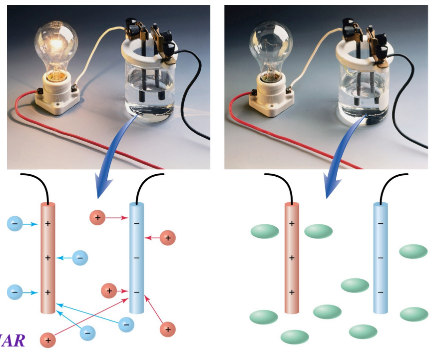


Solution Stoichiometry and Chemical Reactions

Chapter 3 & Chapter 4, or "Chapter 4 Part II"

Chemistry 221
Professor Michael Russell

MAR

Last update: 4/10/23

Terminology

In SOLUTION we need to define the -

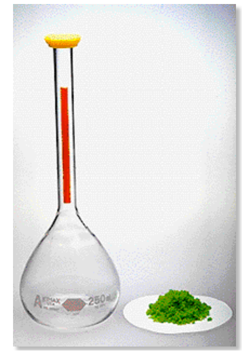
- SOLVENT

the component whose physical state is preserved when solution forms

- SOLUTE

the other solution component

- Compounds are *soluble* when they dissolve, *insoluble* when they stay as solids



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Water Solubility of Ionic Compounds

SOLUBLE COMPOUNDS	EXCEPTIONS
Almost all salts of Na^+, K^+, NH_4^+	
Salts of nitrate, NO_3^-; chlorate, ClO_3^-; perchlorate, ClO_4^-; acetate, $CH_3CO_2^-$	
Almost all salts of Cl^-, Br^-, I^-	Halides of Ag^+, Hg_2^{2+}, Pb^{2+}
Compounds containing F^-	Fluorides of Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}
Salts of sulfate, SO_4^{2-}	Sulfates of Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}

INSOLUBLE COMPOUNDS	EXCEPTIONS
Most salts of carbonate, CO_3^{2-}; phosphate, PO_4^{3-}; oxalate, $C_2O_4^{2-}$; chromate, CrO_4^{2-}	Salts of NH_4^+ and the alkali metal cations
Most metal sulfides, S^{2-}	
Most metal hydroxides and oxides	

If one ion from the "Soluble Compd." list is present in a compound, the compound is water soluble.

$Ba(NO_3)_2(aq)$? **soluble**

$BaCl_2(aq)$? **soluble**

$BaSO_4(aq)$? **insoluble** *should write $BaSO_4(s)$!*

Use this solubility guide in CH 221-223!

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WATER SOLUBILITY OF IONIC COMPOUNDS

Not all ionic compounds dissolve in water. Some are INSOLUBLE.

Many ions, however, make compounds SOLUBLE *all* of the time.

Examples: Na^+, K^+, Li^+, NH_4^+, NO_3^-, ClO_3^-, ClO_4^-, $CH_3CO_2^-$, and *most* SO_4^{2-}, Cl^-, Br^- and I^- compounds.

SOLUBLE COMPOUNDS	EXCEPTIONS
Almost all salts of Na^+, K^+, NH_4^+	
Salts of nitrate, NO_3^-; chlorate, ClO_3^-; perchlorate, ClO_4^-; acetate, $CH_3CO_2^-$	
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INSOLUBLE COMPOUNDS	EXCEPTIONS
Most salts of carbonate, CO_3^{2-}; phosphate, PO_4^{3-}; oxalate, $C_2O_4^{2-}$; chromate, CrO_4^{2-}	Salts of NH_4^+ and the alkali metal cations
Most metal sulfides, S^{2-}	
Most metal hydroxides and oxides	

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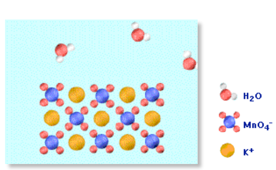
Ionic Compounds in Aqueous Solution

Many reactions involve soluble ionic compounds, especially reactions in water - aqueous solutions.

$KMnO_4$ in water



$K^+(aq)$ + $MnO_4^-(aq)$

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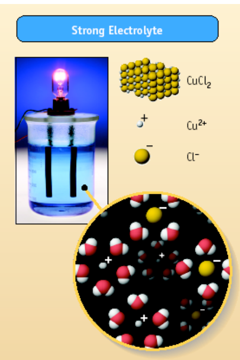
Aqueous Solutions

How do we know ions are present in aqueous solutions?

The solutions conduct electricity! The ions are called ELECTROLYTES

HCl, $KMnO_4$, $MgCl_2$, and NaCl are strong electrolytes. They dissociate completely (*or nearly so*) into ions.

$KMnO_4(aq)$ ---> $K^+(aq)$ + $MnO_4^-(aq)$



A strong electrolyte conducts electricity. $CuCl_2$ is completely dissociated into Cu^{2+} and Cl^- ions.

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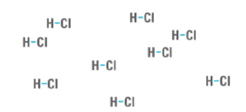
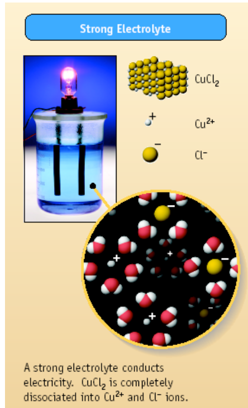
Aqueous Solutions

HCl, $MgCl_2$, and NaCl are **strong electrolytes.** They dissociate completely (or nearly so) into ions.





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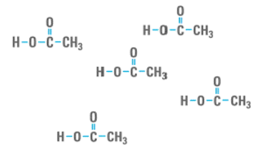
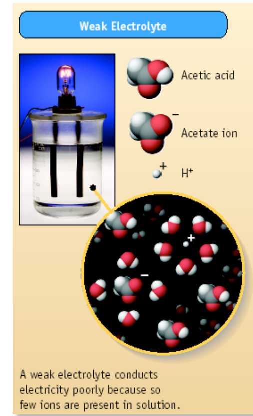
Aqueous Solutions

Acetic acid ionizes only to a small extent, so it is a **weak electrolyte**

$CH_3CO_2H(aq)$ --->

$CH_3CO_2^-(aq)$ + $H^+(aq)$





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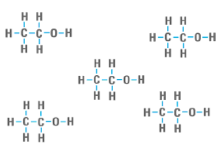
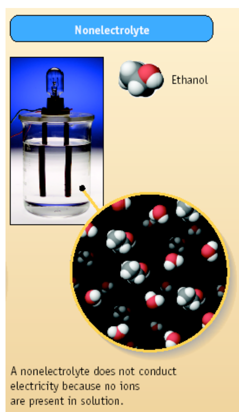
Aqueous Solutions

Some compounds (sugar, ethanol, acetone, etc.) dissolve in water but do not conduct electricity. They are called **nonelectrolytes.**



See "Dissolve, Dissociate and Electrolyte" Guide



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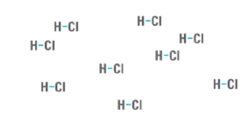
Acids

An acid -------> H^+ in water

Some **strong** acids include:

HCl	hydrochloric
HNO_3	nitric
$HClO_4$	perchloric
H_2SO_4	sulfuric

All strong acids are strong electrolytes



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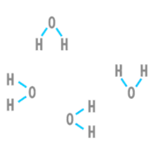
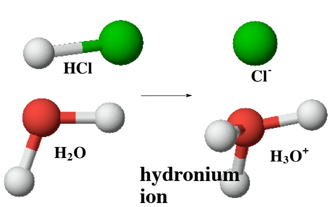


The Nature of Acids



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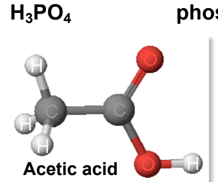
Weak Acids

All weak acids are **weak electrolytes**

CH_3CO_2H	acetic acid
H_2CO_3	carbonic acid
H_3PO_4	phosphoric acid



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BASES

Base ---> OH^- in water

Bases are often metal hydroxides

$NaOH(aq) \text{ ---> } Na^+(aq) + OH^-(aq)$

NaOH is a strong base

NaOH NaOH NaOH NaOH NaOH NaOH

All strong bases are strong electrolytes

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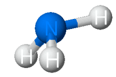
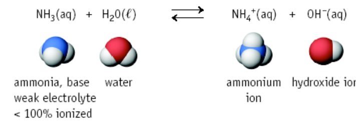
Ammonia, NH_3

An Important Weak Base





All weak bases are weak electrolytes

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Common Acids and Bases			
Strong Acids (Strong Electrolytes)		**Strong Bases (Strong Electrolytes)**	
HCl	Hydrochloric acid	LiOH	Lithium hydroxide
HBr	Hydrobromic acid	NaOH	Sodium hydroxide
HI	Hydroiodic acid	KOH	Potassium hydroxide
HNO_3	Nitric acid		
$HClO_4$	Perchloric acid		
H_2SO_4	Sulfuric acid		
Weak Acids (Weak Electrolytes)*		**Weak Base (Weak Electrolyte)**	
H_3PO_4	Phosphoric acid	NH_3	Ammonia
H_2CO_3	Carbonic acid		
CH_3CO_2H	Acetic acid		
$H_2C_2O_4$	Oxalic acid		
$C_4H_6O_6$	Tartaric acid		
$C_6H_8O_7$	Citric acid		
$C_9H_8O_4$	Aspirin		

*These are representative of hundreds of weak acids.

Know the strong acids & bases!

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Net Ionic Equations

$Mg(s) + 2\,HCl(aq) \text{ --> } H_2(g) + MgCl_2(aq)$

We really should write:

$Mg(s) + 2\,H^+(aq) + 2\,Cl^-(aq) \text{ ---> } H_2(g) + Mg^{2+}(aq) + 2\,Cl^-(aq)$

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Net Ionic Equations

$Mg(s) + 2\,HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$

Aqueous solutes (HCl, $MgCl_2$) dissociate; we *really* should write:

$Mg(s) + 2\,H^+(aq) + 2\,Cl^-(aq) \rightarrow H_2(g) + Mg^{2+}(aq) + 2\,Cl^-(aq)$

We leave the spectator ions (Cl^-) out in writing the NET IONIC EQUATION:

$Mg(s) + 2\,H^+(aq) \rightarrow H_2(g) + Mg^{2+}(aq)$

See Net Ionic Reactions Handout

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Net Ionic Equations

$K_2CrO_4(aq) + Pb(NO_3)_2(aq) \text{ --> } PbCrO_4(s) + 2\,KNO_3(aq)$

NET IONIC EQUATION

$Pb^{2+}(aq) + CrO_4^{2-}(aq) \text{ ---> } PbCrO_4(s)$

K^+ and NO_3^- are spectators

See Net Ionic Reactions Handout

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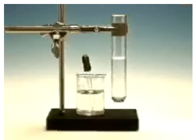
CHEMICAL REACTIONS IN WATER

We will look at
EXCHANGE REACTIONS

$AX + BY \longrightarrow AY + BX$



The anions exchange places between cations

$Pb(NO_3)_2(aq) + 2\ KI(aq)$
$\text{---->}\ PbI_2(s) + 2\ KNO_3(aq)$

Exchange reactions often called Double Displacement Reactions

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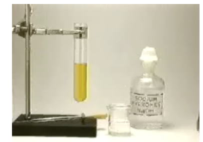
Precipitation Reactions

The "driving force" is the formation of an insoluble compound - a precipitate.

$Fe(NO_3)_3(aq) + 3\ NaOH(aq)$
----->
$3\ NaNO_3(aq) + Fe(OH)_3(s)$



Net ionic equation
$Fe^{3+}(aq) + 3\ OH^-(aq)\ \text{--->}\ Fe(OH)_3(s)$

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See "Five Types of Reactions" Handout

Acid-Base Reactions

Acids react readily with bases. The "driving force" is the formation of water.

$NaOH(aq) + HCl(aq) \rightarrow$
$NaCl(aq) + H_2O(liq)$

Net ionic equation:
$OH^-(aq) + H^+(aq) \rightarrow$
$H_2O(liq)$

This applies to ALL reactions of STRONG acids and bases.

Acid-base reactions often called "neutralizations", water and "salt" created

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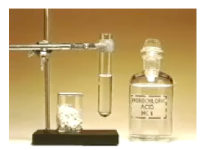
See "Five Types of Reactions" Handout



Gas-Forming Reactions

$CaCO_3(s) + 2\ HCl(aq)\ \text{--->}$
$CaCl_2(aq) + H_2CO_3(aq)$

Carbonic acid is unstable and forms CO_2 & H_2O

$H_2CO_3(aq)\ \text{--->}\ CO_2(g) + \text{water}$

Another gas forming species:

$NH_4OH(aq)\ \text{--->}\ NH_3(g) + \text{water}$

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See "Five Types of Reactions" Handout

Combustion Reactions

A special example of a gas-forming reaction

Used in quantitative chemistry; high temperatures

Reactants: oxygen (O_2) *and* "*something organic*" *(C, H, sometimes O or N)*

Products: water *and* carbon dioxide *(also* NO_2 *if N present)*

Examples:

$$C_2H_{4(g)} + 3\ O_{2(g)} \rightarrow 2\ H_2O_{(g)} + 2\ CO_{2(g)}$$
$$4\ C_6H_5NO_2 + 29\ O_{2(g)} \rightarrow 10\ H_2O_{(g)} + 24\ CO_{2(g)} + 4\ NO_{2(g)}$$

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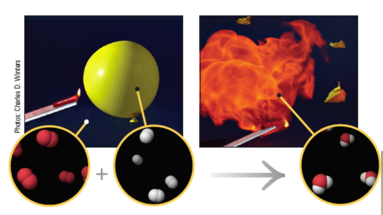
See "Five Types of Reactions" Handout

Oxidation-Reduction Reactions

REDOX = reduction & oxidation

$2\ H_2(g) + O_2(g)\ \text{--->}\ 2\ H_2O(liq)$



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See "Five Types of Reactions" Handout

LEO says GER

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LEO says GER

Lose **E**lectrons **O**xidized — **G**ain **E**lectrons **R**educed

$Zn(s) \rightarrow Zn^{2+} + 2e^-$ *Oxidized*

$Cu^{2+} + 2e^- \rightarrow Cu(s)$ *Reduced*

*Can also use **"OIL RIG":***
***OIL = "Oxidation is Losing"** (electrons)*
***RIG = "Reduction is Gaining"** (electrons)*

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REDOX REACTIONS

In all reactions: if something has been oxidized then something has also been reduced:

$Cu(s) + 2\ Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2\ Ag(s)$

Redox reactions incredibly useful (fuels, batteries, much more)

Oxidation numbers help visualize electron transfer pathways

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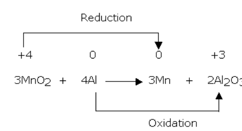
*Use **oxidation number rules** to determine redox activity:*

- **Atoms in free element have ox. no. = 0**
  $Zn(s)$, $O_2(g)$, $Br_2(liq)$
- *In simple ions,* **ox. no. = charge on ion**
  -1 for Cl^-, +2 for Mg^{2+}
- **In compounds, F is *always* -1, O is -2** *(except peroxides (O = -1) and with F) and* **H is +1** *(except hydrides (H = -1))*
- **Sum of oxidation numbers = 0** *for a* **compound or equals the overall charge** *for an* **ion**

OXIDATION NUMBERS



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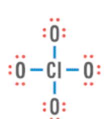
OXIDATION NUMBERS

Determining oxidation numbers takes practice

HF
H: +1
F: -1



ClO_4^-
Cl: +7
O: -2

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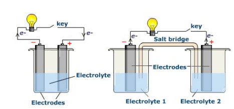
Recognizing a Redox Reaction

$2\ Al(s) + 3\ Cu^{2+}(aq) \text{---> } 2\ Al^{3+}(aq) + 3\ Cu(s)$

$Al(s) \text{--> } Al^{3+}(aq) + 3\ e^-$

- **Ox. no. of Al *increases* as e^- are donated by the metal; Al is OXIDIZED (or the REDUCING AGENT)**



$Cu^{2+}(aq) + 2\ e^- \text{--> } Cu(s)$

- **Ox. no. of Cu *decreases* as e^- are accepted by the ion; Cu^{2+} is REDUCED (or the OXIDIZING AGENT)**

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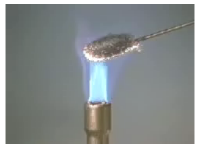
Examples of Redox Reactions



NO = reducing agent
O_2 = oxidizing agent
$2\ NO + O_2 \rightarrow 2\ NO_2$

Fe = reducing agent
Cl_2 = oxidizing agent
$2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$

reducing agent = oxidized
oxidizing agent = reduced

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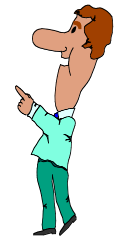
Concentration (Molarity) of Solute

The amount of solute in a solution is given by its concentration

$$\text{Molarity (M)} = \frac{\text{moles solute}}{\text{liters of solution}}$$



Concentration (M) = […]
"3.6 M" means a concentration of 3.6 molarity
"concentration" and molarity often the same

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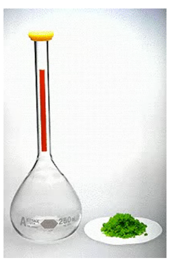
PROBLEM: Dissolve 5.00 g of $NiCl_2 \cdot 6\ H_2O$ in enough water to make 250. mL of solution. Calculate molarity.



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PROBLEM: Dissolve 5.00 g of $NiCl_2 \cdot 6\ H_2O$ in enough water to make 250. mL of solution. Calculate molarity.

Step 1: Calculate moles of $NiCl_2 \cdot 6H_2O$

$$5.00\ g \cdot \frac{1\ mol}{237.7\ g} = 0.0210\ mol$$

Step 2: Calculate molarity

$$\frac{0.0210\ mol}{0.250\ L} = 0.0841\ M$$

$[NiCl_2 \cdot 6\ H_2O] = 0.0841\ M$

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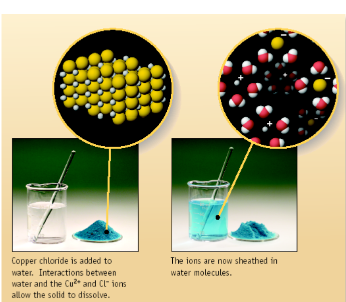
The Nature of a $CuCl_2$ Solution Ion Concentrations



$CuCl_2(aq)$ -->

$Cu^{2+}(aq) + 2\ Cl^-(aq)$

If $[CuCl_2] = 0.30$ M, then

$[Cu^{2+}] = 0.30$ M

$[Cl^-] = 2 \times 0.30$ M = 0.60 M

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USING MOLARITY

What mass of oxalic acid, $H_2C_2O_4$, is required to make 250. mL of a 0.0500 M solution?

$$\text{moles} = M \cdot V$$

Step 1: Calculate moles of acid required.

(0.0500 mol/L)(0.250 L) = 0.0125 mol

Step 2: Calculate mass of acid required.

(0.0125 mol)(90.00 g/mol) = 1.13 g

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Preparing Solutions

Weigh out a solid solute and dissolve in a given quantity of solvent

or

Dilute a concentrated solution to give one that is less concentrated.

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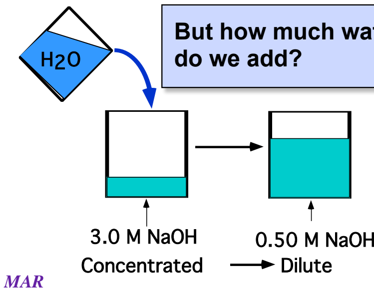
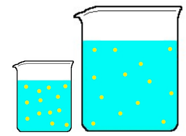
You have 50.0 mL of 3.0 M NaOH and you want 0.50 M NaOH. What do you do?



But how much water do we add?

The important point:

moles of NaOH in ORIGINAL solution = moles of NaOH in FINAL solution



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

Moles of NaOH in original solution =

M * V =

(3.0 mol/L)(0.0500 L) = 0.15 mol NaOH

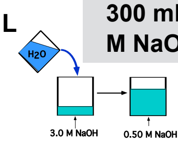
Therefore, moles of NaOH in final solution must also = 0.15 mol NaOH

(0.15 mol NaOH)(1 L/0.50 mol) = 0.30 L

or 300 mL = volume of final solution

Conclusion:

add 250 mL of water to 50.0 mL of 3.0 M NaOH to make 300 mL of 0.50 M NaOH.



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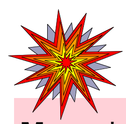
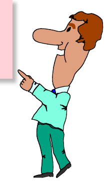
Preparing Solutions by Dilution



A shortcut

$$M_{initial} * V_{initial} = M_{final} * V_{final}$$



Often abbreviated: $M_iV_i = M_fV_f$ ***or*** $C_1V_1 = C_2V_2$

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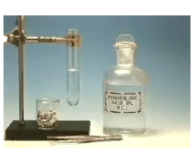
SOLUTION STOICHIOMETRY

Zinc reacts with acids to produce H_2 gas. What volume of 2.50 M HCl is needed to convert 10.0 g of Zn?



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

Zinc reacts with acids to produce H_2 gas. What volume of 2.50 M HCl is needed to convert 10.0 g of Zn?

Step 1: Calculate moles of Zn

$$10.0 \text{ g Zn} \bullet \frac{1.00 \text{ mol Zn}}{65.39 \text{ g Zn}} = 0.153 \text{ mol Zn}$$

Step 2: Use the stoichiometric factor

$$0.153 \text{ mol Zn} \bullet \frac{2 \text{ mol HCl}}{1 \text{ mol Zn}} = 0.306 \text{ mol HCl}$$

Step 3: Calculate volume of HCl required

$$0.306 \text{ mol HCl} \bullet \frac{1.00 \text{ L}}{2.50 \text{ mol}} = 0.122 \text{ L HCl}$$

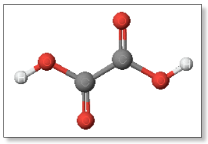
MAR

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

ACID-BASE REACTIONS
Titrations

$H_2C_2O_4$(aq) + 2 NaOH(aq) --->
acid base
$Na_2C_2O_4$(aq) + 2 H_2O(liq)

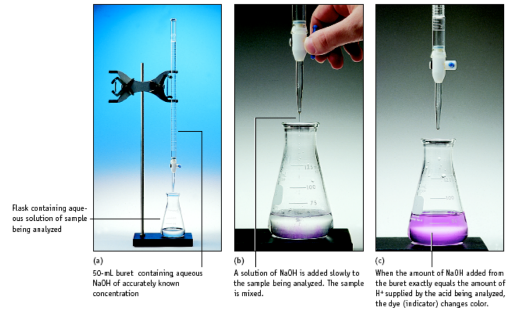
Carry out this reaction using a TITRATION.



Oxalic acid, $H_2C_2O_4$

MAR

Setup for titrating an acid with a base



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LAB PROBLEM #1: Standardize a solution of NaOH - i.e., accurately determine its concentration.

1.065 g of $H_2C_2O_4$ (oxalic acid) requires 35.62 mL of NaOH for titration to an equivalence point. What is the concentration of the NaOH?

MAR

$H_2C_2O_4$(aq) + 2 NaOH(aq) ---> $Na_2C_2O_4$(aq) + 2 H_2O(liq)

1.065 g of $H_2C_2O_4$ (oxalic acid) requires 35.62 mL of NaOH for titration to an equivalence point. What is the concentration of the NaOH?

Step 1: Calculate moles of $H_2C_2O_4$

$$1.065\text{ g} * \frac{1\text{ mol}}{90.04\text{ g}} = 0.01183\text{ mol}$$

Step 2: Calculate moles of NaOH req'd

$$0.01183\text{ mol acid} \bullet \frac{2\text{ mol NaOH}}{1\text{ mol acid}} = 0.02366\text{ mol NaOH}$$

MAR

$H_2C_2O_4$(aq) + 2 NaOH(aq) ---> $Na_2C_2O_4$(aq) + 2 H_2O(liq)

1.065 g of $H_2C_2O_4$ (oxalic acid) requires 35.62 mL of NaOH for titration to an equivalence point. What is the concentration of the NaOH?

Step 1: Calculate moles of $H_2C_2O_4$
= 0.01183 mol acid

Step 2: Calculate moles of NaOH req'd
= 0.02366 mol NaOH

Step 3: Calculate concentration of NaOH

$$\frac{0.02366\text{ mol NaOH}}{0.03562\text{ L}} = 0.6642\text{ M}$$

[NaOH] = 0.6642 M

MAR

$H_2C_2O_4$(aq) + 2 NaOH(aq) ---> $Na_2C_2O_4$(aq) + 2 H_2O(liq)

LAB PROBLEM #2: Use standardized NaOH to determine the amount of an acid in an unknown.

Apples contain malic acid, $C_4H_6O_5$.

$C_4H_6O_5$(aq) + 2 NaOH(aq) --->
$Na_2C_4H_4O_5$(aq) + 2 H_2O(liq)

76.80 g of apple requires 34.56 mL of 0.6642 M NaOH for titration. What is weight % of malic acid?

MAR

76.80 g of apple requires 34.56 mL of 0.6642 M NaOH for titration. What is weight % of malic acid?

Step 1: **Calculate moles of NaOH used.**

M * V = (0.6642 M)(0.03456 L)

= 0.02295 mol NaOH

Step 2: **Calculate moles of acid titrated.**

$$0.02295 \text{ mol NaOH} \bullet \frac{1 \text{ mol acid}}{2 \text{ mol NaOH}}$$

= 0.01148 mol acid

MAR

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

76.80 g of apple requires 34.56 mL of 0.6642 M NaOH for titration. What is weight % of malic acid?

Step 1: **moles of NaOH = 0.02295**

Step 2: **moles of acid titrated = 0.01148**

Step 3: **Calculate mass of acid titrated.**

$$0.01148 \text{ mol acid} \bullet \frac{134.1 \text{ g}}{\text{mol}} = 1.539 \text{ g}$$

Step 4: **Calculate % malic acid.**

(1.539 g acid / 76.80 g apple) *100 =

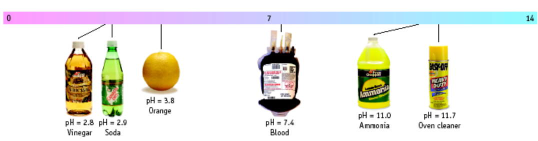
2.004 %

MAR

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

pH, a Concentration Scale

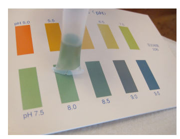
pH: a way to express acidity - the concentration (M) of H^+ in solution.



Low pH: high $[H^+]$ **High pH: low $[H^+]$**

Acidic solution	pH < 7
Neutral	pH = 7
Basic solution	pH > 7

MAR



The pH Scale

pH = - log $[H^+]$

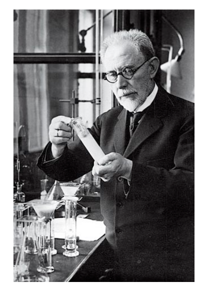
In a neutral solution,

$[H^+]$ = $[OH^-]$ = 1.00 x 10^{-7} M at 25 °C

pH = - log $[H^+]$

= -log (1.00 x 10^{-7})

= - (-7) = 7



Søren Sørensen, creator of the pH scale

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$[H^+]$ and pH

If the $[H^+]$ of soda is 1.6 x 10^{-3} M, the pH is ____?

Because pH = - log $[H^+]$

then

pH= - log (1.6 x 10^{-3})

pH = - (-2.80)

pH = 2.80

MAR

pH and $[H^+]$

If the pH of Coke is 3.12, it is ___________.

Because pH = - log $[H^+]$ then

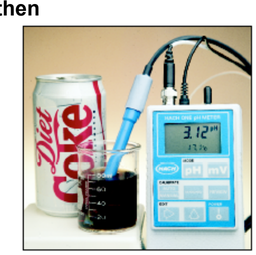
log $[H^+]$ = - pH

Take antilog and get

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

$[H^+]$ = $10^{-3.12}$

$[H^+]$ = 7.6 x 10^{-4} M



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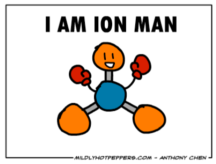
more on acids, bases and pH in CH 223...

End of Chapter Four Part 2



See also:

- *Chapter Four Part 2 Study Guide*
- *Chapter Four Part 2 Concept Guide*
- *Important Equations (following this slide)*
- *End of Chapter Problems (following this slide)*

MAR

Important Equations, Constants, and Handouts from this Chapter:

- Know how the **solubility guide** works
- Know what makes an acid acidic (and bases basic) and strong or weak; know how to use the pH scale
- Know how to write and determine net ionic equations and find spectator ions
- Know how to use molarity with solution stoichiometry problems
- Molarity (M) = mol of solute per Liter of solution
- $M_1V_1 = M_2V_2$

Solutions: Solute, solvent, aqueous, electrolyte (strong, weak, non), solubility (use the Net Ionics solubility table), precipitation, types of reactions, molarity (M)

Know the five types of reactions: precipitation, acid-base, gas forming, combustion and redox. Know how to determine if something has been **oxidized** or **reduced** (and the **oxidizing agent** and **reducing agent**)

MAR

End of Chapter Problems: *Test Yourself*

1. Predict whether these compounds would be labeled as insoluble or soluble: HCl, NaCl, AgCl
2. Predict the products of this precipitation reaction and write the net ionic equation: $NiCl_2(aq) + (NH_4)_2S(aq) \rightarrow$? List any spectator ions.
3. In the following reaction, decide which reactant is oxidized and which is reduced. Designate the oxidizing agent and the reducing agent. **$Si(s) + 2\ Cl_2(g) \rightarrow SiCl_4(l)$**
4. Identify the ions and their concentration that exist in this aqueous solution: **0.25 M $(NH_4)_2SO_4$**
5. What volume of 0.109 M HNO_3, in milliliters, is required to react completely with 2.50 g of $Ba(OH)_2$? **$2\ HNO_3(aq) + Ba(OH)_2(s) \rightarrow 2\ H_2O(l) + Ba(NO_3)_2(aq)$**
6. A table wine has a pH of 3.40. What is the hydrogen ion concentration of the wine? Is it acidic or basic?
7. If 50.0 mL of 0.0135 M $BaCl_2$ is diluted to a total of 400. mL, what is the new concentration of $BaCl_2$?

MAR

End of Chapter Problems: *Answers*

1. Soluble: HCl(aq), NaCl(aq). Insoluble: AgCl(s)
2. $NiCl_2(aq) + (NH_4)_2S(aq) \rightarrow NiS(s) + 2\ NH_4Cl(aq)$
   $Ni^{2+}(aq) + S^{2-}(aq) \rightarrow NiS(s)$ *Spectator ions:* NH_4^{+1} and Cl^{-1}
3. Si is oxidized and is the reducing agent; Cl_2 is reduced and is the oxidizing agent
4. 0.50 M NH_4^{+1}; 0.25 M SO_4^{2-}
5. 268 mL
6. acidic; $[H^+] = 4.0 \times 10^{-4}$ M
7. 0.00169 M

MAR