Chapter 8
Acids, Bases, and Acid-Base Reactions

An Introduction to Chemistry

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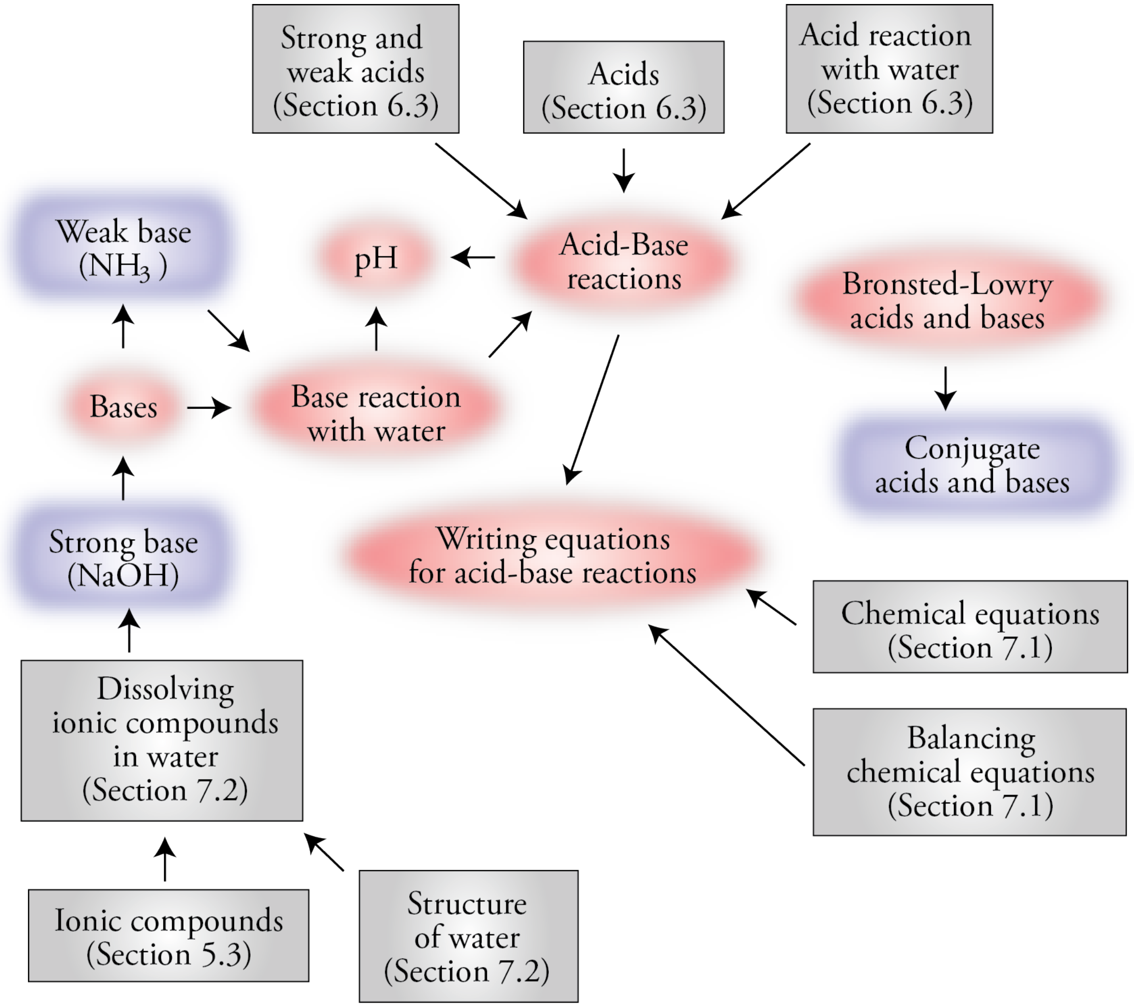
Chapter Map



Strong and weak acids (Section 6.3)
Acids (Section 6.3)
Acid reaction with water (Section 6.3)
Weak base (NH_3)
pH
Acid-Base reactions
Bronsted-Lowry acids and bases
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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

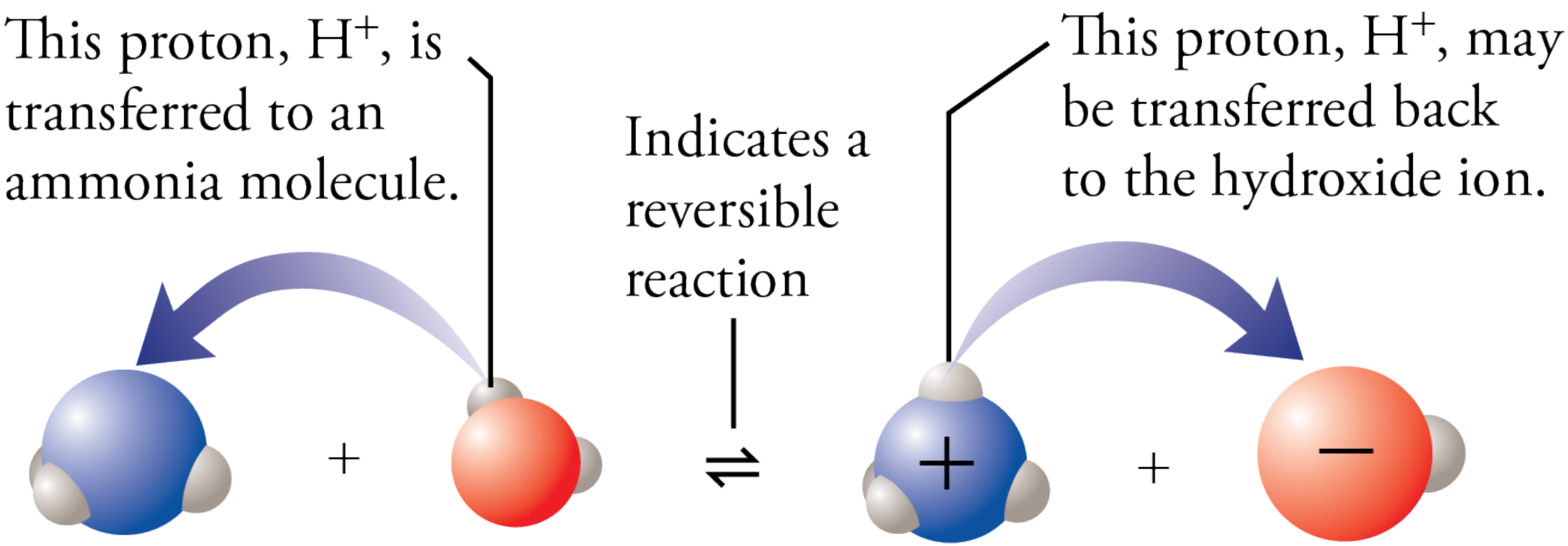
- Bases have a bitter taste.
- Bases feel slippery on your fingers.
- Bases turn litmus from red to blue.
- Bases react with acids.

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.

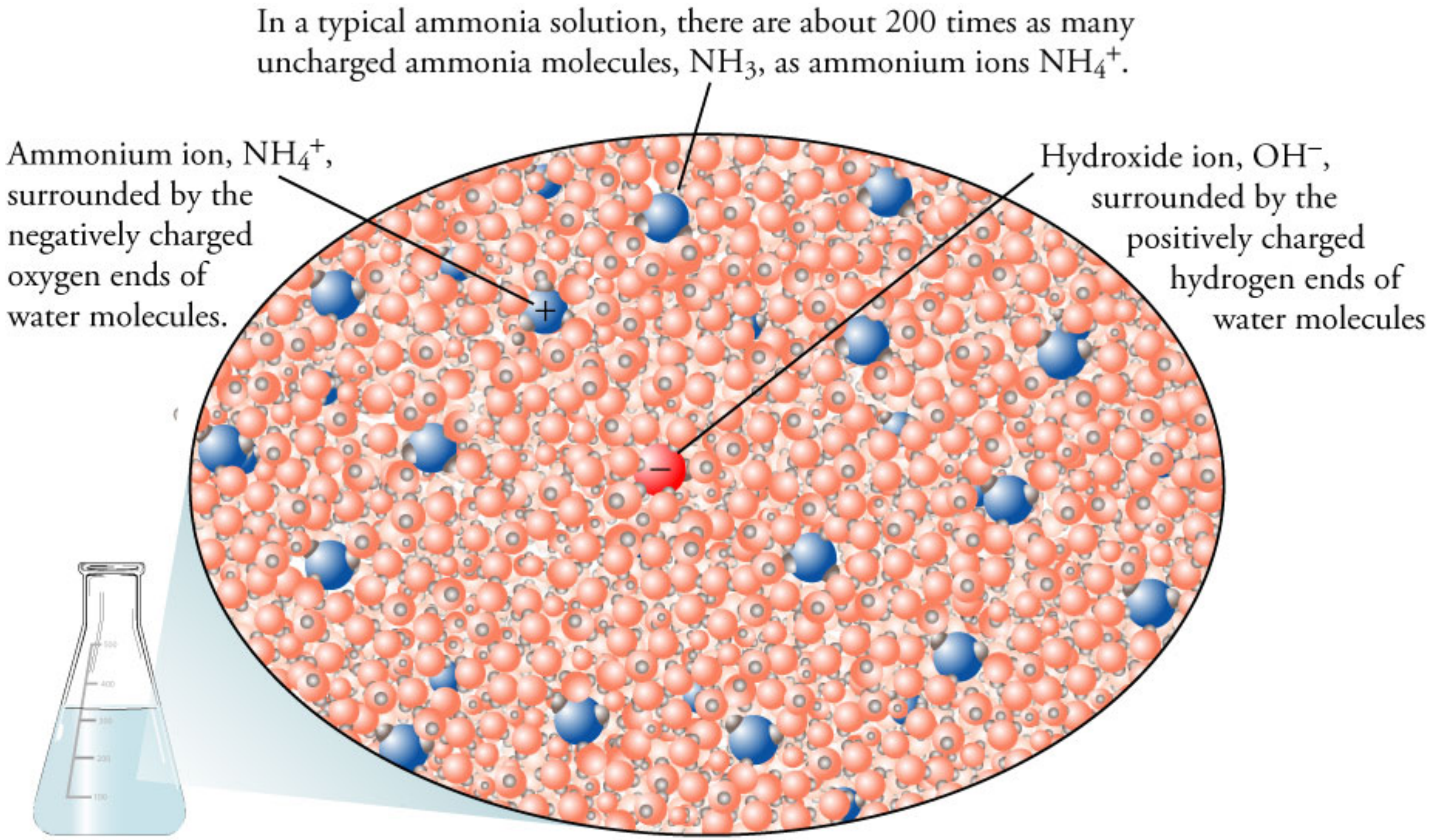


$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

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

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

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

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

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

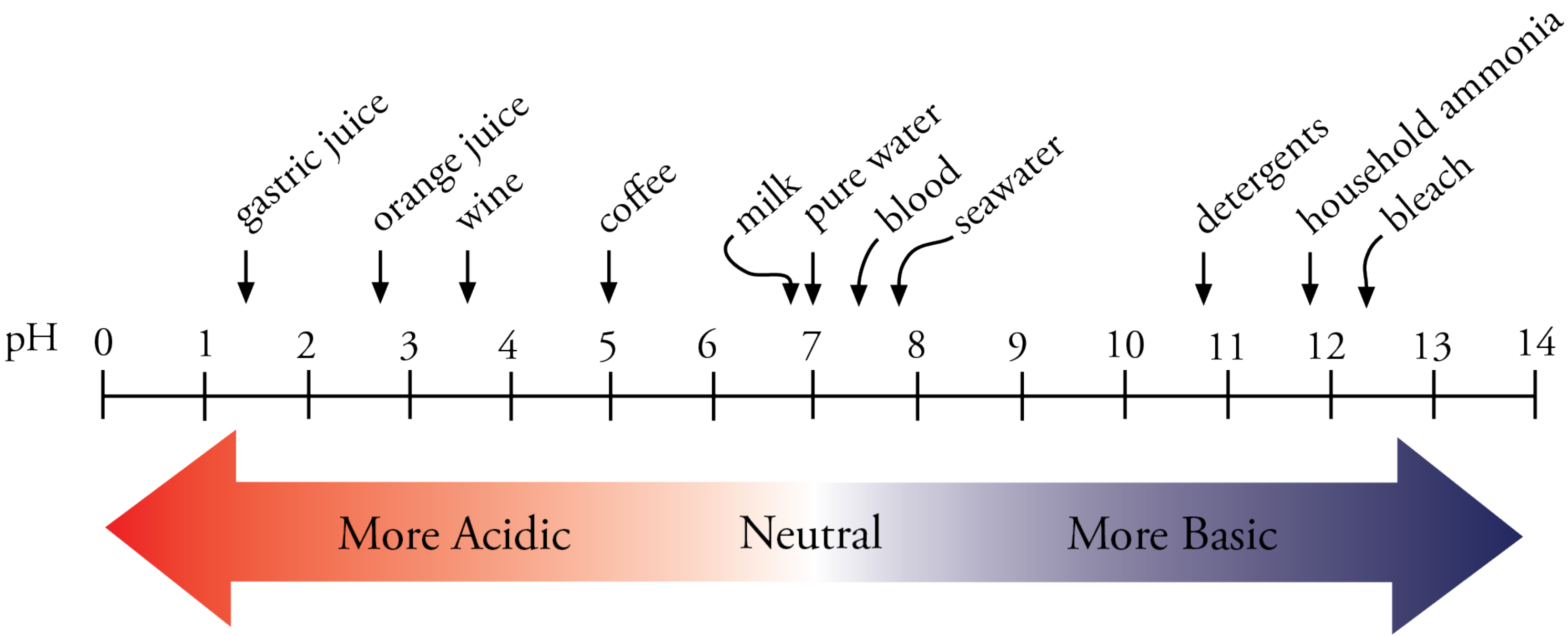
Arrhenius Bases

	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



Acidic solutions have pH values less than 7.

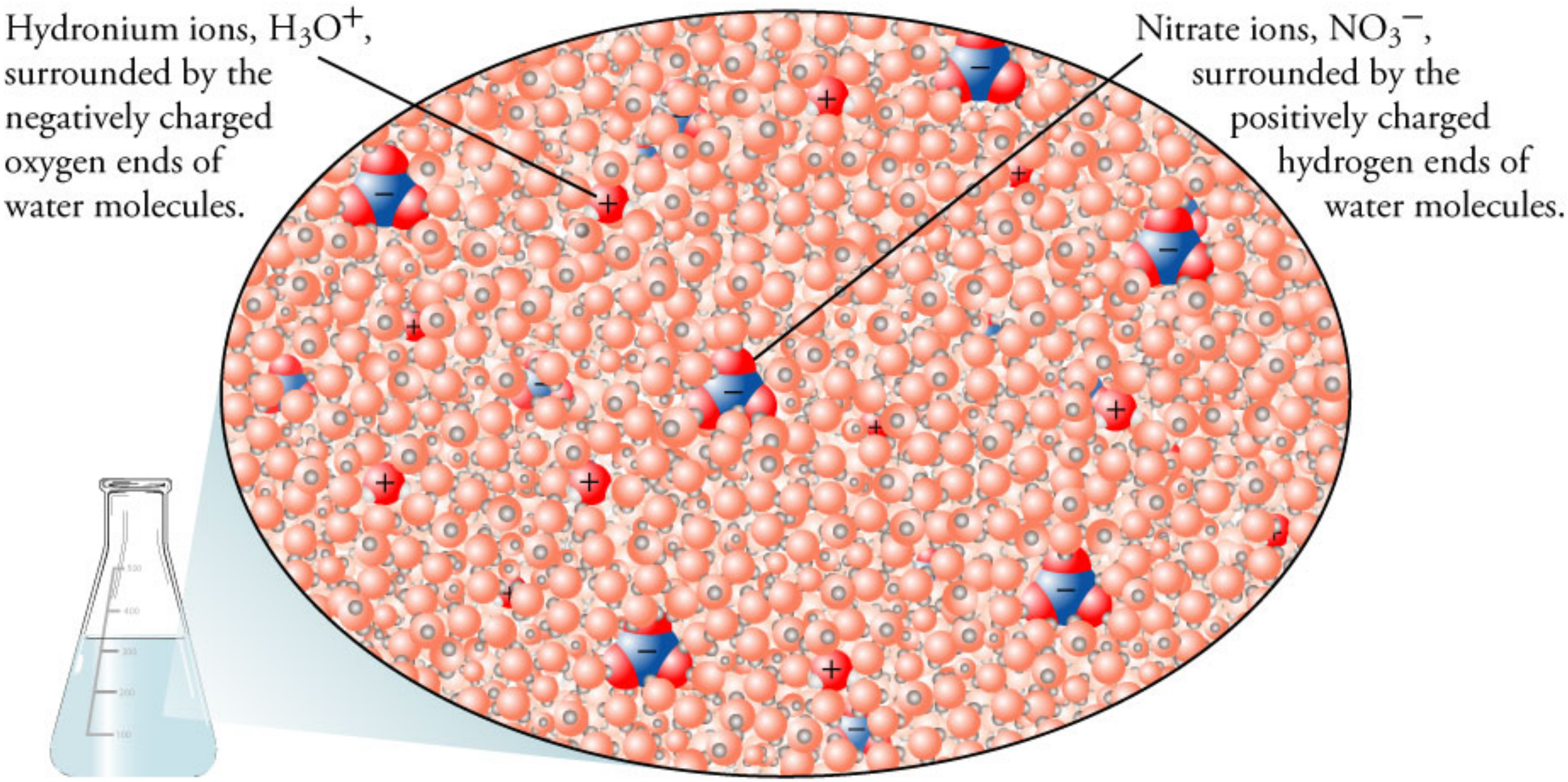
Basic solutions have pH values greater than 7.

Neutralization Reactions

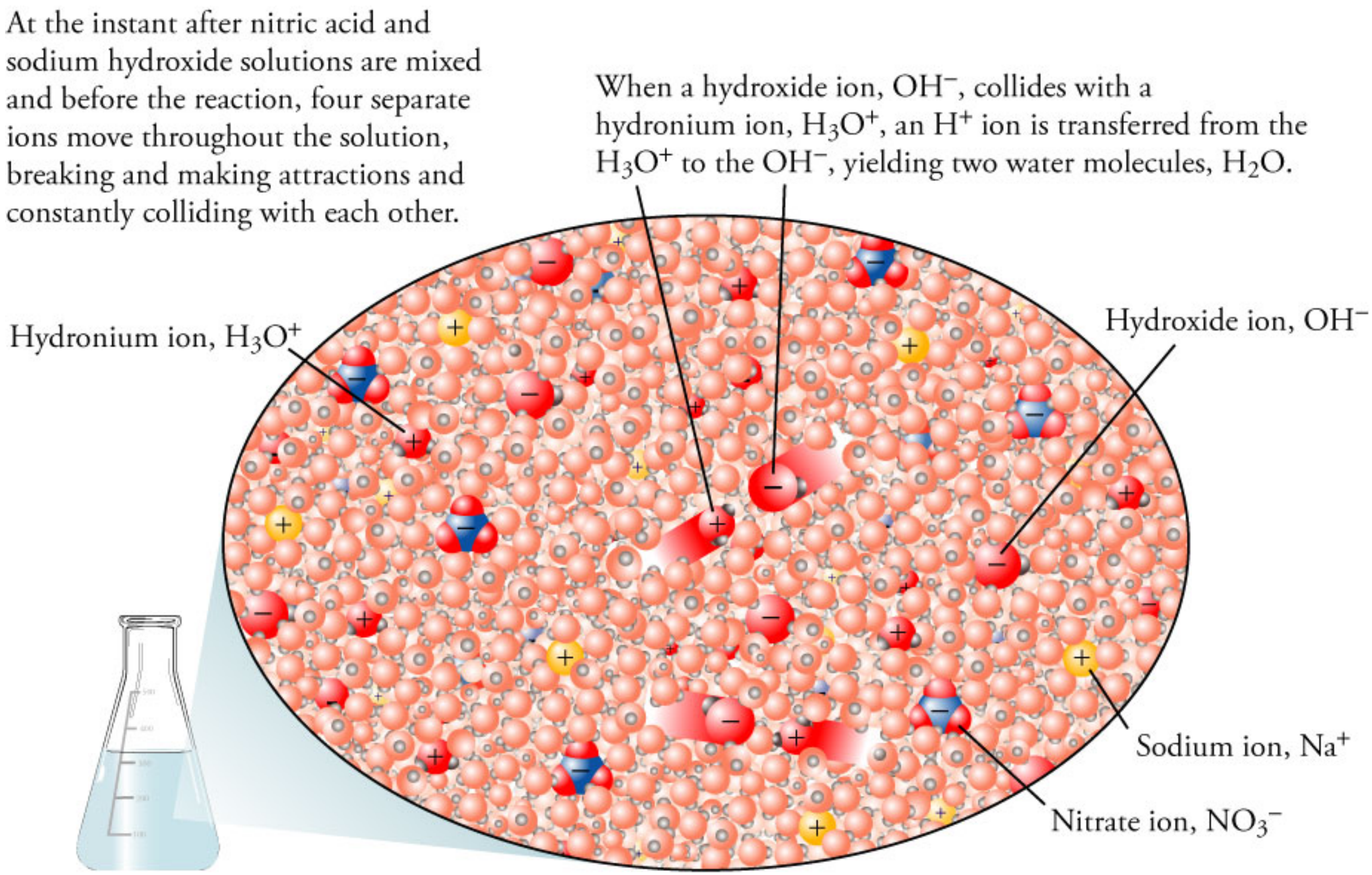
- Reactions between Arrhenius acids and Arrhenius bases are called ***neutralization reactions***.

$$HNO_3(aq) + NaOH(aq) \rightarrow H_2O(l) + NaNO_3(aq)$$

Aqueous Nitric Acid



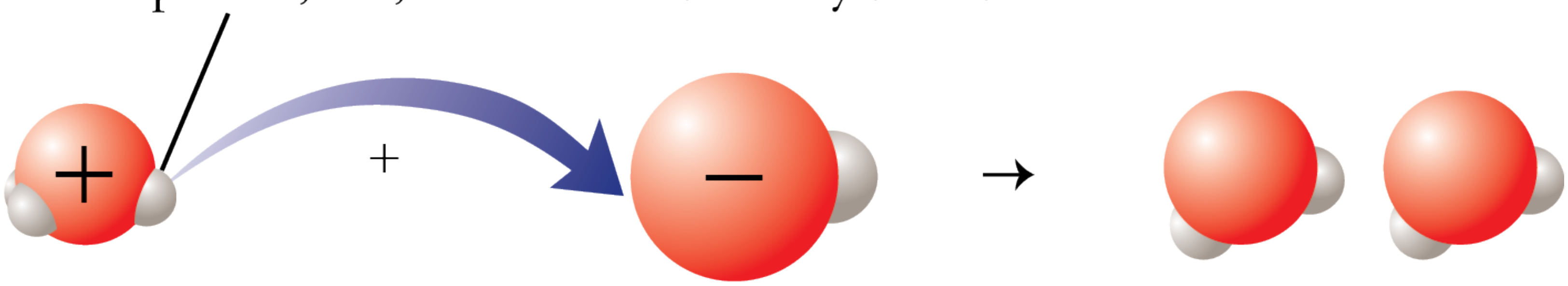
Mixture of HNO_3 and NaOH Before Reaction



Strong Acid and Strong Base Reaction

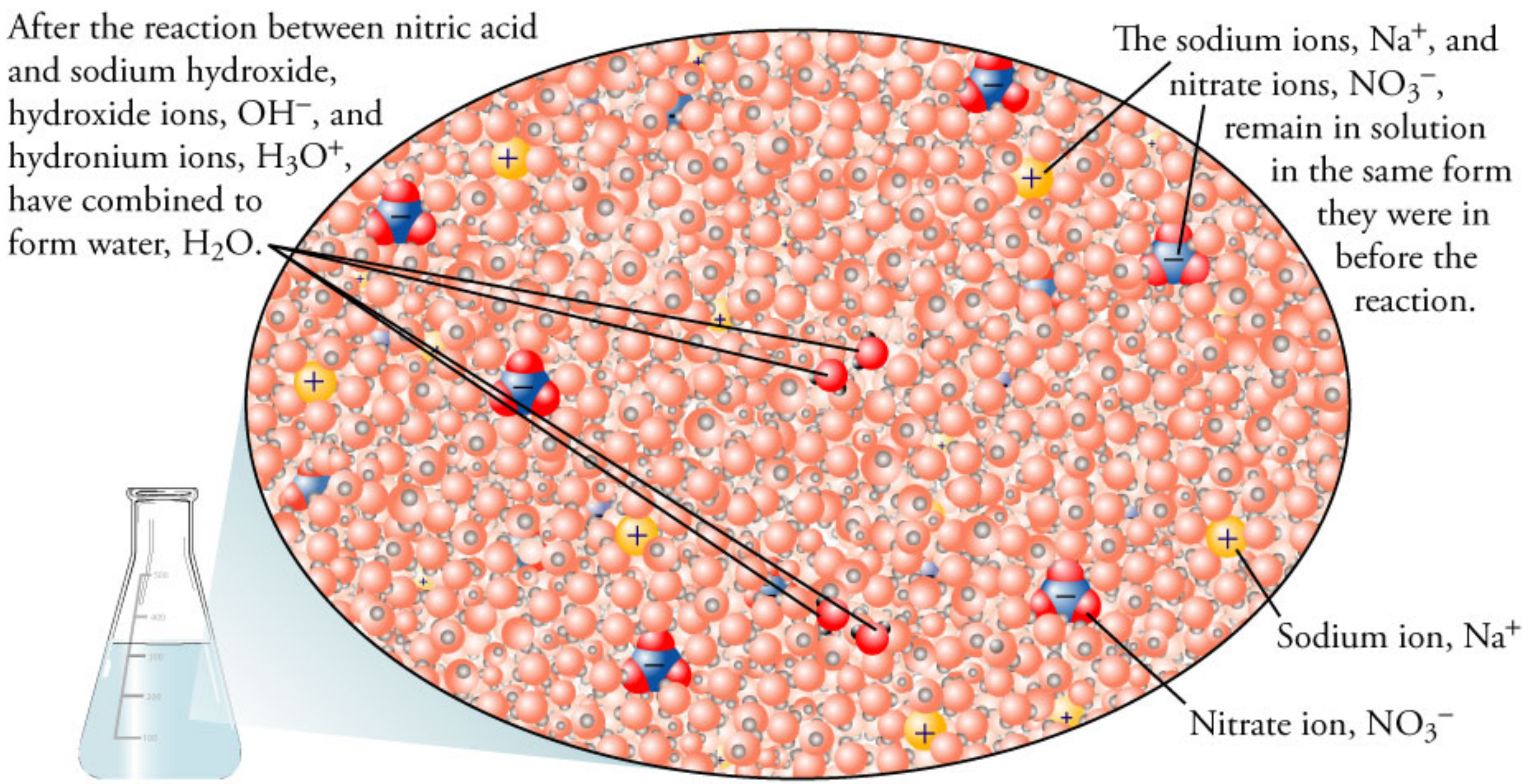
The hydronium ion, H_3O^+, from the strong acid reacts with the hydroxide ion, OH^-, from the strong base to form water, H_2O.

This proton, H^+, is transferred to a hydroxide ion.



$$H_3O^+(aq) \quad + \quad OH^-(aq) \quad \rightarrow \quad 2H_2O(l)$$

Mixture of HNO_3 and NaOH After the Reaction



https://preparatorychemistry.com/neutralization_Canvas.html

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.

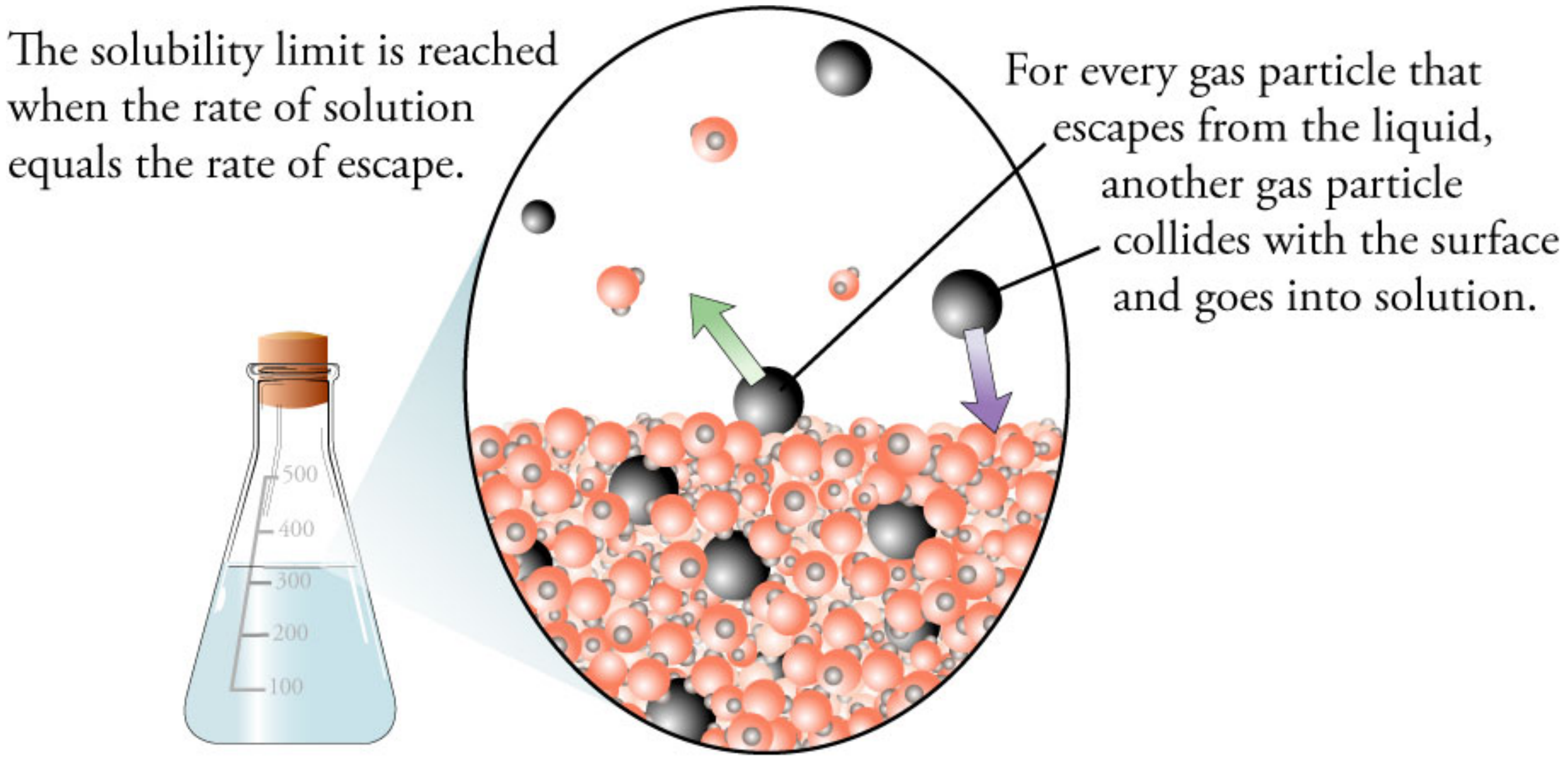
Reaction between an Acid and a Carbonate Base

- 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.

Dynamic Equilibrium for Gas Dissolved in Liquid



Oceanic Carbon

- Carbon enters the ocean mainly through solution of atmospheric carbon dioxide.

  $CO_2(g) \rightleftharpoons CO_2(aq)$

- The net rate of solution is determined by
  - the rate at which CO_2 molecules collide with the surface of the water and move into the water (R_{soln})
  - the rate at which CO_2 escapes from the water into the atmosphere (R_{escape}) , which is determined by the concentration of CO_2 in the water and the temperature of the water.
- If these two rates are equal, the system will be in equilibrium with no net change in the concentrations of CO_2 in the ocean or the atmosphere.

Gas Solubility

Add a gas above a liquid in a closed container

↓

Initially, the rate of solution is greater than the rate of escape → Net shift of particles into solution

↓

Increased rate of escape... ← Increased concentration of dissolved gas

↓

...Until the rate of escape equals rate of solution → Constant changes between dissolved and undissolved gas, but no net change in amount of either

Dynamic equilibrium (solubility limit) ←

Partial Pressure and Gas Solubility

- As the concentration of CO_2 in the atmosphere increases, the ocean absorbs more CO_2.
- Increased concentration of CO_2 in the atmosphere leads to an increase in the rate of collisions with the ocean, increasing the rate of solution, disrupting the dynamic equilibrium, making the $R_{soln} > R_{escape}$, and leading to a net shift of CO_2 into the ocean.

Increased partial pressure of a gas over a liquid in a system initially at dynamic equilibrium (Rate of solution = Rate of escape)

↓

Increased rate of collision between gas particles and liquid → Increased rate of solution

↓

Net movement of gas particles into solution ← Rate of solution greater than rate of escape

↓

Increased concentration of solute in solution → Increased rate of escape until it equals the higher rate of solution

↓

Greater solubility

Partial Pressure and Gas Solubility

- As the concentration of CO_2 in the atmosphere increases, the ocean absorbs more CO_2.
- Increased concentration of CO_2 in the atmosphere leads to an increase in the rate of collisions with the ocean, increasing the rate of solution, disrupting the dynamic equilibrium, making the $R_{soln} > R_{escape}$, and leading to a net shift of CO_2 into the ocean.

CO_2 and Ocean Acidity

- CO_2 molecules react with water to form carbonic acid.

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

- Carbonic acid reacts with water to form hydronium and hydrogen carbonate ions.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

CO_2 and Ocean Acidity

- The absorption of human generated CO_2 has acidified the surface layers of the ocean, with a steady decrease of about 0.02 pH units per decade over the past 30 years and an overall decrease since the pre-industrial period of 0.1 pH units.
- Because the pH scale is a logarithmic scale, this is a 30% increase in hydronium ion concentration
- This leads to substantial changes in ocean chemistry.

Effects of Increasing Ocean Acidity

- Carbonate ions combine with calcium ions in the ocean to form calcium carbonate, which forms shells, skeletons for coral reefs and other sea organisms, and other $CaCO_3$ structures of sea organisms.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s)$$

- Hydronium ions react with carbonate ions to form hydrogen carbonate ions, decreasing the carbonate ions available to build and maintain calcium carbonate structures.

$$H_3O^+(aq) + CO_3^{2-}(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$$

Effects of Increasing Ocean Acidity

- Ocean acidification affect organisms in other ways than decreasing carbonate ions. For example,
  - seagrasses may grow faster if more dissolved carbon dioxide is available,
  - the number of oysters may decrease as fewer larvae complete their life cycle,
  - the ability of some fish, such as clownfish, to detect predators and find suitable habitats decreases in more acidic waters, threatening the whole ocean food web.