Acids and Bases

Word	Definition
Acidity	The property of exhibiting the qualities of an acid.
Alkalinity	The property of exhibiting the qualities of a base
Amphiprotic	A species that can act either as a B/L acid or a B/L base, depending on what other species it is reacting with.
Amphoteric	A species that can act either as a B/L acid or a B/L base, depending on what other species it is reacting with.
Arrhenius Acid	An electrolyte that ionizes in aqueous solution to yield H^+ as the only positive ion in solution.
Arrhenius Base	An electrolyte that ionizes in aqueous solution to yield OH^- as the only negative ion in solution.
Basicity	The property of exhibiting the qualities of a base
Bronsted/Lowry Acid	A species that donates H^+ to a B/L base in a chemical reaction.
Bronsted/Lowry Base	A species that accepts H^+ from a B/L acid in a chemical reaction.
Buret	A piece of laboratory equipment that precisely measures how much liquid has been let out of it by the valve on the bottom.
Caustic	A substance that will destroy or irreversibly damage any substance or surface it comes into contact with through a chemical change, usually used to describe bases.
Conjugate pair	An acid/base pair that differ only by one H^+. Acids turn into conjugate bases, bases turn into conjugate acids.
Corrosive	A substance that will destroy or irreversibly damage any substance or surface it comes into contact with through a chemical change, usually used to describe acids.
Electrolyte	A compound that ionizes in water, allowing the solution to conduct electricity.
Hydrolysis	The process whereby a base reacts with a glycerol ester (fat) to produce soap.
Indicator	A substance whose color is sensitive to the pH of a solution to which it is added.
Neutralization	A double-replacement reaction where an acid and base react to form water and a salt.
Nonelectrolytes	A molecular compound that does not ionize in water, preventing the solution from conducting electricity.
pH	The negative log of the hydrogen ion concentration. A pH less than 7 indicates an acidic solution, a pH of greater than 7 indicates a basic solution and a pH of 7 indicates a neutral solution.
Protonation	The addition of an acid's H^+ ion (proton) to a water molecule to form hydronium (H_3O^+).
Salt	An ionic compound formed when an acid and base neutralize each other. This compound consists of the anion of the acid and the cation of the base.
Titration	A process of controlled acid-base neutralization, carried out in burets.

1) Properties of Arrhenius Acids and Bases (HW: p. 13, 14)

Essential Question: Which is more dangerous; an acid or base?

"Oh my goodness! It's acid! It's gonna get you!!! It's gonna eat you up, eat you up, eat you up!"

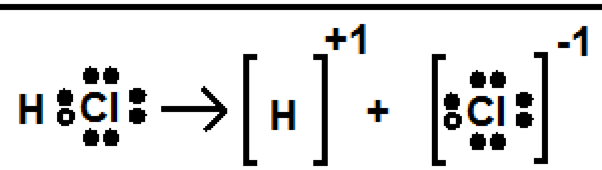
When I took chemistry in high school, my friend Tim was a bit of a prankster. He took an eyedropper with water in it and chased a friend of his around the lab room shouting what you see above. His friend ran in fear, mortal terror that he would be eaten away by an acid. Why didn't Tim shout "it's a base! It's a base!" Would his friend have run in terror?

Acids and bases are a cornerstone of chemistry. These two substances have uses in industry, medicine, geology, cosmetics and in the home as well. Ammonia (NH_4OH) is a base that is used to clean grease buildup on floors. Hydrochloric acid (HCl) is used to partially dissolve the surface of concrete flooring so that it roughens to hold floor paint better. Hydrofluoric acid (HF) is used to etch glass. Sulfuric acid (H_2SO_4) is used as a catalyst for certain reactions, and as a reactant in refining iron ore. Sodium hydroxide (NaOH) is reacted with animal fat or vegetable oil to form soap, and it is also used for drain cleaner.

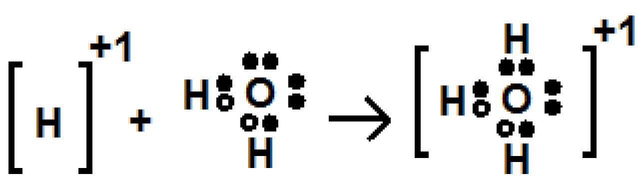
Svante Arrhenius (1859-1927) was the first to describe the conductivity of electrolyte solutions, and to hypothesize that solutions that conduct electricity contain dissolved ions. He also described acids and bases in terms of their properties. What follows is the **Arrhenius Definition** of acids and bases!

<u>ACIDS: substances that contain H^+ ions that ionize when dissolved in water.</u>

Acids are the only molecules that ionize when dissolved in water. Acids are electrolytes, unlike other molecular substances like water (H_2O) and sugar ($C_6H_{12}O_6$). The H leaves the acid and bonds to the water molecule to form a hydronium ion (H_3O^+).



1) The acid ionizes to form a hydrogen ion and an anion. In this case, the anion is the chloride ion.



2) The hydrogen ion bonds to the water molecule by using a sneaky kind of bonding. H+ doesn't have any valence electrons of its own to share, and there are no unpaired electrons in the water molecule. The hydrogen mooches two electrons off of the oxygen. Notice how the other two bonds are represented as a circle and a dot? That shows one electron from each bonding atom pairing up. The hydrogen on top is bonded with two dots...both shared electrons originally belonged to just the oxygen atom. This is called a COORDINATE COVALENT BOND.

Examples:

$HCl\ (g) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + Cl^-\ (aq)$
The acid HCl contains 1 H^+ which combines with 1 H_2O to form 1 H_3O^+

$H_2SO_4\ (l) + 2\ H_2O\ (l) \rightarrow 2\ H_3O^+\ (aq) + SO_4^{-2}\ (aq)$
The acid H_2SO_4 contains 2 H^+ which combines with 2 H_2O to form 2 H_3O^+

$H_3PO_4\ (l) + 3\ H_2O\ (l) \rightarrow 3\ H_3O^+\ (aq) + PO_4^{-3}\ (aq)$
The acid H_3PO_4 contains 3 H^+ which combines with 3 H_2O to form 3 H_3O^+

Properties Of Acids:

Table J
Activity Series

Metals (Most → Least)	Nonmetals (Most → Least)
Li	F_2
Rb	Cl_2
K	Br_2
Cs	I_2
Ba	
Sr	
Ca	
Na	
Mg	
Al	
Ti	
Mn	
Zn	
Cr	
Fe	
Co	
Ni	
Sn	
Pb	
**H_2	
Cu	
Ag	
Au	

a) Acids eat away (oxidize) active metals (above H_2 on Table J)

Metals like Li, Mg and Zn can be oxidized by an acid to produce hydrogen gas. They are listed above hydrogen (H_2) on Table J. The three metals listed below hydrogen (Cu, Ag and Au) cannot be oxidized by an acid. There are some exceptions to this, but they will not be covered in this unit. The significance of this positioning will be explained in more detail in the next unit.

This is a single replacement reaction:

$$2\ Li + 2\ HCl \rightarrow 2\ LiCl + H_2$$

$$Ca + HCl \rightarrow CaCl_2 + H_2$$

The active metal kicks out the hydrogen in the acid. This is one way to prepare a sample of hydrogen gas!

b) Acids have a pH less than 7.

pH is a scale that measures the acidity or alkalinity of a solution. A pH of 7 is a neutral solution, and acids have a pH of less than 7. Each decrease of one in pH is a tenfold increase in acid strength. An acid with a pH of 3 is ten times more acidic than one with a pH of 4, and one hundred times more acidic than a solution with a pH of 5.

c) Acidic solutions conduct electricity.

Acids are electrolytes, because they form ions in solution. The stronger the acid, the more it ionizes, and therefore the better it conducts electricity.

Strong acids (strong electrolytes) include HI, HCl, HNO_3 and H_2SO_4.

Weak acids (weak electrolytes) include H_2CO_3 (found in soda) and $HC_2H_3O_2$ (found in vinegar).

d) Dilute solutions of acids taste sour.

Citric acid is found in citrus fruits like lemons and grapefruits. It is also used in sour candies to give it that extra sour kick.

e) Acids react with carbonates to form CO_2, salt and water vapor

Baking soda and vinegar: $NaHCO_3$ (s) + $HC_2H_3O_2$ (aq) $\rightarrow$ CO_2 (g) + H_2O (l) + $NaC_2H_3O_2$ (aq)

This is the "volcano" reaction…the CO_2 gas given off causes the solution to foam up and out.

f) Acids can be formed by reaction of gaseous oxides with water

Burning fossil fuels releases nonmetallic oxides (CO_2, NO_2, SO_2 and similar molecules) into the atmosphere. When they combine with the water in the atmosphere, they form weak acids that can cause ecological problems. Plants and fish thrive in a narrow range of pH values. The acidification of rain has brought the pH of my lawn down so much that moss grows better than grass does, and the only way to reverse it is to place hundreds of pounds of lime (calcium carbonate, a weak base) on the lawn to bring the pH up so that the moss can't grow as well and the grass has a chance!

Naming Acids (Reference Table K):

Table K
Common Acids

Formula	Name
$HCl(aq)$	hydrochloric acid
$HNO_3(aq)$	nitric acid
$H_2SO_4(aq)$	sulfuric acid
$H_3PO_4(aq)$	phosphoric acid
$H_2CO_3(aq)$ or $CO_2(aq)$	carbonic acid
$CH_3COOH(aq)$ or $HC_2H_3O_2(aq)$	ethanoic acid (acetic acid)

a) **Binary Acids:** hydro- prefix, followed by nonmetal ion name with last syllable replaced with –ic acid

Naming:

HCl (aq): hydro + (chloride – ide + ic acid) = **hydrochloric acid**

HBr (aq): hydro + (bromide – ide + ic acid) = **hydrobromic acid**

H_2S (aq): hydro + (sulfide – ide + ic acid) = **hydrosulfic acid, also called hydrosulfuric acid**

H_3N (aq): hydro + (nitride – ide + ic acid) = **hydronitric acid**

Writing: just as you would write the name of any ionic compound, putting the H^{+1} first, and the negative ion second.

Hydrofluoric acid: H^{+1} and fluoride (F^{-1}) → **HF (aq)**

Hydrophosphoric acid: H^{+1} and phosphide (P^{-3}) → **H_3P (aq)**

a) **Ternary Acids:** no hydro- prefix, polyatomic ion name followed by –ic acid if ion ends in _ide, –ate or followed by –ous acid if ion ends in –ite

Table E
Selected Polyatomic Ions

H_3O^+	hydronium	CrO_4^{2-}	chromate
Hg_2^{2+}	dimercury (I)	$Cr_2O_7^{2-}$	dichromate
NH_4^+	ammonium	MnO_4^-	permanganate
$C_2H_3O_2^-$ / CH_3COO^-	acetate	NO_2^-	nitrite
		NO_3^-	nitrate
CN^-	cyanide	O_2^{2-}	peroxide
CO_3^{2-}	carbonate	OH^-	hydroxide
HCO_3^-	hydrogen carbonate	PO_4^{3-}	phosphate
$C_2O_4^{2-}$	oxalate	SCN^-	thiocyanate
ClO^-	hypochlorite	SO_3^{2-}	sulfite
ClO_2^-	chlorite	SO_4^{2-}	sulfate
ClO_3^-	chlorate	HSO_4^-	hydrogen sulfate
ClO_4^-	perchlorate	$S_2O_3^{2-}$	thiosulfate

Naming:

HNO_3 (aq): nitrate – ate + ic acid = **nitric acid**

HNO_2 (aq): nitrite – ite + ous acid = **nitrous acid**

$HClO_3$ (aq): chlorate – ate + ic acid = **chloric acid**

$HClO_2$ (aq): chlorite – ite + ous acid = **chlorous acid**

HCN (aq): cyanide – ide + ic acid = **cyanic acid**

Writing:

Sulfuric acid: H^+ and sulfate (SO_4^{-2}) → **H_2SO_4 (aq)**

Sulfurous acid: H^+ and sulfite (SO_3^{-2}) → **H_2SO_3 (aq)**

BASES: substances that contain hydroxide (OH^{-1}) ions dissolved in aqueous solution.

Table L
Common Bases

Formula	Name
$NaOH(aq)$	sodium hydroxide
$KOH(aq)$	potassium hydroxide
$Ca(OH)_2(aq)$	calcium hydroxide
$NH_3(aq)$	aqueous ammonia

$NaOH (s) \rightarrow Na^{+1} (aq) + OH^{-1} (aq)$	(sodium hydroxide)
$Ca(OH)_2 (s) \rightarrow Ca^{+2} (aq) + 2\ OH^{-1} (aq)$	(calcium hydroxide)
$Al(OH)_3 (s) \rightarrow Al^{+3} (aq) + 3\ OH^{-1} (aq)$	(aluminum hydroxide)

Properties Of Bases:

a) Bases have a pH greater than 7

pH is a scale that measures the **acidity** or **alkalinity** (basicity) of a solution. A pH of 7 is a neutral solution, and bases have a pH of more than 7. Each increase of one in pH is a tenfold increase in base strength. A base with a pH of 10 is ten times more basic than one with a pH of 9, and one hundred times more basic than a solution with a pH of 8.

b) Basic solutions conduct electricity.

Bases are electrolytes, because they form ions in solution. The stronger the base (the more alkaline the solution, in other words), the more it ionizes, and therefore the better it conducts electricity.

Strong bases (strong electrolytes) include Group 1 metal hydroxides (LiOH, NaOH, RbOH and CsOH).

Weak bases (weak electrolytes) include $Ca(OH)_2$, $Mg(OH)_2$ and $Al(OH)_3$, which can all be found in antacids. Antacids neutralize excess stomach acid that causes heartburn.

c) Bases taste bitter

Alkaloids, which are often found in medicines, have a bitter taste. So does coffee!

d) Bases can be formed when Group 1 and 2 metals react with water, hydrogen is released too.

$2\ Na (s) + H_2O (l) \rightarrow 2\ NaOH (aq) + H_2 (g)$ ← sodium is reacting with water to form sodium hydroxide

$Mg (s) + 2\ H_2O (l) \rightarrow Mg(OH)_2 (aq) + H_2 (g)$ ← magnesium is reacting with water to form magnesium hydroxide

What metal has to be reacted with water to form lithium hydroxide? Lithium!

e) Bases hydrolyze fats (turns them into soap, also called "saponification")

Drain cleaner usually contains sodium hydroxide, which reacts with grease (nonpolar, so it can't dissolve in water) that is clogging the drain and turns it into soap (which is a sodium salt of a fatty acid and therefore ionic, which is soluble in water), which washes down the drain.

The manufacture of soap involves heating up animal fat or vegetable oil, (for example, glyceryl stearate) dissolving it in alcohol and adding NaOH or KOH to it slowly. This forms a soap (for example, sodium stearate), which can now be used for cleaning!

Ammonium hydroxide (NH_3 (aq) or NH_4OH) is a solution used to clean floors and countertops of greasy buildup or residue. NEVER mix ammonia with bleach or products containing bleach, as this can cause a serious health risk.

HOW DO WE KNOW IF A SOLUTION IS ACIDIC OR BASIC?

1) pH probes

pH probes contain an electrode that detects electrical conductivity. Before using this electronic device, it has to be calibrated by giving it a taste of two different solutions with different pH's. These come in pocket devices that run on batteries or in computer interface probe form.

Table M
Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.2–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8.2–10	colorless to pink
litmus	5.5–8.2	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

2) Acid-Base Indicators and narrowing down pH using multiple indicators (mixture of indicators gives great range of colors, pH paper)

Indicators are chemicals that have a certain characteristic color, depending on the pH. They can be used to determine if a solution is acidic or basic, or even to narrow the range of pH of a solution down. pH paper is paper soaked with a mixture of indicators that give a specific color at a specific pH, which is found on a chart on the pH paper bottle so you can compare the results to the chart. Litmus paper is paper soaked with litmus solution that has been allowed to dry.

Methyl orange is RED from a pH of 3.2 or lower, and YELLOW from a pH of 4.4 or more. The middle of the range is an intermediate color (in this case, ORANGE).

A solution yields the following results when tested with various indicators:

Methyl Orange = yellow
Phenolphthalein = colorless
Bromcresol Green = blue
Thymol Blue = yellow

Can the pH be:
a) 2.8 b) 6.5 c) 8.5 d) 4.8

Well, let's use the reference table to figure out at what pH the above indicators will be the specified colors.

1) Methyl Orange = yellow at pH's above 4.4 (it's red at pH's below 3.2 and changes from red to yellow between 3.2 and 4.4)

Since the pH must be above 4.4, we can eliminate choice A.

2) Phenolphthalein = colorless at pH's below 8.2 (it's pink at pH's above 10 and changes from colorless to pink between 8.2 and 10)

Since the pH must be below 8.2, choice C can be eliminated. Only choices B and D are left.

3) Bromcresol Green = blue at pH's above 5.4 (it's yellow at pH's below 3.8 and changes from yellow to green between 3.8 and 5.4)

Since the pH must be above 5.4, choice D can be eliminated.

The answer must be Choice B. Let's see if that holds up with the last indicator:

4) Thymol Blue = yellow at pH's below 8.0, which 6.5 certainly is.

The answer is therefore choice B, pH = 6.5.

2) Acid and Base Neutralization (HW: p. 15- 17)

Essential Question: How do antacids work?

Neutralization

When acidic and basic solutions are mixed, the H^+ of the acid and the OH^- of the base combine to form water. The anion of the acid and the cation of the base come together to form a salt. A salt is defined as an ionic compound that can be formed by acid-base neutralization.

This is a simple double replacement reaction. The water formed is considered to be the precipitate. To make writing these reactions easier, water will be written as HOH.

One mole of H^+ ions exactly neutralizes 1 mole of OH^- ions

Completing Neutralization Reactions: it's exactly the same as you completed double replacement reactions!

HCl (aq) + NaOH (aq) → **NaCl** (aq) + HOH (l)
Acid Base **Salt** Water

H_2SO_4 (aq) + 2 **KOH** (aq) → K_2SO_4 (aq) + 2 HOH (l)
Acid **Base** Salt Water .

2 HNO_3 (aq) + **$Ca(OH)_2$** (aq) → $Ca(NO_3)_2$ (aq) + 2 HOH (l)
Acid **Base** Salt Water

Titration - the controlled process of acid-base neutralization. It is used to determine the concentration of an acid or base.

Problem - You find a bottle labeled "NaOH", with no concentration written on it. You want to find out the concentration, because unless the concentration is known, this sample is totally useless in the lab. How can this be done?

1) Put a certain volume of the base in a buret
2) Place a certain volume of standardized solution acid with some phenolphthalein indicator into an Erlenmeyer flask.
3) Add the base to the acid drop-wise until the indicator just begins to turn color.
4) Record the volume of base necessary to neutralize the acid.

The point where the indicator turns color is called the "endpoint". Because the indicator might not turn color at exactly pH = 7, it might be a little off from the equivalence point, or the point where all of the acid H^+ ions might have in fact reacted with all of the base OH^- ions. The best way to do a titration is to use a pH meter.

ENDPOINT: The pH at which an indicator that has been added to a titration setup turns color.

Phenolphthalein turns from colorless to pink at a pH of 8.2, which is slightly on the base side of neutral. When base is added to acid with phenolphthalein in it, the solution will gradually take longer to get the pink color out of until one drop of base turns the solution permanently pink. This will be a pH or 8.2. This is the endpoint.

EQUIVALENCE POINT: The point at which the titrated solution has a pH of 7. The concentration of hydronium is equivalent to the concentration of hydroxide. This can be determined by using a pH probe to determine when the solution is neutral rather than an indicator.

The best indicators give an endpoint close to the equivalence point. To determine if a solution has been neutralized, choose an indicator that changes color closest to a pH of 7. Phenolphthalein is the most commonly used indicator for titration, though bromthymol blue does a nice job as well. If you really have the big bucks, buy a pH probe…just stop titrating when the pH reaches 7!

Solving Titration Problems

1) One mole of H^+ neutralizes one mole of OH^-.

2) moles of H^+ = moles of OH^-

3) Since we are dealing with solutions and molarities, recall the formula M = moles/L. Rearrange this to **moles = M x L**. Liters are a unit of volume, so the formula now becomes moles = M x V. Therefore:

moles of acid = M_{acid} x V_{acid} and moles of base = M_{base} x V_{base}

This gives the formula

$$M_{acid} \times V_{acid} = M_{base} \times V_{base}$$

Which can be abbreviated $M_aV_a = M_bV_b$. This can be remembered by saying out loud:

MAH-VAH EQUALS MUB-VUB!

Now, since acids may have more than one H and bases may have more than one OH, the equation has to be finalized as:

$$\# \text{ H } M_aV_a = \# \text{ OH } M_bV_b$$

If you are just trying to solve for moles instead of molarity, the formula can be simplified to

$$\# \text{ H Moles}_a = \# \text{ OH Moles}_b$$

Here are a lot of sample problems for you!

How many moles of LiOH are needed to exactly neutralize 2.0 moles of H_2SO_4?

Since we are given moles of both acid and base, use the equation # H Moles_a = # OH Moles_b.

H Moles_a = # OH Moles_b, rearranged to solve for moles of base is Moles_b = # H Moles_a / # OH

Moles_b = # H Moles_a / # OH = (2 X 2.0 moles) / 1 = **4.0 moles of LiOH**

How many moles of H_2SO_4 are needed to exactly neutralize 5.0 moles of NaOH?

Since we are given moles of both acid and base, use the equation # H Moles_a = # OH Moles_b.

H Moles_a = # OH Moles_b, rearranged to solve for moles of acid is Moles_a = # OH Moles_b / # H

OH Moles_b / # H = (1 X 5.0 moles) / 2 = **2.5 moles of H_2SO_4**

How many moles of HCl are needed to neutralize 0.10 L of 2.0 M NaOH?

This requires a mixture of both equations. Since moles = M x V, one can easily be substituted for the other. We are given moles for the acid, so use # H Moles_a for that part. We are given molarity and volume for the base, so use # OH M_bV_b for that part.

H Moles_a = # OH M_bV_b, rearranged to solve for moles of acid is Moles_a = # OH M_bV_b / # H

OH M_bV_b / # H = [(1) (2.0 M) (0.10 L)] / 1 = **0.20 moles of HCl**

How many moles of NaOH are needed to neutralize 0.010 L of 0.20 M H_2SO_4?

This requires a mixture of both equations. Since moles = M x V, one can easily be substituted for the other. We are given moles for the base, so use # OH $Moles_b$ for that part. We are given molarity and volume for the acid, so use # H M_aV_a for that part.

H M_aV_a = # OH $Moles_b$, rearranged to solve for moles of base is $Moles_b$ = # H M_aV_a / # OH

H M_aV_a / # OH = [(2) (0.20 M) (0.010 L)] / 1 = **0.0040 moles of HCl**

How many mL of 0.100 M HCl are needed to neutralize 40.0 mL of 0.500 M NaOH?

If it takes 15.0 mL of 0.40 M NaOH to neutralize 5.0 mL of HCl, what is the molar concentration of the HCl solution?

Since we are given molarity and volume for both acid and base, use the equation # H M_aV_a = # OH M_bV_b

H M_aV_a = # OH M_bV_b, rearranged to solve for molarity of acid is M_a = # OH M_bV_b / # H V_a

M_a = # OH M_bV_b / # H V_a = [(1) (0.40 M) (15.0 mL)] / [(1) (5.0 mL)] = **1.2 M HCl**

If it takes 10.0 mL of 2.0 M H_2SO4 to neutralize 30.0 mL of KOH, what is the molar concentration of the KOH?

Since we are given molarity and volume for both acid and base, use the equation # H M_aV_a = # OH M_bV_b

H M_aV_a = # OH M_bV_b, rearranged to solve for molarity of base is M_b = # H M_aV_a / # OH V_b

M_b = # H M_aV_a / # OH V_b = [(2) (2.0 M) (10.0 mL)] / [(1) (30.0 mL)] = **1.3 M KOH**

How many mL of 2.0 M H_2SO_4 are required to neutralize 30.0 mL of 1.0 M NaOH?

Since we are given molarity and volume for both acid and base, use the equation # H M_aV_a = # OH M_bV_b

H M_aV_a = # OH M_bV_b, rearranged to solve for volume of acid is V_a = # OH M_bV_b / # H M_a

V_a = # OH M_bV_b / # H M_a = [(1) (1.0 M) (30.0 mL)] / [(2) (2.0 M)] = **7.5 mL H_2SO_4**

How many mL of 0.10 M $Ca(OH)_2$ are required to neutralize 25.0 mL of 0.50 M HNO_3?

Since we are given molarity and volume for both acid and base, use the equation # H M_aV_a = # OH M_bV_b

H M_aV_a = # OH M_bV_b, rearranged to solve for volume of base is V_b = # H M_aV_a / # OH M_b

V_b = # H M_aV_a / # OH M_a = [(1) (0.50 M) (25.0 mL)] / [(2) (0.10 M)] = **63 mL $Ca(OH)_2$**

3) pH (HW: p. 18)

Essential Question: So what is this pH that we use to keep our fish alive and our bodies stink-free?

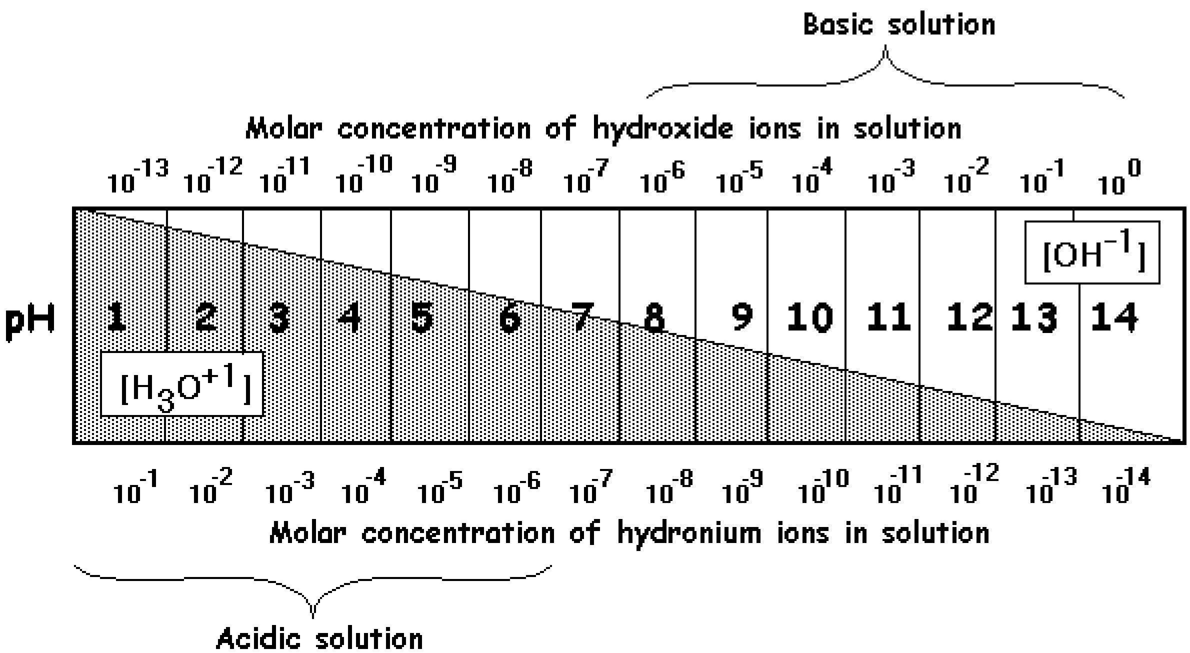
pH, Power of Hydronium Ion In A Solution

Ah, pH. It's the easiest method to use for comparing the strengths of acids and bases. We test our fishtanks (fish pee out ammonia, which is a base, and brings the pH up), our lawns (acid rain brings the pH of the soil down) and even food is pH tested as it is being made to make sure that it falls within the right range. You wouldn't want your super-sour candy to have too little bite, would you? So just what is this pH, what does it mean, and how is it measured?

Water breaks up very slightly to form hydrogen ions and hydroxide ions:

$$H_2O \rightarrow H^{+1} + OH^{-1}$$

In neutral water, the concentration of H+ = 1.0 X 10^{-7} M, so the pH = 7



ADDING ACIDS TO WATER- adding an acid to water increases the H_3O^+ concentration, so that the pH increases by 1 as the acid strength increases tenfold.

When the concentration of $H^+ = 10^{-1}$ M, the pH = 1

When the concentration of $H^+ = 10^{-2}$, the pH = 2

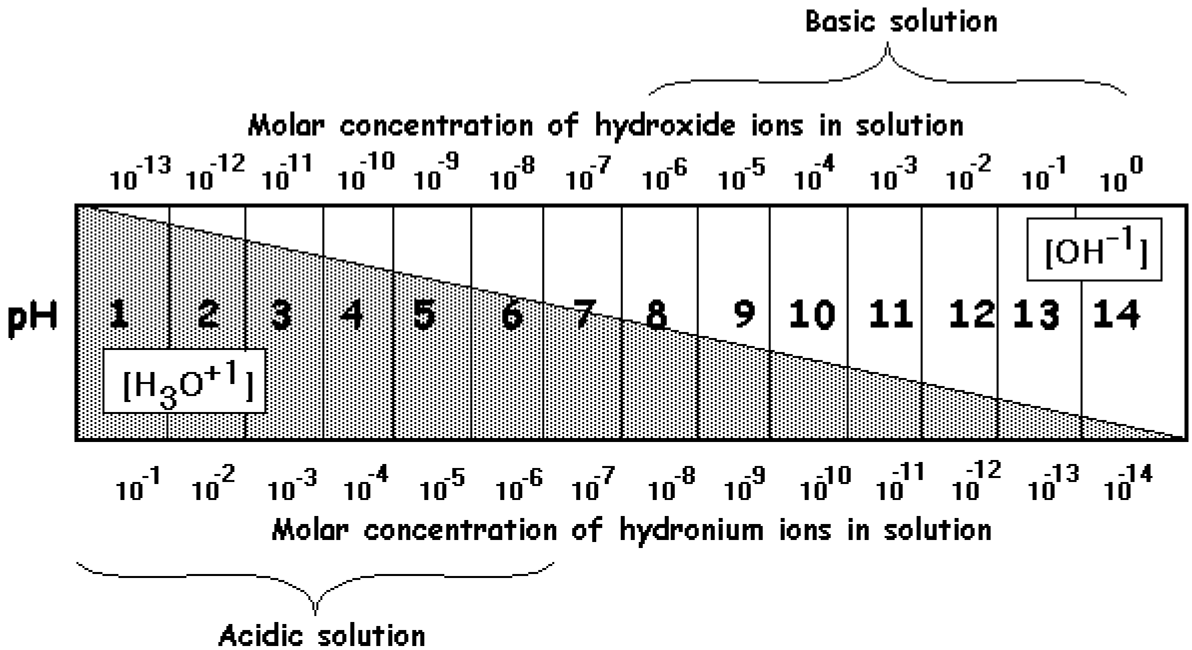
When the concentration of $H^+ = 10^{-3}$, the pH = 3

When the concentration of $H^+ = 10^{-4}$, the pH = 4

A solution with a pH of 3 is 10 times more acidic than a solution with a pH of 4.

A solution with a pH of 3 is 100 times more acidic than a solution with a pH of 5.

A solution with a pH of 3 is a 1000 times more acidic than a solution with a pH of 6.



ADDING BASES TO WATER- adding a base to water decreases the H_30^+ concentration, so that the pH decreases by one as the base strength increases tenfold.

When the concentration of OH^- = 10^{-1} M, the pH = 13

When the concentration of OH^- = 10^{-2}, the pH = 12

When the concentration of OH^- = 10^{-3}, the pH = 11

When the concentration of OH^- = 10^{-4}, the pH = 10

A solution with a pH of 13 is 10 times more basic than a solution with a pH of 12.

A solution with a pH of 13 is 100 times more basic than a solution with a pH of 11.

A solution with a pH of 13 is a 1000 times more basic than a solution with a pH of 10.

pH Of Common Substances

Substance	pH
Apples	About 3
Orange Juice	3
Grapes	About 4
Carrots	About 5
Potatoes	About 6
Seawater	8-9
Soap	9-10
Milk of Magnesia antacid	10
Household ammonia	11
Household bleach	12

4) Bronsted-Lowry Definition of Acids and Bases (HW: p. 19)

Essential Question: If all poodles are dogs, are all dogs poodles?

Over the course of the last few topics, we have focused on acids and bases as discovered by Svante Arrhenius. There are other theories on what acids and bases are. This theory, developed by Johannes Brönsted and Thomas Lowry (published separately, but within months of each other, so they both got credit), is more general in nature. All poodles are dogs, but not all dogs are poodles. The Arrhenius theory is the "poodle" theory, and the alternate theory is the "dog" theory.

According to Svante Arrhenius:

Acid – a compound that dissolves in water to produce H^{+1} as the only positively charged ion in solution
Base – a compound that dissolves in water to produce OH^{-1} as the only negatively charged ion in solution

According to this alternate theory put forth by Johannes Brönsted and Thomas Lowry:

Acid - a proton (H^+) donor

H^+ is a proton. Think about the hydrogen atom. It's made of one protons with an electron zipping around at a distance. How does H become H^{+1}? By removing that one and only electron, leaving a proton. A "naked" proton. According to this theory, an acid is a substance that gives up an H^+ ion to another substance.

Base - a proton (H^+) acceptor

According to this theory, a base is a substance that takes an H^+ ion from another substance.

$HCl + H_2O \Leftrightarrow H_3O^+ + Cl^-$
Acid Base The HCl gives its H^+ to the H_2O

$NH_3 + H_2O \Leftrightarrow NH_4^+ + OH^-$
Base Acid The H_2O gives is H^+ to the NH_3

$HC_2H_3O_2 + H_2O \Leftrightarrow H_3O^+ + C_2H_3O_2^-$
Acid Base The $HC_2H_3O_2$ gives its H^+ to the H_2O.

HCl (acid) + H_2O (base) $\Leftrightarrow$ H_3O^+ + Cl^-	The HCl loses its H^{+1} to H_2O. HCl is the acid in this reaction because it lost (donated) a proton (H^{+1}) H_2O is the base in this reaction because it gained (accepted) a proton (H^{+1})
NH_3 (base) + H_2O (acid) $\Leftrightarrow$ NH_4^+ + OH^-	The H_2O loses its H^{+1} to NH_3. H_2O is the acid in this reaction because it lost (donated) a proton (H^{+1}) NH_3 is the base in this reaction because it gained (accepted) a proton (H^{+1})
$HC_2H_3O_2$ (acid) + H_2O (base) $\Leftrightarrow$ H_3O^+ + $C_2H_3O_2^-$	The $HC_2H_3O_2$ loses its H^{+1} to H_2O. $HC_2H_3O_2$ is the acid in this reaction because it lost (donated) a proton (H^{+1}) H_2O is the base in this reaction because it gained (accepted) a proton (H^{+1})

Student Name:________________________________ Grades: ______, ______, ______, ______
A & B, Titration, pH, B/L A/B

1) ACIDS AND BASES HOMEWORK

A) Short-Answer

1) Name a metal that can react with an acid:______________________________

2) Give a pH value that indicates an alkaline solution:_________________________

3) Why does HCl (aq) conduct electricity while $C_6H_{12}O_6$ (aq) cannot? Explain in terms of *ionization*.

B) Identify each as an acid or base based on their formulas and properties.

Property	Acid or Base?	Property	Acid or Base?
Turns litmus red		Turns bromthymol blue yellow	
Tastes sour		Tastes bitter	
Hydrolyzes fats into soap		Reacts with active metals to form H_2	
HCl (aq)		KOH (aq)	
pH of 12		Forms H_3O^+ in water	

C) Name the following acids:

1) HCl (aq) ____

2) $HClO_3$ (aq) ____

3) $HClO_2$ (aq) ____

4) HNO_3 (aq) ____

5) HNO_2 (aq) ____

6) H_2SO_4 (aq) ____

7) HBr (aq) ____

8) $HC_2H_3O_2$ (aq)____

D) Write the formulas of the following acids:

1) Hydrosulfuric acid ______________________________

2) Perchloric acid ______________________________

3) Sulfurous acid ______________________________

4) Hypochlorous acid ______________________________

5) Phosphoric acid ______________________________

6) Chromic acid ______________________________

7) Hydrobromic acid ______________________________

8) Nitrous acid ______________________________

E) Name the following bases:

1) KOH (aq)______________________________

2) $Ca(OH)_2$ (aq)______________________________

3) LiOH (aq)______________________________

F) Write the formulas for the following bases:

1) aluminum hydroxide______________________________

2) barium hydroxide______________________________

3) sodium hydroxide______________________________

G) What is the pH of a solution that turns methyl orange to yellow, phenolphthalein to colorless, bromcresol green to blue and thymol blue to yellow?

a) 2.7 b) 5.6 c) 9.0 d) 10.2

Explain how you arrived at your answer, using the process of elimination to show how you used Reference Table M to eliminate each choice.

2) Acid and Base Neutralization Homework

A) Write the formula of the salt formed in each reaction:

1) H_2SO_4 (aq) + $Mg(OH)_2$ (aq) → 2 HOH + ________________

2) H_3PO_4 (aq) + 3 NaOH (aq) → 3 HOH + ________________

3) H_2CO_3 (aq) + 2 KOH (aq) → 2 HOH + ________________

4) H_2SO_4 (aq) + 2 KOH (aq) → 2 HOH + ________________

B) Write the formula of the acid used in each reaction and then balance the reaction:

1) ______________________ (aq) + ____ $Al(OH)_3$ (aq) → ____ HOH (l) + ____ $Al_2(SO_4)_3$ (aq)

2) ______________________ (aq) + ____ $Ba(OH)_2$ (aq) → ____ HOH (l) + ____ $Ba(C_2H_3O_2)_2$ (aq)

3) ______________________(aq) + ____ NH_4OH (aq) → ____ HOH (l) + ____ $(NH_4)_2CO_3$ (aq)

C) Write the formula of each base used in each reaction and then balance the reaction:

8) ____ H_2SO_3 (aq) + __________________ (aq) → ____ HOH (l) + ____ $MgSO_3$ (aq)

9) ____ H_3PO_4 (aq) + __________________ (aq) → ____ HOH (l) + ____ $Ca_3(PO_4)_2$ (aq)

10) ____ HCl (aq) + _________________ (aq) → ____ $CaCl_2$ (aq) + ____ HOH (l)

C) Solve the following titration problems:

1) How many moles of KOH are needed to neutralize 1.5 moles of H_2SO_4?

2) How many moles of NaOH are needed to neutralize 3.0 moles of HCl?

3) What volume of 0.80 M HCl will exactly neutralize 100. mL of 0.40 M KOH?

4) If exactly 5.0 mL of HNO_3 will neutralize 15 mL of 2.0 M NaOH, what is the molarity of the HNO_3 solution?

5) What volume of 5.0 M NaOH is needed to neutralize 40. mL of 2.0 M HCl?

6) What is the molarity of an H_2CO_3 solution if it takes 50. mL of H_2CO_3 to exactly neutralize 100. mL of 0.50 M NaOH?

7) What is the molarity of a NaOH solution if it takes 100. mL of NaOH to neutralize 50. mL of 0.10 M H_2SO_4?

8) 50. mL of H_2SO_4 of unknown concentration is titrated with 25 mL of 5.0 M NaOH. What is the molarity of the H_2SO_4?

9) How many mL of 1.0 M H_3PO_4 are required to neutralize 50. mL of 3.0 M NaOH?

10) How many moles of H_2SO_4 can be neutralized by 0.10 L of 0.50 M NaOH?

SAFETY NOTE - It used to be standard practice that if a base was swallowed, the victim should drink acid to neutralize it, and vice versa. The chemistry is correct, but the damage to the tissues of the mouth, throat and stomach would be severe. Never induce vomiting in someone who has consumed acid or base, but rather dilute it and send for medical help immediately.

3) pH

A) Multiple Choice Questions: Place your answer in the space in front of each question.

_____1) Which of the following solution pH values is the most acidic?
a) 5 b) 7 c) 9 d) 11

_____2) A pH of 14 is how many times more basic than a pH of 12?
a) 10 times b) 100 times c) 1000 times d) 10000 times

_____3) Which of the following solutions can have a pH of 5?
a) a 10^{-5} M solution of HCl b) a 10^{-5} M solution of NaOH
c) a 10^{-5} M solution of NaCl d) a 10^{-5} M solution of CH_4

_____4) What is the pH of a solution formed when equal volumes of 0.1 M HCl and 0.1 M NaOH are added to a beaker?
a) less than 7 b) more than 7 c) exactly 7

_____5) Strong acids and bases have more dissolved ions per liter than weak acids and bases. Which pH value indicates the solution that is an acid that conducts electricity the best?
a) 3 b) 5 c) 9 d) 12

_____6) Which pH value indicates the solution that is a base that conducts electricity the poorest?
a) 3 b) 5 c) 9 d) 12

B) Short-Answer: please place your answers in the provided spaces.

1) A pH of 4 is how many times more acidic than a pH of 6?_________________________

2) A pH of 11 is how many times more basic than a pH of 8?_________________________

3) Complete the following Chart:

Indicator used	pH of solution	Color of indicator in solution	Is the solution an aci
Methyl orange	9		
Litmus	10		
Bromcresol green	2		
Thymol blue	13		

4) Explain why methyl orange would be a poor choice of indicator to use if you were testing to see if a solution was definitively an acid or a base.

4) Bronsted-Lowry Definition of Acids and Bases

A) For each of the following systems, identify the Bronsted/Lowry acids and bases by writing A for the acid and B for the base on the reactant side:

1.	HBr +	H_2O	<====>	H_3O^+ +	Br^-	
2.	H_2O +	H_2O	<====>	H_3O^+ +	OH^-	
3.	NH_3 +	OH^-	<====>	NH_2^- +	H_2O	
4.	H_2O +	HPO_4^{2-}	<====>	PO_4^{3-} +	H_3O^+	
5.	H_3PO_4 +	H_2O	<====>	$H_2PO_4^-$ +	H_3O^+	
6.	CH_3COO^- +	H_3O^+	<====>	HCH_3COO +	H_2O	
7.	$H_2PO_4^-$ +	CH_3COO^-	<====>	HCH_3COO +	HPO_4^{2-}	
8.	H_2O +	S^{2-}	<====>	HS^- +	OH^-	
9.	CN^- +	HCH_3COO	<====>	HCN +	CH_3COO^-	
10.	OH^- +	NH_4^+	<====>	H_2O +	NH_3	

Chem Quiz: Neutralization

Name____

Here's a quick quiz for you! Sneed just swallowed 430.0 mL of 4.000 M HCl. How many mL of 2.000 M NaOH will be necessary to neutralize his excess stomach acid?

WAIT A MINUTE! I think the acid was H_2SO_4. What's the answer now?

(Note: assume that this is the good old days when people used to do this kind of thing!!!!)