Acids and Bases

Learning Outcomes

1. Identify an acid or base according to the Arrhenius or Bronsted–Lowry definitions.

2. Explain why the term “strong” is used differently when applied to an acid or a cup of coffee.

3. Use K_a to access how strong/weak an acid is.

Class Question!

When poll is active, respond at **PollEv.com/matthewfonta586**

Text **MATTHEWFONTA586** to **22333** once to join

How would you describe an acid and a base? What are some of their respective properties?

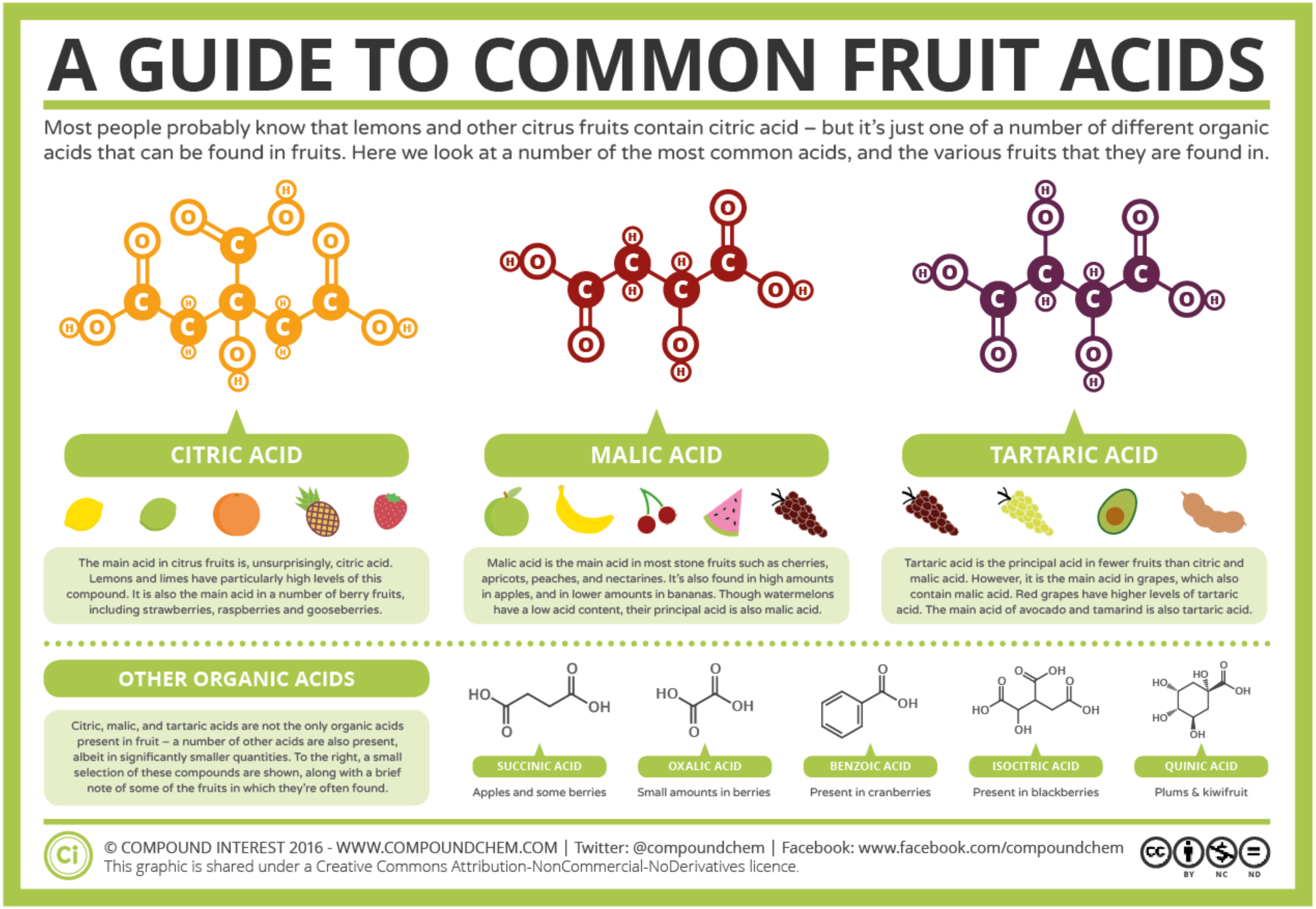
No responses received yet. They will appear here...

Poll Everywhere Answers to this poll are anonymous

Acids and Bases

https://www.youtube.com/watch?v=mnbS56HQbaU

Fruit Acids



A GUIDE TO COMMON FRUIT ACIDS
Most people probably know that lemons and other citrus fruits contain citric acid – but it's just one of a number of different organic acids that can be found in fruits. Here we look at a number of the most common acids, and the various fruits that they are found in.
CITRIC ACID
The main acid in citrus fruits is, unsurprisingly, citric acid. Lemons and limes have particularly high levels of this compound. It is also the main acid in a number of berry fruits, including strawberries, raspberries and gooseberries.
MALIC ACID
Malic acid is the main acid in most stone fruits such as cherries, apricots, peaches, and nectarines. It's also found in high amounts in apples, and in lower amounts in bananas. Though watermelons have a low acid content, their principal acid is also malic acid.
TARTARIC ACID
Tartaric acid is the principal acid in fewer fruits than citric and malic acid. However, it is the main acid in grapes, which also contain malic acid. Red grapes have higher levels of tartaric acid. The main acid of avocado and tamarind is also tartaric acid.
OTHER ORGANIC ACIDS
Citric, malic, and tartaric acids are not the only organic acids present in fruit – a number of other acids are also present, albeit in significantly smaller quantities. To the right, a small selection of these compounds are shown, along with a brief note of some of the fruits in which they're often found.
SUCCINIC ACID
Apples and some berries
OXALIC ACID
Small amounts in berries
BENZOIC ACID
Present in cranberries
ISOCITRIC ACID
Present in blackberries
QUINIC ACID
Plums & kiwifruit
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Acids Are Sour

SOUR WORMS

Nutrition Facts

Serving Size: (0.0g)
Servings Per Container: 1

Calories 120
Calories from Fat 0

Amount/serving	% Daily Value*	Amount/serving	% Daily Value*
Total Fat 0g	**0**%	**Total Carbohydrate** 29g	**10**%
Saturated Fat 0g	**0**%	Dietary Fiber 0g	**0**%
Trans Fat 0g		Sugars 18g	
Cholesterol 0mg	**0**%	**Protein** 2g	
Sodium 5mg	**0**%		

Vitamin A 0% • Vitamin C 0% • Calcium 0% • Iron 0%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

INGREDIENTS: CORN SYRUP (FROM CORN), SUGAR (FROM BEETS), WATER, GELATIN, LACTIC ACID, CITRIC ACID, NATURAL AND ARTIFICIAL FLAVORS, FUMARIC ACID, PECTIN (DERIVED FROM FRUIT), TITANIUM DIOXIDE (COLOR), FD&C YELLOW #5, FD&C RED #40, FD&C YELLOW #6, FD&C BLUE #1.

BEDFORD CANDIES
106E. PITT ST
BEDFORD, PA 15522

Citric Acid + Sugar = Sour Sanding

Acids Dissolve Many Metals

Acids Can Dissolve Teeth

Brush your teeth 30 minutes ***after*** drinking an acidic beverage

In an interview with Reuters Health, Dr. Attin said that tooth enamel appears to suffer less damage when brushing occurs after the tooth has had time to mount its own defense against acidic erosion.

"Acidic substances attack tooth enamel, and upper layers of the tooth can even be dissolved in some acidic drinks," he said. "However, protective agents in saliva may help repair and rebuild damaged tooth enamel."

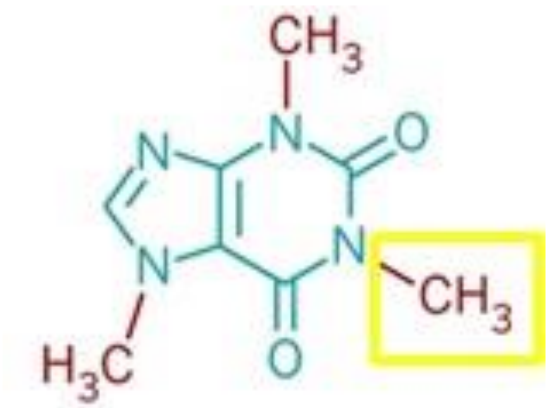
Compiled by Amy E. Lund, editorial coordinator.

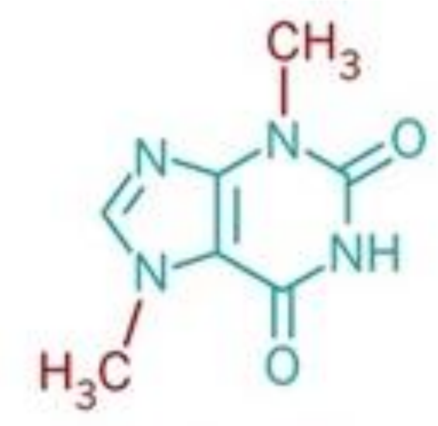
Bases Are Bitter

Chocolate Nibs

Chocolate Bar

Why Are Nibs Bitter?

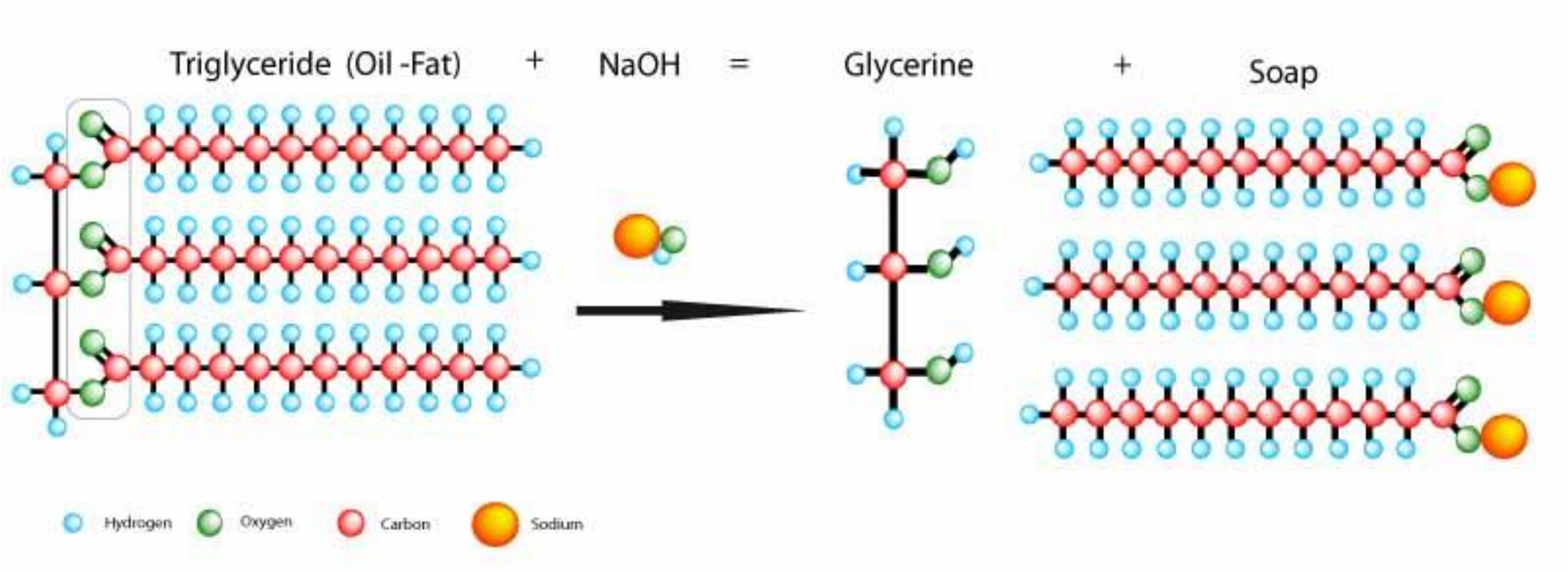




Caffeine

Theobromine

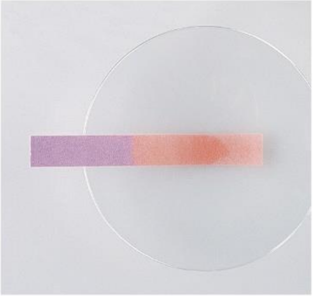
Bases Are Slippery



Products With Bases

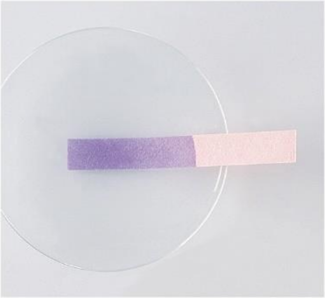
Acids and Bases
Change the Colors of Indicators

Acids turn blue litmus paper red



Hydrangea in Acidic Soil!

Bases turn red litmus paper blue



Hydrangea in Basic Soil!

Cabbage Juice!

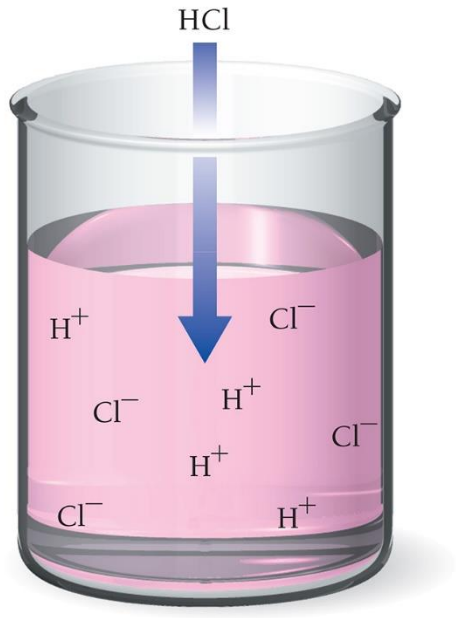
Acids Produce H_3O^+

Acid produce H_3O^+ (hydronium ion)

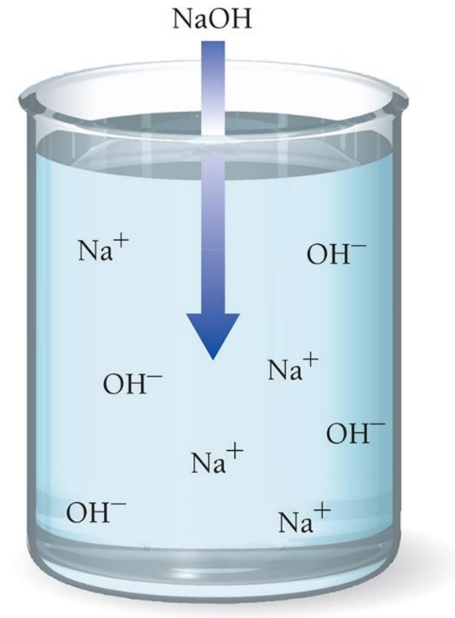
H_3O^+ is often abbreviated as “H^+”

In CHEM 42 we will sometimes use both notations. In some applications one notation is more useful/helpful/instructive.

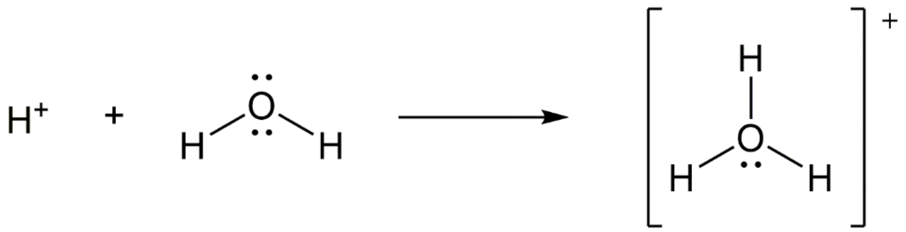
Arrhenius Definition:
Acids Produce H^+ and Bases Produce OH^-



$$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$$



$$NaOH(aq) \longrightarrow Na^+(aq) + OH^-(aq)$$



Hydronium Ion

Bronsted-Lowry Definition

Acid: Proton (H^+) donor

Base: Proton (H^+) acceptor

$$\mathrm{HCl\,(aq) + H_2O\,(l) \longrightarrow H_3O^+\,(aq) + Cl^-\,(aq)}$$

Problem 1

Identify the acid and base in the following acid-base reaction.

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

Problem 2

Identify the acid and base in the following acid-base reaction.

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

Problem 3

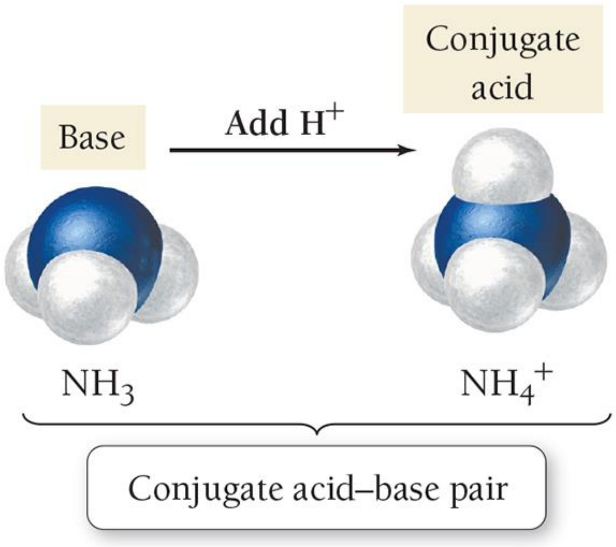
What do you notice about the two acids and two bases in the following chemical equation?

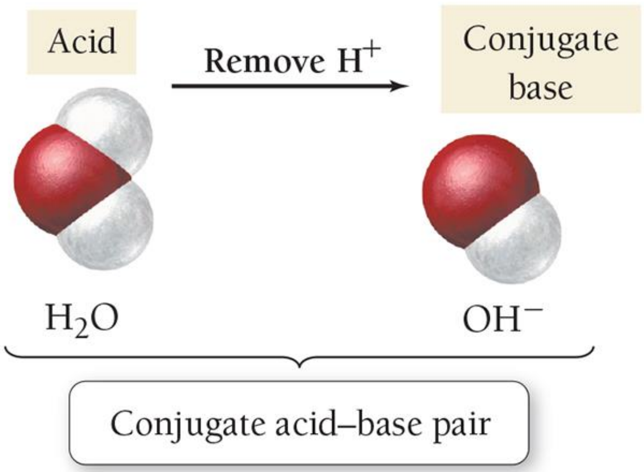
$$NH_3\,(aq) + H_2O\,(l) \rightleftharpoons NH_4^+\,(aq) + OH^-\,(aq)$$

Conjugate Acids and Bases

$$\underset{\text{Base}}{NH_3\,(aq)} + \underset{\text{Acid}}{H_2O\,(l)} \rightleftharpoons \underset{\text{Conjugate Acid}}{NH_4^+\,(aq)} + \underset{\text{Conjugate Base}}{OH^-\,(aq)}$$

Conjugate Acids and Bases





Reactions of Acids and Bases

What are the products of the following acid-base reaction? Hint, consider how you solved precipitation reactions?

$$\mathrm{HCl\,(aq) + NaOH\,(s)} \longrightarrow$$

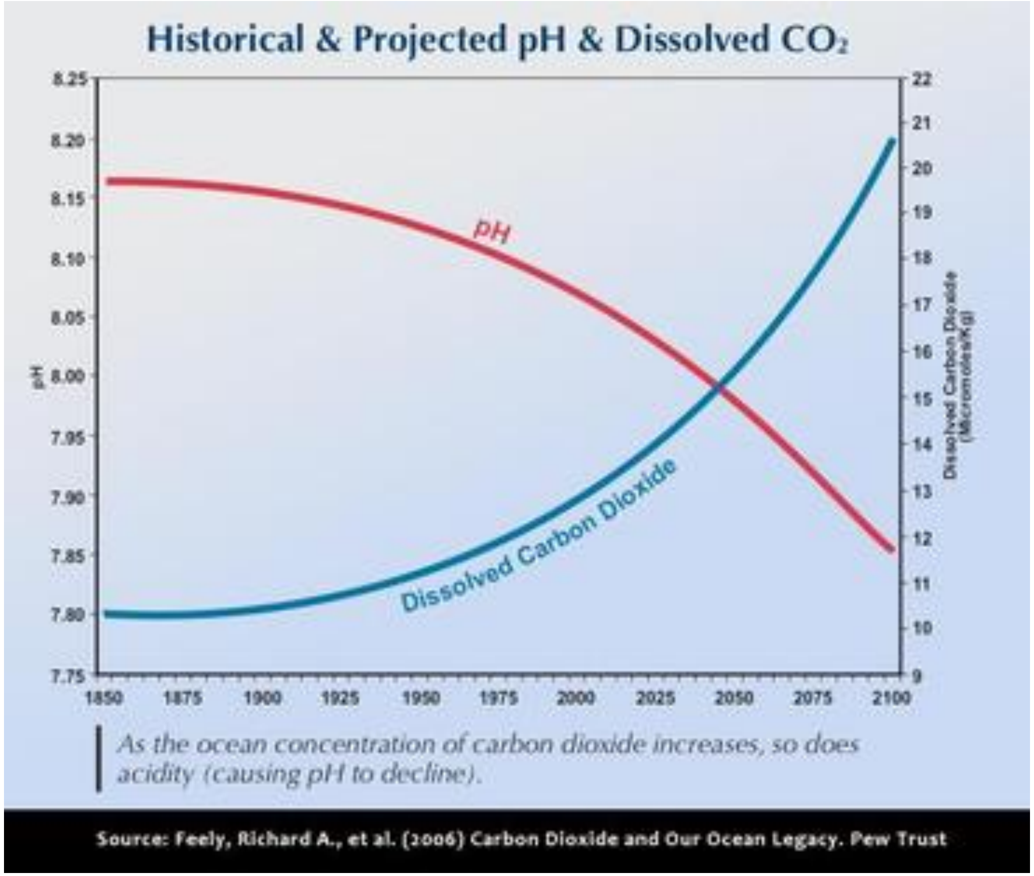
Neutralization Reactions

Acid + Base ⟶ Water + Salt

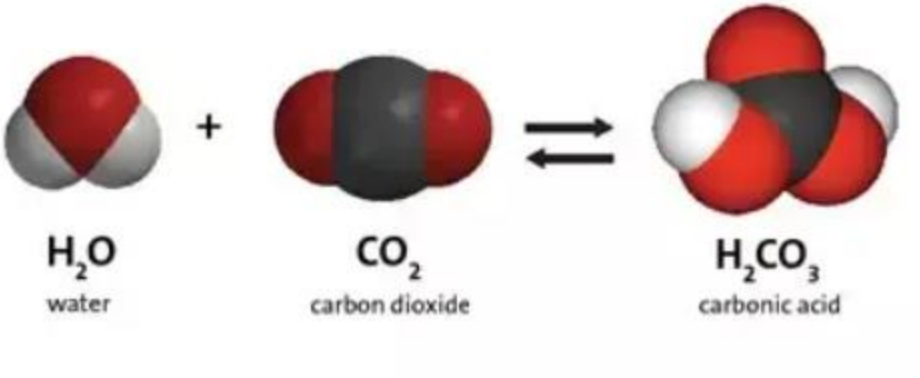
Salt: Ionic compound that contains the cation from the base and the anion from the acid

$$\underset{\text{Acid}}{HCl\,(aq)} + \underset{\text{Base}}{KOH\,(aq)} \longrightarrow \underset{\text{Water}}{H_2O\,(l)} + \underset{\text{Salt}}{KCl\,(aq)}$$

Why Does CO_2 Make Water Acidic?



Acidification of Water



Acid Rain Chemical Equations

$$CO_2\,(g) + H_2O\,(l) \longrightarrow H_2CO_3\,(aq)$$

Carbonic Acid

$$SO_2\,(g) + H_2O\,(l) \longrightarrow H_2SO_3\,(aq)$$

Sulfurous Acid

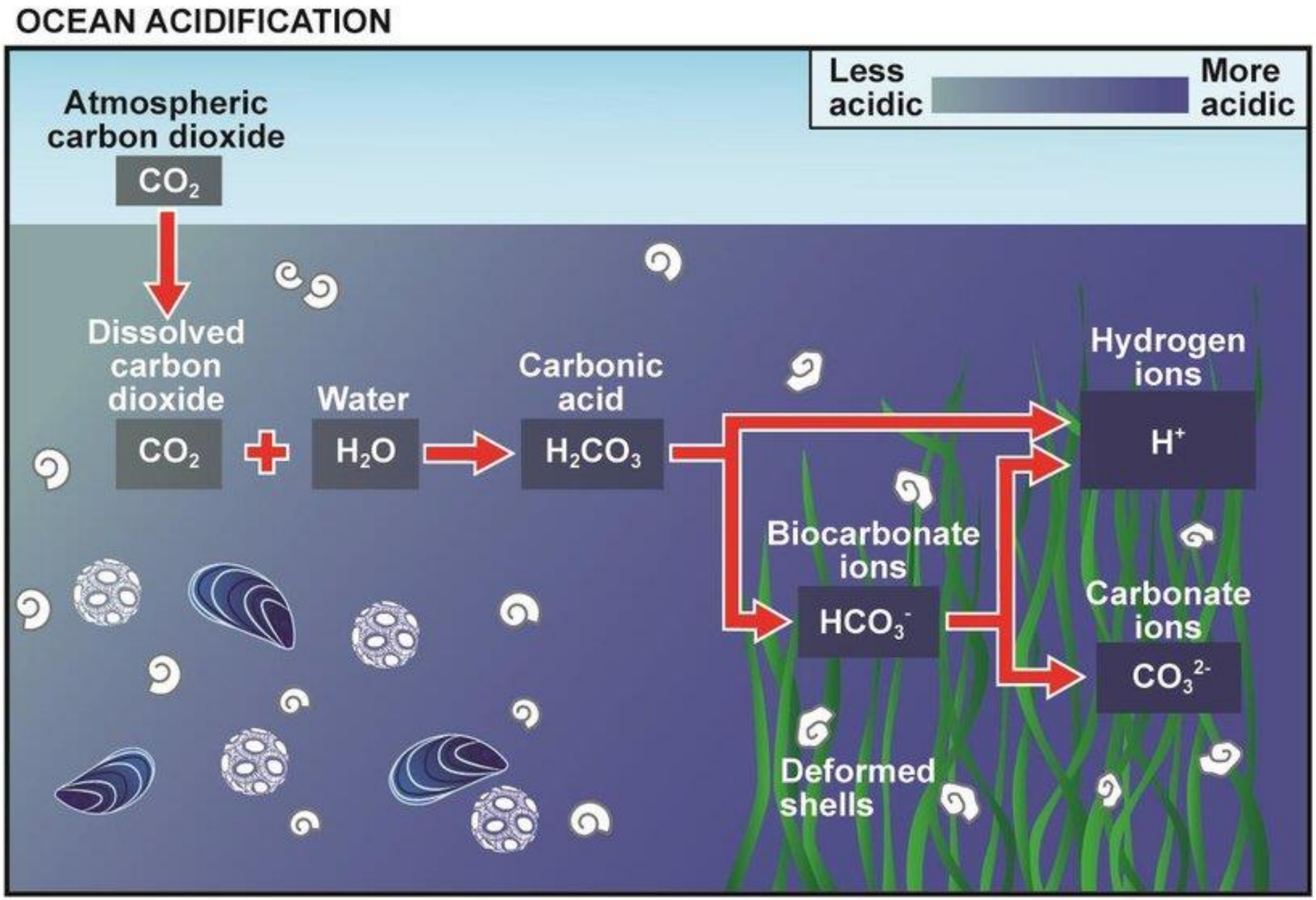
$$SO_3\,(g) + H_2O\,(l) \longrightarrow H_2SO_4\,(aq)$$

Sulfuric Acid

$$4\,NO_2\,(g) + 2\,H_2O\,(l) + O_2\,(g) \longrightarrow 4\,HNO_3\,(aq)$$

Nitric Acid

Ocean Acidification



Class Question!

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What makes a strong acid strong and a weak acid weak?

No responses received yet. They will appear here...

Poll Everywhere

Answers to this poll are anonymous

Think-Pair Share

A strong cup of coffee is coffee that is more concentrated. Is a strong acid a more concentrated acid solution?

Strong Acids

TABLE 14.3 Strong Acids

hydrochloric acid (HCl)	nitric acid (HNO_3)
hydrobromic acid (HBr)	perchloric acid ($HClO_4$)
hydroiodic acid (HI)	sulfuric acid (H_2SO_4) (*diprotic*)

Weak Acids

TABLE 14.4 Weak Acids

hydrofluoric acid (HF)	sulfurous acid (H_2SO_3) *(diprotic)*
acetic acid ($HC_2H_3O_2$)	carbonic acid (H_2CO_3) *(diprotic)*
formic acid ($HCHO_2$)	phosphoric acid (H_3PO_4) *(triprotic)*

Strong Bases

TABLE 14.5 Strong Bases	
lithium hydroxide ($LiOH$)	strontium hydroxide ($Sr(OH)_2$)
sodium hydroxide ($NaOH$)	calcium hydroxide ($Ca(OH)_2$)
potassium hydroxide (KOH)	barium hydroxide ($Ba(OH)_2$)

Weak Bases

TABLE 14.6 Some Weak Bases

Base	Ionization Reaction
ammonia (NH_3)	$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
pyridine (C_5H_5N)	$C_5H_5N(aq) + H_2O(l) \rightleftharpoons C_5H_5NH^+(aq) + OH^-(aq)$
methylamine (CH_3NH_2)	$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$
ethylamine ($C_2H_5NH_2$)	$C_2H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_2H_5NH_3^+(aq) + OH^-(aq)$
bicarbonate ion (HCO_3^-)*	$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$

*The bicarbonate ion must occur with a positively charged ion such as Na^+ that serves to balance the charge but does not have any part in the ionization reaction. It is the bicarbonate ion that makes sodium bicarbonate ($NaHCO_3$) basic.

Acid Strength is Determined by K_a

When K_a is **INFINITY** (or a VERY, VERY, large number), the acid is **STRONG**. This means for **ONE** mole of acid you get one mole of H_3O^+

When K_a is **NOT INFINITY** (in most cases a number less than 1), the acid is **WEAK**. This means that for **MANY** moles of acid, you get one mole of H_3O^+

Analogy

One strong person can lift one car

Many weak people can lift one car

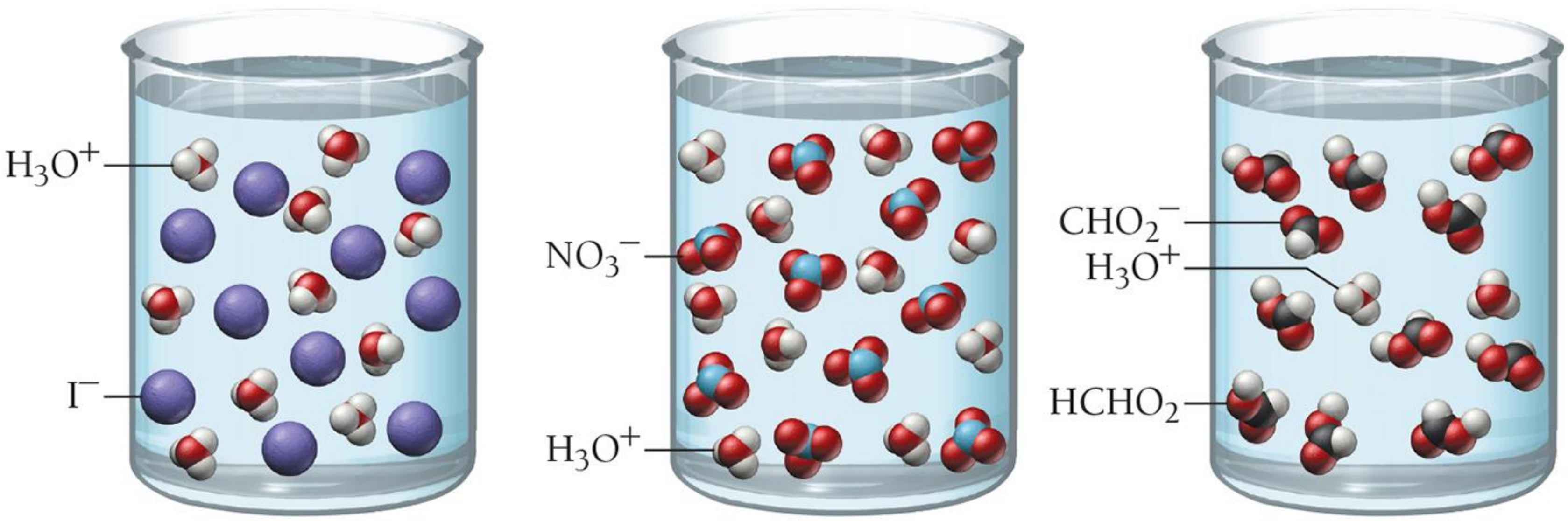
Star Wars Analogy

Yoda is ***strong*** in the Force and can move Luke Skywalker's X-Wing

Luke is ***weak*** in the Force and cannot move his X-Wing

Problem 4

Identify each of the following as either a strong acid or a weak acid.



HI

HNO_3

$HCHO_2$
(Formic Acid)

Learning Outcomes

1. Demonstrate by example that water can act as an acid or a base.
2. Identify a solution as acidic, basic, or neutral.
3. Calculate the pH of a solution.
4. Explain why a difference of one pH unit is a factor of 10 difference in the hydronium ion concentration.
5. Explain what a buffer is and how blood pH is regulated with H_2CO_3/HCO_3^-.

Water Can Act As Either an Acid or a Base!

Water is amphoteric!

Water acting as a base

$$\underset{\substack{\text{Acid} \\ \text{(Proton donor)}}}{HCl(aq)} + \underset{\substack{\text{Base} \\ \text{(Proton acceptor)}}}{H_2O(l)} \longrightarrow H_3O^+(aq) + Cl^-(aq)$$

Water acting as an acid

$$\underset{\substack{\text{Base} \\ \text{(Proton acceptor)}}}{NH_3(aq)} + \underset{\substack{\text{Acid} \\ \text{(Proton donor)}}}{H_2O(l)} \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

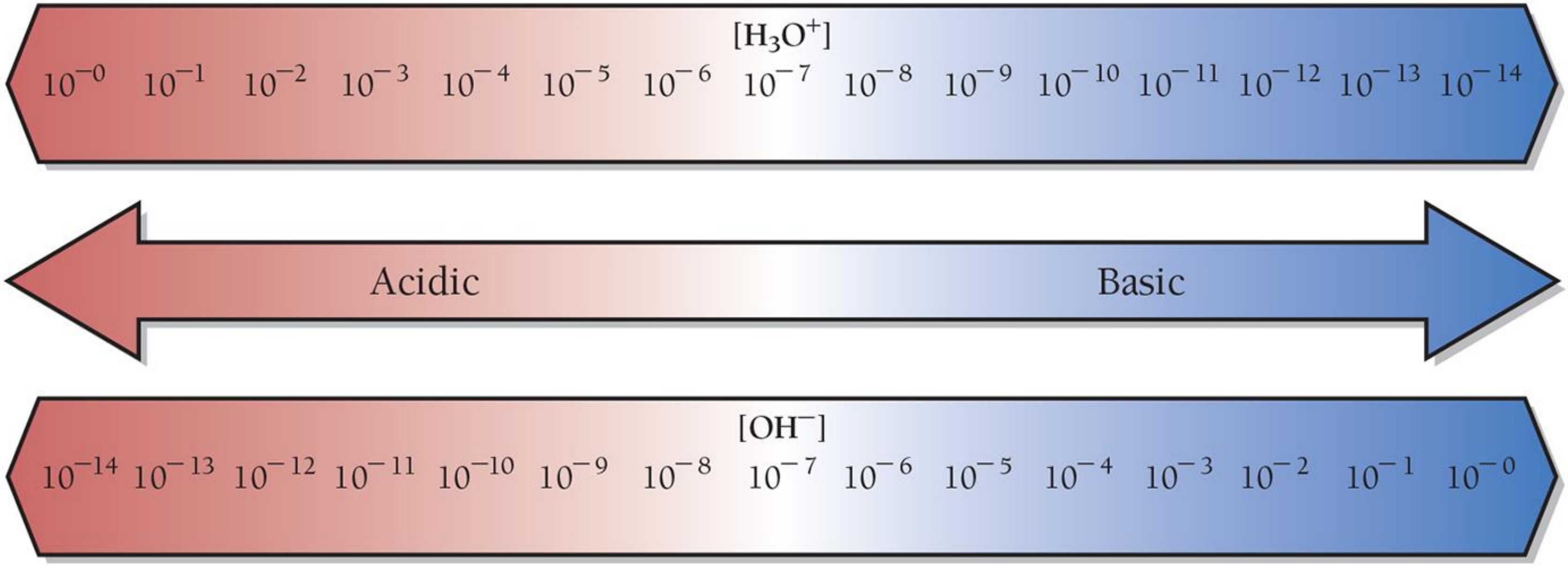
Quantifying a Solution as Acidic, Basic, or Neutral

Acidic: $[H_3O^+] > [OH^-]$

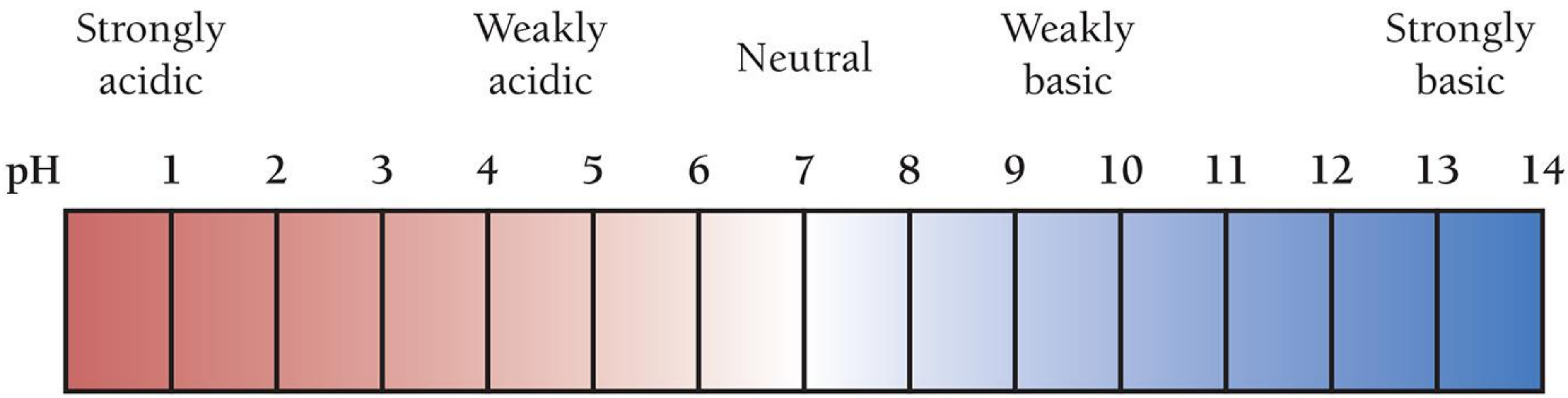
Basic: $[OH^-] > [H_3O^+]$

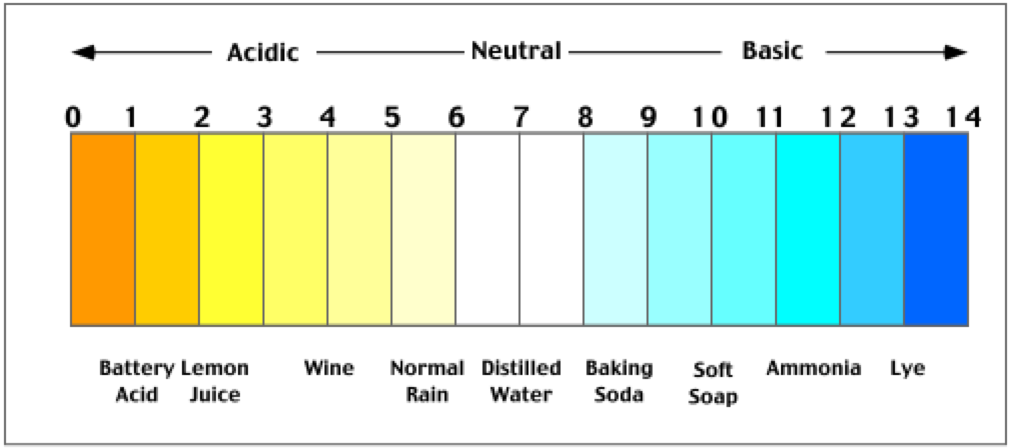
$$[H_3O^+][OH^-] = 1 \times 10^{-14} = K_w$$

Neutral: $[H_3O^+] = [OH^-]$



pH Quantifies How Acidic or Basic A Solution Is





pH of Everyday Items!!

TABLE 14.7 The pH of Some Common Substances

Substance	pH
gastric (human stomach) acid	1.0–3.0
limes	1.8–2.0
lemons	2.2–2.4
soft drinks	2.0–4.0
plums	2.8–3.0
wine	2.8–3.8
apples	2.9–3.3
peaches	3.4–3.6
cherries	3.2–4.0
beer	4.0–5.0
rainwater (unpolluted)	5.6
human blood	7.3–7.4
egg whites	7.6–8.0
milk of magnesia	10.5
household ammonia	10.5–11.5
4% NaOH solution	14

pH and pOH Definitions

$$pH = -\log\left[H_3O^+\right]$$

$$pOH = -\log\left[OH^-\right]$$

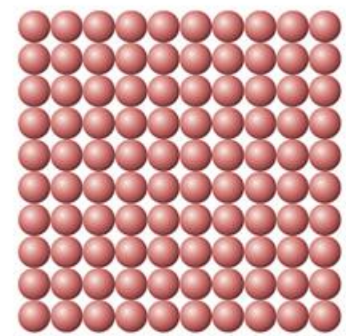
$$pH + pOH = 14$$

Problem 5

A solution has a H_3O^+ concentration of 9.5×10^{-9} M. Calculate the pH and determine whether the solution is acidic or basic.

pH is a Log Scale!!

H_3O^+ Concentration (M)	$pH = -\log_{10}[H_3O^+]$
1×10^{-1}	1
1×10^{-2}	2
1×10^{-3}	3
1×10^{-4}	4
1×10^{-5}	5
1×10^{-6}	6
1×10^{-7}	7
1×10^{-8}	8
1×10^{-9}	9
1×10^{-10}	10
1×10^{-11}	11
1×10^{-12}	12
1×10^{-13}	13
1×10^{-14}	14

pH	$[H_3O^+]$	$[H_3O^+]$ Representation
4	10^{-4}	
3	10^{-3}	
2	10^{-2}	

$$\left(\text{Each circle represents } \frac{10^{-4}\text{ mol H}^+}{\text{L}}\right)$$

Problem 6

Which of the following are possible?

(a) A pH between 1 and 14

(b) A pH less than 1

(c) A pH greater than 14

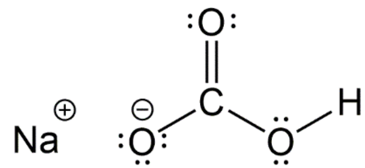
(d) A negative pH

Buffers

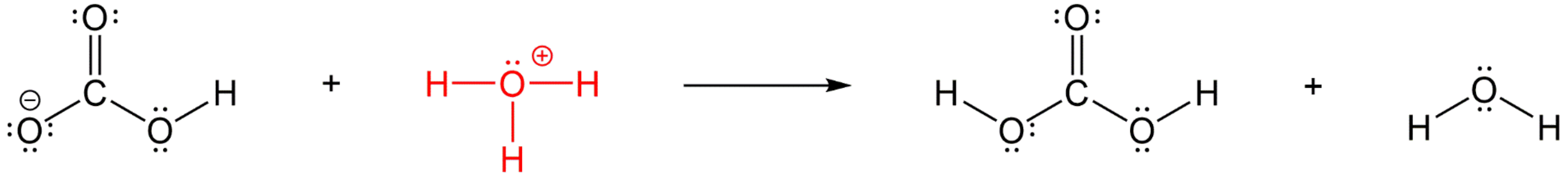
A buffer is a solution that resists pH change.

Buffer	pH Range
Acetate	3.6–5.6
Bis-Tris	5.8–7.2
Citrate (pK_{a1})	2.2–6.5
Citrate (pK_{a2})	3.0–6.2
Citrate (pK_{a3})	5.5–7.2
Methylamine	9.5–11.5
Phosphate (pK_{a1})	1.7–2.9
Phosphate (pK_{a2})	5.8–8.0
Succinate (pK_{a1})	3.2–5.2
Succinate (pK_{a2})	5.5–6.5

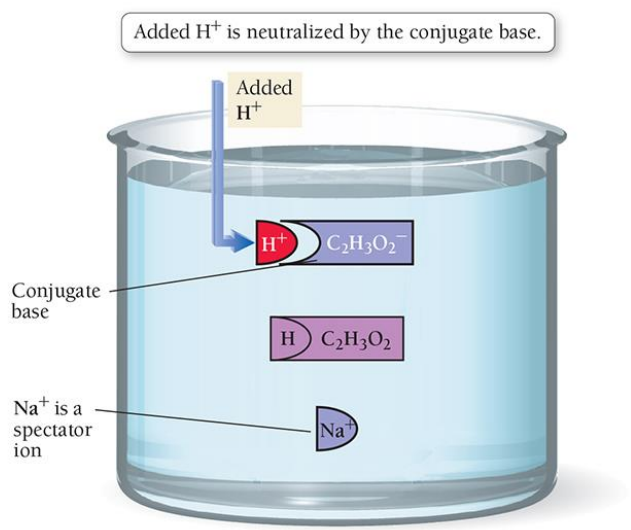
Buffers Resist pH Change When Acid is Added



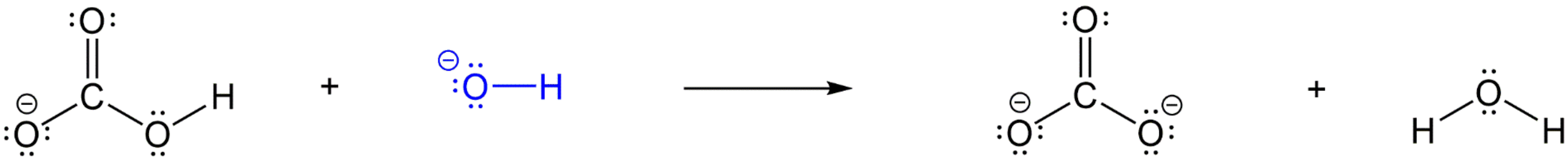
Sodium Bicarbonate
($NaHCO_3$)



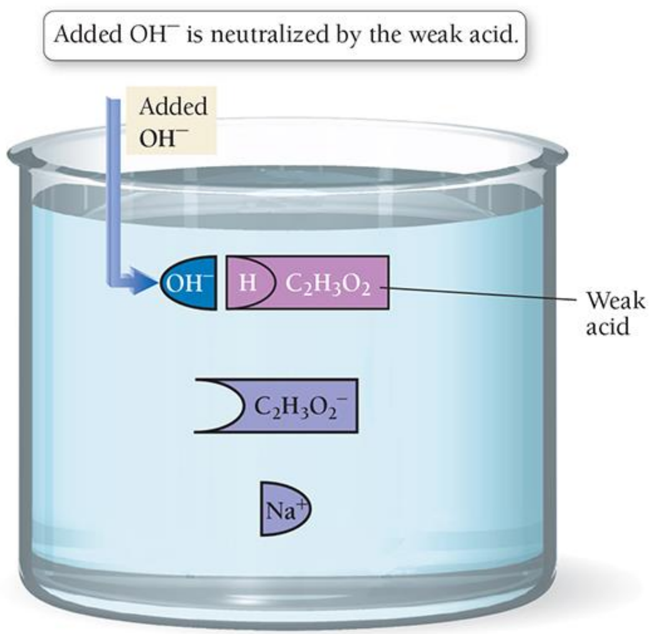
Bicarbonate Ion (HCO_3^-) + Hydronium Ion (H_3O^+) → Carbonic Acid (H_2CO_3) + Water (H_2O)



Buffers Resist pH Change When Base is Added



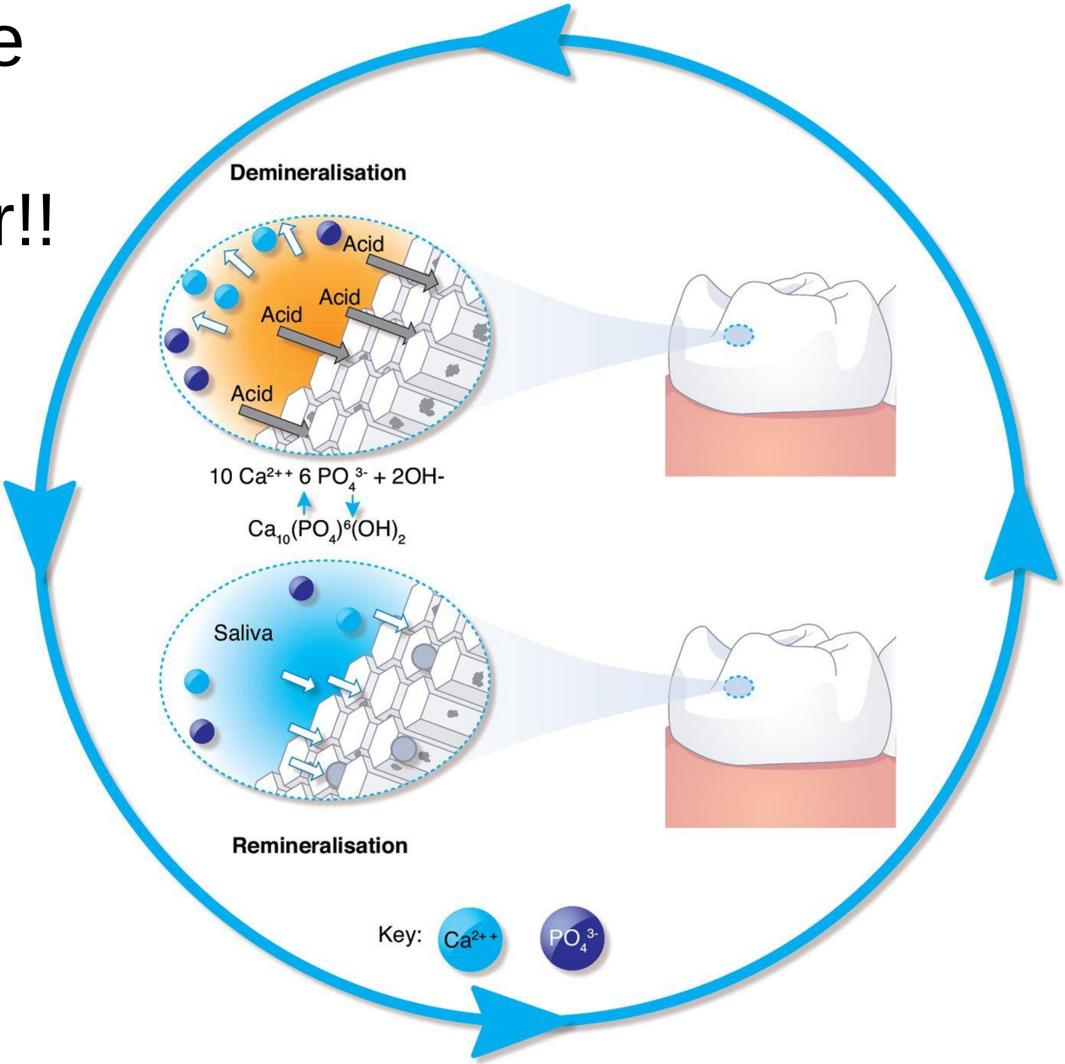
Bicarbonate Ion (HCO_3^-) + Hydroxide Ion (OH^-) → Carbonate Ion (CO_3^{2-}) + Water (H_2O)



Why Must You Wait 30 Minutes to Brush Your Teeth After Drinking a Cola?

1) Saliva has phosphate

2) Phosphate is a buffer!!



Problem 7

Blood must have a pH around 7.4. When the pH falls below 7.35 the body has acidosis and when the pH rises above 7.45 the body has alkalosis. When the pH deviates strongly from 7.4 the result is very harmful to the body. Which buffer do you think the body produces for the bloom steam to regulate the blood pH?

Buffer	pH Range
Acetate	3.6–5.6
Bicarbonate	5.1–7.1
Citrate (pK_{a1})	2.2–6.5
Citrate (pK_{a2})	3.0–6.2
Methylamine	9.5–11.5
Phosphate (pK_{a1})	1.7–2.9
Succinate (pK_{a1})	3.2–5.2
Succinate (pK_{a2})	5.5–6.5