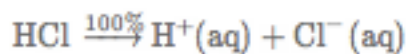


12.4 Strong and Weak Acids and Bases and Their Salts

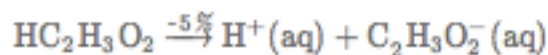
LEARNING OBJECTIVES

1. Define a strong and a weak acid and base.
2. Recognize an acid or a base as strong or weak.
3. Determine if a salt produces an acidic or a basic solution.

Except for their names and formulas, so far we have treated all acids as equals, especially in a chemical reaction. However, acids can be very different in a very important way. Consider HCl(aq) . When HCl is dissolved in H_2O , it completely dissociates into $\text{H}^+(\text{aq})$ and $\text{Cl}^-(\text{aq})$ ions; all the HCl molecules become ions:



Any acid that dissociates 100% into ions is called a **strong acid**. If it does not dissociate 100%, it is a **weak acid**. $\text{HC}_2\text{H}_3\text{O}_2$ is an example of a weak acid:



Because this reaction does not go 100% to completion, it is more appropriate to write it as an equilibrium:



As it turns out, there are very few strong acids, which are given in [Table 12.2 "Strong Acids and Bases"](#). If an acid is not listed here, it is a weak acid. It may be 1% ionized or 99% ionized, but it is still classified as a weak acid.

The issue is similar with bases: a **strong base** is a base that is 100% ionized in solution. If it is less than 100% ionized in solution, it is a **weak base**. There are very few strong bases (see [Table 12.2 "Strong Acids and Bases"](#)); any base not listed is a weak base. All strong bases are OH^- compounds. So a base based on some other mechanism, such as NH_3 (which does not contain OH^- ions as part of its formula), will be a weak base.

Table 12.2 Strong Acids and Bases

Acids	Bases
HCl	LiOH
HBr	NaOH
HI	KOH
HNO_3	RbOH
H_2SO_4	CsOH
HClO_3	$\text{Mg}(\text{OH})_2$
HClO_4	$\text{Ca}(\text{OH})_2$

Acids	Bases
	$\text{Sr}(\text{OH})_2$
	$\text{Ba}(\text{OH})_2$

EXAMPLE 6

Identify each acid or base as strong or weak.

1. HCl
2. $\text{Mg}(\text{OH})_2$
3. $\text{C}_5\text{H}_5\text{N}$

Solution

1. Because HCl is listed in [Table 12.2 "Strong Acids and Bases"](#), it is a strong acid.
2. Because $\text{Mg}(\text{OH})_2$ is listed in [Table 12.2 "Strong Acids and Bases"](#), it is a strong base.
3. The nitrogen in $\text{C}_5\text{H}_5\text{N}$ would act as a proton acceptor and therefore can be considered a base, but because it does not contain an OH compound, it cannot be considered a strong base; it is a weak base.

Test Yourself

Identify each acid or base as strong or weak.

1. RbOH
2. HNO_2

Answers

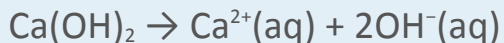
1. strong base
2. weak acid

EXAMPLE 7

Write the balanced chemical equation for the dissociation of Ca(OH)_2 and indicate whether it proceeds 100% to products or not.

Solution

This is an ionic compound of Ca^{2+} ions and OH^- ions. When an ionic compound dissolves, it separates into its constituent ions:



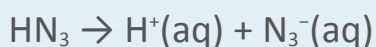
Because Ca(OH)_2 is listed in [Table 12.2 "Strong Acids and Bases"](#), this reaction proceeds 100% to products.

Test Yourself

Write the balanced chemical equation for the dissociation of hydrazoic acid (HN_3) and indicate whether it proceeds 100% to products or not.

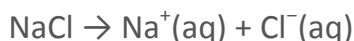
Answer

The reaction is as follows:



It does not proceed 100% to products because hydrazoic acid is not a strong acid.

Certain salts will also affect the acidity or basicity of aqueous solutions because some of the ions will undergo hydrolysis, just like NH_3 does to make a basic solution. The general rule is that salts with ions that are part of strong acids or bases will not hydrolyze, while salts with ions that are part of weak acids or bases will hydrolyze. Consider NaCl . When it dissolves in an aqueous solution, it separates into Na^+ ions and Cl^- ions:



Will the $\text{Na}^+(\text{aq})$ ion hydrolyze? If it does, it will interact with the OH^- ion to make NaOH :



However, NaOH is a strong base, which means that it is 100% ionized in solution:
 $\text{NaOH} \rightarrow \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq})$

The free $\text{OH}^-(\text{aq})$ ion reacts with the $\text{H}^+(\text{aq})$ ion to remake a water molecule:
 $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}$

The net result? There is no change, so there is no effect on the acidity or basicity of the solution from the $\text{Na}^+(\text{aq})$ ion. What about the Cl^- ion? Will it hydrolyze? If it does, it will take an H^+ ion from a water molecule:
 $\text{Cl}^-(\text{aq}) + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{OH}^-$

However, HCl is a strong acid, which means that it is 100% ionized in solution:
 $\text{HCl} \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$

The free $\text{H}^+(\text{aq})$ ion reacts with the $\text{OH}^-(\text{aq})$ ion to remake a water molecule:
 $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}$

The net result? There is no change, so there is no effect on the acidity or basicity of the solution from the $\text{Cl}^-(\text{aq})$ ion. Because neither ion in NaCl affects the acidity or basicity of the solution, NaCl is an example of a **neutral salt**.



Things change, however, when we consider a salt like $\text{NaC}_2\text{H}_3\text{O}_2$. We already know that the Na^+ ion won't affect the acidity of the solution. What about the acetate ion?

If it hydrolyzes, it will take an H^+ from a water molecule:



Does this happen? Yes, it does. Why? *Because $\text{HC}_2\text{H}_3\text{O}_2$ is a weak acid.* Any chance a weak acid has to form, it will (the same with a weak base). As some $\text{C}_2\text{H}_3\text{O}_2^-$ ions hydrolyze with H_2O to make the molecular weak acid, OH^- ions are produced.

OH^- ions make solutions basic. Thus $\text{NaC}_2\text{H}_3\text{O}_2$ solutions are slightly basic, so such a salt is called a **basic salt**.

There are also salts whose aqueous solutions are slightly acidic. NH_4Cl is an example.

When NH_4Cl is dissolved in H_2O , it separates into NH_4^+ ions and Cl^- ions. We have already seen that the Cl^- ion does not hydrolyze. However, the NH_4^+ ion will:

$$\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O} \rightarrow \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$$

Recall from [Section 12.1 "Arrhenius Acids and Bases"](#) that H_3O^+ ion is the hydronium ion, the more chemically proper way to represent the H^+ ion. This is the classic acid species in solution, so a solution of $\text{NH}_4^+(\text{aq})$ ions is slightly acidic. NH_4Cl is an example of an acid salt. The molecule NH_3 is a weak base, and it will form when it can, just like a weak acid will form when it can.

So there are two general rules: (1) If an ion derives from a strong acid or base, it will not affect the acidity of the solution. (2) If an ion derives from a weak acid, it will make the solution basic; if an ion derives from a weak base, it will make the solution acidic.

EXAMPLE 8

Identify each salt as acidic, basic, or neutral.

1. KCl
2. KNO_2
3. NH_4Br

Solution

1. The ions from KCl derive from a strong acid (HCl) and a strong base (KOH). Therefore, neither ion will affect the acidity of the solution, so KCl is a neutral salt.
2. Although the K^+ ion derives from a strong base (KOH), the NO_2^- ion derives from a weak acid (HNO_2). Therefore the solution will be basic, and KNO_2 is a basic salt.
3. Although the Br^- ions derive from a strong acid (HBr), the NH_4^+ ion derives from a weak base (NH_3), so the solution will be acidic, and NH_4Br is an acidic salt.

Test Yourself

Identify each salt as acidic, basic, or neutral.

1. $(\text{C}_5\text{H}_5\text{NH})\text{Cl}$
2. Na_2SO_3

Answers

1. acidic
2. basic

Some salts are composed of ions that come from both weak acids and weak bases. The overall effect on an aqueous solution depends on which ion exerts more influence on the overall acidity. We will not consider such salts here.

KEY TAKEAWAYS

- Strong acids and bases are 100% ionized in aqueous solution.
- Weak acids and bases are less than 100% ionized in aqueous solution.
- Salts of weak acids or bases can affect the acidity or basicity of their aqueous solutions.

EXERCISES

1. Differentiate between a strong acid and a weak acid.
2. Differentiate between a strong base and a weak base.
3. Identify each as a strong acid or a weak acid. Assume aqueous solutions.
 - a. HF
 - b. HCl
 - c. HC_2O_4
4. Identify each as a strong base or a weak base. Assume aqueous solutions.
 - a. NaOH
 - b. $\text{Al}(\text{OH})_3$
 - c. $\text{C}_4\text{H}_9\text{NH}_2$
5. Write a chemical equation for the ionization of each acid and indicate whether it proceeds 100% to products or not.
 - a. HNO_3
 - b. HNO_2



- c. HI_3
6. Write a chemical equation for the ionization of each base and indicate whether it proceeds 100% to products or not.
- a. NH_3
b. $(\text{CH}_3)_3\text{N}$
c. $\text{Mg}(\text{OH})_2$
7. Write the balanced chemical equation for the reaction of each acid and base pair.
- a. $\text{HCl} + \text{C}_5\text{H}_5\text{N}$
b. $\text{H}_2\text{C}_2\text{O}_4 + \text{NH}_3$
c. $\text{HNO}_2 + \text{C}_7\text{H}_9\text{N}$
8. Write the balanced chemical equation for the reaction of each acid and base pair.
- a. $\text{H}_3\text{C}_5\text{H}_5\text{O}_7 + \text{Mg}(\text{OH})_2$
b. $\text{HC}_3\text{H}_3\text{O}_3 + (\text{CH}_3)_3\text{N}$
c. $\text{HBr} + \text{Fe}(\text{OH})_3$
9. Identify each salt as neutral, acidic, or basic.
- a. NaBr
b. $\text{Fe}(\text{NO}_3)_2$
c. $\text{Fe}(\text{NO}_3)_3$
10. Identify each salt as neutral, acidic, or basic.

- a. NH_4I
- b. $\text{C}_2\text{H}_5\text{NH}_3\text{Cl}$
- c. KI

11. Identify each salt as neutral, acidic, or basic.

- a. NaNO_2
- b. NaNO_3
- c. NH_4NO_3

12. Identify each salt as neutral, acidic, or basic.

- a. $\text{KC}_2\text{H}_3\text{O}_2$
- b. KHSO_4
- c. KClO_3

13. Write the hydrolysis reaction that occurs, if any, when each salt dissolves in water.

- a. K_2SO_3
- b. KI
- c. NH_4ClO_3

14. Write the hydrolysis reaction that occurs, if any, when each salt dissolves in water.

- a. NaNO_3
- b. CaC_2O_4



c. $\text{C}_5\text{H}_5\text{NHCl}$

15. When NH_4NO_2 dissolves in H_2O , both ions hydrolyze. Write chemical equations for both reactions. Can you tell if the solution will be acidic or basic overall?
16. When pyridinium acetate ($\text{C}_5\text{H}_5\text{NHC}_2\text{H}_3\text{O}_2$) dissolves in H_2O , both ions hydrolyze. Write chemical equations for both reactions. Can you tell if the solution will be acidic or basic overall?
17. A lab technician mixes a solution of 0.015 M $\text{Mg}(\text{OH})_2$. Is the resulting OH^- concentration greater than, equal to, or less than 0.015 M? Explain your answer.
18. A lab technician mixes a solution of 0.55 M HNO_3 . Is the resulting H^+ concentration greater than, equal to, or less than 0.55 M? Explain your answer.

ANSWERS

1. A strong acid is 100% ionized in aqueous solution, whereas a weak acid is not 100% ionized.
3. a. weak acid
b. strong acid
c. weak acid
5. a. $\text{HNO}_3(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$; proceeds 100%
b. $\text{HNO}_2(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{NO}_2^-(\text{aq})$; does not proceed 100%



- c. $\text{HI}_3(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{I}_3^-(\text{aq})$; does not proceed 100%
7. a. $\text{HCl} + \text{C}_5\text{H}_5\text{N} \rightarrow \text{Cl}^- + \text{C}_5\text{H}_5\text{NH}^+$
 b. $\text{H}_2\text{C}_2\text{O}_4 + 2\text{NH}_3 \rightarrow \text{C}_2\text{O}_4^{2-} + 2\text{NH}_4^+$
 c. $\text{HNO}_2 + \text{C}_7\text{H}_9\text{N} \rightarrow \text{NO}_2^- + \text{C}_7\text{H}_9\text{NH}^+$
9. a. neutral
 b. acidic
 c. acidic
11. a. basic
 b. neutral
 c. acidic
13. a. $\text{SO}_3^{2-} + \text{H}_2\text{O} \rightarrow \text{HSO}_3^- + \text{OH}^-$
 b. no reaction
 c. $\text{NH}_4^+ + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{H}_3\text{O}^+$
15. $\text{NH}_4^+ + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{H}_3\text{O}^+$; $\text{NO}_2^- + \text{H}_2\text{O} \rightarrow \text{HNO}_2 + \text{OH}^-$; it is not possible to determine whether the solution will be acidic or basic.
17. greater than 0.015 M because there are two OH^- ions per formula unit of $\text{Mg}(\text{OH})_2$