Chapter 14

Preview

- Lesson Starter
- Objectives
- Acids
- Bases
- Arrhenius Acids and Bases

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Lesson Starter

- The solutions in the beakers are different because they have a different pH.
- One beaker contains a basic solution and the other beaker contains an acidic solution

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Objectives

- **List** five general properties of aqueous acids and bases.
- **Name** common binary acids and oxyacids, given their chemical formulas.
- **List** five acids commonly used in industry and the laboratory, and give two properties of each.
- **Define** acid and base according to Arrhenius’s theory of ionization.
- **Explain** the differences between strong and weak acids and bases.

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Acids

1. Aqueous solutions of acids have a sour taste.
2. Acids change the color of acid-base indicators.
3. Some acids react with active metals and release hydrogen gas, H_2.

$$Ba(s) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + H_2(g)$$

4. Acids react with bases to produce salts and water.
5. Acids conduct electric current.

Properties of Acids

Click below to watch the Visual Concept.

Acids, *continued*

Acid Nomenclature

- A **binary acid** is an acid that contains only two different elements: hydrogen and one of the more electronegative elements.
  - HF, HCl, HBr, and HI

- Binary Acid Nomenclature
  1. The name of a binary acid begins with the prefix hydro-.
  2. The root of the name of the second element follows this prefix.
  3. The name then ends with the suffix -ic.

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Acids, *continued*

Acid Nomenclature, *continued*

Formula	Acid name
HF	hydrofluoric acid
HCl	hydrochloric acid
HBr	hydrobromic acid
HI	hydriodic acid
H_2S	hydrosulfuric acid

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Acids, *continued*

Acid Nomenclature, *continued*

- An **oxyacid** is an acid that is a compound of hydrogen, oxygen, and a third element, usually a nonmetal.
  - HNO_3, H_2SO_4
- The names of oxyacids follow a pattern.
- The names of their anions are based on the names of the acids.

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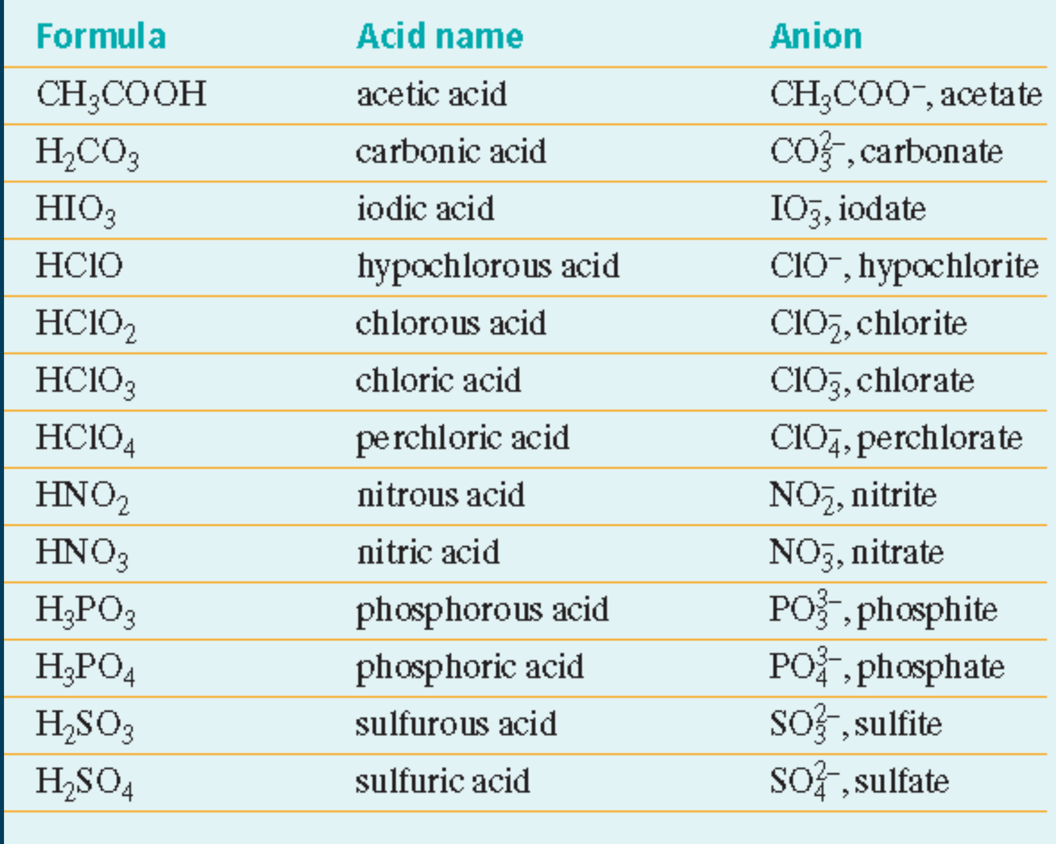
Acids, *continued*

Acid Nomenclature, *continued*



Formula	Acid name	Anion
CH_3COOH	acetic acid	CH_3COO^-, acetate
H_2CO_3	carbonic acid	CO_3^{2-}, carbonate
HIO_3	iodic acid	IO_3^-, iodate
$HClO$	hypochlorous acid	ClO^-, hypochlorite
$HClO_2$	chlorous acid	ClO_2^-, chlorite
$HClO_3$	chloric acid	ClO_3^-, chlorate
$HClO_4$	perchloric acid	ClO_4^-, perchlorate
HNO_2	nitrous acid	NO_2^-, nitrite
HNO_3	nitric acid	NO_3^-, nitrate
H_3PO_3	phosphorous acid	PO_3^{3-}, phosphite
H_3PO_4	phosphoric acid	PO_4^{3-}, phosphate
H_2SO_3	sulfurous acid	SO_3^{2-}, sulfite
H_2SO_4	sulfuric acid	SO_4^{2-}, sulfate

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Naming Oxyacids

Click below to watch the Visual Concept.

Visual Concept

Some Common Industrial Acids

- **Sulfuric Acid**
  - Sulfuric acid is the most commonly produced industrial chemical in the world.
- **Nitric Acid**
- **Phosphoric Acid**
- **Hydrochloric Acid**
  - Concentrated solutions of hydrochloric acid are commonly referred to as *muriatic acid*.
- **Acetic Acid**
  - Pure acetic acid is a clear, colorless, and pungent-smelling liquid known as *glacial acetic acid*.

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Bases

1. Aqueous solutions of bases taste bitter.
2. Bases change the color of acid-base indicators.
3. Dilute aqueous solutions of bases feel slippery.
4. Bases react with acids to produce salts and water.
5. Bases conduct electric current.

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Properties of Bases

Click below to watch the Visual Concept.

Visual Concept

Arrhenius Acids and Bases

- An **Arrhenius acid** is a chemical compound that increases the concentration of hydrogen ions, H^+, in aqueous solution.

- An **Arrhenius base** is a substance that increases the concentration of hydroxide ions, OH^-, in aqueous solution.

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Arrhenius Acids and Bases

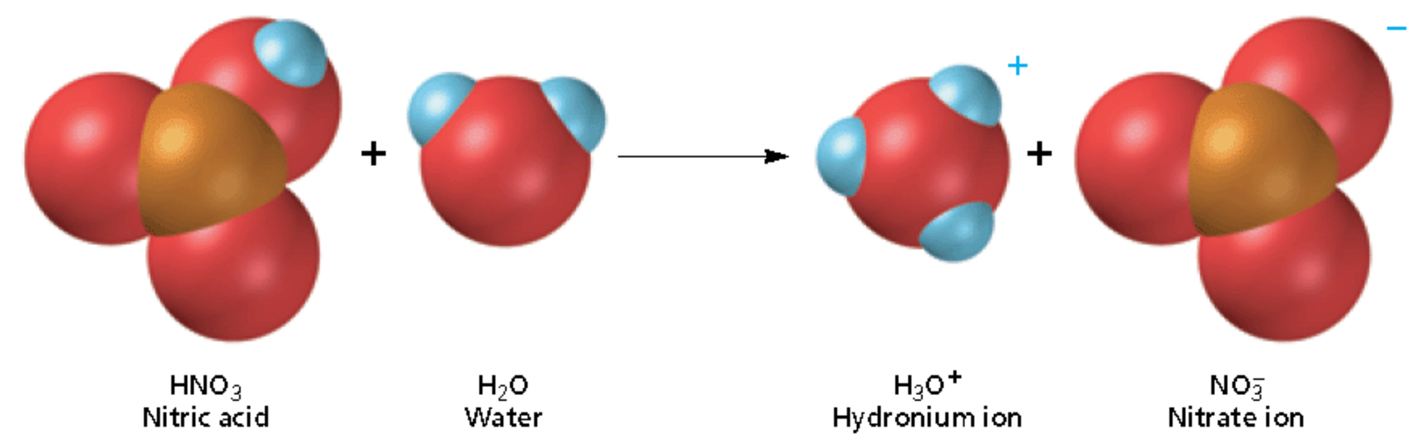
Click below to watch the Visual Concept.

Visual Concept

Arrhenius Acids and Bases, *continued*

Aqueous Solutions of Acids

- Arrhenius acids are molecular compounds with ionizable hydrogen atoms.
- Their water solutions are known as *aqueous acids*.
- All aqueous acids are electrolytes.



Arrhenius Acids and Bases, *continued*

Aqueous Solutions of Acids, *continued*

- Common Aqueous Acids

Strong acids	Weak acids
$HI + H_2O \longrightarrow H_3O^+ + I^-$	$HSO_4^- + H_2O \rightleftarrows H_3O^+ + SO_4^{2-}$
$HClO_4 + H_2O \longrightarrow H_3O^+ + ClO_4^-$	$H_3PO_4 + H_2O \rightleftarrows H_3O^+ + H_2PO_4^-$
$HBr + H_2O \longrightarrow H_3O^+ + Br^-$	$HF + H_2O \rightleftarrows H_3O^+ + F^-$
$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$	$CH_3COOH + H_2O \rightleftarrows H_3O^+ + CH_3COO^-$
$H_2SO_4 + H_2O \longrightarrow H_3O^+ + HSO_4^-$	$H_2CO_3 + H_2O \rightleftarrows H_3O^+ + HCO_3^-$
$HClO_3 + H_2O \longrightarrow H_3O^+ + ClO_3^-$	$H_2S + H_2O \rightleftarrows H_3O^+ + HS^-$
	$HCN + H_2O \rightleftarrows H_3O^+ + CN^-$
	$HCO_3^- + H_2O \rightleftarrows H_3O^+ + CO_3^{2-}$

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Arrhenius Acids and Bases, *continued*

Strength of Acids

- A **strong acid** is one that ionizes completely in aqueous solution.
    - a strong acid is a strong electrolyte
    - $HClO_4$, HCl, HNO_3
- A **weak acid** releases few hydrogen ions in aqueous solution.
    - hydronium ions, anions, and dissolved acid molecules in aqueous solution
    - HCN
    - *Organic acids* (—COOH), such as acetic acid

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Arrhenius Acids and Bases, *continued*

Aqueous Solutions of Bases

- Most bases are ionic compounds containing metal cations and the hydroxide anion, OH^-.
  - dissociate in water

$$NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$$

- Ammonia, NH_3, is molecular
  - Ammonia produces hydroxide ions when it reacts with water molecules.

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

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Arrhenius Acids and Bases, *continued*

Strength of Bases

- The strength of a base depends on the extent to which the base dissociates.
- Strong bases are strong electrolytes

Strong bases	**Weak bases**
$Ca(OH)_2 \longrightarrow Ca^{2+} + 2OH^-$	$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
$Sr(OH)_2 \longrightarrow Sr^{2+} + 2OH^-$	$C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$
$Ba(OH)_2 \longrightarrow Ba^{2+} + 2OH^-$	
$NaOH \longrightarrow Na^+ + OH^-$	
$KOH \longrightarrow K^+ + OH^-$	
$RbOH \longrightarrow Rb^+ + OH^-$	
$CsOH \longrightarrow Cs^+ + OH^-$	

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Strength and Weakness of Acids and Bases

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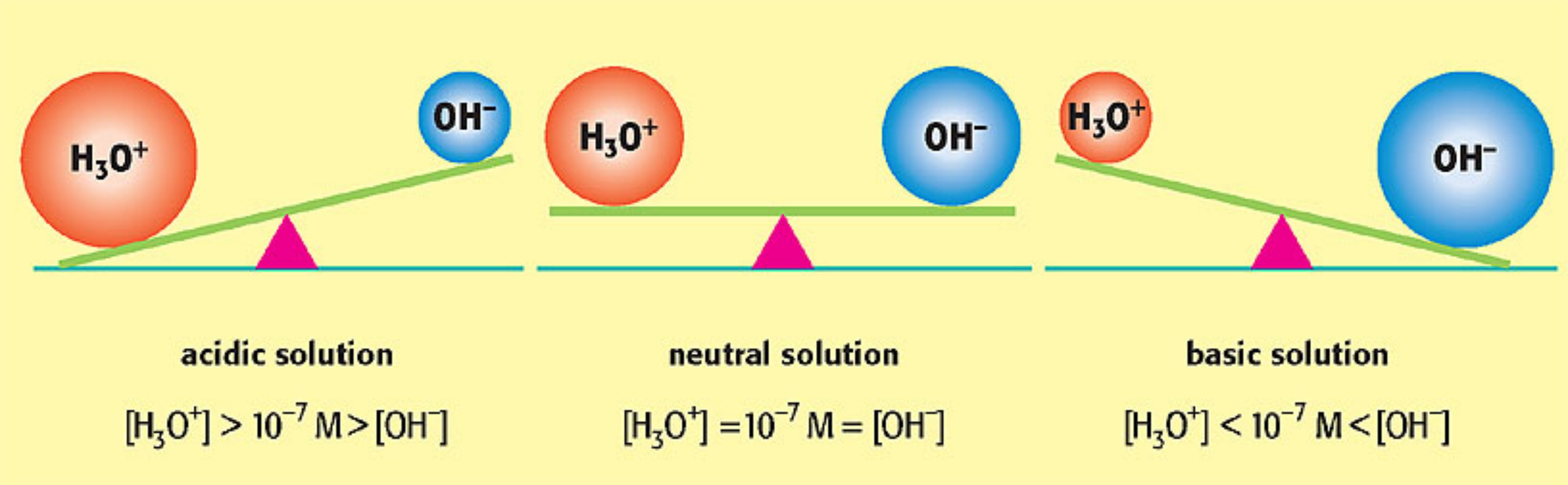
Visual Concept

Relationship of [H3O+] to [OH–]



acidic solution

$[H_3O^+] > 10^{-7}\ M > [OH^-]$

neutral solution

$[H_3O^+] = 10^{-7}\ M = [OH^-]$

basic solution

$[H_3O^+] < 10^{-7}\ M < [OH^-]$

Preview

- Lesson Starter
- Objectives
- Brønsted-Lowry Acids and Bases
- Monoprotic and Polyprotic Acids
- Lewis Acids and Bases

Lesson Starter

- List three terms that describe the person in the photo.
- The person has been described in many different ways, but he or she is still the same person.
- Acids and bases also can be described differently based on the circumstances.

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Objectives

- **Define** and **recognize** *Brønsted-Lowry acids* and *bases*.
- **Define** a *Lewis acid* and a *Lewis base*.
- **Name** compounds that are acids under the Lewis definition but are not acids under the Brønsted-Lowry definition.

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Brønsted-Lowry Acids and Bases

- A **Brønsted-Lowry acid** is a molecule or ion that is a proton donor.

- Hydrogen chloride acts as a Brønsted-Lowry acid when it reacts with ammonia.

$$HCl + NH_3 \rightarrow NH_4^+ + Cl^-$$

- Water can act as a Brønsted-Lowry acid.

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

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Brønsted-Lowry Acids and Bases, *continued*

- A **Brønsted-Lowry base** is a molecule or ion that is a proton acceptor.
- Ammonia accepts a proton from the hydrochloric acid. It acts as a Brønsted-Lowry base.

$$HCl + NH_3 \rightarrow NH_4^+ + Cl^-$$

- The OH^- ion produced in solution by Arrhenius hydroxide bases (NaOH) is the Brønsted-Lowry base.
  - The OH^- ion can accept a proton

Brønsted-Lowry Acids and Bases, *continued*

- In a **Brønsted-Lowry acid-base reaction,** protons are transferred from one reactant (the acid) to another (the base).

$$\underset{acid}{HCl} + \underset{base}{NH_3} \rightarrow NH_4^+ + Cl^-$$

Brønsted-Lowry Acids and Bases

Click below to watch the Visual Concept.

Visual Concept

Monoprotic and Polyprotic Acids

- A **monoprotic acid** is an acid that can donate only one proton (hydrogen ion) per molecule.
  - $HClO_4$, HCl, HNO_3
  - only one ionization step

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

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Monoprotic and Diprotic Acids

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

$$H_2SO_4 + H_2O \longrightarrow H_3O^+ + HSO_4^-$$
$$HSO_4^- + H_2O \rightleftarrows H_3O^+ + SO_4^{2-}$$

Monoprotic and Polyprotic Acids, *continued*

- A **polyprotic acid** is an acid that can donate more than one proton per molecule.
  - H_2SO_4, H_3PO_4
  - Multiple ionization steps

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

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

  - Sulfuric acid solutions contain H_3O^+, HSO_4^- and SO_4^{2-} ions

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Monoprotic and Polyprotic Acids, *continued*

- A **diprotic acid** is the type of polyprotic acid that can donate two protons per molecule
  - H_2SO_4
- A **triprotic acid** is the type of polyprotic acid that can donate three protons per molecule.
  - H_3PO_4

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Comparing Monoprotic and Polyprotic Acids

Click below to watch the Visual Concept.

Visual Concept

Lewis Acids and Bases

- A **Lewis acid** is an atom, ion, or molecule that accepts an electron pair to form a covalent bond.
  - The Lewis definition is the broadest of the three acid definitions.
  - A bare proton (hydrogen ion) is a Lewis acid

$$H^+(aq) + \ :NH_3(aq) \rightarrow [H\text{—}NH_3]^+(aq) \text{ or } [NH_4]^+(aq)$$

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Lewis Acids and Bases, *continued*

- The formula for a Lewis acid need not include hydrogen.
    - The silver ion can be a Lewis acid

$$\mathrm{Ag^+}(aq) + 2:\mathrm{NH_3}(aq) \rightarrow [\mathrm{H_3N}-\mathrm{Ag}-\mathrm{NH_3}]^+(aq) \text{ or } [\mathrm{Ag(NH_3)_2}]^+$$

- Any compound in which the central atom has three valence electrons and forms three covalent bonds can react as a Lewis acid.

$$\mathrm{BF_3}(aq) + \mathrm{F^-}(aq) \rightarrow \mathrm{BF_4^-}(aq)$$

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Lewis Acids and Bases

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Visual Concept

Lewis Acids and Bases, *continued*

Acid Base Definitions

Type	**Acid**	**Base**
Arrhenius	H^+ or H_3O^+ producer	OH^- producer
Brønsted-Lowry	proton (H^+) donor	proton (H^+) acceptor
Lewis	electron-pair acceptor	electron-pair donor

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Comparing Arrhenius, Brønsted-Lowry, and Lewis Acids and Bases

Click below to watch the Visual Concept.

Visual Concept

Preview

- Lesson Starter
- Objectives
- Conjugate Acids and Bases
- Amphoteric Compounds
- Neutralization Reactions
- Acid Rain

Lesson Starter

- What is the meaning of the word *neutralization*.
- How is the word used in everyday life?
- How is it likely to apply to acids and bases?

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Objectives

- **Describe** a conjugate acid, a conjugate base, and an amphoteric compound.
- **Explain** the process of neutralization.
- **Define** *acid rain*, give examples of compounds that can cause acid rain, and describe effects of acid rain.

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Conjugate Acids and Bases

- The species that remains after a Brønsted-Lowry acid has given up a proton is the **conjugate base** of that acid.

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

acid

conjugate base

Conjugate Acids and Bases, *continued*

- Brønsted-Lowry acid-base reactions involve two acid-base pairs, known a conjugate acid-base pairs.

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

acid₁	*base₂*	*base₁*	*acid₂*

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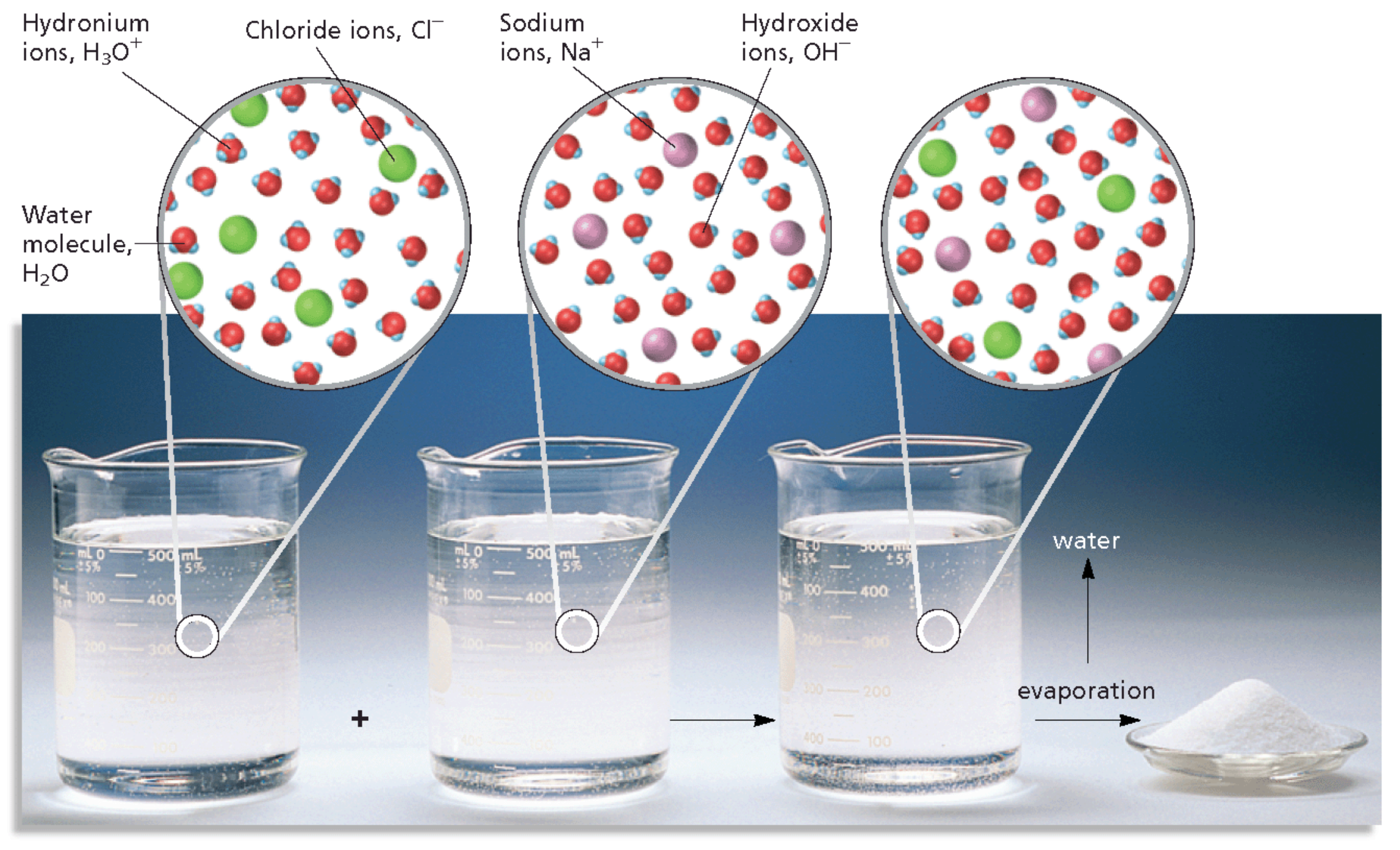
Neutralization Reactions



Conjugate Acids and Bases, *continued*

Strength of Conjugate Acids and Bases

- The stronger an acid is, the weaker its conjugate base
- The stronger a base is, the weaker its conjugate acid

$$\underset{\text{strong acid}}{HCl(g)} + \underset{\text{base}}{H_2O(l)} \rightarrow \underset{\text{acid}}{H_3O^+(aq)} + \underset{\text{weak base}}{Cl^-(aq)}$$

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Conjugate Acids and Bases, *continued*

Strength of Conjugate Acids and Bases, *continued*

- Proton transfer reactions favor the production of the weaker acid and the weaker base.

$$HClO_4(aq) + H_2O(l) \rightarrow H_3O^+(aq) + ClO_4^-(aq)$$

stronger acid	*stronger base*	*weaker acid*	*weaker base*

- The reaction to the right is more favorable

$$CH_3COOH(aq) + H_2O(l) \leftarrow H_3O^+(aq) + CH_3COO^-(aq)$$

weaker acid	*weaker base*	*stronger acid*	*stronger base*

- The reaction to the left is more favorable

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Conjugated Acids and Bases

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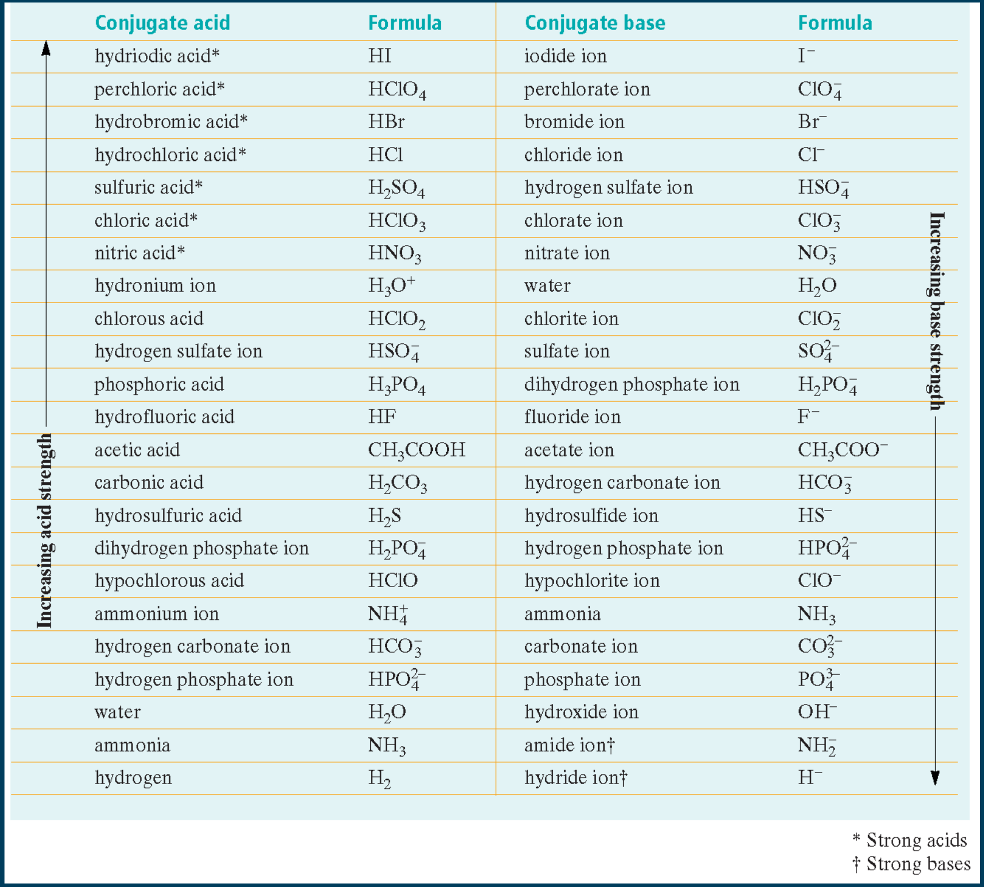
Visual Concept

Relative Strengths of Acids and Bases

Relative Strengths of Acids and Bases



Conjugate acid	Formula	Conjugate base	Formula
hydriodic acid*	HI	iodide ion	I^-
perchloric acid*	$HClO_4$	perchlorate ion	ClO_4^-
hydrobromic acid*	HBr	bromide ion	Br^-
hydrochloric acid*	HCl	chloride ion	Cl^-
sulfuric acid*	H_2SO_4	hydrogen sulfate ion	HSO_4^-
chloric acid*	$HClO_3$	chlorate ion	ClO_3^-
nitric acid*	HNO_3	nitrate ion	NO_3^-
hydronium ion	H_3O^+	water	H_2O
chlorous acid	$HClO_2$	chlorite ion	ClO_2^-
hydrogen sulfate ion	HSO_4^-	sulfate ion	SO_4^{2-}
phosphoric acid	H_3PO_4	dihydrogen phosphate ion	$H_2PO_4^-$
hydrofluoric acid	HF	fluoride ion	F^-
acetic acid	CH_3COOH	acetate ion	CH_3COO^-
carbonic acid	H_2CO_3	hydrogen carbonate ion	HCO_3^-
hydrosulfuric acid	H_2S	hydrosulfide ion	HS^-
dihydrogen phosphate ion	$H_2PO_4^-$	hydrogen phosphate ion	HPO_4^{2-}
hypochlorous acid	$HClO$	hypochlorite ion	ClO^-
ammonium ion	NH_4^+	ammonia	NH_3
hydrogen carbonate ion	HCO_3^-	carbonate ion	CO_3^{2-}
hydrogen phosphate ion	HPO_4^{2-}	phosphate ion	PO_4^{3-}
water	H_2O	hydroxide ion	OH^-
ammonia	NH_3	amide ion†	NH_2^-
hydrogen	H_2	hydride ion†	H^-

* Strong acids
† Strong bases

Amphoteric Compounds

- Any species that can react as either an acid or a base is described as **amphoteric.**
    - example: water
        - water can act as a base

$$\underset{acid_1}{H_2SO_4(aq)} + \underset{base_2}{H_2O(l)} \rightarrow \underset{acid_2}{H_3O^+(aq)} + \underset{base_1}{HSO_4^-(aq)}$$

- water can act as an acid

$$\underset{base_1}{NH_3(g)} + \underset{acid_2}{H_2O(l)} \rightleftharpoons \underset{acid_1}{NH_4^+(aq)} + \underset{base_2}{OH^-(aq)}$$

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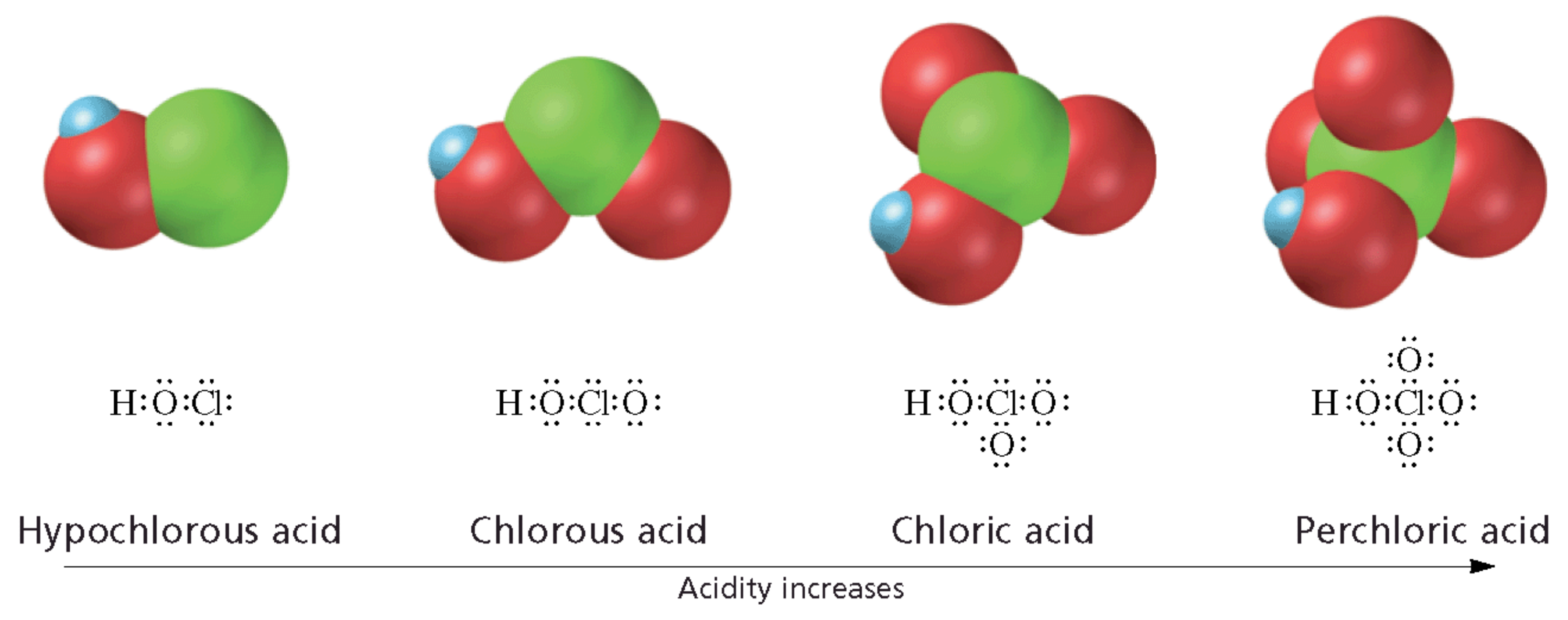
Amphoteric Compounds, *continued*

–OH in a Molecule

- The covalently bonded IOH group in an acid is referred to as a *hydroxyl group.*
- Molecular compounds containing —OH groups can be acidic or amphoteric.
- The behavior of a compound is affected by the number of oxygen atoms bonded to the atom connected to the —OH group.

Oxyacids of Chlorine



Amphoterism

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Visual Concept

Neutralization Reactions

Strong Acid-Strong Base Neutralization

- In aqueous solutions, **neutralization** is the reaction of hydronium ions and hydroxide ions to form water molecules.

- A **salt** is an ionic compound composed of a cation from a base and an anion from an acid.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Neutralization Reaction

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Visual Concept

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Acid Rain

- NO, NO_2, CO_2, SO_2, and SO_3 gases from industrial processes can dissolve in atmospheric water to produce acidic solutions.
  - example: $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
- Very acidic rain is known as *acid rain.*
- Acid rain can erode statues and affect ecosystems.

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Acid Precipitation

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Chemical Weathering

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Visual Concept

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