Ch09

Solutions

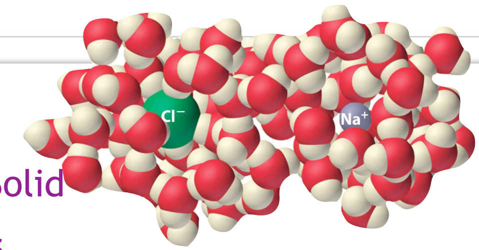
A closer look at mixtures.

Solutions and reactions in solution.

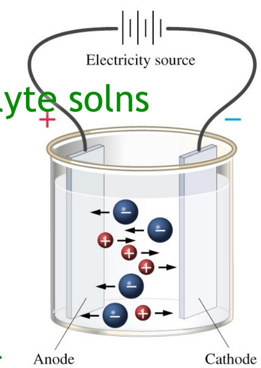
version 1.5

Ch09

Solutions



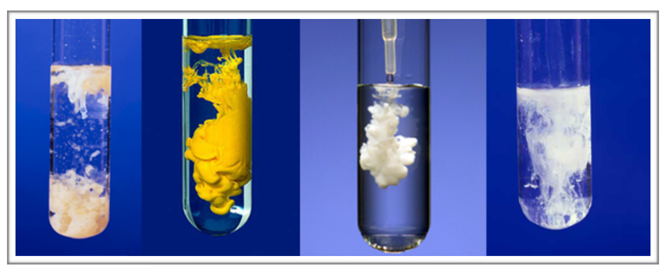
- Solubility
  - Why Solids are Solid
  - Making solutions
    - Molecular solvation
    - Ionic solvation — Dissociation
  - Electrolyte solutions
    - Electrolyte & Non-Electrolyte solns
    - Electrolyte strength



- Solution Concentration
  - Measures of concentration.
    - Molarity and mass percent.
    - Using molarity as a conversion factor.
    - Solving for molarity.
  - Dilution
- Reactions in Solution
  - Double Displacement: AB + CD ⇄ AD + CB
  - Precipitation Reactions
  - Ionic eqns (complete & net)
    - Predicting Precipitation Reactions

- Heterogenous Mixures
  - Colloids & Suspensions
  - Membranes

- Reactions with Solutions
  - Reduction & Oxidation
    - Oxidation States
      - Molecular Substances
      - Organic Molecules
    - Combustion Reactions
  - Red-Ox Reactions
  - Single Displacement: A + BC ⇄ B + AC
  - Metal Activity
    - Predicting Red-Ox Reactions



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.

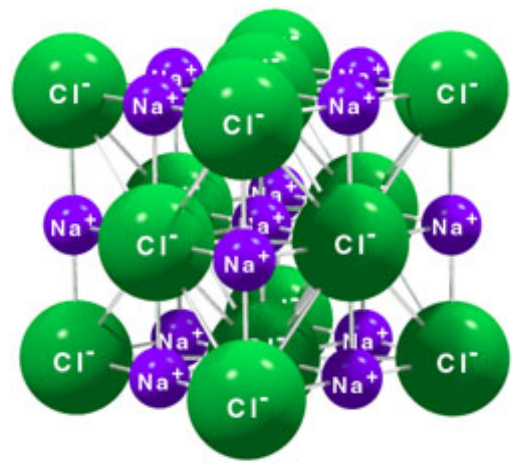
A solution is a homogenous mixture.

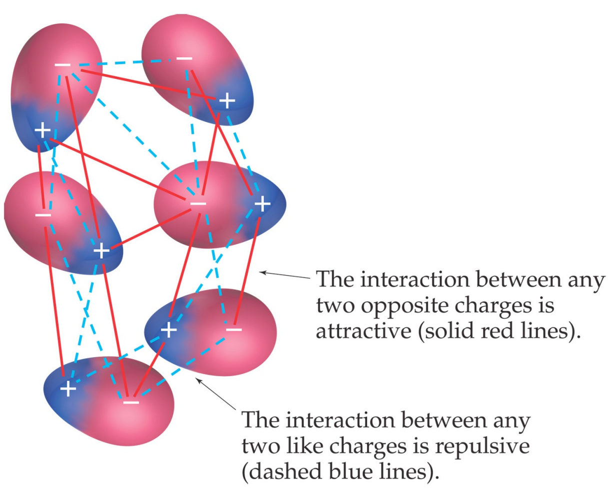
A solvent is the largest component of the mixture.

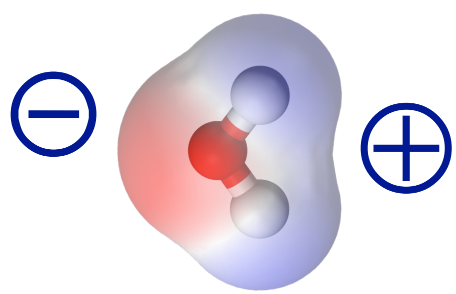
A solute is a smaller components of the mixture.

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.







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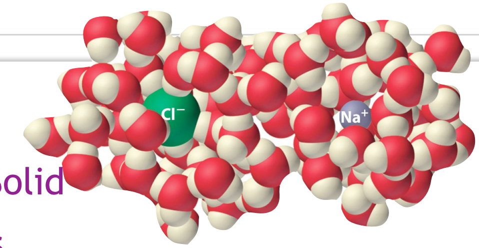

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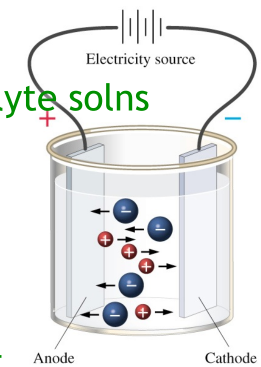

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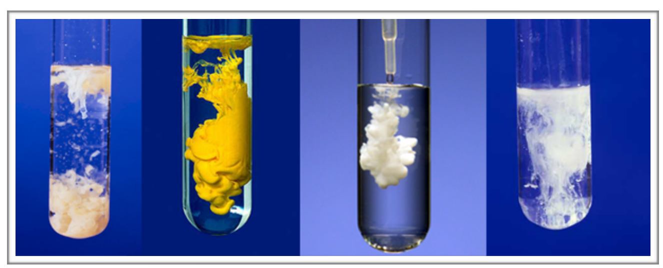
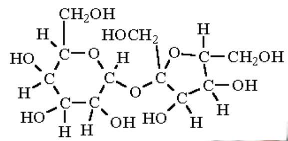
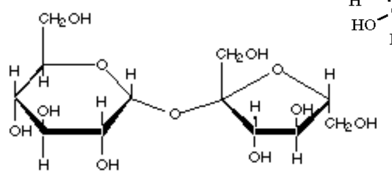
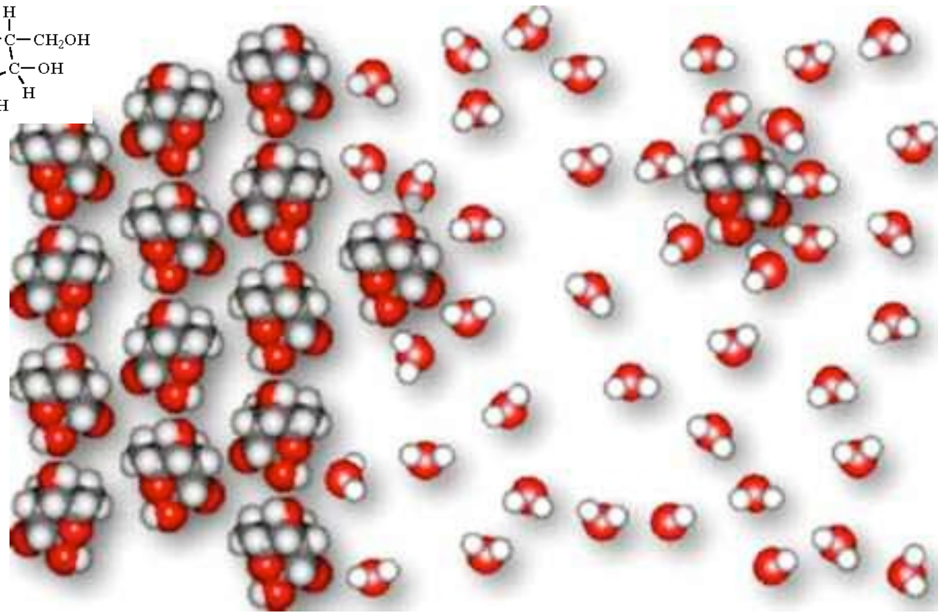


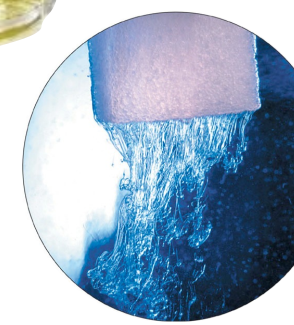
Molecular Solids Dissolve in Water





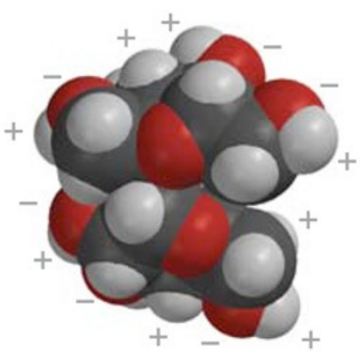
Sucrose
(glucose (α1-->2) fructose)



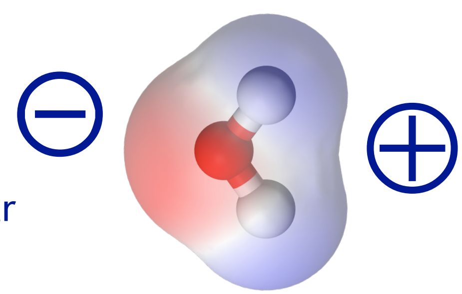


$$C_{12}H_{22}O_{11}\ (s) \xrightarrow{H_2O} C_{12}H_{22}O_{11}\ (aq)$$

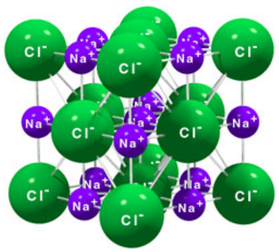
Sugar dissolving in water

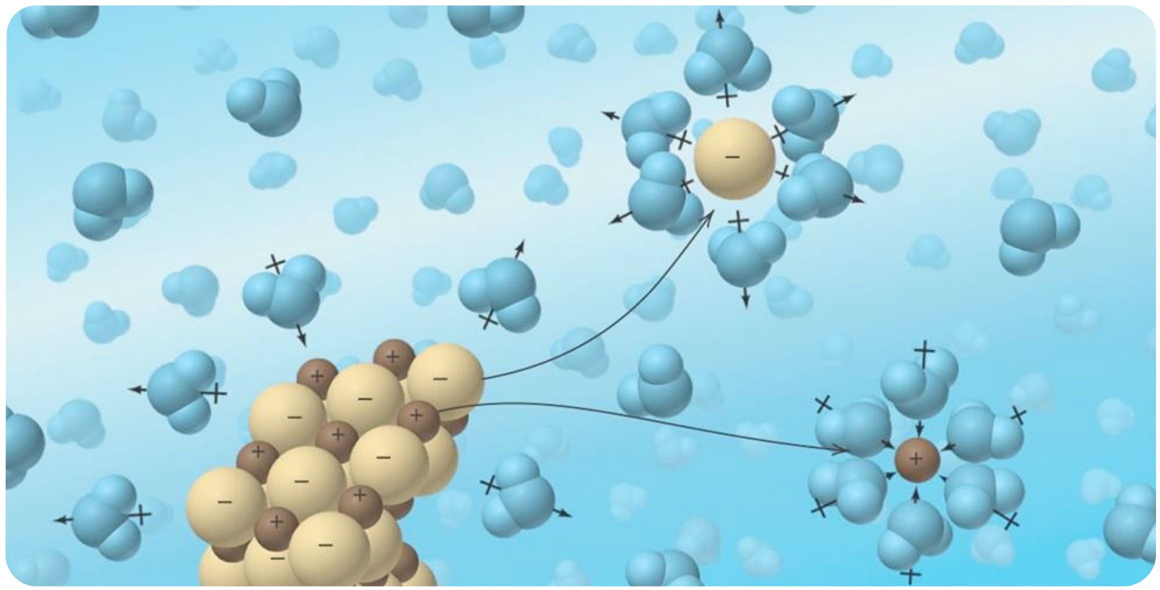


- Sugar dissolves in water.
- The molecules remain intact.
- Water molecules get in between sugar molecules.
- The result is a mixture of sugar and water.
- Mostly water.



Ionic Solids Dissolve in Water

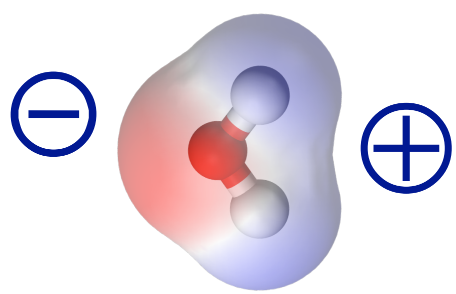




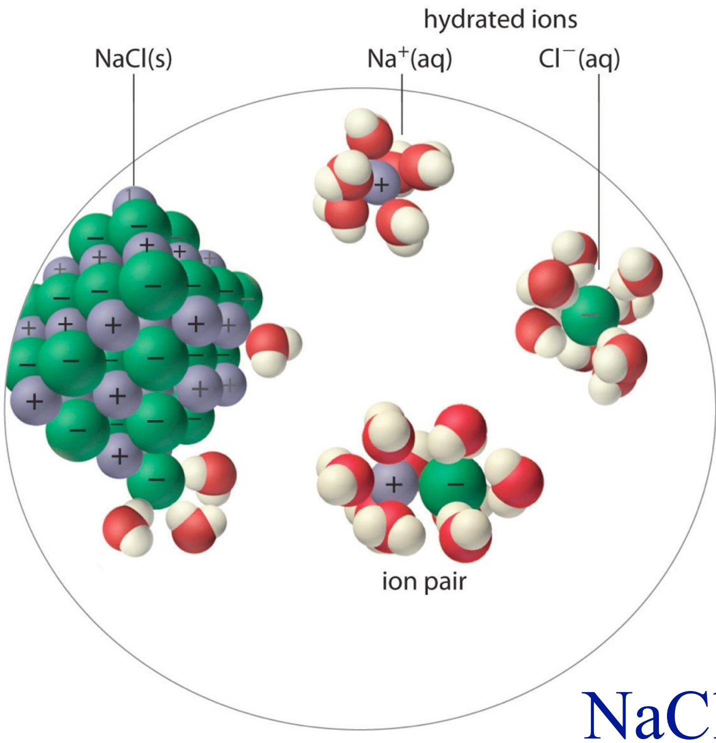
$$NaCl_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)}$$

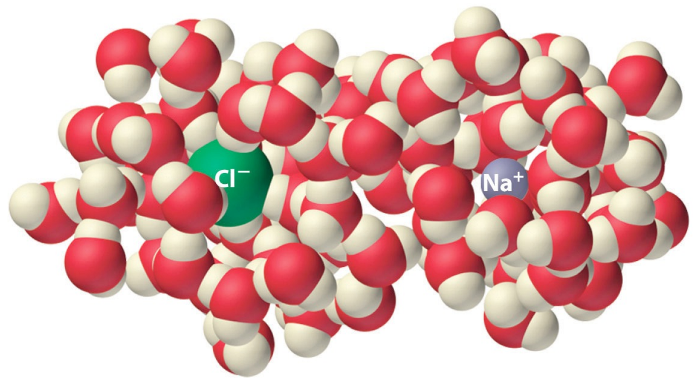
Dissociation of sodium chloride in water

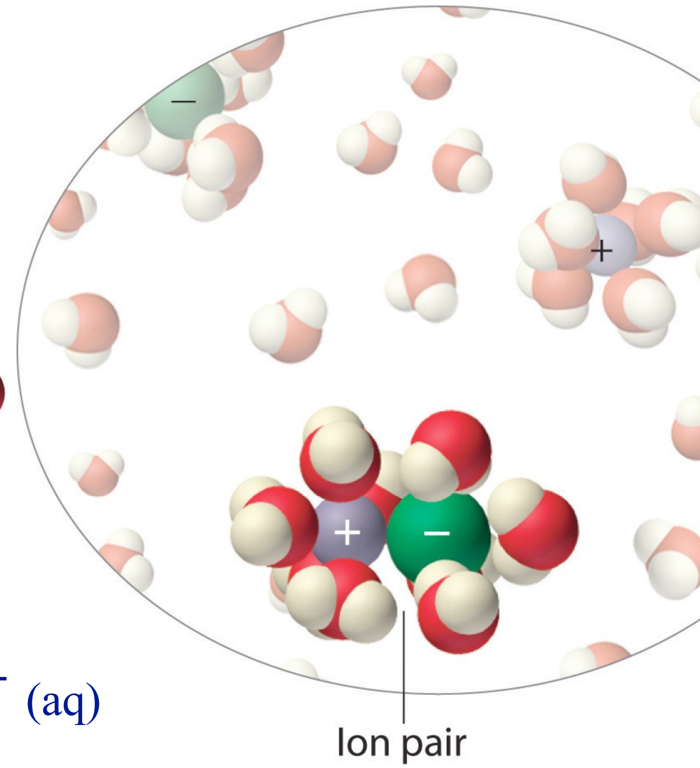
- Salt dissolves in water.
- The the ions separate.
- Water molecules get in between the ions.
- The result is a mixture of ions and water.
- Mostly water.
- Ions separating in solution is a process called dissociation.



Dissociation is often Reversible







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

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

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

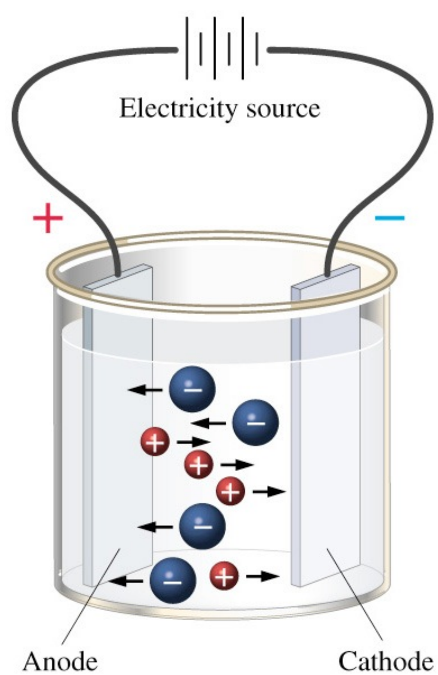
$KNO_{3\,(aq)} \rightleftarrows K^+_{(aq)} + NO_3^{1-}{}_{(aq)}$

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

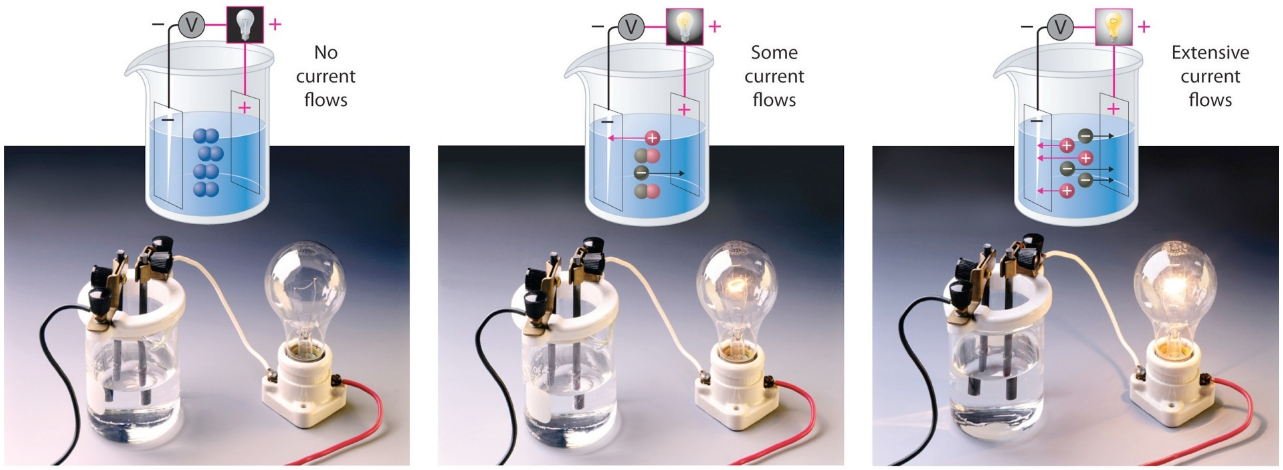
$NaCl_{(aq)} \rightleftarrows Na^+_{(aq)} + Cl^{1-}_{(aq)}$

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

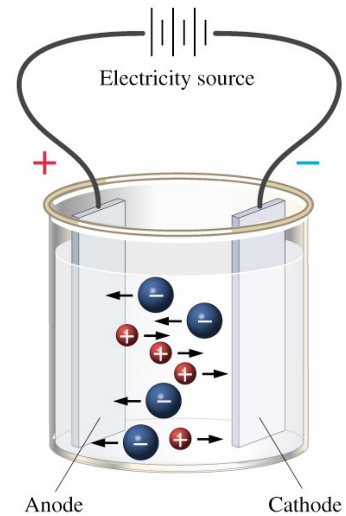
$HF_{(aq)} \rightleftarrows H^+_{(aq)} + F^{1-}_{(aq)}$



Electrolyte Strength



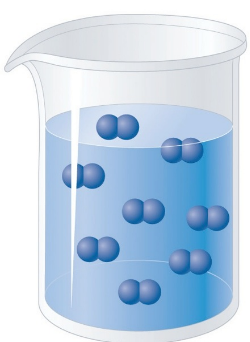
(a) Nonelectrolyte (b) Weak electrolyte (c) Strong electrolyte



Nonelectrolytes

- Molecular Substances
- Insoluble Ionic Salts

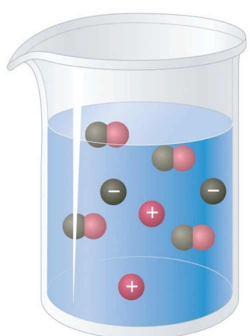
eg Sugar, AgCl, NO_2



Weak Electrolytes

- Weak Acids
- Weak Bases
- Partially soluble Ionic Salts

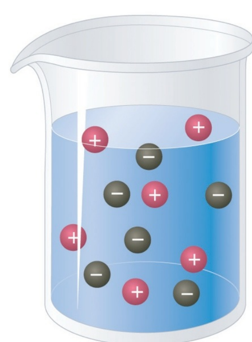
eg HOAc, HF (aq)



Strong Electrolytes

- Strong Acids
- Strong Bases
- Soluble Ionic Salts

eg HCl (aq), NaCl, H_2SO_4



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

4 of 100 molecules dissociate

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

100 of 100 dissociate

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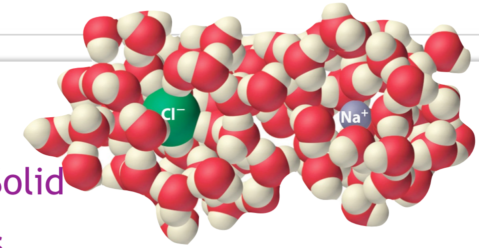

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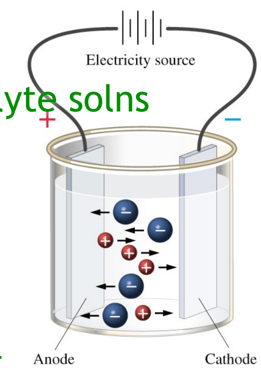

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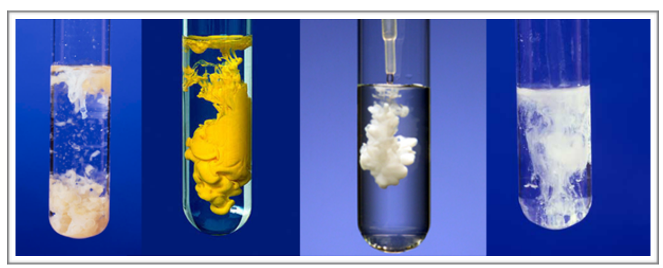
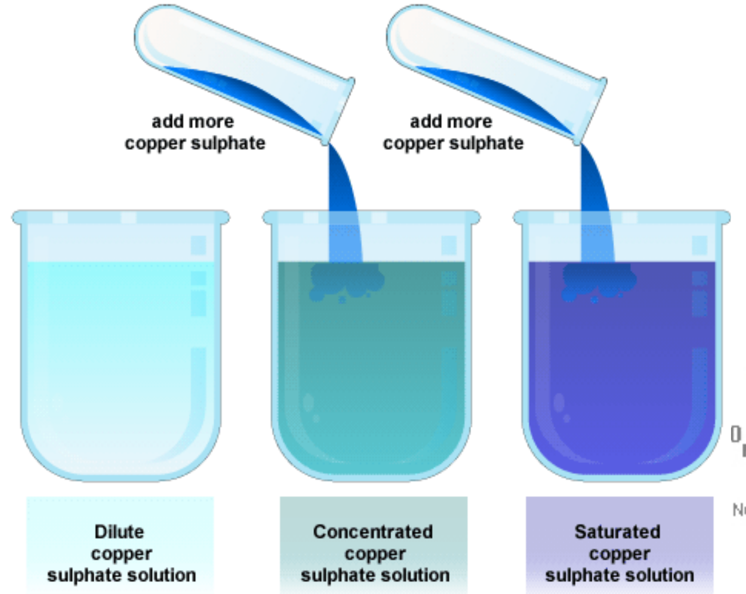


Solutions & Concentration

- 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.

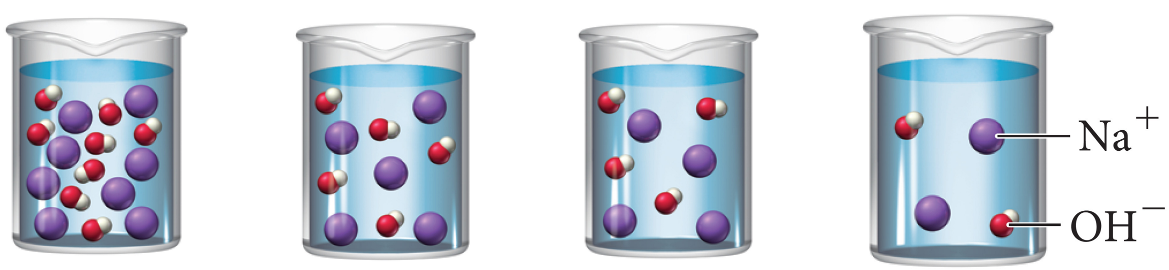
- Concentration is the relationship between amount of a minor component of the mixture (a solute) to the major component of the mixture (the solvent).
- Concentration is how "crowded" the mixture is in a substance.
- Concentration is the amount of a solute in a given quantity of solvent.
- Solutions 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.

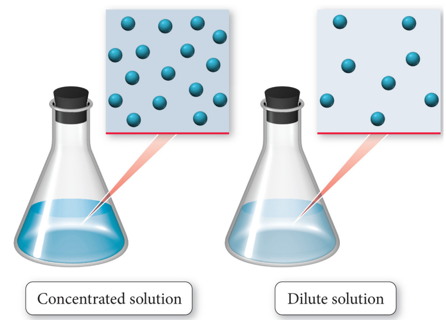
A solute is a smaller components of the mixture.



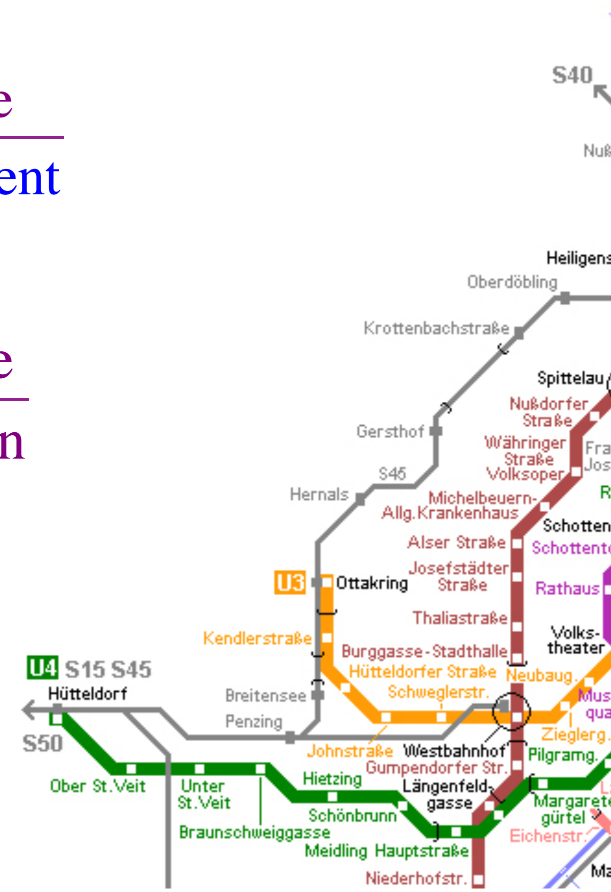
Measures of Concentration

- 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.
  - Molality (m)
    - Moles of solute, per kg of solution.
    - We won't use this.
  - Molarity (M)
    - Moles of solute per liter of solution.
    - We'll use this **a lot** for liquids.

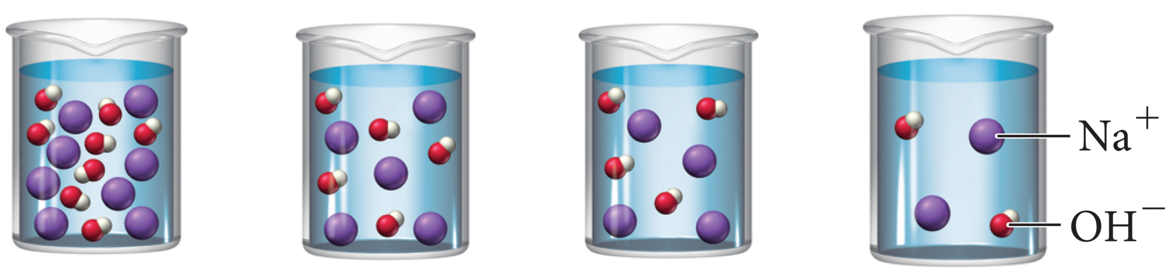
$$X = \frac{\text{moles of solute}}{\text{moles of solution}}$$



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



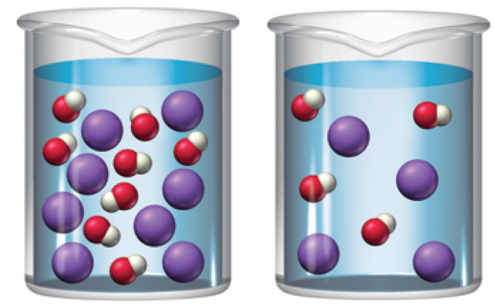
$$M = \frac{\text{moles of solute}}{\text{liters of solution}}$$



Molarity

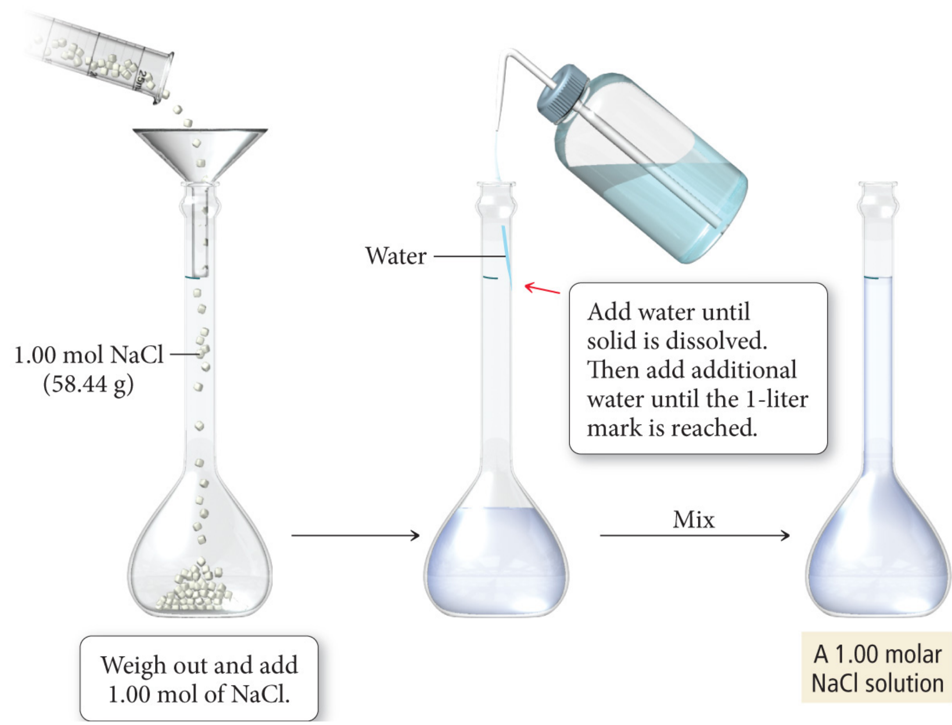
$$\frac{\text{mol solute}}{\text{L solution}}$$

- Molarity is a measure of concentration.
- The units of molarity are mol/L. We abbreviate mol/L as "M"
  - M is not the same as mol
  - M is mol/L
- Molarity is the moles of a solute divided by the volume of the solution.
  - Don't confuse volume of solution with 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 diluted to 1.0L in water is:

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



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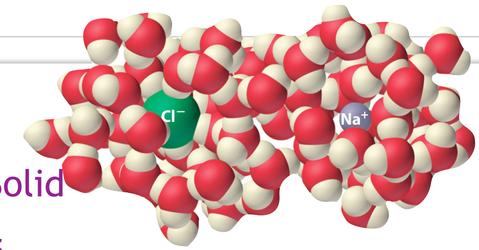

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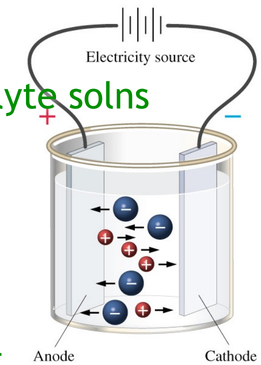

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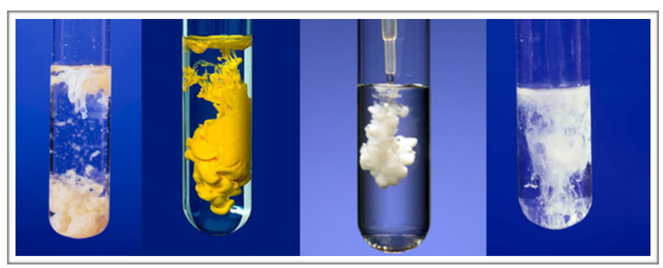


Molarity

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

- Molarity is the number of moles of a solute divided by the total volume of solution.
- 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?

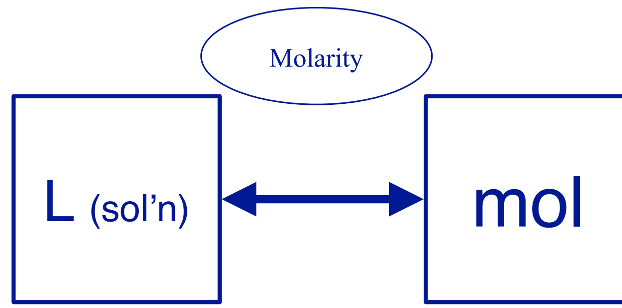
$L \xrightarrow{1} mol$ 1 $3.0\,mol = 1\,L$

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

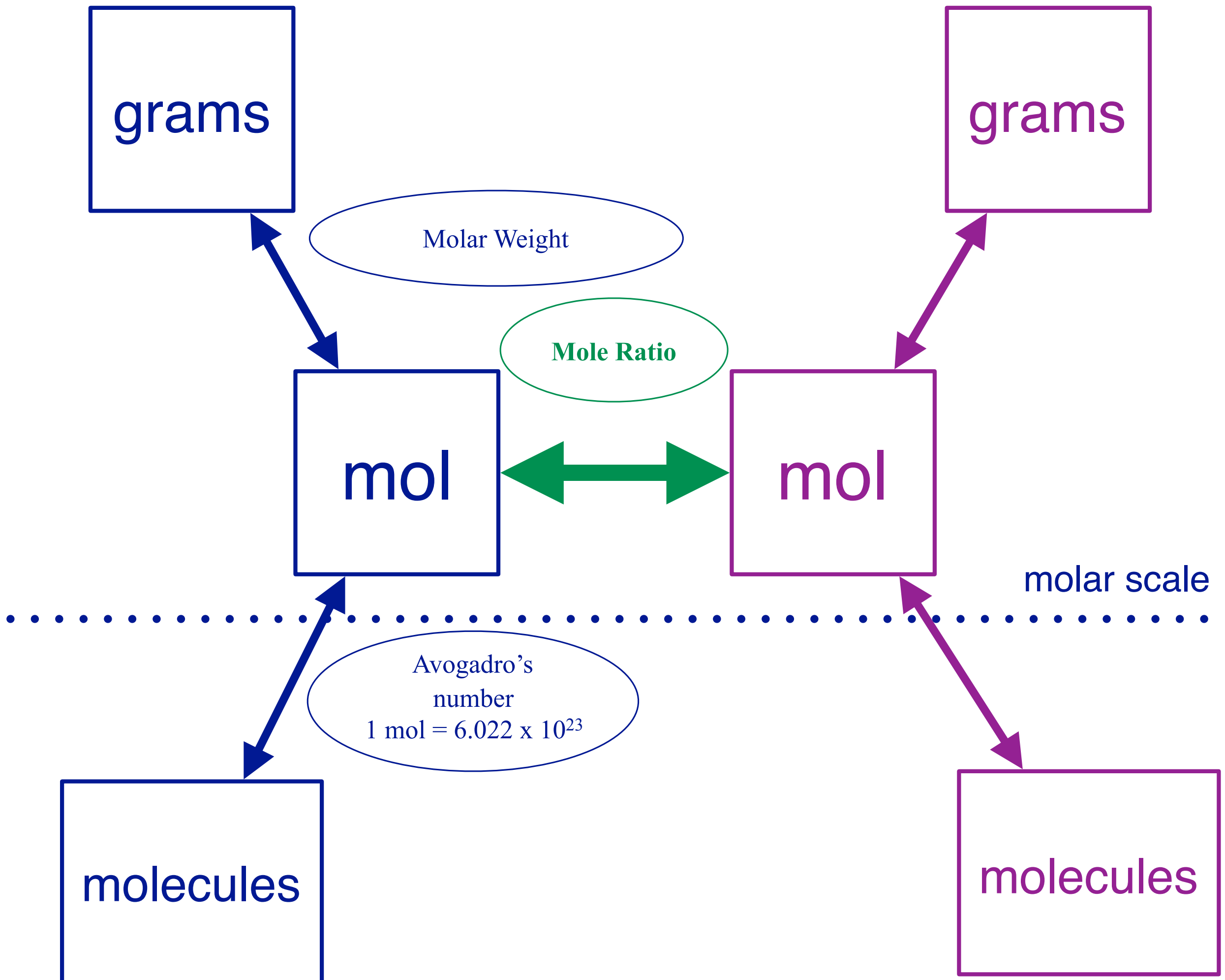
  - What volume do I need to get 0.42 mol?

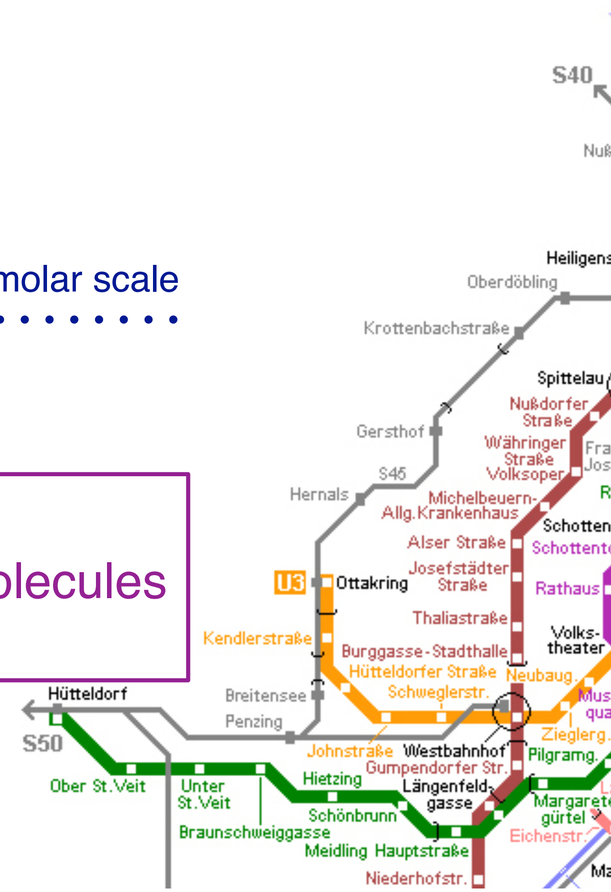
$mol \xrightarrow{1} L$ 1 $3.0\,mol = 1\,L$

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



The Molar Subway



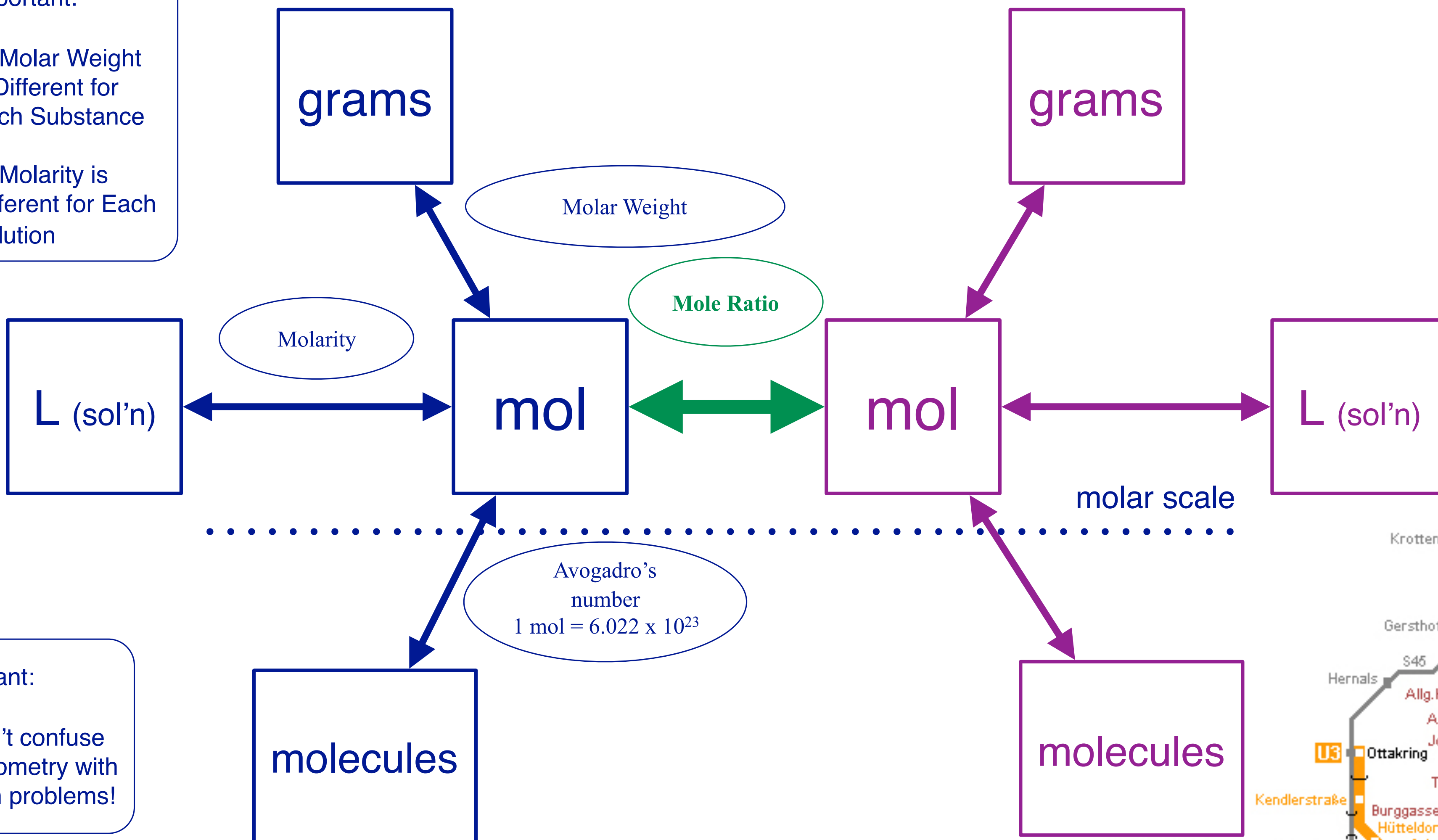


The Molar Subway

Important:

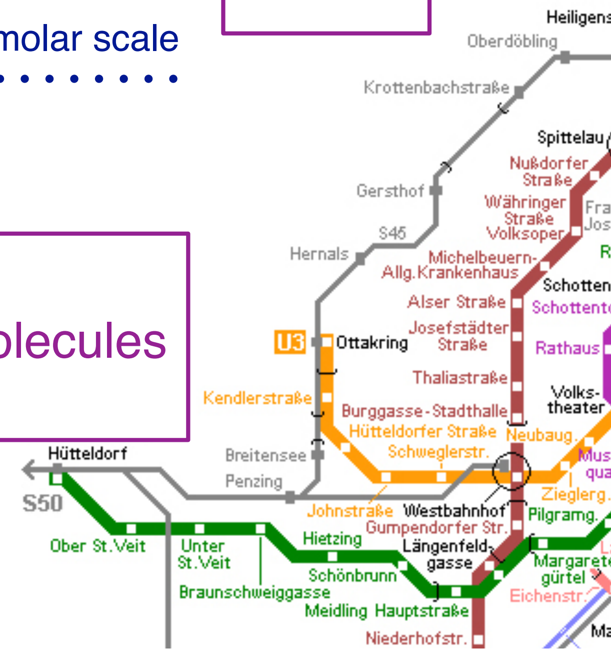
— Molar Weight is Different for Each Substance

— Molarity is Different for Each Solution



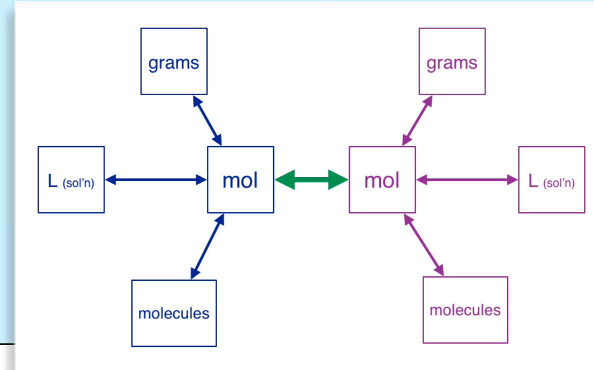
Important:

— 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. 1 (Ca) 40.078
   2 (Cl) 70.906
   110.984

$110.984\,g = 1\,mol$

3 s.f. ∞ 3 s.f. ∞ 6 s.f.

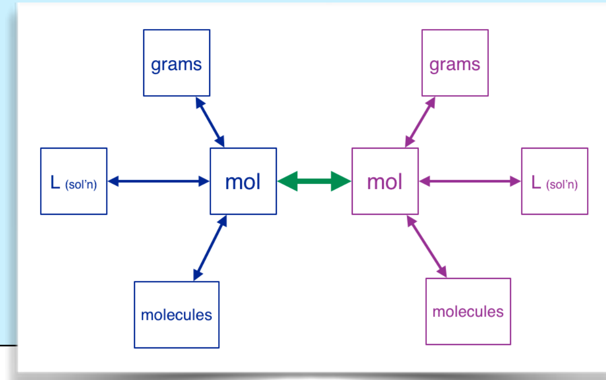
$$25.0\,mL \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0.100\,mol}{1\,L} \cdot \frac{1\,CaCl_2}{2\,AgNO_3} \cdot \frac{110.984\,g}{1\,mol} =$$

$$0.13873\,g$$

$$= \boxed{0.139\,g\,CaCl_2}$$

Problem:

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



Solution

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

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

1. $24.3050\,g = 1\,mol$
2. $1\,Mg = 2\,HNO_3$
3. $3.0\,M\ HNO_3$
4. $1\,L = 1000\,mL$

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

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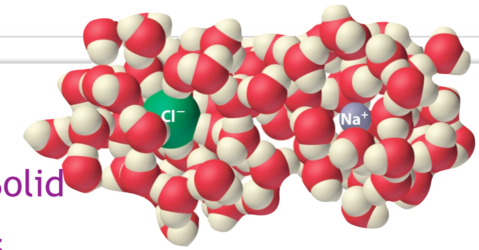
Solutions



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  - Why Solids are Solid
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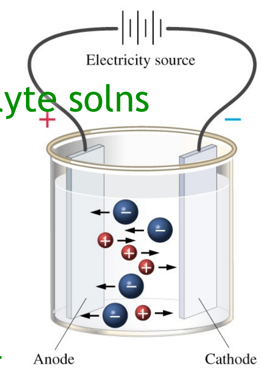
    - Ionic solvation — Dissociation
  - Electrolyte solutions
    - Electrolyte & Non-Electrolyte solns
    - Electrolyte strength



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- Heterogenous Mixures
  - Colloids & Suspensions
  - Membranes

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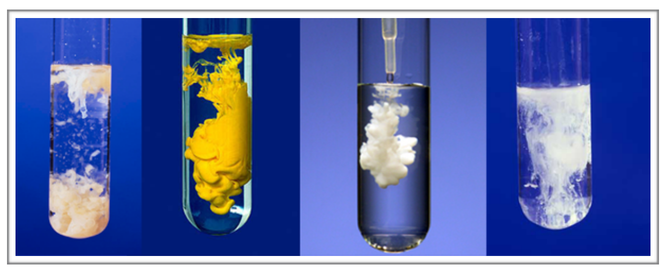
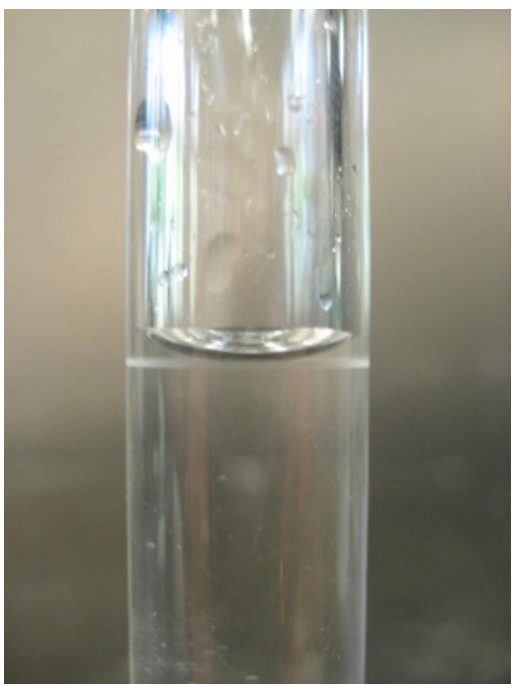
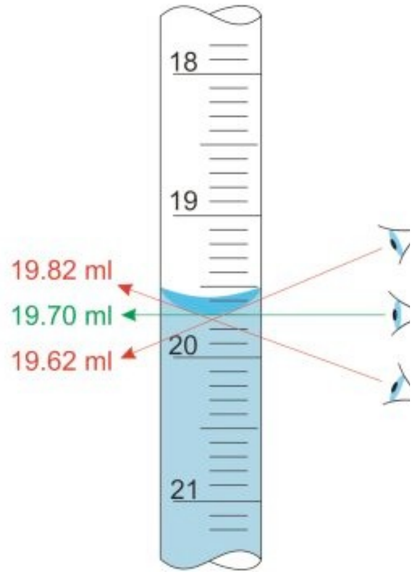
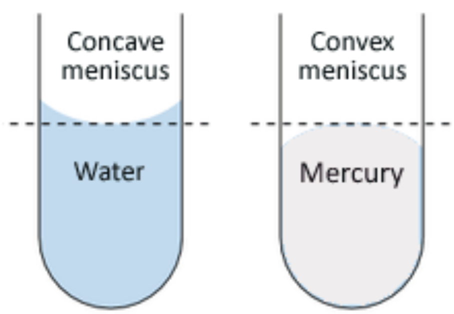


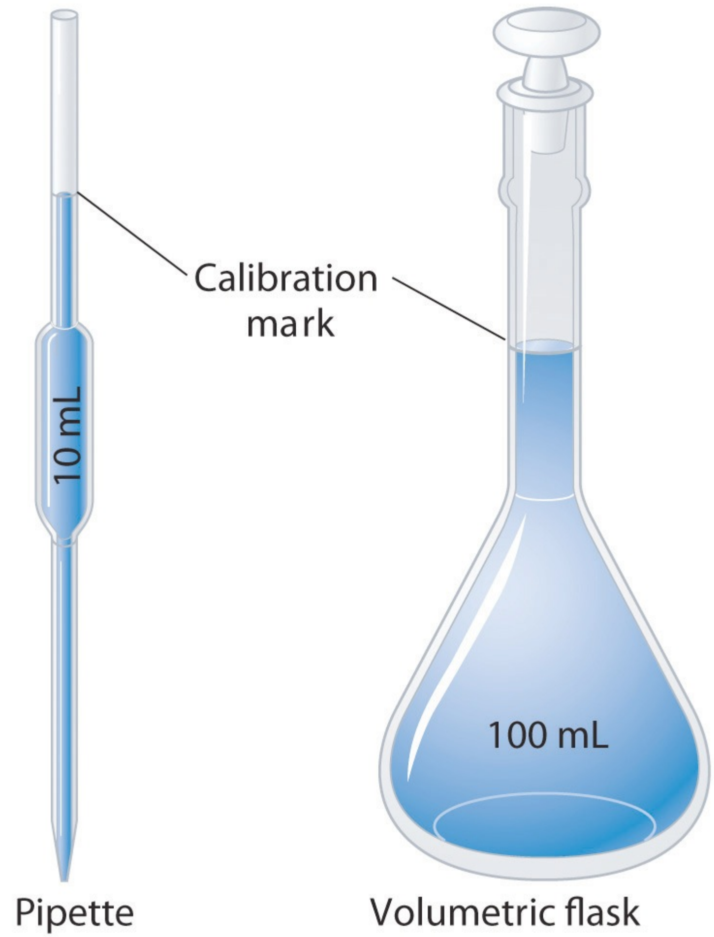
Volumetric Glassware

- 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!

$$\text{molarity} \times \text{volume} = \text{moles}$$

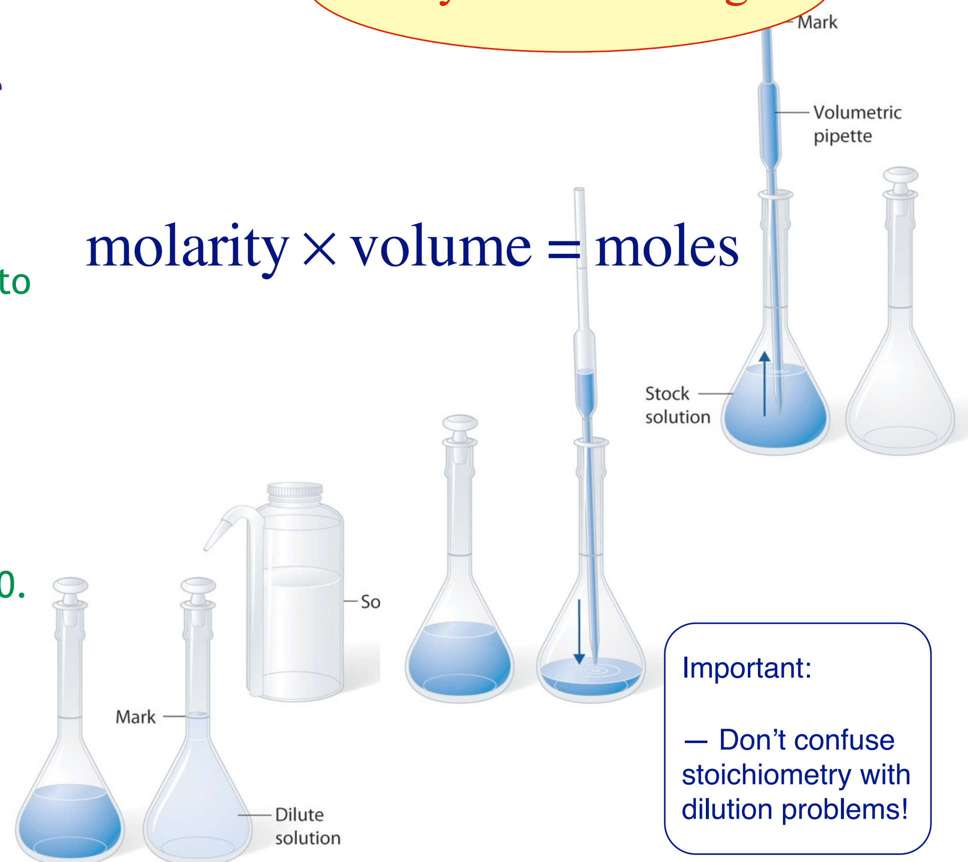
- What volume must you dilute 25 mL of 8.0 M $Ca(NO_3)_2$ to make a 2.0 M solution?

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

$(1.0 \times 10^2 mL)$

- 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:

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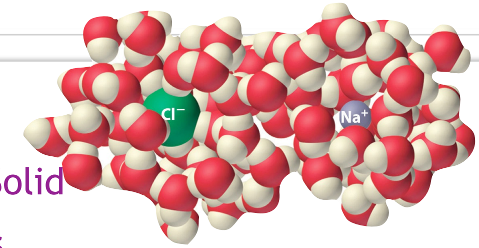
Solutions



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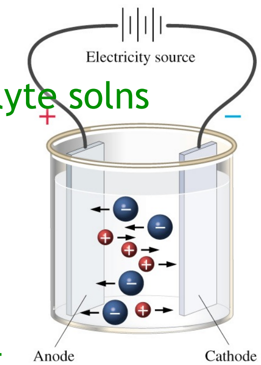

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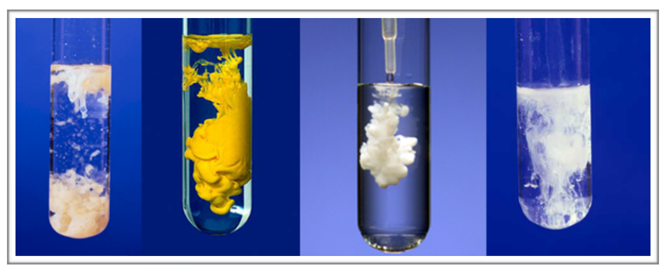


Reactions in Solution

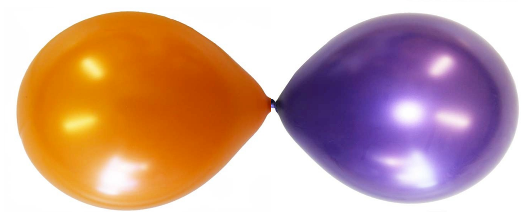
- If you dissolve more than one electrolyte in solution, you get a mixture of ions.
- The ions bump into each other and apart again, trading partners and just bouncing around the solution.
- That's not exciting.

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

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

$$KI_{(aq)} + NaNO_{3\,(aq)} \rightleftarrows K^{+}_{(aq)} + I^{1-}_{(aq)} + Na^{+}_{(aq)} + NO_3{}^{1-}_{(aq)} \rightleftarrows NaI_{(aq)} + KNO_{3\,(aq)}$$

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



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

$$KI_{(aq)} + Pb(NO_3)_{2\,(aq)} \rightleftarrows K^{+}_{(aq)} + I^{1-}_{(aq)} + Pb^{2+}_{(aq)} + NO_3{}^{1-}_{(aq)}$$

$$KI_{(aq)} + Pb(NO_3)_{2\,(aq)} \rightleftarrows K^{+}_{(aq)} + I^{1-}_{(aq)} + Pb^{2+}_{(aq)} + NO_3{}^{1-}_{(aq)} \rightarrow PbI_{2\,(s)}\downarrow + KNO_{3\,(aq)}$$

- 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:

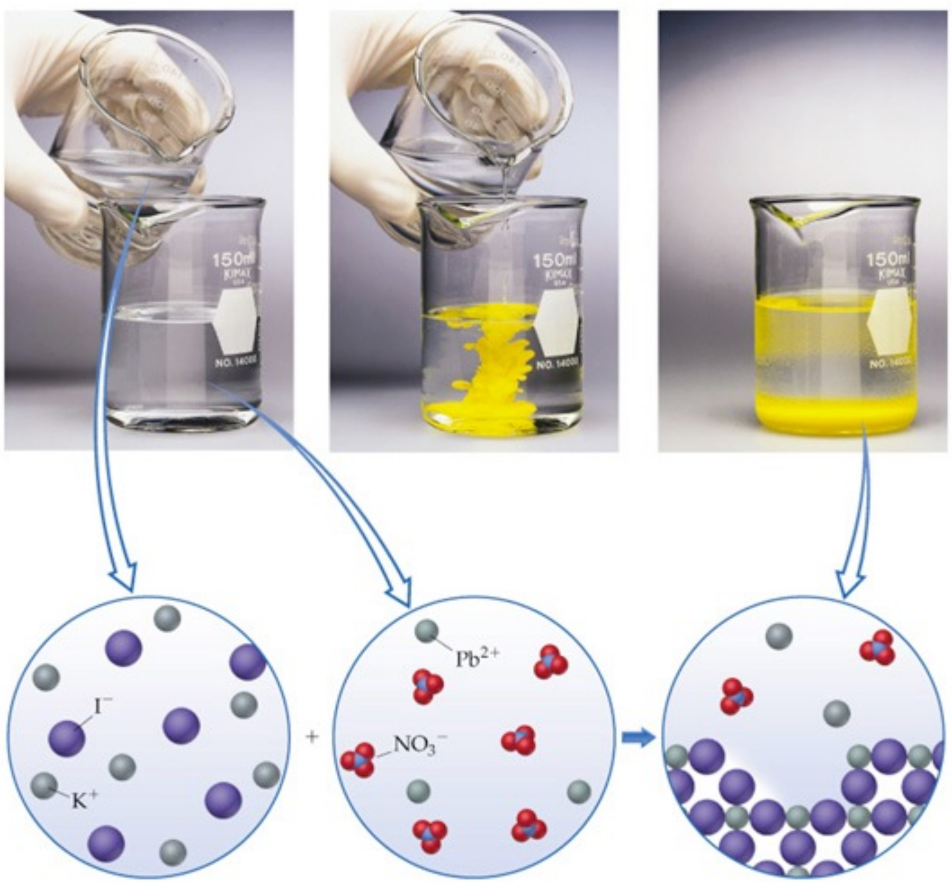
$$KI_{(s)} + Pb(NO_3)_{2\,(s)} \rightarrow N/R$$

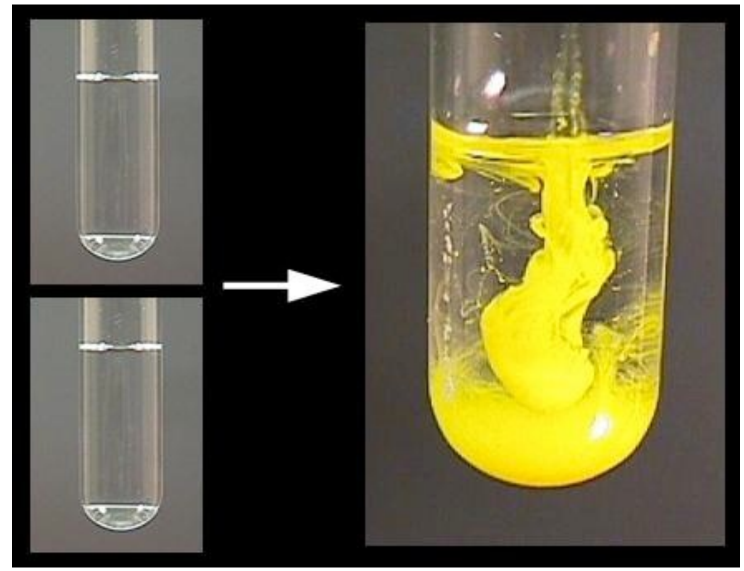
- How do you know if there's a reaction? (non-electrolytes)

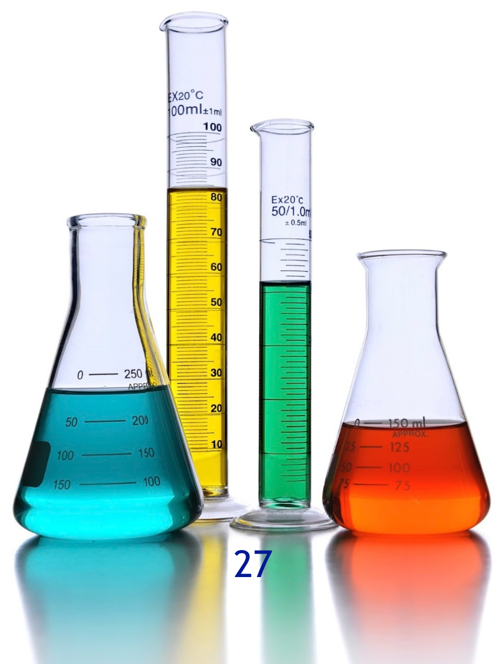
If one of the following products form, you know a reaction occurred:
(a) An insoluble solid (precipitate) (b) a Gas (c) Water

Solubility & Precipitation

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







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?

Magnesium Chloride$_{(aq)}$ + Lead(II) Acetate$_{(aq)}$ → ?

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

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

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

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

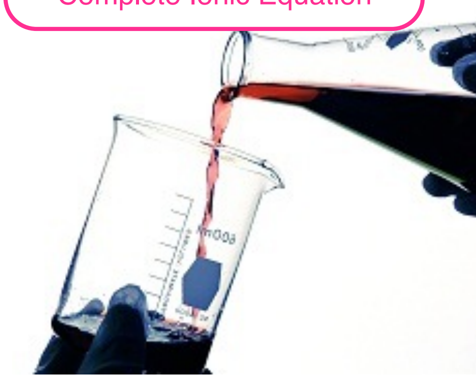
Spectator ions appear on both sides of the arrow.

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

Net Ionic Equation

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

Balanced Net Ionic Equation



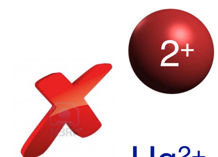
What forms a precipitate?

Check each step, **in order**.

Solubility Rules you are responsible for.

	Solubility Rules	Soluble (no precipitate)	Insoluble (forms precipitate)
Step 1 ANIONS	Acetates (OAc^{1-} or $CH3COO^{1-}$) Nitrates (NO_3^{1-})	Always	Never
Step 2 CATIONS	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

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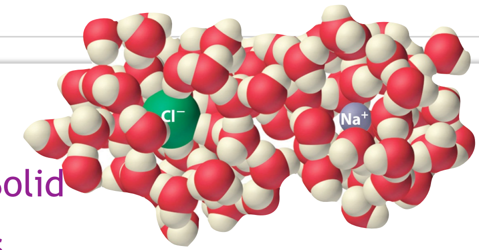
Solutions



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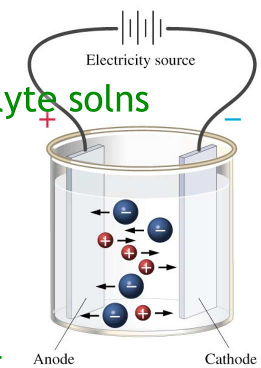

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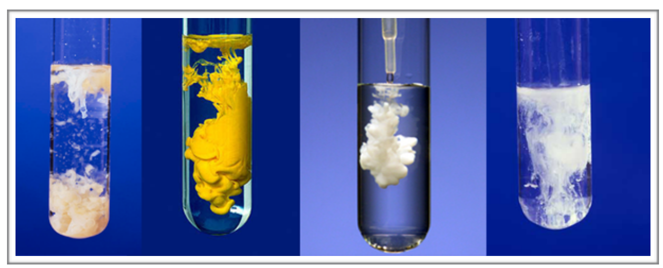
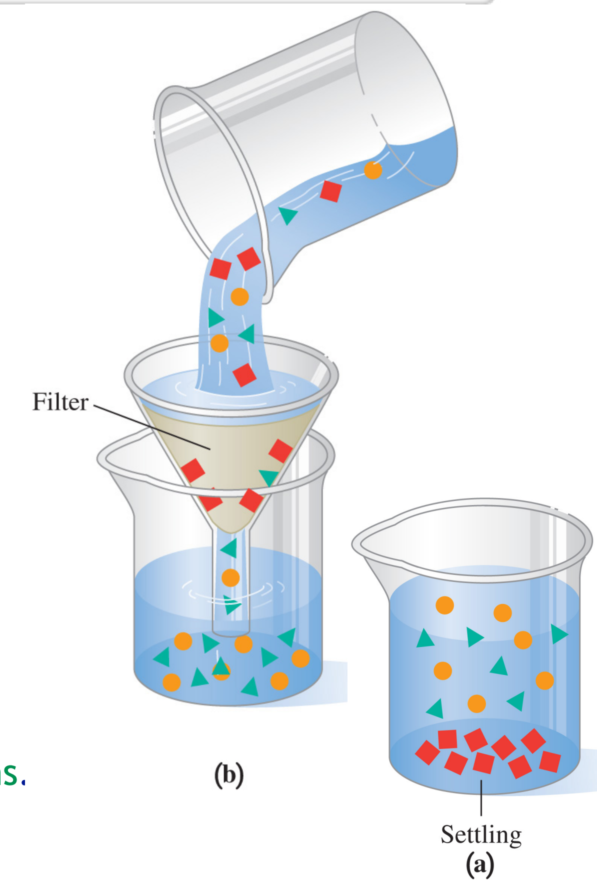


Heterogeneous Mixtures

- Mixtures whose particles are not mixed uniformly are heterogenous.
- Mixtures whose particles are mixed uniformly ***may be*** homogenous.
  - It depends on the difference in particle sizes.
  - Small molecules have sizes about 0.1 to 2.0 nm.
  - If the particles of one substance are very large compared to others, the particles themselves can constitute separate phases.
    - This produces heterogeneous properties in the mixture, regardless of how well you mix the substances.
- Mixtures of particles 0.1 to 2.0 nm uniformly distributed are usually solutions.
  - Solutions are transparent (light passes through them).
  - Once mixed, they stay mixed.
    - They don't spontaneously separate or settle.
- Mixtures of particles larger than 1000 nm uniformly distributed are suspensions.
  - Suspensions are opaque (light does not pass through them).
  - If not continuously mixed, they won't stay uniform.
    - Larger particles will stick to each other, the mixture will separate.
    - Lighter particles will float over heavier particles, the mixture will settle.



Colloids

- Distinguishing between colloids and solutions can be difficult.
  - To be classified as a colloid, the substance in the dispersed phase must be larger than the size of a molecule but smaller than what can be seen with the naked eye.
  - This can be more precisely quantified as one or more of the substance's dimensions must be between 1 and 1000 nanometers.
  - If the dimensions are smaller than this the substance is considered a solution and if they are larger than the substance is a suspension.
- Kinds of Colloids
  - Sol is a colloid containing solid particles.
  - Emulsion is a colloid containing liquid particles.
  - Foam is formed when many gas particles are trapped in a liquid or solid.
  - Aerosol contains small particles of liquid or solid dispersed in a gas.

Dispersion Medium	Dispersed Phase	Type of Colloid	Example
Solid	Solid	Solid sol	Ruby glass
Liquid	Solid	Sol	Paints, cell fluids
Liquid	Liquid	Emulsion	Milk, oil in water
Solid	Liquid	Solid emulsion/gel	Pearl, cheese
Solid	Gas	Solid foam	Lava, pumice
Liquid	Gas	Foam	Soap suds, whipped cream
Gas	Solid	Aerosol	Smoke
Gas	Liquid	Aerosol	Fog, mist

Three Types of Mixtures

Solutions	Colloids	Suspensions
composed of molecules of roughly the same size	composed of molecules of different sizes	have very large and very small particles
light passes through (are transparent)	scatters light (semi-opaque)	block light (are opaque)
do not separate	can be separated	can be separated
do not settle	do not settle	settle unless stirred
Saline solution Lemonade	Blood plasma Butter	Blood platelets Muddy water
Homogenous	Have properties of both.	Heterogeneous

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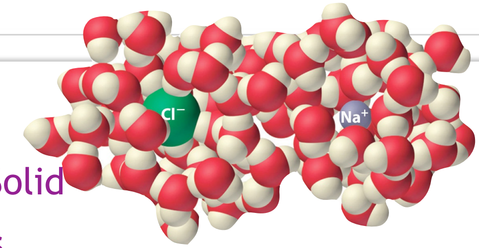
Solutions



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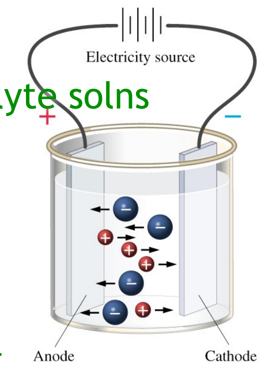

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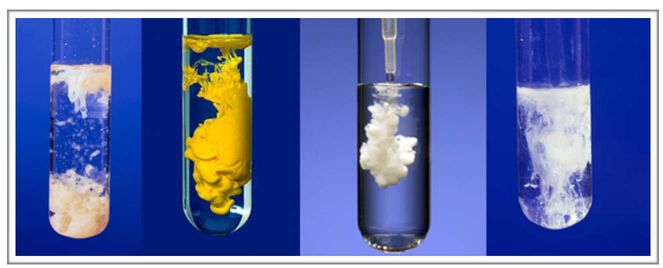
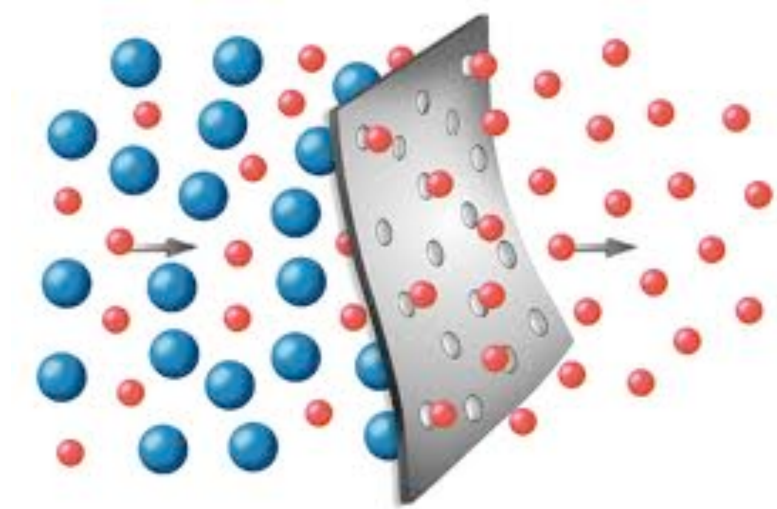
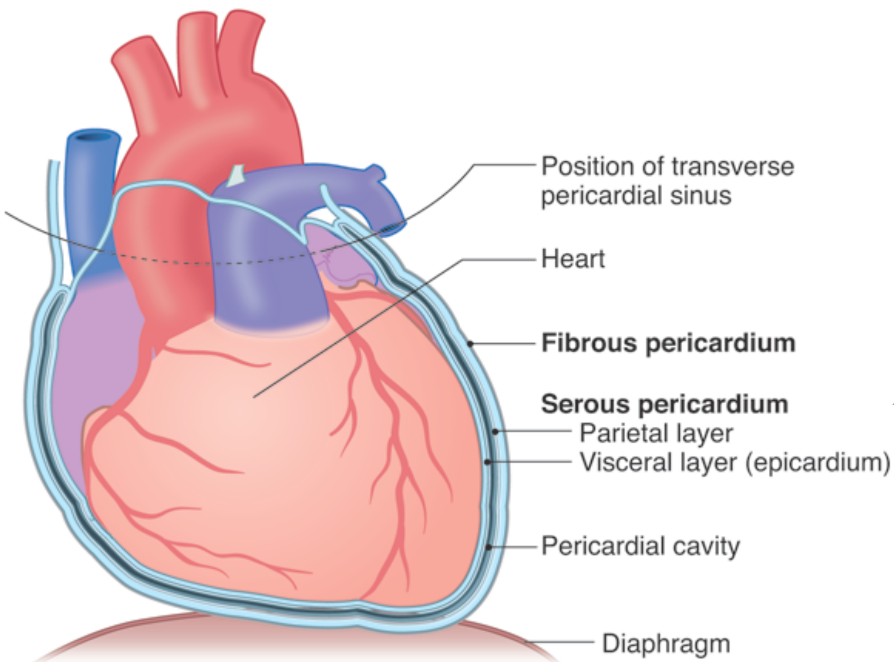
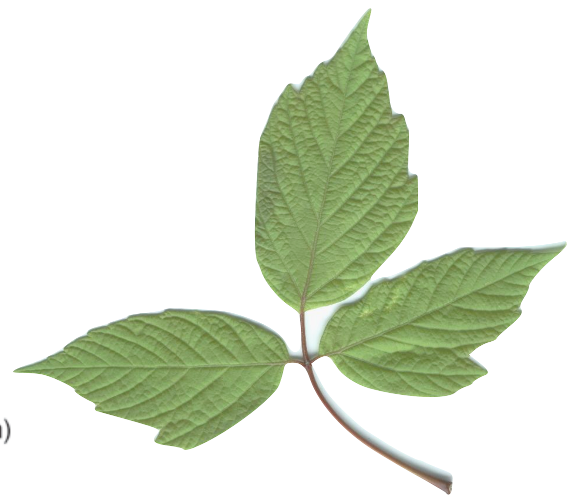


Membranes

- A membrane is a barrier.
- Biology creates barriers to separate substances into difference phases.
- That separation is part of many biological functions in plants and animals.

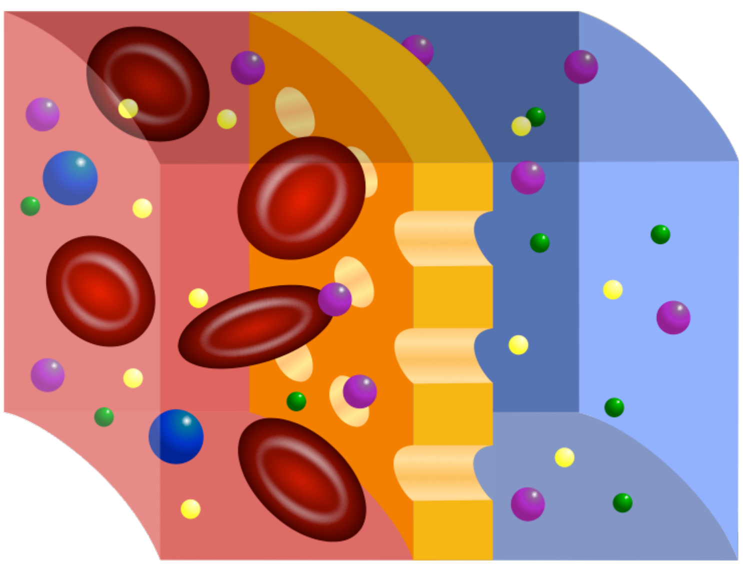


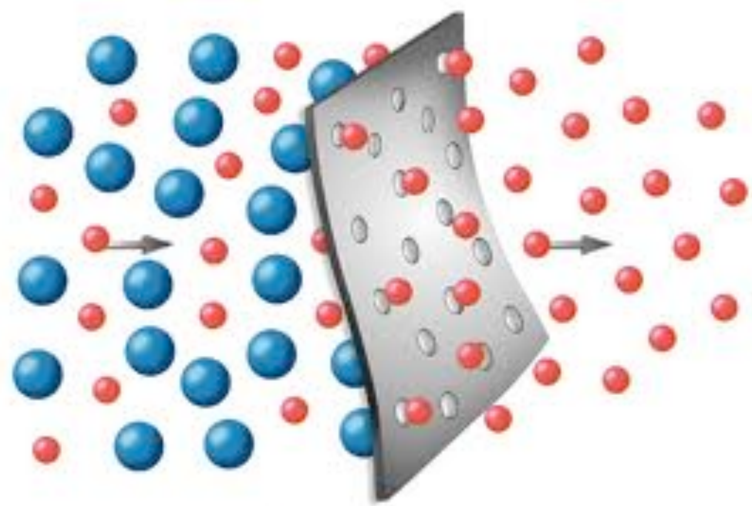


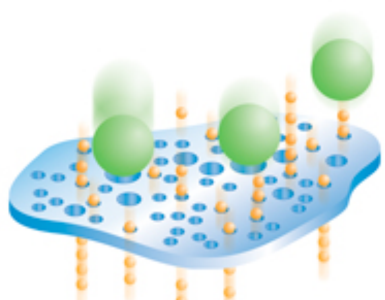


Semi-permeable Membrane

- Some barriers are semi-permeable.
  - They let some stuff permeate (go through) but not other stuff.
- Cell walls are an example of a semi-permeable layer.
- They separate "medium" particles from "small" particles.
- Semi-permeable membranes are another way to distinguish between colloids and solutions.



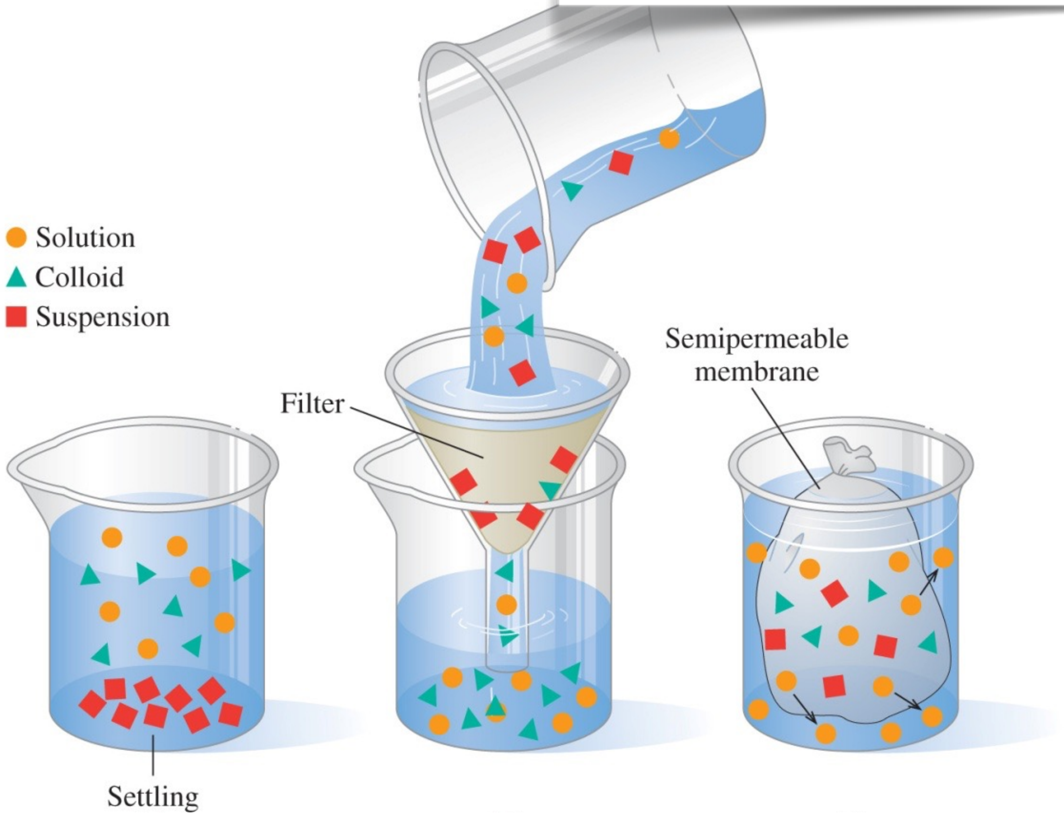




Types of Mixtures

- Separation and settling properties can be used to distinguish between types of mixtures.

Type of Mixture	Type of Particle	Settling	Separation
Solution	Small particles such as atoms, ions, or small molecules	Particles do not settle	Particles cannot be separated by filters or semipermeable membranes
Colloid	Larger molecules or groups of molecules or ions	Particles do not settle	Particles can be separated by semipermeable membranes but not by filters
Suspension	Very large particles that may be visible	Particles settle rapidly	Particles can be separated by filters



Ch09

Solutions

- Solubility
  - Why Solids are Solid
  - Making solutions
    - Molecular solvation
    - Ionic solvation – Dissociation
  - Electrolyte solutions
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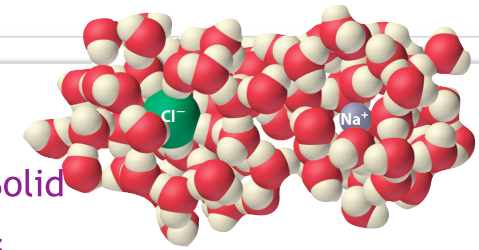

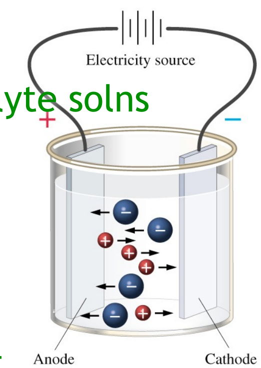

- Heterogenous Mixures
  - Colloids & Suspensions
  - Membranes
  - Osmotic Pressure
- Reactions with Solutions
  - Reduction & Oxidation
    - Oxidation States
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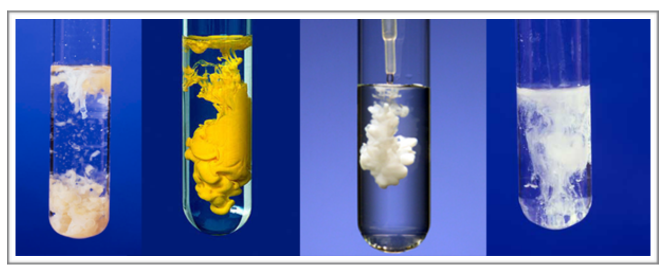
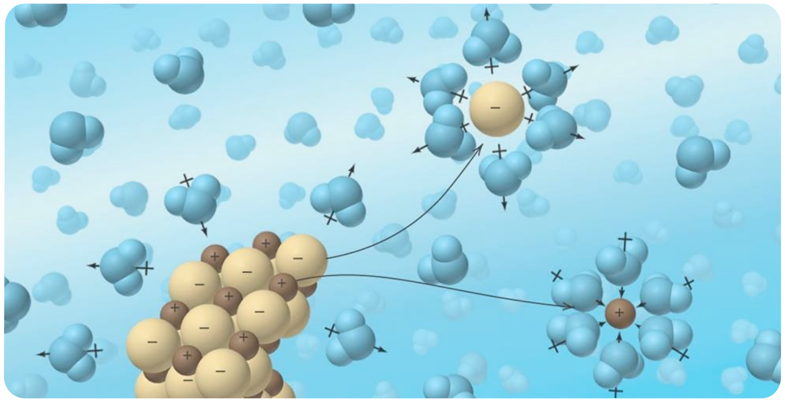
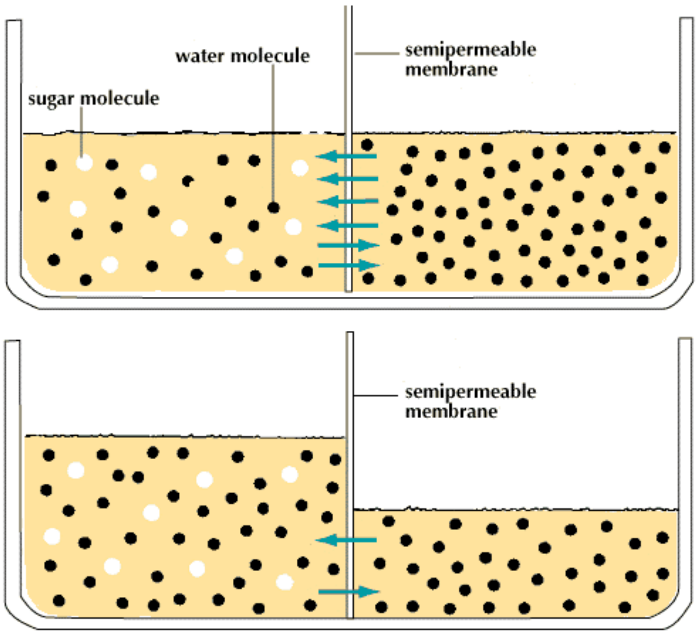
    - Combustion Reactions
  - Red-Ox Reactions
  - Single Displacement: A + BC ⇄ B + AC
  - Metal Activity
    - Predicting Red-Ox Reactions



Osmosis

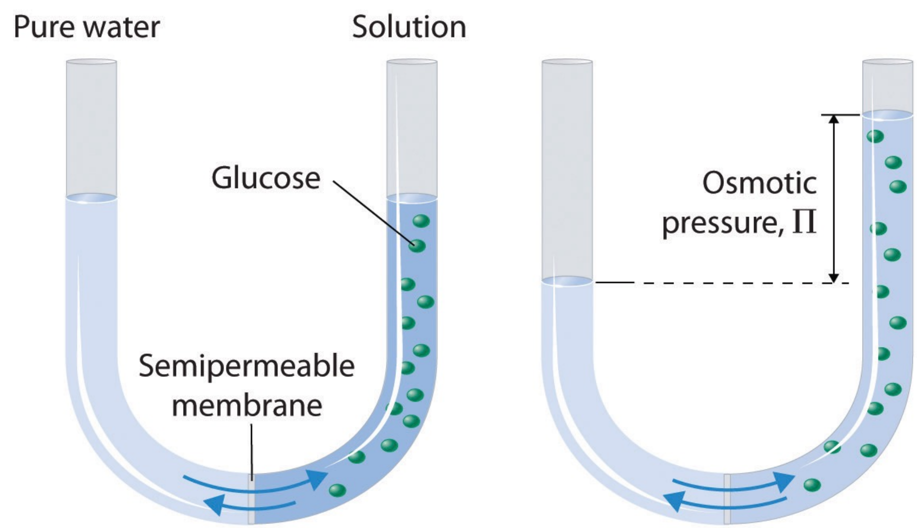


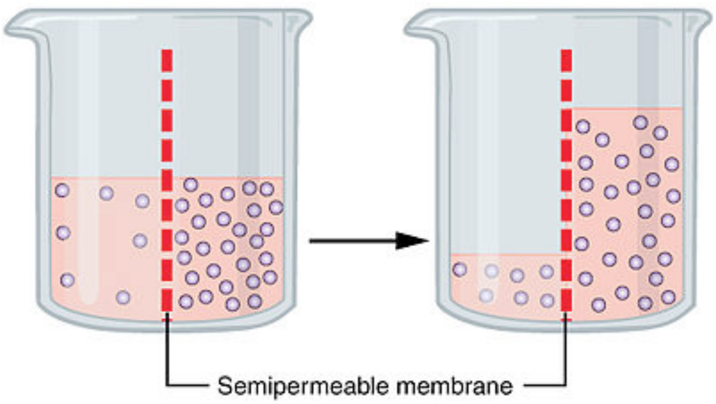


- Solvent will aggregate around ions.
- Otherwise it will spread out evenly if it can freely move around a space.
- If you have more ions on one side of a semi-permeable membrane than on the other.
  - One that blocks ions from moving across the membrane.
  - Water will move preferentially to the side that has more ions.
- This process is called osmosis.
- It's driven by the solution trying to produce equal concentrations on either side of the barrier.

Osmotic Pressure

- Solvent moving to produce equal concentrations on either side of a semi-permeable membrane will produce a pressure due to the electrolyte imbalance.
- This pressure is called osmotic pressure.
- Since red blood cells have semi-permeable membranes, electrolyte imbalances between the inside of the cell and plasma can create osmotic pressure on the cells.



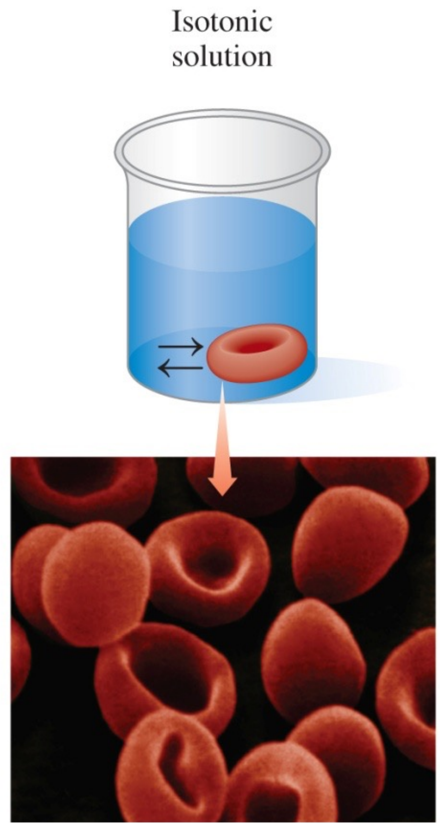


Isotonic Solutions

An **isotonic solution**

- exerts the same osmotic pressure as body fluids such as red blood cells (RBCs)
- of 5.0% (m/v) glucose or 0.90% (m/v) NaCl is a typical isotonic solution

(a) In an isotonic solution, a red blood cell retains its normal volume.

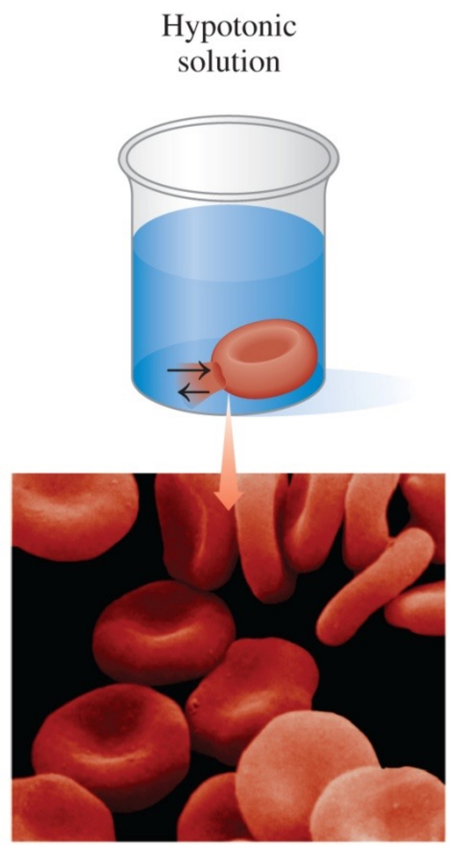


Hypotonic Solution

A **hypotonic solution**

- has a lower solute concentration than RBCs
- means water flows into cells by osmosis

The increase in fluid causes the cells to swell and burst, a condition called **hemolysis**.



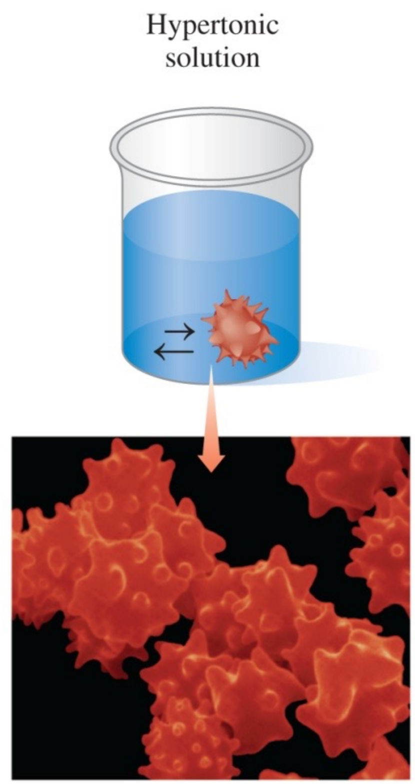
(b) Hemolysis: In a hypotonic solution, water flows into a red blood cell, causing it to swell and burst.

Hypertonic Solution

A **hypertonic solution**

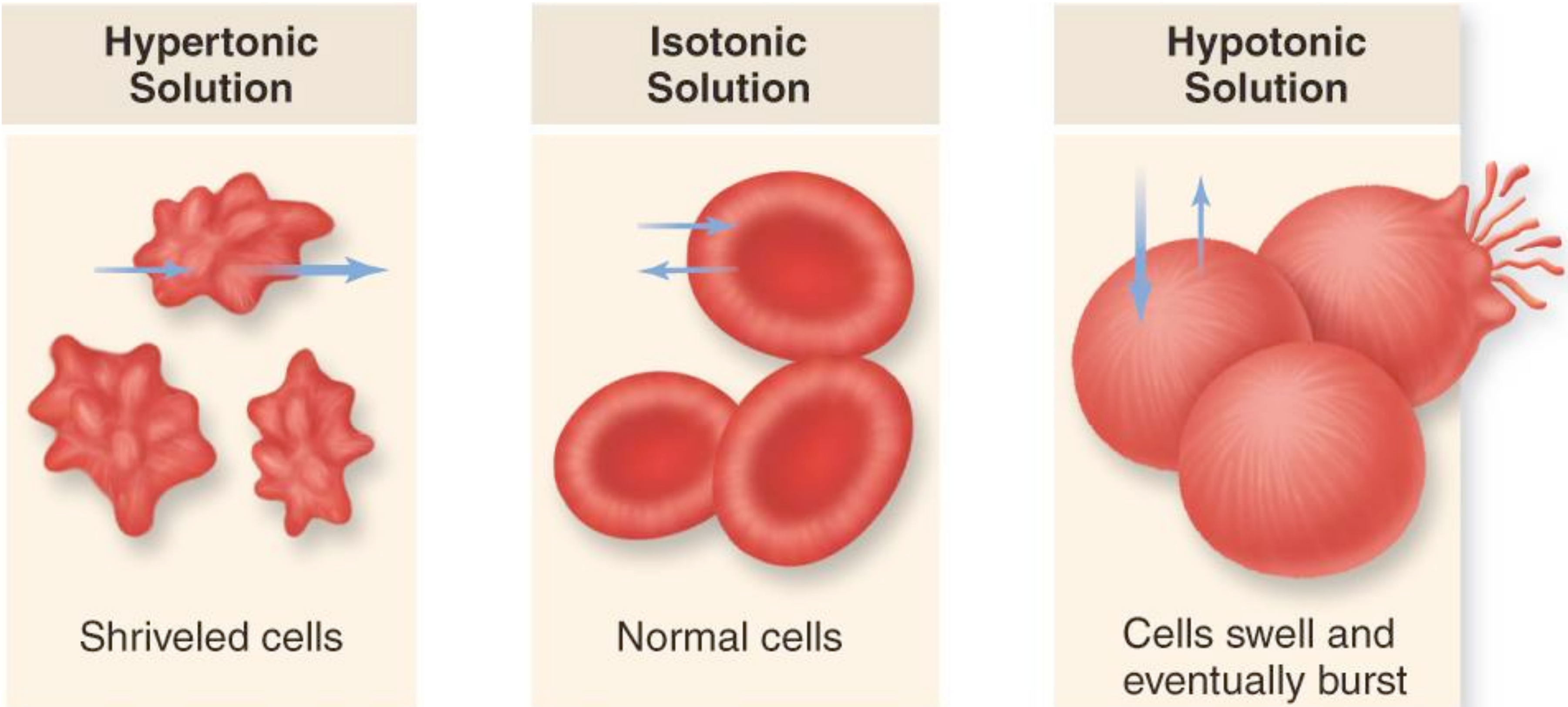
- has a higher solute concentration than RBCs
- causes **crenation**: RBCs shrink in size

In a hypertonic solution, water goes out of the cells by osmosis.



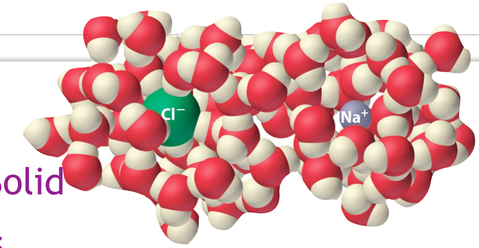
(c) Crenation: In a hypertonic solution, water leaves the red blood cell, causing it to shrink.

Osmotic Pressure



Ch09

Solutions



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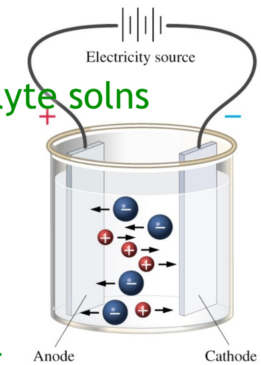

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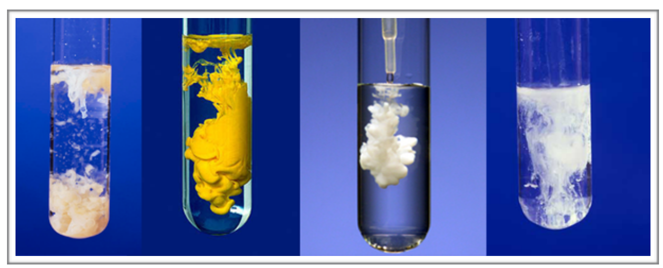


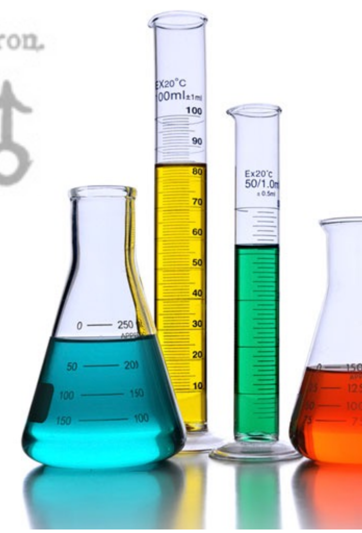
Reduction

- 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



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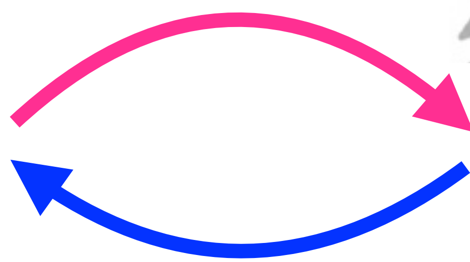
reduction

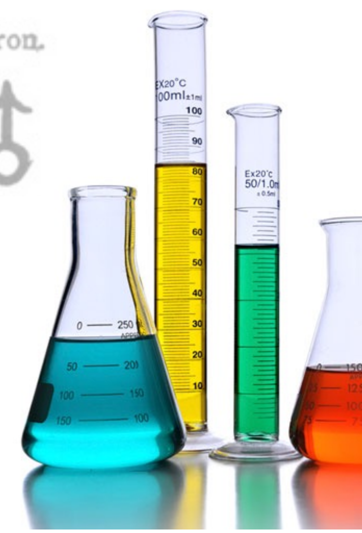
Fe_2O_3



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.



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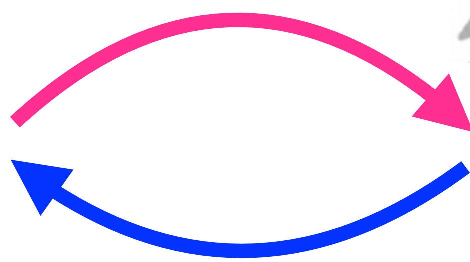
Fe_2O_3

Fe^{3+}

reduction

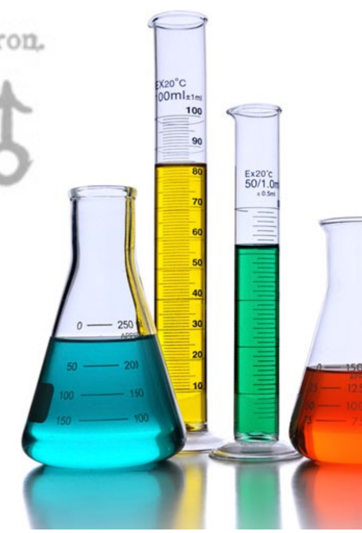
adding electrons



oxidation

removing electrons

Fe^{0}



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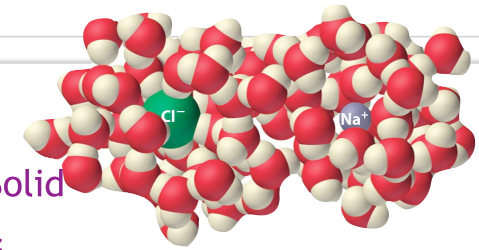
Ch09

Solutions



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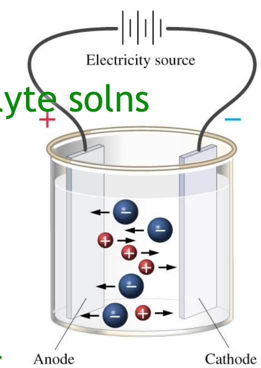

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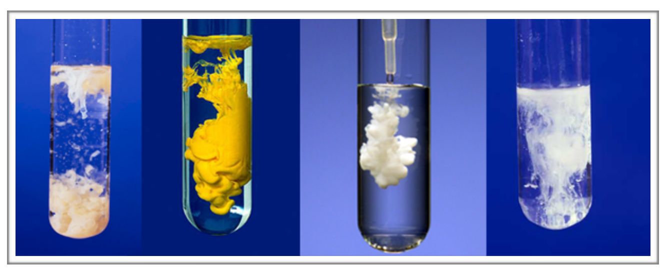


Oxidation State

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

$Fe^{3+} \rightarrow Fe^{0}$

reduction

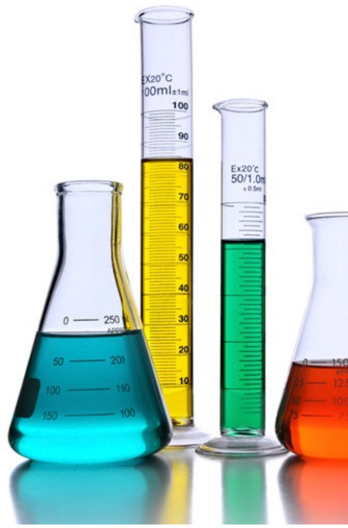
$Cl_2 \rightarrow Cl^{1-}$

reduction

$Al \rightarrow Al^{3+}$

oxidation

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



Oxidation State

- The balance between electrons and protons in an atom can be changed by adding/removing electrons.
  - An excess of either charge changes how the atom behaves.
  - Atoms adopt new properties in each of these different modes.
- These modes are called oxidation states.
- We describe oxidation states using oxidation numbers.

Elements in their natural state have an oxidation number of 0.

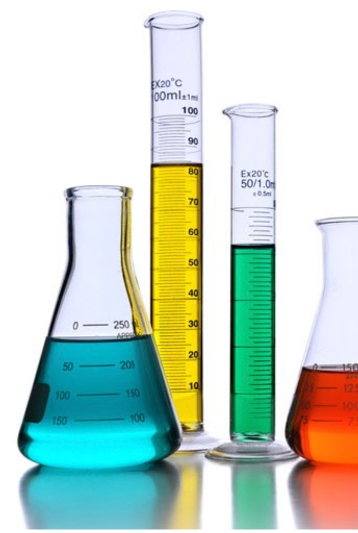
Monoatomic ions have an oxidation number equal to their charge.

$$\underset{\boxed{+6}}{Cr^{6+}} \underset{[ox]}{\overset{[red]}{\rightleftharpoons}} \underset{\boxed{+3}}{Cr^{3+}} \underset{[ox]}{\overset{[red]}{\rightleftharpoons}} \underset{\boxed{+2}}{Cr^{2+}} \underset{[ox]}{\overset{[red]}{\rightleftharpoons}} \underset{\boxed{0}}{Cr^{0}}$$

oxidation state

- Knowing the change in oxidation number helps us see whether an atom was oxidized or reduced.
  - An oxidation number going up, the atom was oxidized.
  - An oxidation number going down, the atom was reduced.

$$\underset{\boxed{0}}{H_2} \xrightarrow{[ox]} \underset{\boxed{+1}}{H^{1+}} \xrightarrow{[red]} \underset{\boxed{-1}}{H^{1-}}$$



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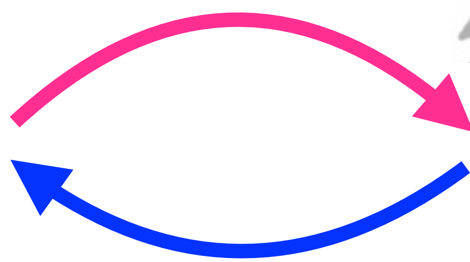
Fe^{3+}

Fe_2O_3

reduction

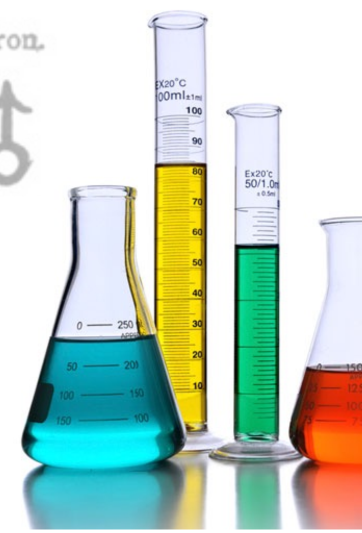
adding electrons



oxidation

removing electrons

Fe^0



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Ch09

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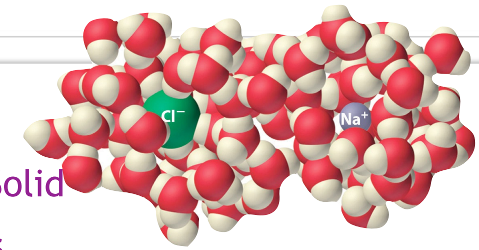

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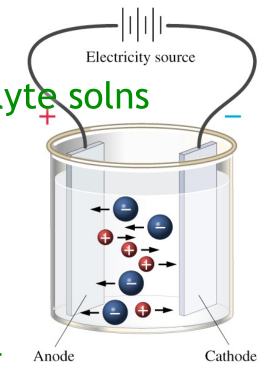

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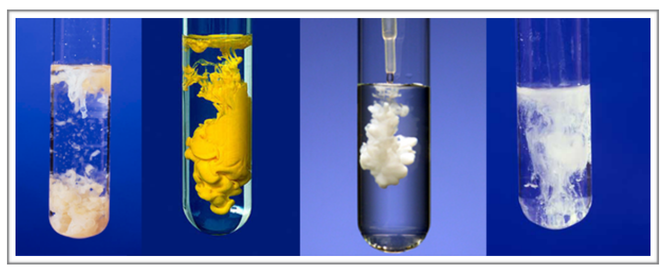
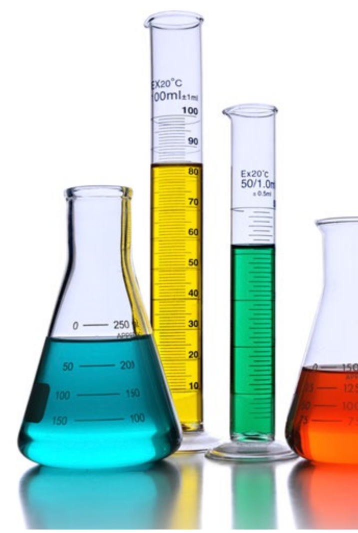


Molecular Compounds

- Reduction and oxidation reactions occur with molecular compounds and polyatomic ions as well.
- Shared electrons in covalent bonds are often not shared equally.
  - The shared electrons are often more on one atom than another.
- When atoms in molecular compounds rearrange, the new arrangement often changes the electrons an atom "owns."
- Oxidation numbers help track this change in these reactions.
  - 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.

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

$$SF_4 + F_2 \rightarrow SF_6$$



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    - 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.
  - 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 decreasing electronegativity, 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.

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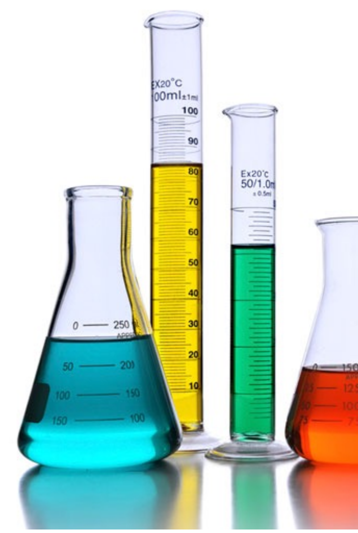

Chlorine's oxidation number?

0 Cl_2

-1 $NaCl$

ClO^{1-}

$HClO_3$

$ClOF_5$

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-} Cl^{X}

$$-2 + X = -1$$

$$X = ?$$

Chlorine's oxidation number?

0	Cl_2
-1	$NaCl$
+1	ClO^{1-}
+5	$HClO_3$
	$ClOF_5$
	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.

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

Chlorine's oxidation number?

0	Cl_2
-1	$NaCl$
+1	ClO^{1-}
+5	$HClO_3$
+7	$ClOF_5$
+9	Cl_2O_9

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

Cl^X Cl^X

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

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

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$$\boxed{-4} \xrightarrow{[ox]} \boxed{+4}$$

$$SF_4 + F_2 \rightarrow SF_6$$

$$\boxed{+4} \xrightarrow{[red]} \boxed{+6}$$

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**

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

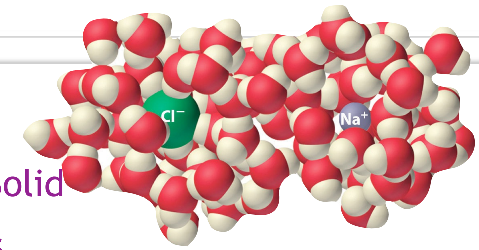
$\underline{Mn}O_4^{1-}{}_{(aq)} + I^{1-}{}_{(aq)} \rightarrow \underline{Mn}^{2+}{}_{(aq)} + I_{2\ (s)}$ **Reduced**

$\underline{Na}_3PO_{4\ (aq)} + H_2SO_{4\ (aq)} \rightarrow H_3PO_{4\ (aq)} + \underline{Na}_2SO_{4\ (aq)}$ **Neither**

Precipitating gold metal from gold ions in sea water. **Reduced**

Ch09

Solutions



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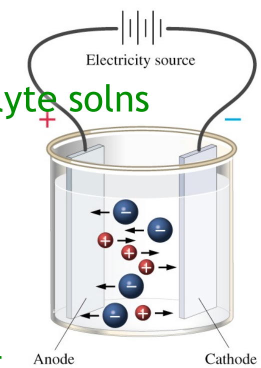

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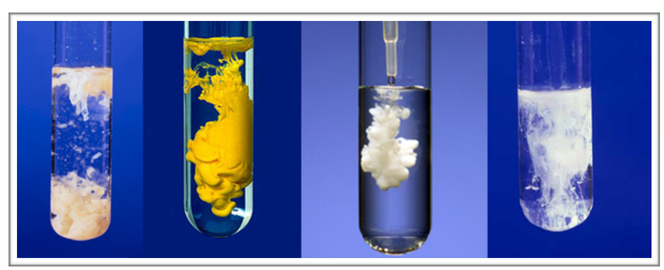


Hydrogen Oxygen Short-Cut

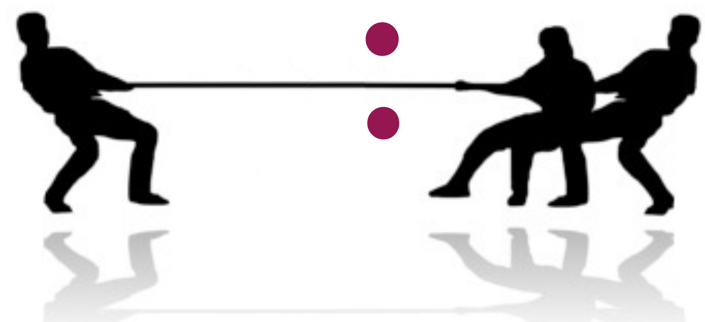
Reduction occurs by adding electrons.

When you add H you are giving carbon electrons.

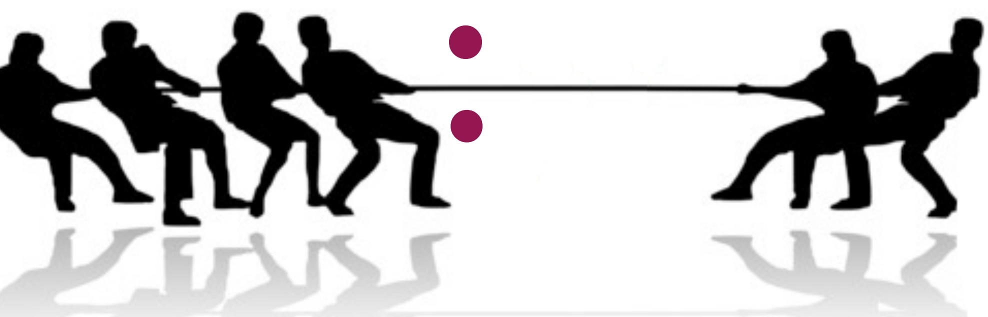
When you loose H, you are taking electrons from carbon.

H : C

each H-C bond is like
carbon getting extra electrons



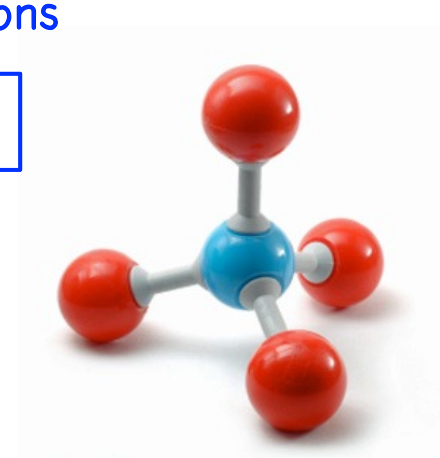
reduction



O : C

each O-C bond is like
carbon loosing electrons

oxidation



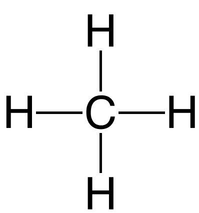
Oxidation occurs by removing electrons.

When you add O, you are taking electrons from carbon.

When you loose O, you are giving carbon back it's electrons.

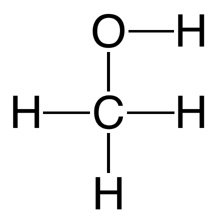
Hydrogen Oxygen Short-Cut

- When we talk about reducing or oxidizing a molecule, we are talking about a change in the oxidation state of it's central atoms.
  - Hydrogen and oxygen are at the extreme bottom and top of the electronegativity scale for molecular substances.
  - Everything else is usually between the two.
    - The most common element at the core of molecular substances is carbon.



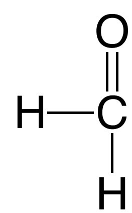
$\boxed{-4}$

CH_4



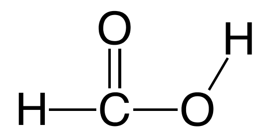
$\boxed{-2}$

CH_4O



$\boxed{0}$

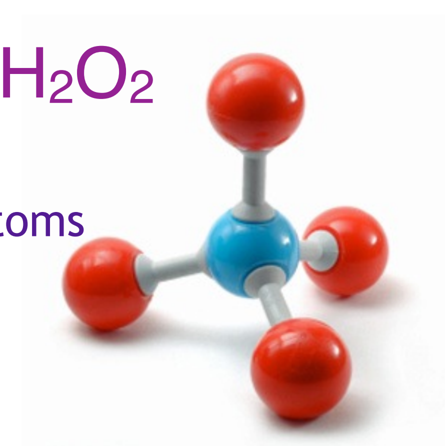
CH_2O



$\boxed{+2}$

CH_2O_2

- If the only change in a molecule is count of oxygen of hydrogen atoms you can use that change to decide if the molecule was oxidized or reduced.



Hydrogen Oxygen Short-Cut

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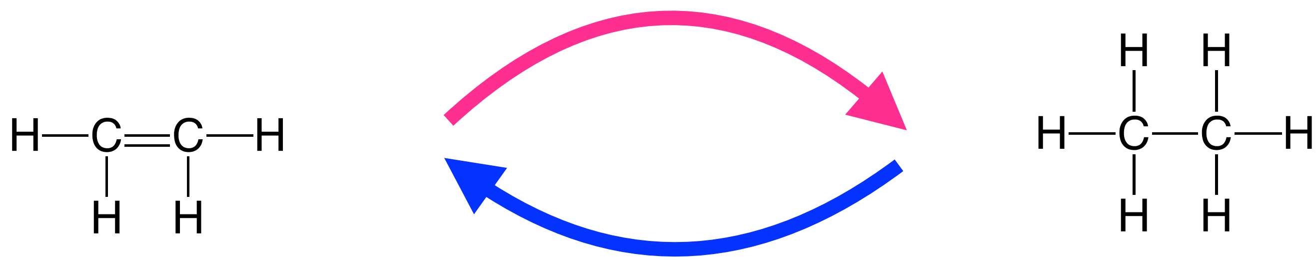
When you loose H, you are taking electrons from carbon.

reduction

adding electrons

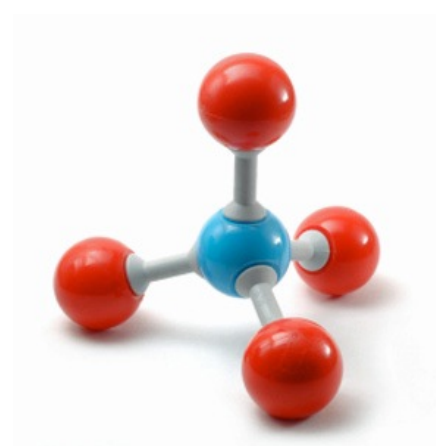
molecule gained two hydrogens
carbon gained electrons



oxidation

removing electrons

molecule lost two hydrogens
carbon lost electrons



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Hydrogen Oxygen Short-Cut

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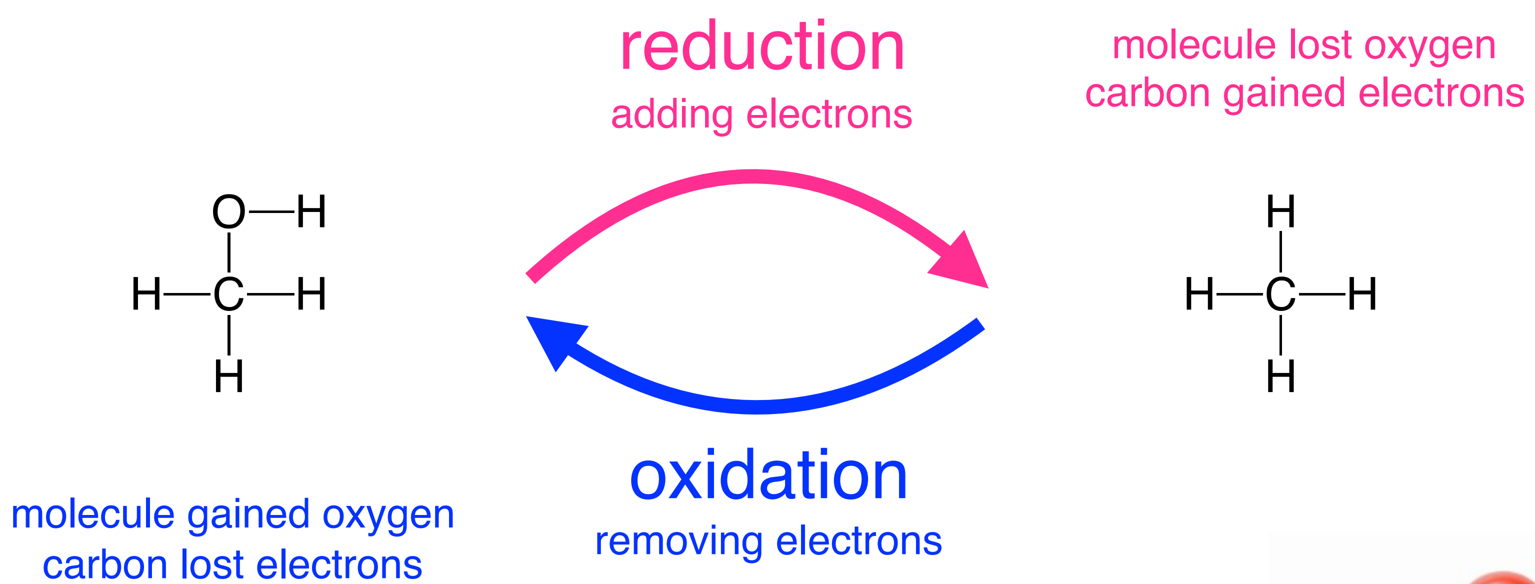

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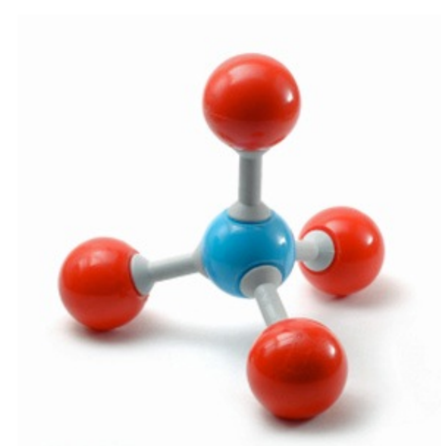
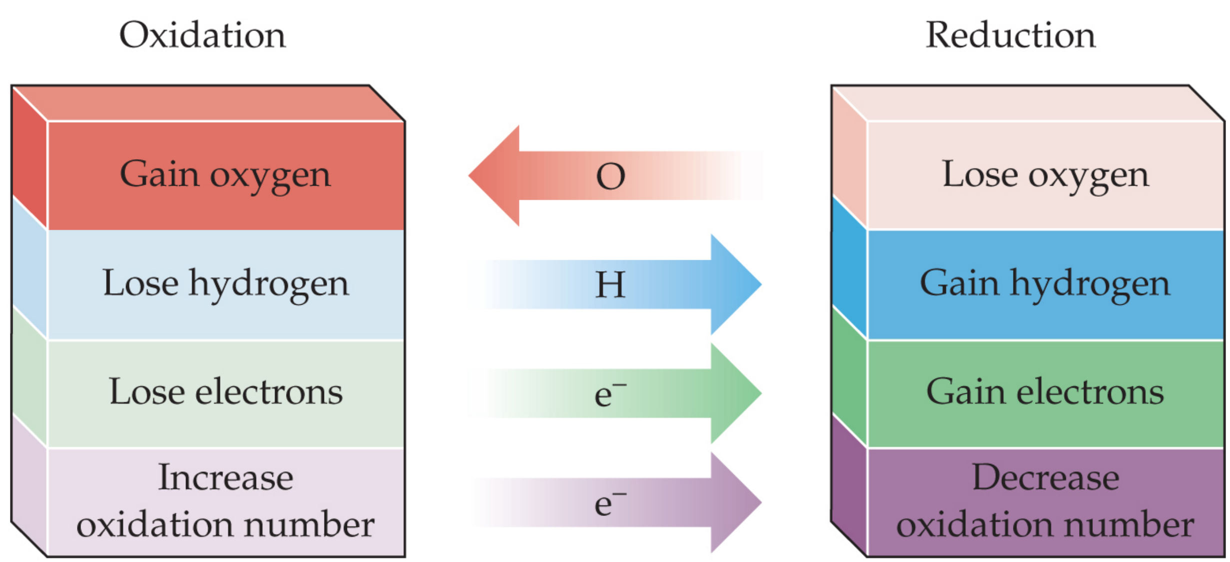
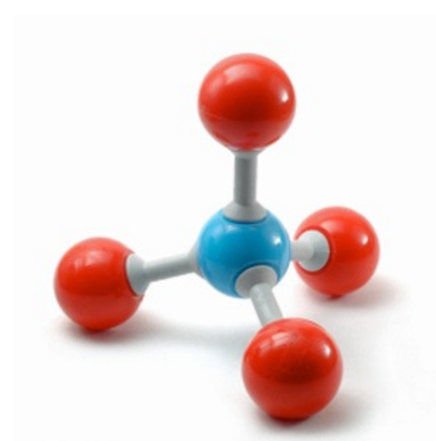
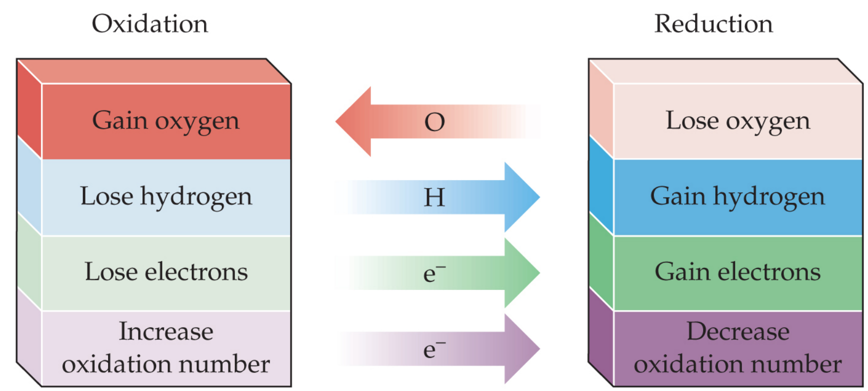


Hydrogen Oxygen Short-Cut

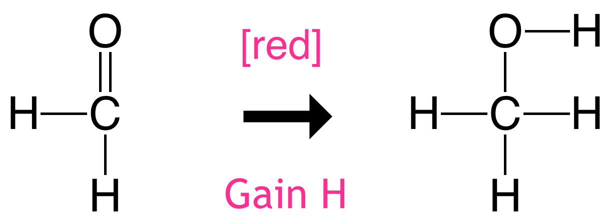
- Oxidation is the process of removing electrons.
- Reduction is the process of adding electrons.
- For organic molecules, we will focus on the oxidation state of carbon.
- It can be complicated to calculate what happened to the carbon atoms in an organic reaction, but there is a short cut.
  - Adding O-C bonds or loosing H atoms oxidizes the organic molecule.
  - Adding H-C bonds or loosing O atoms reduces the organic molecule.



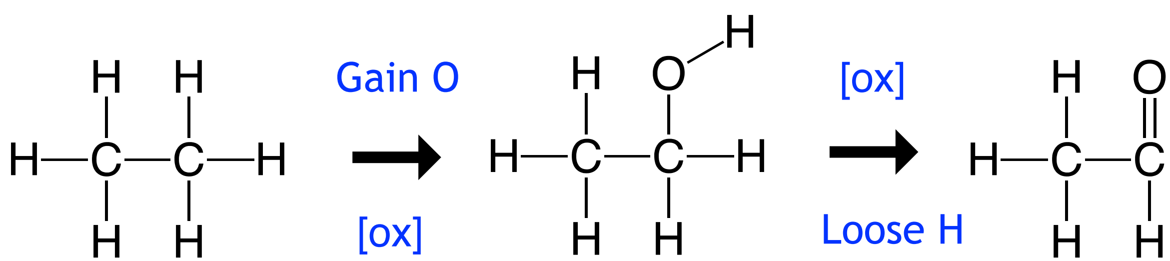




a.



b.

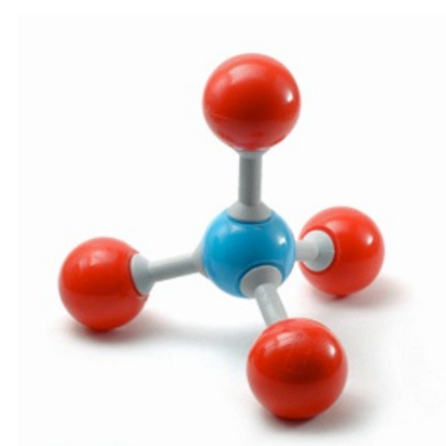


c.

$$H_2SO_4 \xrightarrow[\text{[red]}]{\text{Loose O}} H_2SO_3$$

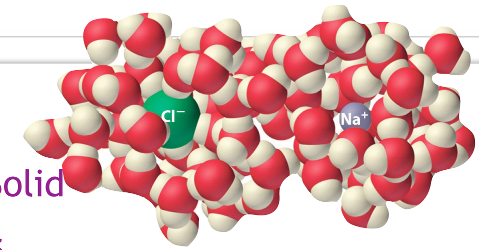
d.

$$CH_4 + O_2 \xrightarrow[\text{[ox]}]{\text{Gain O}} CO_2 + H_2O$$



Ch09

Solutions



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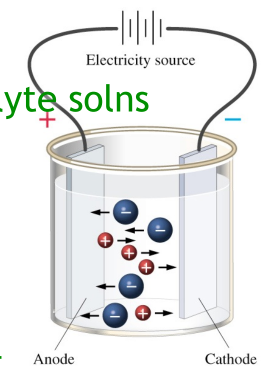

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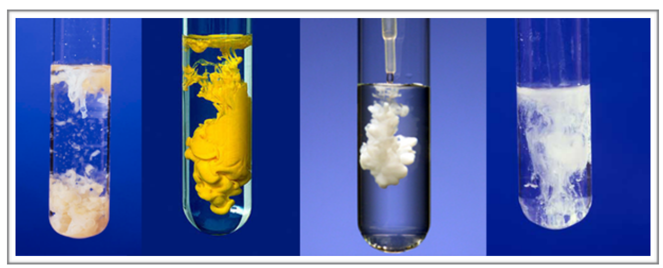
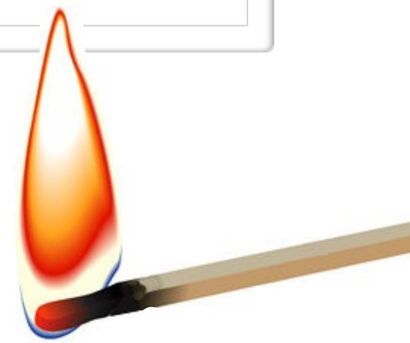
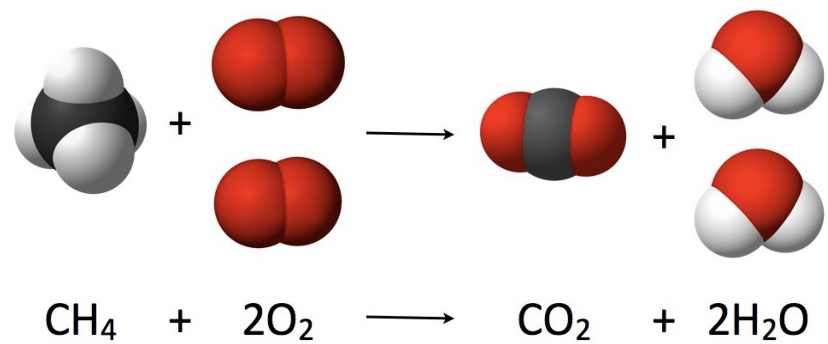


Combustion Reactions



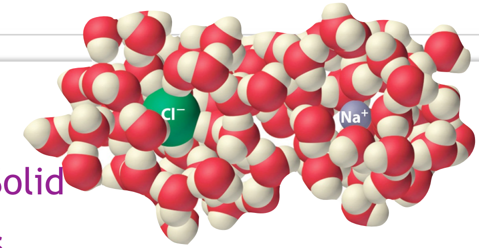
- Burning something is causing it to combust.
- Combustion reactions are reacting any substance with oxygen to form the most stable binary compounds of it's elements and oxygen.
- The most common products are CO_2 and H_2O. Other common products are NO_2 and P_2O_5.
- Combustion reactions are red-ox reactions, in which oxygen is reduced and other elements are oxidized.
- 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.
  - That property is also how the human body releases energy from food through respiration.



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

Ch09

Solutions



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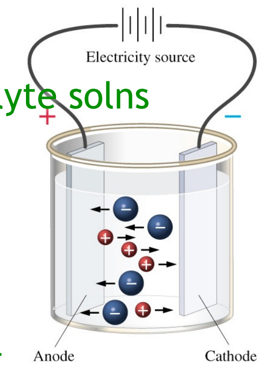

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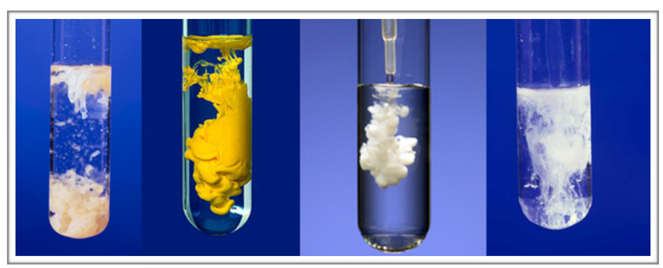
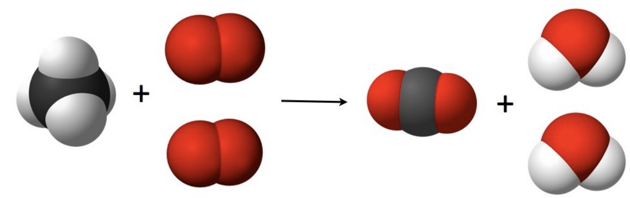


Red-Ox Reactions

- Electrons being added to one atom are lost by another.
  - When one substance is oxidized, another is reduced.
- We classify chemical reactions by the type of reactivity and also by kinetics.
  - A red-ox reaction is any chemical reaction in which the oxidation states of atoms are changed.
    - Combustion, respiration, and many of the most important chemical processes on earth are red-ox reactions.
    - Metals reacting with acids or electrolyte solutions are good illustrations of red-ox reactions.



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

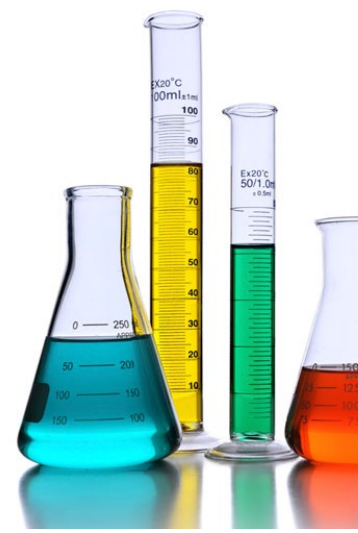
[red] +8e

C 4 O C 4 O

1 (−4) 4 (0) 1 (+4) 4 (−2)

[ox] -8e

- 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.



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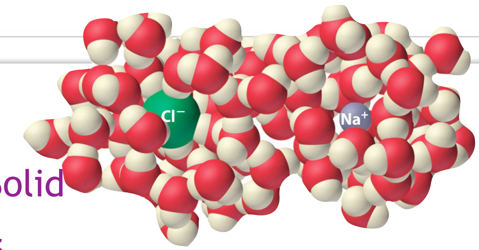

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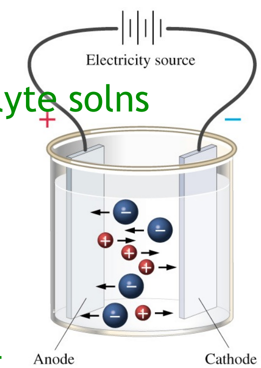

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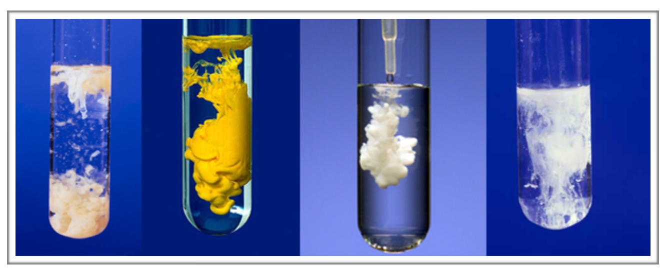


Red-Ox Reactions

- 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.

$$Zn_{(s)} + CuBr_{(aq)} \rightarrow ZnBr_{2(aq)} + Cu_{(s)}$$

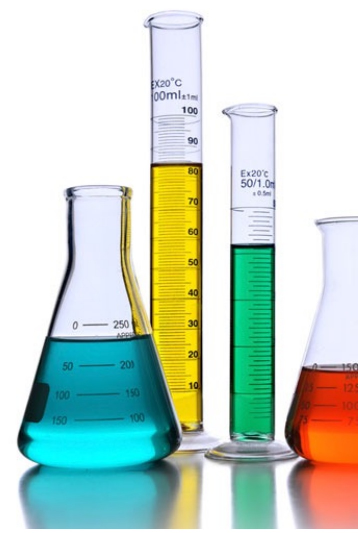
$$Zn_{(s)} + Cu^{1+}{}_{(aq)} + Br^{1-}{}_{(aq)} \rightarrow Zn^{2+}{}_{(aq)} + Br^{1-}{}_{(aq)} + Cu_{(s)}$$

$$0 \qquad +1 \qquad -1 \qquad\qquad +2 \qquad\qquad -1 \qquad\qquad 0$$

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

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

- 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.

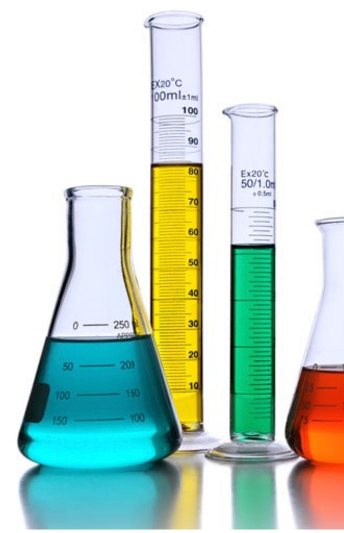
$$Zn_{(s)} + HBr_{(aq)} \rightarrow ZnBr_{2(aq)} + H_{2(g)}$$

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

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

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

  - How can we know if these reactions will occur?



Half Reactions

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

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

$$Mg_{(s)} + Pb^{2+} + \cancel{NO_3}^{1-} \rightarrow Mg^{2+} + \cancel{NO_3}^{1-} + Pb_{(s)}$$ Complete Ionic Equation

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

$$Mg_{(s)} + Pb^{2+} \rightarrow Mg^{2+} + Pb_{(s)}$$ Net Ionic Equation

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

$$Mg_{(s)} \rightarrow Mg^{2+} + 2e^-$$
$$Pb^{2+} + 2e^- \rightarrow Pb_{(s)}$$
Half Reaction Equations

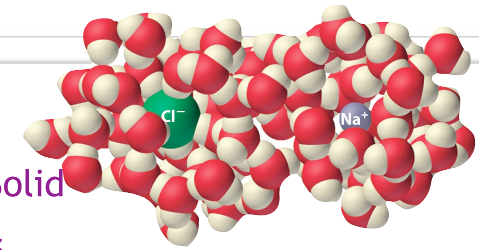
- The two half reactions show that we're looking at a competition for electrons. It's basically a tug of war.
- You can turn around one equation to compare them side to side.
We need to decide who's gonna win the fight over those two electrons.

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

- 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.

Ch09

Solutions



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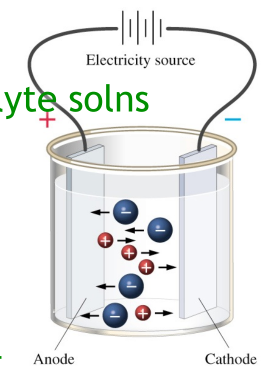

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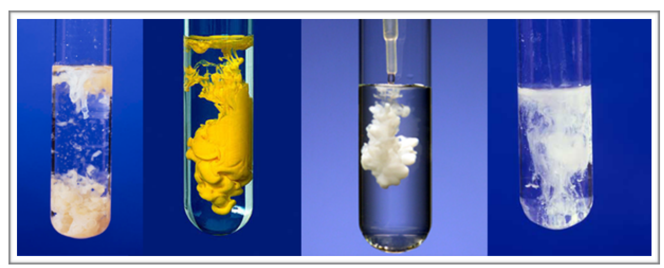

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Activity Series

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

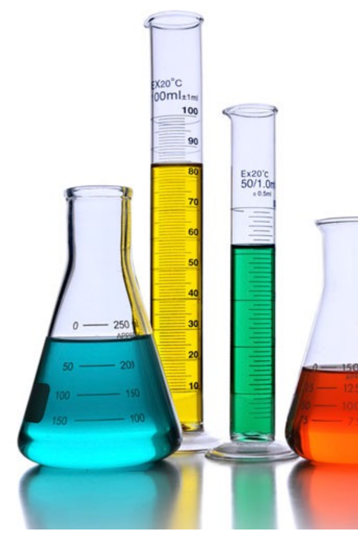
ACTIVITY

- 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.

$$A + BC \rightarrow AC + B$$
$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^-$$
$$2e^- + Mg^{2+} \leftarrow Mg_{(s)}$$



Activity Series

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Sodium	Na
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Aluminum	Al
Zinc	Zn
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Cobalt	Co
Nickel	Ni
Tin	Sn
Lead	Pb
Hydrogen	H_2
Copper	Cu
Silver	Ag
Gold	Au

ACTIVITY

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

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

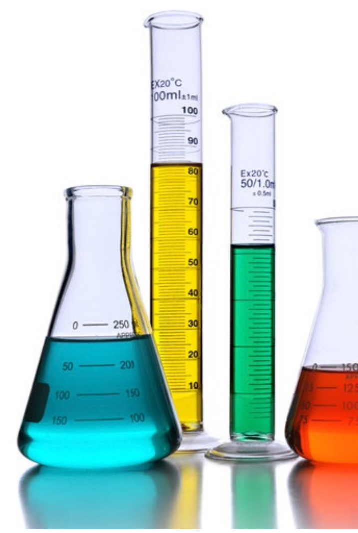
$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^-$$

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

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

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

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



Activity Series

K Ca Na Mg

Al Zn

Fe Co Ni

Sn Pb

H

Cu Ag Au

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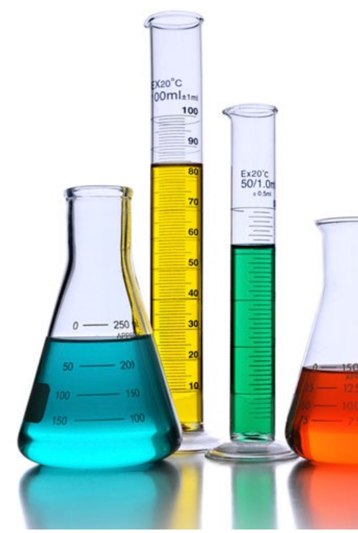
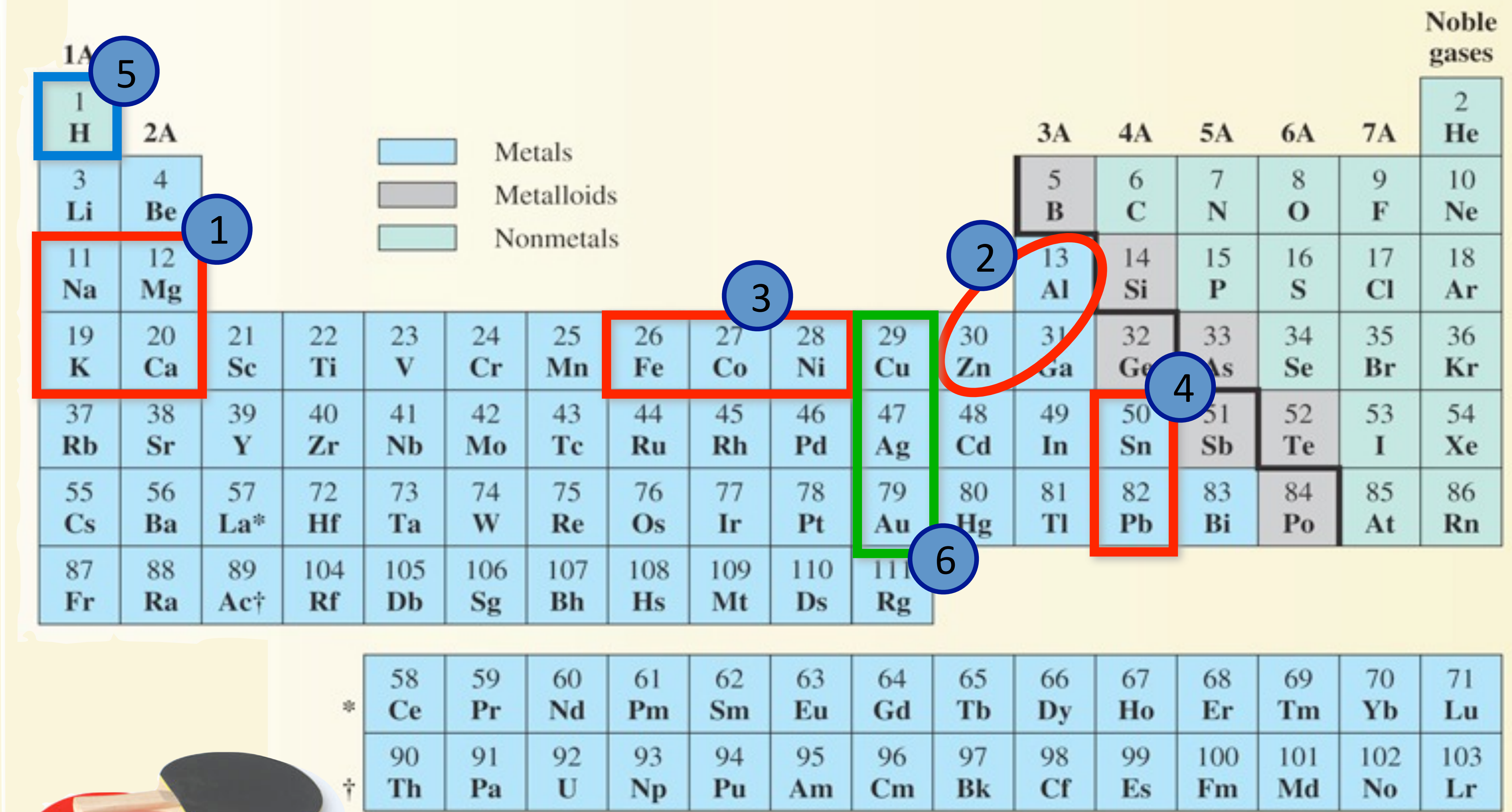


Metal Activity Series



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)?
  - You can use a periodic table or activity list to justify the decision.

Sodium or Iron?

Al or Co?

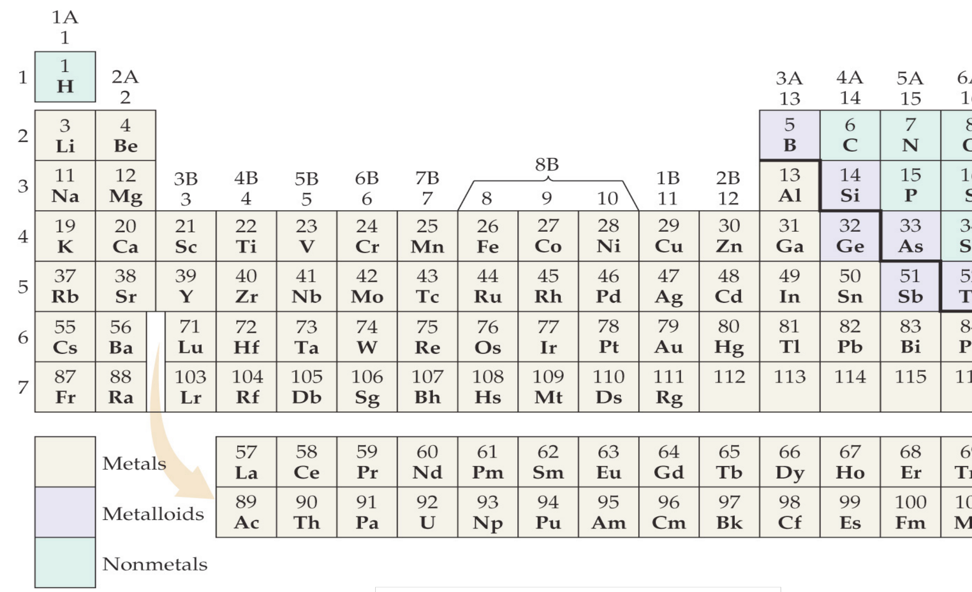
H_2 or Mg?

Hydrogen or Gold?

Zinc or Sodium?

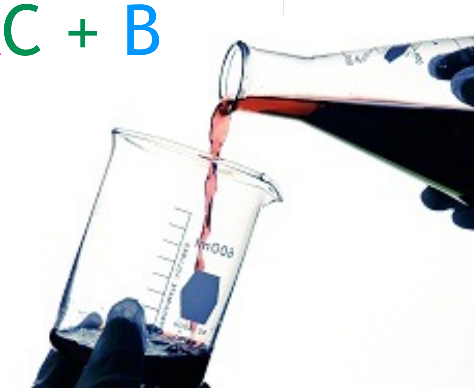
Pb or Cu?

Nickel or Calcium?



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

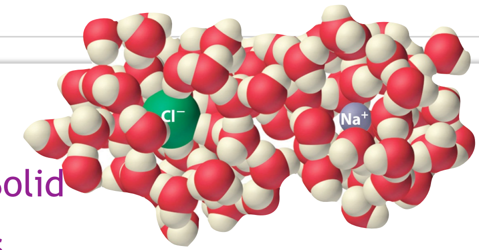
If "A" is more active, the reaction occurs.

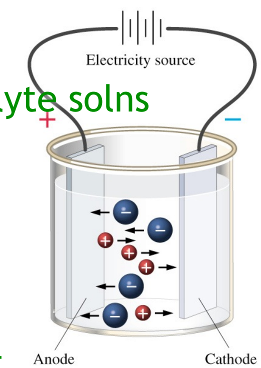


Ch09

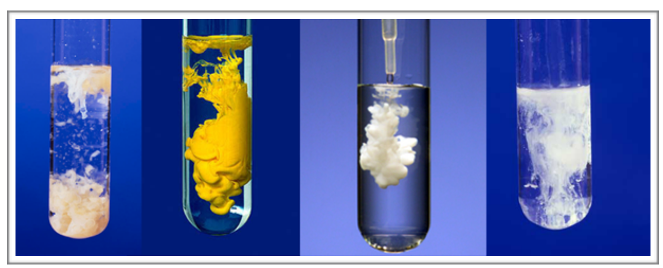
Solutions

- Solubility
  - Why Solids are Solid
  - Making solutions
    - Molecular solvation
    - Ionic solvation – Dissociation
  - Electrolyte solutions
    - Electrolyte & Non-Electrolyte solns
    - Electrolyte strength
- Solution Concentration
  - Measures of concentration.
    - Molarity and mass percent.
    - Using molarity as a conversion factor.
    - Solving for molarity.
  - Dilution
- Reactions in Solution
  - Double Displacement: AB + CD ⇄ AD + CB
  - Precipitation Reactions
  - Ionic eqns (complete & net)
    - Predicting Precipitation Reactions





- Heterogenous Mixures
  - Colloids & Suspensions
  - Membranes
- Reactions with Solutions
  - Reduction & Oxidation
    - Oxidation States
      - Molecular Substances
      - Organic Molecules
    - Combustion Reactions
  - Red-Ox Reactions
  - Single Displacement: A + BC ⇄ B + AC
  - Metal Activity
    - Predicting Red-Ox Reactions



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.

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

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

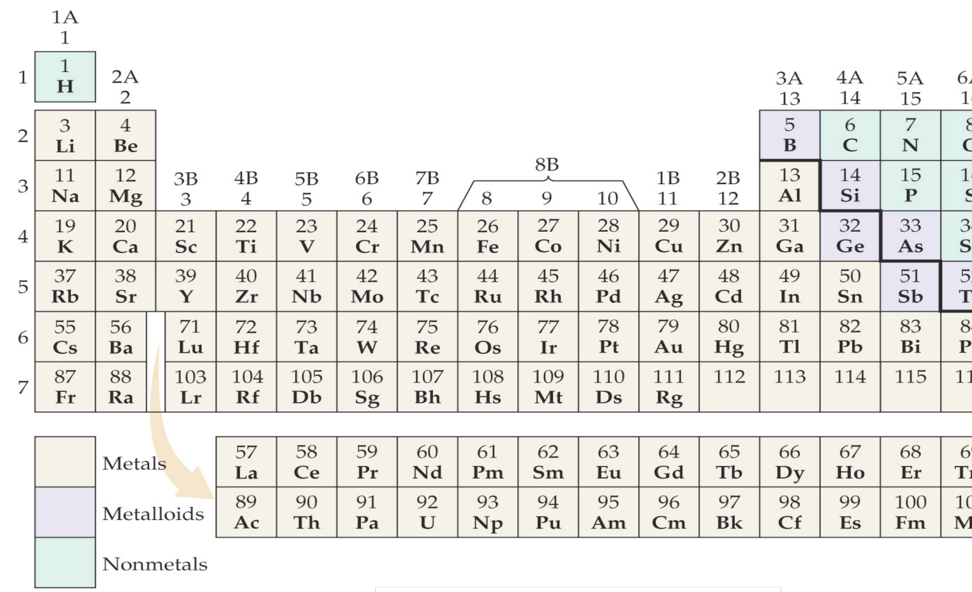
Fe more active than Zn? No.

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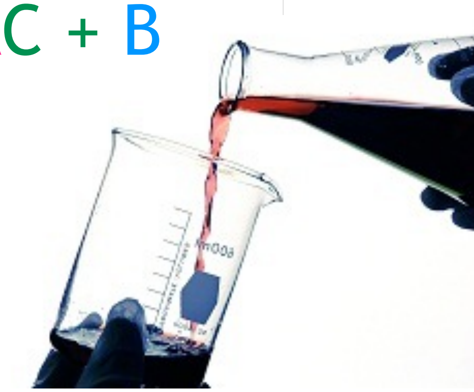


Reaction Types

Considering…

- Kinetics (what could be formed?)
  - Double Displacement
  - Single Displacement
- Driving force (will it happen?)
  - Precipitation Reactions
  - Reduction-Oxidation Reactions
    - Metal Activity
    - Combustion
  - Coming up next, other driving forces…
    - Combustion Acid Base Reactions
    - Gas Evolution Reactions

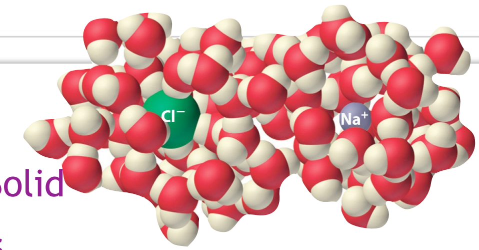
$$AB + CD \rightarrow AD + CB$$

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

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

Ch09

Solutions



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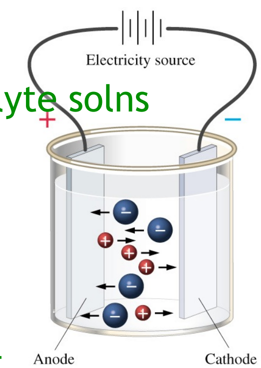

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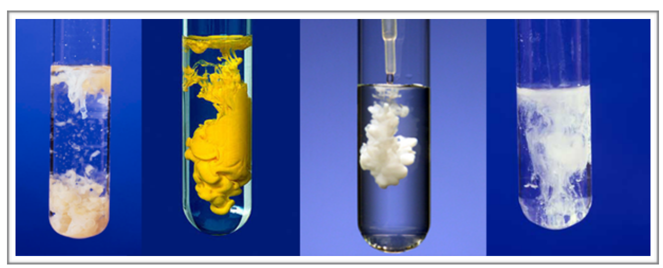

Questions?