# Objective 6

Double replacement reactions 2: balancing acid-base and gas forming reactions,
identifying strong and weak acids,
write net ionic equations to predict whether a reaction occurs,
perform C-V-mole and mole ratio calculations (volumetric)

3 types of **<u>Double Replacement</u>** reactions:

1. Precipitation: see solubility rules table.

2. Acid-base

3. Gas forming (<u>type of acid-base reaction</u>):

   one reactant is a **<u>base</u>** that contains $CO_3^{2-}$ or $HCO_3^-$

   What is the other reactant?

   one product is $H_2CO_3$ --> $H_2O + CO_2$ (g).

   3 products total.

# Acids and Bases are very common substances

| | Acids | Bases |
|---|---|---|
| Definition | $H^+$ donor | $H^+$ acceptor |
| Taste | Sour | Bitter |
| Litmus | Blue --> Red | Red --> Blue |
| Phenolphthalein | Colorless | Pink |
| pH | < 7 | > 7 |
| Reactivity | With metals | Does NOT react with metals |
| | With Bases | With Acids |

Acids/Bases can donate/accept more than 1 $H^+$ (polyprotic)

Acids: $H^+$ donor so formula has at least one H
Bases: are anions (accept $H^+$)

| Common Acids | Strength | Common Bases | Strength |
|---|---|---|---|
| HCl | strong | NaOH (lye) | strong |
| $H_2SO_4$ (battery acid) | strong | $Ca(OH)_2$ | strong |
| $HNO_3$ | strong | NaClO (bleach) | weak |
| $H_3PO_4$ | weak | $NaHCO_3$ | weak |
| $HC_2H_3O_2$ (in vinegar) | weak | $NH_3$ (ammonia) | weak |
| $H_3C_6H_5O_7$ (Citric acid) | weak | soap | weak |
| $H_2O$ | weak | $H_2O$ | weak |

Acids and Bases are often Solutions

Volumetric Analysis involves Solutions, Concentration, and Volume.

A SOLUTION contains a ____ and _____.

$$\text{Concentration} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

Concentration units = Molarity (M)

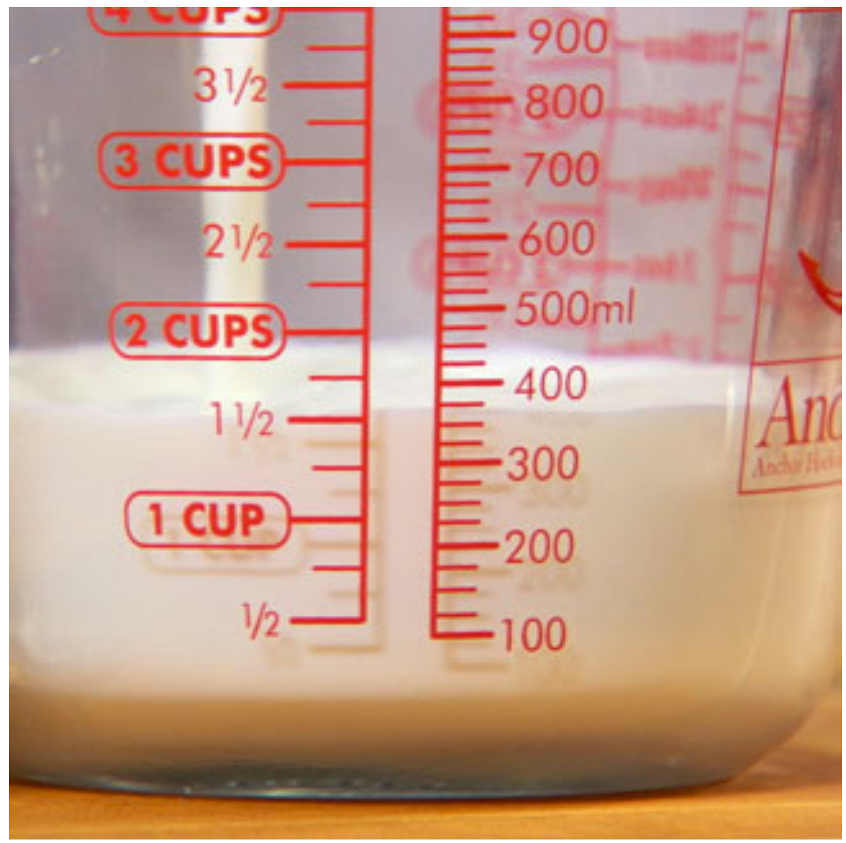
moles = Concentration in Molarity x volume in liters

<u>Objective</u>: calculate moles of solute in solution

240 ml (1 cup) of vinegar (0.9 M acetic acid) contains ____ moles of acetic acid.

a. 216 moles
b. 0.216 moles
c. 0.267 moles
d. 1 mole


http://my-beautiful-muslim-life.blogspot.com/2010/05/1001-uses-for-white-distilled-vinegar.html




http://creamyvanillablog.wordpress.com/2012/06/05/the-cup-measurement-2/

## *Water and Aqueous Solutions Contain $H^+$ and $OH^-$*

**pH is a measure of $[H^+]$**

| | |
|---|---|
| $pH = -\log [H^+]$ | $[H^+] = 10^{-pH}$ |

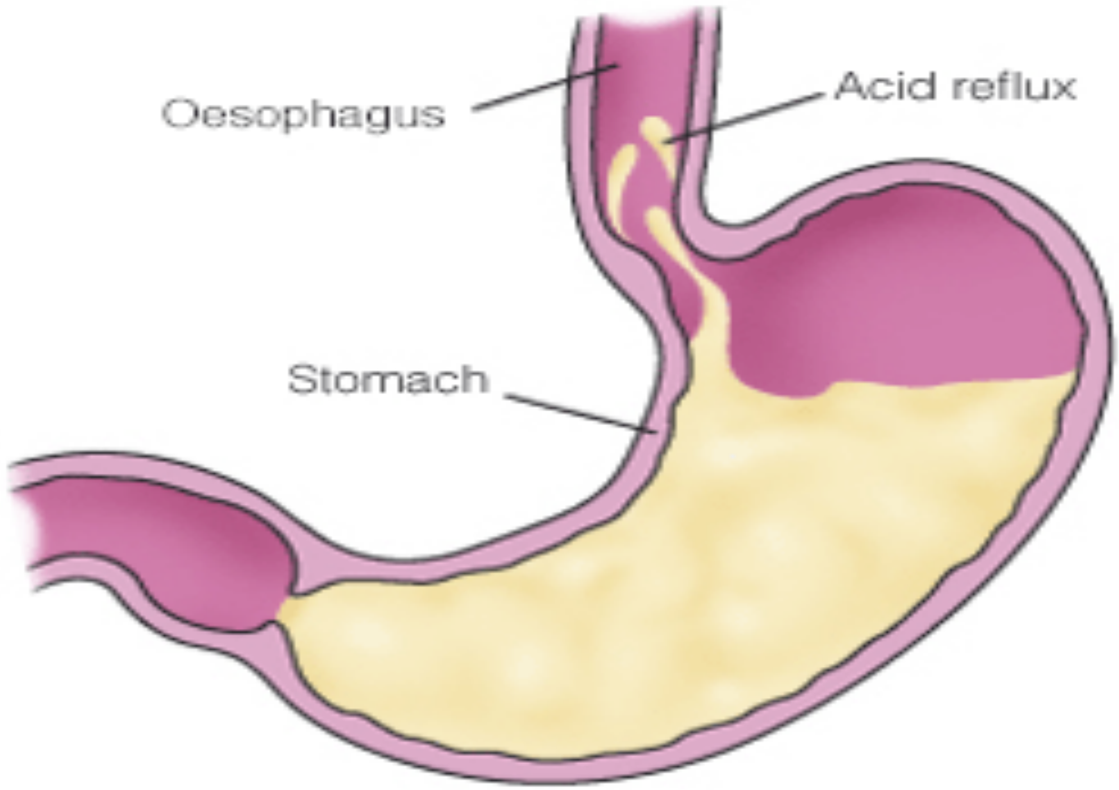
**pOH is a measure of $[OH^-]$**

| | |
|---|---|
| $pOH = -\log [OH^-]$ | $[OH^-] = 10^{-pOH}$ |

**pH and pOH are related**:

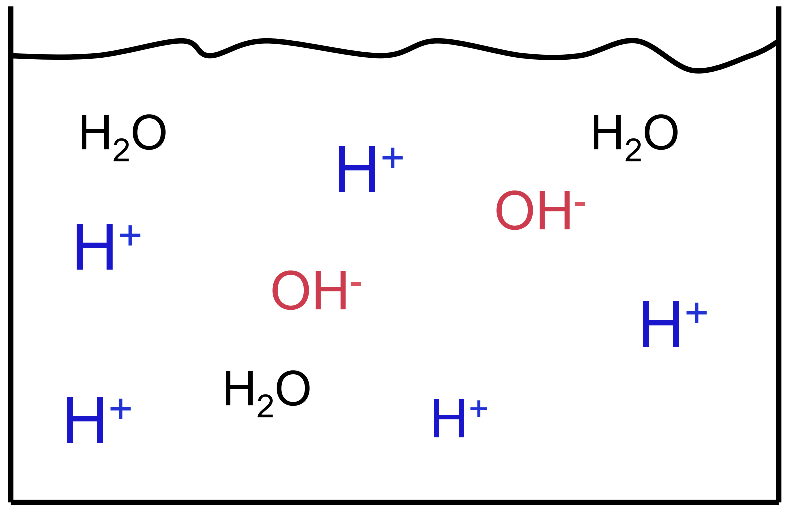
| | |
|---|---|
| $pH + pOH = 14$ | $[H^+][OH^-] = 1x10^{-14}$ |

Our stomach contains acid, which helps digest food.
What is stomach acid?
The pH of stomach acid is 2.5. What is $[H^+]$?
What is the pOH of stomach acid?
What is the $[OH^-]$ of stomach acid?




http://www.care2.com/news/member/956805373/322081

# *pH 2.5 HCl Contains ___ $H^+$ and _____ $OH^-$*




$[H^+] = 10^{-pH} = 10^{-2.5} = 3.2 \times 10^{-3}$ M

pOH = 14 - pH = 11.5

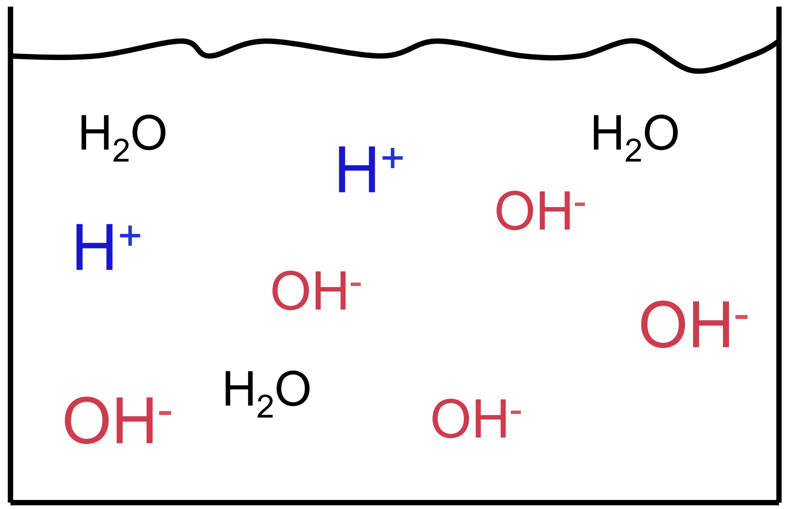
$[OH^-] = 10^{-pOH} = 10^{-11.5} = 3.2 \times 10^{-12}$ M

http://en.wikipedia.org/wiki/Sodium_hydroxide

Sodium hydroxide is used by the chemical industry, in paper making, as a cleaning agent, and in food preparation.

What is the pH of 0.1 M NaOH?
What is the $[H^+]$ of 0.1 M NaOH?
What is the pOH of 0.1 M NaOH?
What is the $[OH^-]$ of 0.1 M NaOH?

## *0.1 M NaOH Contains ___ $H^+$ and _____ $OH^-$*




0.1 M NaOH ➔ $[OH^-] = 0.1$ M

$pOH = -\log [OH^-] = -\log (0.1) = 1$

$pH = 14 - pOH = 13$

$[H^+] = 10^{-pH} = 10^{-13} = 1 \times 10^{-13}$ M

See Practice Problem 1.

a. Fill in the blanks.

b. Which substances are acids?

c. As pH increases, what happens to $[H^+]$?

d. What does "neutral" solution mean?

| Substance | pH | pOH | $[H^+]$, M | $[OH^-]$, M |
|---|---|---|---|---|
| pure water | 7.0 | | | |
| milk | | 7.5 | | |

Objective: Predict the product(s) and balance the equation.
**Acid-Base** reaction

HCl + NaOH -->

*Hint*: A = _____, B = ______, C = _______, D = _______

***Use charge and subscripts to write a correct chemical formula.***

***Use coefficients to balance the chemical equation.***

## A ***Net Ionic Equation*** Shows What Is Happening in Solution

***IDENTIFY*** "Active" reactants and "spectator" ions.

$$HCl + NaOH \text{ --> } H_2O + NaCl$$

Break appropriate compounds into ions (show **sign** and **magnitude**):

*Molecular compound*: leave as molecule (why?)

*Ionic compound* soluble in water: break into two ions

*Ionic compound* insoluble in water: leave as compound

*Strong acid*: break into two ions (why?)

*Weak acid*: leave as molecule (why?)

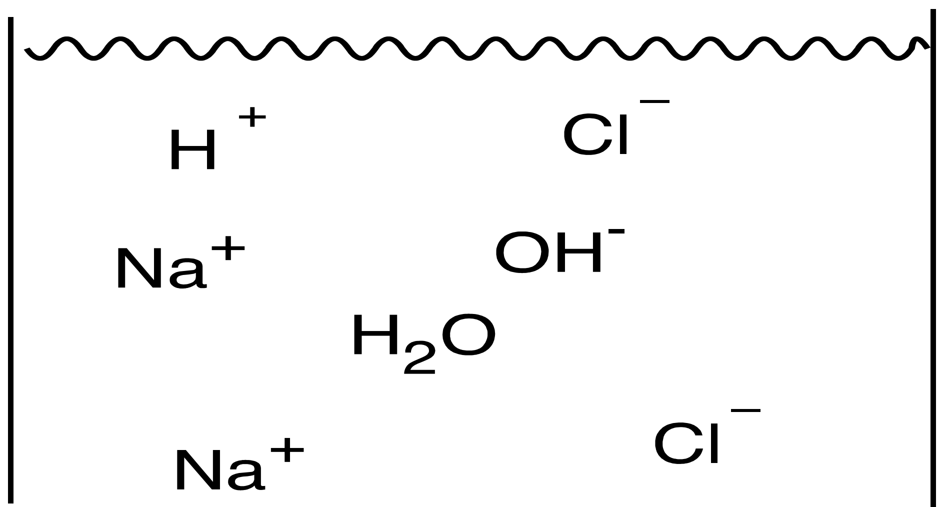
***Where do I find this information about acids and solubility?***

# A ***Net Ionic Equation*** Shows What Is Happening in Solution

$HCl + NaOH \dashrightarrow H_2O + NaCl$

HCl = strong acid
NaOH = soluble

$H_2O$ = molecular compound
NaCl = soluble



*Molecular eq*: $HCl + NaOH \text{ --> } H_2O + NaCl$

*Ionic eq*: $H^+ + Cl^- + Na^+ + OH^- \text{ --> } H_2O + Na^+ + Cl^-$

Spectator ions ($Na^+$ and $Cl^-$) do not participate in the reaction.

*Net Ionic eq*: $H^+ + OH^- \text{ --> } H_2O$

If *you can write a Net Ionic Equation*: a **Reaction occurs**! (Prediction)

If *All the ions are spectator ions*: No ionic equation and *No reaction occurs*.

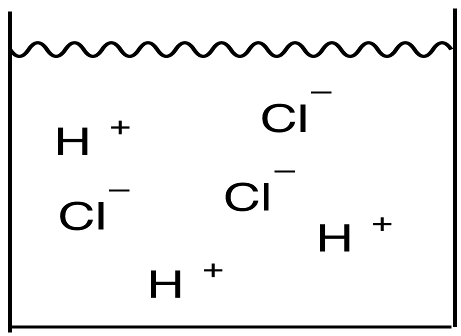
***Nothing happens by just watching!***

## **Acids are Givers; Bases are Takers**

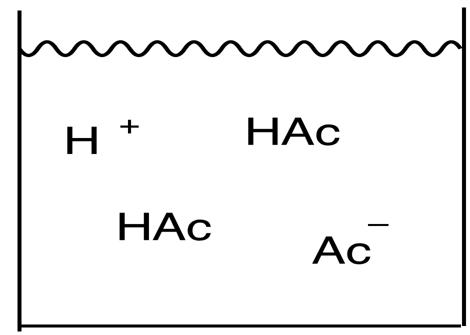
Some Acids are Better Givers (Stronger Acids) than Others

Some Bases are Better Takers (Stronger Bases) than Others

*Strong Acid*: easily donates its $H^+$, dissociates completely into its ions




*Weak Acid*: does not easily donate its H+, dissociates partially into its ions




pH measures $[H^+]$ ==> $pH = -\log [H^+]$ or $[H^+] = 10^{-pH}$

Low pH means high $[H^+]$ (acid)

High pH means low $[H^+]$ (base)

# A Good Relationship Involves *Give and Take*

Every Acid Has a ***Partner*** (Conjugate) Base
Every Base Has a ***Partner*** (Conjugate) Acid

| | | | | | |
|---|---|---|---|---|---|
| HCl | + | $H_2O$ | ----> | $Cl^-$ + | $H_3O^+$ |
| acid | | base | | conjugate base | conjugate acid |

*(Shortcut)* HCl (aq) ----> $Cl^-$ + $H^+$ (aq)

# A Good Relationship Involves *Give and Take*

Some Acids **EASILY** give their $H^+$ = *Strong* Acid (lots $H^+$ in solution)
Other Acids do **NOT** easily give their $H^+$ = *Weak Acid* (few $H^+$ in solution)
http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/flash.mhtml

http://www.bet.com/news/national/photos/2012/06/black-buying-power-by-the-numbers.html#!062512-national-spending-big-spender-money-economy

A strong acid is like a Big *Spender*

http://blogs.wsj.com/juggle/2008/06/26/are-you-a-cheapskate-or-a-spendthrift/

A weak acid is like a *Cheapskate*

With you and your lab partner, are you a *strong* or weak *acid* or base?

Using The ***Acid-Base Strength Table***: (Table 16.2)

- Acid and Conjugate Base pairs
- Acids are listed from strongest to weakest; Bases are listed from weakest to strongest.
- Acids below $H_3O^+$ are considered weak.
- An acid reacts with any base below it or a base reacts with any acid _____ it.
- Predict the products of an acid-base reaction.

| | Acid | ----> | Conjugate Base + $H^+$ | |
|---|---|---|---|---|
| Strongest acid | $HClO_4$ | ----> | $ClO_4^-$ | Weakest base |
| | $HCl$ | ----> | $Cl^-$ | |
| | $H_2SO_4$ | ----> | $HSO_4^-$ | |
| | $H_3O^+$ | ----> | $H_2O$ | |
| | $HC_2H_3O_2$ | ----> | $C_2H_3O_2^-$ | |
| Weakest acid | $H_2O$ | ----> | $OH^-$ | Strongest base |

You are given a colorless liquid and told it is either muriatic acid or vinegar. What test would you do to identify this liquid?


http://rossendental.com/whats-the-easiest-way-to-clean-my-retainer-or-nightguard


http://www.lowes.com/pd_58558-78-GKGM75006C_0__?productId=3220089

Car batteries contain sulfuric acid, $H_2SO_4$. $H_2SO_4$ is a stronger acid than $H_3O^+$. $HSO_4^-$ is a weaker acid than $H_3O^+$.


http://www.pepboys.com/parts/batteries/batteries/

a. Draw a picture that shows the ions in sulfuric acid.
b. Is it possible to make a better electrolyte by replacing water with a different solvent? If so, which solvent would you choose?

Predict whether the following reaction occurs.
If so, write a molecular equation and net ionic equation.

TSP ($Na_3PO_4$) is used to remove kitchen grease or fat.
Kitchen grease is an acid.

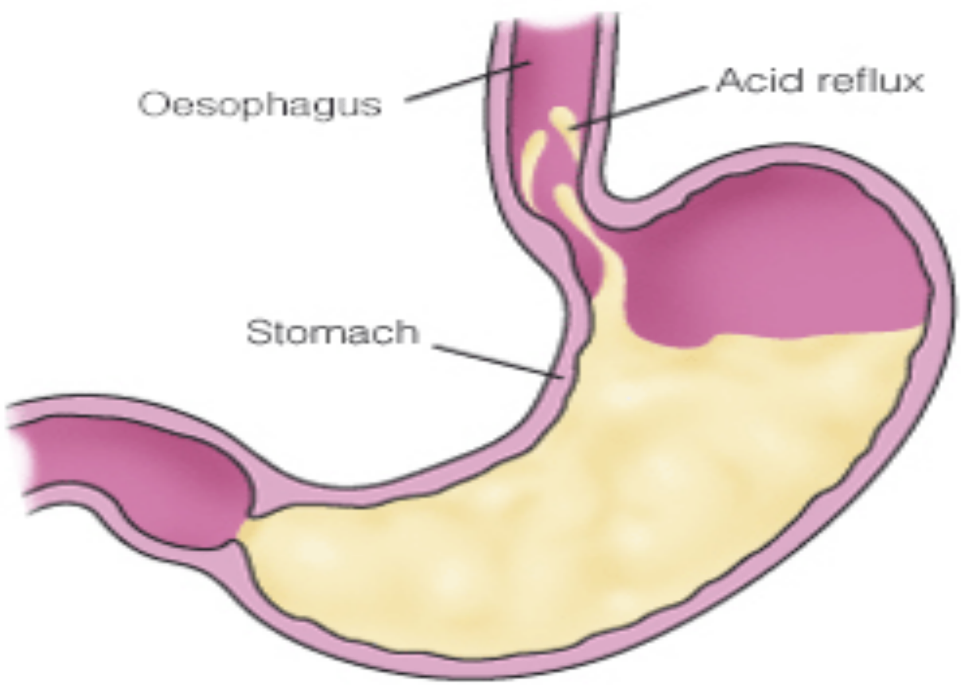
$$Na_3PO_4\,(s) \;+\; HC_2H_3O_2\,(aq) \text{ -----> }$$


http://www.nelsonpaint.com/S10621.html

Stomach acid consists of hydrochloric acid, HCl. Indigestion occurs when excess acid is produced.

a. What type of substance is an antacid?

b. Magnesium hydroxide is the active ingredient in Milk of Magnesia (MoM). Write a chemical equation and net ionic equation that shows how MoM works.




http://www.care2.com/news/member/956805373/322081 http://aidicine.com/about-your-teeth/

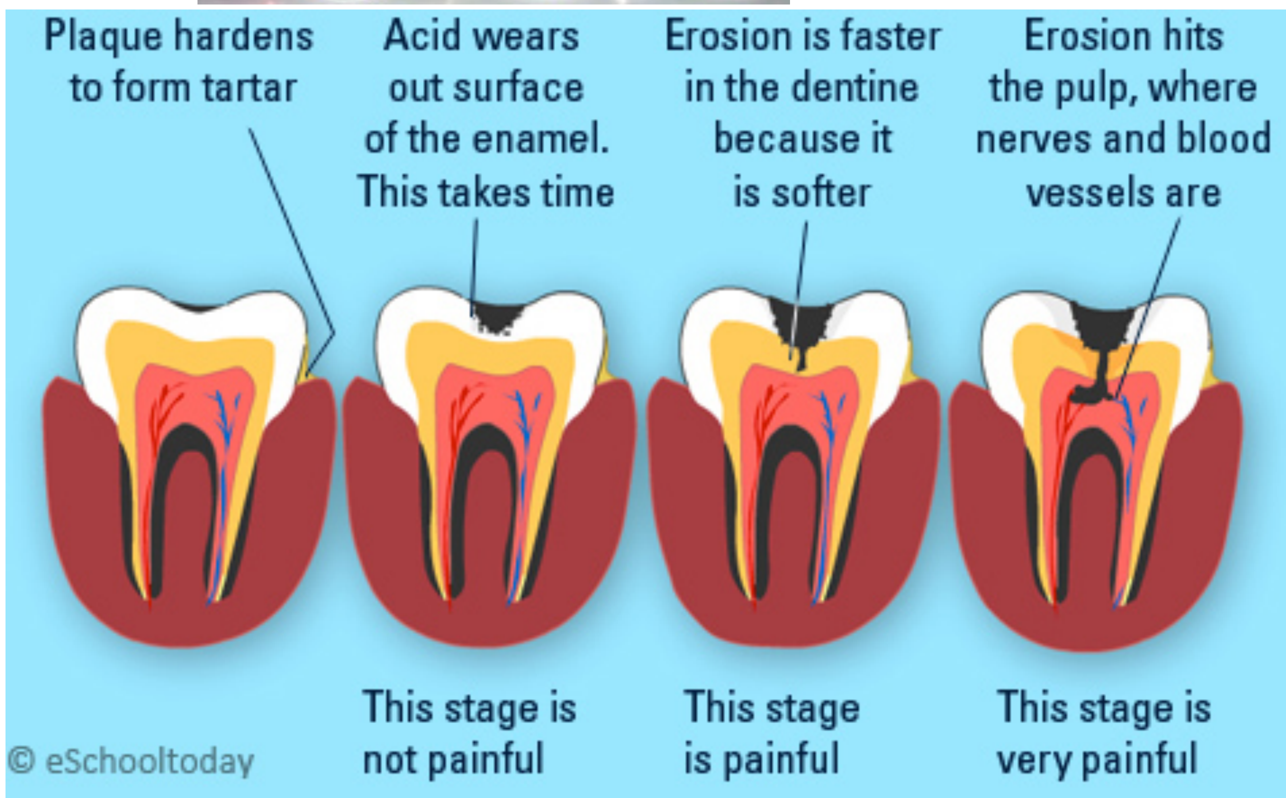
***Tooth*** enamel is the mineral apatite, $Ca_5(PO_4)_3(OH)$.

*Enamel is the hardest substance in our body*


http://blogs.sacurrent.com/index.php/soda-tax-would-likely-reduce-diabetes-rates-in-san-antonio/

Acidic foods, like soda and tomato sauce, can remove tooth enamel and lead to tooth decay (cavities).

Write a chemical equation that represents this reaction.




http://www.eschooltoday.com/tooth-care-for-children/tooth-gum-dental-decay.html

***A Gas Forming Reaction*** is a Type of Acid-Base Reaction

- Involves a Base reactant that contains $HCO_3^-$ or $CO_3^{2-}$
- Produces $H_2CO_3$ as one product
- Replace $H_2CO_3$ with $H_2O$ and $CO_2$ (g)

Example:

$NaHCO_3$ + HCl ---> ________ + _______

A = _____, B = ______, C = _______, D = _______

1. ID products. Use charge and subscripts to write chemical formulas.

$NaHCO_3$ + HCl ---> _______ + $H_2CO_3$

2. Whenever you see $H_2CO_3$ as a product, replace it with $H_2O$ and $CO_2$ (g).

$NaHCO_3$ + HCl ---> _______ + $H_2O$ + $CO_2$ (g)

3. Use coefficients to balance chemical equation.
4. Write a net ionic equation.

Predict whether the following reaction occurs.
If so, write a molecular equation and net ionic equation.

Does Baking soda react with vinegar?

$NaHCO_3$ (s) + $HC_2H_3O_2$ (aq) ----->

You ate too much and have an upset stomach.
Should I take Alka-Seltzer (Baking soda, $NaHCO_3$) or Milk of Magnesia ($Mg(OH)_2$). See Practice Problems 4 and 5.


http://www.alka-seltzer.com/home/index.html

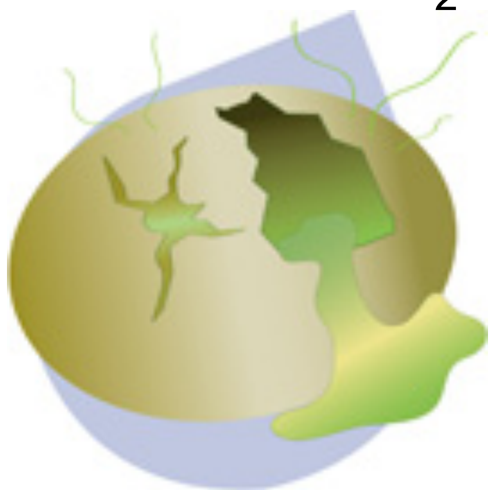

http://phillipsrelief.com/products/phillips-milk-magnesia

1. For each antacid, write a balanced molecular equation and net ionic equation that shows how each antacid works.
2. Which antacid will make you burp?

## *Some Gases Stink or are Toxic!*

Other **gas forming** reactions

Rotten egg odor: FeS + HCl --> $H_2S$ (g) + ___



http://www.3mwater.com/your-water/concerns-benefits?___store=dealer&zip=93906

Toxic (Chicago Tylenol murders, 1982):

KCN + acid ---> HCN (g) + _____

http://cen.acs.org/articles/89/i42/Detecting-H2S-Vivo.html

10/17/13, CEN, p. 60 Detecting $H_2S$ in vivo

$H_2S$ plays a role in cell signaling: it mediates blood pressure, metabolic rate, angiogenesis, and anti-inflammatory effects

Predict whether the following reaction occurs.
If so, write a molecular equation and net ionic equation.

Does washing soda (laundry detergent) react with battery acid?

$Na_2CO_3$ (aq) + $H_2SO_4$ (aq) ----->

# Chemistry Toolbox contains the ***Tools*** to solve problems

*Periodic Table* tells you Element Type tells you Compound Type
*Group #* tells you Charge tells you Chemical Formula
*Molar Mass* of Element tells you Molar Mass of Compound
Chemical Formula tells you MOLE Ratio of Elements
Chemical Equation tells you MOLE Ratio of Substances in Reaction
Math Equations:

$$\text{Molar Mass} = \frac{\text{mass}}{\text{moles}} \qquad \text{moles} = \frac{\text{mass}}{\text{molar mass}} \qquad \text{mass} = \text{moles} \times \text{molar mass}$$

$$\text{Concentration (Molarity)} = \frac{\text{moles}}{\text{volume}} \qquad \text{moles} = \text{Concentration} \times \text{volume} \qquad \text{volume} = \frac{\text{moles}}{\text{Concentration}}$$

$$\text{pH} = -\log[\text{H}^+] \qquad [\text{H+}] = 10^{-\text{pH}} \qquad \text{pOH} = -\log[\text{OH}^-] \qquad [\text{OH}^-] = 10^{-\text{pOH}} \qquad \text{pH} + \text{pOH} = 14$$

Tables: Table 2.3 Common ions
Table 4.2 Solubility of Ionic Compounds
Table 16.2 Acid-Base Strength

You: practice using tools --> solve problems
know which tool to use --> solve problems

Lab 4: You're watching a chemistry demonstration. The demonstrator does the following:

(i) Adds 8 g of a white solid to 250 ml of water in a 800 ml flask. The solid disappears and the water turns pink.

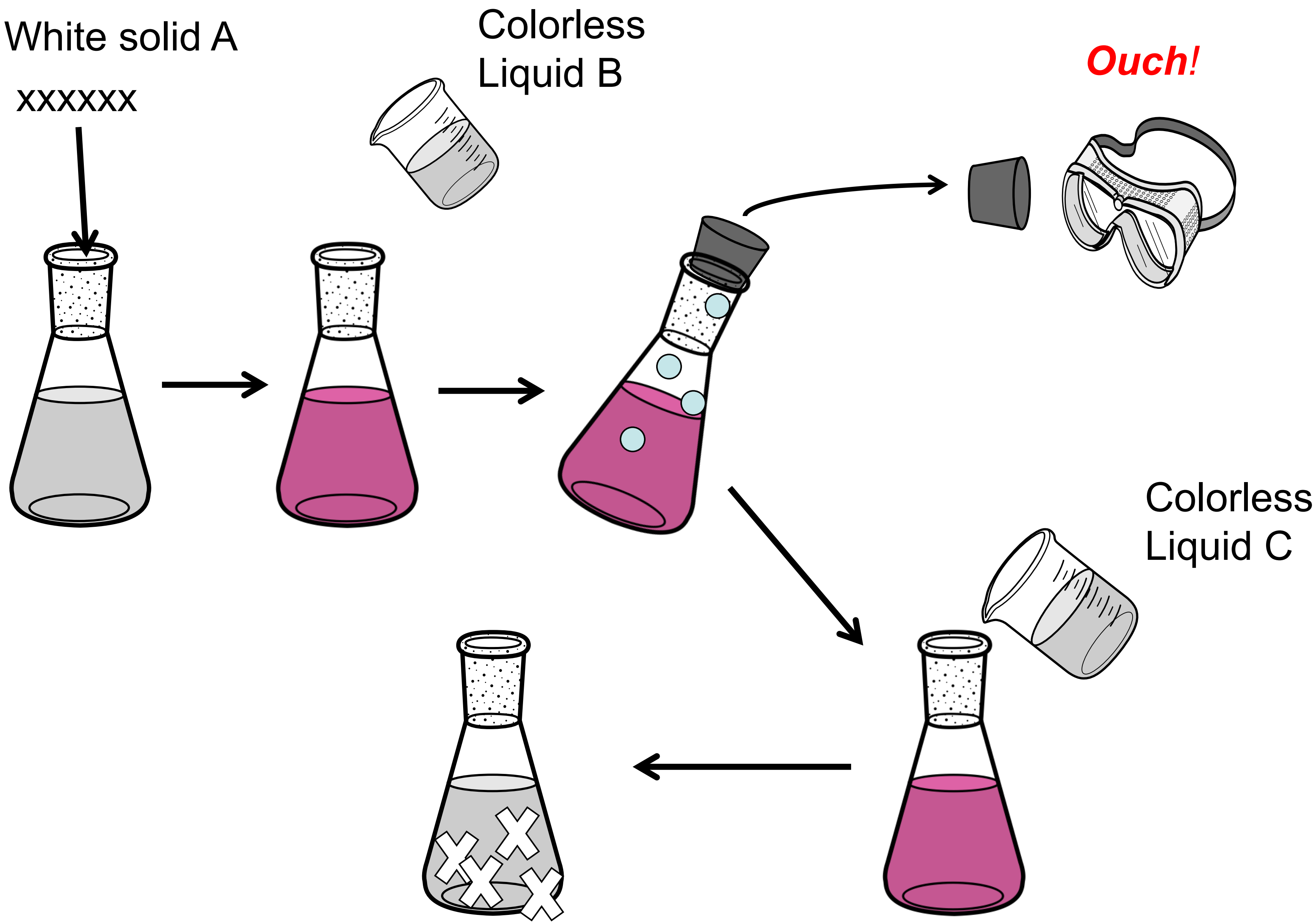
(ii) Pours 100 ml of a colorless liquid into the flask, puts a rubber stopper on the flask, and shakes the flask for a few seconds. The stopper flies through the air.

a. Was the white solid table salt ($NaCl$) or laundry detergent ($Na_2CO_3$) or sugar? Why did the water turn pink?

b. Was the colorless liquid that was poured into the flask water or 1 M $HCl$ or 1 M $NaOH$? Write a chemical equation and net ionic equation that shows why the stopper flew through the air.

c. Was the 100 ml of colorless liquid the limiting reactant or excess reactant in this reaction? Show your calculations.

# Lab 4


White solid A
xxxxxx
Colorless
Liquid B
Ouch!
Colorless
Liquid C

In an experiment, MORE of one reactant than is needed (*EXCESS*) is often used. The reactant that completely reacts is the *LIMITING* reactant. The limiting reactant *limits* the amount of product produced.

Two arms reacts with two legs and one head and one torso to produce one body:

$$2A + 2L + 1H + 1T \rightarrow A_2L_2H_1T_1$$

a. If the initial amount of arms = 11, legs = 15, heads = 20, and torsos = 25, how many bodies are produced?

b. Which reactant is the limiting reactant?

Lab 4: You' re watching a chemistry demonstration. The demonstrator does the following:
(i) Adds 8 g of a white solid to 250 ml of water in a 800 ml flask. The solid disappears and the water turns pink.
(ii) Pours 100 ml of a colorless liquid into the flask, puts a rubber stopper on the flask, and shakes the flask for a few seconds. The stopper flies through the air.

a. Was the white solid table salt (NaCl) or laundry detergent ($Na_2CO_3$) or sugar? Why did the water turn pink? (Hint: see limiting reactant.)

b. Was the colorless liquid that was poured into the flask water or 1 M HCl or 1 M NaOH? Write a chemical equation and net ionic equation that shows why the stopper flew through the air.

c. Was the 100 ml of colorless liquid the limiting reactant or excess reactant in this reaction? Show your calculations.

Chemical Reaction:

1. COEFFICIENTS in balanced equation tell you MOLES and MOLE RATIOS of each reactant/product.

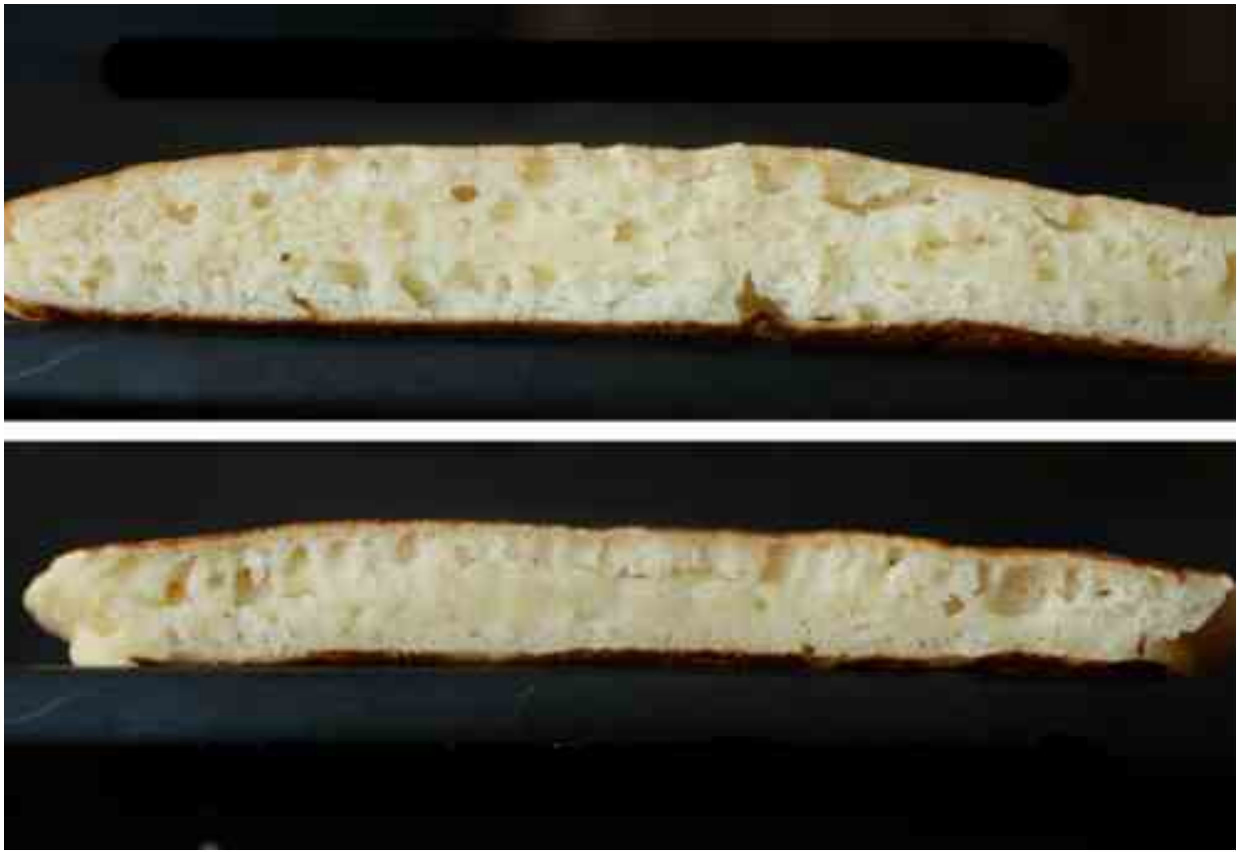
2. MOLE RATIOS: MOLES of a reactant/product enables you to calculate MOLES of another reactant/product.

For pure substances: MOLES = $\frac{\text{mass}}{\text{molar mass}}$

For solutions: MOLES = Concentration in Molarity x volume in l

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{l of solution}}$$

# Lab 5: What Makes my Pancakes Fluffy?



from “The Food Lab: Baking Powder vs. Baking Soda”

Bring to Lab: flour, baking powder (not soda), sugar, milk, frying pan, spatula, mixing bowl, measuring cup/spoons, fork, plate, syrup


https://www.pinterest.com/pin/17662623511592811/

Table 1. Ingredients in Calumet Double Acting Baking Powder.

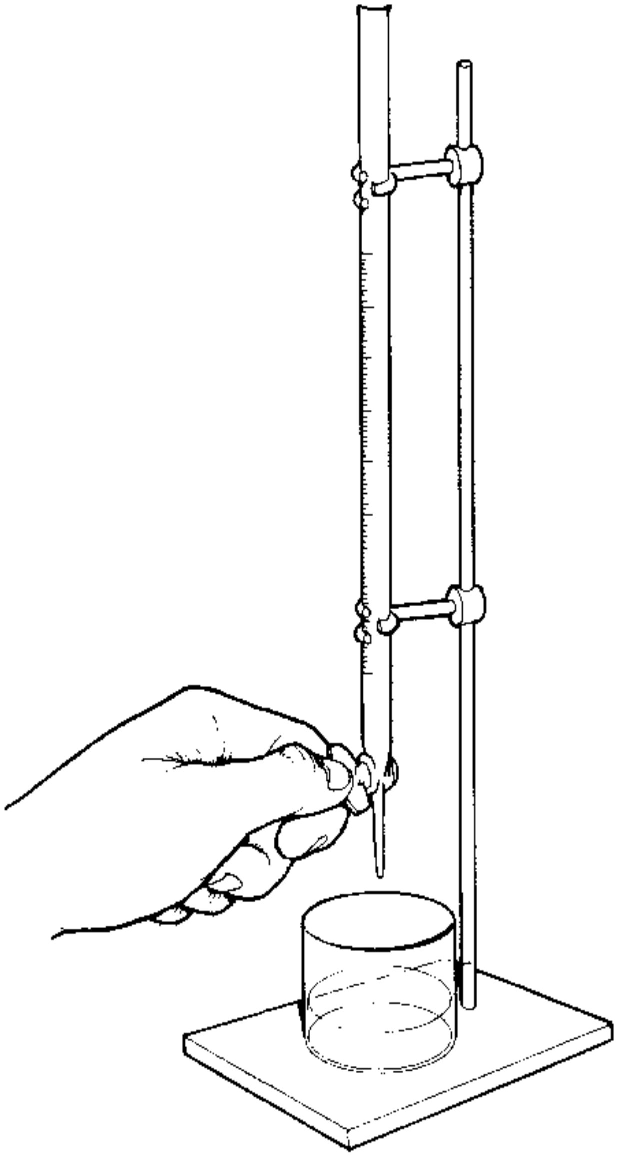
| Ingredient | % Composition |
|---|---|
| Sodium bicarbonate, $NaHCO_3$ | 30 |
| Monocalcium phosphate, $Ca(H_2PO_4)_2$ | 8.7 |
| Sodium aluminum sulfate, $NaAl(SO_4)_2$ | 21 |
| Cornstarch | 26.6 |
| Calcium sulfate, $CaSO_4$ | 13.7 |

Dissociation of Leavening Acids:

$3\ Ca(H_2PO_4)_2 \text{ ---> } Ca_3(PO_4)_2 + 3\ HPO_4^{2-} + H_2PO_4^{-} + 7\ H^{+}$

$NaAl(SO_4)_2 + 3\ H_2O \text{ ---> } Al(OH)_3 + Na^{+} + 2\ SO_4^{2-} + 3\ H^{+}$

Neutralization Reaction: $NaHCO_3 + H^{+} \text{ ---> } Na^{+} + CO_2 + H_2O$



## ***Doing an Experiment Takes Planning***

In an acid-base titration:
Do you want the reaction to be fast or slow? Why?

What % yield of products must you need? Why?

Phenolphthalein is the indicator. What does it indicate? At what pH must the color change? Why?

http://analytical.wikia.com/wiki/Burette

**Lab 5***: Vinegar is 5% acid.* Bring Vinegar to Lab.

***How would you experimentally measure the concentration of acetic acid in vinegar?***


a. Convert 5% acid to molarity.
b. To measure the concentration of Acetic Acid in vinegar, I would _________.

## Plan your experiment:

- What substance reacts with vinegar? How do I make a solution of this substance? Do I need to standardize this substance? If so, how?
- How much vinegar should I titrate with this substance? E.g., 20.00 ml of vinegar is titrated with 0.10 M NaOH to a pink endpoint. Calculate the volume of 0.1 M NaOH that is required to neutralize the vinegar.
- What volume of vinegar should I use in my titration?
- How do I use my experimental data to calculate $[HC_2H_3O_2]$?

Volumetric Analysis involves solutions, concentration, and volume.

For <u>solutions</u>: moles = Concentration in Molarity x volume in l

You want to determine the concentration of a hydrochloric acid solution by titration. 20.00 ml of hydrochloric acid requires 26.74 ml of 0.241 M NaOH.
What is the concentration of HCl?

a. 0.006 M
b. 0.322 M
c. 3.22 M

You want to determine the concentration of battery acid. 2.00 ml of battery acid is titrated with 31.74 ml of 2.241 M NaOH. What is the concentration of battery acid?
See Practice Problem 9.


http://www.pepboys.com/parts/batteries/batteries/

# Lab 5: How much Acid is in Soda?


Bring:
colorless soda to lab

Make sure the soda has
***citric acid***

http://cen.acs.org/articles/90/i4/MouseSiphon-Brew.html

# 1/23/12, CEN, p. 48 Mountain Dew Could Dissolve a Mouse

$50,000 lawsuit filed against PepsiCo by an Illinois man who claims he found a dead mouse in his can of Mountain Dew.

Based on the can's production date, PepsiCo estimates that the mouse would have spent 74 days in the drink. A veterinarian who examined the mouse for the company says there is no way the critter Ball found had spent that much time in the can.

The bones and organs of Ball's mouse were still whole, according to the doctor's affidavit. But at a pH of 3.4, the Mountain Dew would have leeched all the calcium from a submerged rodent's bones in four to seven days, the doctor wrote. The rest of the mouse would have disintegrated into an unrecognizable "jellylike substance" after 30.

Poonam Jain, a professor of dentistry at Southern Illinois University School of Dental Medicine, agrees with the veterinarian: "It would have been impossible to find that mouse in pristine condition." She points out that hydroxyapatite, the calcium phosphate mineral in teeth and bone, readily dissolves in acidic solutions. For tooth enamel, once the pH hits 5.5, the mineralized tissue starts to erode.

But a soft drink's acidity alone doesn't dictate how effectively it will dissolve the mineral, Jain says. In a 2007 study, she and her colleagues researched the enamel-dissolving abilities of 18 brands of soda. They found that although noncola drinks, such as Mountain Dew, were slightly less acidic than colas, such as Pepsi, the noncolas were more erosive. One possible explanation for the difference, Jain says, is that citric acid, the predominant acid in noncolas, chelates calcium more readily than can phosphoric acid, colas' main harsh ingredient.

So science appears to be on PepsiCo's side, but the details give new meaning to Mountain Dew's old slogan: "It'll tickle yore [sic] innards."