Acids & Bases

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Lecture 5

Lecture Goals

- In this chapter you will learn how to:
    - Acids and Base According Arrhenius
    - Acids and Base According Brønsted–Lowry
    - Acid and Base Strength
    - Reaction of Acids and Bases
    - The pH Scale
    - The pH of Body Fluids
    - Buffers
    - Buffers in the Blood

1. Acids and Base According Arrhenius

- The earliest definition of acids and bases was suggested by Swedish chemist Svante Arrhenius in the late nineteenth century. **According to Arrhenius,**

- **An acid** contains a hydrogen atom and dissolves in water to form a hydrogen ion, H^+.

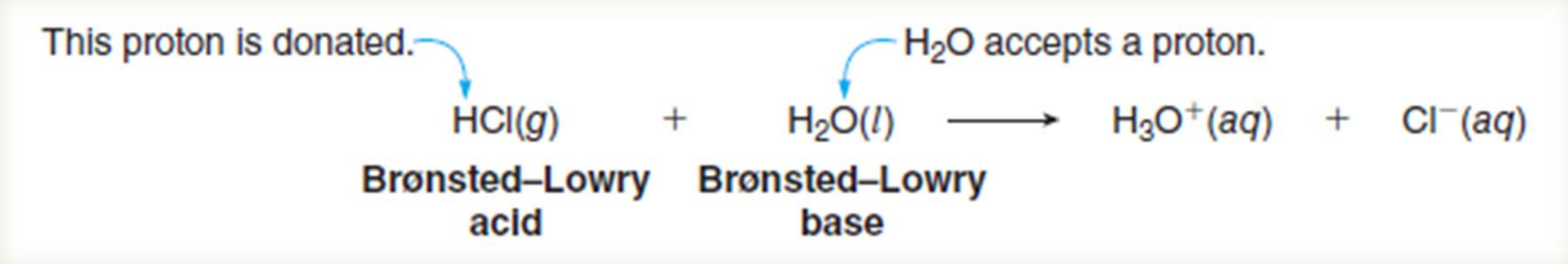
$$HCl \longrightarrow H^+ + Cl^-$$

- **A base** contains hydroxide and dissolves in water to form OH^-.

$$NaOH \longrightarrow Na^+ + {}^-OH$$

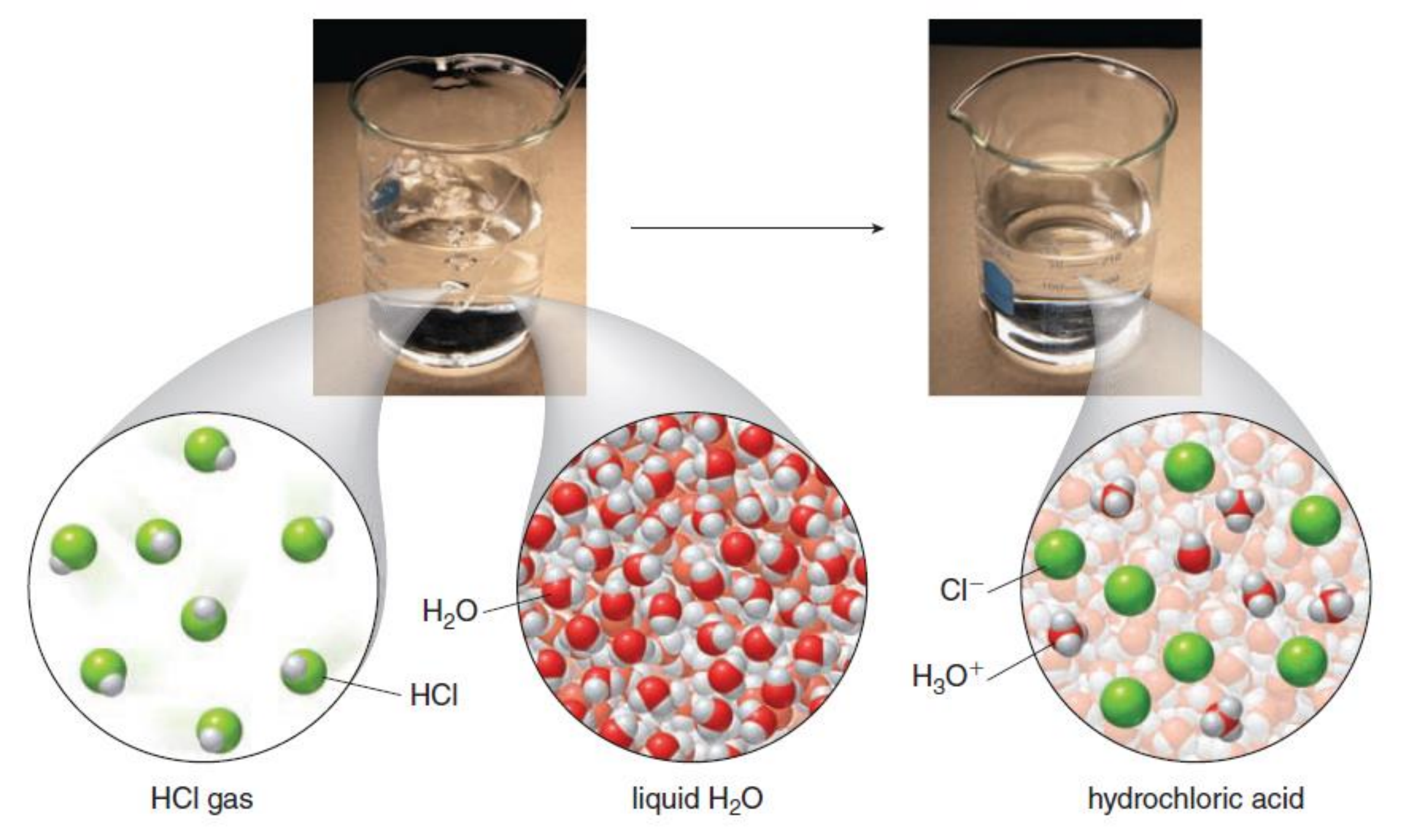
2. Acids and Base According Brønsted–Lowry

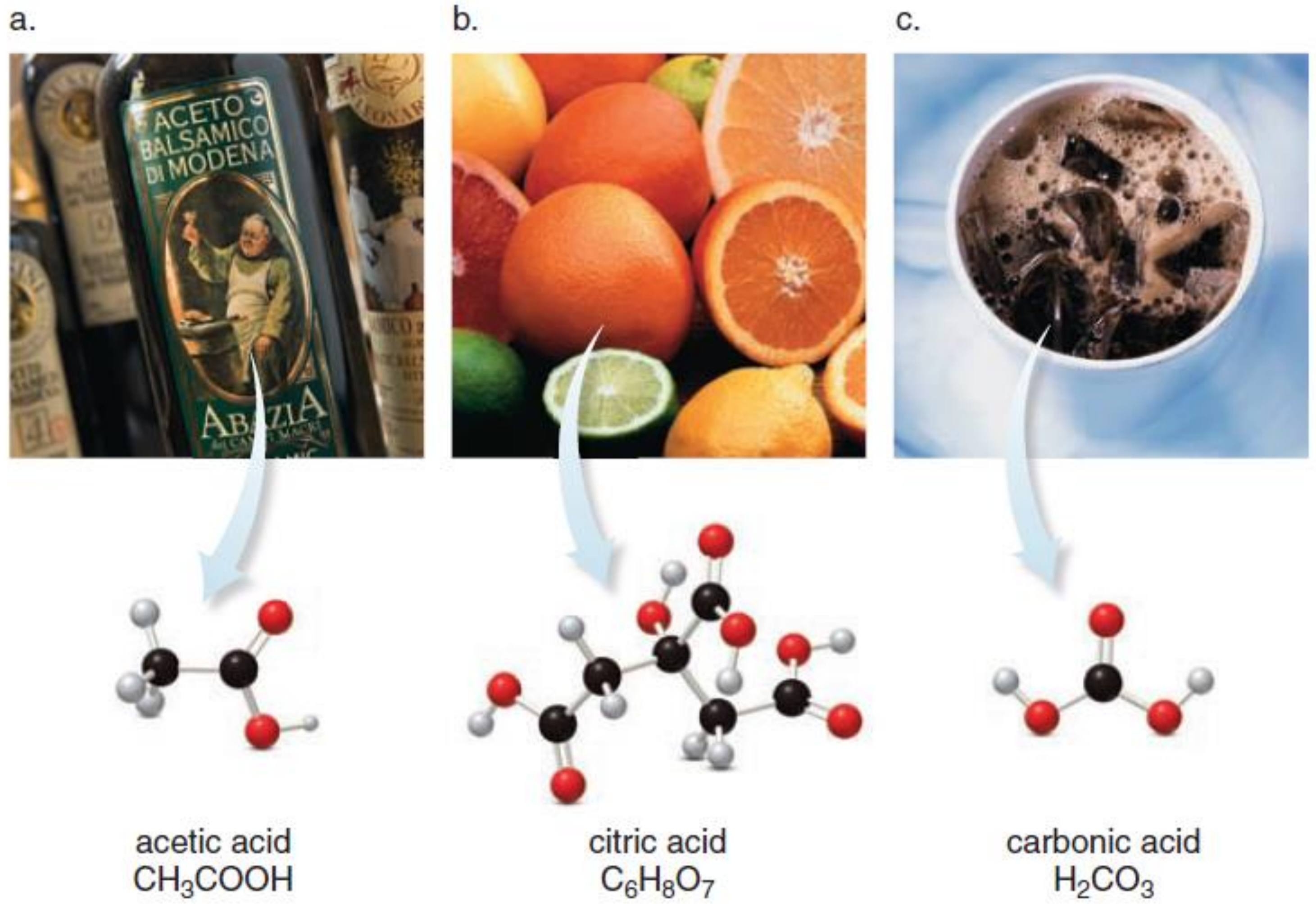
- While the Arrhenius definition correctly predicts the behavior of many acids and bases, this definition is limited and sometimes inaccurate.
- Moreover, several compounds contain no hydroxide anions, yet they still exhibit the characteristic properties of a base. Examples include the neutral molecule ammonia (NH_3) and the salt sodium carbonate (Na_2CO_3).
- A Brønsted–Lowry acid is a proton donor.
- A Brønsted–Lowry base is a proton acceptor.



2A. Brønsted–Lowry Acids

- A Brønsted–Lowry acid must contain a hydrogen atom. HCl is a Brønsted–Lowry acid because it donates a proton (H^+) to water when it dissolves, forming the hydronium ion (H_3O^+) and chloride ($Cl^–$).



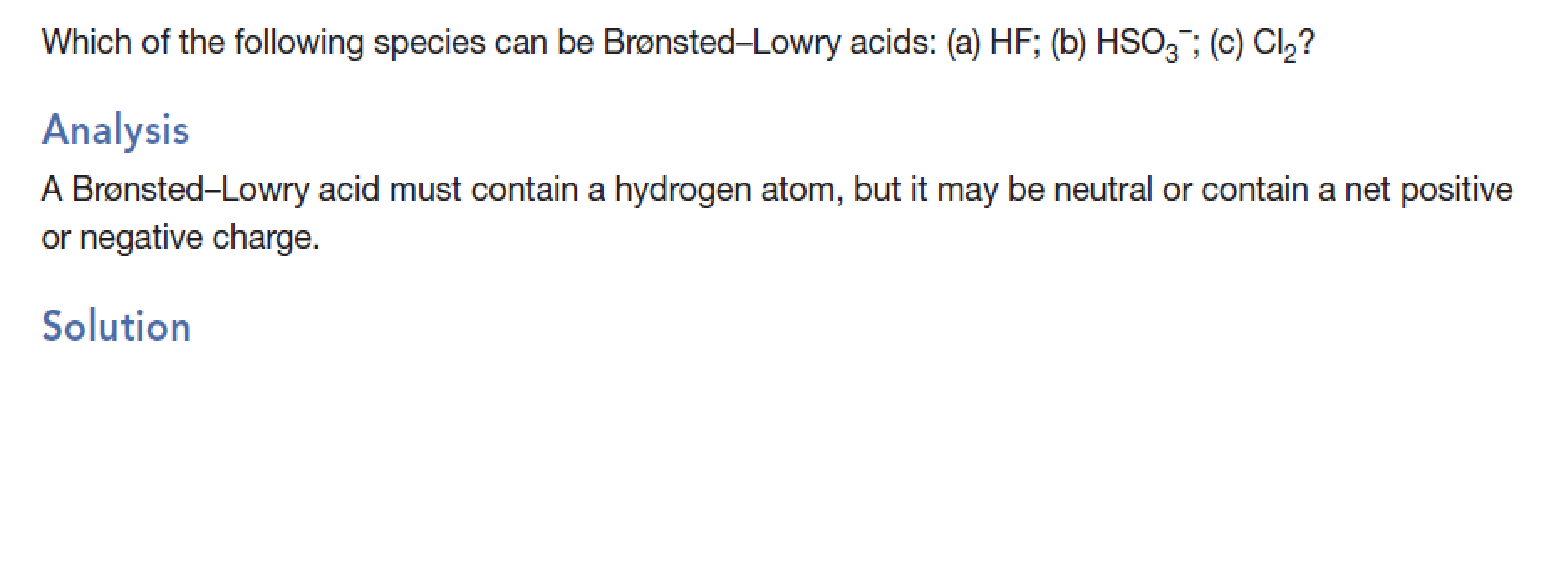


a. Acetic acid is the sour-tasting component of vinegar. The air oxidation of ethanol to acetic acid is the process that makes “bad” wine taste sour.

b. Citric acid imparts a sour taste to oranges, lemons, and other citrus fruits.

c. Carbonated beverages contain carbonic acid, H_2CO_3.

PROBLEM



Which of the following species can be Brønsted–Lowry acids: (a) HF; (b) HSO_3^-; (c) Cl_2?

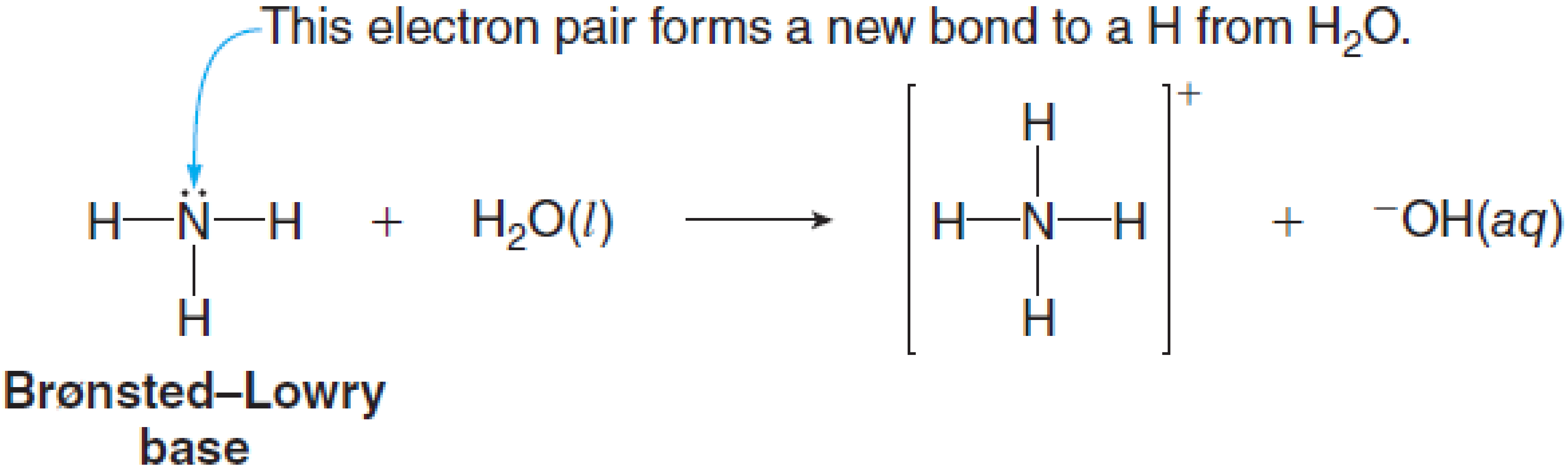
Analysis

A Brønsted–Lowry acid must contain a hydrogen atom, but it may be neutral or contain a net positive or negative charge.

Solution

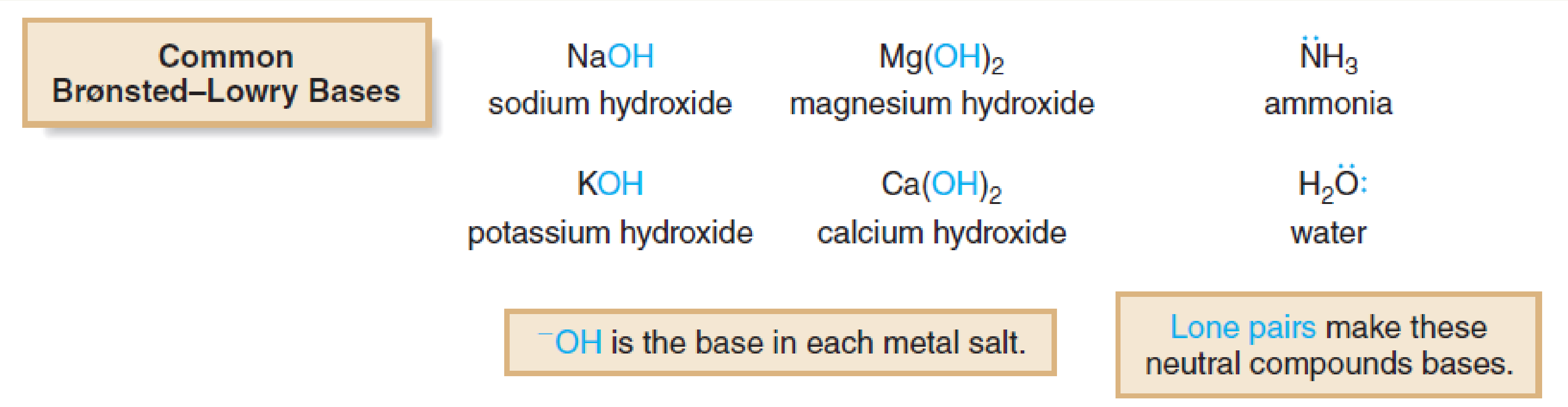
2B. Brønsted–Lowry Bases

- A Brønsted–Lowry base is a proton acceptor and as such, it must be able to form a bond to a proton. Because a proton has no electrons, a base must contain a lone pair of electrons that can be donated to form a new bond. Thus, ammonia (NH_3) is a Brønsted–Lowry base



This electron pair forms a new bond to a H from H_2O.

Brønsted–Lowry base



Common Brønsted–Lowry Bases

$NaOH$
sodium hydroxide

$Mg(OH)_2$
magnesium hydroxide

$\ddot{N}H_3$
ammonia

KOH
potassium hydroxide

$Ca(OH)_2$
calcium hydroxide

$H_2\ddot{O}:$
water

^{-}OH is the base in each metal salt.

Lone pairs make these neutral compounds bases.

PROBLEM

Which of the following species can be Brønsted–Lowry bases: (a) LiOH; (b) Cl^-; (c) CH_4?

Analysis

A Brønsted–Lowry base must contain a lone pair of electrons, but it may be neutral or have a net negative charge.

Solution

PROBLEM

Classify each reactant as a Brønsted–Lowry acid or base.

a. $HF + H_2O \longrightarrow F^- + H_3O^+$

b. $SO_4^{2-} + H_2O \longrightarrow HSO_4^- + {}^-OH$

3. Acid and Base Strength

- ❖ Although all Brønsted–Lowry acids contain protons, some acids readily donate protons while others do not. Similarly, some Brønsted–Lowry bases accept a proton much more readily than others. How readily proton transfer occurs is determined by the strength of the acid and base.
- ❖ **A strong acid** readily donates a proton. When a strong acid dissolves in water, essentially 100% of the acid dissociates into ions.
- ❖ **A weak acid** less readily donates a proton. When a weak acid dissolves in water, only a small fraction of the acid dissociates into ions.
- ✓ *Common strong acids include* ***HI, HBr, HCl,*** $\boldsymbol{H_2SO_4}$, *and* $\boldsymbol{HNO_3}$. *When each acid is dissolved in water, 100% of the acid dissociates, forming* H_3O^+ *and the conjugate base, as shown for HCl and* H_2SO_4.

- ✓ *Acetic acid, CH_3COOH, **is a weak acid**. When acetic acid dissolves in water, only a small fraction of acetic acid molecules donate a proton to water to form H_3O^+ and the conjugate base $CH3COO^-$. The major species in solution is the undissociated acid, CH_3COOH.*

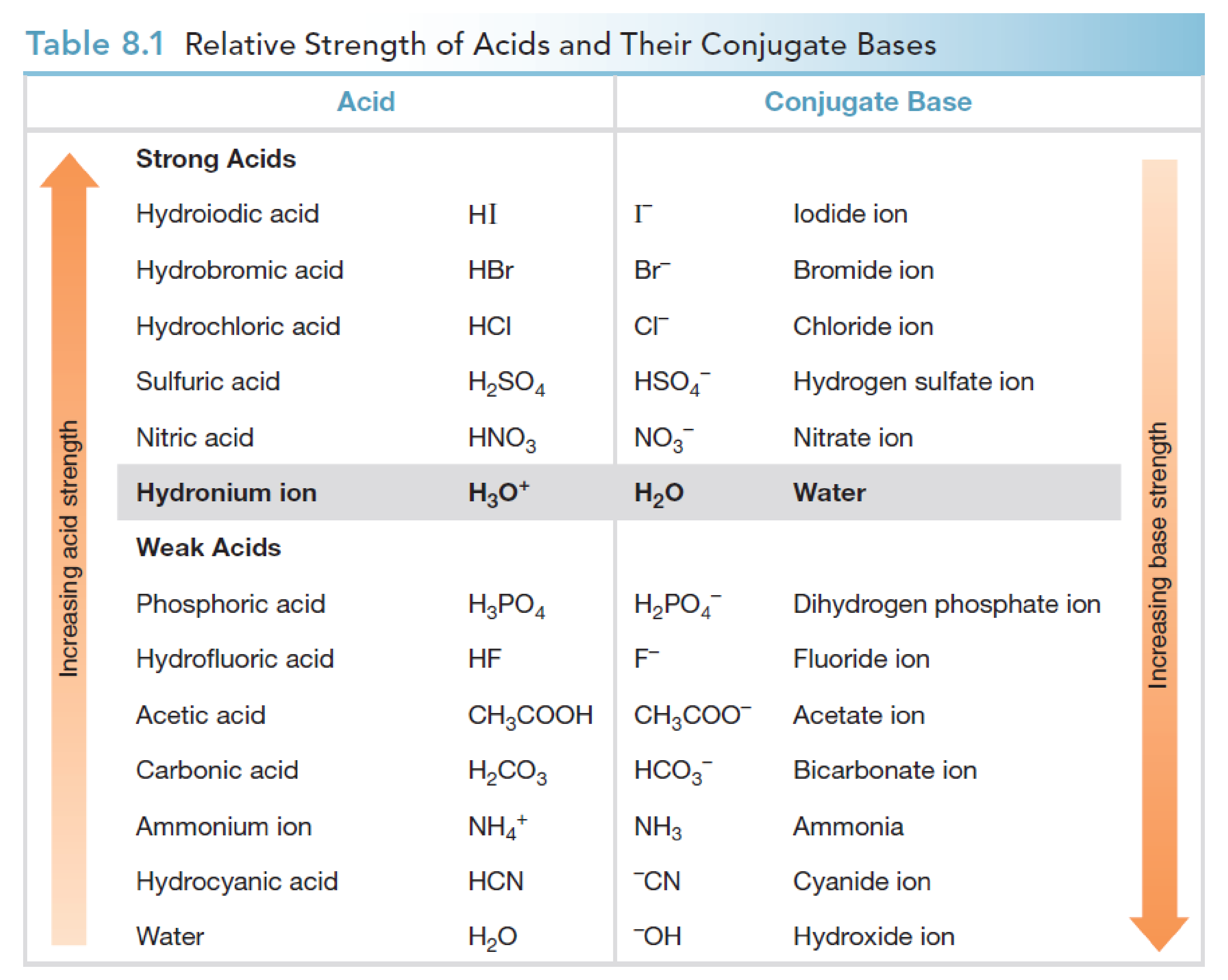
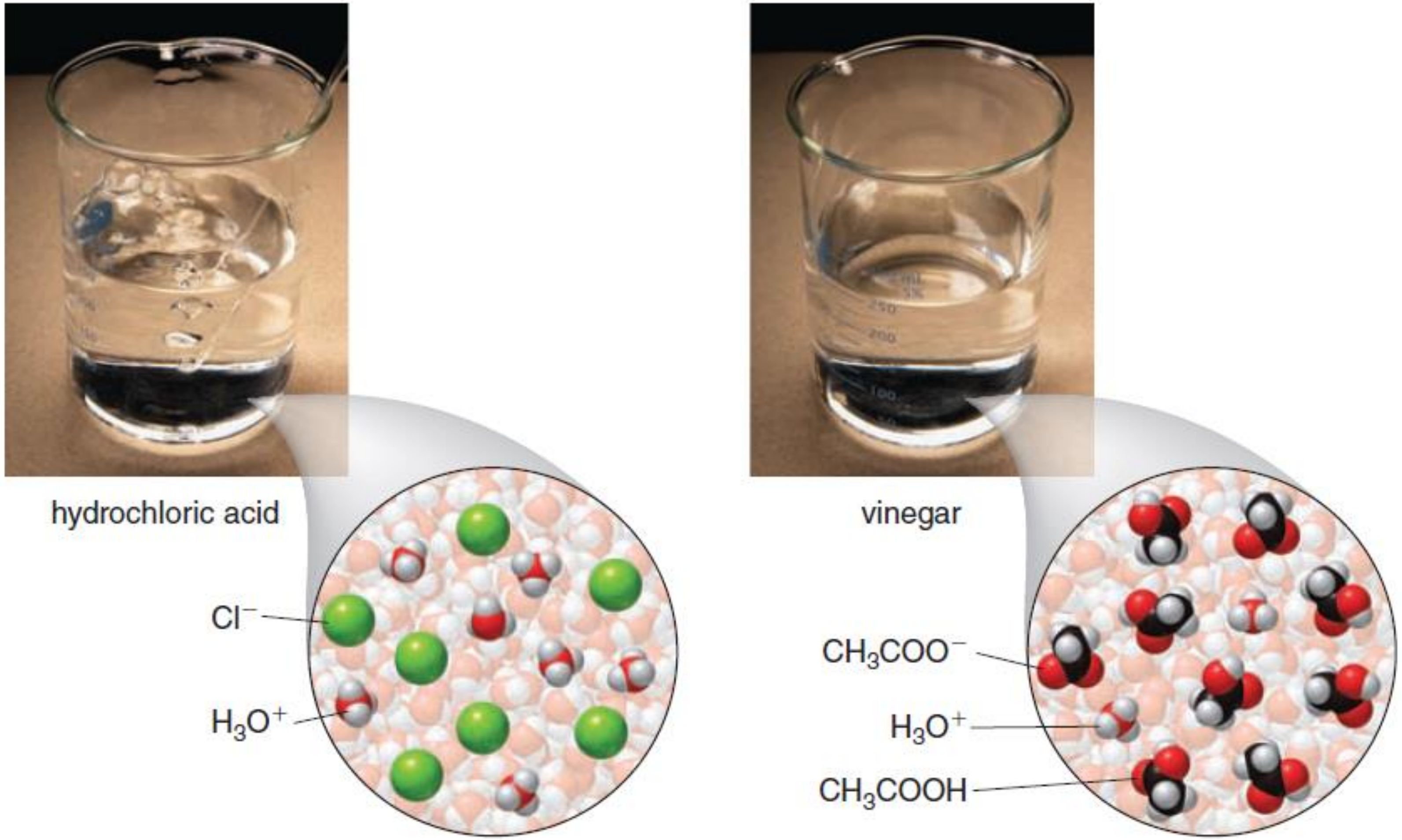


Table 8.1 Relative Strength of Acids and Their Conjugate Bases

Acid		Conjugate Base	
Strong Acids			
Hydroiodic acid	HI	I^-	Iodide ion
Hydrobromic acid	HBr	Br^-	Bromide ion
Hydrochloric acid	HCl	Cl^-	Chloride ion
Sulfuric acid	H_2SO_4	HSO_4^-	Hydrogen sulfate ion
Nitric acid	HNO_3	NO_3^-	Nitrate ion
Hydronium ion	H_3O^+	H_2O	**Water**
Weak Acids			
Phosphoric acid	H_3PO_4	$H_2PO_4^-$	Dihydrogen phosphate ion
Hydrofluoric acid	HF	F^-	Fluoride ion
Acetic acid	CH_3COOH	CH_3COO^-	Acetate ion
Carbonic acid	H_2CO_3	HCO_3^-	Bicarbonate ion
Ammonium ion	NH_4^+	NH_3	Ammonia
Hydrocyanic acid	HCN	^-CN	Cyanide ion
Water	H_2O	^-OH	Hydroxide ion

Figure 8.4

A Strong and Weak Acid Dissolved in Water



A strong acid is completely dissociated.

A weak acid contains mostly undissociated acid, CH_3COOH.

- The strong acid HCl completely dissociates into H_3O^+ and Cl^- in water.
- Vinegar contains CH_3COOH dissolved in H_2O. The weak acid CH_3COOH is only slightly dissociated into H_3O^+ and CH_3COO^-, so mostly CH_3COOH is present in solution.

- ☐ Bases also differ in their ability to accept a proton.
- ☐ **• A strong base readily accepts a proton. When a strong base dissolves in water, 100% of the base dissociates into ions.**
- ☐ **• A weak base less readily accepts a proton. When a weak base dissolves in water, only a small fraction of the base forms ions.**
- ✓ The most common strong base is hydroxide, **$^{-}$OH,** used as a variety of metal salts, including NaOH and KOH. Solid NaOH dissolves in water to form solvated Na^+ cations and ^{-}OH anions.
- ✓ In contrast, when **NH_3,** a weak base, dissolves in water, only a small fraction of NH_3 molecules react to form NH_4^+ and ^{-}OH. The major species in solution is the undissociated molecule, NH_3.

- ***An inverse relationship exists between acid and base strength.***
- *A strong acid readily donates a proton, forming a weak conjugate base.*
- *A strong base readily accepts a proton, forming a weak conjugate acid.*

PROBLEM

Using Table 8.1: (a) Is H_3PO_4 or HF the stronger acid? (b) Draw the conjugate base of each acid an predict which base is stronger.

PROBLEM

Label the stronger acid in each pair. Which acid has the stronger conjugate base?

a. H_2SO_4 or H_3PO_4
b. HF or HCl
c. H_2CO_3 or NH_4^+
d. HCN or HF