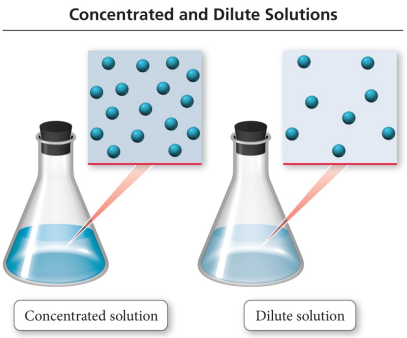
So far we've used grams (mass), In lab:

What about using volume in lab?

Solution Concentration and Solution Stoichiometry



Solutions:
2 (or more) components

We need a system to descried "how much" in a solution

Relate moles of solute to volume of solution (L)

- We can use the molarity of a solution as a conversion factor between moles (mol) of the solute and liters (L) of the solution.

- **Preparing a solution of specific concentration**

(a) An amount of solute is weighed out on an analytical balance and then

(b) A portion of the solvent is added to the volumetric flask.

(c) The mixture is swirled until *all* of the solute is dissolved.

(d) Additional solvent is added up to the mark on the volumetric flask.

http://2012books.lardbucket.org/books/principles-of-general-chemistry-v1.0/s08-02-solution-concentrations.html

 How would you prepare 500.0 mL of a 0.15 M NaCl solution?

4.4 g

 How many moles of NaCl are there in 500. mL of 2.5 M NaCl solution? How many grams?

1.25 mol

73.125g NaCl

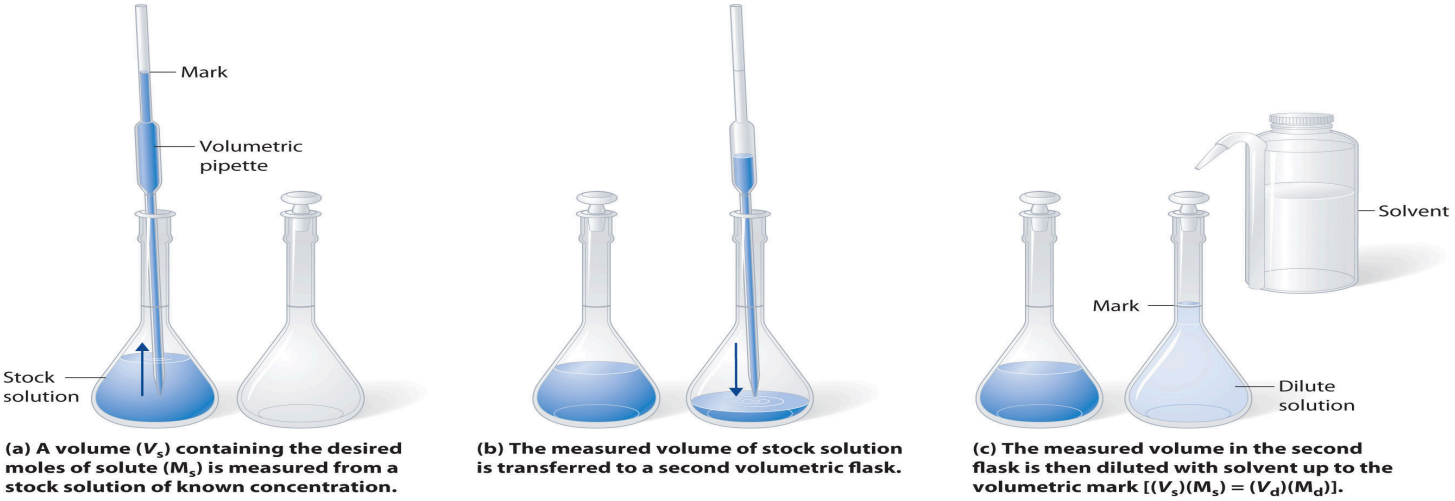
 How many mL of solution is needed to make 0.200M NaCl solution using 0.0500 moles of NaCl?

250

Solution Dilution

- In dilution **<u>the amount of solute doesn't change</u>**, just the volume of solution:

moles solute in concentrated solution = moles solute in diluted solution



(a) A volume (V_s) containing the desired moles of solute (M_s) is measured from a stock solution of known concentration.

(b) The measured volume of stock solution is transferred to a second volumetric flask.

(c) The measured volume in the second flask is then diluted with solvent up to the volumetric mark [$(V_s)(M_s) = (V_d)(M_d)$].

What volume (mL) of a concentrated solution of sodium hydroxide (6.00 M) must be diluted to 200. mL to make a 1.50 M solution of sodium hydroxide?


You have 50.0 mL of 3.0 M NaOH and you want 0.50 M NaOH. What do you do?

300 ml


How many mL of 3.00 M HCl are needed to completely react with 4.85 g $CaCO_3$?

$$2\ HCl(aq) + CaCO_3(s) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

32.3

Practice Zinc reacts with acids to produce H_2 gas. Have 10.0 g of Zn. What volume in mls of 2.50 M HCl is needed to convert the Zn completely?

$$Zn(s) + 2\ HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

122.324

Practice

How many mL of a 0.150 M Na_2S solution are needed to completely react 18.5 mL of 0.225 M $NiCl_2$ solution?

$$NiCl_2(aq) + Na_2S(aq) \longrightarrow NiS(s) + 2\ NaCl(aq)$$

27.75

If 22.8 mL of 0.100 M $MgCl_2$ is needed to completely react 15.0 mL of $AgNO_3$ solution, what is the molarity of the $AgNO_3$ solution?

$MgCl_2(aq) + 2\ AgNO_3(aq) \longrightarrow 2\ AgCl(s) + Mg(NO_3)_2(aq)$

4.56×10^{-3} mol

0.304 M

Solutions and Solubility:

"Like Dissolves Like"

Nonpolar solutes dissolve best in nonpolar solvents

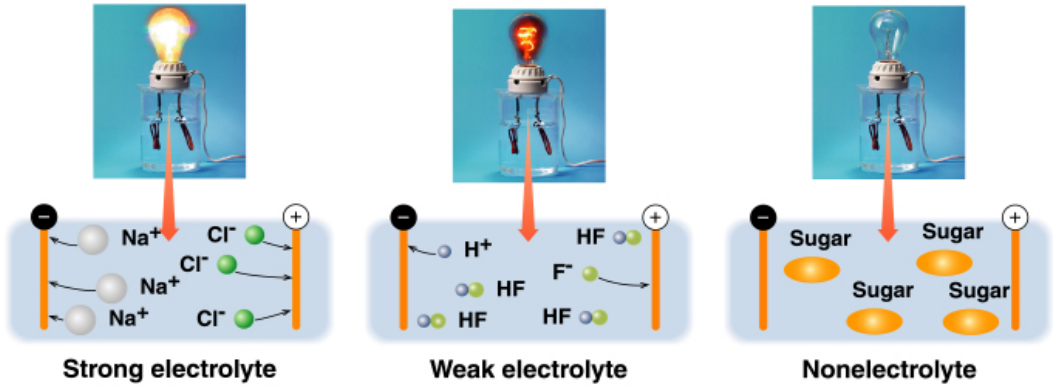
Fats	Benzene
Steroid	Hexane
Waxes	Toluene

Polar and ionic solutes dissolve best in polar solvents

Inorganic Salt	Water
Sugars	Small alcohols
	Acetic acid

- **Aqueous Solutions: (aq) *solvent is water**

Ions in Solution: Electrolytes



- ***Strong Electrolytes: 100% ionization***

Category	***Example***
• ***Ionic compounds soluble in water***	
• ***Strong acids***	
• ***Strong bases***	

- ***Strong Electrolytes: 100% ionization***

Strong Acids	**Strong Bases**
Hydrochloric, HCl Hydrobromic, HBr Hydroiodic, HI Chloric, $HClO_3$ Perchloric, $HClO_4$ Nitric, HNO_3 Sulfuric, H_2SO_4	Group 1A metal hydroxides [LiOH, NaOH, KOH, RbOH, CsOH] Heavy group 2A metal hydroxides [$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$]

Ion producing: hydration (water around ions)

NaCl (aq) +H_2O (l)

❖ ***Weak Electrolytes:*** do not ionize completely. This is represented as a **reversible reaction**

Category	**Example**
Weak acids	
Weak bases	

$HF\ (aq) + H_2O(l) \rightleftharpoons$

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-\ (aq)$

- **Nonelectrolytes: Do not ionize (No ions) no conduction**
  Sugar, Ethanol

✓ **Aqueous Reactions and Net Ionic Equations**

There are many ways to write the chemical equation:

Double Replacement Reactions

Metathesis (Exchange) Reactions : $AX + BY \rightarrow AY + BX$

1. **Molecular equation:**

$K_2SO_4(aq) + 2\ AgNO_3(aq) \rightarrow 2\ KNO_3(aq) + Ag_2SO_4(s)$

2. **Ionic Equation:** write all soluble **ions** and **insoluble compounds make sure to write the state of each.**

- Rules of writing the complete ionic equation:
- Aqueous strong electrolytes are written as ions.
- **Soluble salts**
- **strong acids**
- **strong bases**

- Insoluble substances, weak electrolytes, and nonelectrolytes are written in molecule form.
  - **Solids,**
  - **liquids,**
  - **gases**
  - are not dissolved, hence molecule form

Ionic Equation:

3. **Net Ionic Equation:** Only include what is changing! (cancel out similar species " **Spectator ions**" on both sides of the equation)

Three common reaction types in aqueous solution:

1. **Precipitation Reactions**

$AgNO_{3\,(aq)} + KCl_{\,(aq)} \longrightarrow AgCl_{\,(s)} + KNO_{3\,(aq)}$

$Pb(NO_3)_2(aq) + KI(aq)$

$BaCl_2(aq) + Na_2SO_4(aq)$

- Precipitte is the deriving force for the reaction

✓ Precipitation reactions do not always occur when two water soluble salts are mixed
NaCl (aq) + KI (aq)
How do you know it will happen?

TABLE 4.1 Solubility Rules for Ionic Compounds in Water

Compounds Containing the Following Ions Are Generally Soluble	Exceptions
Li^+, Na^+, K^+, and NH_4^+	None
NO_3^- and $C_2H_3O_2^-$	None
Cl^-, Br^-, and I^-	When these ions pair with Ag^+, Hg_2^{2+}, or Pb^{2+}, the resulting compounds are insoluble.
SO_4^{2-}	When SO_4^{2-} pairs with Sr^{2+}, Ba^{2+}, Pb^{2+}, Ag^+, or Ca^{2+}, the resulting compound is insoluble.
Compounds Containing the Following Ions Are Generally Insoluble	**Exceptions**
OH^- and S^{2-}	When these ions pair with Li^+, Na^+, K^+, or NH_4^+, the resulting compounds are soluble.
	When S^{2-} pairs with Ca^{2+}, Sr^{2+}, or Ba^{2+}, the resulting compound is soluble.
	When OH^- pairs with Ca^{2+}, Sr^{2+}, or Ba^{2+}, the resulting compound is slightly soluble.
CO_3^{2-} and PO_4^{3-}	When these ions pair with Li^+, Na^+, K^+, or NH_4^+, the resulting compounds are soluble.

? What is soluble in water?

$(NH_4)_2CO_3$ $BaSO_4$ Li_2S

$Mg(OH)_2$ $AgBr$ $Pb(NO_3)_2$

**When writing ionic equations remember that :
solids, liquids, gases, weak acids and weak bases **DON'T FORM IONS.**
Write them in the ionic equation in the same form as they appear in the molecular equation (copy and past)

Write the molecular, ionic and net ionic equations for the following:

1) $(NH_4)_2SO_4(aq) + Sr(NO_3)_2$

Molecular eqn:

Ionic Eqn:

Net ionic Eqn

2) $MgCl_2\ (aq) + Ca(OH)_{2\ (}aq)$

Molecular eqn:

Ionic Eqn:

Net ionic Eqn

2. Gas-Evolving Reactions

$K_2S(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + H_2S(g)$

$NaHCO_3(aq) + HCl(aq)$

Types of Compounds That Undergo Gas-Evolution Reactions

Reactant Type	Intermediate Product	Gas Evolved	Example
Sulfides	None	H_2S	$2\ HCl(aq) + K_2S(aq) \longrightarrow H_2S(g) + 2\ KCl(aq)$
Carbonates and bicarbonates	H_2CO_3	CO_2	$2\ HCl(aq) + K_2CO_3(aq) \longrightarrow H_2O(l) + CO_2(g) + 2\ KCl(aq)$
Sulfites and bisulfites	H_2SO_3	SO_2	$2\ HCl(aq) + K_2SO_3(aq) \longrightarrow H_2O(l) + SO_2(g) + 2\ KCl(aq)$
Ammonium	NH_4OH	NH_3	$NH_4Cl(aq) + KOH(aq) \longrightarrow H_2O(l) + NH_3(g) + KCl(aq)$

Practice Write the balanced molecular, Ionic and net ionic equation for precipitation reaction when aqueous solutions of $CaCl_2$ and Na_2CO_3 are mixed

Molecular eqn:

Ionic Eqn:

Net ionic Eqn

Acid–Base Reactions (Neutralization)

Arrhenius Definitions:

- **Acid:** Substance that produces **H^+ when dissolves in water**
  $HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

- **Base:** Substance that produces **OH^- ions in aqueous solution**
  $NaOH(aq) \longrightarrow Na^+(aq) + OH^-(aq)$

**H^+ and H_3O^+

- ✓ If acid 100% dissociated, then its strong (7 strong acids)

- ✓ Most acids are weak acids (if not listed among the 7 acids)

Additional classifications for acids:

Monoprotic	**Diprotic**	**Triprotic**

Bases have variable strength too

Strong bases: group (IA), Ca, Sr, and Ba hydroxides

Weak bases: Carbonates, bicarbonates, ammonia, and hydroxides that are not strong bases

- **<u>Acids-Base Neutralization</u>**

Acid + base $\longrightarrow$ salt + water

Strong acid + Strong base

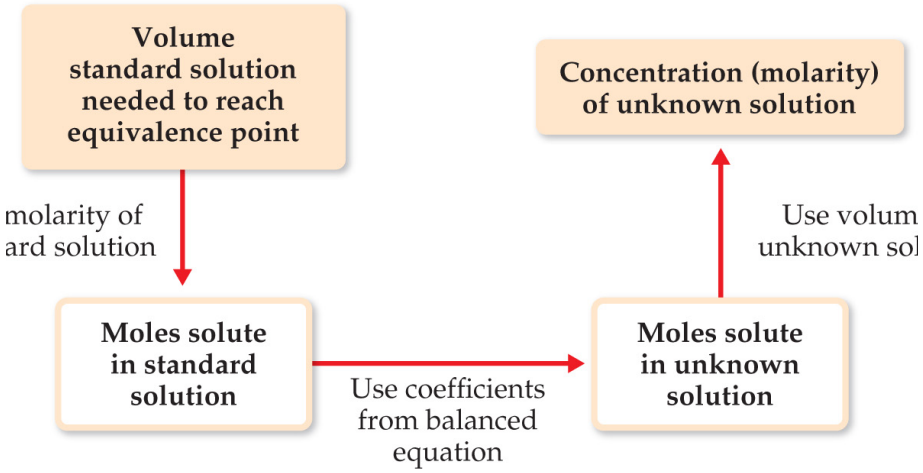
Strong base + weak acid

Also **gas forming** reactions:
HCl (aq) + Na_2CO_3 (aq)

Acid–Base Titrations

Indicator in Titration

Calculations in titration: **Always write the balance chemical equation**



A 31.5 mL aliquot of HNO_3 (aq) of unknown concentration was titrated with 0.0134 M NaOH (aq). It took 23.9 mL of the base to reach the endpoint of the titration. The concentration (M) of the acid was

0.0102

❖ Special case **Short cut**:

Apples contain malic acid, $C_4H_6O_5$.

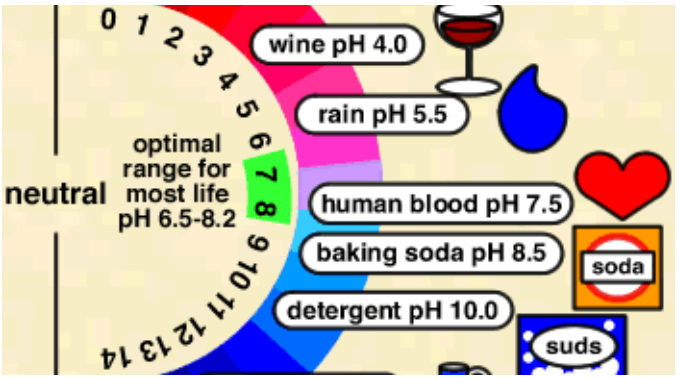
$C_4H_6O_5(aq) + 2\ NaOH(aq) \longrightarrow Na_2C_4H_4O_5(aq) + 2\ H_2O(liq)$

76.80 g of apple requires 34.56 mL of 0.664 M NaOH for titration. What is weight % of malic acid?

1.5386

2.00%

pH and Buffers: For more information read from chapters **15.5- 15.6 and 16.2**



pH = -log [H_3O^+]
= - log [H^+]

pH scale ranges from 1.0 to 14.0.
- Neutral pH is 7.0.
- Acidic solutions have pH < 7.0
- Basic solutions have pH > 7.0

pOH = 14 - pH
pOH = -log [OH^-]

Find the pH for [H^+]=10^{-3}M

Find the pH for [H^+]=5 X10^{-3}M

- To find pH in the hydronium ion concentration is known
- [H+]= 10^{-pH}

What is the H+ concentration for a solution with a pH of 12.2?

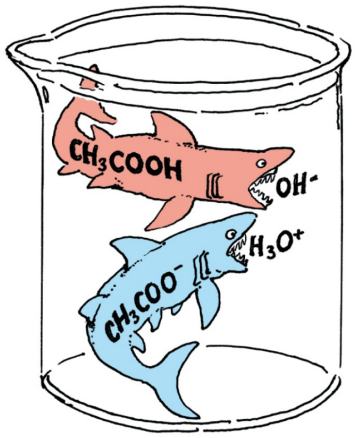
Find the [H^+] for pH=5

Find the [H+] for pH=5.8

Buffer

– A solution contains a **weak acid** and its **conjugate base** with the ability to resist changes in pH.

Weak acid	Conjugate base
Acetic acid, CH_3COOH	Acetate ion, CH_3COO^-
Carbonic acid, H_2CO_3	Bicarbonate ion, HCO_3^-



In this acetate buffer, the weak acid acetic acid, CH_3COOH, goes after any added OH^- ions and the weak base acetate ion, CH_3COO^-, goes after any added H_3O^+ ions.

Weak acid	Conjugate base

Oxidation-Reduction Reactions "Redox"

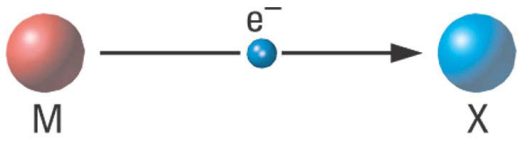
Oxidation: loose one or more electron

$$\overset{0}{Na} \rightarrow \overset{+1}{Na} + e^-$$

Reduction: Gain one or more electron

$$\overset{0}{Cl} + e^- \rightarrow \overset{-1}{Cl}$$

$$2\overset{0}{Na} + \overset{0}{Cl_2} \rightarrow 2\overset{+1}{Na}\overset{-1}{Cl}$$



M loses electron(s)
M is oxidized
M is the reducing agent

X gains electron(s
X is reduced
X is the oxidizing agent

The Oxidation Number Rules – SIMPLIFIED

- ✓ The sum of the oxidation numbers in ANYTHING is equal to its charge
- ❖ Oxidation states are imaginary charges assigned based on a set of rules.
- ❖ Ion charges are real, measurable charges.
- Atoms in their natural state will always have an oxidation number of zero. Examples include Na (s), Cl_2(g), H_2(g), Hg(l), N_2(g), Fe(s), etc.
- For ions with only a single atom, the oxidation number is equal to the charge on the ion.

- ➢ Elements in Group 1A: always +1
- ➢ Elements in Group 2A: always +2
- ➢ Aluminum: always +3
- ➢ Fluorine is always -1 in compounds with other elements.
- ➢ Oxygen is always -2 in compounds with other elements except when combined with fluorine or peroxides.
- ➢ Cl, Br and I will always be -1 in compounds with other elements unless combined with oxygen or fluorine.
- ➢ Hydrogen is always +1 in compounds with other elements except when combined with metals to form metal hydrides. The oxidation number for a hydride (H^-) is -1.

- **Remember the sum of the oxidation numbers is zero (0) for a neutral compound and is equal to the net charge for a polyatomic ion.**

Determine the oxidation number of the element in each of the following :

NH_3	N =
ClO^-	Cl =
H_3PO_4	P =
MnO_4^-	Mn =
$Cr_2O_7^{2-}$	Cr
$H_2PO_4^-$	P
SO_3^{2-}	S
N_2O_4	N

Combustion Reactions: type of redox reaction

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

Oxidation state: −4 +1 0 +4 −2 +1 −2

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$$

CHEM 134-F 2018 ICE 1 Name_____
Lab Sec_____ UMDID#_____

1) Silver ions can be precipitated from aqueous solutions by the addition of aqueous chloride
$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl\,(s)$

Silver chloride is virtually insoluble in water so that the reaction appears to go to completion. How many grams of solid NaCl must be added to 25.0 mL of 0.366 M $AgNO_3$ solution to completely precipitate the silver?

2) How would you prepare 9.70 g of $PbCl_2(s)$ from a
0.100 M solution of $Pb(NO_3)_2$ and a 0.200 M solution of $CaCl_2$?

CHEM 134-Fall 2018 ICE 2 Name_____
Lab Sec_____ UMDID#_____

A 25.0 mL sample of H_2SO_4 is neutralized with NaOH. What is the concentration of the H_2SO_4 if 35.0 mL of 0.150 *M* NaOH are required to completely neutralize
the acid?