Yes	Acid
Ascorbic acid	$\text{H}_2\text{C}_6\text{H}_6\text{O}_6(\text{aq})$	Vitamin C	Sour	Red	Yes	Acid
Magnesium hydroxide	$\text{Mg}(\text{OH})_2(\text{aq})$	Milk of magnesia	Bitter	Blue	Yes	Base
Aluminum hydroxide	$\text{Al}(\text{OH})_3(\text{aq})$	Antacids	Bitter	Blue	Yes	Base
Barium hydroxide	$\text{Ba}(\text{OH})_2(\text{aq})$	Lubricants	POISON	Blue	Yes	Base
Sodium hydroxide	$\text{NaOH}(\text{aq})$	Drain cleaner	POISON	Blue	Yes	Base

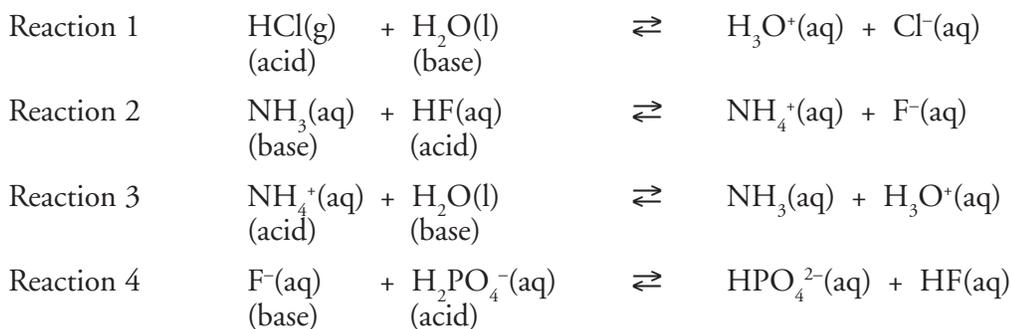
1. Refer to Model 1.
  - a. What is the common chemical name for Vitamin C?
  - b. Is Vitamin C classified as an acid or a base?
2. Examine the properties of the Arrhenius acids in Model 1. List three properties that all Arrhenius acids have in common.
3. Examine the chemical formulas for the Arrhenius acids in Model 1. What feature do all the Arrhenius acid chemical formulas have in common?
4. Examine the properties of the Arrhenius bases in Model 1. List two properties that all Arrhenius bases have in common.

- Examine the chemical formulas for the Arrhenius bases in Model 1. What anion do all the Arrhenius base chemical formulas have in common?
- A student dissolved a small amount of baking soda in water and tested it with litmus paper. The litmus paper turned blue. Is baking soda likely an acid or a base?

## Read This!

In 1903 Svante Arrhenius won the Nobel Prize in Chemistry for defining acids and bases in terms of the ions produced. An Arrhenius acid is any substance that produces hydrogen ions [or hydronium ions ( $\text{H}_3\text{O}^+$ ) a hydrogen ion attached to a water molecule] when dissolved in water. An Arrhenius base is any substance that produces hydroxide ions when dissolved in water. While the Arrhenius definitions of acids and bases is useful, it is limited. Johannes Brønsted and Thomas Lowry developed more general definitions for acids and bases using  $\text{H}^+$  ion (proton) transfer as the focus.

## Model 2 – Brønsted-Lowry Acids and Bases

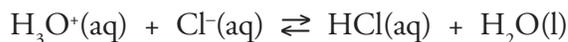


- Identify the Brønsted-Lowry acids in Model 2.
  - Atoms of which element are present in all of the Brønsted-Lowry acids in Model 2?
  - How can you tell from Reaction 1 that HCl loses an  $\text{H}^+$  ion rather than a hydrogen atom when the reaction occurs? *Hint:* Look at the products.
- For each acid–base reaction in Model 2, describe the role of the Brønsted-Lowry *acid* in the  $\text{H}^+$  ion (proton) transfer that occurs.
- For each acid–base reaction in Model 2, describe the role of the Brønsted-Lowry *base* in the proton ( $\text{H}^+$  ion) transfer that occurs.

10. As you saw in Model 1, all Arrhenius bases in Model 1 have an  $\text{OH}^-$  ion in their chemical formulas. Write a balanced chemical reaction for the reaction of  $\text{HCl}(\text{aq})$  with  $\text{OH}^-(\text{aq})$  to illustrate that the hydroxide ion is also a Brønsted-Lowry base.



11. If you reverse Reaction 1 in Model 2, the following reaction is obtained.

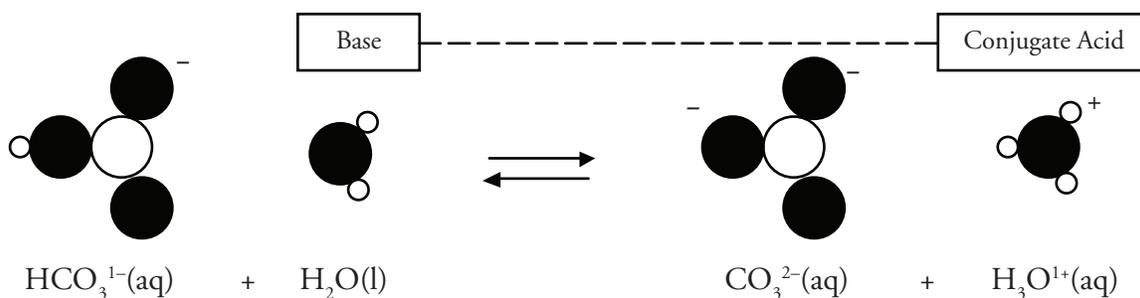


- a. For the reaction above, which reactant is acting like a Brønsted-Lowry acid? How can you tell?
- b. For the reaction above, which reactant is acting like a Brønsted-Lowry base? How can you tell?
12. Write the reverse reactions for Reactions 2 and 3 in Model 2. Label the Brønsted-Lowry acid and base reactants for each reaction.

Reaction 2

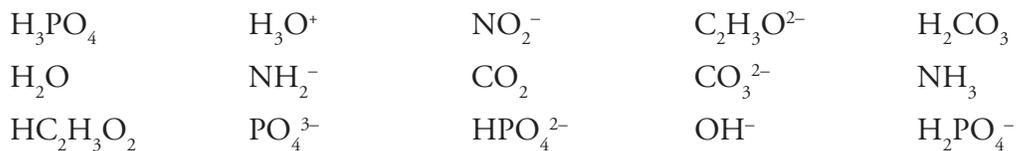
Reaction 3

### Model 3 – Conjugate Acid–Base Pairs



13. All acid–base reactions have two conjugate acid–base pairs. One conjugate acid–base pair in the reaction in Model 3 is  $\text{H}_3\text{O}^+/\text{H}_2\text{O}$ . List the other acid–base pair in the reaction.
14. Why is  $\text{HCO}_3^-$  considered the “acid” part of the pair in the reaction in Model 3?
15. Why is  $\text{CO}_3^{2-}$  considered the “base” part of the pair in the reaction in Model 3?
16. The “*Read This!*” box before Model 2 calls the transfer of a  $\text{H}^+$  ion a “proton transfer.” Explain why “ $\text{H}^+$  ion” and “proton” are synonymous.

17. Examine the charges on the species in the Model 3 reaction. Why does the charge on the carbon-containing ion change from  $-1$  to  $-2$ ?
18. Using the list of substances below, select pairs that are conjugate acids and bases. Enter the pairs in the tables below. The first acid–base pair has been entered for you. Note that you may use a substance more than once or not at all.

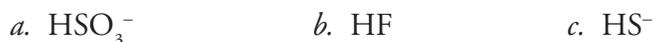


	Acid	Conjugate Base
1	$\text{H}_3\text{PO}_4$	$\text{H}_2\text{PO}_4^-$
2		
3		
4		

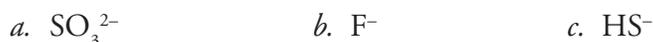
	Acid	Conjugate Base
5		
6		
7		



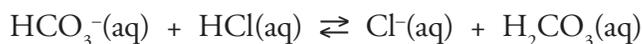
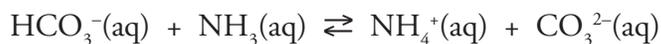
19. Write the formula for the conjugate base of each of the following acids. *Hint:* Be sure to consider charges.



20. Write the formula for the conjugate acid of each of the following bases. *Hint:* Be sure to consider charges.



21. For the following reactions, label the acid and base in the reactants, and the conjugate acid and conjugate base in the products.



22. Is the role of a conjugate acid in the reverse direction the same as the role of an acid in the forward direction? Explain.

## Extension Questions

23. Some of the substances used in this activity can behave as both an acid and a base. These substances are said to be **amphiprotic** or **amphoteric**. Provide two examples of amphoteric substances found in this activity.
24. Water is an amphoteric substance. In any sample of water some of the molecules perform acid–base reactions with each other. This is called the **autoionization** of water. Write a chemical reaction showing the acid–base reaction of two water molecules.