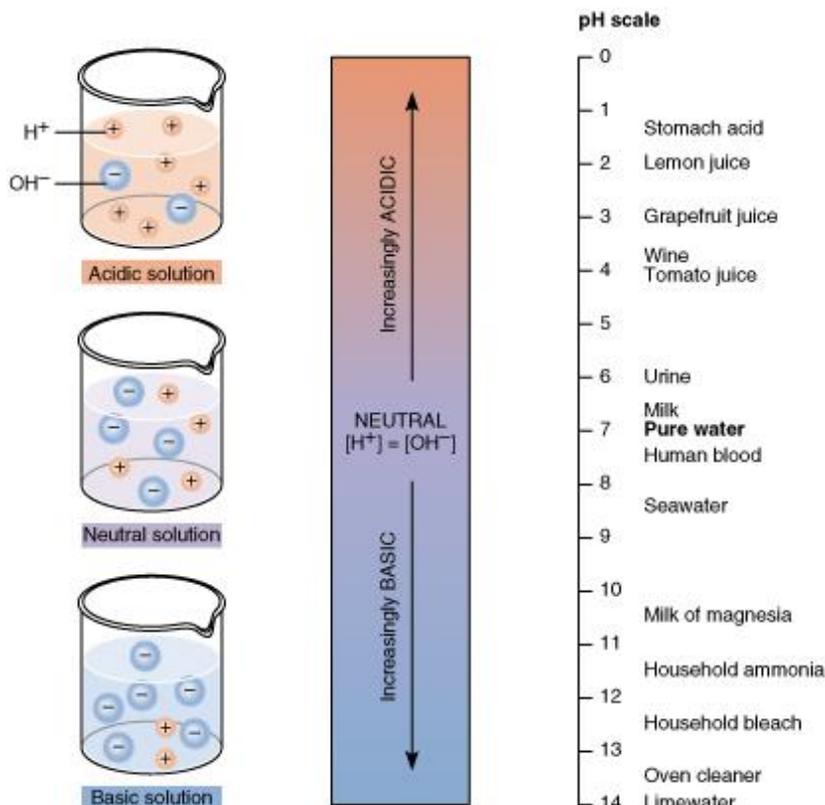


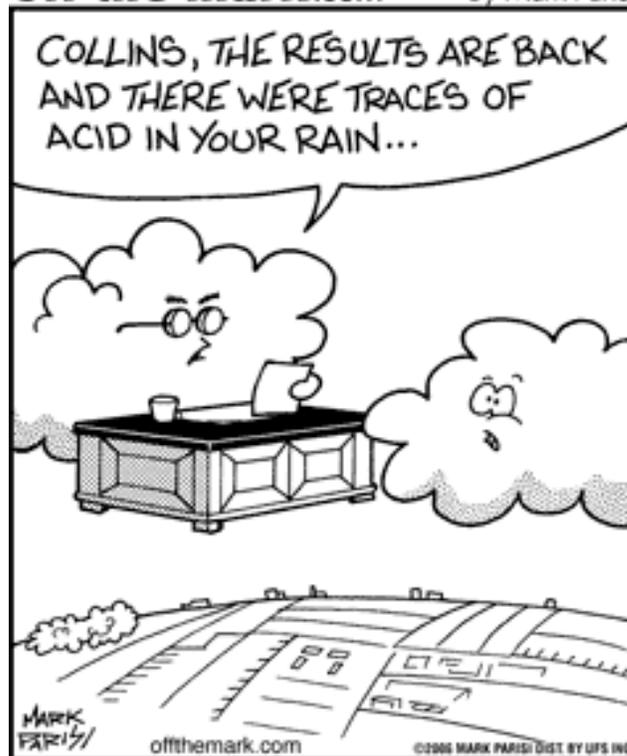
UNIT 13 NOTES: ACIDS AND BASES

STUDENT OBJECTIVES: Your fascinating teachers would like you amazing learners to be able to...

- Distinguish between the different theories (Lewis, Arrhenius, Brønsted-Lowry) that describe acids and bases.
- Identify acid/conjugate base pairs and base/conjugate acid pairs.
- Name and write formulas for acids.
- Compare and contrast the physical properties of acids and bases.
- Describe the colors that form in acidic and basic solutions with litmus paper and phenolphthalein.
- Explain the difference between strong acids or bases and weak acids or bases.
- Memorize the strong acids and bases.
- Define the terms polyprotic and amphoteric.
- Perform calculations using the following formulas:
 - $\text{pH} = -\log [\text{H}^+]$
 - $\text{pOH} = -\log [\text{OH}^-]$
 - $[\text{H}^+] = 10^{-\text{pH}}$
 - $[\text{OH}^-] = 10^{-\text{pOH}}$
 - $[\text{H}^+][\text{OH}^-] = 1 \times 10^{-14}$
 - $\text{pH} + \text{pOH} = 14$
- Perform stoichiometry calculations for strong acids and bases, incorporating the formulas above.
- Write neutralization reactions.
- Define the concept of a buffer system.
- Understand the purpose of a titration.
- Understand what the equivalence point and the endpoint are for a titration.
- Perform titration calculations.
- Understand the impact of acid rain on the environment.



off the mark.com by Mark Parisi



LEGGETT PRE-AP CHEM ACIDS BASES 13-1 (8:52)	Acid base theories (p. 1-3)	http://vimeo.com/39387047	http://youtu.be/WR68qqIDSR4
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I. WHAT DEFINES A SUBSTANCE AS BEING AN ACID OR BASE?

Acids and Bases are all around us! Our stomach contains Hydrochloric Acid. Many fruits contain Citric Acid. Soda water is slightly acidic. Many cleaners and soaps are basic in nature. With all of these substances around us, it's important that we know some basics about acids and bases.

If you are trying to make a quick identification of an acid or base based strictly on the substance's formula, we can sometimes use the following guidelines...

_____ : An aqueous solution containing the _____ ion (ex: HCl (aq) = Hydrochloric acid)

_____ : An aqueous solution containing the _____ ion; sometimes referred to as an "_____ " solution (ex: NaOH (aq) = Sodium Hydroxide base) Also, there are some funky bases that contain Nitrogen, Hydrogen, and sometimes Carbon! These are called amine bases. An example of an amine base is Ammonia (NH₃).

However, there are some problems with using these basic definitions! There are acids and bases that exist that do not fit these basic formulas. This is where we look to some acid & base theories that were developed by scientists.

A. **Arrhenius Theory** – this is the simplest of all acid/base theories. Arrhenius' theory stated the following:

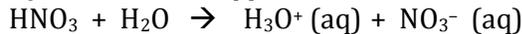
Acid: A substance that forms the _____ ion in water

As we know, an acid dissociates and releases hydrogen ions. But, hydrogen ions cannot exist alone in water solutions, since it's so highly charged. It kinda feels lonely, so it pairs with H₂O to form hydronium ion, H₃O⁺.

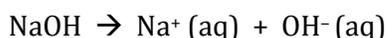
This is how we would have shown the dissociation before...



But really, this is what happens in a water solution!!!



Base: A substance that forms the _____ ion in water



Benefit of Arrhenius Theory: Easy to sort substances into acids and bases

Problem: Many bases do not actually contain hydroxides, like the funky nitrogen bases!

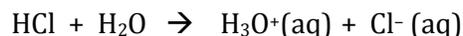
B. **Brønsted-Lowry Theory** – it addresses some of the issues that exist with the funky nitrogen bases! NH₃ (ammonia) is a base, but it doesn't fit Arrhenius' theory. But, it does fit in this acid/base theory!

STRONG: ionizes 100 % (reaction goes 100 % to products)

WEAK: ionizes less than 100% (there will be reactants and products remaining at end)

Hydrogen ions (H⁺) and Hydronium ions (H₃O⁺) basically show the same thing, so they tend to be used interchangeably!

Acid: A substance that _____ a _____ (H^+).
The substance remaining after a proton is donated is then called a conjugate base. (We will practice more with this in a little bit!)



A one-way arrow was used because it's a strong acid!

HCl gave away its H^+ (proton) to water, so it's a Brønsted-Lowry acid. Cl^- will be considered the conjugate base, as it is what remains of the original acid.

Base: A substance that _____ a _____ (H^+). The substance remaining after a proton is accepted is then called a conjugate acid. (Just a little while longer... and we'll practice!)



A two-way arrow was used because it's a weak base!

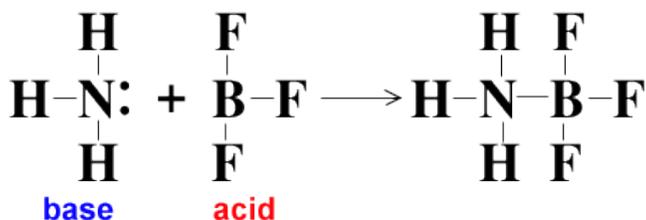
NH_3 accepted the H^+ from water, so it's a Brønsted-Lowry base. NH_4^+ will be considered the conjugate acid, as it is what remains of the original base.

- C. **Lewis Theory** – one more guy decided to throw his name into the books with regards to acids & bases. Lewis developed his theory based on his favorite subatomic particle – the electron!

Lewis' theory is by far the most inclusive of all the theories – there are many substances that aren't considered acids or bases using Arrhenius' or Brønsted-Lowry's theories, but would be an acid or base when using Lewis' theory!

Acid: A substance that _____ an electron pair around the central atom.

Base: A substance that _____ an electron pair from around the central atom.



LEGGETT PRE-AP CHEM
ACIDS BASES 13-2 (14:34)

Conjugates
(p. 3-4)

<http://vimeo.com/39387487>

<http://youtu.be/UBtnHmMBDns>

II. PRACTICING WITH CONJUGATE PAIRS

- A. Acids and bases don't always have to take the normal format! They can look different, but behave like an acid or base. It all comes down to one question... will it donate or accept a proton?

Most of the time, we use Brønsted-Lowry's theory to define an acid or base. If it loses an H^+ , it's an acid... if it gains an H^+ , it's a base. In undergoing these processes, we end up forming

_____ of the original substances.

Conjugate base:

- What is left of the acid (reactant) after it donates its proton
- Called a conjugate base (product) because it is the substance that would accept the proton (base) in the *reverse* reaction.

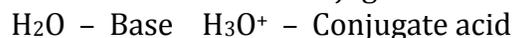
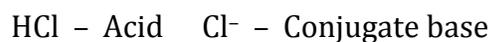
Conjugate acid

- What the base (reactant) becomes after it has accepted a proton

- Called a conjugate acid (product) because it is the substance that would donate the proton (acid) in the *reverse* reaction.

Some important things to remember about conjugate pairs....

- A conjugate acid/base pair differs **ONLY** by ONE PROTON!
- The acid / base will always be reactants, and the conjugate pairs will always be products!



EXAMPLE 13-1. Identify the acid, base, conjugate base, and conjugate acid in the following reactions:



EXAMPLE 13-2. Determine the conjugate pairs for the following substances:

Base	Conjugate Acid?	Acid	Conjugate Base?
NH ₃		NH ₃	
(CH ₃) ₂ NH		H ₂ PO ₄ ⁻	
Sulfate ion		Nitric acid	
Water		Water	

Important to Note:
For the funky nitrogen bases, H⁺ is added to or removed from the end of the formula. For everything else, H⁺ is added to or removed from the beginning of the formula!

EXAMPLE 13-3. Fill in the following chart with the appropriate partner.

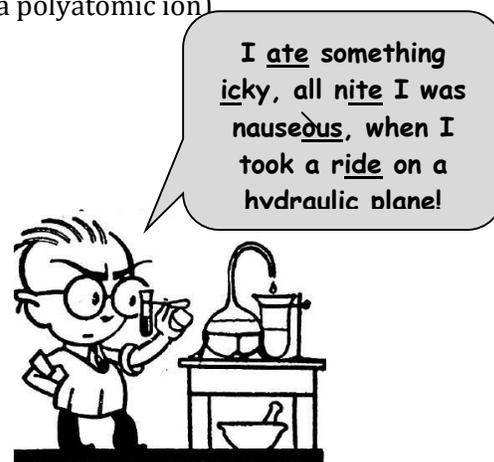
Acid	Base	Conjugate Acid	Conjugate Base
		HF	
			Bicarbonate ion
H ₂ SO ₄			
	Cyanide ion		
H ₂ PO ₄ ⁻²			

LEGGETT PRE-AP CHEM ACIDS BASES 13-3 (11:20)	Naming & Formulas (p. 5-6)	http://vimeo.com/39388183	http://youtu.be/fUmspLpSFPE
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III. LET'S REFRESH ACID AND BASE NAMING...

- A. **Acid Naming & Formula Writing**... YES, WE HAVE DONE THIS BEFORE!!! Acids can be divided into two general groups...
- Binary Acids: Contain two types of elements only (H⁺ with a non-metal)
 - Ternary Acids: Contain three types of elements (H⁺ with a polyatomic ion)

Formula of Acid	Anion Name	Acid Name
H ⁺ + poly ion (per-ate)	Per___ate	Per___ic acid
H ⁺ + poly ion (-ate)	___ate	___ic acid
H ⁺ + poly ion (-ite)	___ite	___ous acid
H ⁺ + poly ion (hypo-ite)	Hypo___ite	Hypo___ous acid
H ⁺ + non-metal	___ide	Hydro___ic acid



When writing the formula, don't forget to add enough H⁺ to balance out the charge on the anion!

EXAMPLE 13-4. Write the name for the following acids.

	Anion formula	Anion Name	Acid Name
HBr			

	Anion formula	Anion Name	Acid Name
H ₂ SO ₄			
HNO ₂			
HClO ₂			
HBrO ₃			
H ₃ P			
HIO			
H ₃ PO ₄			
H ₂ Se			

EXAMPLE 13-5. Write the formulas for the following acids.

	Anion Name	Anion formula	Acid formula
Phosphorous acid			
Perchloric acid			
Sulfurous acid			
Nitric acid			
Perbromic acid			
Hydrosulfuric acid			
Acetic acid			
Hypochlorous acid			
Iodous acid			

- B. **Base Naming & Formula Writing**... we are only going to need to be able to do this for the hydroxide bases (not for the funky nitrogen ones). And guess what... YOU HAVE DONE THIS BEFORE TOO! All you need to do is use your ionic rules for naming and formula writing.

EXAMPLE 13-6. Fill in the missing blanks for the following table.

Base Name	Base Formula
Strontium Hydroxide	
Potassium Hydroxide	
Lithium Hydroxide	
	Mg(OH) ₂
	NaOH
	Ba(OH) ₂

LEGGETT PRE-AP CHEM ACIDS BASES 13-4 (16:33)	pH, pOH etc calculations (p. 7-8)	http://vimeo.com/39388264	http://youtu.be/Bw-KGqO19wc
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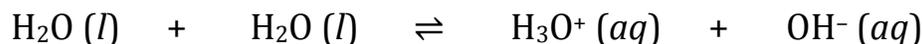
IV. pH and pOH CALCULATIONS

A. Self-Ionization of Water

Okay, so we've seen how water is weird before... well, guess what - it's weird in this unit as well! We know water is covalent. But, it does something very peculiar for a covalent substance... to a VERY SMALL extent, it will complete something

called "_____".

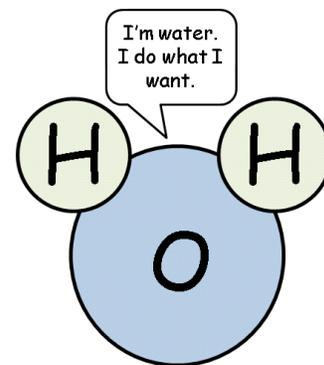
What that means is that to a VERY SMALL extent, water will turn into ions. (Crazy, right?!?!?) When it does so, it will form a very small amount of hydrogen (hydronium) ions, as well as hydroxide ions. However, it's such a small amount that it's not enough to conduct any type of electrical current.



Since this equation does not go to completion, it is considered to create an equilibrium solution. That means an equilibrium calculation can be performed. It has the following mathematical relationship:

$$[\text{H}^+][\text{OH}^-] = 1 \times 10^{-14}$$

(note: this is the same thing as $[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$)



**Brackets =
Molarity!**

- B. What does all this "self-ionization of water" stuff mean for us?!?!?

Acids release H⁺ ions into a water solution. But because water is present, and it self-ionizes, there will still be OH⁻ ions as well.

Bases release OH⁻ ions into a water solution. But again, because water is present, and it self-ionizes, there will still be H⁺ ions as well.

If $[H^+] > [OH^-]$, then we have an _____ solution.

If $[H^+] < [OH^-]$, then we have a _____ (alkaline) solution.

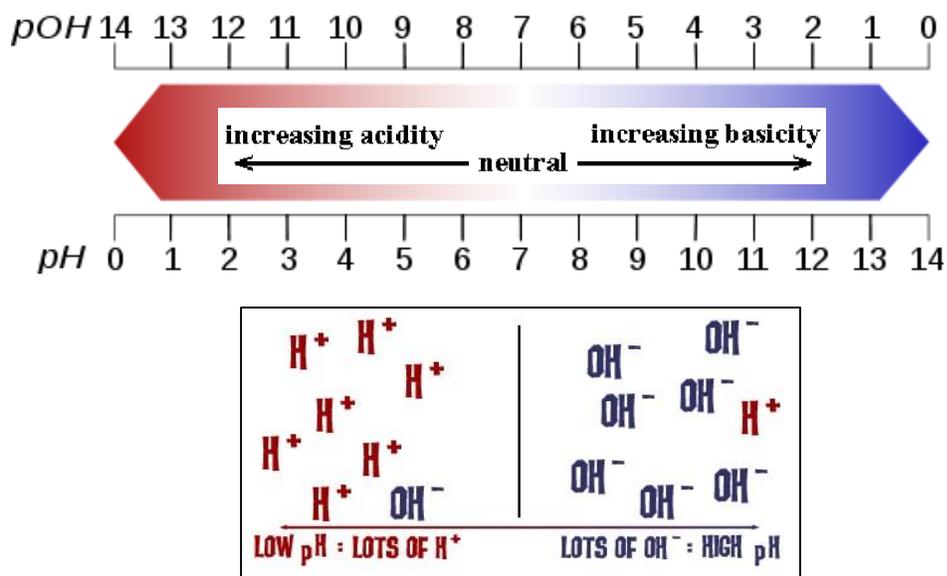
If $[H^+] = [OH^-]$, then we have a _____ solution.

C. The pH Scale

In order to make things easy for us to identify an acid from a base, a scale was created... called the pH scale. This scale is based on the amount of H^+ (H_3O^+) ions present in the solution.

On this scale, an acid is classified as anything having a pH of _____. A base is classified as anything having a pH of _____. If a substance has a pH of exactly 7, it is classified as being _____.

There is a "backwards" scale called the pOH scale. All of the values are the opposite on this scale... an acid is classified as anything having a pOH of 7 to 14, while a base is classified as anything having a pOH of 0 to 7.

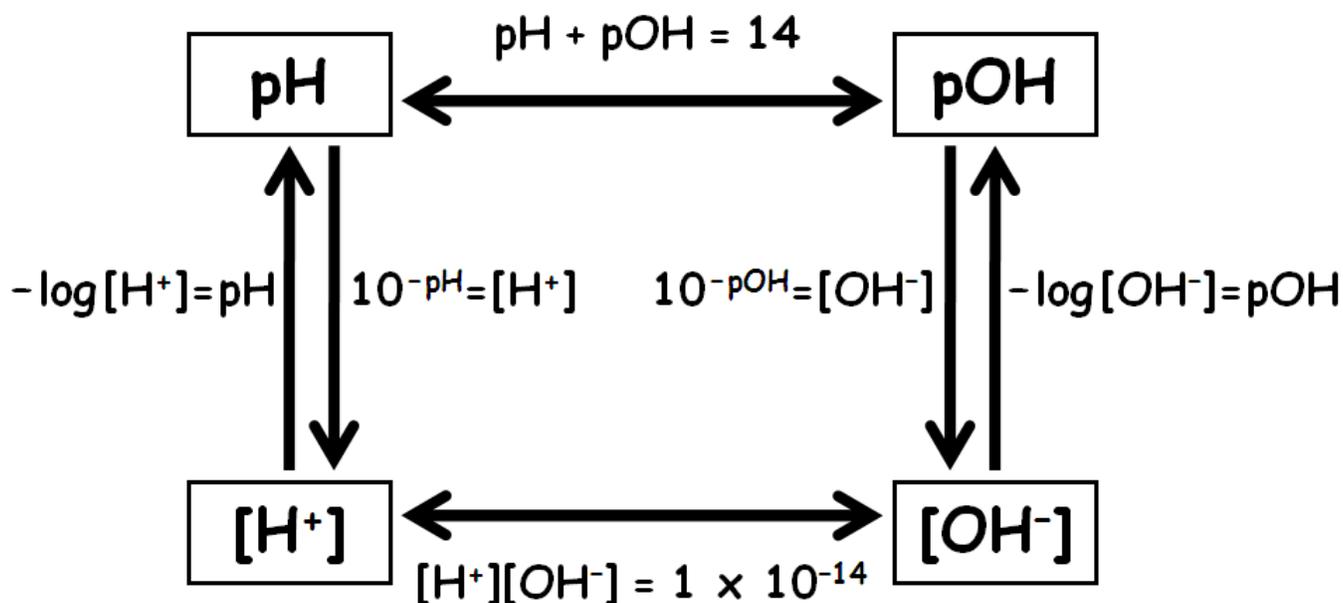


EXAMPLE 13-7. Two clear solutions are placed in separate beakers. The first solution has a pH of 4, and the pH of the second solution is unknown. If the two solutions are mixed and the resulting pH is 5, what do you know about the pH and hydroxide concentration - $[OH^-]$ - of the second solution, in comparison to the first solution?

EXAMPLE 13-8. If the pH of a swimming pool currently has a pH value above the desired pH of 7.5, should you add an acid or a base?

D. **Calculations for Acids & Bases**

Calculating with pH and pOH is all about picking the right formula to use. The calculations aren't hard, if you know what formula you should use in certain situations! All of the formulas are given to you on your periodic table. As you get used to using the formulas, here's a helpful chart to use!



LEGGETT PRE-AP CHEM ACIDS BASES 13-5 (12:23)	pH, pOH etc calculations	https://vimeo.com/40041215	http://youtu.be/WlmeJc16uq8
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EXAMPLE 13-9. If the hydronium ion concentration in a water solution is known to be 4.3×10^{-6} M, what is the hydroxide ion concentration? Is the solution acidic or basic?

Hydrogen ions (H^+) and Hydronium ions (H_3O^+) basically show the same thing, so they tend to be used interchangeably!

EXAMPLE 13-10. If the hydroxide ion concentration in a water solution is known to be $[1.6 \times 10^{-5}]$, what is the hydrogen ion concentration? Is the solution acidic or basic?

EXAMPLE 13-11. If the pOH of a solution is 5.6, what is the pH of the solution? Is the solution acidic or basic?

EXAMPLE 13-12. If the pH of a solution is known to be 4.2, what is the hydrogen ion concentration? Is the solution acidic or basic?

EXAMPLE 13-13. What is the pH of a solution if the $[\text{H}_3\text{O}^+]$ ion concentration is known to be $5.5 \times 10^{-10} \text{ M}$? Is the solution acidic or basic?

EXAMPLE 13-14. If the pOH of a solution is 3.4, what is the $[\text{H}^+]$ ion concentration? Is the solution acidic or basic?

EXAMPLE 13-15. What is the $[\text{OH}^-]$ ion concentration of the solution in the previous example?

EXAMPLE 13-16. If the pH of a solution is 7.9, what is the hydroxide ion concentration? Is the solution acidic or basic?

EXAMPLE 13-17. What is the hydronium ion concentration of the solution in the previous example?

LEGGETT PRE-AP CHEM ACIDS BASES 13-6 (14:15)	Acid/Base Properties, Buffers, Amphoteric	https://vimeo.com/40041216	http://youtu.be/pEK5I3Qxudc
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V. ACID AND BASE PROPERTIES

A. Let's look at some basic properties of acids and bases...

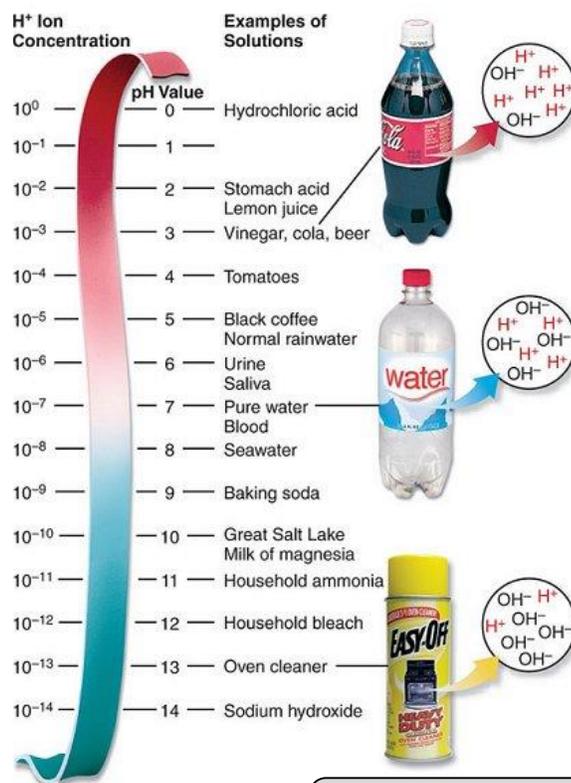
Property	Acid	Base
Taste...		
Found In...		
Feel...		
Conduct Electricity?		
React with Metals?		
Color with Phenolphthalein (an acid/base indicator)		
Color with Litmus Paper (an acid/base indicator)		
pH Scale Values		
Contain more H ⁺ or OH ⁻ in solution?		

B. Buffers

A buffer is a solution that _____
 _____ when small amounts of acid or base are added. A buffer solution usually consists of a mixture of a weak acid and its conjugate base, or a weak base and its conjugate acid.

Buffer solutions are used as a means of keeping pH at a nearly constant value in a wide variety of chemical applications. An example of a buffer solution is our

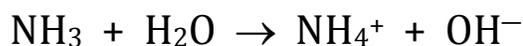
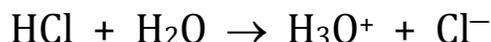
own _____! We eat and drink a lot of acidic things, but our blood likes to keep a constant pH around 7.4. Therefore, the blood contains a buffer solution to resist the changes in pH that could come from taking in acidic substances.



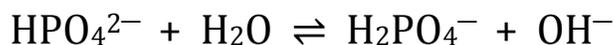
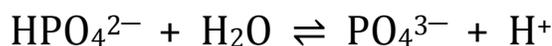
C. Amphiprotic (Amphoteric) Substances

These are substances that can act as an acid or a base, based on Brønsted-Lowry's definition. The most common Amphiprotic substance is water!

EXAMPLE 13-18. In which of the following reactions is water behaving like an acid, and in which one is water behaving like a base?



EXAMPLE 13-19. Circle the amphiprotic/amphoteric substance(s) in the following reactions. Indicate in which reaction the substance is acting as a base, and in which it is acting as an acid.



LEGGETT PRE-AP CHEM ACIDS BASES 13-7 (13)	Polyprotic, Dissociation	https://vimeo.com/40041217	http://youtu.be/DfKbUgywww0
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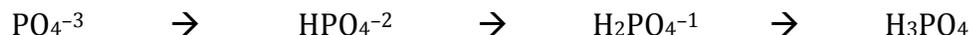
D. Polyprotic Acids

These are acids that have more than one H⁺ ion to give away. Polyprotic acids have forms that are amphiprotic.

EXAMPLE 13-20. Which of the following acids would be considered polyprotic?



EXAMPLE 13-21. Multiple steps of the formation of polyprotic Phosphoric Acid are shown below. Which of the steps would be considered amphiprotic?



VI. DISSOCIATION OF ACIDS AND BASES

As a reminder, acids and bases dissociate just like ionic compounds do.

_____ acids and bases completely dissociate – it completely dissociates into ions, so we show the dissociation with a one-way arrow. Since they form lots of ions, their pH/pOH values tend to be on the more extreme ends of the scale.

_____ acids and bases only partially dissociate, so we show them with a double arrow. Since they don't form as many ions, their pH/pOH values tend to be closer to the center of the scale (meaning closer to neutral).

How do I know what's a strong acid or a strong base???

Strong Acids:

HCl, HBr, HI, HNO₃, H₂SO₄, HClO₃, and HClO₄

Strong Bases:

OH⁻ with a metal from Group 1 or Group 2, except Be & Mg

Every other acid and base is considered to be weak.

You need to
MEMORIZE this list
for your quizzes &
tests this unit!!!



Strong Acids & Bases are _____ conductors of electricity, while weak acids and bases are _____ conductors of electricity.

As we've already discussed, there are some funky bases that contain nitrogen, called amine bases. **For the funky nitrogen bases, you MUST show water in the dissociation equation.** It won't work out if you leave off the water!

EXAMPLE 13-22. Write the acid or base dissociation equation for the following aqueous solutions. If they are strong, use one arrow, if they are weak use a double arrow.

Acids	Dissociation Equation
HClO ₃	
HMnO ₄	
HC ₂ H ₃ O ₂	
Bases	Dissociation Equation
Ba(OH) ₂	
Aniline, C ₆ H ₅ NH ₂	
Trimethylamine, (CH ₃) ₃ N	

LEGGETT PRE-AP CHEM ACIDS BASES 13-8 (14:03)	Strong Acid/Base Calculations (p.14)	https://vimeo.com/40041218	http://youtu.be/1AReTb4fLLI
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VII. STRONG ACID & BASE CALCULATIONS

- A. Remember, in strong acids and bases, 100% of the original acid or base will split into ions. How does this help us? Well, it means we can use mole to mole ratios to help us make calculations involving strong acids and bases.
- B. We will be making a couple of types of calculations...
- Molarity of acid or base is given, we need to find pH/pOH
 - pH/pOH is given, and we need to find molarity of the acid or base
 - The above calculations, but also using $M = (\text{mass/MM solute})/(\text{Kg solvent})$

Sample #1: What is the pH of a 0.033 M nitric acid solution?

	HNO ₃ →	H ⁺	NO ₃ ⁻
S_{start}	0.033 M	0	0
S_{shift}	-0.033 M	+0.033 M	+0.033 M
S_{stop}	0	0.033	0.033

$$\text{pH} = -\log[0.033\text{M}] \quad \text{pH} = 1.48$$

Sample #2: What is the pH of a 0.033 M strontium hydroxide solution?

	$\text{Sr}(\text{OH})_2 \rightarrow$	$2\text{OH}^- +$	Sr^{+2}
S_{start}	0.033 M	0	0
S_{shift}	-0.033 M	$+0.033 \times \left(\frac{2}{1}\right)$	+0.033 M
S_{stop}	0	0.066	0.033

$$\text{pOH} = -\log(0.066) = 1.18$$

$$\text{pH} + \text{pOH} = 14$$

$$\text{pH} = 14 - 1.18 = 12.82$$

NOTE: TWO moles of hydroxide are formed for every ONE mole of strontium hydroxide that dissociates!

EXAMPLE 13-23. What is the pH of a 0.050 M Chloric Acid solution?

EXAMPLE 13-24. What is the pH of a 0.0667 M Sodium Hydroxide solution?

EXAMPLE 13-25. What is the pH of a 0.0682 M Calcium Hydroxide solution?

EXAMPLE 13-26. What is the pH of a 0.0550 M Sulfuric Acid solution?

LEGGETT PRE-AP CHEM ACIDS BASES 13-9 (14:54)	Strong Acid/Base Calculations (p.14)	https://vimeo.com/40041222	http://youtu.be/xCd93DriYok
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EXAMPLE 13-27. If the pH of a Hydrobromic Acid solution is known to be 3.2, what is the hydrogen ion concentration?

EXAMPLE 13-28. In the previous question, what was the molar concentration of the acid to start with?

EXAMPLE 13-29. What is the nitrate ion concentration and the hydrogen ion concentration of a Nitric Acid solution if the pH is known to be 1.3?

EXAMPLE 13-30. If the pH of a Barium Hydroxide solution is known to be 10.4, what is the original molar concentration of the base?

EXAMPLE 13-31. If the hydrogen ion concentration in a solution of Calcium Hydroxide is known to be 1.2×10^{-12} M, what is the calcium ion concentration? Hydroxide ion concentration? pH of the solution?

EXAMPLE 13-32. If 4.5 grams of Potassium Hydroxide are dissolved in water to make 500. mL of solution, what is the pH of the solution?

EXAMPLE 13-33. How many grams of Calcium Hydroxide must be dissolved in water to make 1500 mL of solution whose pH is 10.2?

LEGGETT PRE-AP CHEM ACIDS BASES 13-10 (16:18)	Neutralization & Titrations	https://vimeo.com/40042031	http://youtu.be/QgghwpkUC5g
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VIII. REMEMBERING NEUTRALIZATION REACTIONS

When an acid and base react together, they will always form an _____ and _____. Because we are forming a neutral substance (water), we call this type of reaction a neutralization reaction.

Neutralization reactions are a special type of double replacement reaction. We have written these reactions before! Let's see if we can remember how...

EXAMPLE 13-34. Write the reaction for the neutralization of Sulfuric Acid with Potassium Hydroxide.

EXAMPLE 13-35. Calcium Hydroxide and Phosphoric Acid

EXAMPLE 13-36. Lithium Hydroxide and Chlorous Acid

EXAMPLE 13-37. Aluminum Hydroxide and Nitric Acid

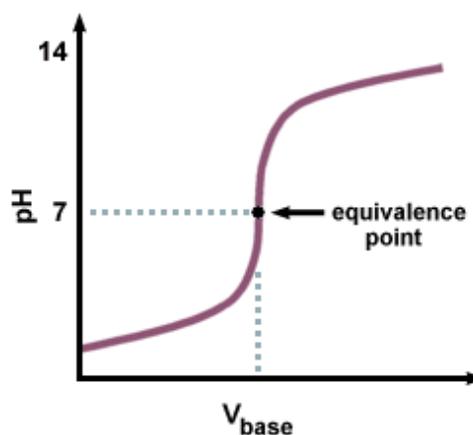
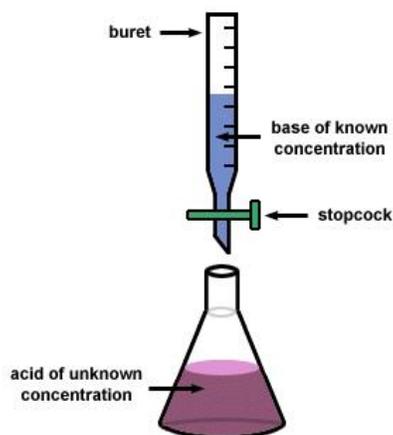
IX. TITRATIONS

A titration is a technique that is used to determine the unknown _____ of an acid or base. A solution of known _____ is added drop by drop to the other solution (of unknown molarity) using a _____. A neutralization reaction takes place.

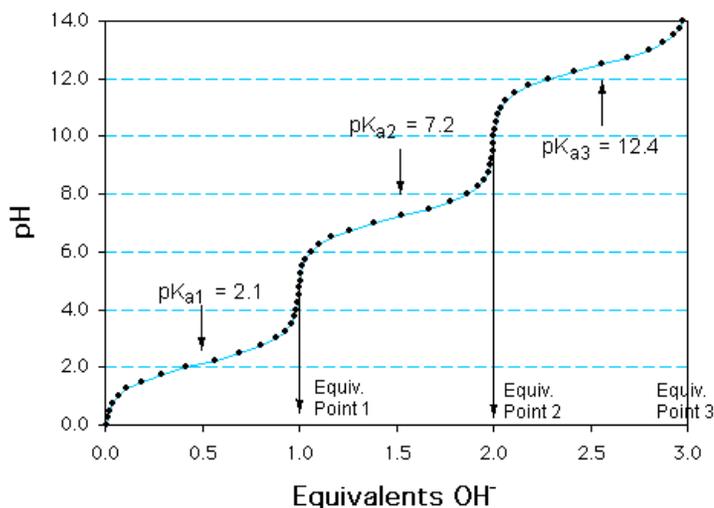
The solution is added until the _____ is reached. This is the point when all of the acid is neutralized by the base.

Once we have reached the equivalence point for the solutions, we would say we have reached the _____ of the titration, meaning we can stop the titration!

_____ are used to show when the equivalence point is reached. One of the most common indicators to use in a titration is phenolphthalein.



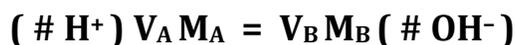
Phosphate Titration



Polyprotic acids will have multiple equivalence points... basically, an equivalence point for each H^+ that will come off. The titration curve shown to the left is for H_3PO_4 , Phosphoric Acid.

Once the titration is complete, there is more than one way to calculate the unknown molarity. One can use stoichiometry to make the calculation, similar to what we did last unit!

However, a quicker way to complete the calculation is to use a modified version of $V_A M_A = V_B M_B$ (vooom-vooom from last unit) to find the unknown molarity. The modified version takes into account the fact that there might be more than one mole of H^+ or OH^- involved in the titration.



EXAMPLE 13-38. If 45.8 mL of a 0.500 M solution of $\text{Ca}(\text{OH})_2$ is required to titrate 25.0 mL of HCl, what is the molarity of the HCl solution?

EXAMPLE 13-39. 50.0 mL of H_3PO_4 is titrated with 45.0 mL of a 0.75 M solution of $\text{Sr}(\text{OH})_2$. What is the molarity of the acid?

Remind me: We will discuss this in class!

X. ACID RAIN

- Acid rain is a broad term used to describe the _____ and _____ acids that fall to the Earth during rain, snow, or fog.
- These chemicals form in our atmosphere when pollutants released into the air through the burning of _____ blend with other substances in the atmosphere, including water vapor.
- When precipitation falls, these substances return to the Earth's surface where they get into rivers, streams, and groundwater – literally making those waters become more _____ and _____ the pH.
- Acid rain hurts both plant and animal life – especially aquatic life.
- Acid rain's effects can also be seen in the cracks, discoloration, and dissipating of buildings and statues.
- Emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are primarily to blame.
- 95% of these emissions come from burning fossil fuels in industrial _____ and _____.



