Ch04

Solutions

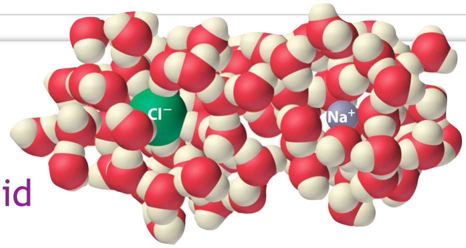
A closer look at mixtures.

Solutions and reactions in solution.

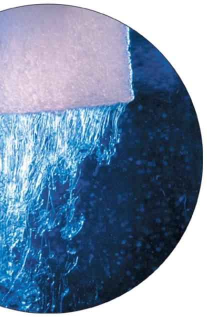
version 1.5

Ch04

Reactions in Solution



- Solubility
  - Why Solids are Solid
  - Making solutions
  - Electrolyte solutions
    - Electrolyte strength
- Concentration
  - Measures of concentration.
    - Molarity
    - Molarity as a conversion factor.
  - Dilution
    - Calculating volumes
    - Calculating concentrations.
  - Titration
- Reaction in Solution
  - Double Displacement: AB + CD ⇄ AD + CB
  - Equilibrium
  - Molecular, Complete & Net Ionic Eons
  - Precipitation/Solubility Rules



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  - Acid-Base Reactions
    - Neutralization; $H_2O_{(l)}$
  - Gas Evolution Reactions
    - $H_2S_{(g)}$, $CO_{2\,(g)}$, $NH_{3\,(g)}$, NH_4OH

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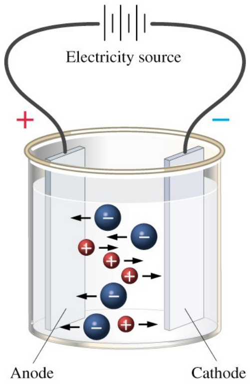
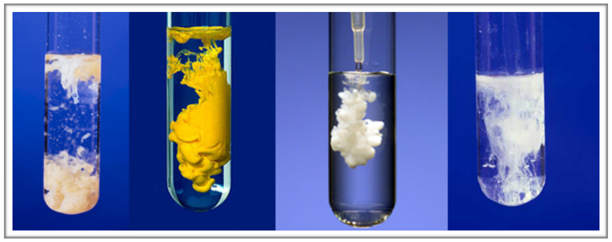
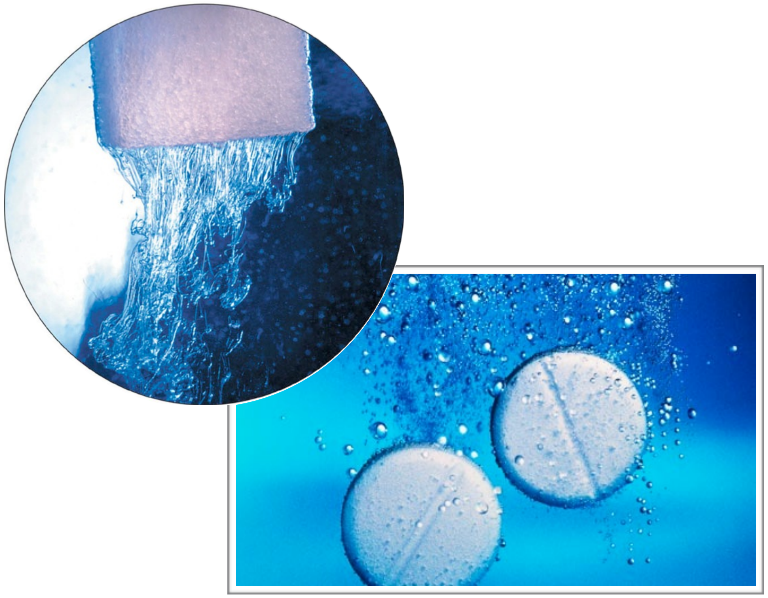




Solutions

- Solutions are homogenous mixtures.
- Mixtures can be liquids, gas, or solid.
- We're going to discuss the structure of mixtures.
- How substances come into mixtures and how substances can be driven out of mixtures.
- How substances in mixtures interact.
  - … and how that interaction facilitates chemical reaction between the mixtures components.



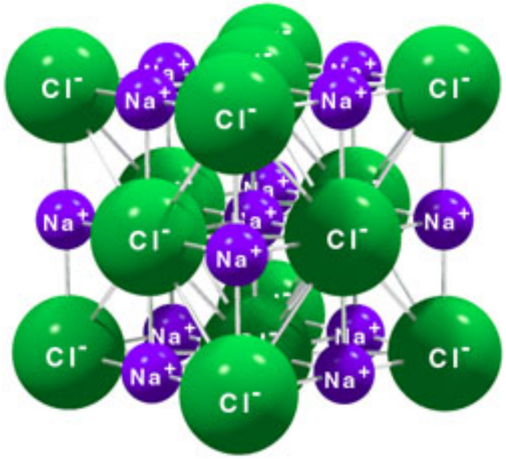
A solution is a homogenous mixture.

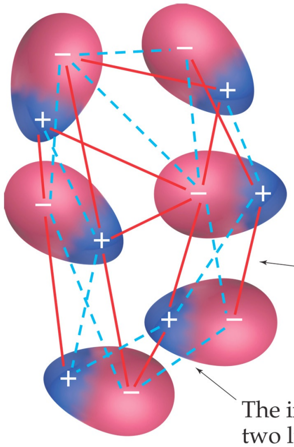
A solvent is the largest component of the mixture.

A solute is a smaller components of the mixture.

Why solids are solid.

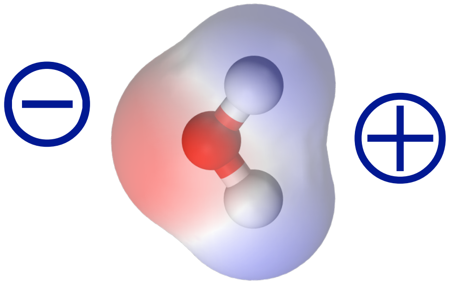
- Intermolecular forces hold solids together.
  - It’s usually about plus being attracted to minus (electrostatic attraction).
  - Molecular Solids are held together by many types of intermolecular forces.
    - The quick story is molecules have a negative end and a positive end.
    - The negative end of one molecule sticks to the positive end of another.
    - We’ll discuss the rest in Chapter 11.
  - Ionic Solids are held together by one type of intermolecular force.
    - It’s a simpler story.
    - The cations stick to a bunch of anions.
    - Those anions stick to more cations.
    - The result is a big clump of particles.



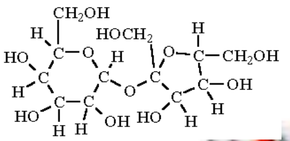


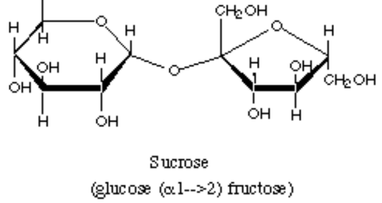
The interaction between any two opposite charges is attractive (solid red lines).

The interaction between any two like charges is repulsive (dashed blue lines).

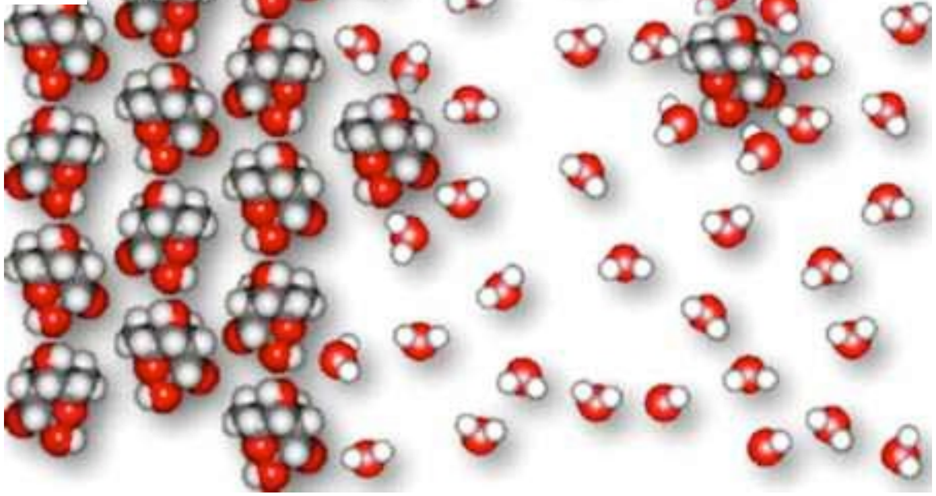


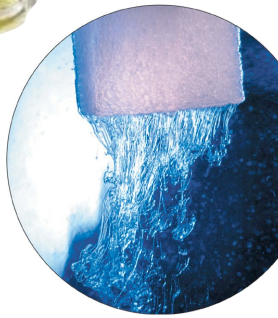
Molecular Solids Dissolve in Water





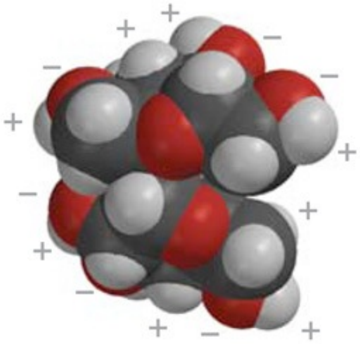
Sucrose
(glucose (α1-->2) fructose)



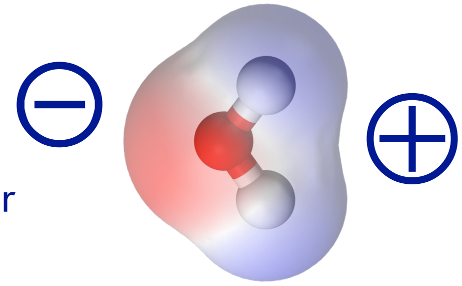


$$C_{12}H_{22}O_{11}\ (s) \xrightarrow{H_2O} C_{12}H_{22}O_{11}\ (aq)$$

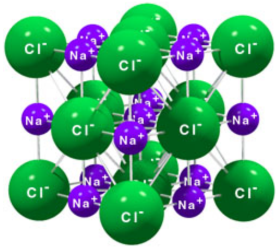
Sugar dissolving in water

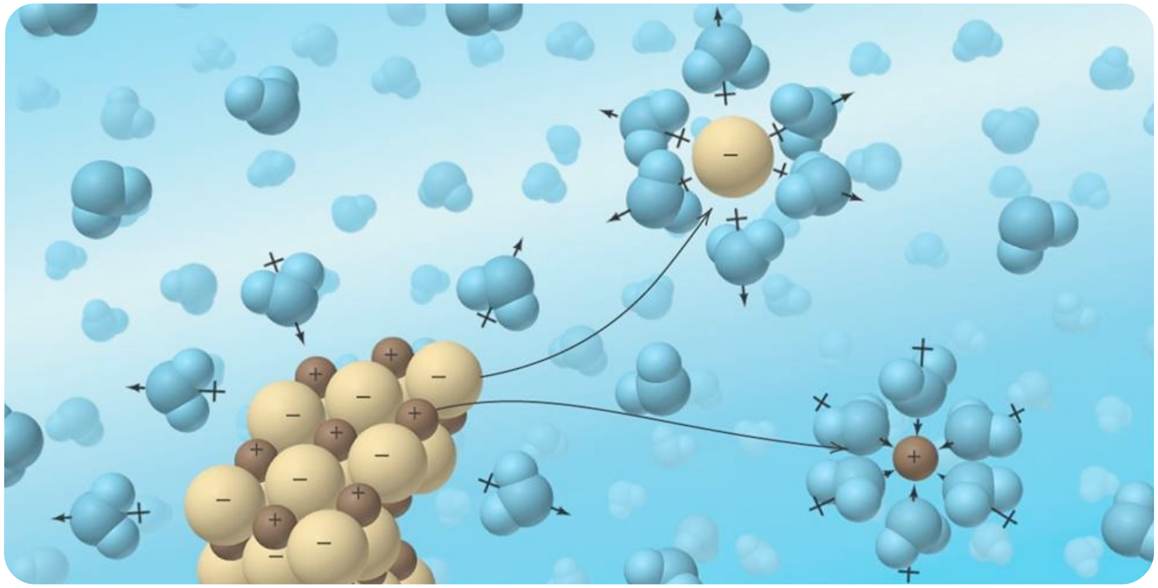


- Sugar dissolves in water.
- The molecules remain intact.
- Water molecules get in between sugar molecules.
- The result is a mixture of sugar and water.
- Mostly water.



Ionic Solids Dissolve in Water

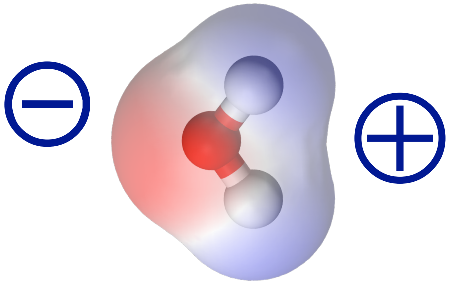




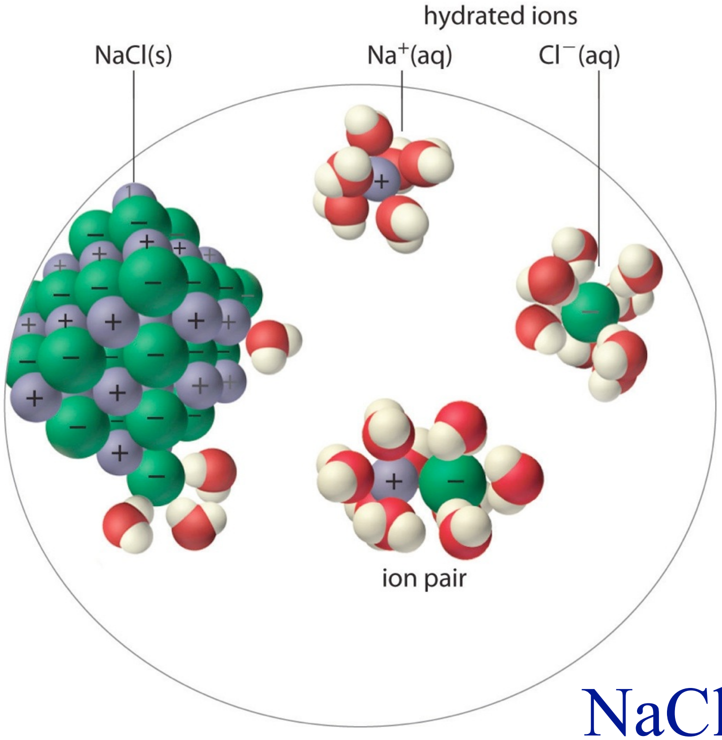
$$NaCl_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)}$$

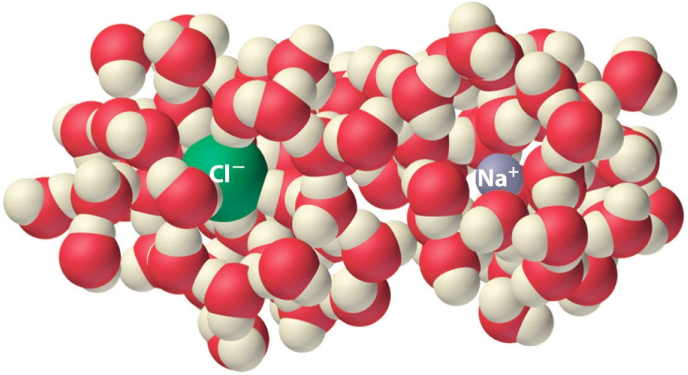
Dissociation of sodium chloride in water

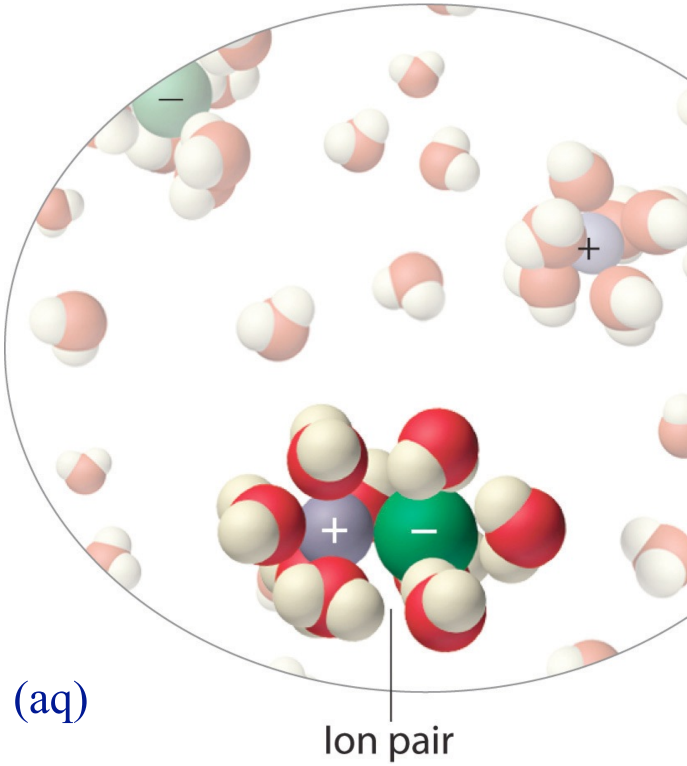
- Salt dissolves in water.
- The the ions separate.
- Water molecules get in between the ions.
- The result is a mixture of ions and water.
- Mostly water.
- Ions separating in solution is a process called dissociation.



Dissociation is often Reversible







$$\mathrm{NaCl}_{(aq)} \xrightleftharpoons{H_2O} \mathrm{Na}^+_{(aq)} + \mathrm{Cl}^-_{(aq)}$$

Dissociation of sodium chloride in water

- Dissolved ions in solution can find other dissolved ions.
- If the attraction between those ions is strong, they can re-associate.
- These dissolved ions form ion pairs.
- The ion pair is not a solid, it’s still dissolved in solution.
- Ions that dissociate and re-associate in solution are a kind of reversible reaction.

Electrolytes & Acids in Solution

- Substances that dissociate in water are electrolytes.
- Those that do not dissociate in water are non-electrolytes.
- Electrolytic solutions contain dissociated ions.
- Substances that release H^{+} are acids.
- Substances that accept H^{+} are bases.
- Equilibrium is the state of a reversible reaction where the forward and reverse reactions are happening at the same rate.
- At equilibrium the ratio of products to reactants is constant.
- Different materials will have different product to reactant ratios.
- Electrolytic solutions conduct electricity.
- The more ions, the better it conducts.
- Electrical conductivity can be used to test the equilibrium ratio of dissociated ions to associated acids and electrolytes.
- Acids and electrolytes that favor the dissociated state are called strong.
- Acids and electrolytes that favor the associated state in water are called weak.

Electrolytes:

eg: HCl, KNO_3, $NaCl$, CH_3COOH, HF

Acids:

eg: HCl, CH_3COOH, HF, NH_4^{+}

Bases:

eg: Cl^{1-}, CH3COO $^{1-}$, F^{1-}, NH_3

$HCl_{(aq)} \rightleftarrows H^{+}_{(aq)} + Cl^{1-}_{(aq)}$

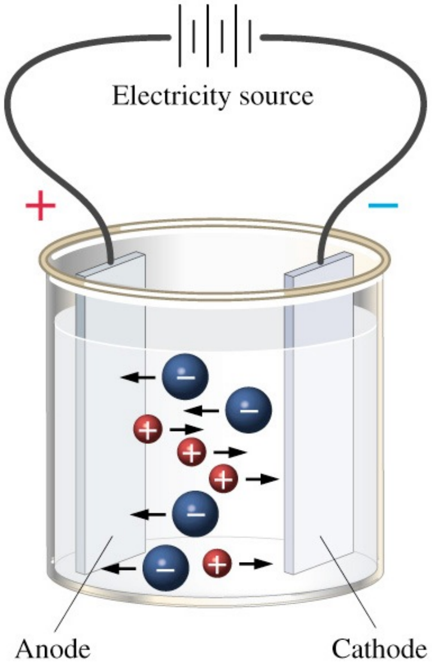
$KNO_{3\,(aq)} \rightleftarrows K^{+}_{(aq)} + NO_3{}^{1-}_{(aq)}$

$NH_4{}^{+}_{(aq)} \rightleftarrows H^{+}_{(aq)} + NH_{3\,(aq)}$

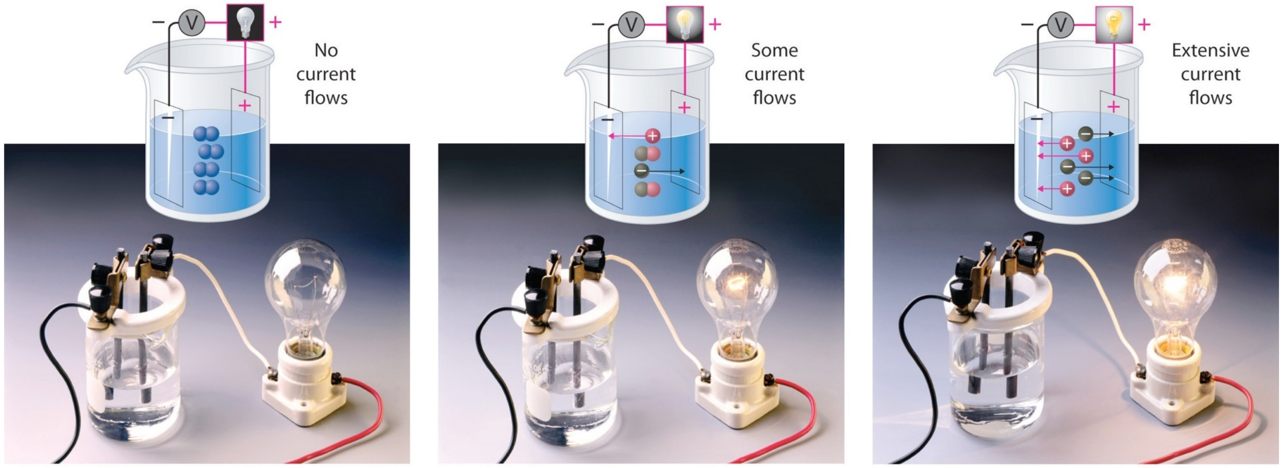
$NaCl_{(aq)} \rightleftarrows Na^{+}_{(aq)} + Cl^{1-}_{(aq)}$

$CH_3COOH_{(aq)} \rightleftarrows CHCOO^{1-}_{(aq)} + H^{+}_{(aq)}$

$HF_{(aq)} \rightleftarrows H^{+}_{(aq)} + F^{1-}_{(aq)}$



Electrolyte Strength



(a) Nonelectrolyte (b) Weak electrolyte (c) Strong electrolyte

Nonelectrolytes

- Molecular Substances
- Insoluble Ionic Salts

eg Sugar, AgCl, NO_2

Weak Electrolytes

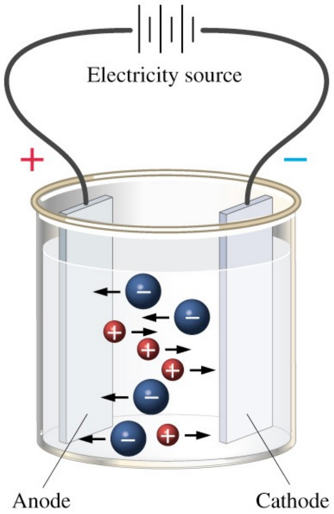
- Weak Acids
- Weak Bases
- Partially soluble Ionic Salts

eg HOAc, HF (aq)

Strong Electrolytes

- Strong Acids
- Strong Bases
- Soluble Ionic Salts

eg HCl (aq), NaCl, H_2SO_4

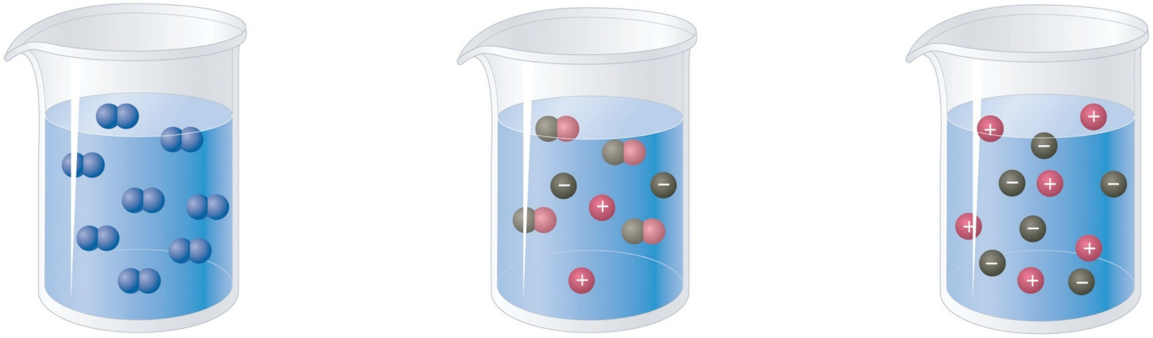


$$CH_3COOH_{(aq)} \rightleftarrows CHCOO^-_{(aq)} + H^+_{(aq)}$$

4 of 100 molecules dissociate

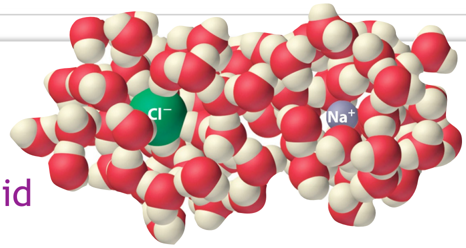
$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

100 of 100 dissociate



Ch04

Reactions in Solution



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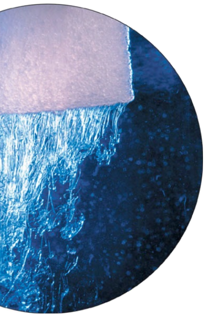

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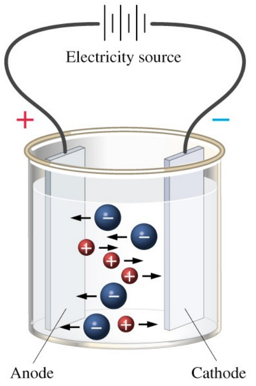
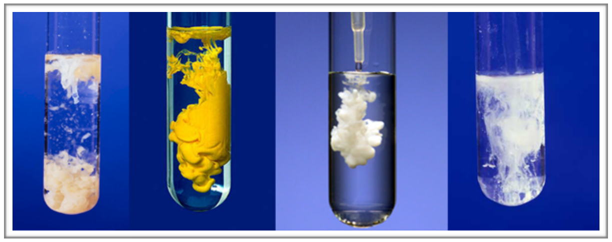


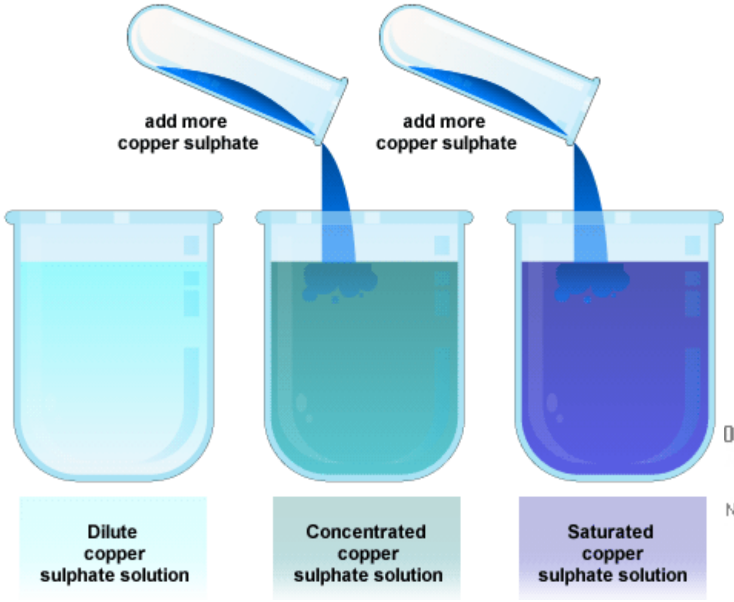


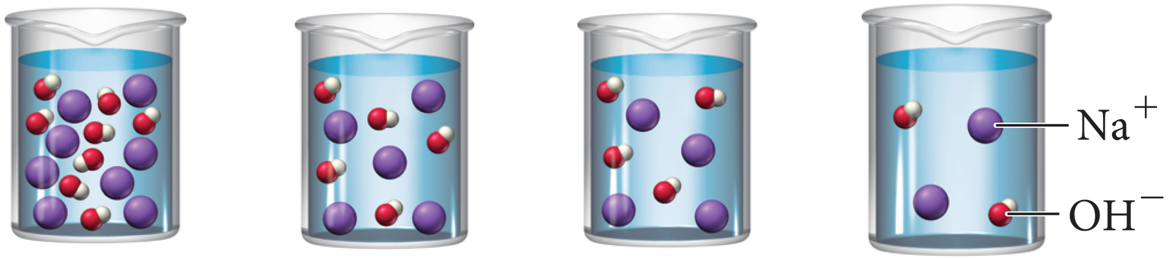
Solutions & Concentration

- Solutions are homogeneous mixtures.
- We know mixtures have tunable properties.
- The properties vary with the ratio of the pure substances that make up that mixture.

We describe that ratio as concentration.

- Concentration is the relationship between amount of a minor component of the mixture (a solute) to the major component of the mixture (the solvent).
- Concentration is how “crowded” the mixture is in a substance.
- Concentration is the amount of a solute in a given quantity of solvent.
- Solutions that contain greater amounts of solute are said to be more concentrated.
- Solutions that contain lesser amounts of solute are said to be more dilute.
- Solutions that contain the maximum amount of solute a solution can hold are said to be saturated.





A solution is a homogenous mixture.

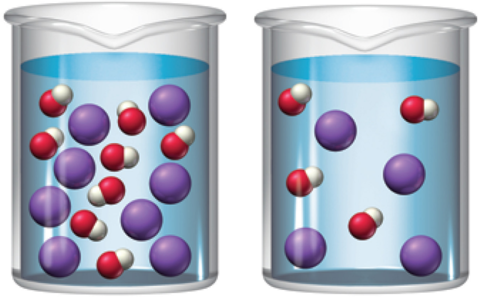
A solvent is the largest component of the mixture.

A solute is a smaller components of the mixture.

Molarity

$$\frac{\text{mol solute}}{\text{L solution}}$$

- Molarity is a measure of concentration.
- The units of molarity are mol/L. We abbreviate mol/L as “M”
- Molarity is the moles of a solute divided by the volume of the solution.
  - Don’t confuse volume of solution with volume of solvent.
  - Because the solute(s) also add to the volume of the solution Molarity is not the same thing as dividing the moles of solute by volume of solvent.
- It is easier to calculate molarity if we know the total volume of the solution rather than the volume of the solvent.



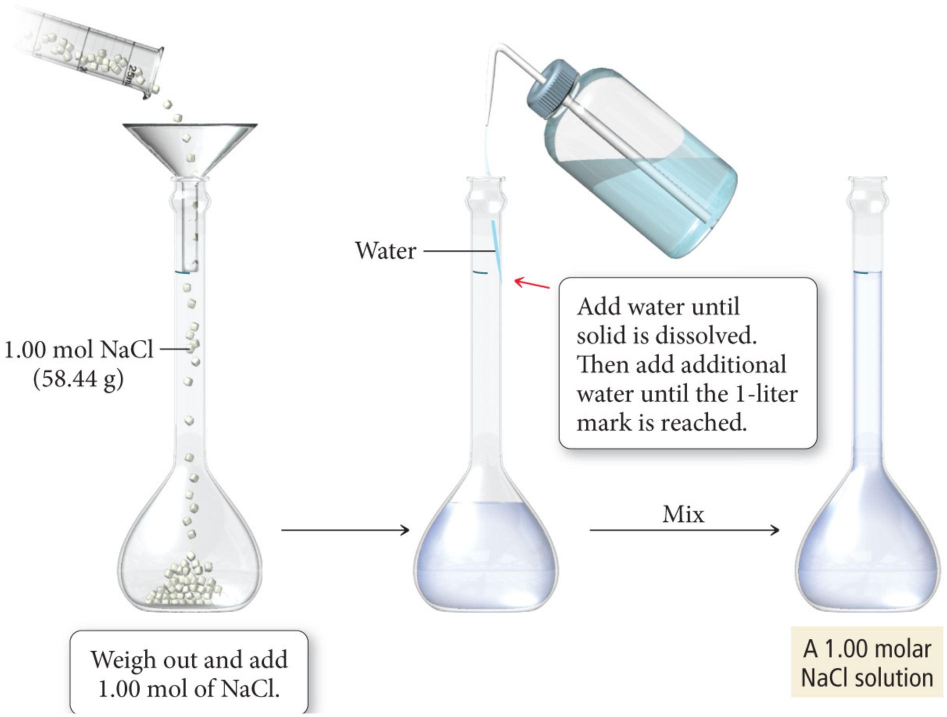
3.0 mol H_2SO_4 dissolved in 1.0 L water is:

$$\frac{3.0 \text{ mol } H_2SO_4}{1.0 \text{ L water} + 160 \text{ mL } H_2SO_4} = \frac{3.0 \text{ mol } H_2SO_4}{1.16 \text{ L solution}} =$$

2.6 molar or 2.6 M

3.0 mol H_2SO_4 diluted to 1.0 L in water is:

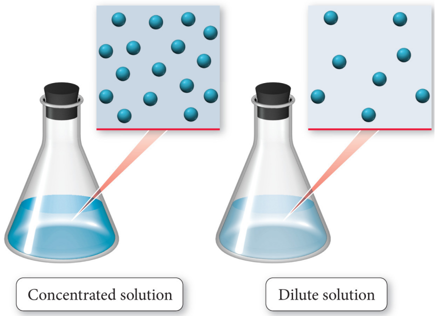
$$\frac{3.0 \text{ mol } H_2SO_4}{1.0 \text{ L solution}} = 3.0 \text{ molar or } 3.0 \text{ M}$$



Measures of Concentration

- There are a lot of ways we measure concentration.
- Three common ones are:
  - Mole Fraction (X)
    - Moles of solute per mole of solution.
    - We'll use this when we discuss gases, it's less useful for liquids.

$$X = \frac{\text{moles of solute}}{\text{moles of solution}}$$

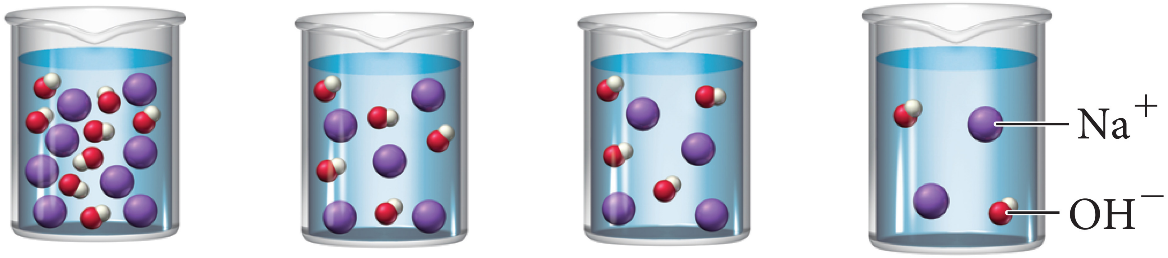


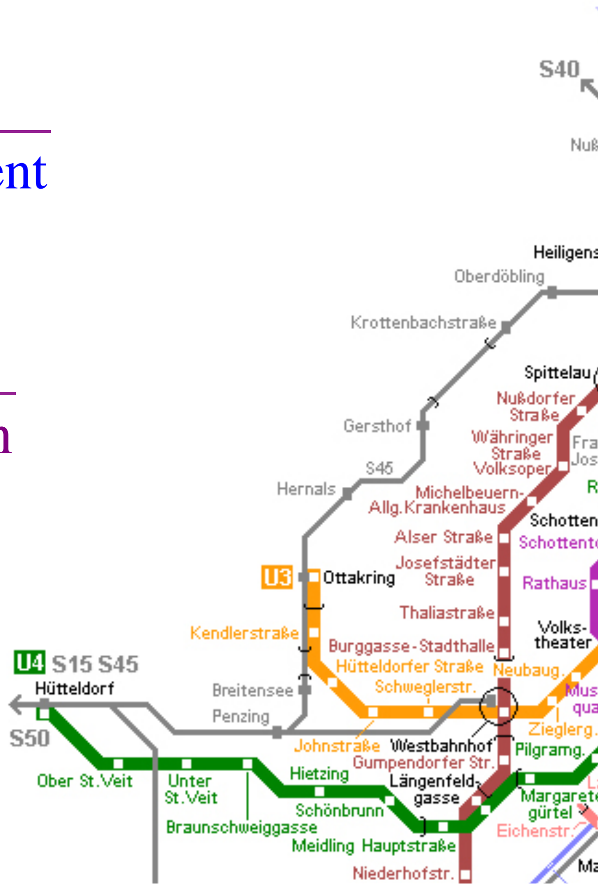
  - Molality (m)
    - Moles of solute, per kg of solution.
    - We won't use this.

$$m = \frac{\text{moles of solute}}{\text{kilogram of solvent}}$$

  - Molarity (M)
    - Moles of solute per liter of solution.
    - We'll use this **a lot** for liquids.

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





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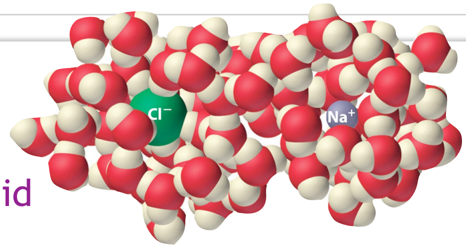

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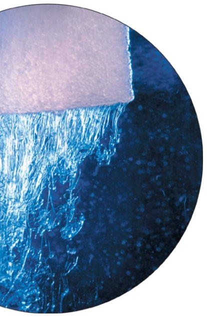

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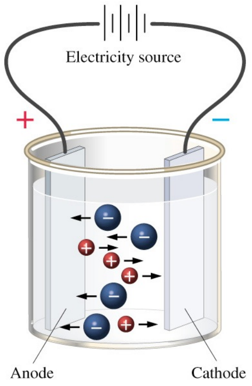
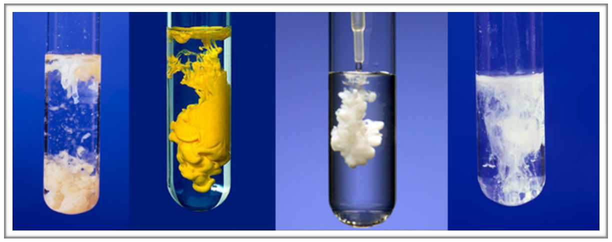
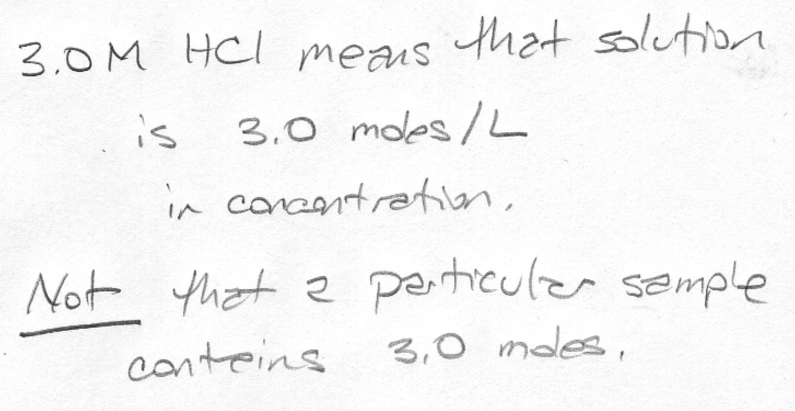




Molarity

- Molarity is the number of moles of a solute divided by the total volume of the solution in L.
- Molarity (M) means moles per liter (mol/L).

$$M = \frac{\text{mol solute}}{\text{L solution}}$$



3.0 M HCl means that solution
is 3.0 moles/L
in concentration.

Not that a particular sample
contains 3.0 moles.

Molarity

- Molarity is the number of moles of a solute divided by the total volume of the solution in L.
- Molarity makes it easy to interconvert between volumes of a solution and mols of solute.
- e.g. if I have 3.0 M H_2SO_4
  - How many mols H_2SO_4 in 0.150 L?

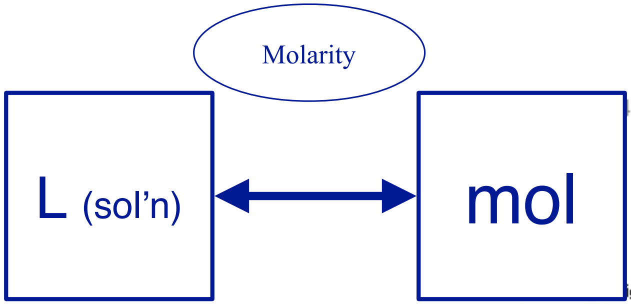
$L \xrightarrow{①} \text{mol}$ ① 3.0mol = 1L

$$0.150\ L \cdot \frac{3.0\ \text{mol}}{1L} = 0.45\ \text{mol}\ H_2SO_4$$

  - What volume do I need to get 0.42 mol?

$\text{mol} \xrightarrow{①} L$ ① 3.0mol = 1L

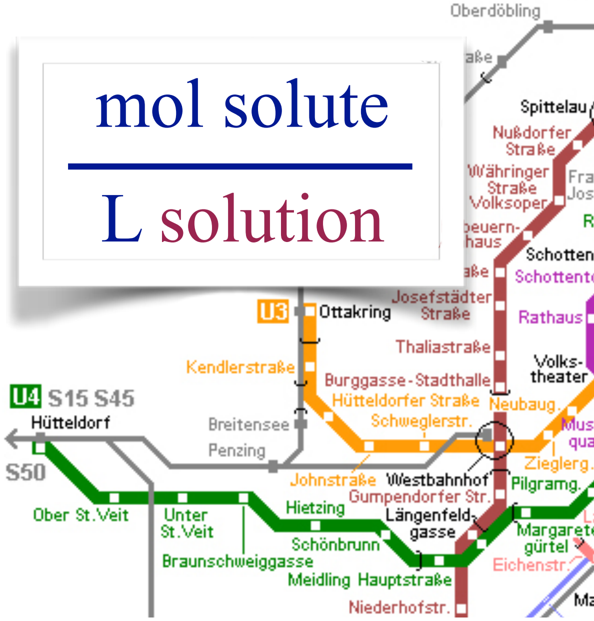
$$0.42\ \text{mol} \cdot \frac{1L}{3.0\ \text{mol}} = 0.14\ L\ \ (140\ mL)$$


Molarity

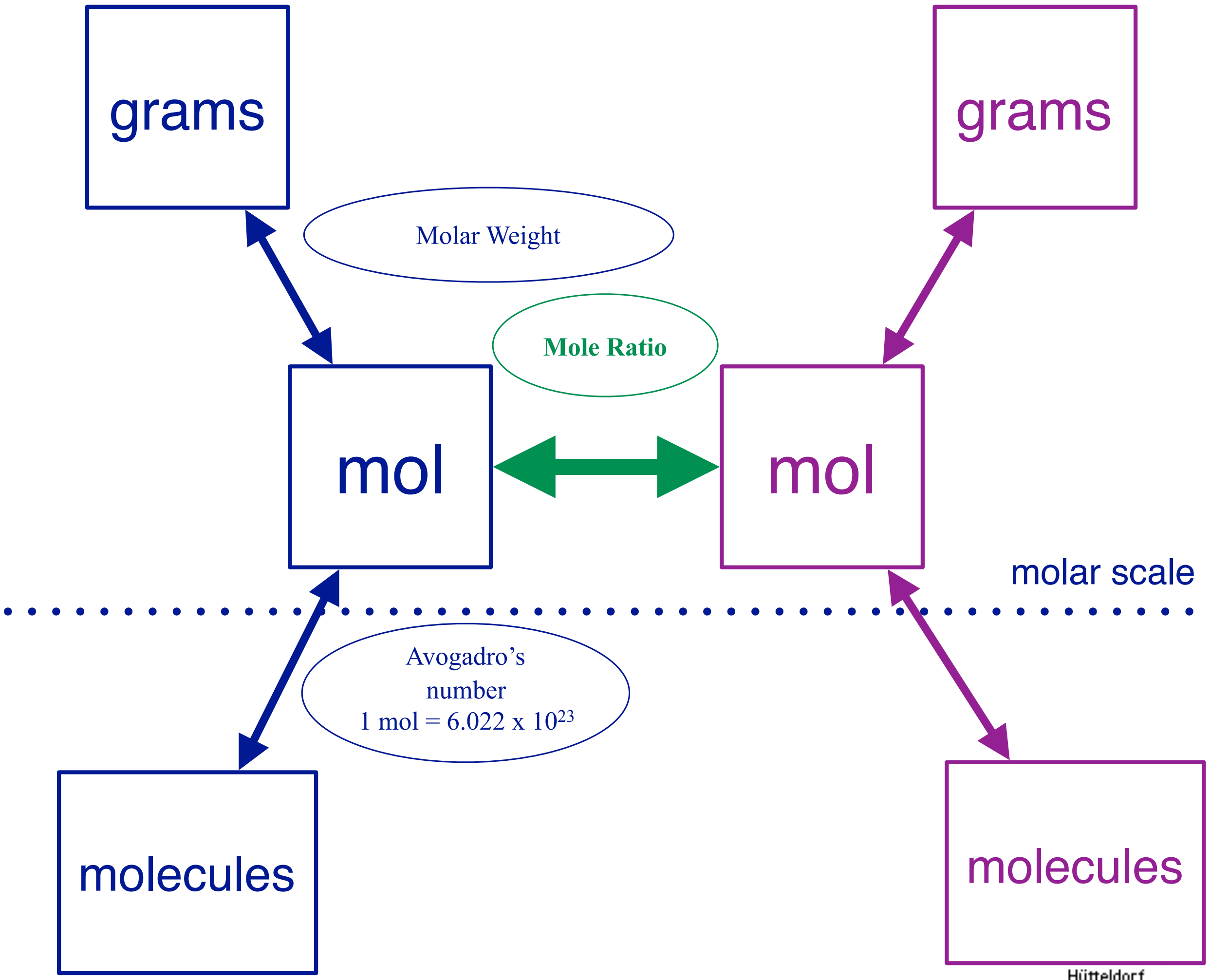
L (sol'n)

mol

$$\frac{\text{mol solute}}{\text{L solution}}$$



The Molar Subway



grams

grams

Molar Weight

Mole Ratio

mol

mol

molar scale

Avogadro's number
1 mol = 6.022 x 10^{23}

molecules

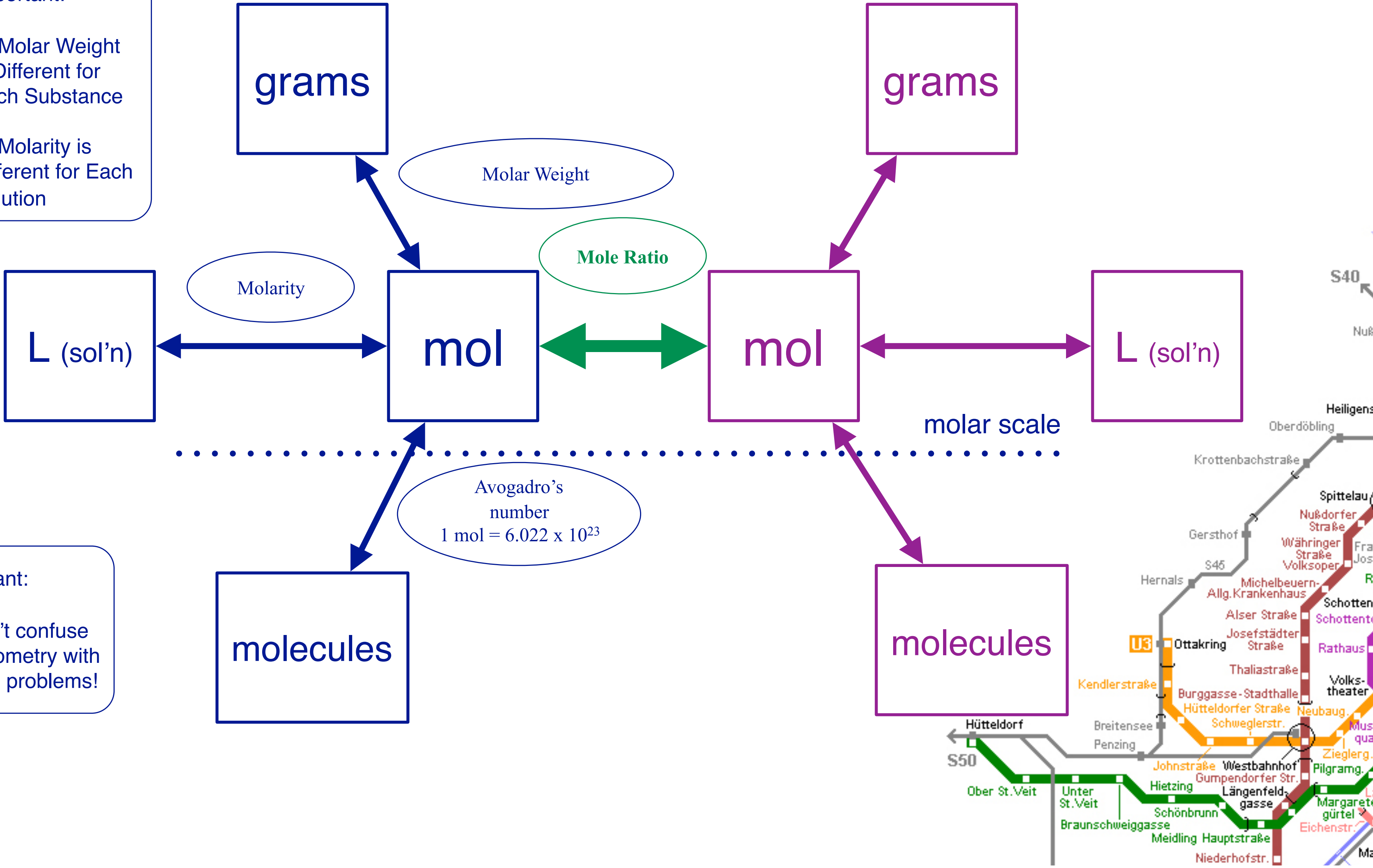
molecules

The Molar Subway

Important:

— Molar Weight is Different for Each Substance

— Molarity is Different for Each Solution



grams

grams

Molar Weight

Mole Ratio

Molarity

L (sol'n)

mol

mol

L (sol'n)

molar scale

Avogadro's number
1 mol = 6.022×10^{23}

molecules

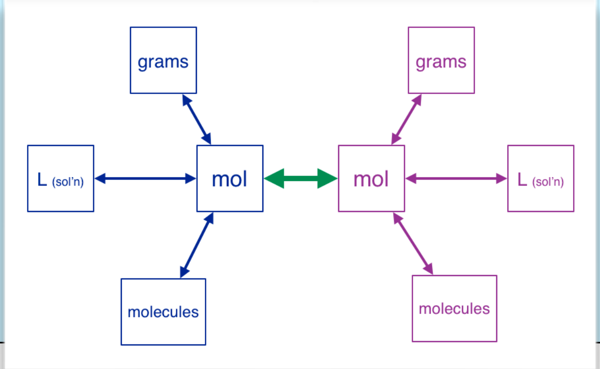
molecules

Important:

— Don't confuse stoichiometry with dilution problems!

Problem:

How many grams of $CaCl_2$ are needed to completely react with 25.0 mL of 0.100 M $AgNO_3$?



Solution

$$CaCl_{2\,(s)} + 2\,AgNO_{3\,(aq)} \rightarrow Ca(NO_3)_{2\,(aq)} + 2\,AgCl_{(s)}$$

$$\underbrace{mL \xrightarrow{①} L \xrightarrow{②} mol}_{AgNO_3} \xrightarrow{③} \underbrace{mol \xrightarrow{④} g}_{CaCl_2}$$

① 1000 mL = 1 L

② 0.100 mol = 1 L

③ 2 $AgNO_3$ = 1 $CaCl_2$

④

$$\begin{array}{lr} 1\,(Ca) & 40.078 \\ 2\,(Cl) & 70.906 \\ \hline & 110.984 \end{array}$$

110.984 g = 1 mol

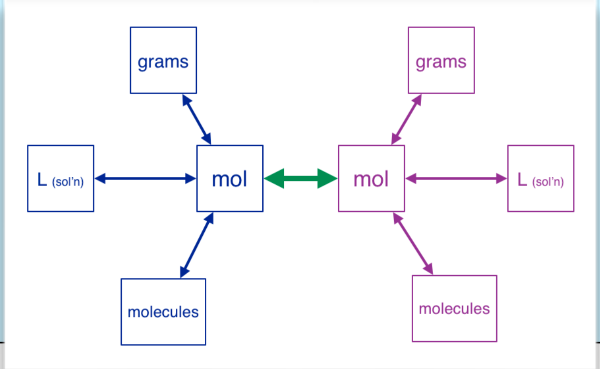
$$\overset{3\,s.f.}{25,0\,mL} \cdot \overset{\infty}{\frac{1\,L}{1000\,mL}} \cdot \overset{3\,s.f.}{\frac{0,100\,mol}{1\,L}} \cdot \overset{\infty}{\frac{1\,CaCl_2}{2\,AgNO_3}} \cdot \overset{6\,s.f.}{\frac{110,984\,g}{1\,mol}} =$$

0,13873 g

$$= \boxed{0,139\text{ g } CaCl_2}$$

Problem:

How many mL of 3.0 M HNO_3 are needed to completely consume 2.7 g Mg?



Solution

$$Mg_{(s)} + 2\,HNO_{3\,(aq)} \rightarrow Mg(NO_3)_{2\,(aq)} + H_{2(g)}$$

$$\underbrace{g\,Mg \xrightarrow{①} mol\,Mg}_{Mg} \xrightarrow{②} \underbrace{mol \xrightarrow{③} L \xrightarrow{④} mL}_{HNO_3}$$

① $24.3050\,g = 1\,mol$

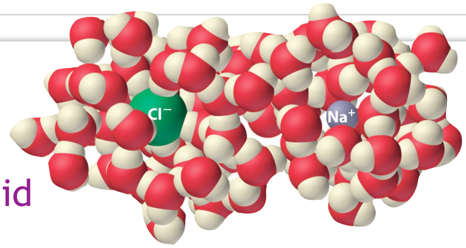
② $1\,Mg = 2\,HNO_3$

③ $3.0\,M\ HNO_3$

④ $1\,L = 1000\,mL$

$$2.7\,g \cdot \frac{1\,mol}{24.3050\,g} \cdot \frac{2\,HNO_3}{1\,Mg} \cdot \frac{1\,L}{3.0\,mol} \cdot \frac{1000\,mL}{1\,L} = \boxed{74\,mL}$$

Reactions in Solution



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  - Making solutions
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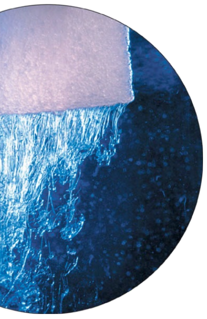

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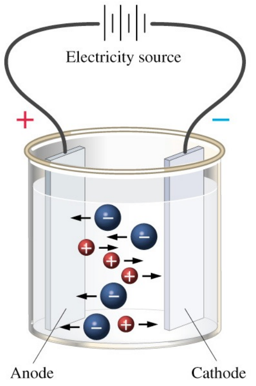
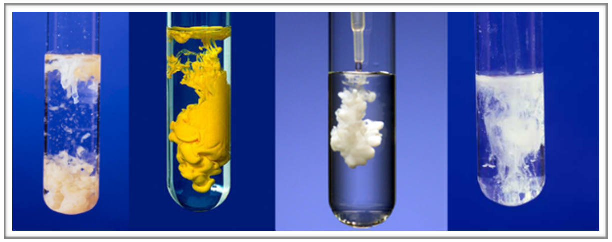
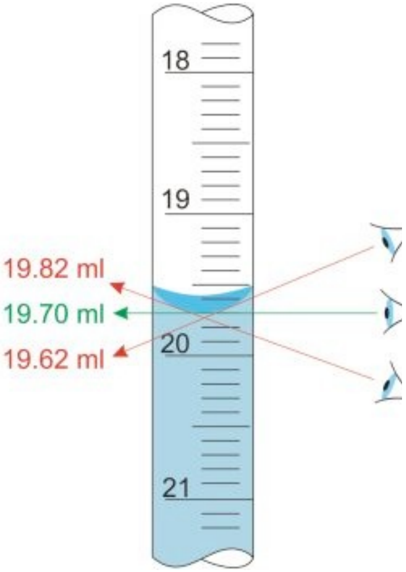
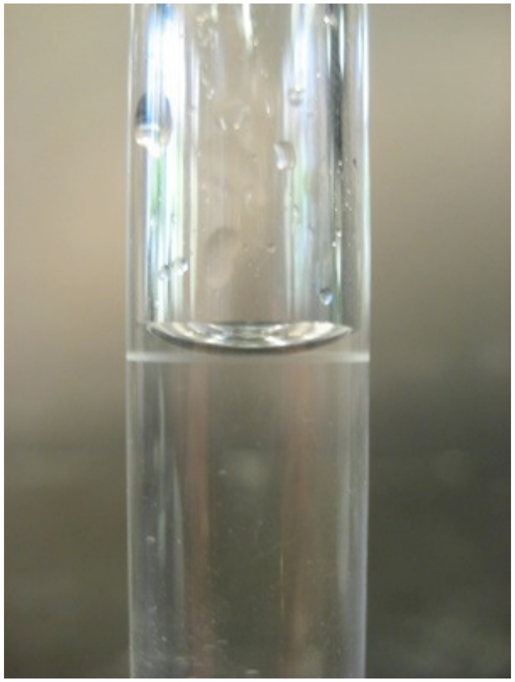


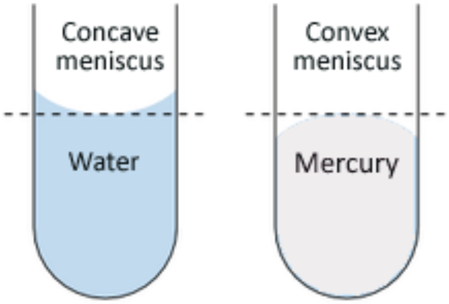


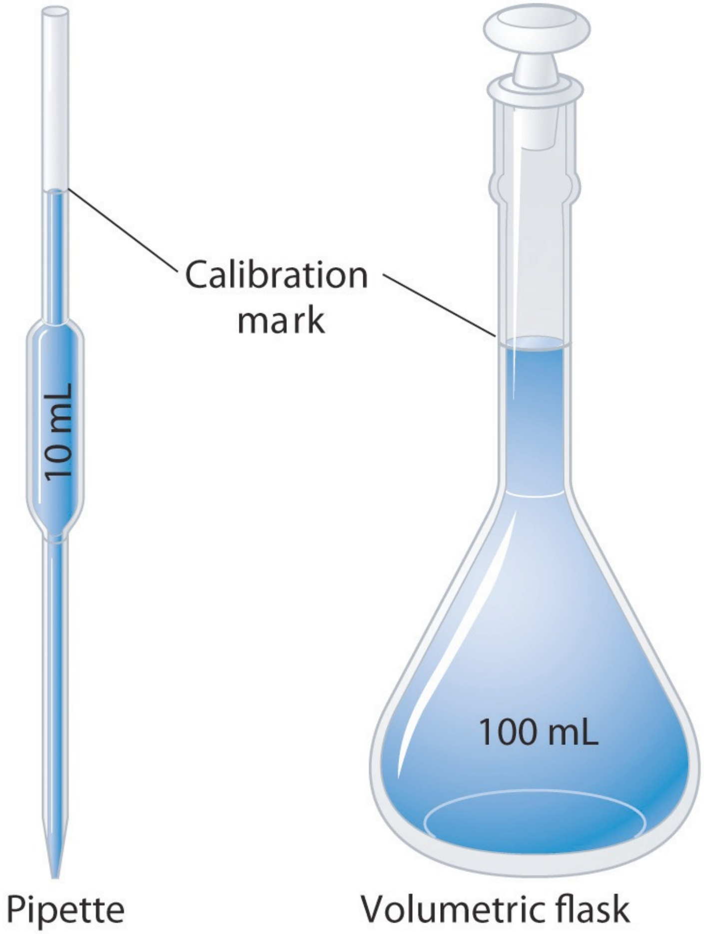
Volumetric Glassware

- Volumetric Pipets and Volumetric Flasks have a long thin neck and with a calibration mark.
- Small changes in volume make big changes in the level of the liquid allowing you to precisely measure the volume for which the device is calibrated.
- The volume is right when the meniscus of the liquid meets the calibration mark.









Dilution

- Stock solutions are solutions of known concentration.
- Most solutions are made by diluting a stock solution to a new molarity.
- Dilution just means adding more solvent.
- Dilution never changes the number of mols dissolved in the solution.
  - just the volume of the solution around them.
- Molarity and volume change with dilution, but because the mols don't change…
  - the ratio of volume to molarity is constant.

moles before = moles after

$$v_{before} M_{before} = v_{after} M_{after}$$

only when diluting!

molarity × volume = moles

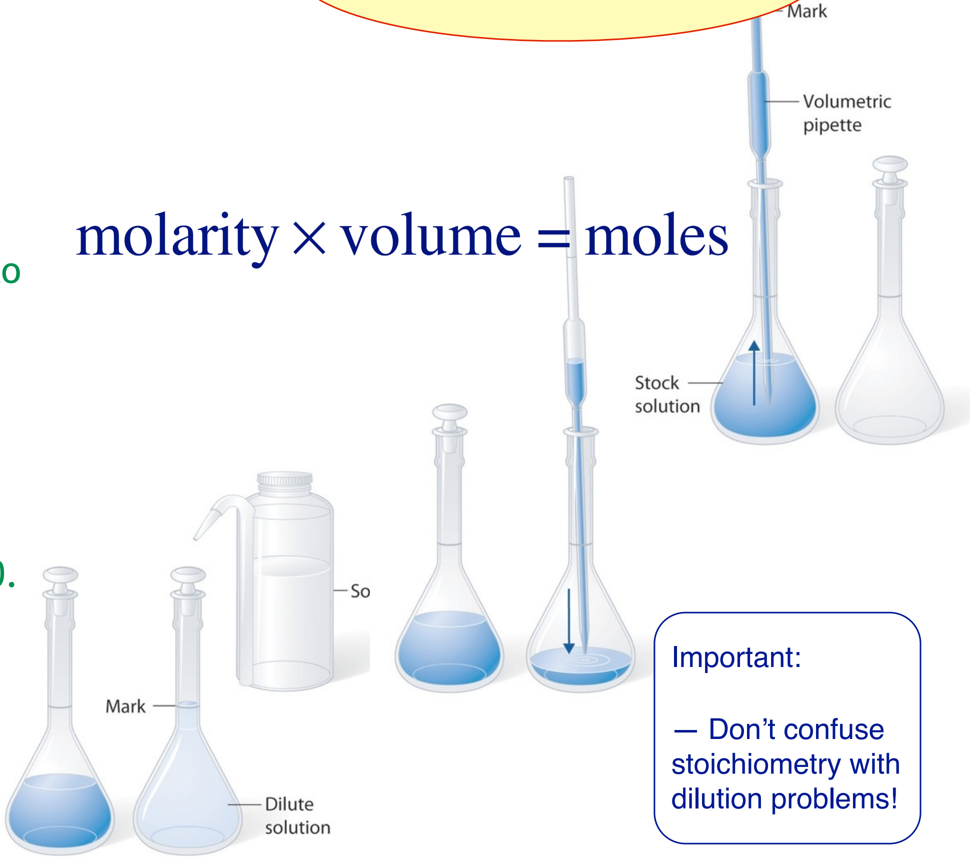
- What volume must you dilute 25 mL of 8.0 M $Ca(NO_3)_2$ to make a 2.0 M solution?

$$V_A = \frac{V_B M_B}{M_A} = \frac{8.0M \cdot 25mL}{2.0M} = 100mL$$

$$(1.0 \times 10^2 mL)$$

- How many mL of 6.0 M $HCl_{(aq)}$ do you need to make 200. mL of 2.0 M $HCl_{(aq)}$?

$$V_B = \frac{V_A M_A}{M_B} = \frac{200. mL \cdot 2.0M}{6.0M} = 67mL$$

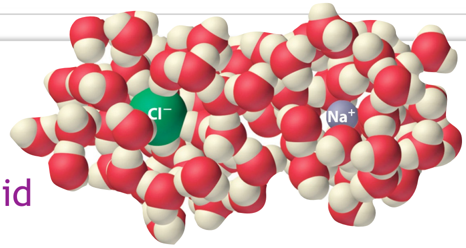


Important:

— Don't confuse stoichiometry with dilution problems!

Ch04

Reactions in Solution



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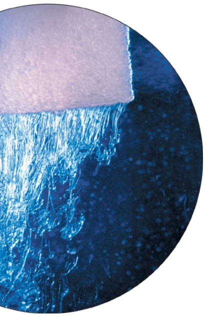

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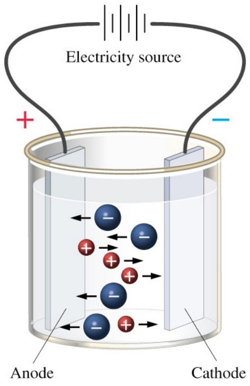
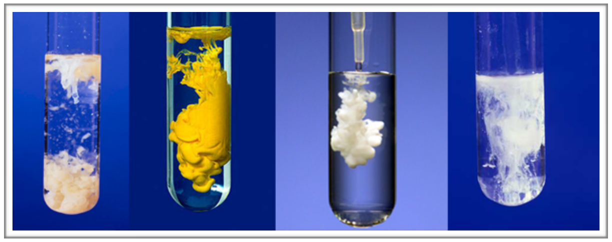
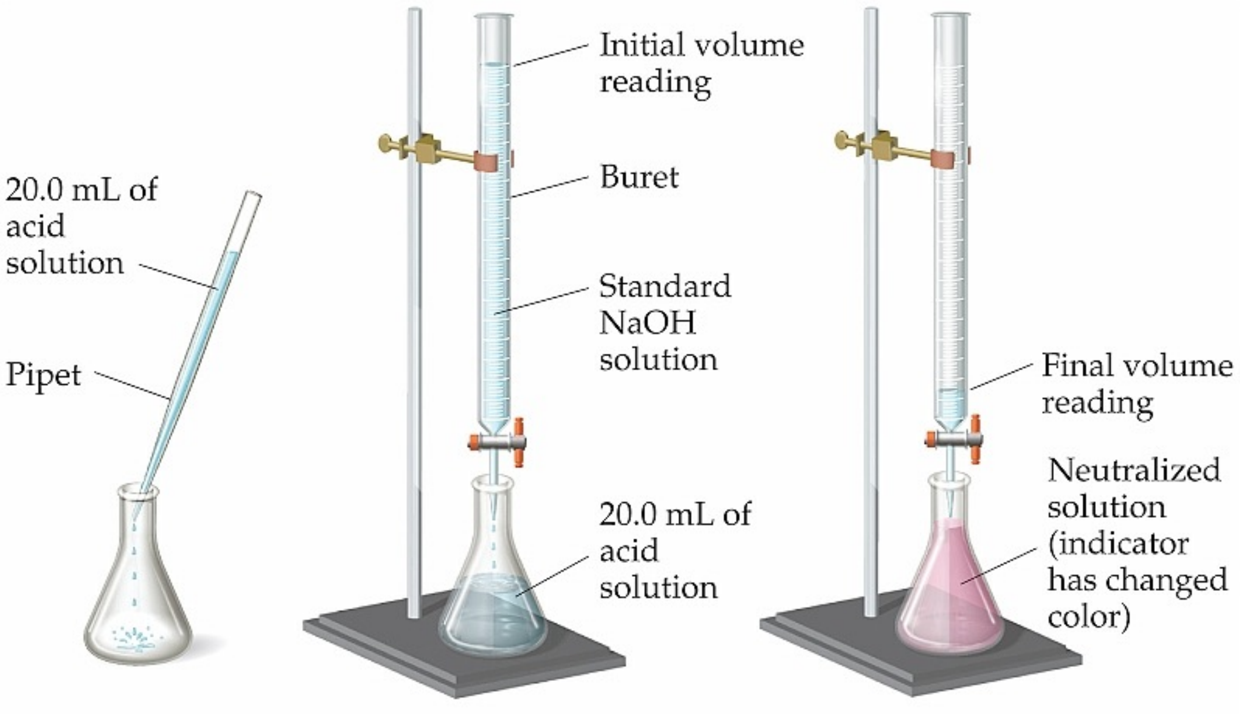




Titration

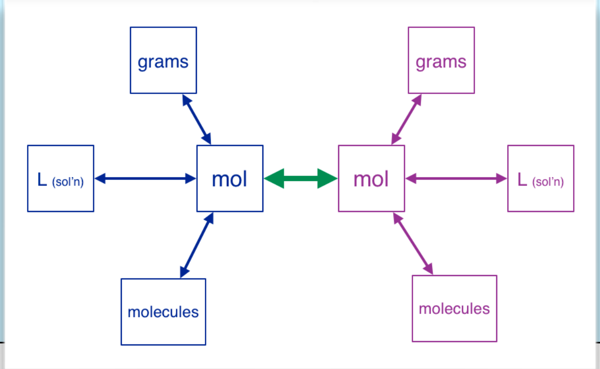
$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

- Titration is an analytic technique for determining the concentration in one solution by carefully adding a measured quantity of a known solution and observing a clear end point.
- The unknown is called an analyte.
- The standard solution is called a titrant or titrator.
- The end point is the point in the experiment where an indicator suggests the quantities of analyte and titrant are equal.
- The equivalence point is the point where they actually are.
  - With a good chemical indicator, the two should be close, but your equivalence point is almost always reached before you see the end point.
- An indicator is a chemical added to the mixture that changes color close to the equivalence point.
- Finding the end point with a chemical indicator requires some skill.



Problem:

A 20.0 mL sample of $NaOH_{(aq)}$ is titrated to an end point with 45.7 mL of 0.500 M $H_2SO_{4\,(aq)}$, what is concentration of the NaOH solution?



Solution

$$2\ NaOH_{(aq)} + H_2SO_{4\,(aq)} \rightarrow Na_2SO_{4\,(aq)} + 2\ H_2O_{(l)}$$

$$\underbrace{mL \xrightarrow{\textcircled{1}} L \xrightarrow{\textcircled{2}} mol}_{H_2SO_4} \xrightarrow{\textcircled{3}} mol\ NaOH \; ; \; \frac{mol}{vol} = molarity$$

① 1000 mL = 1 L

② 0.500 mol = 1 L

③ 2 NaOH = 1 H_2SO_4

Part A

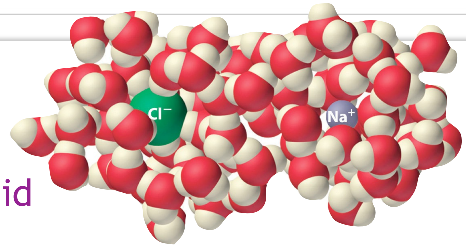
$$45.7\,mL \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0.500\,mol}{1\,L} \cdot \frac{2\,NaOH}{H_2SO_4} = 4.57\times10^{-2}\,mol$$

Part B

$$20.0\,mL = 0.0200\,L$$

$$\frac{4.57\times10^{-2}\,mol}{0.0200\,L} = \boxed{2.29\ M}$$

Reactions in Solution



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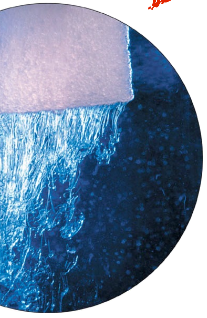

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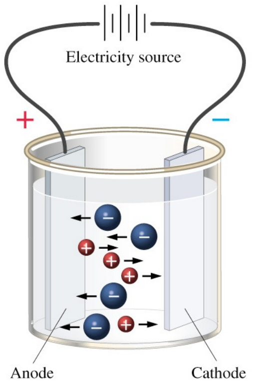
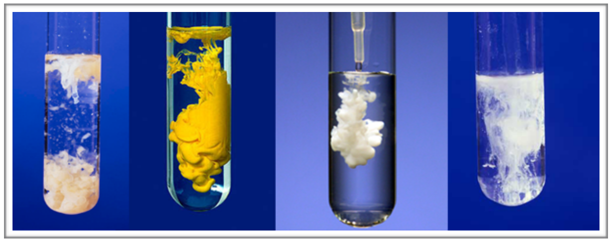




Labeled by Kinetics

Combination Reaction:

$$A + B \rightarrow C$$

eg. $C(s) + O_2\ (g) \rightarrow CO_2\ (g)$

Decomposition Reaction:

$$A \rightarrow B + C$$

eg. $Cu(OH)_2\ (s) \rightarrow CuO\ (s) + H_2O\ (l)$

Single Displacement Reaction:

$$A + BC \rightarrow B + AC$$

eg. $Zn\ (s) + SnCl_2\ (aq) \rightarrow Sn\ (s) + ZnCl_2\ (aq)$

Double Displacement Reaction:

$$AB + CD \rightarrow AD + CB$$

"trade partners"

eg. $2\ KI_{(aq)} + Pb(NO_3)_{2\ (aq)} \rightarrow PbI_{2\ (s)} \downarrow + 2\ KNO_{3\ (aq)}$

- Labels based on what "boxes" the atoms fall into and the general pattern of what moves where.
- A very generic label.
- Each label is mutually exclusive, reaction is one or another – never two.

Reactions in Solution

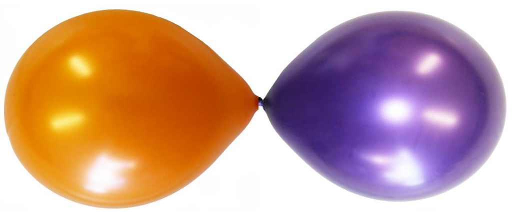
- If you dissolve more than one electrolyte in solution, you get a mixture of ions.
- The ions bump into each other and apart again, trading partners and just bouncing around the solution.
- That’s not exciting.

$$\mathrm{KI}_{(aq)} \rightleftarrows \mathrm{K}^{+}_{(aq)} + \mathrm{I}^{1-}_{(aq)}$$

$$\mathrm{NaNO_3}_{(aq)} \rightleftarrows \mathrm{Na}^{+}_{(aq)} + \mathrm{NO_3}^{1-}_{(aq)}$$

$$\mathrm{KI}_{(aq)} + \mathrm{NaNO_3}_{(aq)} \rightleftarrows \mathrm{K}^{+}_{(aq)} + \mathrm{I}^{1-}_{(aq)} + \mathrm{Na}^{+}_{(aq)} + \mathrm{NO_3}^{1-}_{(aq)} \rightleftarrows \mathrm{NaI}_{(aq)} + \mathrm{KNO_3}_{(aq)}$$

- But those ions sometimes pair up to form things that are non-electrolytes.
- When they do an irreversible reaction occurs.



$$\mathrm{Pb(NO_3)_2} \rightleftarrows \mathrm{Pb}^{2+}_{(aq)} + \mathrm{NO_3}^{1-}_{(aq)}$$

$$\mathrm{KI}_{(aq)} + \mathrm{Pb(NO_3)_2}_{(aq)} \rightleftarrows \mathrm{K}^{+}_{(aq)} + \mathrm{I}^{1-}_{(aq)} + \mathrm{Pb}^{2+}_{(aq)} + \mathrm{NO_3}^{1-}_{(aq)}$$

$$\mathrm{KI}_{(aq)} + \mathrm{Pb(NO_3)_2}_{(aq)} \rightleftarrows \mathrm{K}^{+}_{(aq)} + \mathrm{I}^{1-}_{(aq)} + \mathrm{Pb}^{2+}_{(aq)} + \mathrm{NO_3}^{1-}_{(aq)} \rightarrow \mathrm{PbI_2}_{(s)}\downarrow + \mathrm{KNO_3}_{(aq)}$$

- This removes dissociated ions from equilibrium. Which pulls more substrate ions into the dissociated state.
- And drives the reaction to complete formation of the non-electrolyte product.
- Possible non-electrolytes that can drive the reaction include:
  - insoluble solids (precipitates)
  - volatile gases (NH_3, CO_2, H_2S)
  - water (H_2O)

Double Displacement Reactions

- We call this class of reaction, where two electrolytes react in solution, a double displacement reaction.

$$AB + CD \rightarrow AD + CB$$

- It's only a reaction if a product is a non-electrolyte.

$KI_{(s)} + NaNO_{3\,(s)} \rightleftarrows KNO_{3\,(aq)} + NaI_{(aq)}$ ← no reaction (write "N/R")

$KI_{(s)} + Pb(NO_3)_{2\,(s)} \rightarrow PbI_{2\,(s)}\downarrow + KNO_{3\,(aq)}$ ← a reaction because PbI_2 is not soluble in water

- When there is a reaction you can show it three different ways:

Molecular Equation $KI_{(aq)} + Pb(NO_3)_{2\,(aq)} \rightarrow PbI_{2\,(s)}\downarrow + KNO_{3\,(aq)}$

Complete Ionic Equation $K^{+}_{(aq)} + I_{(aq)} + Pb^{2+}_{(aq)} + NO_3^{1-}{}_{(aq)} \rightarrow PbI_{2\,(s)}\downarrow + K^{+}_{(aq)} + NO_3^{1-}{}_{(aq)}$

Net Ionic Equation $I^{1-}_{(aq)} + Pb^{2+}_{(aq)} \rightarrow PbI_{2\,(s)}\downarrow$

Remove the spectator Ions

- When there is no reaction you show it this way:

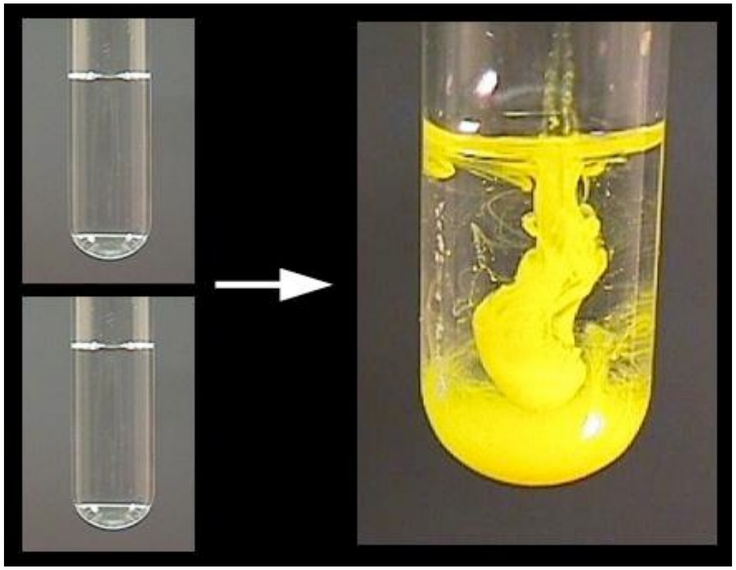
$$KI_{(s)} + Pb(NO_3)_{2\,(s)} \rightarrow N/R$$

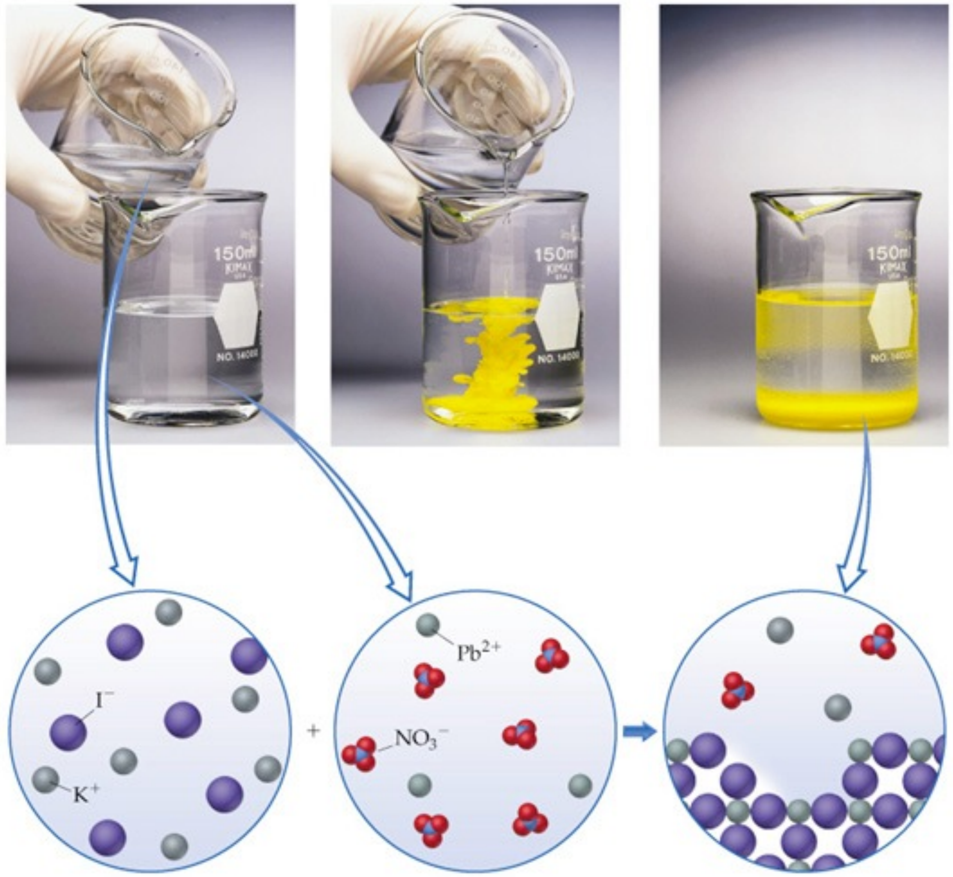
- How do you know if there's a reaction? (non-electrolytes)

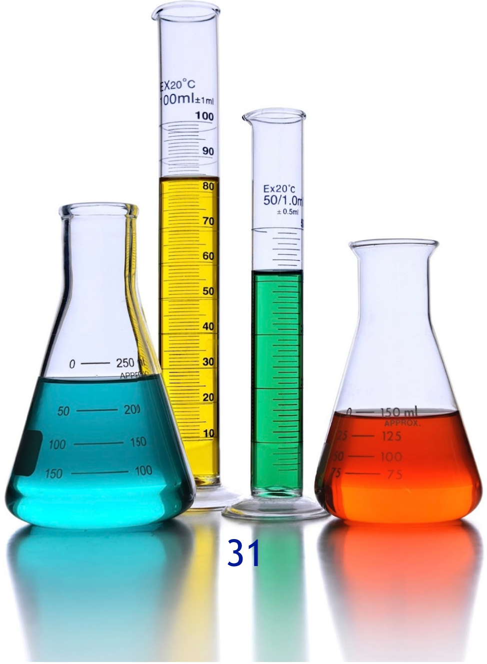
If one of the following products form, you know a reaction occurred:
(a) An insoluble solid (precipitate) (b) a Gas (c) Water

Solubility & Precipitation

- Different materials have different solubility properties.
- If an insoluble material forms in solution, it precipitates or falls out of solution.

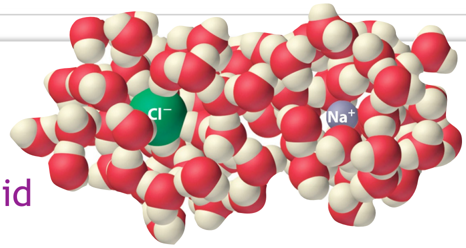






Ch04

Reactions in Solution



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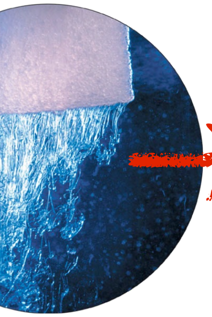

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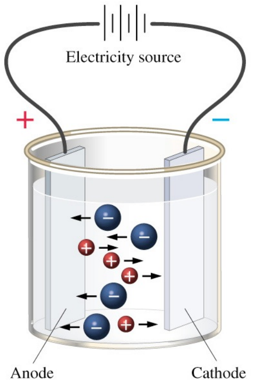
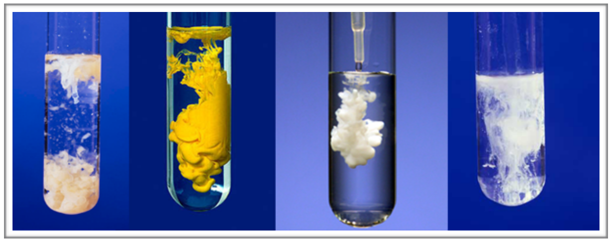




Finding the Net Equation

Aqueous solutions of magnesium chloride and lead (II) acetate, are mixed, a bright yellow solid appears in the solution. What happened?

$\text{Magnesium Chloride}_{(aq)} + \text{Lead(II) Acetate}_{(aq)} \rightarrow ?$

$$AB + CD \rightarrow AD + CB$$

$$MgCl_{2(aq)} + Pb(OAc)_{2(aq)} \rightleftarrows Mg(OAc)_{2(aq)} + PbCl_{2(aq)}$$

$$MgCl_{2(aq)} + Pb(OAc)_{2(aq)} \rightarrow Mg(OAc)_{2(aq)} + PbCl_{2(s)}\downarrow$$

Molecular Equation

$$\cancel{Mg^{2+}}_{(aq)} + Cl^{1-}_{(aq)} + Pb^{2+}_{(aq)} + \cancel{OAc^{1-}}_{(aq)} \rightarrow \cancel{Mg^{2+}}_{(aq)} + \cancel{OAc^{1-}}_{(aq)} + PbCl_{2(s)}\downarrow$$

Complete Ionic Equation

Spectator ions appear on both sides of the arrow.

$$Cl^{1-}_{(aq)} + Pb^{2+}_{(aq)} \rightarrow PbCl_{2(s)}\downarrow$$

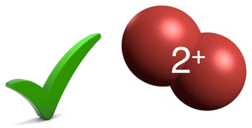
Net Ionic Equation

$$2\ Cl^{1-}_{(aq)} + Pb^{2+}_{(aq)} \rightarrow PbCl_{2(s)}\downarrow$$

Balanced Net Ionic Equation

What forms a precipitate?

Check each step, **in order**.	Solubility Rules you are responsible for.	Soluble no precipitate	Insoluble forms precipitate
Step 1 ANIONS	Acetates (OAc^{1-} or $CH3COO^{1-}$) Nitrates (NO_3^{1-})	Always	Never
Step 2 CA+IONS	Ammonium (NH_4^{1+}) Alkali metal (Na^{1+}, Li^{1+}, K^{1+}...) Acids (the ones we learned)	Always	Never
Step 3 ANIONS	Carbonates (CO_3^{2-}) Phosphates (PO_4^{3-})	Never	Always
Step 4 has exceptions ANIONS	Halogens (Cl^{1-}, Br^{1-}, I^{1-}, F^{1-})	Usually	Except: Ag+, Hg_2^{2+} or Pb^{2+}
	Sulfates (SO_4^{2-})	Usually	Hg_2^{2+} or Pb^{2+} Sr^{2+}, Ba^{2+}
	Sulfides (S^{2-}) Hydroxy Salts (OH^{1-})	Except: Sr^{2+}, Ba^{2+}, Ca^{2+}	Usually



Hg_2^{2+}
mercury (I) ion

Hg^{2+}
mercury (II) ion

If you remember 1-3 you'll be good 85% of the time
If you remember 1-3 and 4 you'll be good 95%
Remembering the exceptions isn't that hard
— there's only six ions that cause exceptions
and lead, mercury, and silver are the most commonly encountered ones.

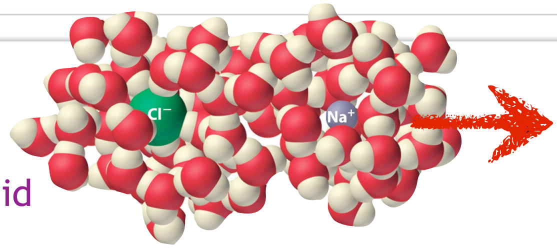
Is it soluble?

- ✓ KNO_3
- ✓ $(NH_4)_3P$
- ✓ $MnCl_2$
- ✗ $PbCl_2$
- ✓ $HClO_3$
- ✓ $CuCH_3CO_2$
- ✓ $Ca(OAc)_2$
- ✗ $CaCO_3$

Always:	Acetates Nitrates
	Ammonium Alkali metal Acids
	Carbonates Phosphates

Usually:	
	Halogens
	Sulfates
	Sulfides Hydroxy Salts

Reactions in Solution



- Solubility
  - Why Solids are Solid
  - Making solutions
  - Electrolyte solutions
    - Electrolyte strength
- Concentration
  - Measures of concentration.
    - Molarity
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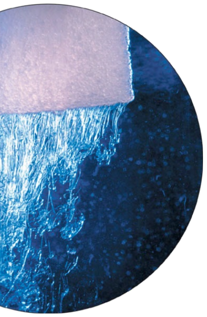
  - Double Displacement: $AB + CD \rightleftarrows AD + CB$
  - Equilibrium
  - Molecular, Complete & Net Ionic Eons
  - Precipitation/Solubility Rules



- Other Reaction Types
  - Acid-Base Reactions
    - Neutralization; $H_2O_{(l)}$
  - Gas Evolution Reactions
    - $H_2S_{(g)}$, $CO_{2\,(g)}$, $NH_{3\,(g)}$, NH_4OH
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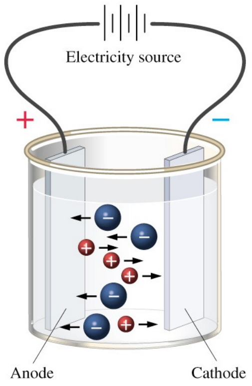
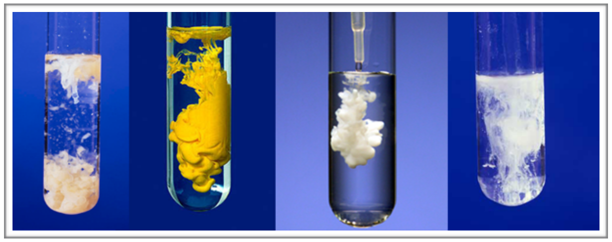
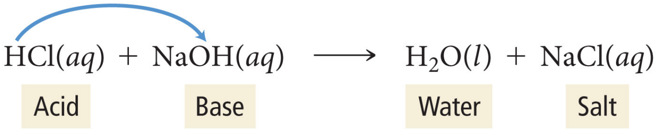




Acid-Base Reactions

- Acids and bases have multiple definitions.
- For now:
  - An **acid** is any substance which dissociates to release H+ (aq).
  - A **base** is any substance which reacts with H+ (aq).

(You will explore other definitions in Chem 220.)



$$HCl(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCl(aq)$$

- **Acid-base reactions** are reactions between an acid and a base.
- **Neutralization reactions** are irreversible reactions between an acid and a base.
- Neutralization reactions produce water.
- The irreversible production of water can drive equilibrium forward, the same as precipitate formation.

$$HCl_{(aq)} + NaOH_{(aq)} \rightleftarrows H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)}$$

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$$

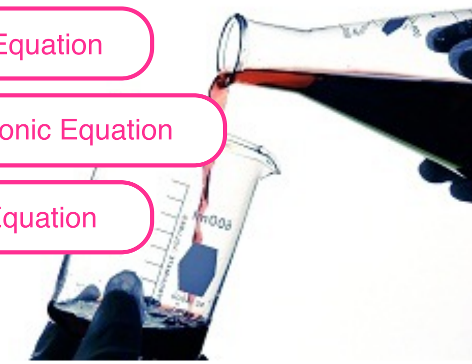
Molecular Equation

$$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)} + Cl^-_{(aq)} + Na^+_{(aq)}$$

Complete Ionic Equation

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

Net Ionic Equation



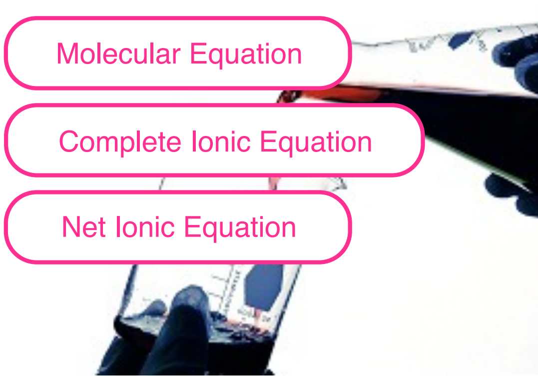
Gas Formation Reactions

- Volatile gases like $CO_{2\ (g)}$, $H_2S_{\ (g)}$ and $NH_{3\ (g)}$ that form immediately bubble off.
- The gases escape, their formation is irreversible.
- Sometimes the double displacement reaction forms an unstable compound that decomposes into the gases. Example:

$$H_2CO_{3\ (aq)} \rightarrow H_2O_{\ (l)} + CO_{2\ (g)} \qquad NH_4OH_{\ (aq)} \rightarrow H_2O_{\ (l)} + NH_{3\ (g)}$$

- If a double displacement reaction forms $CO_{2\ (g)}$, $H_2S_{\ (g)}$, or $NH_{3\ (g)}$ gases this irreversible reaction will drive equilibrium forward.
- If a double displacement reaction forms $H_2CO_{3\ (aq)}$ or $NH_4Cl_{\ (aq)}$ these decompose to gases and drive equilibrium forward.
- Examples:

$$HCl_{\ (aq)} + Na_2S_{\ (aq)} \rightleftarrows H^+_{\ (aq)} + Cl^-_{\ (aq)} + Na^+_{\ (aq)} + S^{2-}_{\ (aq)}$$



Molecular Equation

$$HCl_{\ (aq)} + Na_2S_{\ (aq)} \rightarrow H_2S_{\ (g)}\uparrow + NaCl_{\ (aq)}$$

Complete Ionic Equation

$$H^+_{\ (aq)} + Cl^-_{\ (aq)} + Na^+_{\ (aq)} + S^{2-}_{\ (aq)} \rightarrow H_2S_{\ (g)}\uparrow + Cl^-_{\ (aq)} + Na^+_{\ (aq)}$$

Net Ionic Equation

$$H^+_{\ (aq)} + S^{2-}_{\ (aq)} \rightarrow H_2S_{\ (g)}\uparrow$$

Gas Formation Reactions

- Volatile gases like $CO_{2\,(g)}$, $H_2S_{\,(g)}$ and $NH_{3\,(g)}$ that form immediately bubble off.
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$$H_2SO_{4(aq)} + NaHCO_{3(aq)} \rightleftarrows H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + Na^+_{(aq)} + HCO_3^-{}_{(aq)}$$

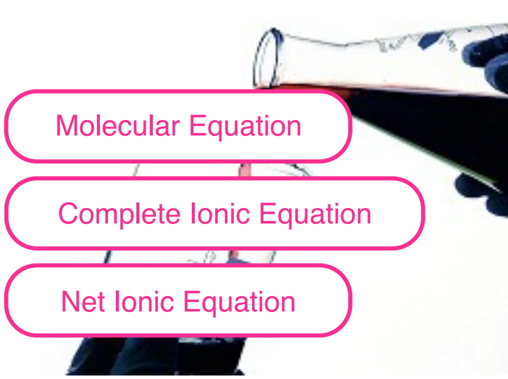
$$H_2SO_{4(aq)} + NaHCO_{3(aq)} \rightarrow SO_4^{2-}{}_{(aq)} + Na^+_{(aq)} + H_2CO_{3(aq)}$$

$$H_2SO_{4(aq)} + NaHCO_{3(aq)} \rightarrow Na_2CO_{3(aq)} + H_2CO_{3(aq)}$$

$$H_2SO_{4(aq)} + NaHCO_{3(aq)} \rightarrow Na_2SO_{4\,(aq)} + H_2O_{(l)} + CO_{2(g)}\uparrow$$

$$H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + Na^+_{(aq)} + HCO_3^-{}_{(aq)} \rightarrow SO_4^{2-}{}_{(aq)} + Na^+_{(aq)} + H_2O_{(l)} + CO_{2(g)}\uparrow$$

$$H^+_{(aq)} + HCO_3^-{}_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)}\uparrow$$



Molecular Equation

Complete Ionic Equation

Net Ionic Equation

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- If a double displacement reaction forms $H_2CO_3\ (aq)$ or $NH_4Cl\ (aq)$ these decompose to gases and drive equilibrium forward.

$$NaOH_{(aq)} + NH_4Cl_{(aq)} \rightleftarrows Na^+{}_{(aq)} + OH^-{}_{(aq)} + NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$$

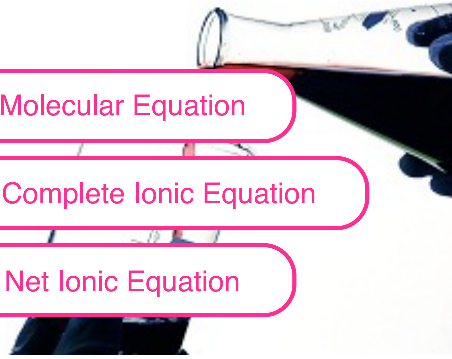
$$NaOH_{(aq)} + NH_4Cl_{(aq)} \rightarrow Na^+{}_{(aq)} + Cl^-{}_{(aq)} + NH_4OH_{(aq)}$$

$$NaOH_{(aq)} + NH_4Cl_{(aq)} \rightarrow NaCl + NH_4OH_{(aq)}$$

$$NaOH_{(aq)} + NH_4Cl_{(aq)} \rightarrow NaCl\ _{(aq)} + H_2O_{(l)} + NH_{3(g)} \uparrow$$

$$Na^+{}_{(aq)} + OH^-{}_{(aq)} + NH_4^+{}_{(aq)} + Cl^-{}_{(aq)} \rightarrow Na^+{}_{(aq)} + Cl^-{}_{(aq)} + H_2O_{(l)} + NH_{3(g)} \uparrow$$

$$OH^-{}_{(aq)} + NH_4^+{}_{(aq)} \rightarrow H_2O_{(l)} + NH_{3(g)} \uparrow$$



Molecular Equation

Complete Ionic Equation

Net Ionic Equation

Double Displacement Reactions

- If I mix two electrolytes (AB & CD), I can look at the two possible double displacement products (AD & CB) to predict if a reaction will occur.
- If either of the two products forms irreversibly, a reaction will occur.
  - Irreversible reactions include precipitation formation, neutralization and gas formation.
- For each pair of possible products below, did a reaction occur?

$AB + CD \rightarrow AD + CB$

$(NH_4)_2SO_4 + H_2CO_3$

$Fe(OAc)_3 + Mn(NO_3)_2$

$H_2SO_4 + Hg_2(NO_3)_2$

$CO_2 + MnCl_2$

$C_2H_4O + AgCl$

$HBrO_3 + H_2S$

$H_2O + KBr$

$NH_4OH + MgCO_3$

Predict the products…

Always:	Acetates Nitrates
	Ammonium Alkali metal Acids
	Carbonates Phosphates

Usually:	
	Halogens
	Sulfates
	Sulfides Hydroxy Salts

$NaCl + Mn(NO_3)_3 \rightarrow N/R$

$NaCl + AgNO_3 \rightarrow AgCl_{(s)} \downarrow + NaNO_{3\,(aq)}$

$K_2CO_3 + Ca(NO_3)_2 \rightarrow KNO_{3\,(aq)} + CaCO_{3\,(s)} \downarrow$

$K_2CO_3 + NaCl \rightarrow N/R$

$K_2CO_3 + HBr \rightarrow KBr_{(aq)} + H_2O_{(l)} + CO_{2(g)} \uparrow$

$FeCl_3 + Hg_2(OAc)_2 \rightarrow Hg_2Cl_{2\,(s)} \downarrow + Fe(OAc)_{3\,(aq)}$

$TiCl_4 + NH_4NO_3 \rightarrow N/R$

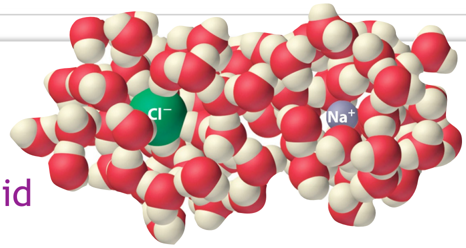
$NH_4OH + H_2SO_4 \rightarrow (NH_4)_2SO_{4\,(aq)} + H_2O_{(l)}$

(a) Precipitate Product (b) Gas Product (c) Water as a Product

Ch04

Reactions in Solution

- Solubility
  - Why Solids are Solid
  - Making solutions
  - Electrolyte solutions
    - Electrolyte strength



- Concentration
  - Measures of concentration.
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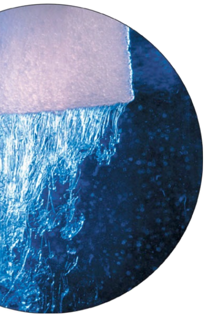

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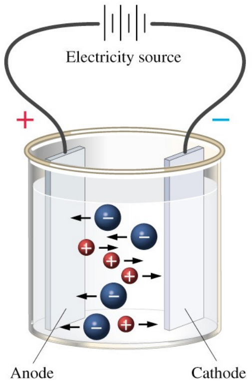
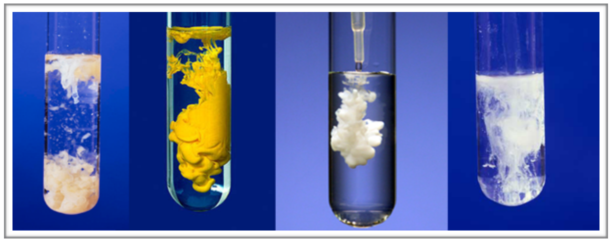
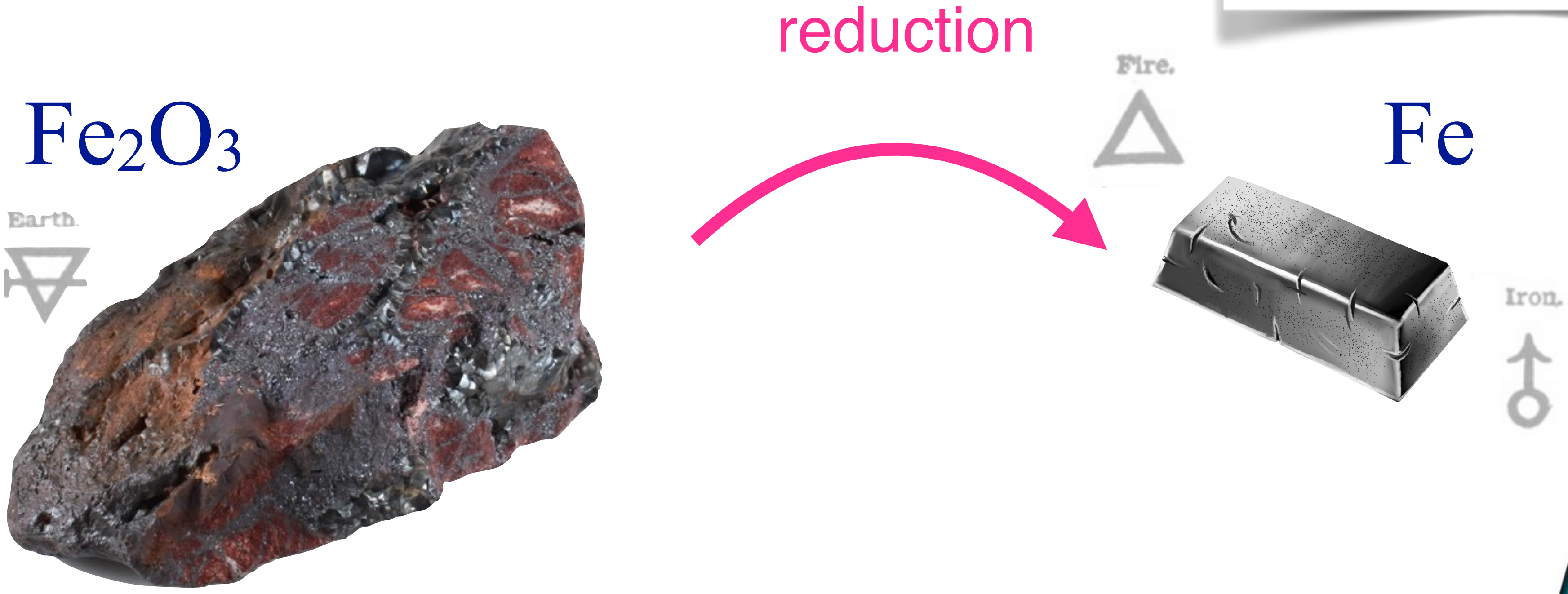




Reduction

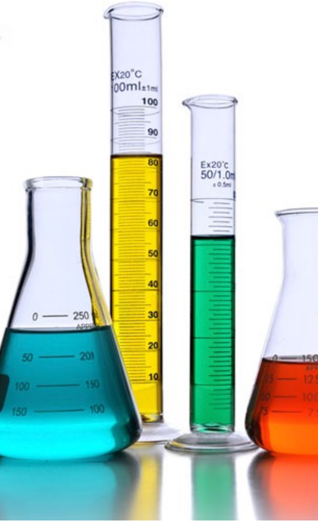
- Oxidation and Reduction are complimentary chemical processes.
- The word reduction comes from the alchemical process of smelting ore.
  - Brittle heavy metal ores were heated with coke (carbon) and the result was pure metals.
  - Iron, copper, tin, lead, mercury and other metals were prepared this way.
  - The metal you got out, always weighed less than the ore that went in, so we called the process reduction.



Fe_2O_3

reduction

Fe



Oxidation

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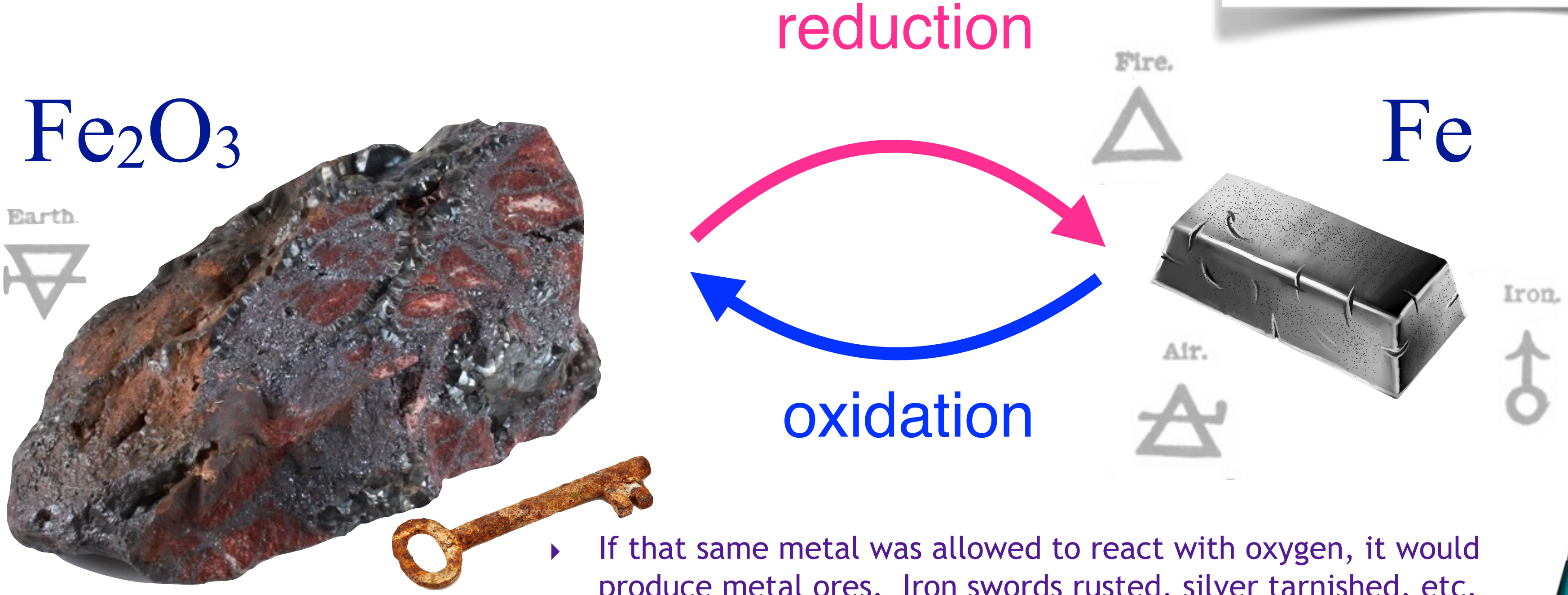

reduction

Fe_2O_3

Fe

oxidation

- If that same metal was allowed to react with oxygen, it would produce metal ores. Iron swords rusted, silver tarnished, etc.
  - The reverse process, reacting metal with oxygen, was called oxidation.

Reduction & Oxidation

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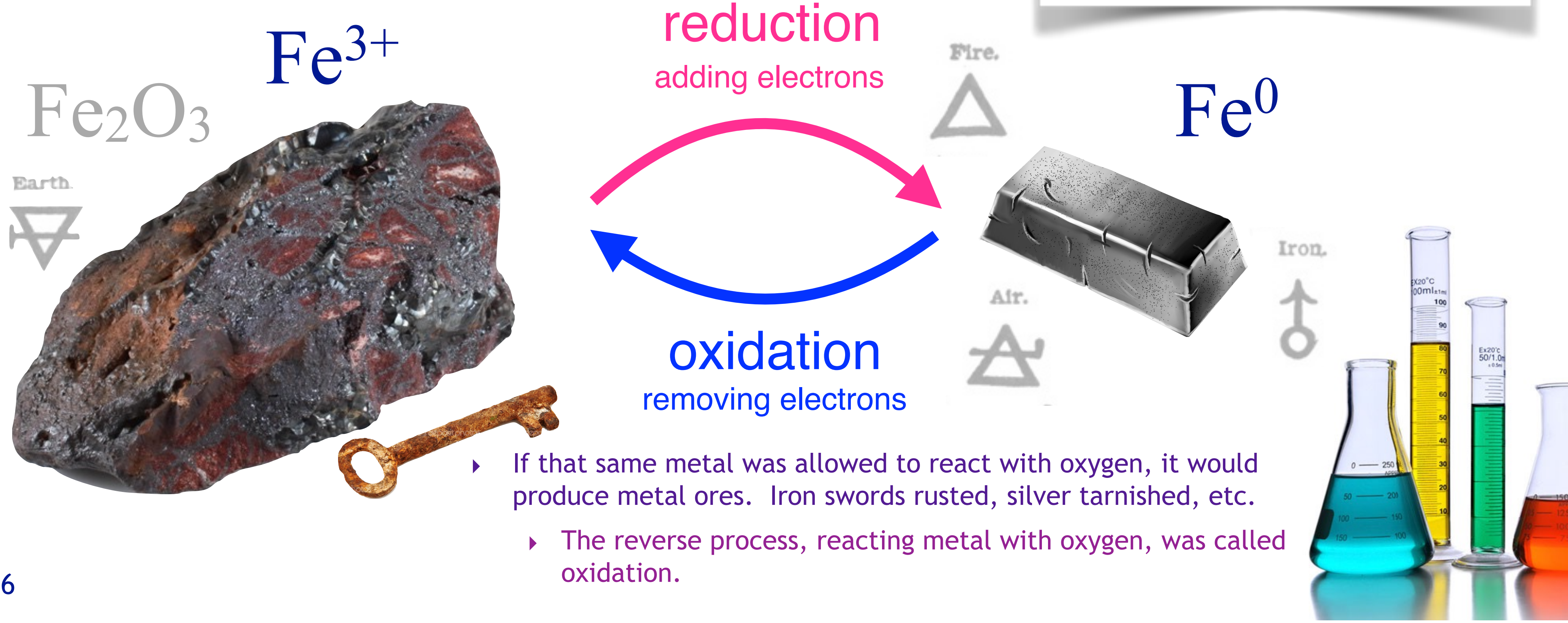


Fe_2O_3

Fe^{3+}

reduction

adding electrons

oxidation

removing electrons

Fe^0

- If that same metal was allowed to react with oxygen, it would produce metal ores. Iron swords rusted, silver tarnished, etc.
  - The reverse process, reacting metal with oxygen, was called oxidation.

Oxidation State

- Oxidation and Reduction are complimentary chemical processes.
  - Reduction occurs by adding electrons to an atom.
  - Oxidation occurs by removing electrons from an atom.

$Fe^{3+} \rightarrow Fe$

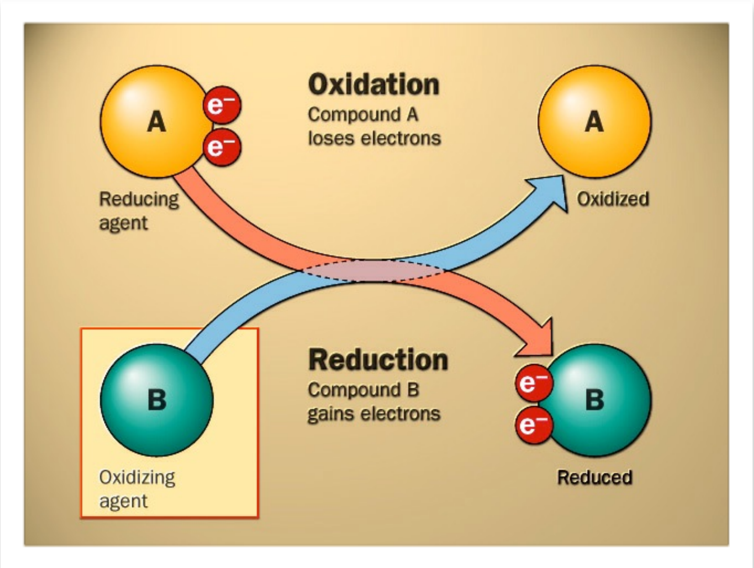
reduction

$Cl_2 \rightarrow Cl^{1-}$

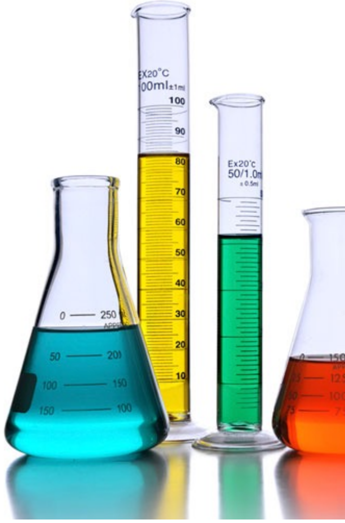
reduction

$Al \rightarrow Al^{3+}$

oxidation

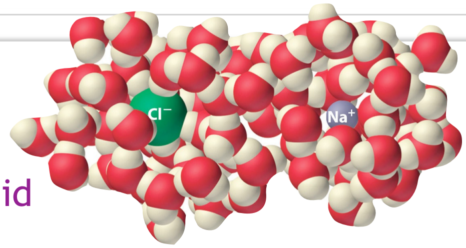


$$H_2 \xrightarrow{[ox]} H^{1+} \xrightarrow{[red]} H^{1-}$$



Ch04

Reactions in Solution



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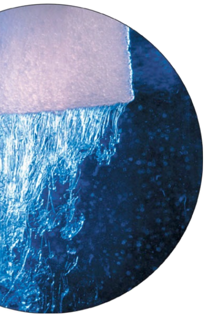

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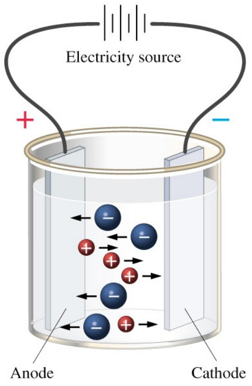
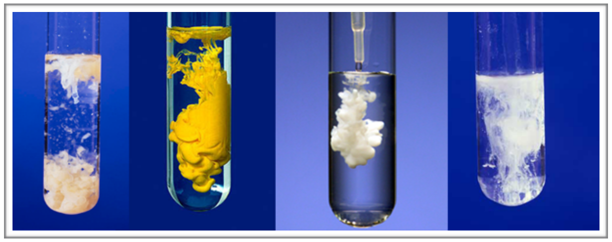


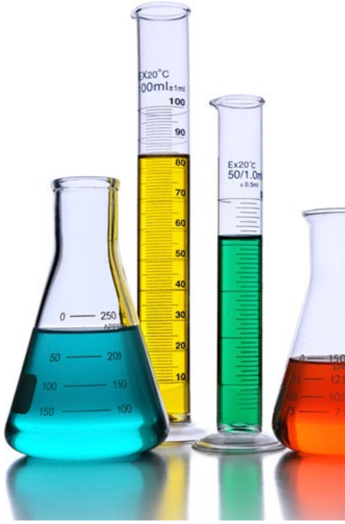


Oxidation Numbers

- Oxidation numbers are assigned by imagining we put enough energy into that molecule to break all it's atoms down into ions.
    - What ions ***would be*** formed if we did reveals the oxidation number of the atom in the molecule.
  - Elements in their natural state (Fe, Cl_2, S_8) have an oxidation number zero.
    - Break S_8 into eight sulfur atoms, the atoms will be equal and no one will take an extra electron.
  - Ionic bonds break into ions as you would expect. Monoatomic ions have a number equal to their charge.
  - Hydrogen is a wild card:
    - If hydrogen is attached to a metal, it get's -1, otherwise it get's +1
  - Then go through the remaining atoms in order of being less anion-like (proximity to fluorine), let each atom take from the molecule whatever electrons necessary to form it's preferred ion.
  - The last element get's whatever is left.
- Molecules have a charge of zero, so that last element **will not get what it wants**, it's like musical chairs – the last guy get's whatever is left.

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

$$SF_4 + F_2 \rightarrow SF_6$$



Chlorine's oxidation number?

0	$\underline{Cl}_2$
-1	$Na\underline{Cl}$
	$\underline{Cl}O^{1-}$
	$H\underline{Cl}O_3$
	$\underline{Cl}OF_5$
	$\underline{Cl}_2O_9$

When an element is in its standard state the atoms in it have an oxidation number of zero.

Break electrolytes into their component ions, monatomic ions then have an oxidation number equal to that ions charge.

Na^{1+} Cl^{1-}

Chlorine's oxidation number?

0	$\underline{Cl}_2$
-1	$Na\underline{Cl}$
+1	$\underline{Cl}O^{1-}$
	$H\underline{Cl}O_3$
	$\underline{Cl}OF_5$
	$\underline{Cl}_2O_9$

With non-electrolytes, imagine what would happen if you put so much energy into the molecule it broke into ions.

Fluorine and atoms closer to it get first choice. Oxygen follows fluorine and chlorine is stuck with whatever is left in this one.

$$O^{2-} \qquad Cl^{X}$$

$$-2 + X = -1$$

$$X = ?$$

Chlorine’s oxidation number?

0	$\underline{Cl}_2$
-1	$Na\underline{Cl}$
+1	$\underline{Cl}O^{1-}$
+5	$H\underline{Cl}O_3$
	$\underline{Cl}OF_5$
	$\underline{Cl}_2O_9$

Hydrogen is your wild card:
on metals it acts like a non-metal (H^{1-})
on non-metals it acts like a metal (H^{1+})

Fluorine and atoms closer to it get first choice.
Oxygen follows fluorine and chlorine is stuck
with whatever is left in this one.

O^{2-}

H^{1+} Cl^{X} O^{2-}

O^{2-}

Chlorine's oxidation number?

0	$\underline{Cl}_2$
-1	$Na\underline{Cl}$
+1	$\underline{Cl}O^{1-}$
+5	$H\underline{Cl}O_3$
+7	$\underline{Cl}OF_5$
+9	$\underline{Cl}_2O_9$

F^{1-} F^{1-}

Cl^X O^{2-} F^{1-} F^{1-}

F^{1-}

Cl^X O^{2-} O^{2-} O^{2-}

O^{2-} O^{2-} O^{2-}

Cl^X O^{2-} O^{2-} O^{2-}

Identifying Red-Ox Reaction

- When an atoms oxidation number goes up in a reaction, it’s been oxidized (lost electrons).
- When an atoms oxidation number goes down in a reaction, it’s been reduced (gained electrons).
- For underlined atom in each reaction below, determine if it’s been oxidized, reduced, or neither.

Iron rusting to Iron (III) oxide. Oxidized

$2\ AgCl_{(s)} + H_{2\ (g)} \rightarrow 2\ H^{1+}_{(aq)} + 2\ Ag_{(s)} + 2\ Cl^{1-}_{(aq)}$ Oxidized

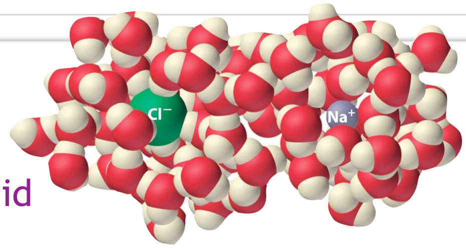
$MnO_4{}^{1-}_{(aq)} + I^{1-}_{(aq)} \rightarrow Mn^{2+}_{(aq)} + I_{2\ (s)}$ Reduced

$Na_3PO_{4\ (aq)} + H_2SO_{4\ (aq)} \rightarrow H_3PO_{4\ (aq)} + Na_2SO_{4\ (aq)}$ Neither

Precipitating gold metal from gold ions in sea water. Reduced

Ch04

Reactions in Solution



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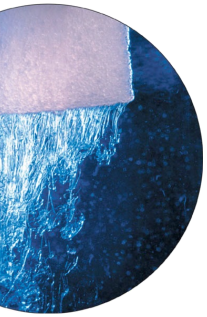

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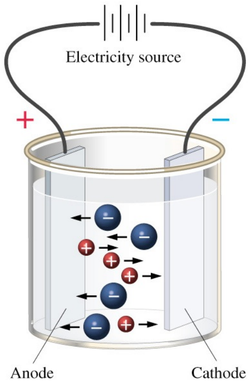
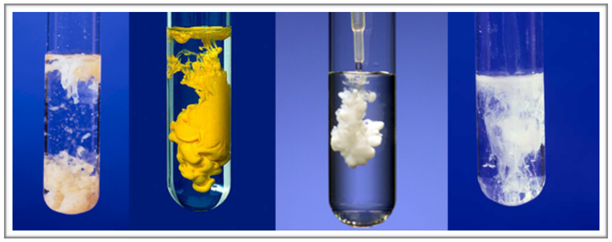




Labeled by Kinetics

Combination Reaction:

$$A + B \rightarrow C$$

eg. $C(s) + O_2\ (g) \rightarrow CO_2\ (g)$

Decomposition Reaction:

$$A \rightarrow B + C$$

eg. $Cu(OH)_2\ (s) \rightarrow CuO\ (s) + H_2O\ (l)$

Single Displacement Reaction:

$$A + BC \rightarrow B + AC$$

eg. $Zn\ (s) + SnCl_2\ (aq) \rightarrow Sn\ (s) + ZnCl_2\ (aq)$

Double Displacement Reaction:

“trade partners”

$$AB + CD \rightarrow AD + CB$$

eg. $2\ KI_{\ (aq)} + Pb(NO_3)_{2\ (aq)} \rightarrow PbI_{2\ (s)} \downarrow + 2\ KNO_{3\ (aq)}$

- Labels based on what “boxes” the atoms fall into and the general pattern of what moves where.
- A very generic label.
- Each label is mutually exclusive, reaction is one or another — never two.

Red-Ox Reactions

- Electrons being added to one atom are lost by another.
  - When one substance is oxidized, another is reduced.
- You can identify what is happening to each component with oxidation numbers.

$$Zn_{(s)} + HBr_{(aq)} \rightarrow ZnBr_{2(aq)} + H_{2(g)}$$

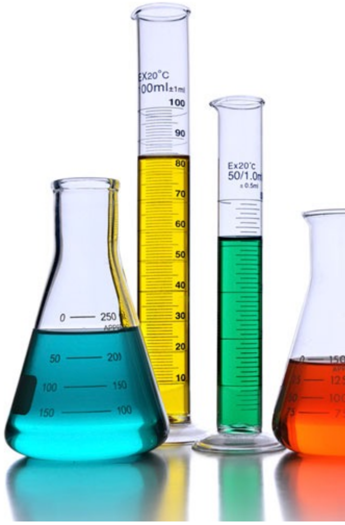
$$Zn_{(s)} + H^{1+}{}_{(aq)} + Br^{1-}{}_{(aq)} \rightarrow Zn^{2+}{}_{(aq)} + Br^{1-}{}_{(aq)} + H_{2(g)}$$

0 +1 -1 +2 -1 0

Zinc is oxidized (0 goes up to +2)
Hydrogen is Reduced (+1 goes down to 0)
Bromine is neither.

A + BC → AC + B

- We also classify chemical reactions by their kinetics, by how the molecules find each other in solution.
- Many metals react vigorously with acids or electrolyte solutions.
  - Single displacement kinetics describe the red-ox action of metals with acid or electrolyte solutions.



Red-Ox Reactions

- Electrons being added to one atom are lost by another.
  - When one substance is oxidized, another is reduced.

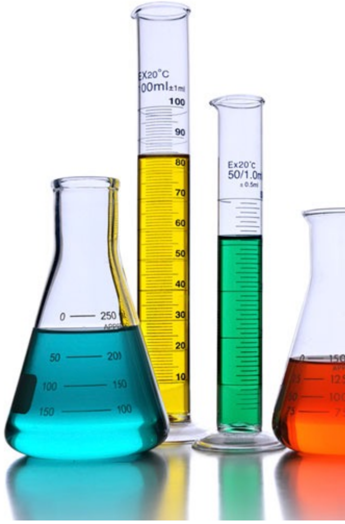
- Many combinations of metals with acids or electrolyte solutions react vigorously.
- Many combinations do nothing.

$$Zn_{(s)} + HBr_{(aq)} \rightarrow ZnBr_{2(aq)} + H_{2(g)}$$

$$A + BC \rightarrow AC + B$$

$$Mg_{(s)} + Pb(NO_3)_{2(aq)} \rightarrow Mg(NO_3)_{2(aq)} + Pb_{(s)}$$

$$Cu_{(s)} + Pb(NO_3)_{2(aq)} \rightarrow N/R$$



  - How can we know if these reactions will occur?

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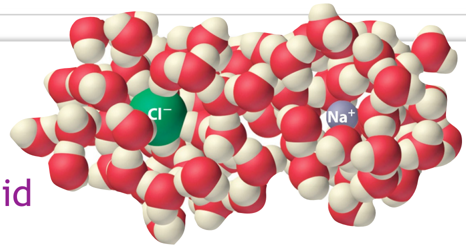
Reactions in Solution



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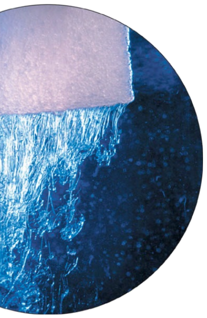

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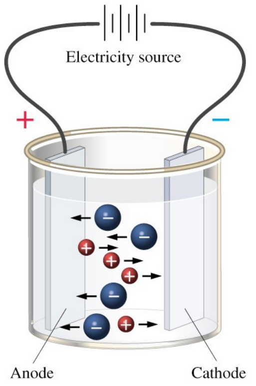
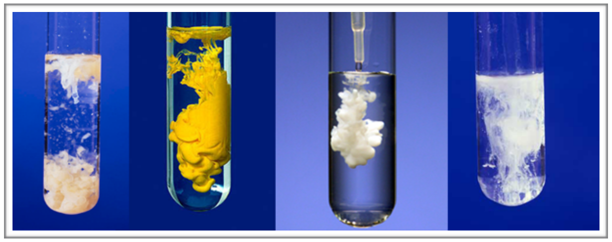




Half Reactions

- How do we know if the reaction happens? Look at the complete ionic equation.

$$\mathrm{Mg}_{(s)} + \mathrm{Pb(NO_3)}_{2(aq)} \rightarrow \mathrm{Mg(NO_3)}_{2(aq)} + \mathrm{Pb}_{(s)}$$

Molecular Equation

$$\mathrm{Mg}_{(s)} + \mathrm{Pb}^{2+} + \cancel{\mathrm{NO_3}}^{1-} \rightarrow \mathrm{Mg}^{2+} + \cancel{\mathrm{NO_3}}^{1-} + \mathrm{Pb}_{(s)}$$

Complete Ionic Equation

- Remove the spectator ions to see the net ionic equation.

$$\mathrm{Mg}_{(s)} + \mathrm{Pb}^{2+} \rightarrow \mathrm{Mg}^{2+} + \mathrm{Pb}_{(s)}$$

Net Ionic Equation

- There are two half reactions which make up this net ionic equation.

$$\mathrm{Mg}_{(s)} \rightarrow \mathrm{Mg}^{2+} + 2e^{-}$$

$$\mathrm{Pb}^{2+} + 2e^{-} \rightarrow \mathrm{Pb}_{(s)}$$

Half Reaction Equations

- The two half reactions show that we're looking at a competition for electrons. It's basically a tug of war.
- You can turn around one equation to compare them side to side.
  We need to decide who's gonna win the fight over those two electrons.

$$\mathrm{Mg}^{2+} + 2e^{-} \rightarrow \mathrm{Mg}_{(s)}$$

$$\mathrm{Pb}^{2+} + 2e^{-} \rightarrow \mathrm{Pb}_{(s)}$$

- We could look up numbers for whose is better at holding electrons,
  or we could just reference a list of "who beat's who" — the activity series.

Activity Series

Potassium	K
Strontium	Sr
Calcium	Ca
Sodium	Na
Magnesium	Mg
Aluminum	Al
Zinc	Zn
Chromium	Cr
Iron	Fe
Cadmium	Cd
Cobalt	Co
Nickel	Ni
Tin	Sn
Lead	Pb
Hydrogen	H_2
Copper	Cu
Silver	Ag
Gold	Au

- Metals are ranked by their potential to loose electrons.
- Which metal (oxidation zero) is more “active”?
- We look at the half reactions.

$$Mg_{(s)} \rightarrow Mg^{2+} + 2e^-$$

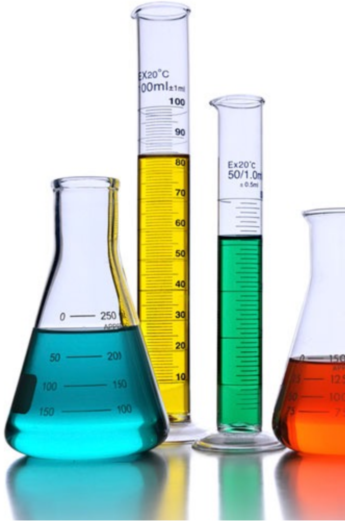
$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^-$$

- An atom of an element in the activity series will displace an atom of an element below it from one of its compounds.

$$A + BC \rightarrow AC + B$$

$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^-$$

$$2e^- + Mg^{2+} \leftarrow Mg_{(s)}$$



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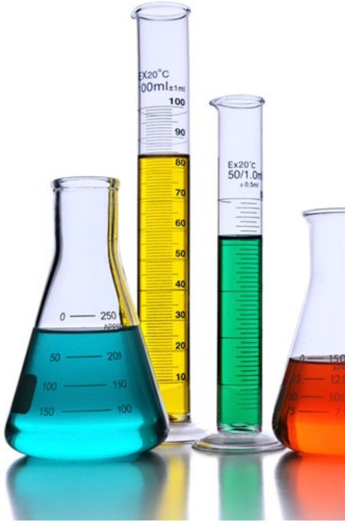
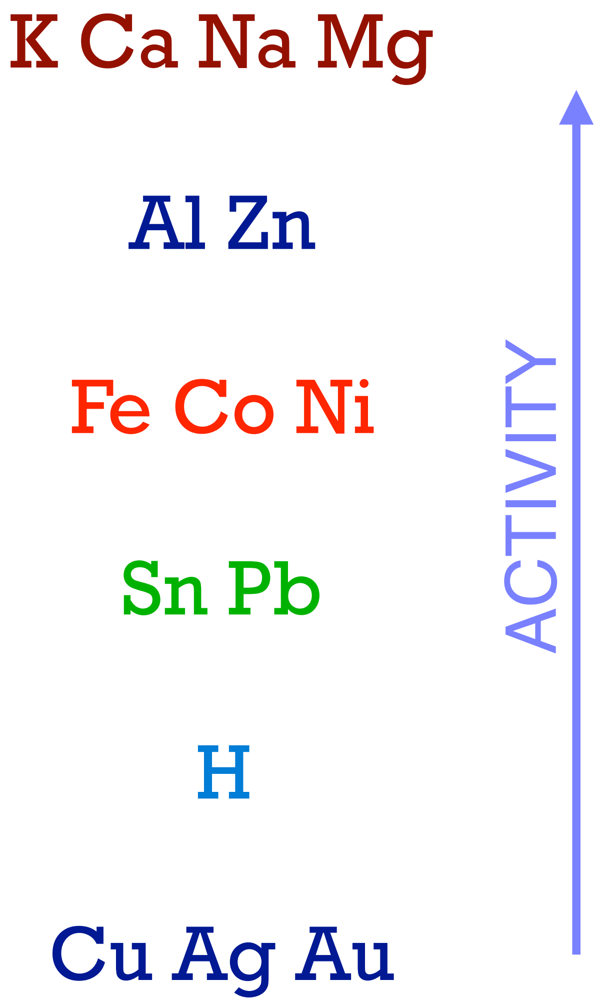
$$A + BC \rightarrow AC + B$$

$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^-$$

$$2e^- + Mg^{2+} \leftarrow Mg_{(s)}$$



Activity Series



K Ca Na Mg

Al Zn

Fe Co Ni

Sn Pb

H

Cu Ag Au

- Metals are ranked by their potential to loose electrons.
- Which metal (oxidation zero) is more “active”?
- We look at the half reactions.

$$Mg_{(s)} \rightarrow Mg^{2+} + 2e^{-}$$

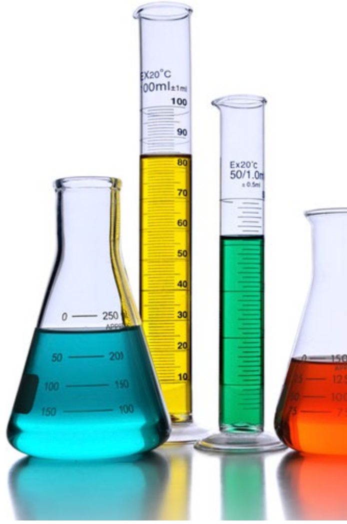
$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^{-}$$

- An atom of an element in the activity series will displace an atom of an element below it from one of its compounds.

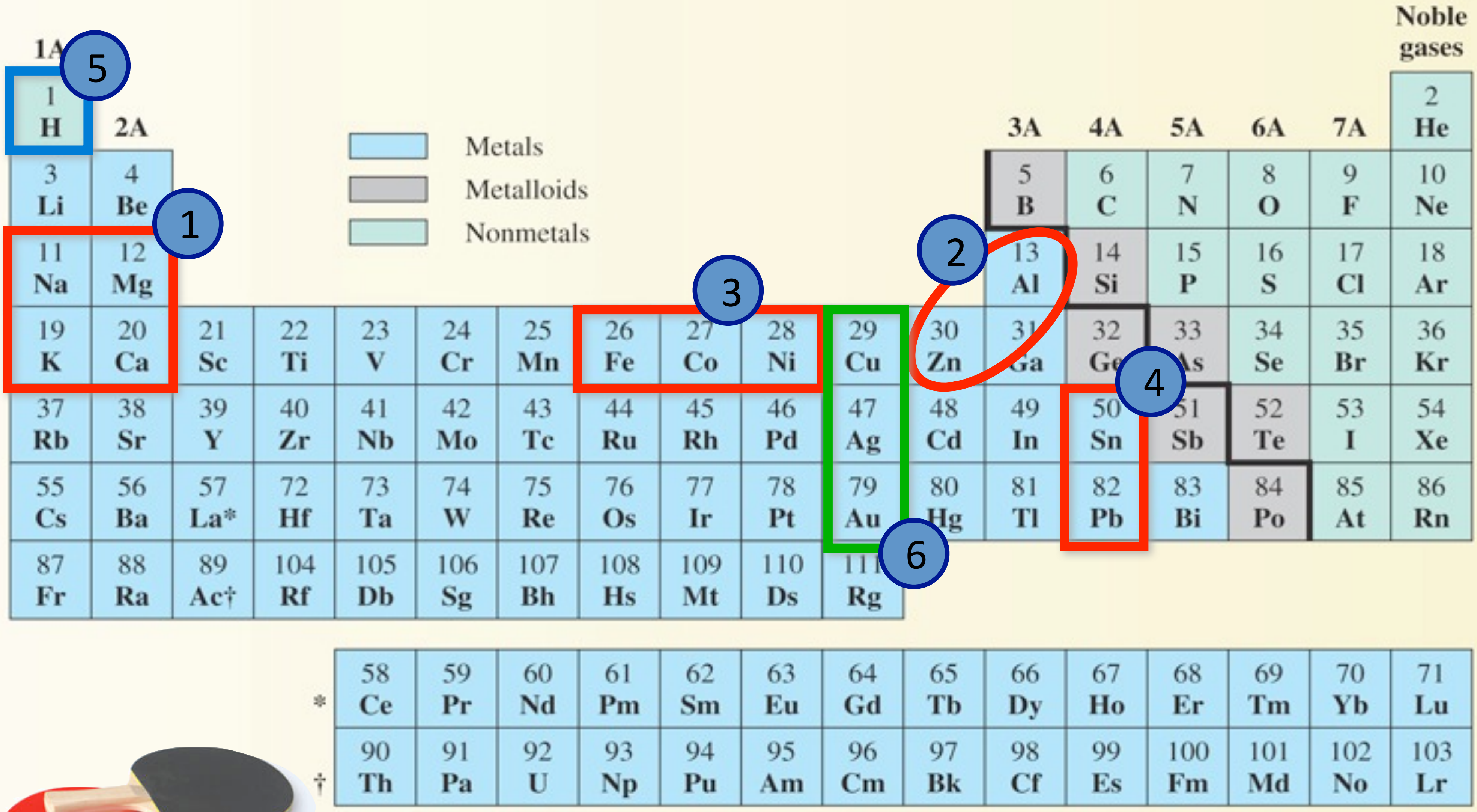
$$A + BC \rightarrow AC + B$$

$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^{-}$$

$$2e^{-} + Mg^{2+} \leftarrow Mg_{(s)}$$



Metal Activity Series



Metals
Metalloids
Nonmetals

1A	2A											3A	4A	5A	6A	7A	Noble gases
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac†	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg							

*	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
†	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Oxidation & Reduction

- How do we know which metal gives up it's electrons? Check "activity." The more active ion is the one more likely to turn into a cation (give up it's electrons).
- Which is more active (more likely to loose it's electrons)?

Sodium or Iron?

Al or Co?

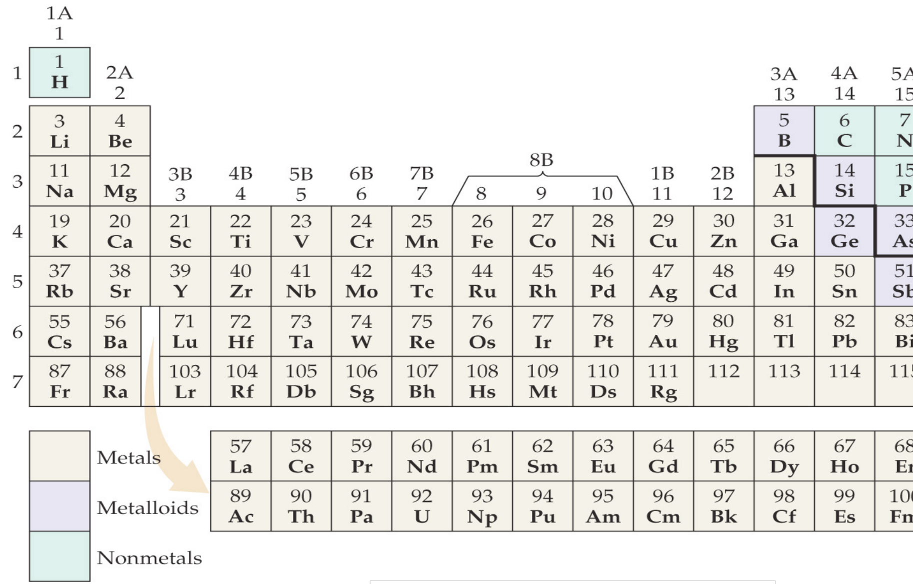
H_2 or Mg?

Hydrogen or Gold?

Sodium or Zinc?

Pb or Cu?

Nickel or Calcium?



	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	9	10	1B 11	2B 12	3A 13	4A 14	5A 15
1	1 **H**														
2	3 **Li**	4 **Be**											5 **B**	6 **C**	7 **N**
3	11 **Na**	12 **Mg**											13 **Al**	14 **Si**	15 **P**
4	19 **K**	20 **Ca**	21 **Sc**	22 **Ti**	23 **V**	24 **Cr**	25 **Mn**	26 **Fe**	27 **Co**	28 **Ni**	29 **Cu**	30 **Zn**	31 **Ga**	32 **Ge**	33 **A**
5	37 **Rb**	38 **Sr**	39 **Y**	40 **Zr**	41 **Nb**	42 **Mo**	43 **Tc**	44 **Ru**	45 **Rh**	46 **Pd**	47 **Ag**	48 **Cd**	49 **In**	50 **Sn**	51 **S**
6	55 **Cs**	56 **Ba**	71 **Lu**	72 **Hf**	73 **Ta**	74 **W**	75 **Re**	76 **Os**	77 **Ir**	78 **Pt**	79 **Au**	80 **Hg**	81 **Tl**	82 **Pb**	83 **B**
7	87 **Fr**	88 **Ra**	103 **Lr**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ds**	111 **Rg**	112	113	114	11

57 **La**	58 **Ce**	59 **Pr**	60 **Nd**	61 **Pm**	62 **Sm**	63 **Eu**	64 **Gd**	65 **Tb**	66 **Dy**	67 **Ho**	68 **E**
89 **Ac**	90 **Th**	91 **Pa**	92 **U**	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	10 **F**

▨	Metals
▨	Metalloids
▨	Nonmetals

Oxidation & Reduction

- How do we know which metal gives up it's electrons? Check "activity." The more active ion is the one more likely to turn into a cation (give up it's electrons).
- Which reactions will occur?

$$A + BC \rightarrow AC + B$$

$$Na_{(s)} + FeBr_{3(aq)} \rightarrow ?$$

Na more active than Fe? Yes.

$$Na_{(s)} + FeBr_{3(aq)} \rightarrow Fe_{(s)} + NaBr_{(aq)}$$

$$Fe_{(s)} + Zn(ClO_3)_{2(aq)} \rightarrow ?$$

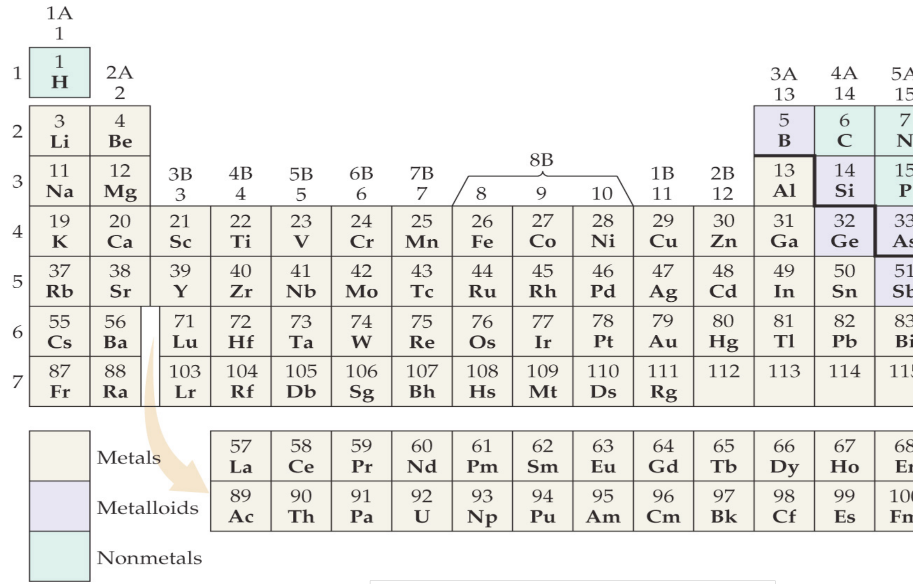
Fe more active than Zn? No.

$$Fe_{(s)} + Zn(ClO_3)_{2(aq)} \rightarrow N/R$$

$$Sn_{(s)} + HNO_{3(aq)} \rightarrow ?$$

Sn more active than H? Yes.

$$Sn_{(s)} + HNO_{3(aq)} \rightarrow H_{2(g)}\uparrow + Sn(NO_3)_{4(aq)}$$



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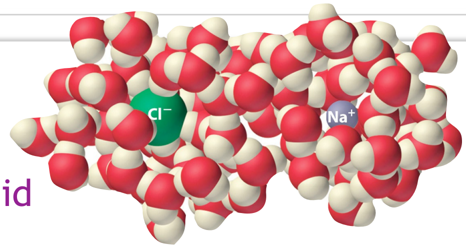
Reactions in Solution



- Solubility
  - Why Solids are Solid
  - Making solutions
  - Electrolyte solutions
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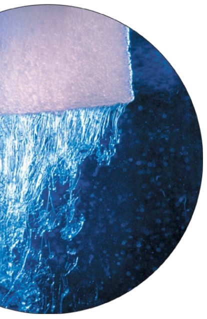

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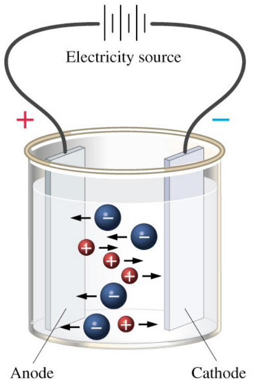
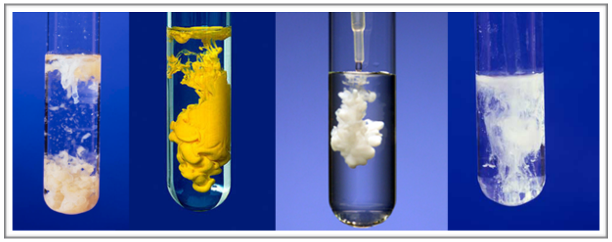
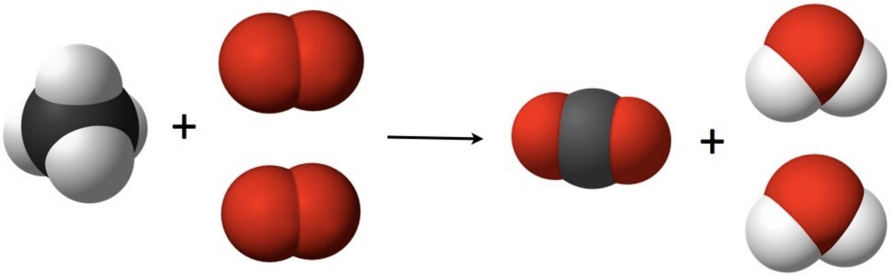




Combustion Reactions

- Burning something is causing it to combust.
- Combustion reactions are reacting any substance with oxygen to form the most stable binary compounds of it’s elements and oxygen.
- The most common products are CO_2 and H_2O. Other common products are NO_2 and P_2O_5.
- Combustion reactions are red-ox reactions, in which oxygen is reduced.
- The driving force in combustion reactions is oxygens fierce demand for electrons. Harnessing that property of oxygen is what gave us the internal combustion engine and is at the heart of most of fuels humans use.



$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$X + O_2 \rightarrow H_2O + CO_2 + NO_2 + P_2O_5 + \ldots$$

Reaction Types

Considering…

- Kinetics (what could be formed?)
    - Double Displacement
    - Single Displacement
- Driving force (will it happen?)
    - Precipitation Reactions
    - Acid Base Reactions
    - Gas Evolution Reactions
    - Reduction-Oxidation Reactions
        - Metal Activity
        - Combustion

$$AB + CD \rightarrow AD + CB$$

$$A + BC \rightarrow B + AC$$

… you can predict if two substances will react and what products it will likely produce.

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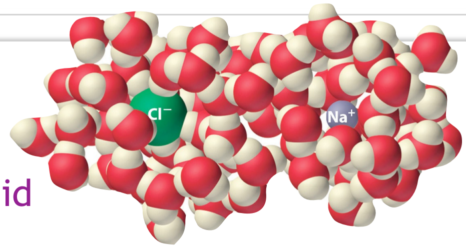
Reactions in Solution



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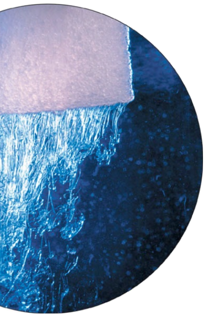

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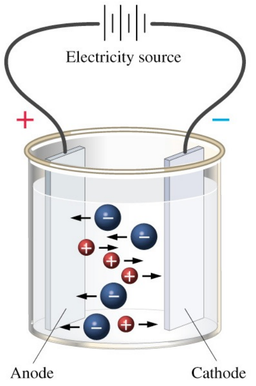

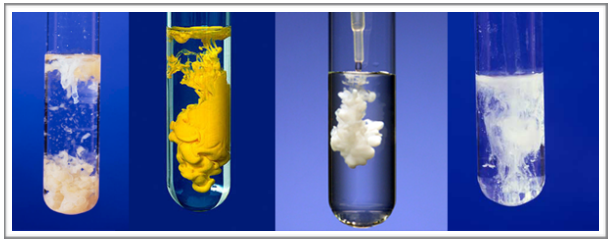

Questions?