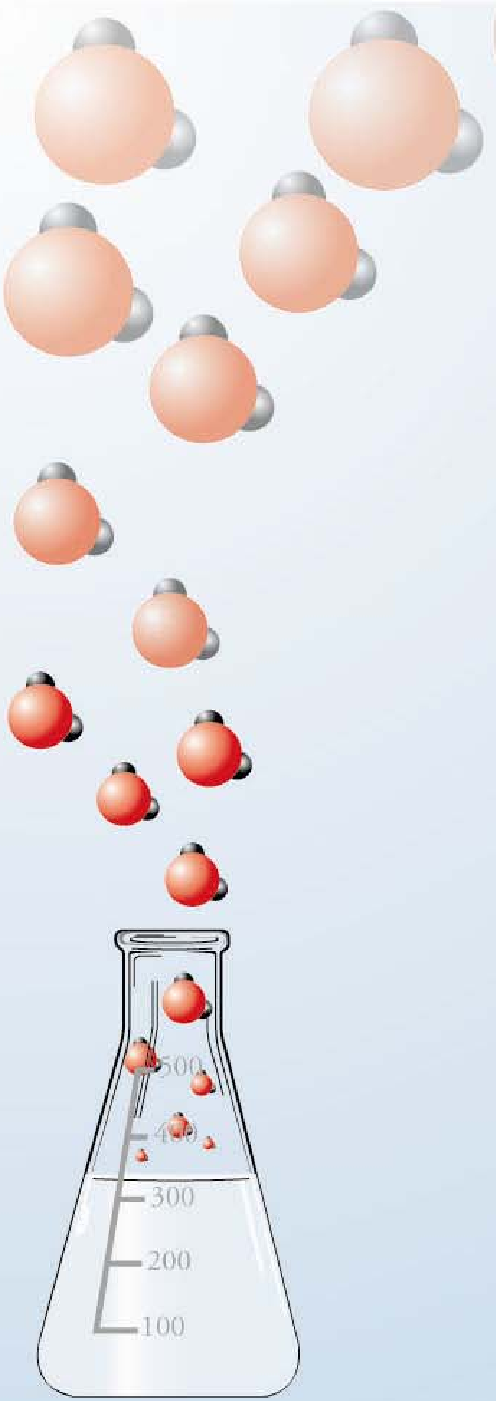


Chapter 6

Acids, Bases, and Acid-Base Reactions

Chapter Map

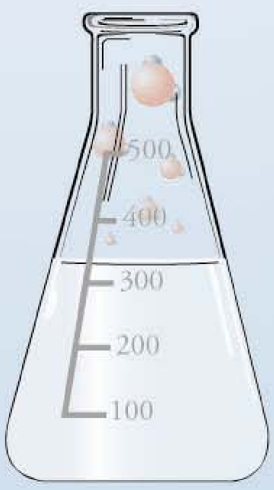
Binary acids and oxyacids
Names and formulas of acids
Summary of chemical nomenclature
Strong and weak acids
Molecular compounds (Section 4.2)
Acids
Mono-, di-, and triprotic acids
Weak base (NH_3)
pH
Acid reaction with water
Bronsted-Lowry acids and bases
Bases
Base reaction with water
Conjugate acids and bases
Acid-Base reactions
Strong base (NaOH)
Chemical equations (Section 5.1)
Writing equations for acid-base reactions
Dissolving ionic compounds in water (Section 5.2)
Balancing chemical equations (Section 5.1)
Ionic compounds (Section 4.5)
Structure of water (Section 4.3)

Arrhenius Acid Definition

- An ***acid*** is a substance that generates hydronium ions, H_3O^+ (often described as H^+), when added to water.
- An ***acidic solution*** is a solution with a significant concentration of H_3O^+ ions.

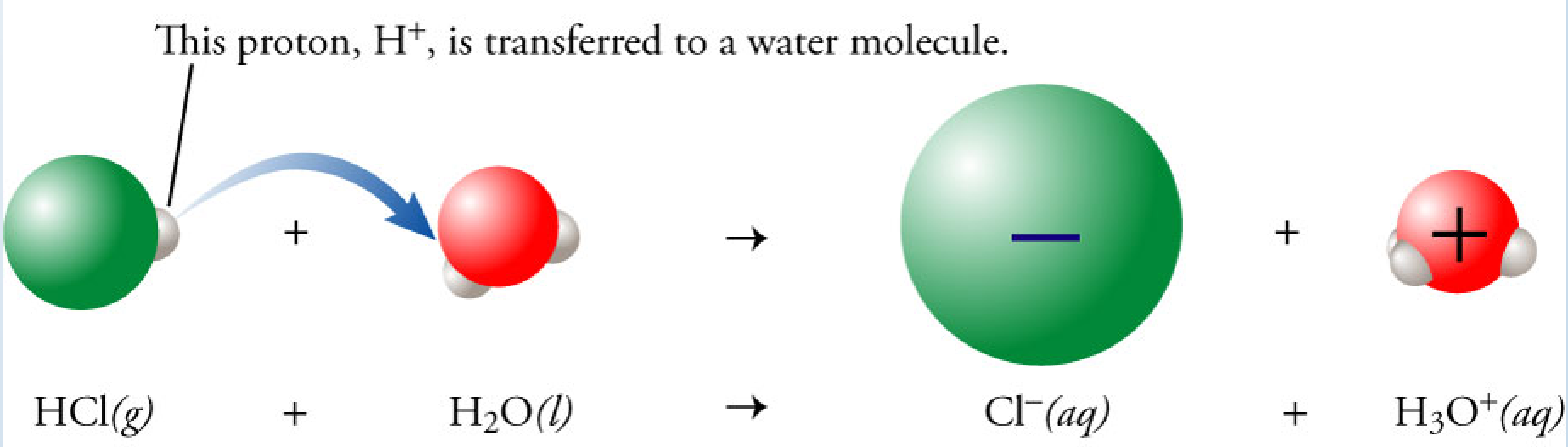
Characteristics of Acids

- Acids have a sour taste.
- Acids turn litmus from blue to red.
- Acids react with bases.

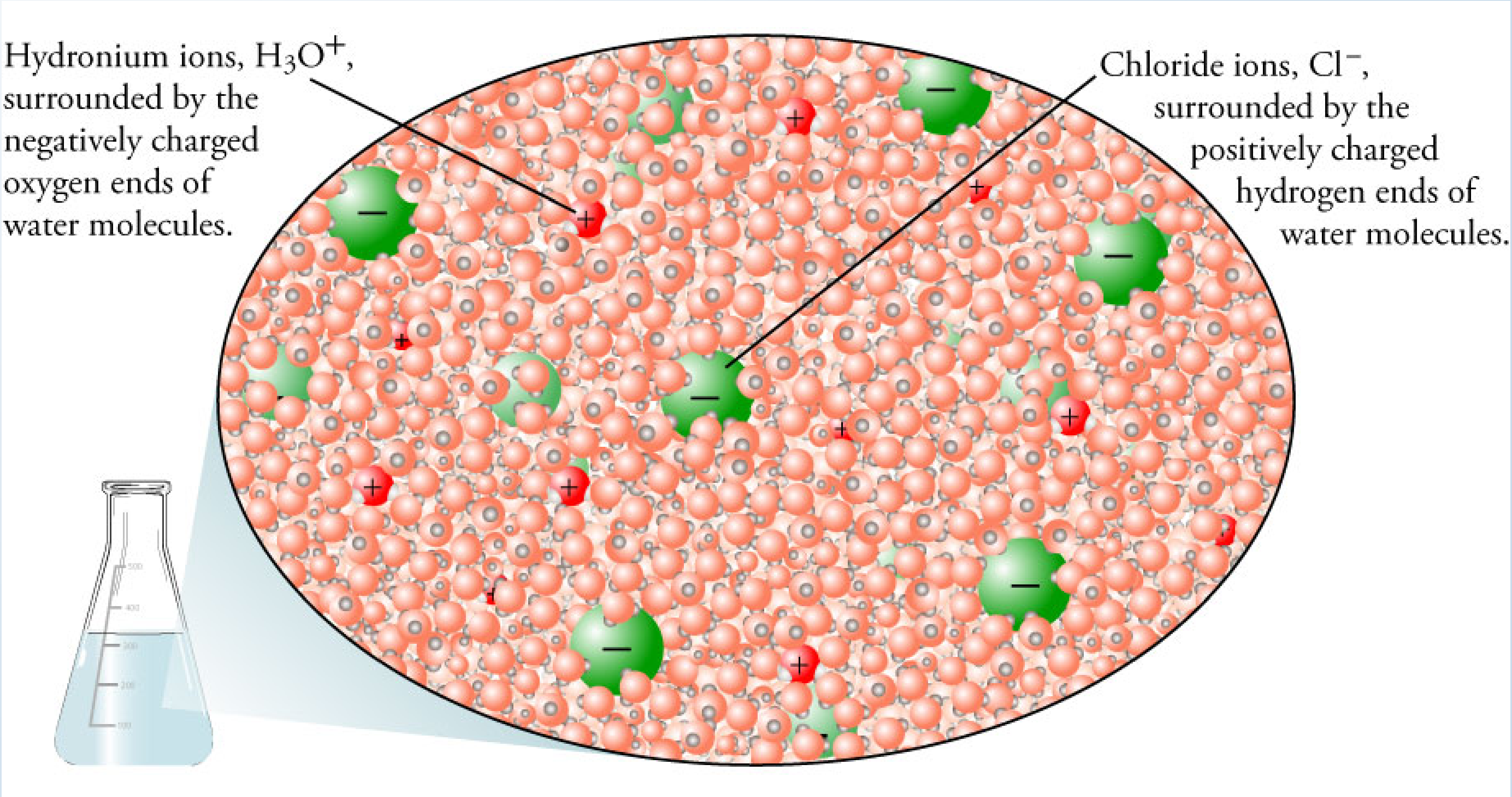


Strong Acid and Water

When HCl dissolves in water, hydronium ions, H_3O^+, and chloride ions, Cl^-, ions form.

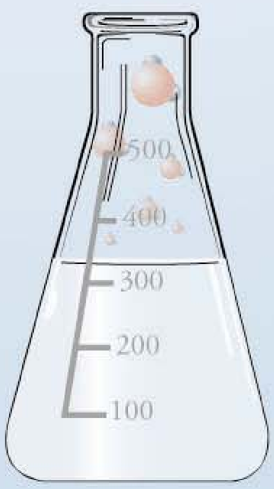


Solution of a Strong Acid

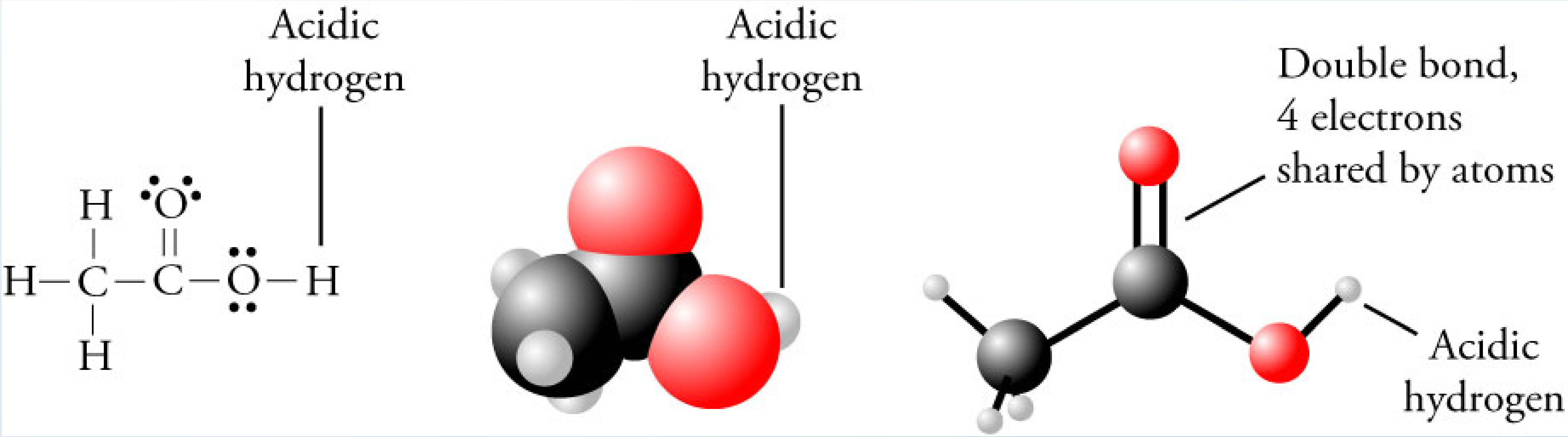


Types of Acids

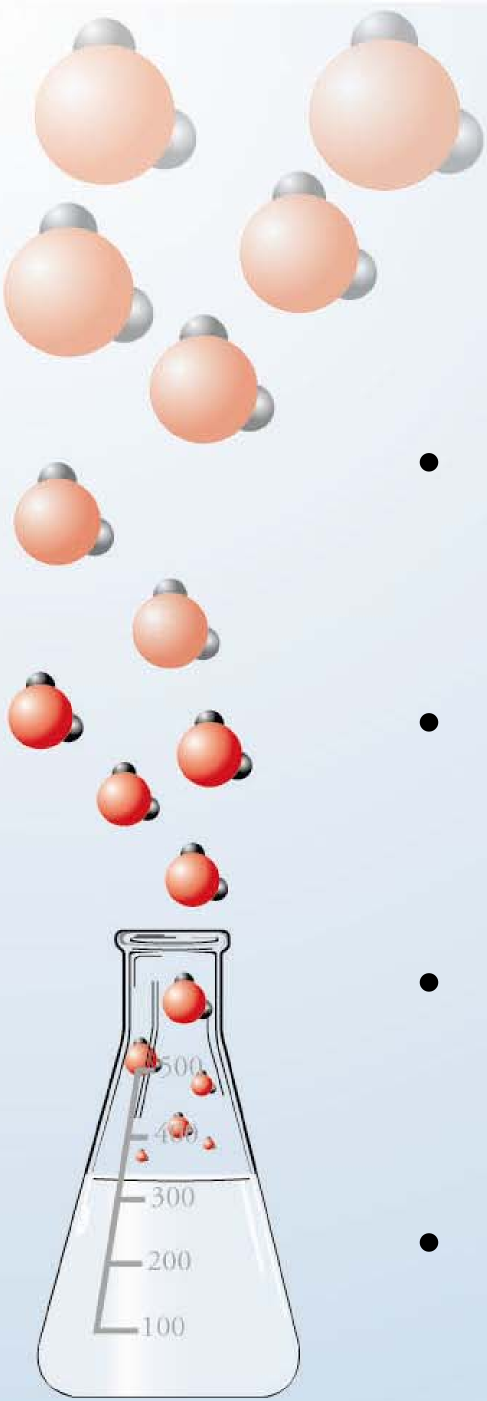
- Binary acids have the general formula of HX(aq)
  - HF(*aq*), HCl(*aq*), HBr(*aq*), and HI(*aq*)
- Oxyacids have the general formula $H_aX_bO_c$.
  - HNO_3 and H_2SO_4
- Organic (carbon-based) acids
  - $HC_2H_3O_2$



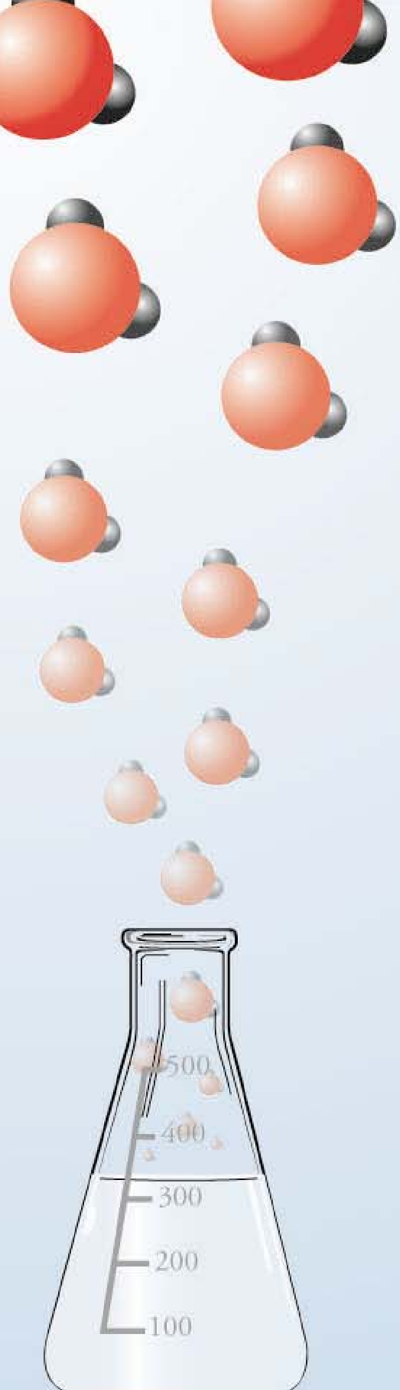
Acetic Acid


Acidic
hydrogen
H
H–C–C–O–H
H
O
Acidic
hydrogen
Double bond,
4 electrons
shared by atoms
Acidic
hydrogen

Monoprotic and Polyprotic Acids



- If each molecule of an acid can donate one hydrogen ion, the acid is called a **monoprotic acid**.
- If each molecule can donate two or more hydrogen ions, the acid is a **polyprotic acid**.
- A **diprotic acid**, such as sulfuric acid, H_2SO_4, has two acidic hydrogen atoms.
- Some acids, such as phosphoric acid, H_3PO_4, are **triprotic acids**.

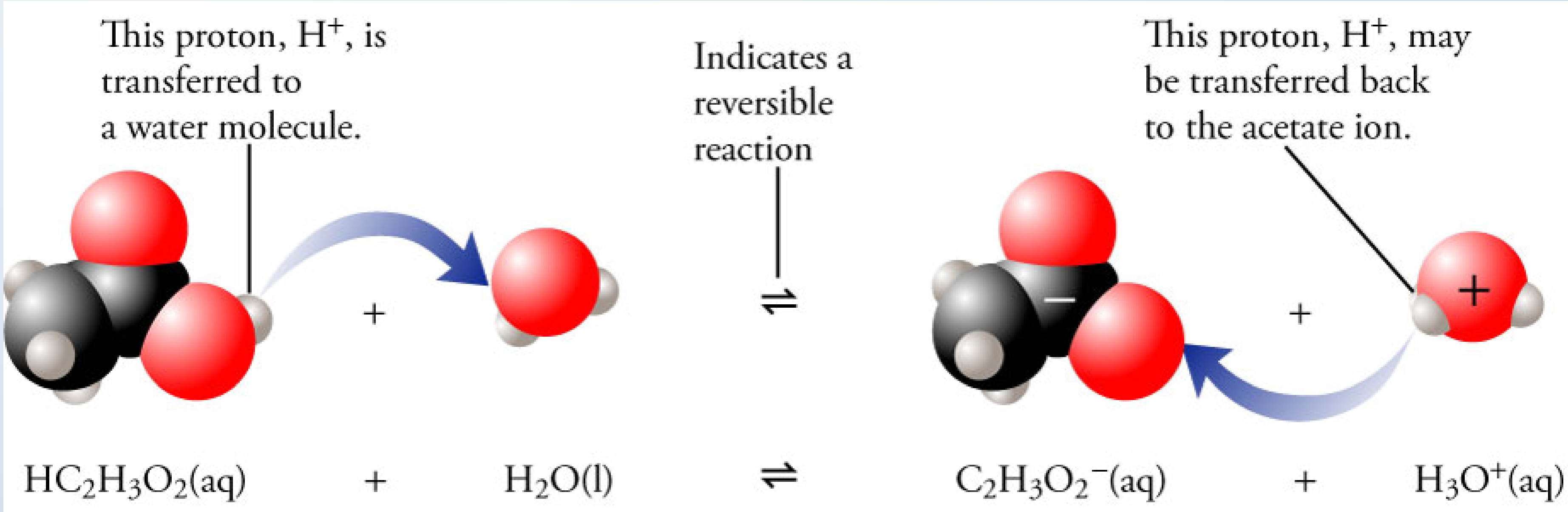


Strong and Weak Acids

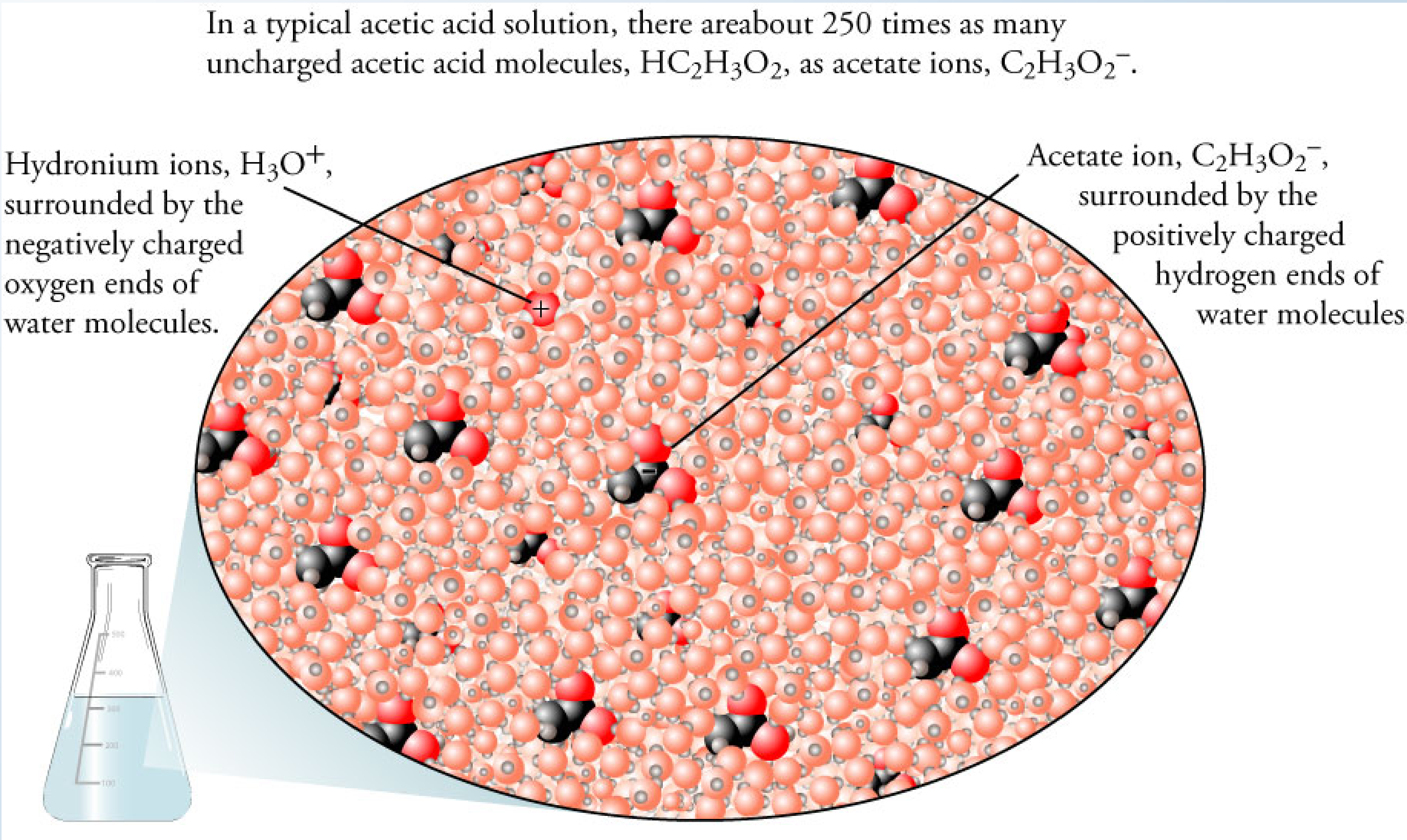
- ***Strong Acid*** = due to a completion reaction with water, generates close to one H_3O^+ for each acid molecule added to water.
- ***Weak Acid*** = due to a reversible reaction with water, generates significantly less than one H_3O^+ for each molecule of acid added to water.

Weak Acid and Water

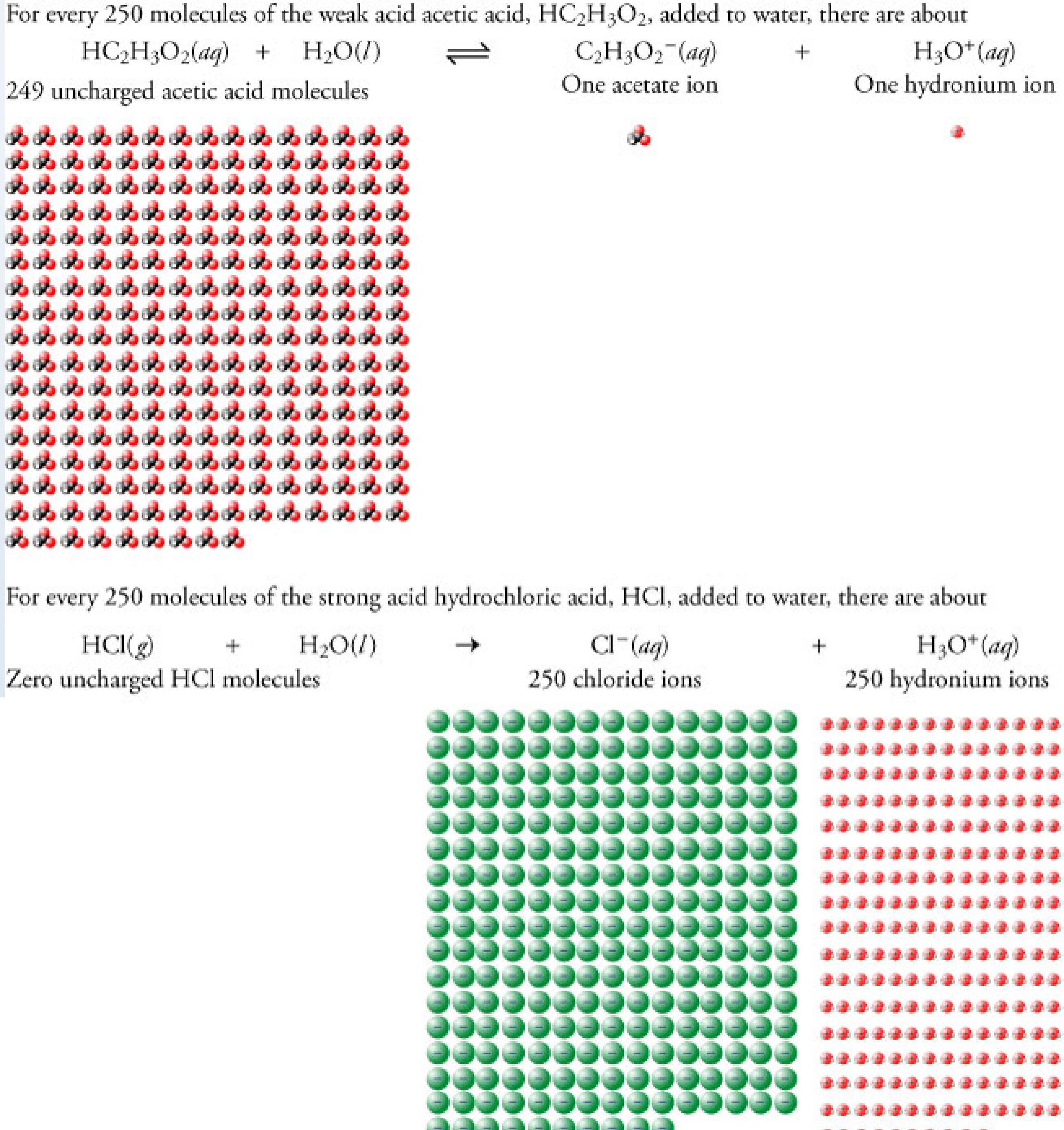
Acetic acid reacts with water in a reversible reaction, which forms hydronium and acetate ions.



Solution of Weak Acid



Strong and Weak Acids



Sulfuric Acid

$$H_2SO_4(aq) + H_2O(l) \rightarrow H_3O^+(aq) + HSO_4^-(aq)$$

$$HSO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_4^{2-}(aq)$$

Acid Summary

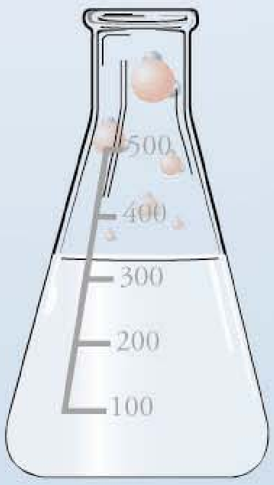
	Strong	Weak
Binary acid	hydrochloric acid, HCl(aq)	hydrofluoric acid
Oxyacid	nitric acid, HNO_3 sulfuric acid, H_2SO_4	other acids with $H_aX_bO_c$
Organic acid	none	acetic acid, $HC_2H_3O_2$

Names and Formulas of Binary Acids

- Names have the general form of *hydro(root)ic acid*, such as hydrochloric acid.
- The formulas are usually followed by (*aq*), such as HCl(*aq*).

Names and Formulas for Oxyacids

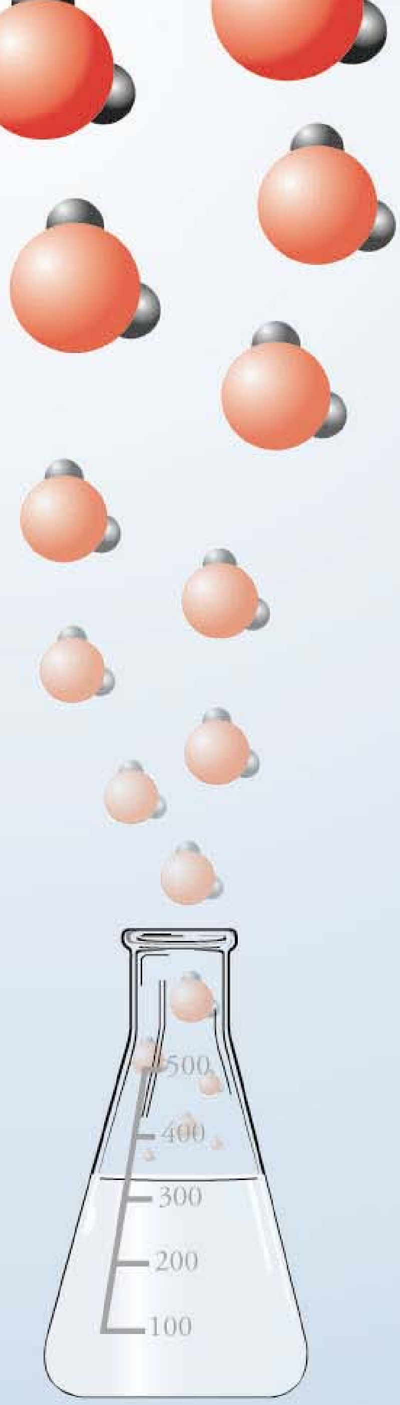
- If enough H^+ ions are added to a (root)ate polyatomic ion to completely neutralize its charge, the (root)ic acid is formed.
  - Nitrate, NO_3^-, goes to nitric acid, HNO_3.
  - Sulfate, SO_4^{2-}, goes to sulfuric acid, H_2SO_4. (Note the -ur- in the name.)
  - Phosphate, PO_4^{3-}, goes to phosphoric acid, H_3PO_4. (Note the -or- in the name.)



Chemical Nomenclature

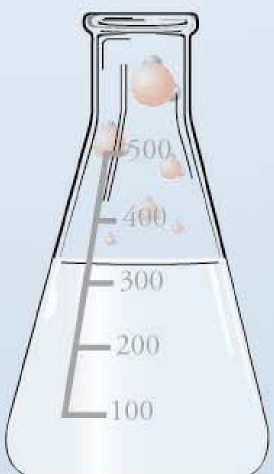
- General procedure for naming compounds (See Table 5.5 in the text.)
  - **Step 1:** Decide what type of compound the name or formula represents.
  - **Step 2:** Apply the rules for writing the name or formula for that type of compound.

Arrhenius Base Definitions



- A ***base*** is a substance that generates OH^- when added to water.
- A ***basic*** solution is a solution with a significant concentration of OH^- ions.

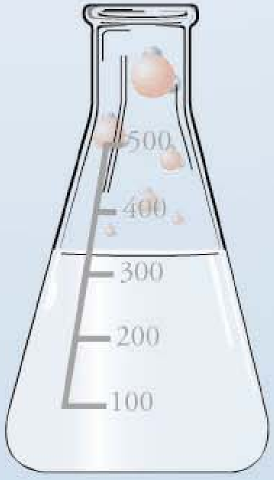
Characteristics of Bases



- Bases have a bitter taste.
- Bases feel slippery on your fingers.
- Bases turn litmus from red to blue.
- Bases react with acids.

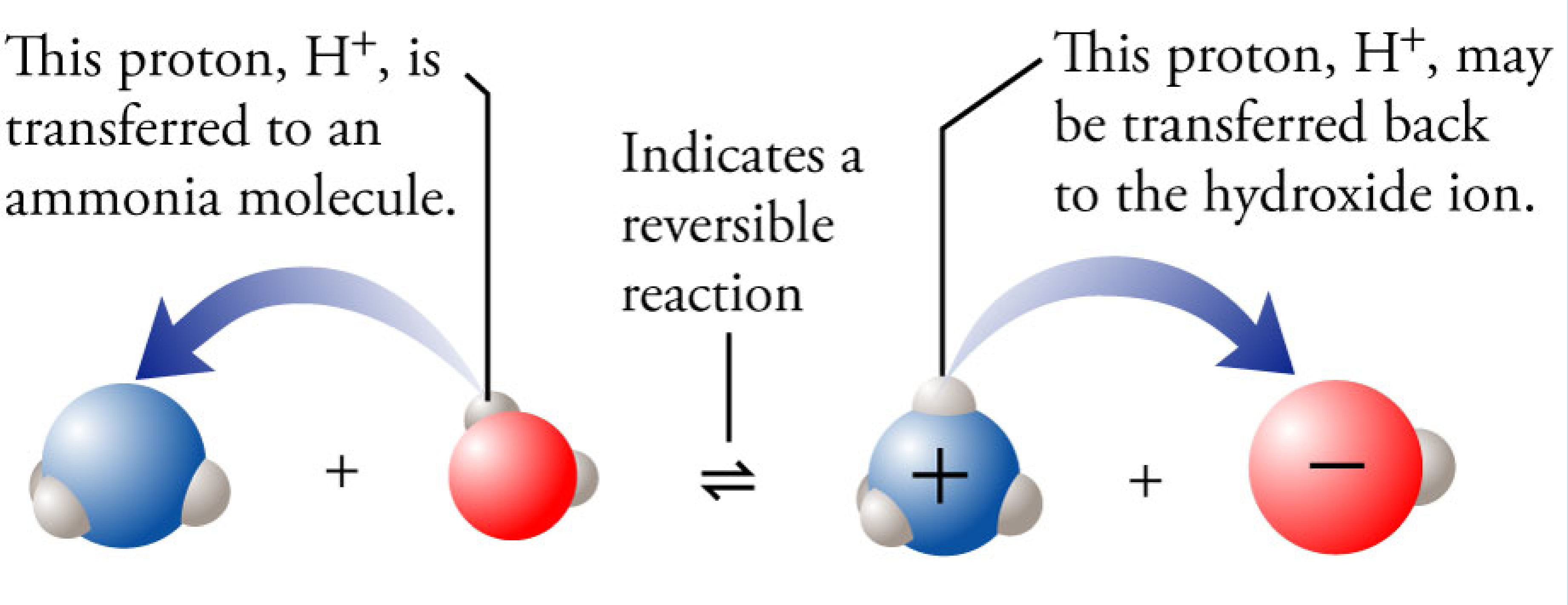
Strong Bases

- ***Strong Base*** = due to a completion reaction with water, generates close to one (or more) OH^- for each formula unit of base added to water.
  - Metal hydroxides are strong bases.



Ammonia and Water

Ammonia reacts with water in a reversible reaction, which forms ammonium and hydroxide ions.

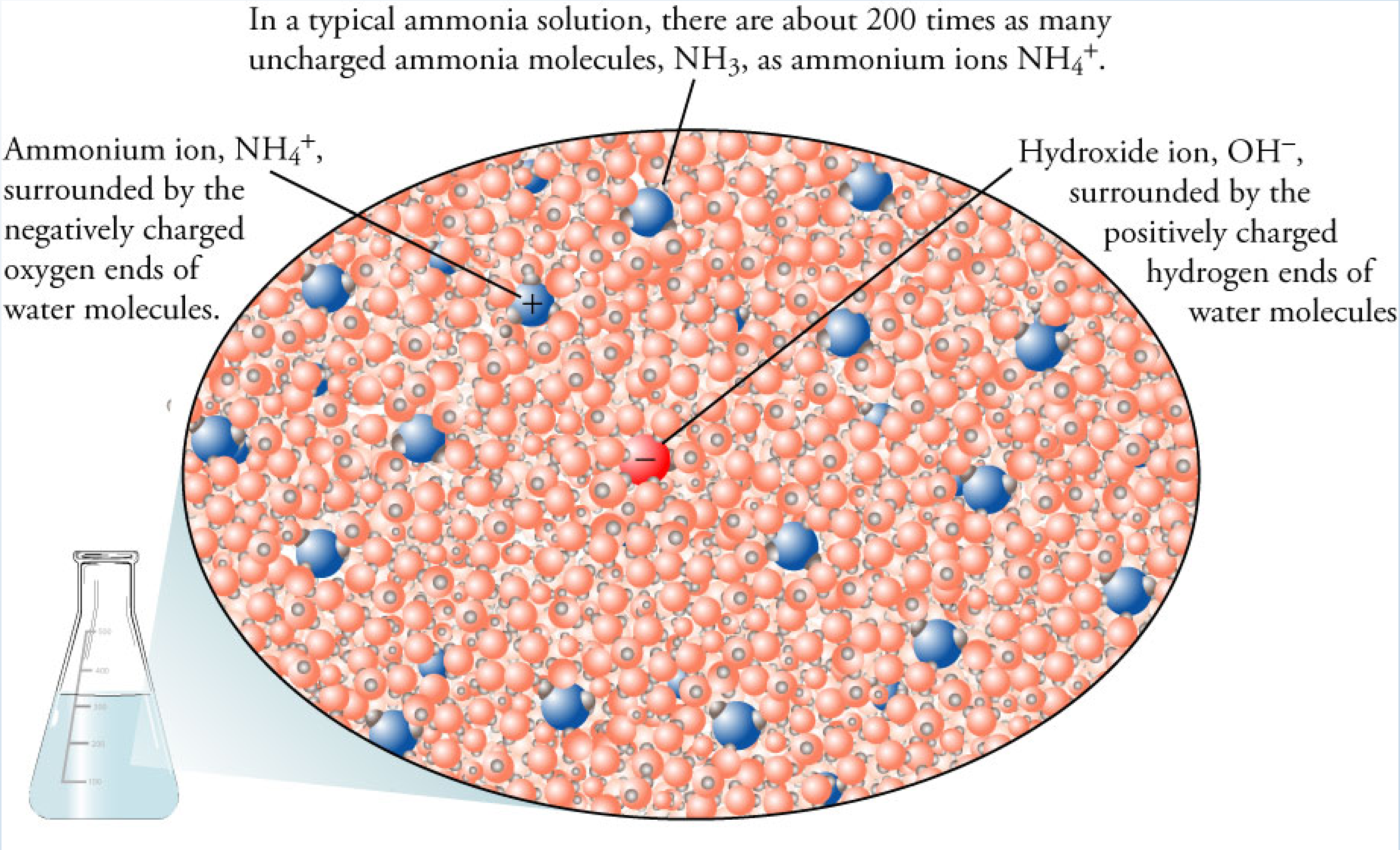


$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

Weak Base

- ***Weak Base*** = due to a reversible reaction with water, generates significantly less than one OH^- for each formula unit of base added to water.
  - Ammonia and ionic compounds that contain CO_3^{2-} or HCO_3^- are weak bases.

Ammonia Solution



Carbonate Bases

$$Na_2CO_3(s) \rightarrow 2Na^+(aq) + CO_3^{2-}(aq)$$

$$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$$

$$NaHCO_3(s) \rightarrow Na^+(aq) + HCO_3^-(aq)$$

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$$

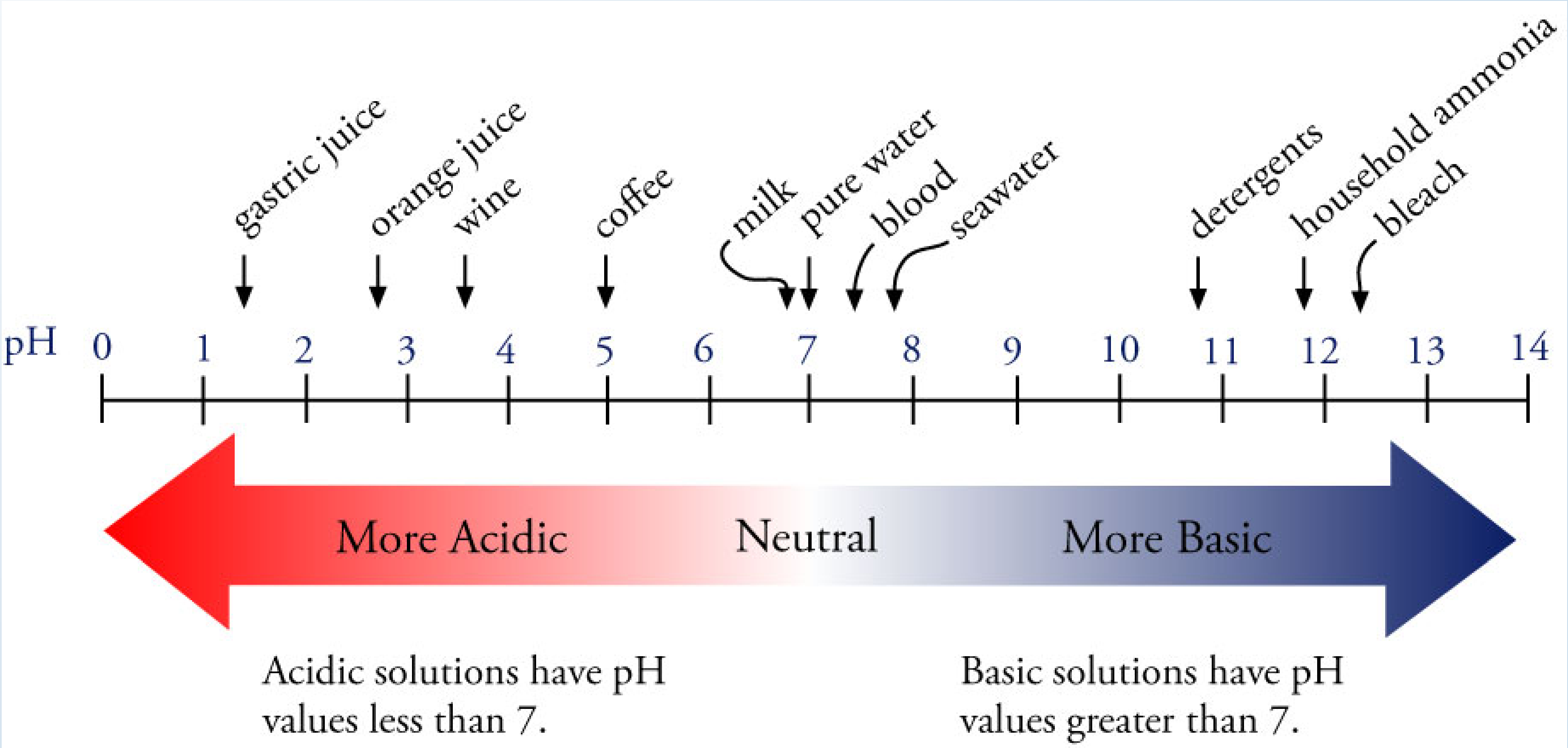
Arrhenius Bases

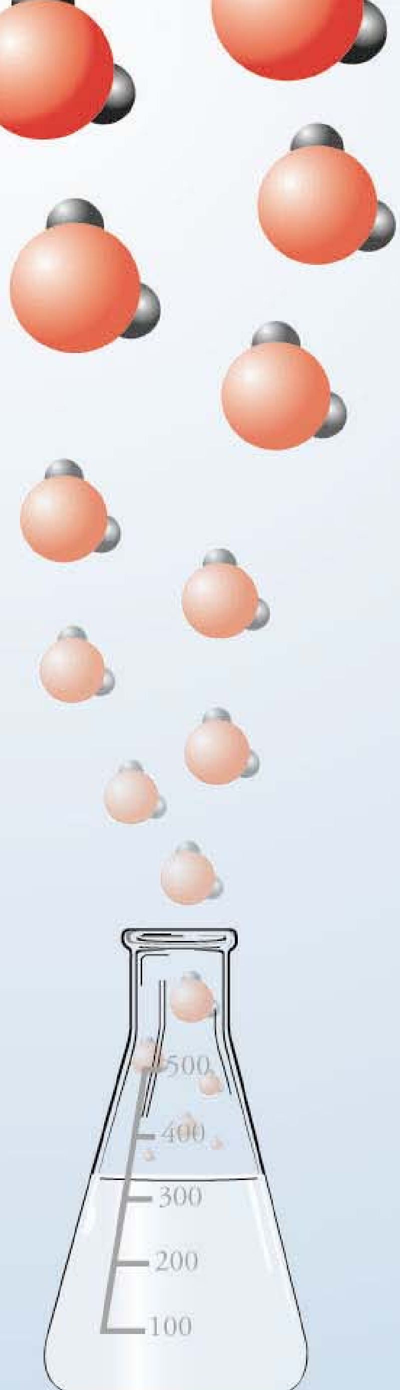
	Strong	**Weak**
Ionic Compounds	Metal hydroxides	Ionic compounds with CO_3^{2-} and HCO_3^{-}
Certain Uncharged molecules	None	NH_3

pH

- Acidic solutions have pH values less than 7, and the more acidic the solution is, the lower its pH.
- Basic solutions have pH values greater than 7, and the more basic the solution is, the higher its pH.

pH Range


gastric juice
orange juice
wine
coffee
milk
pure water
blood
seawater
detergents
household ammonia
bleach
pH
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
More Acidic
Neutral
More Basic
Acidic solutions have pH values less than 7.
Basic solutions have pH values greater than 7.



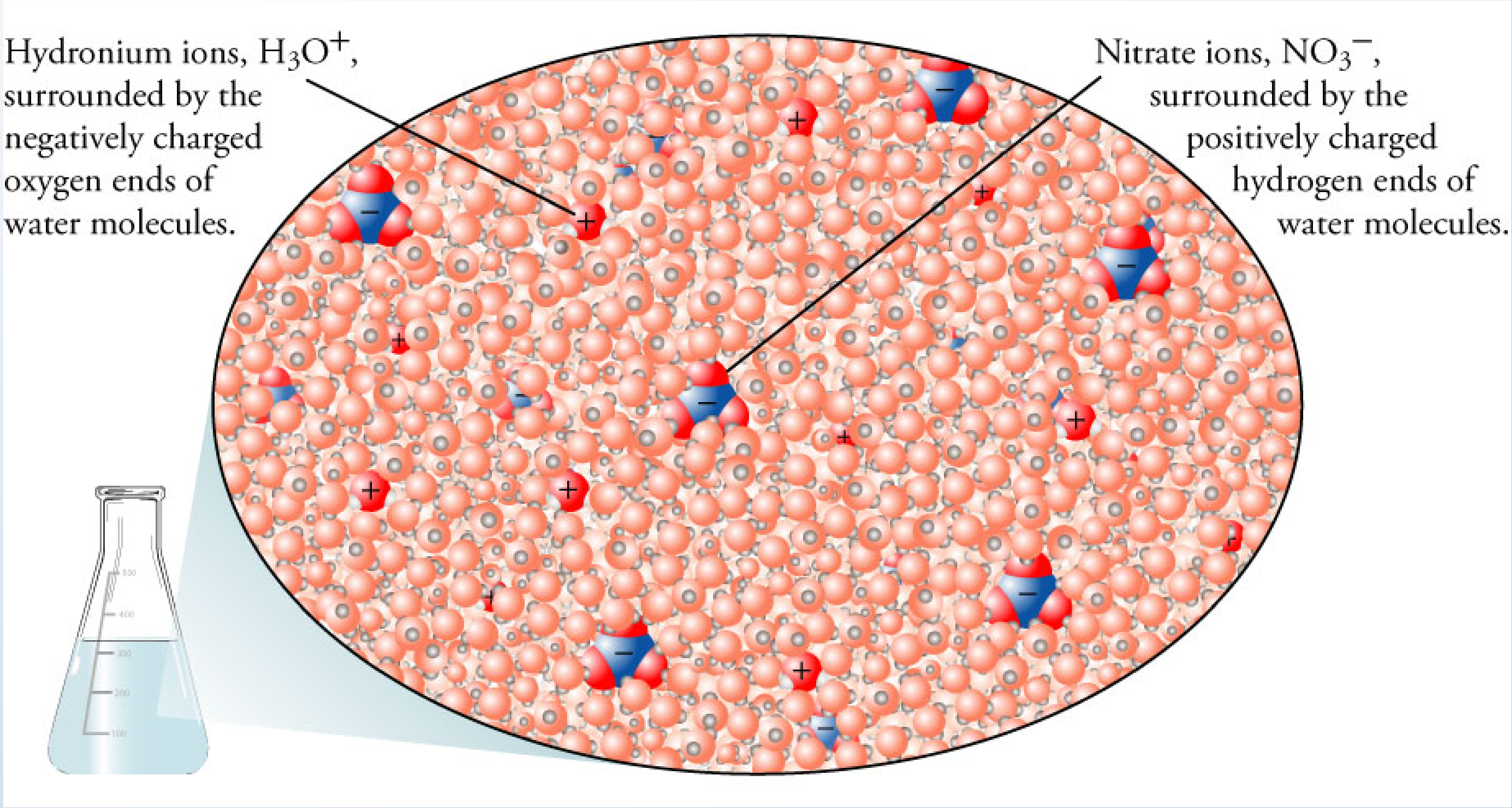
Neutralization Reactions

- Reactions between Arrhenius acids and Arrhenius bases are called ***neutralization reactions***.

$$HNO_3(aq) + NaOH(aq)$$

$$\rightarrow H_2O(l) + NaNO_3(aq)$$

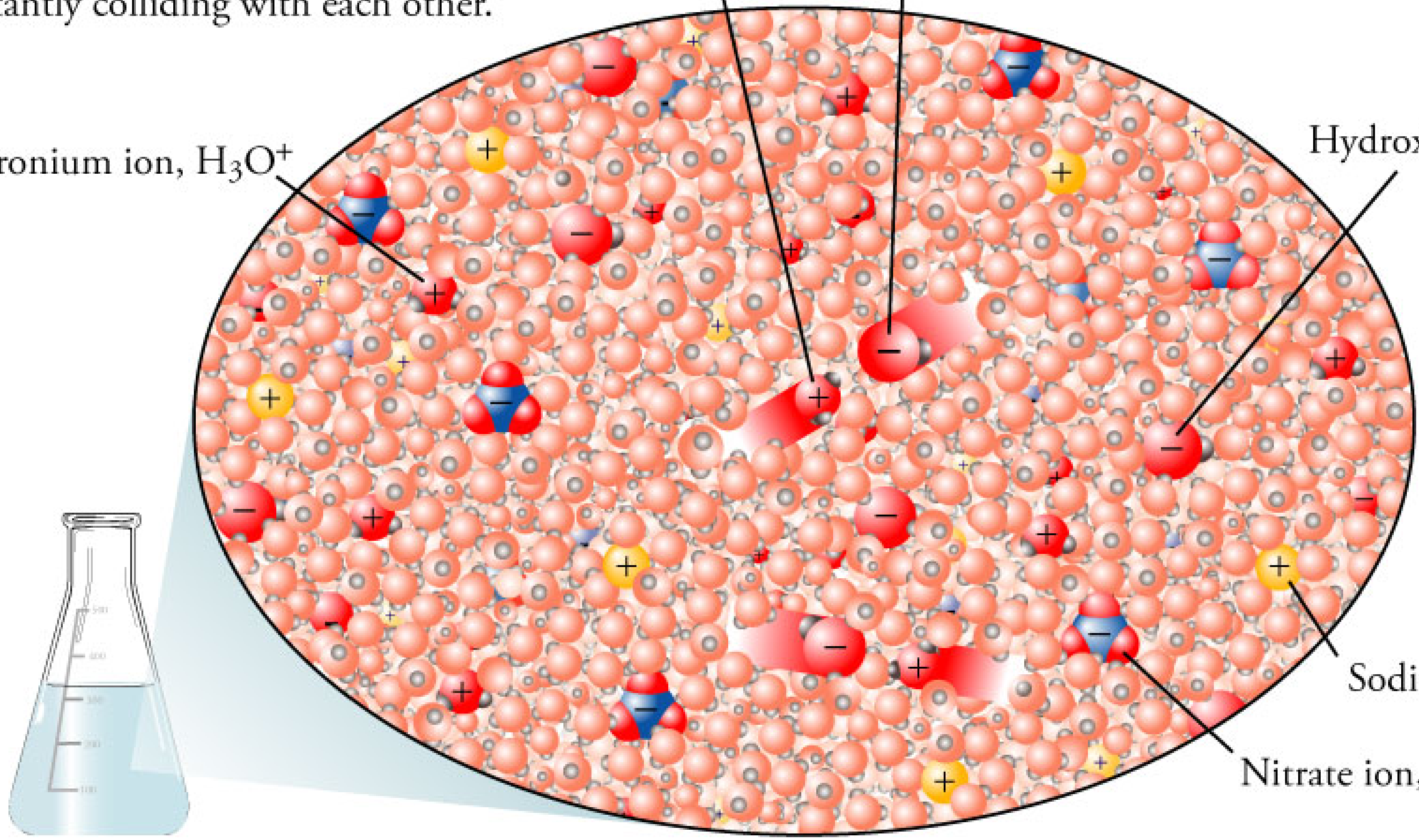
Aqueous Nitric Acid



Mixture of HNO_3 and NaOH Before Reaction

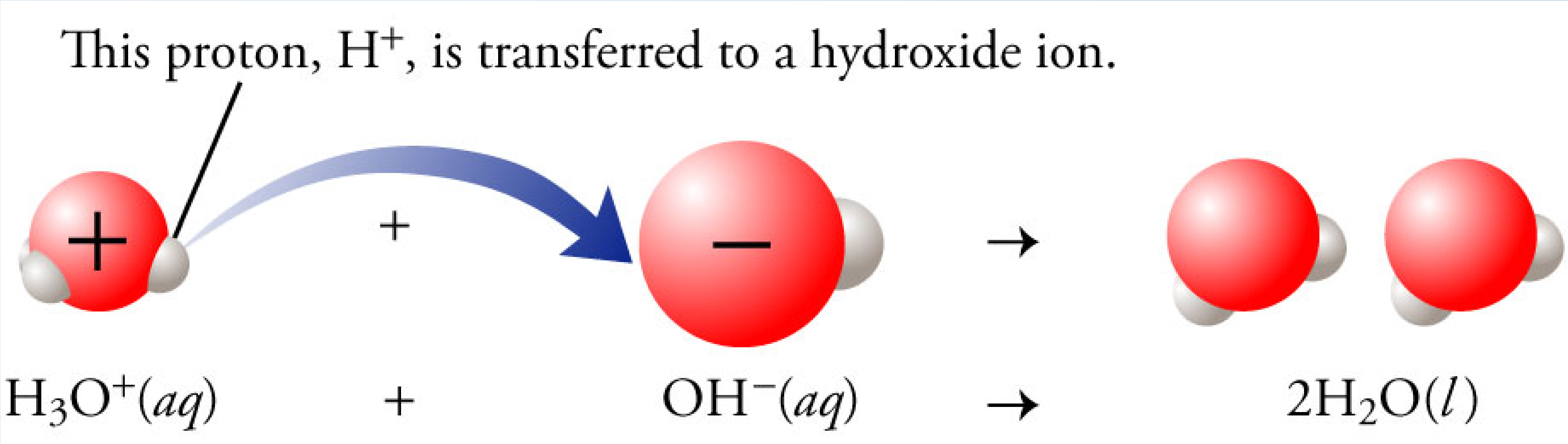
At the instant after nitric acid and sodium hydroxide solutions are mixed and before the reaction, four separate ions move throughout the solution, breaking and making attractions and constantly colliding with each other.

When a hydroxide ion, OH^-, collides with a hydronium ion, H_3O^+, an H^+ ion is transferred from the H_3O^+ to the OH^-, yielding two water molecules, H_2O.

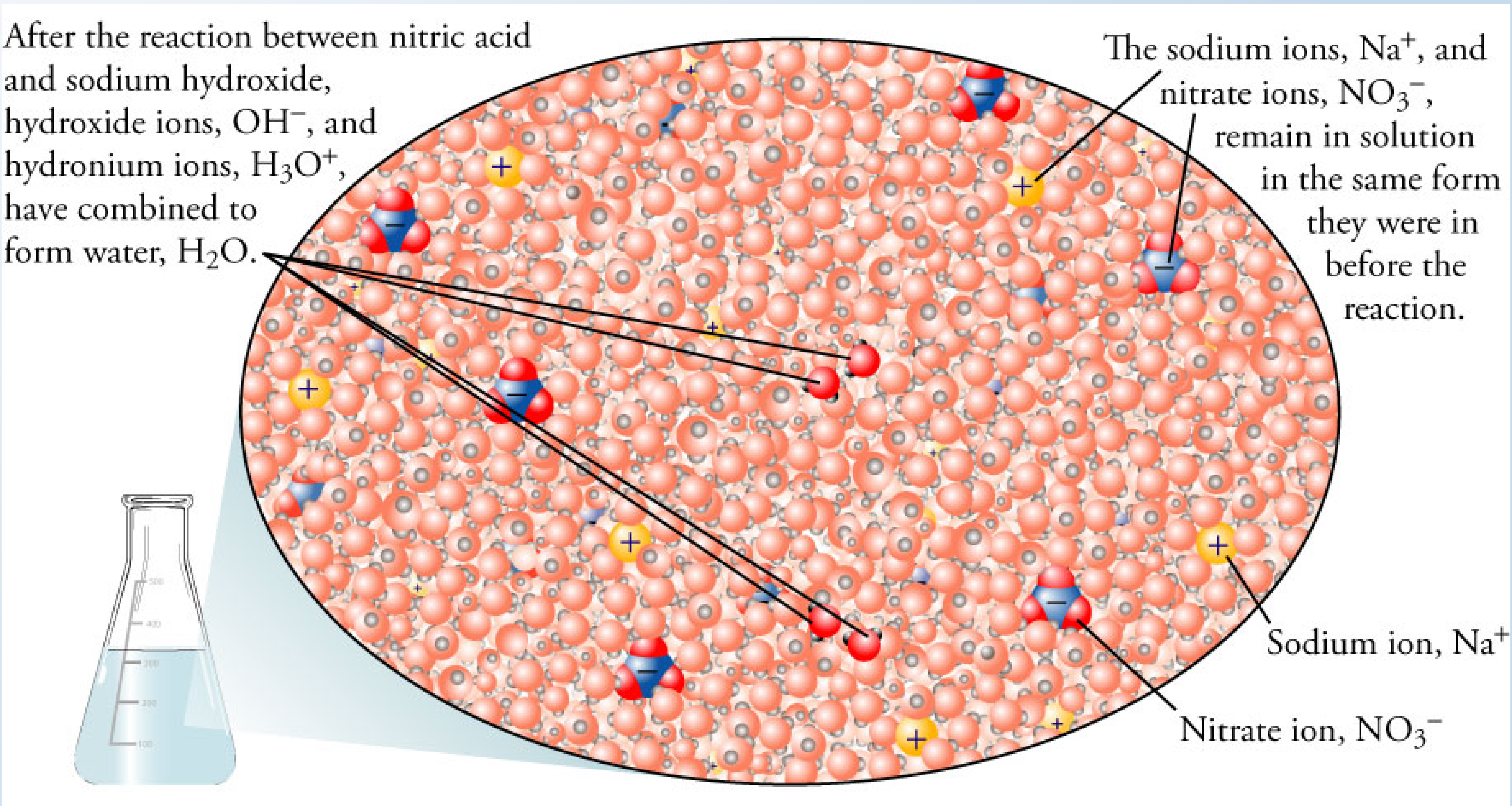


Strong Acid and Strong Base Reaction

The hydronium ion, H_3O^+, from the strong acid reacts with the hydroxide ion, OH^-, from the strong base to form water, H_2O.



Mixture of HNO_3 and NaOH After the Reaction



Reaction between an Acid and a Hydroxide Base.

- The reaction has the double displacement form.

$$AB + CD \rightarrow AD + CB$$

  - The positive part of the acid is H^+.
- The hydroxide base can be soluble or insoluble.
- The products are water and a water-soluble ionic compound.

Reaction between an Acid and a Carbonate Base

- The reaction has the double displacement form.

  $$AB + CD \rightarrow AD + CB$$

  – The positive part of the acid is H^+.

- The products are water, carbon dioxide, and a water-soluble ionic compound. The H_2O and the CO_2 come from the decomposition of the initial product H_2CO_3.

Arrhenius Acid-Base Reactions?

$NH_3(aq) + HF(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)$

base acid

$H_2O(l) + HF(aq) \rightleftharpoons H_3O^+(aq) + F^-(aq)$

neutral acid

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

base neutral

Acid and Base Definitions

- **Acid**
  - Arrhenius: a substance that generates H_3O^+ in water
  - Brønsted-Lowry: a proton, H^+, donor
- **Base**
  - Arrhenius: a substance that generates OH^- in water
  - Brønsted-Lowry: a proton, H^+, acceptor
- **Acid-Base Reaction**
  - Arrhenius: between an Arrhenius acid and base
  - Brønsted-Lowry: a proton (H^+) transfer

Brønsted-Lowry Acids and Bases

$$NH_3(aq) + HF(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)$$

base acid

$$H_2O(l) + HF(aq) \rightleftharpoons H_3O^+(aq) + F^-(aq)$$

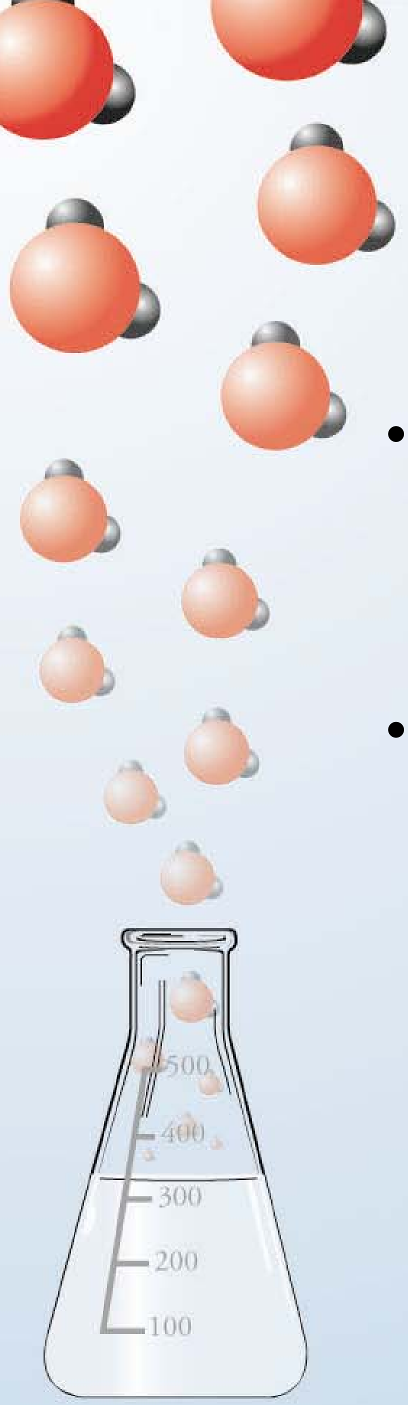
base acid

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

base acid

Why Two Definitions for Acids and Bases? (1)

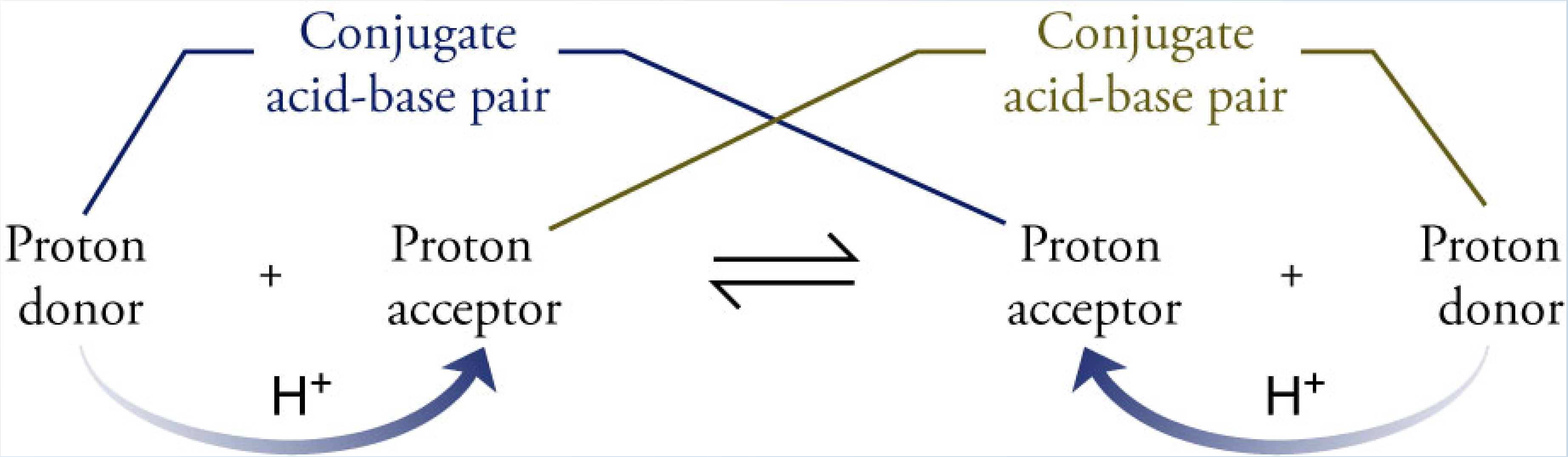
- Positive Aspects of Arrhenius Definitions
  - All isolated substances can be classified as acids (generate H_3O^+ in water), bases (generate OH^- in water), or neither.
  - Allows predictions, including (1) whether substances will react with a base or acid, (2) whether the pH of a solution of the substance will be less than 7 or greater than 7, and (3) whether a solution of the substance will be sour.
- Negative Aspects of Arrhenius Definitions
  - Does not include similar reactions (H^+ transfer reactions) as acid-base reactions.



Why Two Definitions for Acids and Bases? (2)

- Positive Aspects of Brønsted-Lowry Definitions
  - Includes similar reactions (H^+ transfer reactions) as acid-base reactions.
- Negative Aspects of Brønsted-Lowry Definitions
  - Cannot classify isolated substances as acids (generate H_3O^+ in water), bases (generate OH^- in water), or neither. The same substance can sometimes be an acid and sometimes a base.
  - Does not allow predictions of (1) whether substances will react with a base or acid, (2) whether the pH of a solution of the substance will be less than 7 or greater than 7, and (3) whether a solution of the substance will be sour.

Conjugate Acid-Base Pairs



Brønsted-Lowry Acids and Bases

$NH_3(aq)$	+	$HF(aq)$	$\rightleftharpoons$	$NH_4^+(aq)$	+	$F^-(aq)$
base		acid		acid		base
$H_2O(l)$	+	$HF(aq)$	$\rightleftharpoons$	$H_3O^+(aq)$	+	$F^-(aq)$
base		acid		acid		base
$NH_3(aq)$	+	$H_2O(l)$	$\rightleftharpoons$	$NH_4^+(aq)$	+	$OH^-(aq)$
base		acid		acid		base
$H_2PO_4^-(aq)$	+	$HF(aq)$	$\rightleftharpoons$	$H_3PO_4(aq)$	+	$F^-(aq)$
base		acid		acid		base

Amphoteric Substances

Can be a Brønsted-Lowry acid in one reaction and a Brønsted-Lowry base in another?

$HCO_3^-(aq) + HF(aq) \rightleftharpoons CO_2(g) + H_2O(l) + F^-(aq)$

base acid

$HCO_3^-(aq) + OH^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H_2O(l)$

acid base

$H_2PO_4^-(aq) + HF(aq) \rightleftharpoons H_3PO_4(aq) + F^-(aq)$

base acid

$H_2PO_4^-(aq) + 2OH^-(aq) \rightarrow PO_4^{3-}(aq) + 2H_2O(l)$

acid base