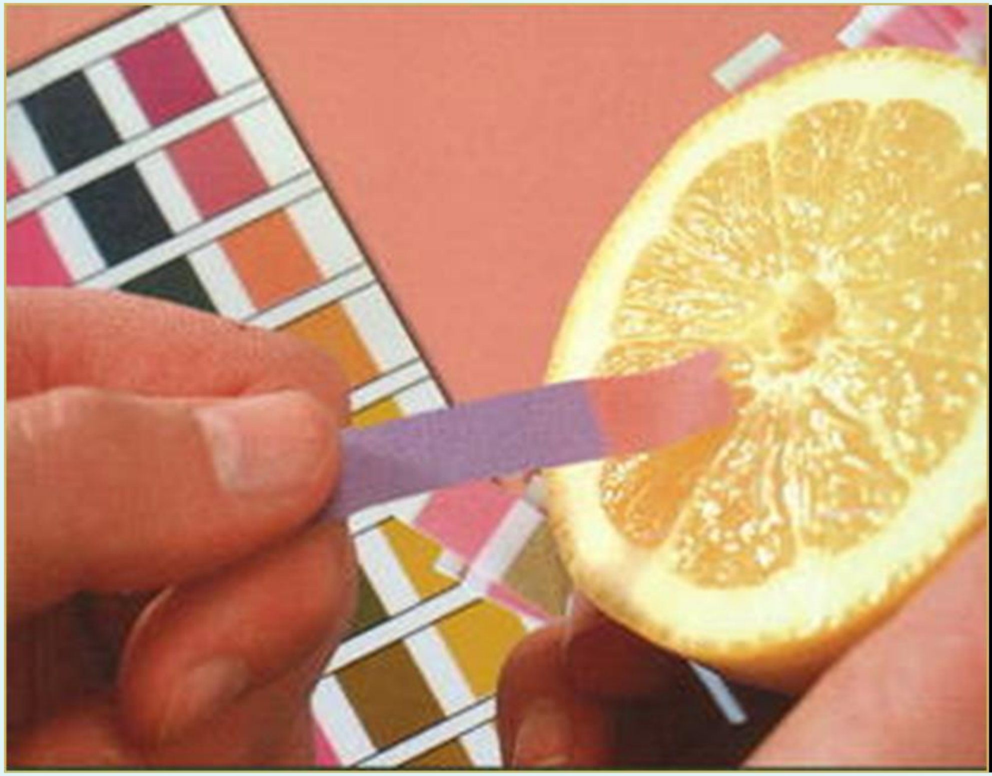


Chapter 8B
Acids and Bases

Properties of Acids & Bases

Neutralization Reactions

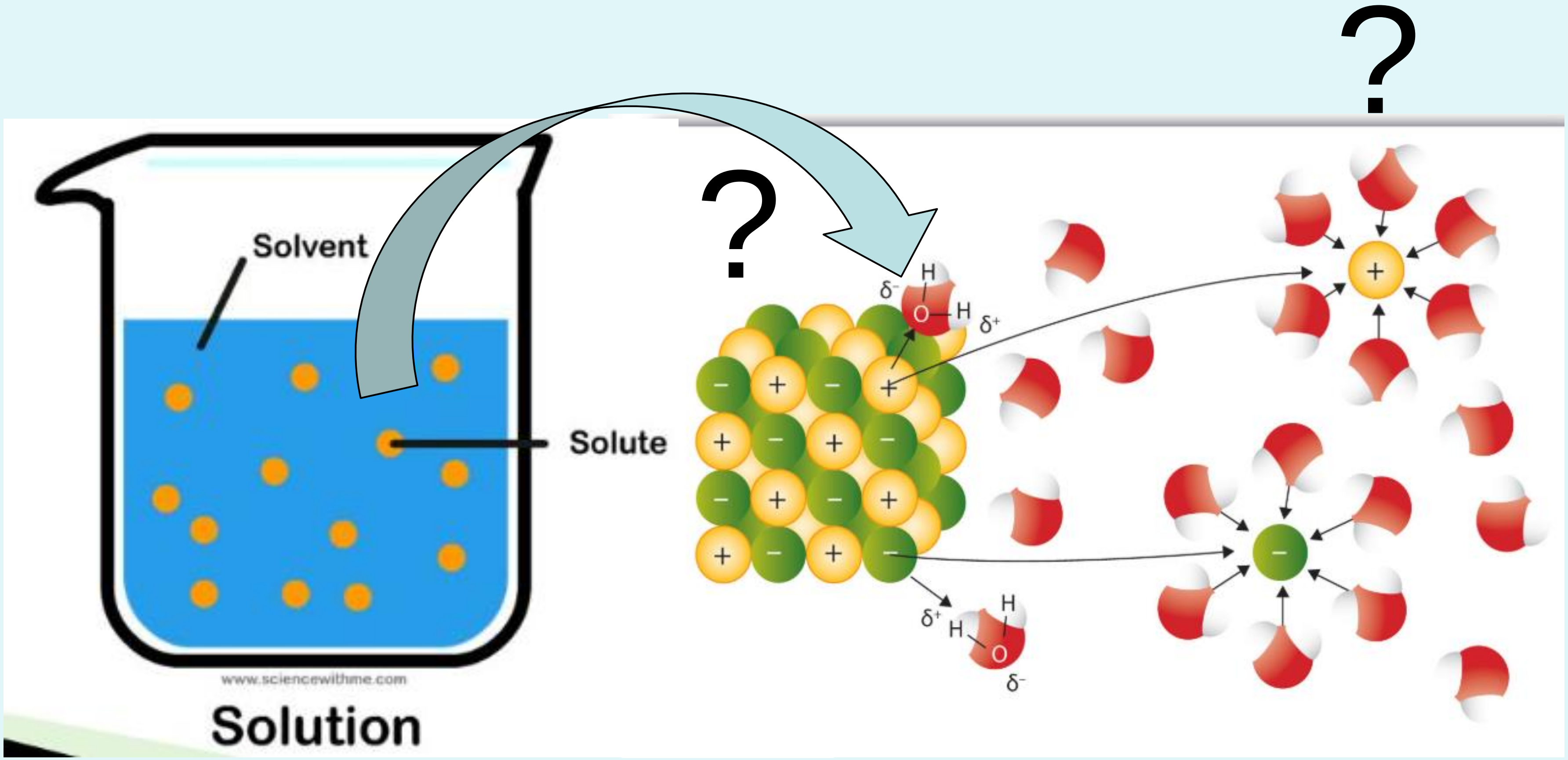
Salts in Solution

Strengths of Acids and Bases

WARM-UP

Label the items

The most important solvent to the chemical world is water **due to its** _____ etc.



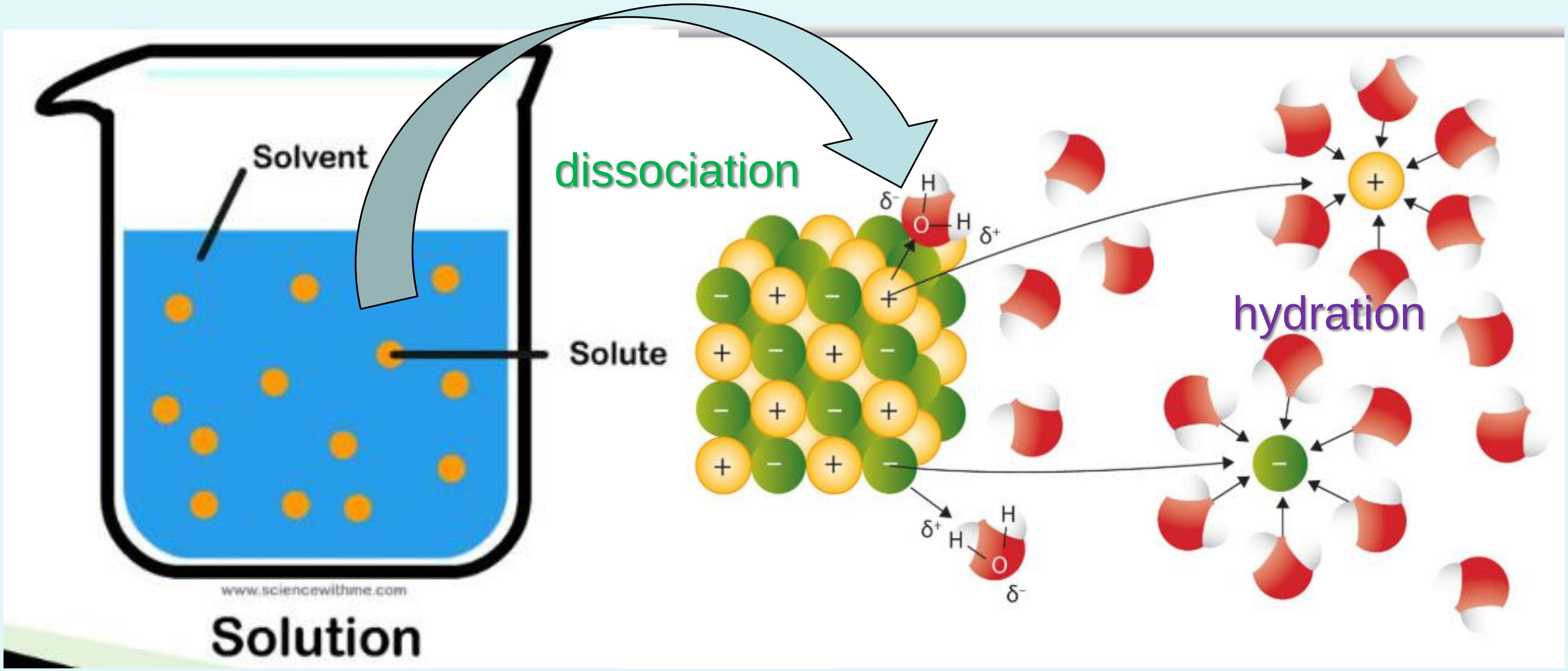
WARM-UP

Dissociation of Water

The most important solvent to the chemical world is water **due to its polarity**.

Water breaks up the solute → **dissociation**

Water surrounds the cations and anions → **hydration**



Acids & Bases
Focus Points

- Explain & identify acids and bases in terms of properties.
- Predict the products of acid-base neutralization reactions.
- Describe acids as proton donors and bases as proton acceptors.
- Define pH and use the pH scale to characterize the acidity and basicity of solutions and the properties of acids and bases.
- Differentiate between strong and weak acids and bases based on dissociation and ionization and related to buffers and electrolytes.

Dissociation of Water

It is easy to forget the important role of water compared to the role of the solute. For example, milk, orange juice, coffee, tea, soft drinks, etc. all have water as the solvent.

$$2H_2O \rightleftarrows H_3O^+_{(aq)} + (OH)^-_{(aq)}$$

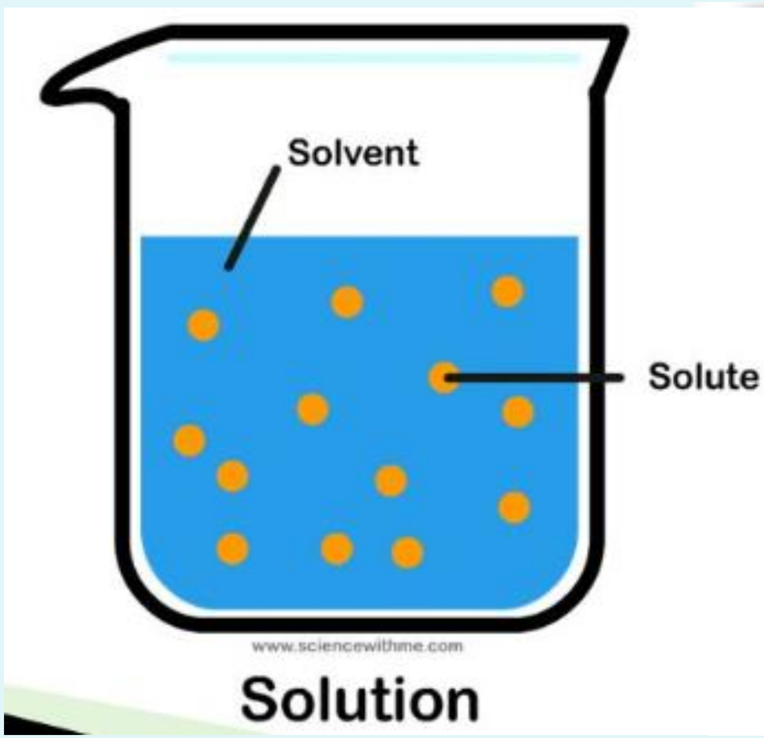
Hydronium ion **Hydroxide ion**

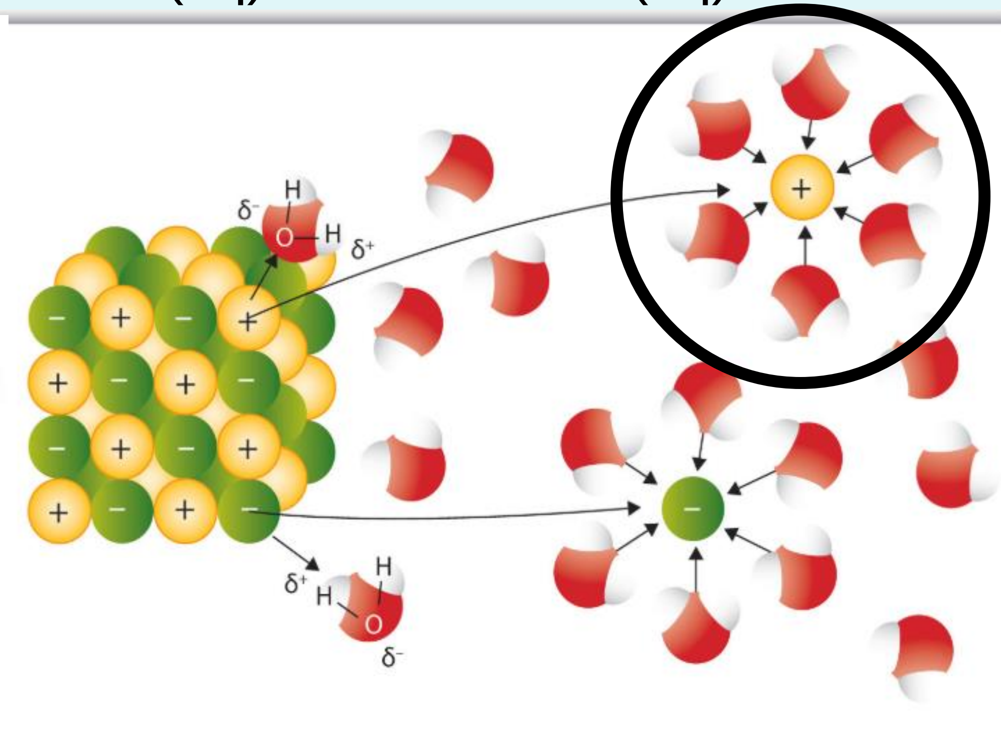
Water only SLIGHTLY dissociates into ions as described by the equilibrium expression: $[H^+][OH^-] = 1.0 \times 10^{-14}$.

Hydration of Water around H+ ions

Water surrounds the **H^+** cations in the dissociation process. This is represented by **hydronium ion (H_3O^+)**.

$$2H_2O \rightleftharpoons H_3O^+_{(aq)} + (OH)^-_{(aq)}$$





Dissociation of Pure Water

In pure water at 25 ºC, the concentration of hydronium ions ($[H_3O^+]$) is only 1×10^{-7} *M*.

The concentration of hydroxide ions ($[(OH)^-]$) is also 1×10^{-7} *M*.

The numbers of H_3O^+ and $(OH)^-$ ions are equal in pure water.

Pure water

$[H^+] = [OH^-]$

$$[H^+] \times [OH^-] = [H^+]^2 = 1.0 \times 10^{-14}$$

$$[H^+] = 10^{-7} = [OH^-]$$

Arrhenius

- **An acid** is a substance that when dissolved in water increases **H_3O^+ (or H^+) concentration**.
- **A base** is a substance that when dissolved in water increases (**OH**)$^-$ **concentration**.
- $k_w = [H^+][(OH)^-]$ … water

Acidic Solutions

STRATEGY

A substance that increases the concentration of H^+ (H_3O^+) ions in solution.

H^+: hydrogen ion … H_3O^+: hydronium ion

$$k_w = [H^+][(OH)^-] = 10^{-14}$$

In acidic solutions, the hydronium-ion concentration is greater than 1×10^{-7} *M*.

$$HCl + H_2O \rightarrow \mathbf{H_3O^+} + Cl^-$$

The solution (reactants) is called hydrochloric acid.

Examples of Acids

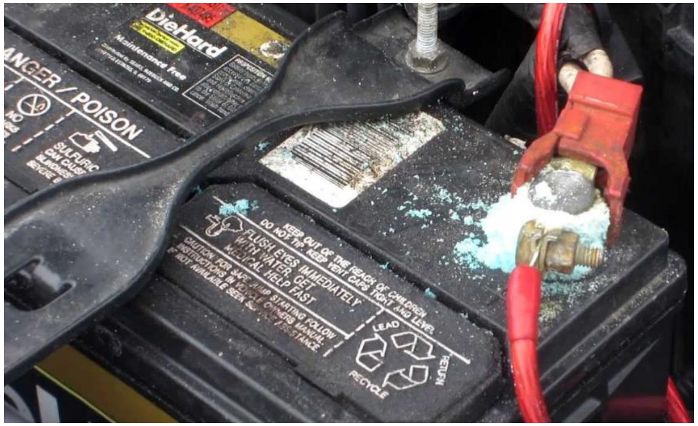
Hydrochloric acid (**H**Cl) …stomach acid

Sulfuric acid (H_2SO_4) … battery acid

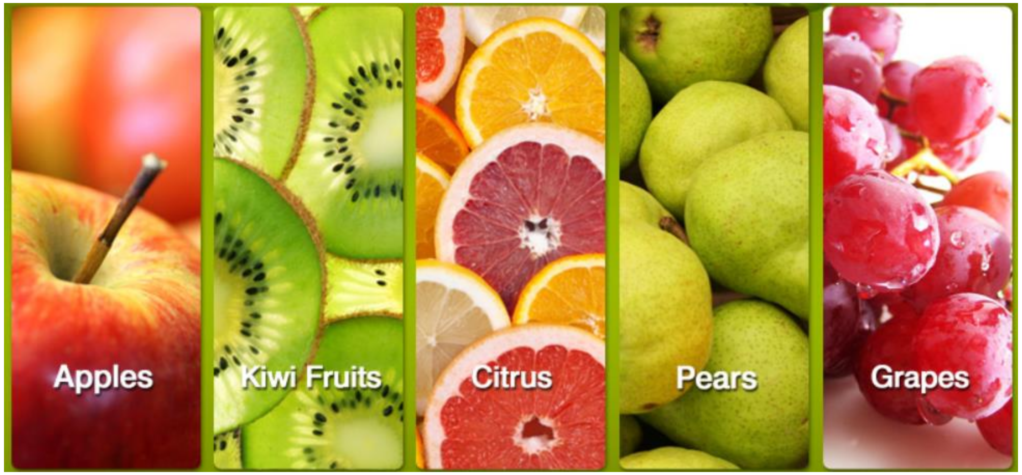
Acetic acid (HCH_3COO) … vinegar

Nitric acid (HNO_3) … explosives, fertilizer

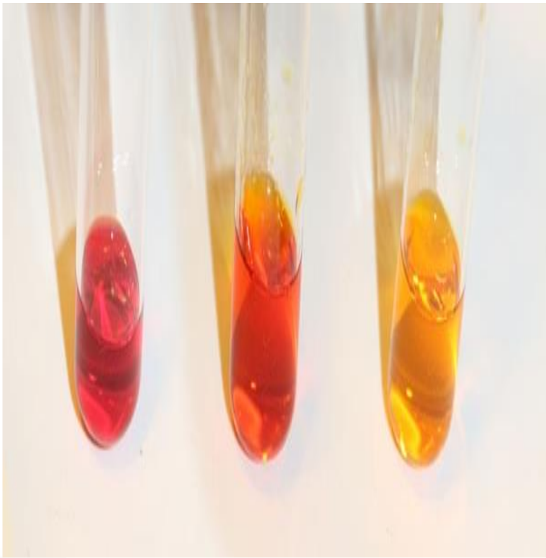
Carbonic acid (H_2CO_3) … soda water



Chemical and Physical Properties of Acids



- Have a sour taste
- Turn blue litmus paper red
- Are neutralized by bases
- React with metals



Basic Solutions

A substance that increases the concentration of $(OH)^-$ ions in solution.

$$k_w = [(OH)^-][H^+] = 10^{-14}$$

The **hydroxide-ion** concentration is greater than $1 \times 10^{-7}\ M$.

Basic solutions are also known as alkaline solutions (e.g. alkaline batteries).

Examples of Bases

- Deodorant: $Al(OH)_3$
- Drain Cleaner:

  Sodium hydroxide ($NaOH$)
- Fertilizer/soap:

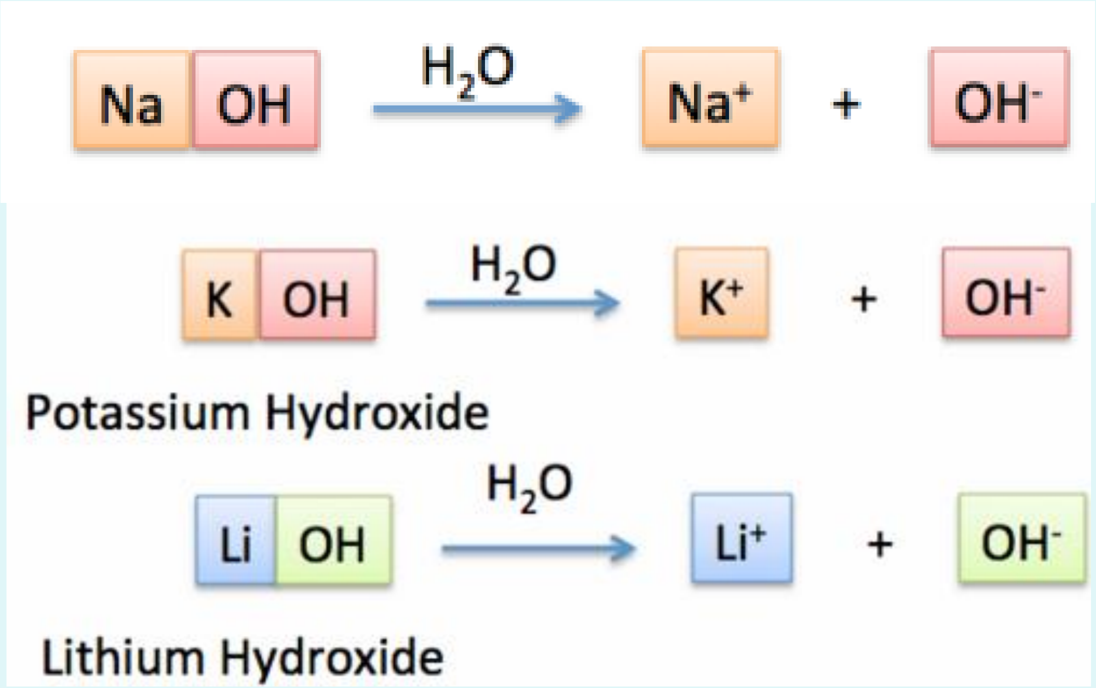
  Potassium hydroxide (KOH)
- Limewater:

  Calcium Hydroxide $Ca(OH)_2$

$K(OH)$

Arrhenius Bases

Ionic compounds that dissociate into $(OH)^-$ ions in an aqueous solution.



Chemical and Physical Properties of Bases

- Taste bitter
- Feel slippery
- Turn red litmus paper blue
- Turn colorless phenolphthalein pink
- Neutralize acids

Acids and Bases SUMMARY

Acids and bases are based on the ___ of water: $H^+(OH^-)$.

- Acids [___], bases [___].
- Acids taste ___; bases taste ___
- Litmus turns ___ in an acid and ___ in a base

?

?

Acids and Bases SUMMARY

Acids and bases are based on the dissociation of water: $H^+(OH^-)$.

- Acids [H_3O^+], bases [OH^-].
- Acids taste sour; bases taste bitter
- Litmus turns red in an acid and blue in a base

Muppets Take Chemistry!

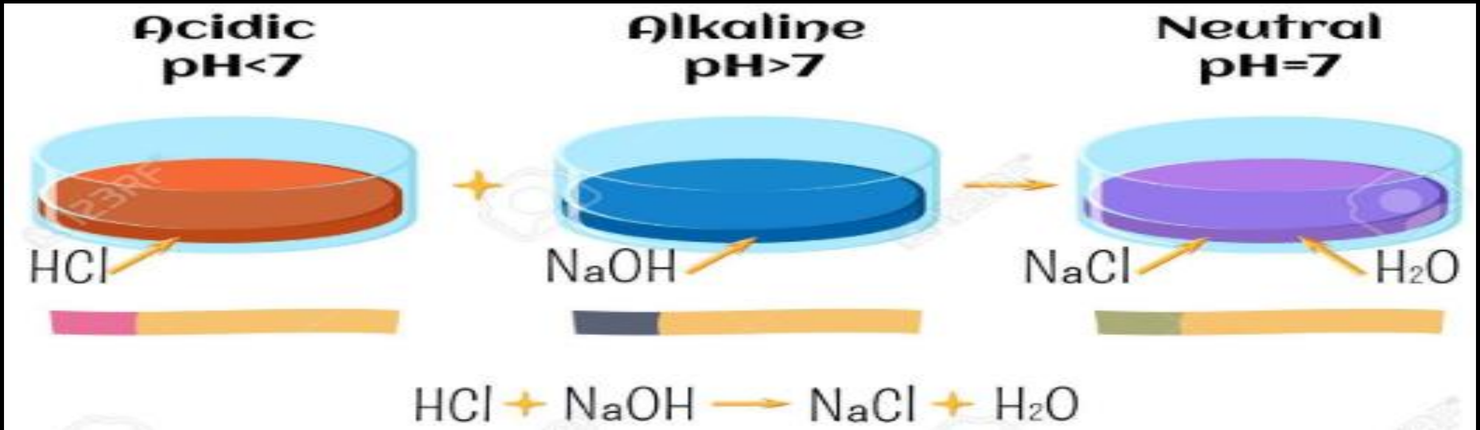
Rainbow Connection

http://somup.com/cFX603niZO (4:04)

Neutralization

- **Neutralization** is the complete reaction of a STRONG acid with a STRONG base to produce a neutral solution.
- A neutral solution has a pH of 7 because it contains equal concentrations of hydrogen ions (H+) and hydroxide ions (OH-).

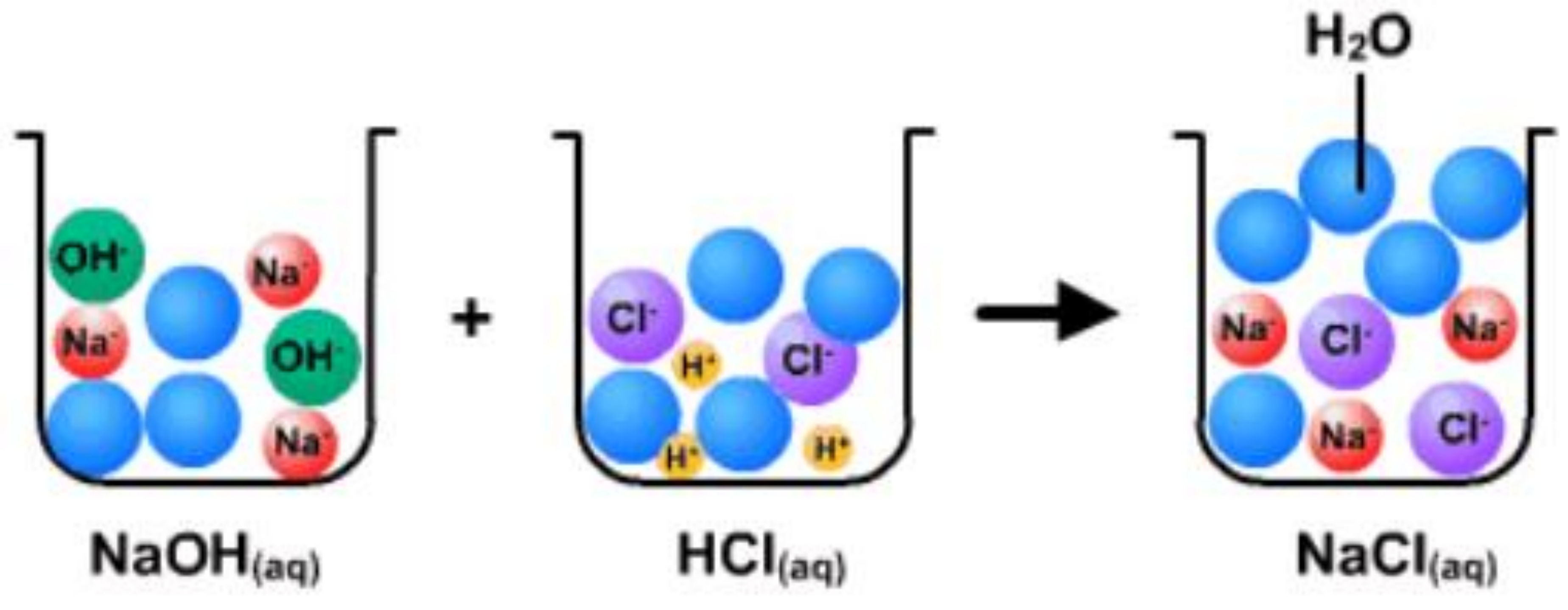
$$[H^+] = [OH^-]$$



Neutralization

The general equation for an acid base neutralization:

Acid + Base → Salt + Water



Neutralization

STRATEGY

The general equation for an acid base neutralization:

Acid + Base → Salt + Water

Salt = the anion from an acid and the cation from a base

$KOH \longrightarrow K^+ + OH^-$

$HBr \longrightarrow H^+ + Br^-$

$KOH + HBr \longrightarrow KBr + H_2O$

↑

Salt

Neutralization Reactions in Everyday Life

- Antacids neutralize excess stomach acid.

$NaHCO_3 + HCl \rightarrow H_2O + NaCl + CO_2$

$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

- Toothpaste contains antacids to cancel acids that would damage teeth.

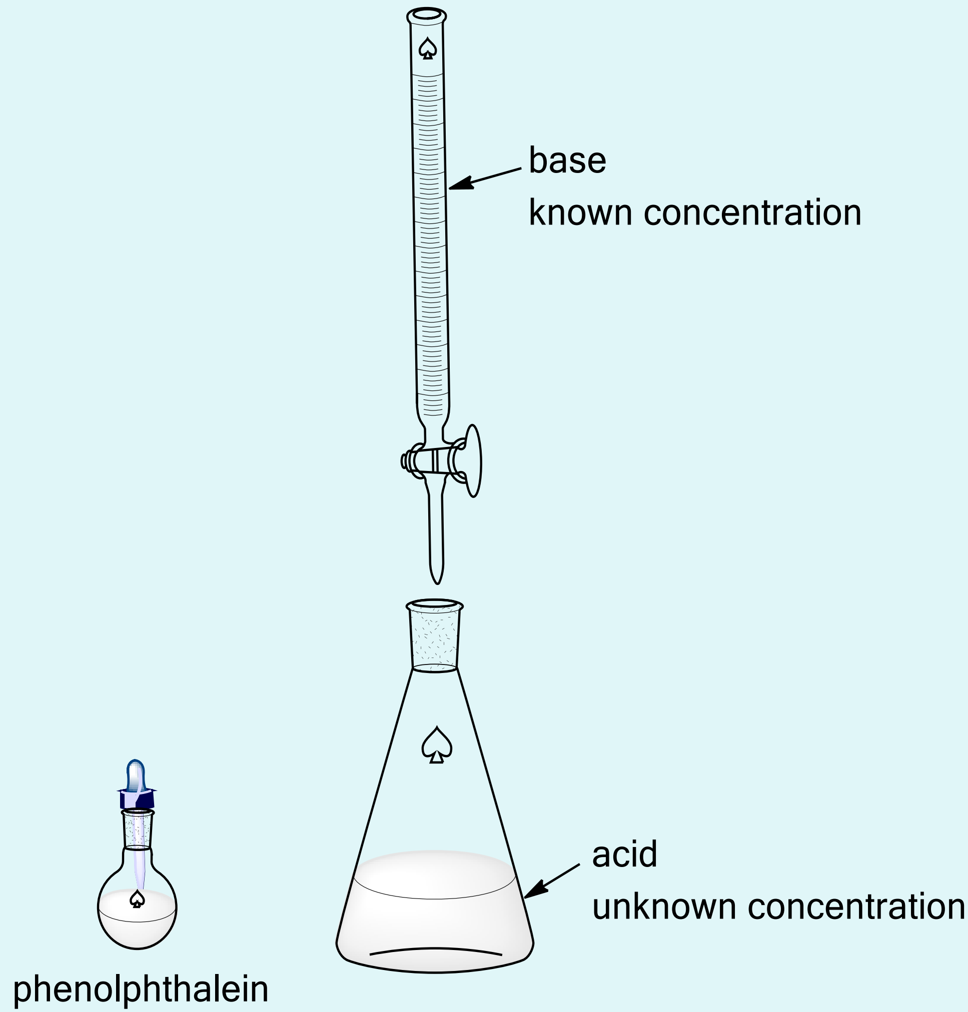
- Lime (calcium hydroxide) is used to neutralize acidic soil.

Titration

Enrichment

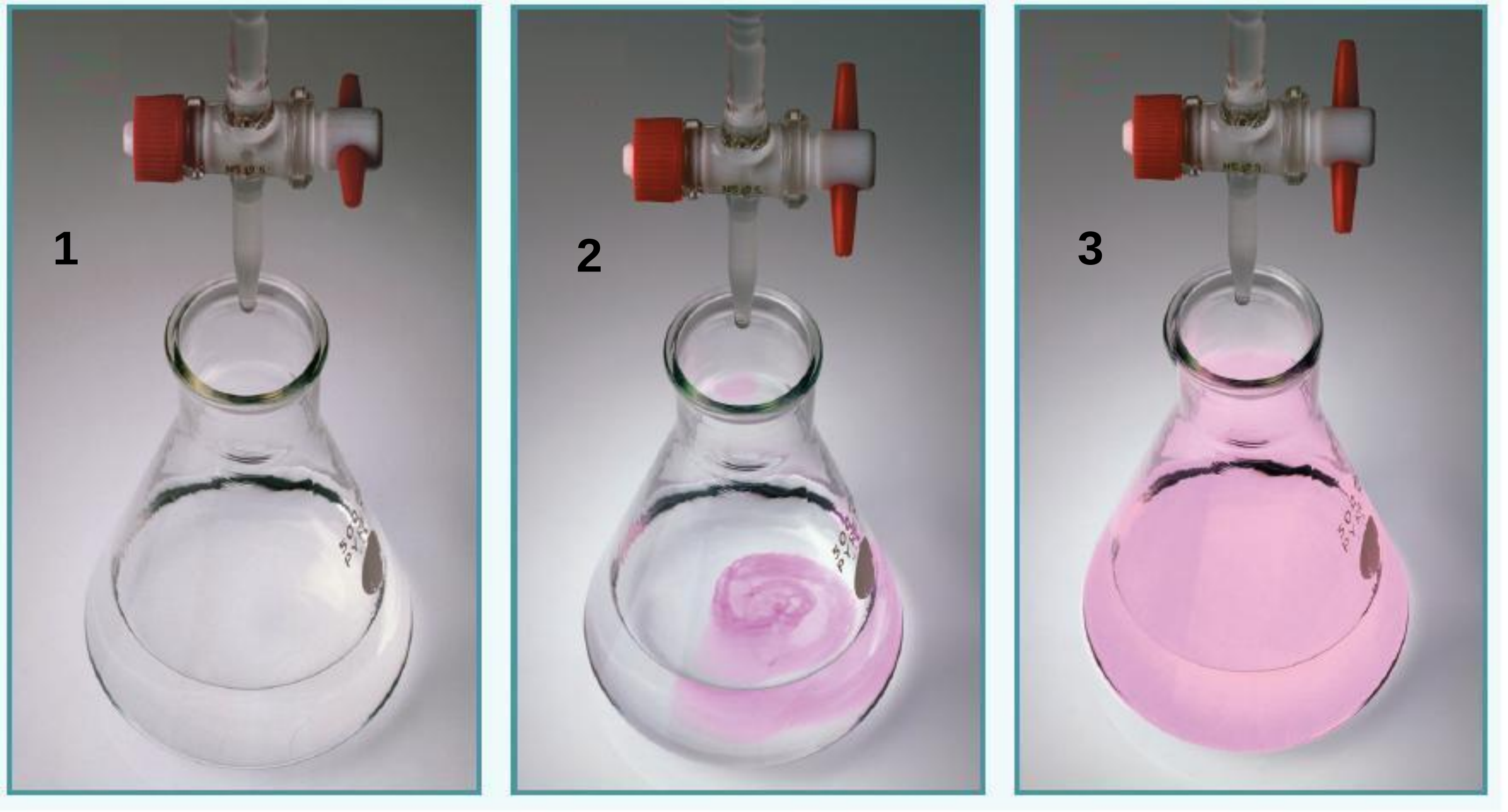
Chemists use a neutralization reaction to determine the concentration of an acid or base.

The process of adding a measured amount of a solution of **known concentration** to a solution of **unknown concentration** is called a **titration**.



https://screencast-o-matic.com/watch/cqfZDaZyxB (1:18)

Titration Enrichment



A flask with a known **volume** of **acid** (and an indicator) is placed beneath a burette that is filled with a base of known **concentration**.

The **base** is slowly added from the burette to the acid.

A stable change in the color of the solution is the signal that **neutralization** has occurred.

Titration Enrichment

- Used to determine the composition or concentration of acids and bases in solution.
- Used to analyze mixtures.
- Used in nearly every laboratory: university, power plants, breweries, etc.
- Titration is one of the most precise methods of chemical analysis [*"Coke," "Pepsi," candy bars, prescription drugs, medicines, coloring in foods & clothing, flavorings, sewage treatment, paint mixing, food testing, water testing, fuels, pregnancy tests, etc.]*

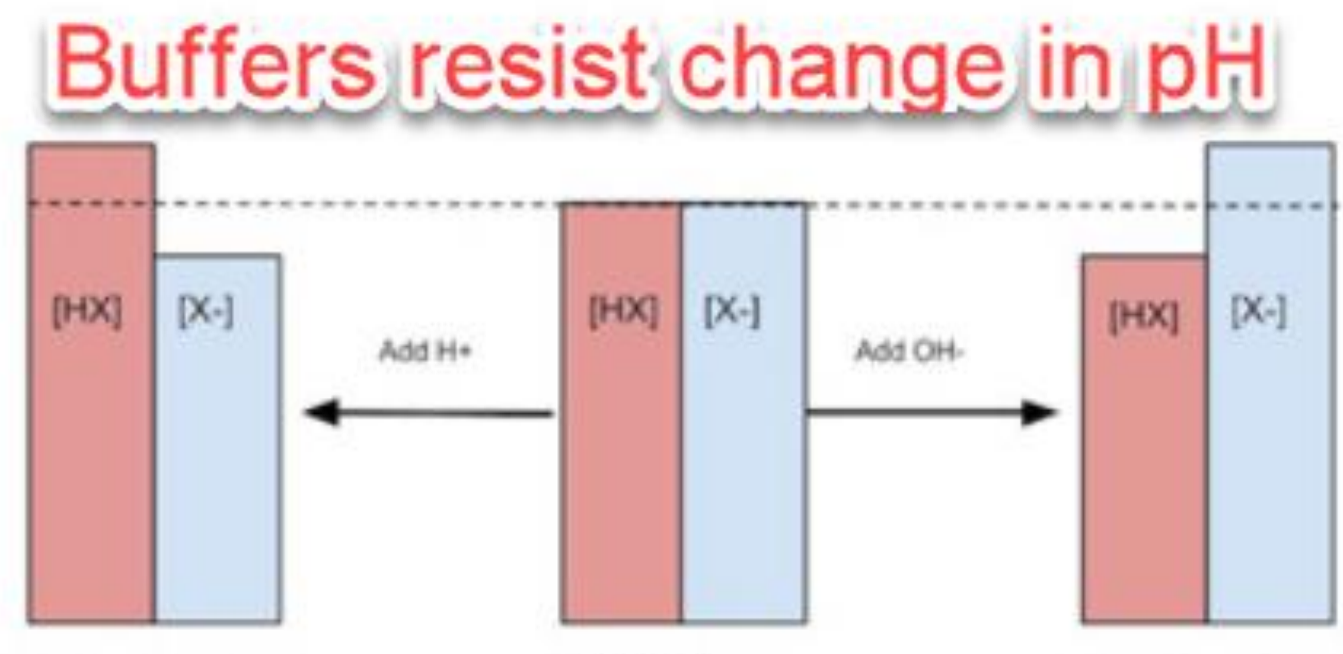
Example: *Something splashes in your eyes. You're not sure what it is … it burns. What should you do?*

- Get a sample of what went into your eye
- Dilute your eye with water for about 15-20 minutes
- Get to the hospital … the lab will TITRATE the substance to determine if it is an acid or a base … then neutralize it.

Buffers

A **buffer** is an water solution that has a highly stable pH.

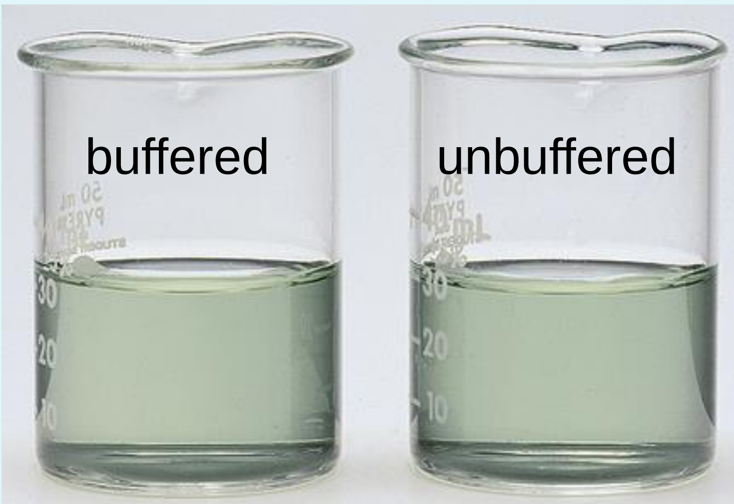
- If you add acid or base to a buffered solution, its pH will not change significantly.



Buffers can be prepared by mixing a weak acid and its salt or a weak base and its salt.

Buffers

Observe what happens when 1.0 mL of 0.10*M* HCl solution is added to buffered and unbuffered solutions.



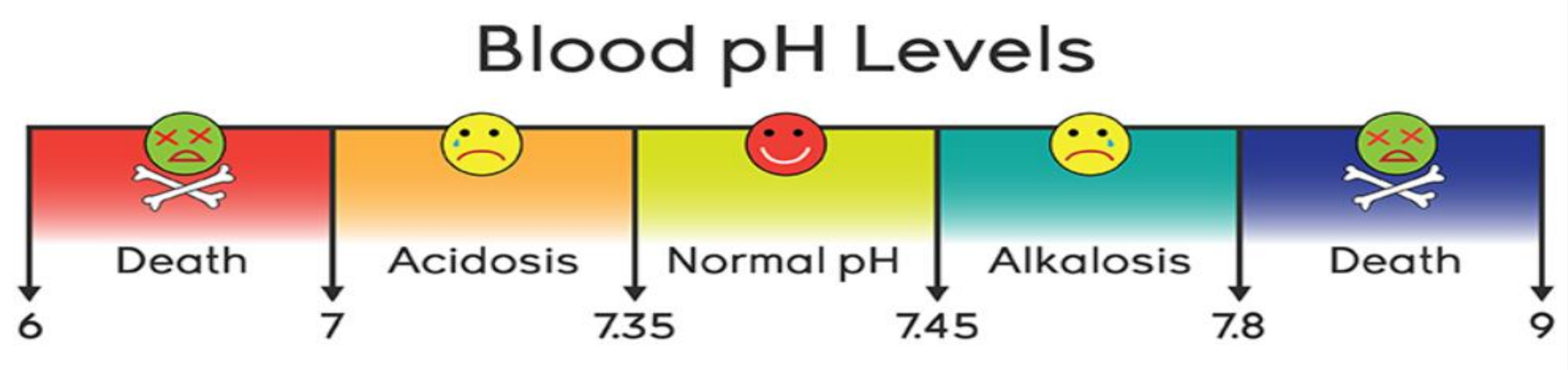
PRIOR to adding acid, the indicator shows that both solutions are basic (pH of about 8).

HCl is added to each solution.

The indicator shows no visible pH change in the buffered solution.

The color change in the unbuffered solution indicates a change in pH from 8 to about 3.

Buffers



Buffers cause neutralization reactions that will not have much effect on the overall pH of the buffer solution.

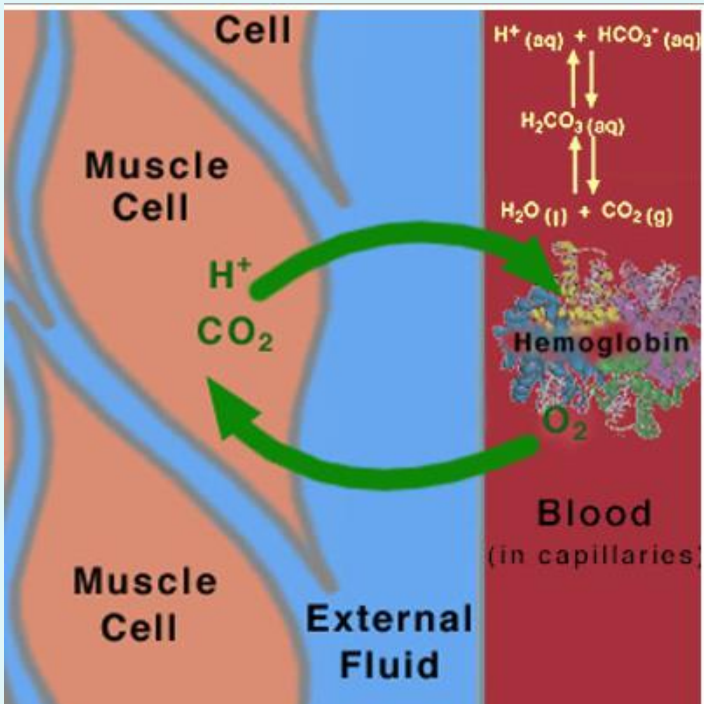
- When hydronium ions are added to a buffer, they will be neutralized by the base in the buffer.
- Hydroxide ions will be neutralized by the acid.

How Buffers Work

A buffer solution is better able to resist drastic changes in pH than pure water since water dissociates so little ($k_w = 10^{-14}$).

A buffer solution contains one component that can react with hydronium ions (hydrogen-ion acceptor) and one that can react with hydroxide ions (hydrogen-ion donor).

These components act as “reservoirs” of neutralizing power that can be tapped when either hydronium ions or hydroxide ions are added to the solution.



Buffer Capacity

Buffers work best in environments with specific pH ranges.

For basic solutions, use a buffer with higher pH range (10.01).

For acidic solutions, use a buffer with lower pH range (4.01).

For neutral solutions, use a buffer with neutral pH range (7.00).

TRY IT

[redacted] ?

Sulfuric acid reacts with sodium hydroxide as shown. What are the general names of the substances produced?

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O.$$

_____ + _____

This type of reaction is called ___.

Which combination of solutes will form a solution that is resistant to pH changes?

a. weak acid and water
b. weak acid and strong base
c. weak acid and its salt
d. strong acid and its salt

TRY IT

Neutralization

Sulfuric acid reacts with sodium hydroxide as shown. What are the general names of the substances produced?

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O.$$

Salt + water

This type of reaction is called **neutralization**.

Which combination of solutes will form a solution that is resistant to pH changes?

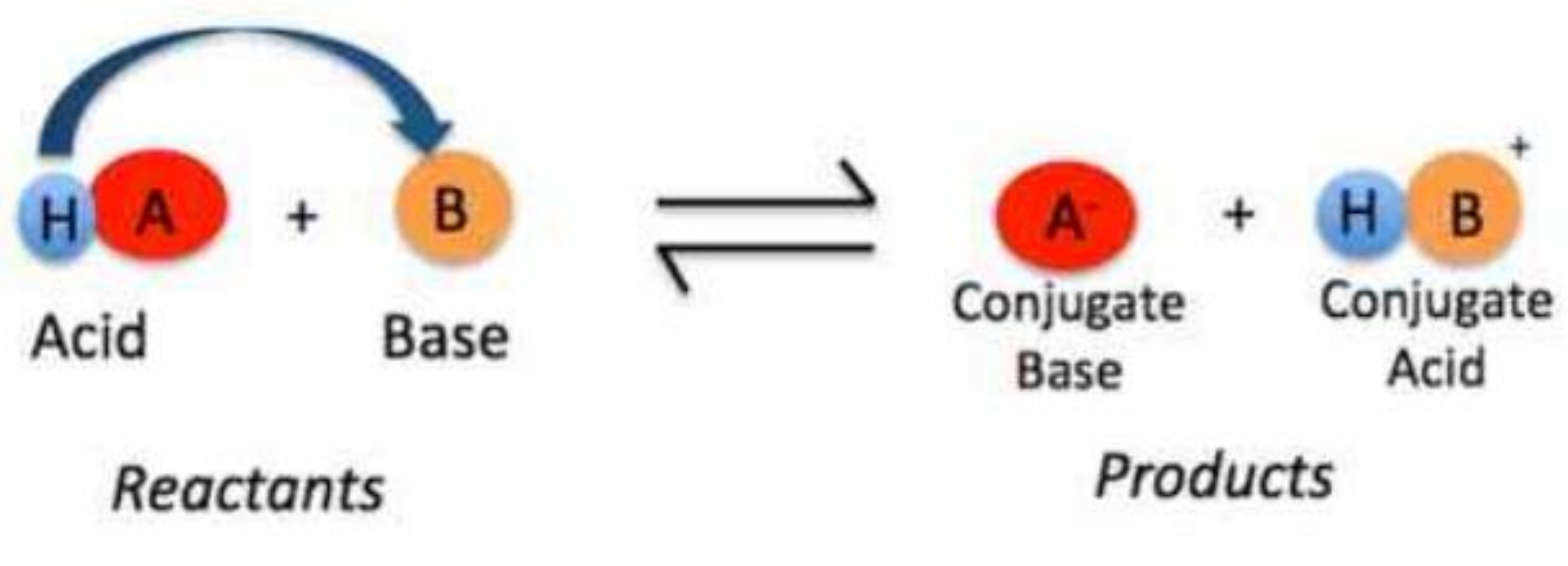
a. weak acid and water
b. weak acid and strong base
c. weak acid and its salt
d. strong acid and its salt

Proton Donors and Acceptors

Brønsted-Lowry

- *A more general definition of acids and bases*
- *Extends the Arrhenius theory*
- *Includes other solvents beside water*

An acid-base reaction in which there is a proton (H^+) transfer from one species to another.

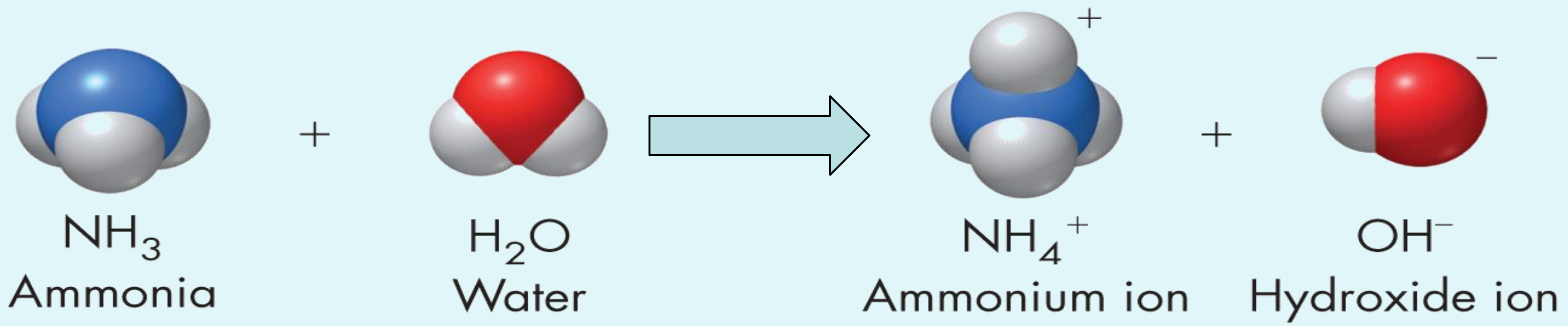


Proton Donors and Acceptors

- The species which <u>donates the proton</u> is an **<u>acid</u>**.
- The species which <u>accepts the proton</u> is a **<u>base</u>**.

THINK ABOUT IT

Proton Donors and Acceptors

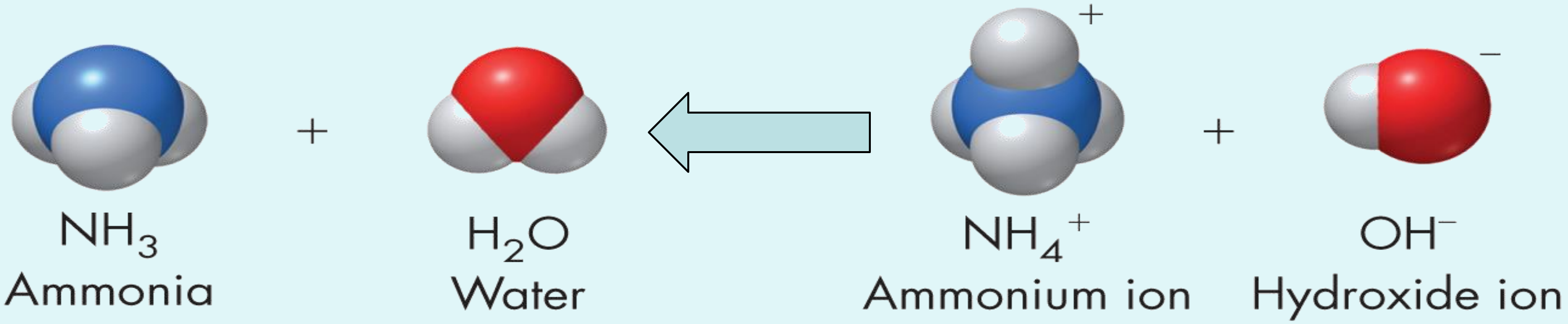


For the forward reaction:

Water donates the H+ … **acid**

Ammonia accepts H+ … base

Proton Donors and Acceptors



The <u>reverse reaction</u> of an acid/base reaction is also an acid/base reaction.

For the reverse reaction:

Ammonium donates the H+ … acid

Hydroxide accepts H+ … base

Acid-Base Pairs

According to the Proton Donors and Acceptors concept, in every reaction, an acid reacts with a base to form another acid and another base.

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

$NH_3(aq)$	$H_2O(l)$	$NH_4^+(aq)$	$OH^-(aq)$
Base	Acid	Conjugate acid	Conjugate base

NH_4^+ is the conjugate acid of the base NH_3.

OH^- is the conjugate base of the acid H_2O.

STRATEGY

Brønsted-Lowry Conjugate Acid-Base Pairs

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

Determine & explain the acids and bases in the forward and reverse reactions.

Brønsted-Lowry Conjugate Acid-Base Pairs

$$\underset{\text{Acid}}{HCl(g)} + \underset{\text{Base}}{H_2O(l)} \rightleftharpoons \underset{\text{Conjugate acid}}{H_3O^+(aq)} + \underset{\text{Conjugate base}}{Cl^-(aq)}$$

Forward Reaction

Hydrogen chloride is the hydrogen-ion donor (acid)

Water is the hydrogen-ion acceptor (base)

Reverse Reaction

H_3O^+ is the conjugate acid of the base H_2O.

Cl^- is the conjugate base of the acid HCl.

Note that water is a ***base*** *here, but it was an acid in the previous reaction. ???*

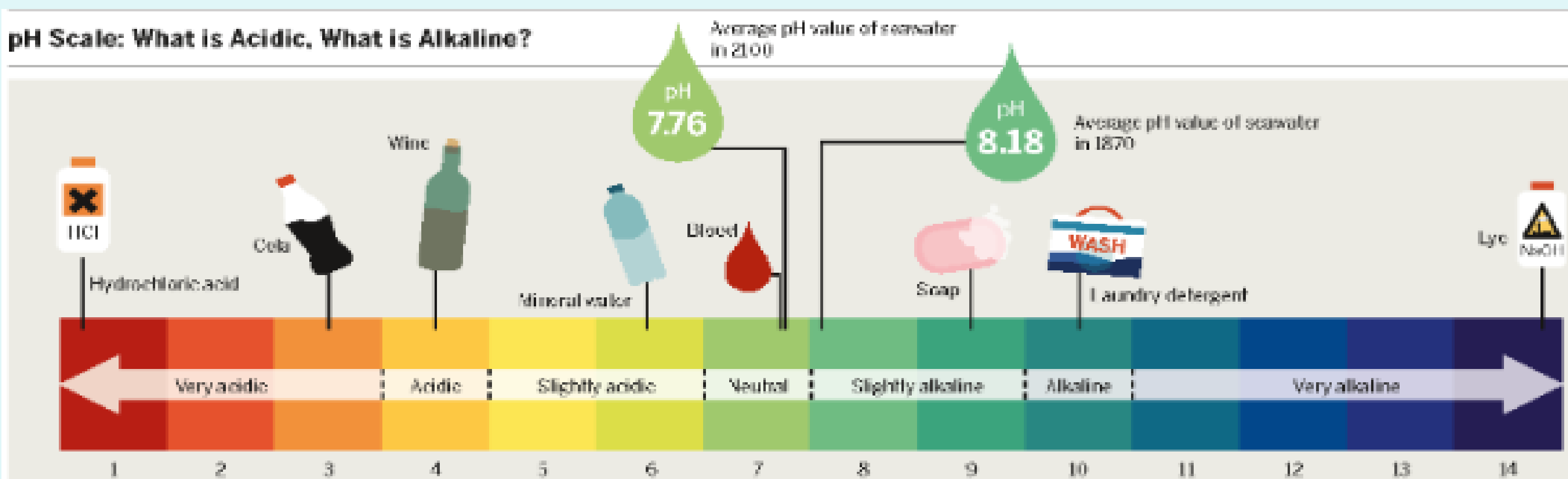
pH

Sorenson

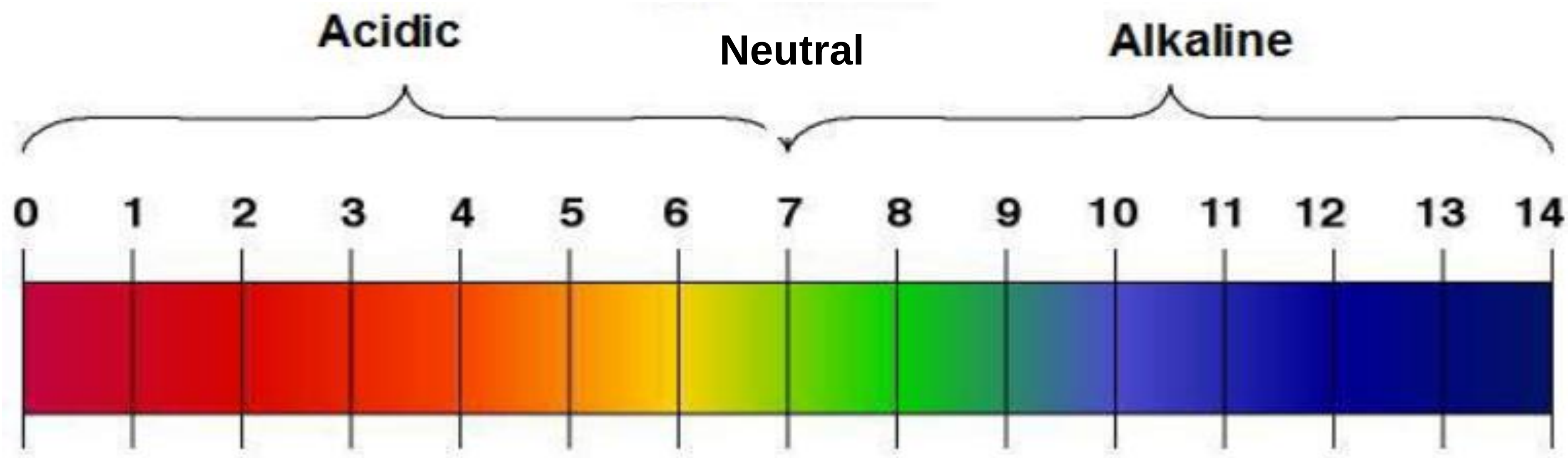
The pH scale helps us classify solutions as acids or bases.

The lower the pH value, the greater the H_3O^+ ion concentration in solution is.

The higher the pH value, the lower the H_3O^+ ion concentration is.



The pH Scale

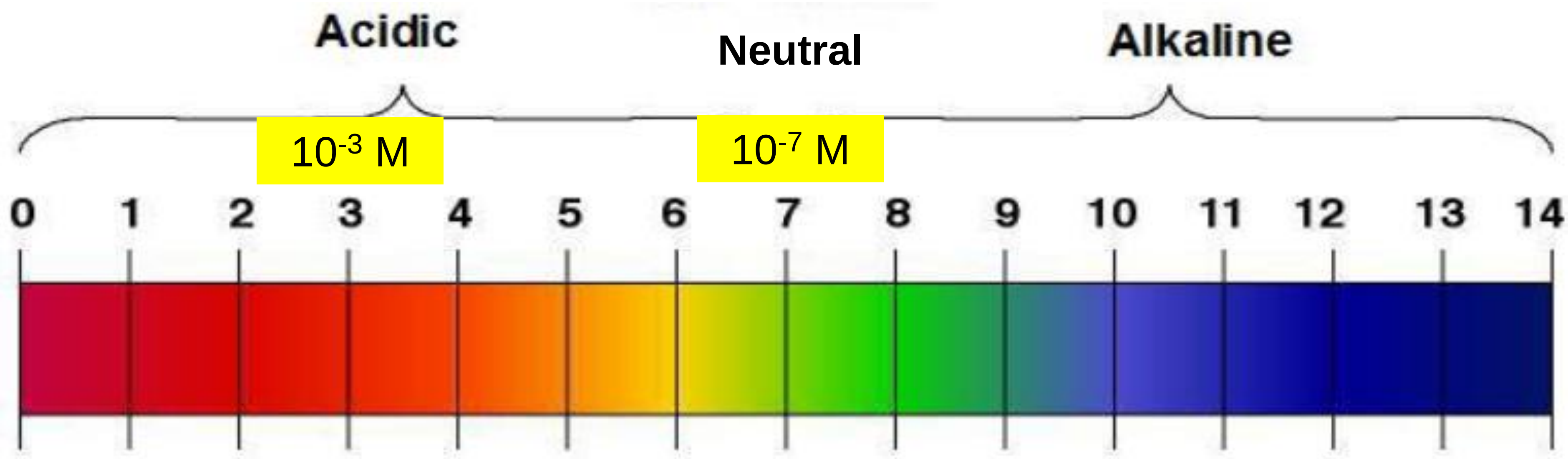


Describe each solution (acidic, neutral, basic)

pH ?

$[H^+]$ & $[(OH)^-]$?

The pH Scale

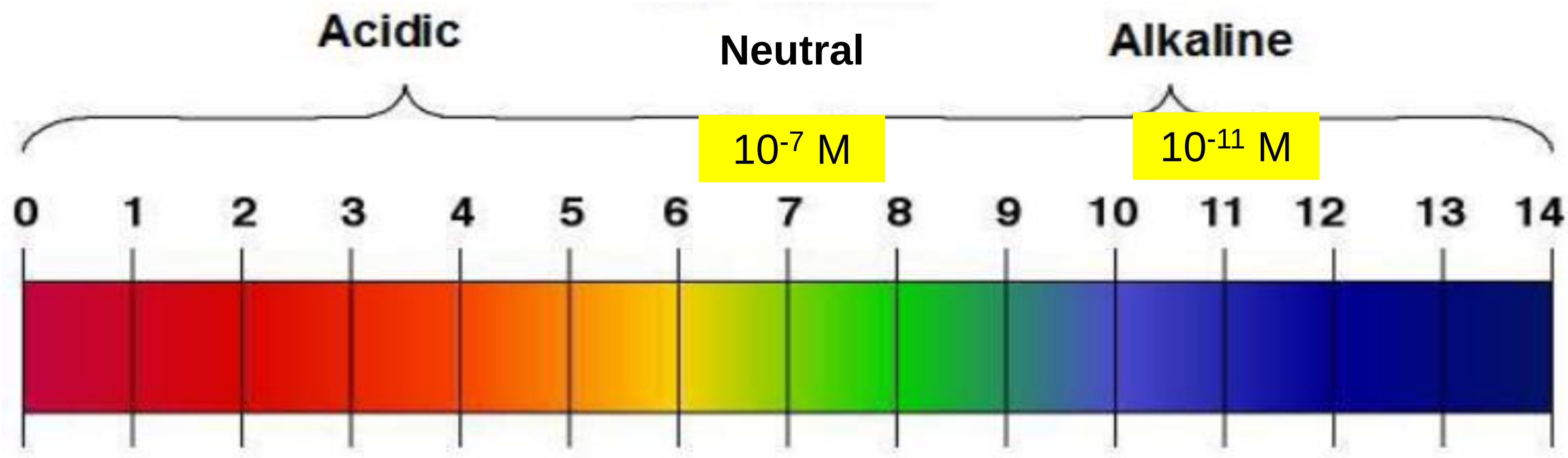


acidity:

pH below 7

- $[H^+] > 1 \times 10^{-7} M$ $[OH^-] < 1 \times 10^{-7} M$
- Lower pH indicates greater acidity

The pH Scale

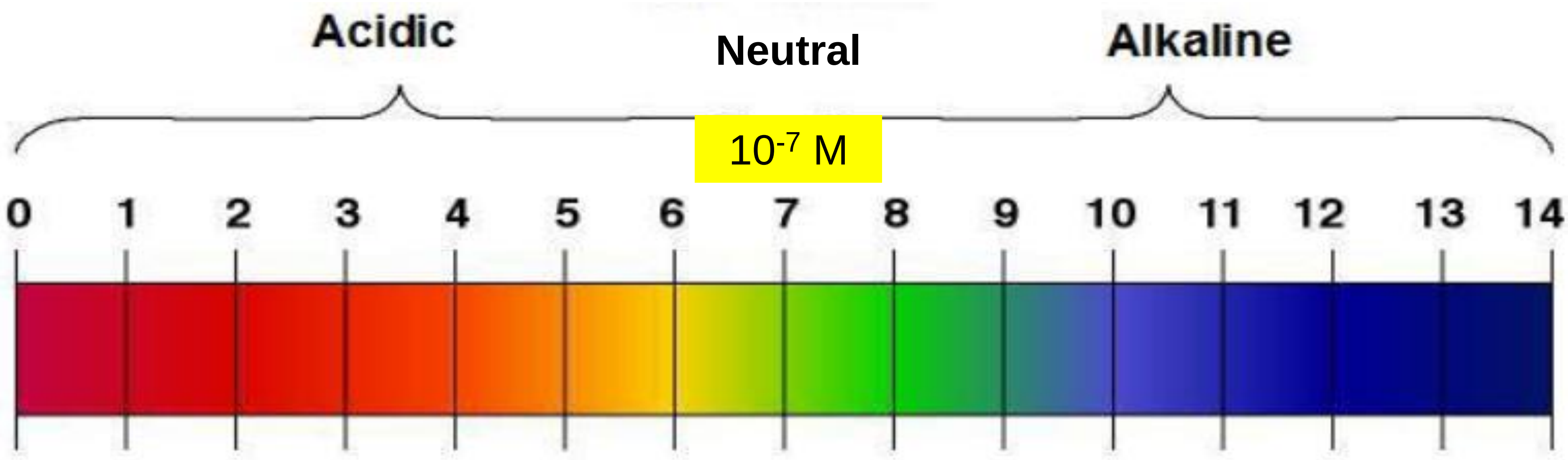


alkalinity:

pH above 7

- $[OH^-] > 1 \times 10^{-7} M$ $[H^+] < 1 \times 10^{-7} M$
- Higher pH indicates greater alkalinity

The pH Scale



Neutral:

pH at 7

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

$[H^+] = [OH^-]$

pH based on Molar Concentrations

TRY IT

$[H^+]$	10^0						10^{-10}		
pH			4		7				14

- **Complete the table above, filling in the missing items.**
- **In the boxes below the chart, indicate acidic, neutral, and basic solutions.**

pH based on Molar Concentrations

TRY IT

$[H^+]$	10^0	10^{-2}	10^{-4}	10^{-6}	10^{-7}	10^{-8}	10^{-10}	10^{-12}	10^{-14}
$[OH^-]$	10^{-14}	10^{-12}	10^{-10}	10^{-8}	10^{-7}	10^{-6}	10^{-4}	10^{-2}	10^{-0}
pH	0	2	4	6	7	8	10	12	14

acidic	neutral	basic

Molar concentrations are described by:

$$k_w = [H^+][OH^-] = 10^{-14}$$

Measuring pH

pH Meters

A pH meter can be easier to use than liquid indicators or indicator strips.

Acid-Base Indicators

Either acid-base indicators or pH meters can be used to measure pH.

Chemists have created a blend of indicators to create universal indicators such as litmus paper.

Acids turn blue litmus paper red.

Bases turn red litmus paper blue.

Acid-Base Indicators

Name	Acid Color	pH Range of Color Change	Base Color
Methyl violet	Yellow	0.0 - 1.6	Blue
Thymol blue	Red	1.2 - 2.8	Yellow
Methyl orange	Red	3.2 - 4.4	Yellow
Bromocresol green	Yellow	3.8 - 5.4	Blue
Methyl red	Red	4.8 - 6.0	Yellow
Litmus	Red	5.0 - 8.0	Blue
Bromothymol blue	Yellow	6.0 - 7.6	Blue
Thymol blue	Yellow	8.0 - 9.6	Blue
Phenolphthalein	Colorless	8.2 - 10.0	Pink
Thymolphthalein	Colorless	9.4 - 10.6	Blue
Alizarin yellow R	Yellow	10.1 - 12.0	Red

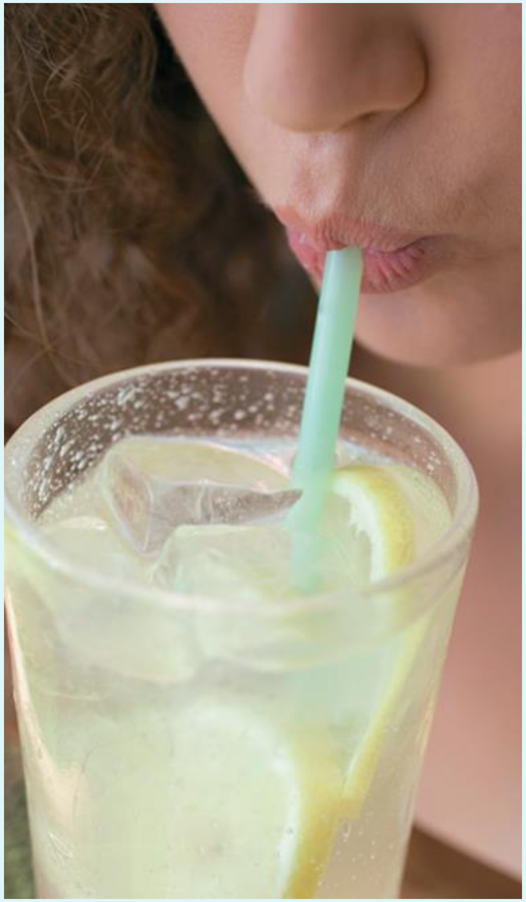
Acid-Base Indicators

When hydrangeas grow in acidic soil, the flowers are bluish-purple.

When hydrangeas grow in basic soil, the flowers are pink.

Strong and Weak Acids and Bases

What makes one acid safer than another?



Lemon juice, which contains citric acid, has a pH of about 2.3 which is relatively strong. Yet, most people love lemonade!

Battery acid is very dangerous (sulfuric acid: $H_2SO_{4\,(aq)}$).

Ionization

The foundational concept of Acids and Bases is their ability to **ionize** in solution.

Electrolytes: acids and bases can conduct electricity due to the presence of free moving ions which exist because of **ionization**.

$HCl_{(aq)}$ is a strong electrolyte (acid)
$NaOH_{(aq)}$ is a strong electrolyte (base)
$CH_3COOH_{(aq)}$ is a weak electrolyte (acid)
Pure water does NOT conduct electricity

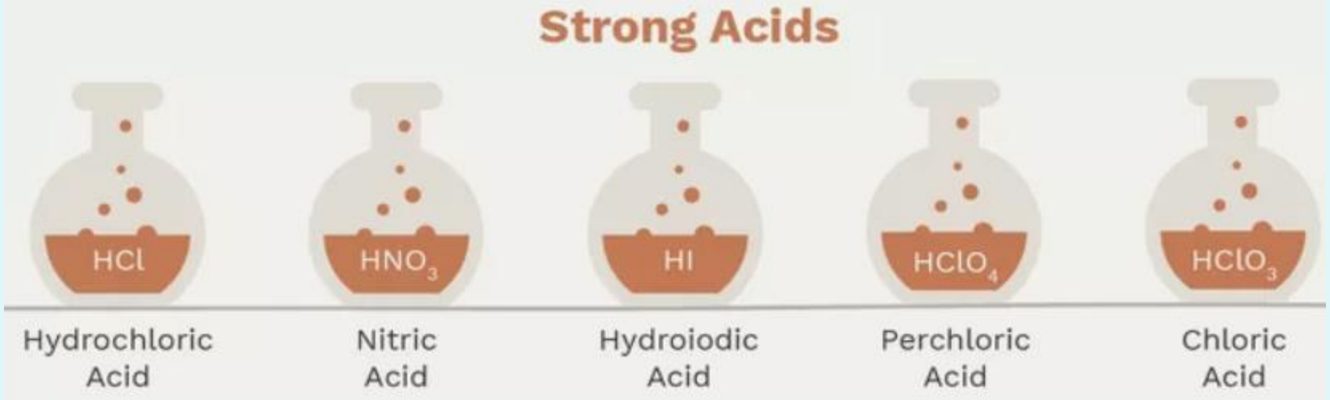
Strong and Weak Acids and Bases

Acids and bases are classified as strong or weak based on the degree to which they **ionize** in water.

In general, a **strong acid** completely ionizes in aqueous solution. Hydrochloric and sulfuric acid are examples of strong acids.

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

$$H_2SO_4(s) + 2H_2O(l) \rightarrow 2H_3O^+(aq) + SO_4^{-2}(aq)$$



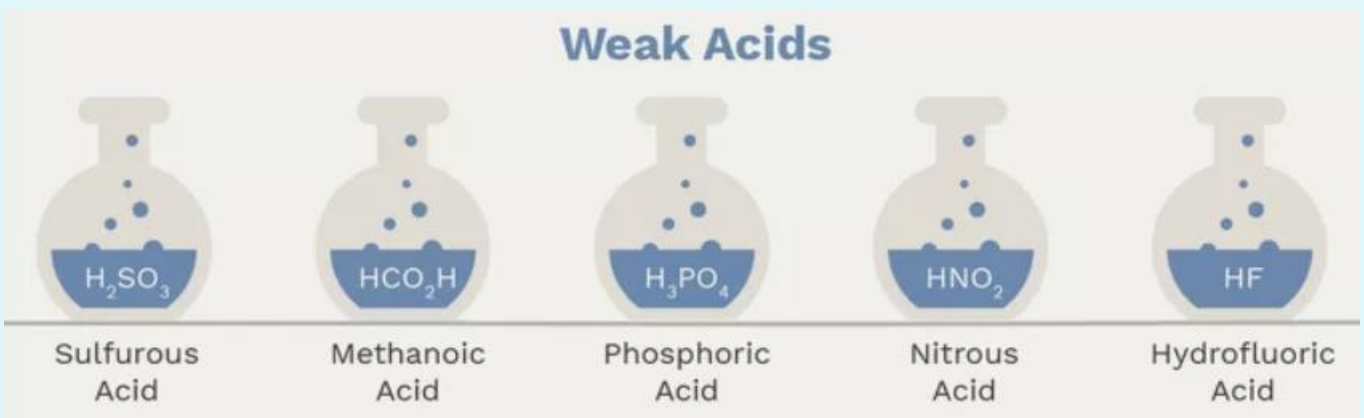
Strong and Weak Acids and Bases

A **weak acid** ionizes only slightly in aqueous solution.

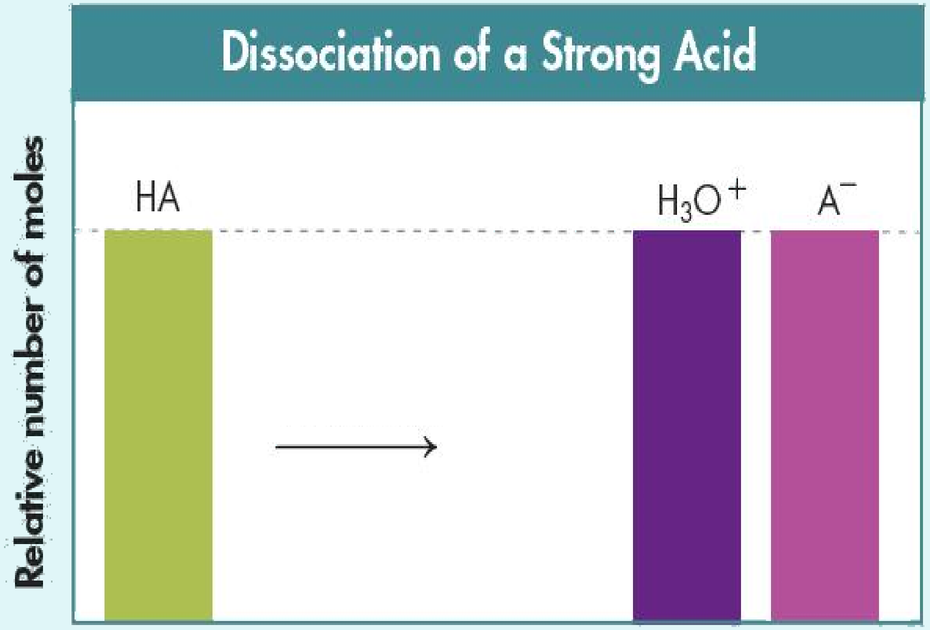
The ionization of acetic acid (CH_3COOH), a typical weak acid, is **<u>not</u>** complete. NOTICE THE EQUILIBRIUM (*arrows*):

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

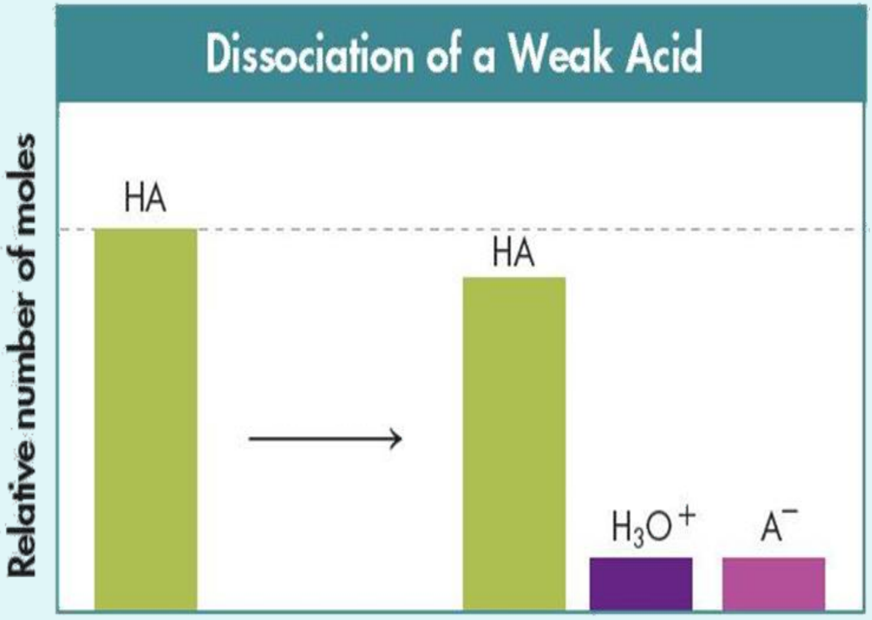
$< 1\%$



Strong and Weak Acids



$$HA(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + A^-(aq)$$



$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

Dissociation of a **strong** acid

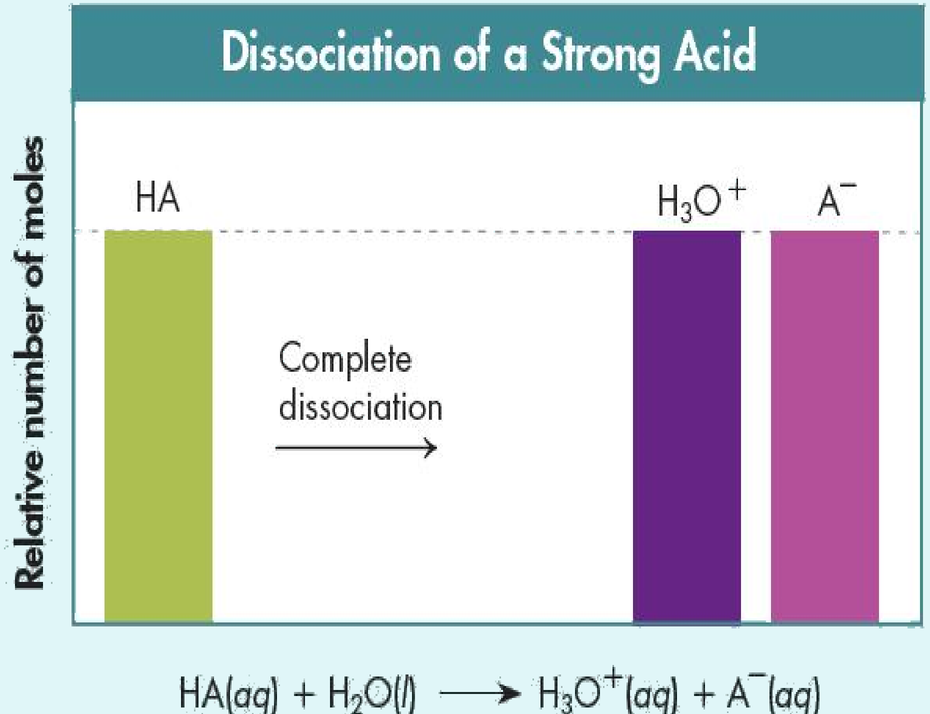
Dissociation of a **weak** acid

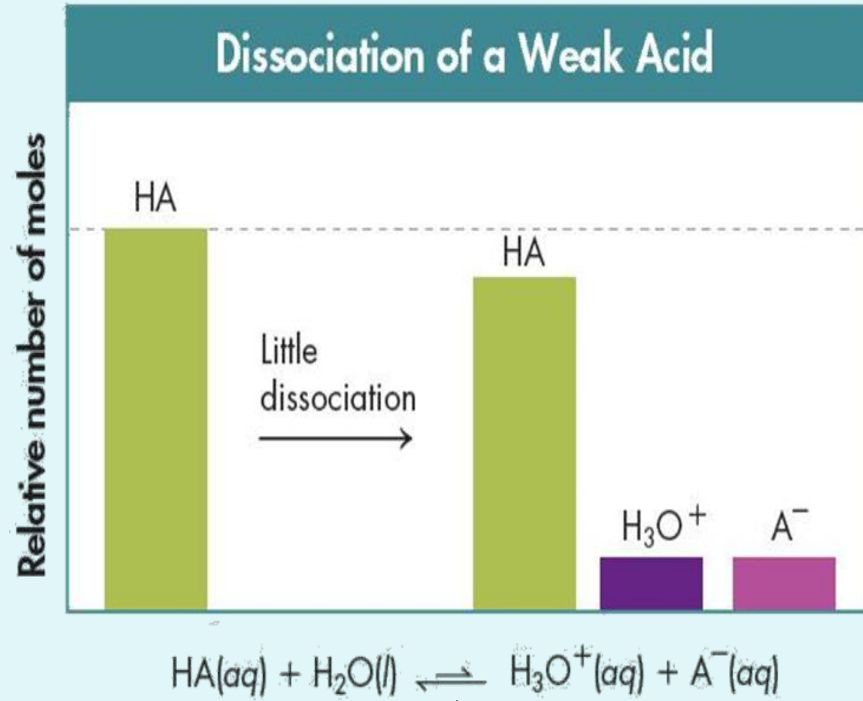
?

- Amount of Ionization
- Favors forward or reverse rxn
- Amount of dissociation
- Strong or weak electrolyte

?

Strong and Weak Acids





Dissociation of a **strong** acid

$$HX_{(aq)} \longrightarrow H^+_{(aq)} + X^-_{(aq)}$$

- Ionizes completely (100%)
- Goes to “completion” (forward rxn)
- 100% dissociation
- Strong electrolyte

Dissociation of a **weak** acid

$$HX_{(aq)} \rightleftharpoons H^+_{(aq)} + X^-_{(aq)}$$

- Fewer ions
- Favors the reverse rxn
- Low % dissociation
- Weak electrolyte