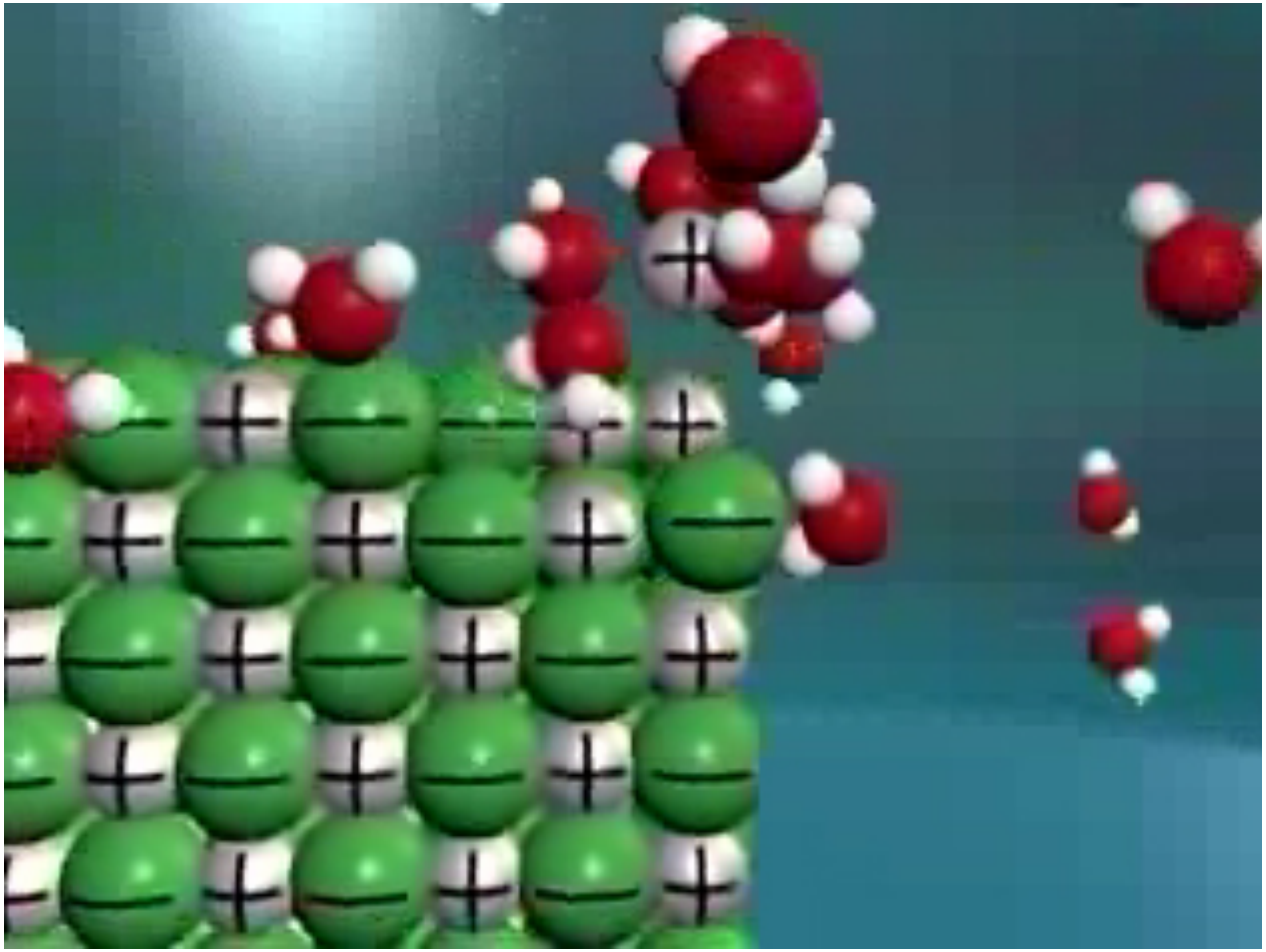
Chapter 4
Aqueous Reactions and Solution Stoichiometry

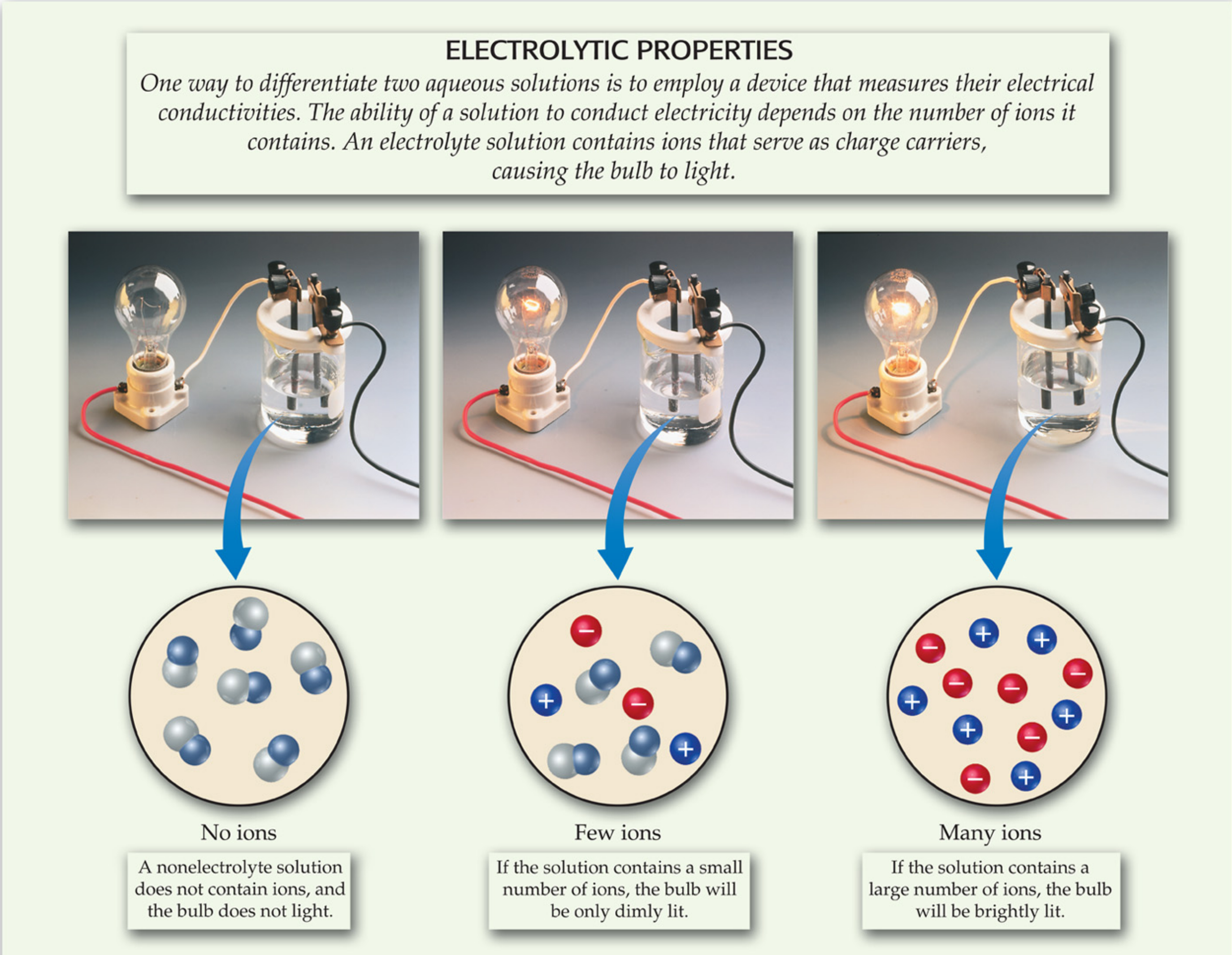
Solutions:

- Homogeneous mixtures of two or more pure substances.
- The solvent is usually present in greatest abundance.
- Or, the solvent is the liquid when a solid is dissolved
- All other substances are solutes.

Dissociation

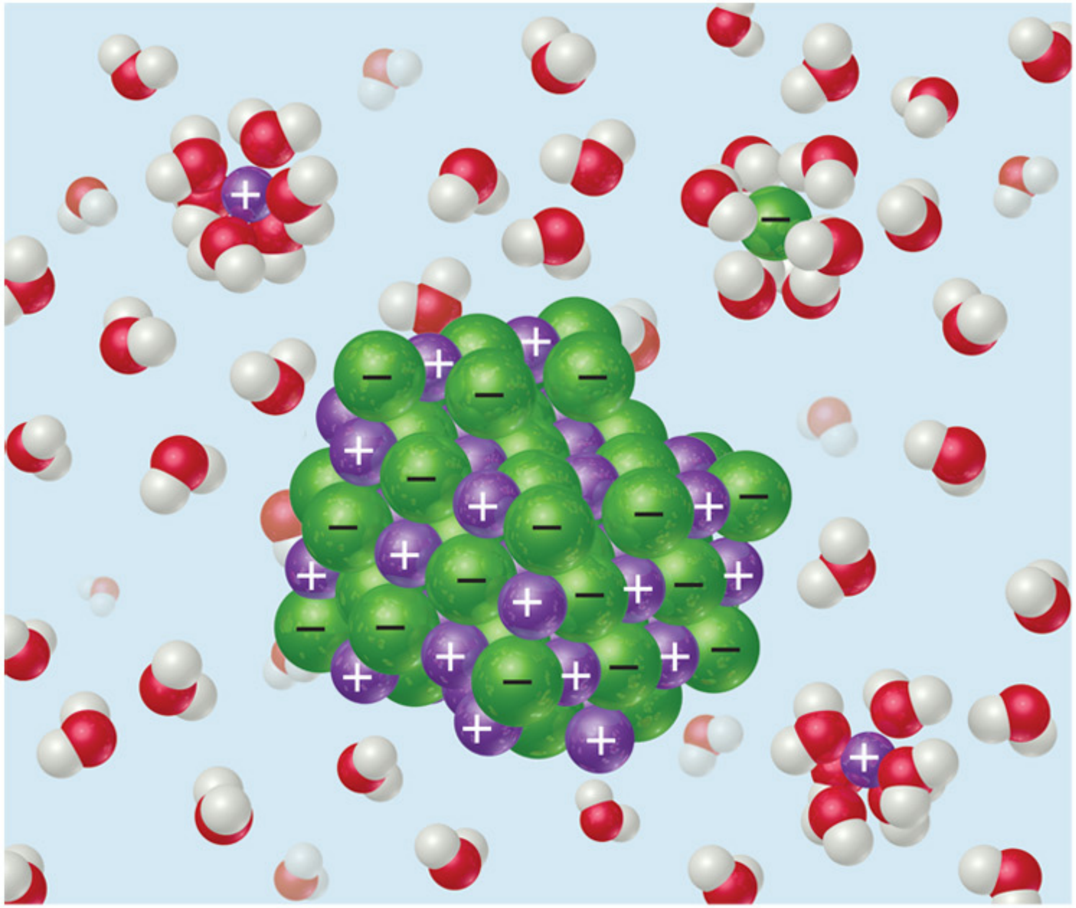


- ionic compound dissolves in water
- individual ions are separated.
- dissociation.



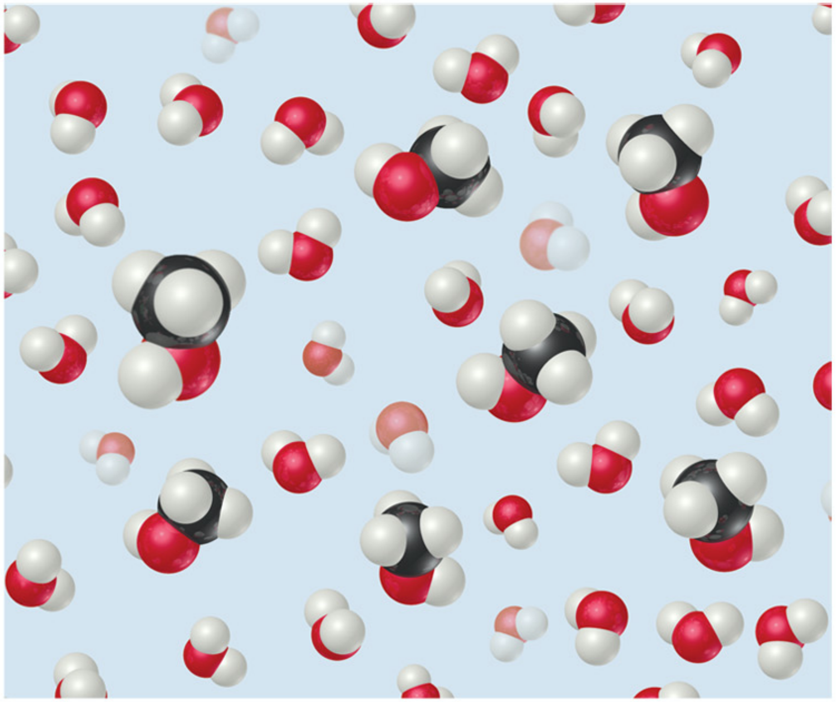
- Substances that dissociate into ions when dissolved in water are electrolytes.
- A nonelectrolyte may dissolve in water,
- but it does not dissociate into ions when it does so.

Electrolytes and Nonelectrolytes



Soluble ionic compounds tend to be electrolytes.

Electrolytes and Nonelectrolytes



Molecular compounds tend to be nonelectrolytes,
except for acids and bases.

Electrolytes

- A ***strong*** electrolyte dissociates completely when dissolved in water.
- A ***weak*** electrolyte only dissociates partially when dissolved in water.
- A ***nonelectrolyte*** does not dissociate in water

	Strong Electrolyte	**Weak Electrolyte**	**Nonelectrolyte**
Ionic	All	None	None
Molecular	Strong acids (see Table 4.2)	Weak acids (H . . .)	
		Weak bases (NH_3)	All other compounds

Strong Electrolytes Are…

- Strong acids

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

The 7 common strong acids **KNOW THEM**

Strong Electrolytes Are…

- Strong acids
- Strong bases

NOTE THIS IS MORE STUFF YOU NEED TO KNOW

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

The strong bases

KNOW THEM!!!!

Strong Electrolytes Are…

- Strong acids
- Strong bases
- Soluble ionic salts
- If the salt doesn’t dissolve, it can’t conduct.

Exam 1 2020

- Covers chap 1 - 3,
- Chap 1:Matter and measurement
  - Molecules, compounds etc.
  - Separations
  - Units, dimensional analysis, sig figs.
- Chap 2, atoms, molecules, ions.
  - History experiments
    - Gold foil
    - Cathode ray tube
    - Mulliken oil drops
    - radioactivity

Exam 1 2019

- Subatomic particles (2)
  - Alpha particles
  - Beta particles
  - Protons
  - Neutrons
  - Electrons
  - Their properties
- Isotopes
- Atomic and formula weight
- Natural abundance
- Average mass
- Periodic table

Exam 1 2019

- Isotopes
- Atomic and formula weight
- Natural abundance
- Average mass
- Periodic table
- Chemical formulas
- Monoatomic ions
- Ionic compounds
- Polyatomic ions
- Acids
- Naming binary compounds

Exam 1 2020

– Molecules/inorganic compounds/elements (2)

-Moles (1)

– Homogeneous, heterogeneous, pure mixtures/solutions (1)

– Physical/chemical properties (1)

– Dimensional analysis/conversions (2)

– Periodic table, groups, periods, atomic comp. (1)

– Stoichiometry/Limiting reagent/percent cmp (3)

– Balancing chemical equations (2)

– History (1)

– Isotopes (2)

– Naming compounds/ions/acids (2)

– Empirical formula (1)

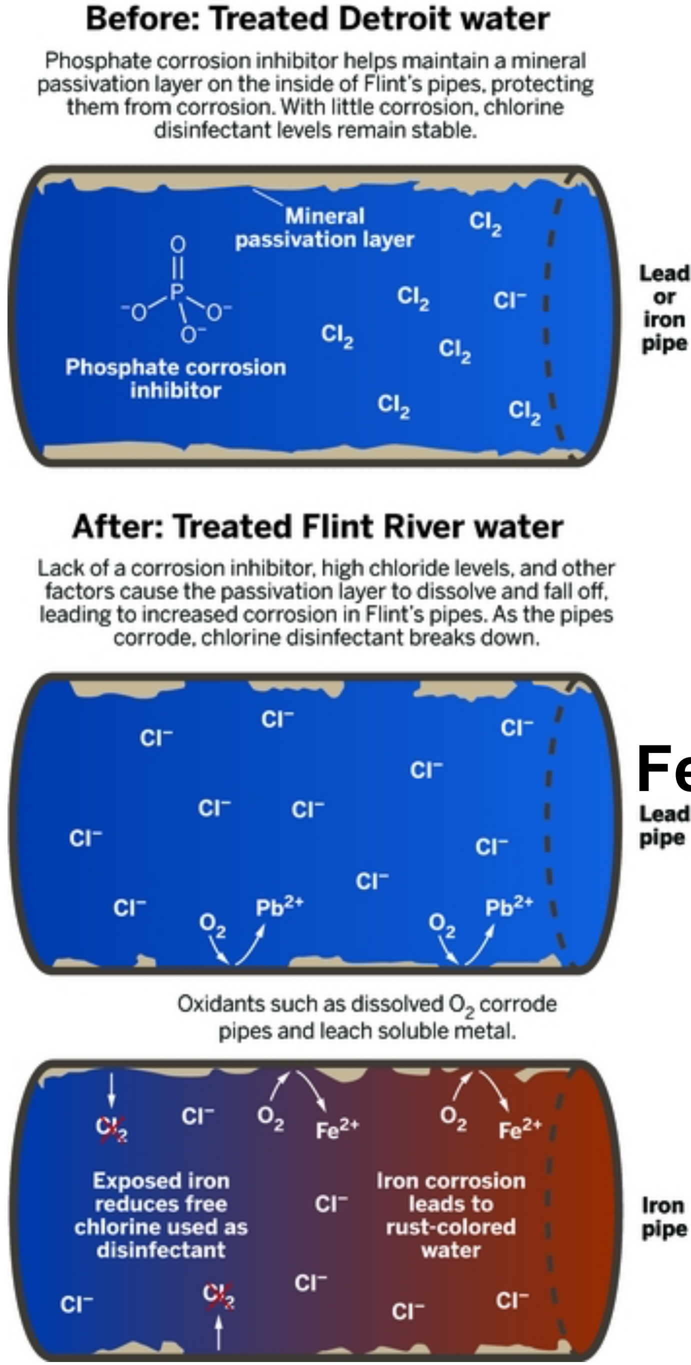
Solubility trends

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	$C_2H_3O_2^-$	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}

Insoluble Ionic Compounds		Important Exceptions
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and NH_4^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

NH_4^+ salts are always soluble

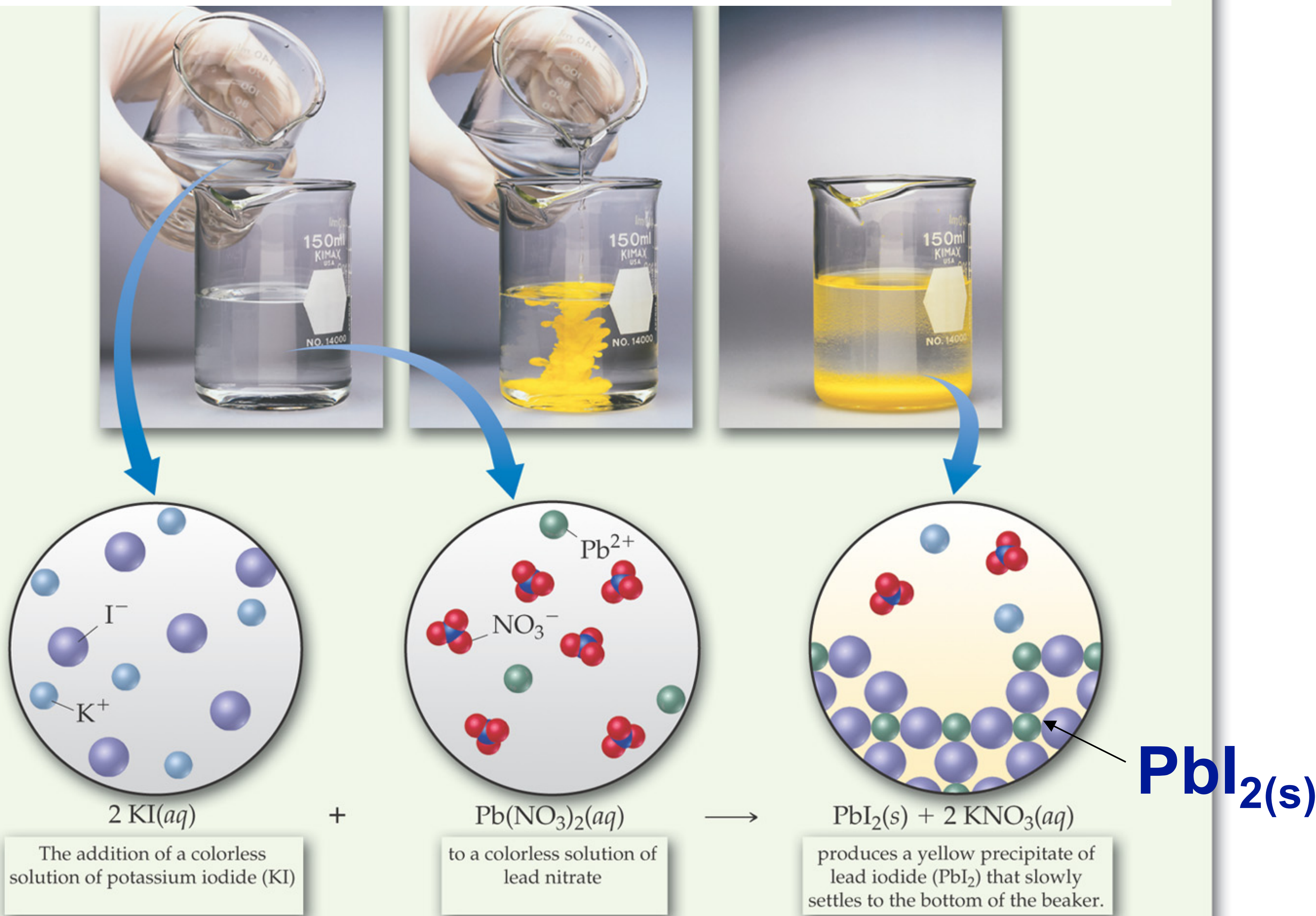
Alkali metal salts are always soluble



$Fe + Cl_2 \rightarrow 2Cl^- + Fe^{2+}$

https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/2016-2017/december-2016/flint-water-crisis.html

Precipitation Reactions



Metathesis (Exchange) Reactions

- Metathesis comes from a Greek word that means "to transpose"
- It appears the ions in the reactant compounds exchange, or transpose, ions

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

Metathesis (Exchange) Reactions

- Metathesis comes from a Greek word that means “to transpose”
- It appears the ions in the reactant compounds exchange, or transpose, ions

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

This is a reaction because the AgCl precipitates. Otherwise, nothing would be happening.

$NaCl_{(aq)}$ + $KBr_{(aq)}$ -------> $KCl_{(aq)}$ + $NaBr_{(aq)}$

Nothing happens!

Solution Chemistry

- pay attention to *exactly* what species are present in a reaction mixture (i.e., solid, liquid, gas, aqueous solution).
- we must be aware of what is changing during the course of a reaction.

Chemical Equation

The chemical equation lists the reactants and products, but the fact that ions are dissociated must be inferred.

$$AgNO_3\,(aq) + KCl\,(aq) \longrightarrow AgCl\,(s) + KNO_3\,(aq)$$

Ionic Equation

- In the ionic equation all strong electrolytes (strong acids, strong bases, and soluble ionic salts) are dissociated into their ions.
- reflects the species that are **actually found** in the reaction mixture.
- Separate all the "aq" stuff and leave the "s" stuff alone

$$Ag^+ (aq) + NO_3^- (aq) + K^+ (aq) + Cl^- (aq) \longrightarrow AgCl (s) + K^+ (aq) + NO_3^- (aq)$$

Net Ionic Equation

- To form the net ionic equation, cross out anything that does not change from the left side of the equation to the right.

$$Ag^{+}(aq) + \cancel{NO_3^{-}(aq)} + \cancel{K^{+}(aq)} + Cl^{-}(aq) \longrightarrow AgCl(s) + \cancel{K^{+}(aq)} + \cancel{NO_3^{-}(aq)}$$

Net Ionic Equation

- To form the net ionic equation, cross out anything that does not change from the left side of the equation to the right.
- The only things left in the equation are those things that change (i.e., react) during the course of the reaction.

$$Ag^{+}(aq) + NO_3^{-}(aq) + K^{+}(aq) + Cl^{-}(aq) \longrightarrow AgCl(s) + K^{+}(aq) + NO_3^{-}(aq)$$

$$Ag^{+}(aq) + Cl^{-}(aq) \longrightarrow AgCl(s)$$

Net Ionic Equation

- To form the net ionic equation, cross out anything that does not change from the left side of the equation to the right.
- The only things left in the equation are those things that change (i.e., react) during the course of the reaction.
- Those things that didn't change (and were deleted from the net ionic equation) are called spectator ions.

$$Ag^+(aq) + \cancel{NO_3^-(aq)} + \cancel{K^+_{(aq)}} + Cl^-(aq) \longrightarrow$$

$$AgCl\,(s) + \cancel{K^+(aq)} + \cancel{NO_3^-(aq)}$$

Writing Net Ionic Equations

1. Write a ***balanced*** chemical equation.
2. ***Dissociate*** all strong electrolytes.
3. ***Cross out*** anything that remains unchanged from the left side to the right side of the equation.
4. Write the species that remain, ***the net ionic equation***.

Writing Net Ionic Equations

1. $NaCl_{(aq)} + AgNO_{3(aq)}$ ---------> $AgCl_{(s)} + NaNO_{3(aq)}$

   $\cancel{Na^+} + Cl^- + Ag^+ + \cancel{NO_3^-}$ ----> $AgCl_{(s)} + \cancel{Na^+} + \cancel{NO_3^-}$

   $Ag^+ + Cl^-$ -----> $AgCl_{(s)}$

2. $2NaBr_{(aq)} + MgCl_{2(aq)}$ -----> $2NaCl_{(aq)} + MgBr_{2(aq)}$

   $\cancel{2Na^+} + \cancel{2Br^-} + \cancel{Mg^{2+}} + \cancel{2Cl^-}$ ----> $\cancel{2Na^+} + \cancel{2Cl^-} + \cancel{Mg^{2+}} + \cancel{2Br^-}$

Acids:

- Substances that **increase the concentration of H^+** when dissolved in water.

Acids

Acids: Increase concentration of H^+

Strong: Fully dissociate into anion and H^+ (strong electrolytes)

Weak: Do not fully dissociate (weak electrolyte)

There are only seven strong acids:

- Hydrochloric (HCl)
- Hydrobromic (HBr)
- Hydroiodic (HI)
- Nitric (HNO_3)
- Sulfuric (H_2SO_4)
- Chloric ($HClO_3$)
- Perchloric ($HClO_4$)
- YOU MUST REMEMBER THESE.

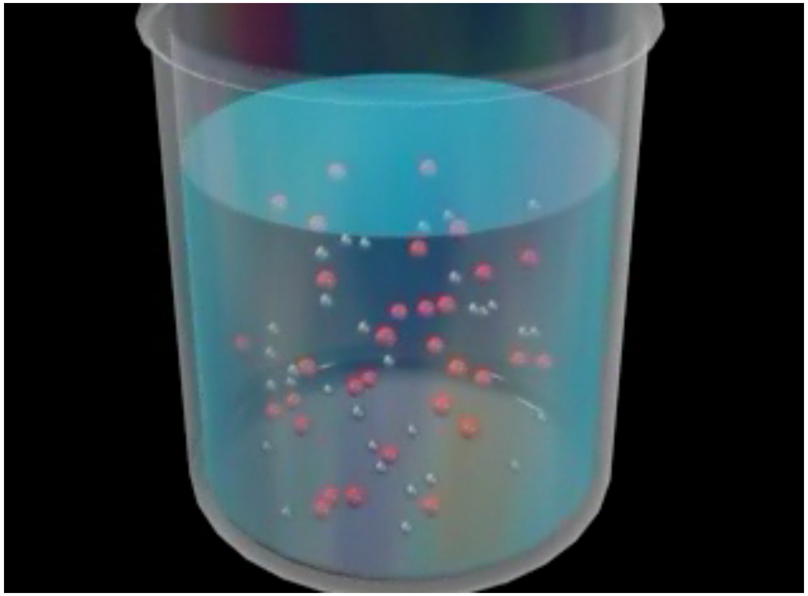
Bases:

- Substances that increase the concentration of OH^{-} when dissolved in water.

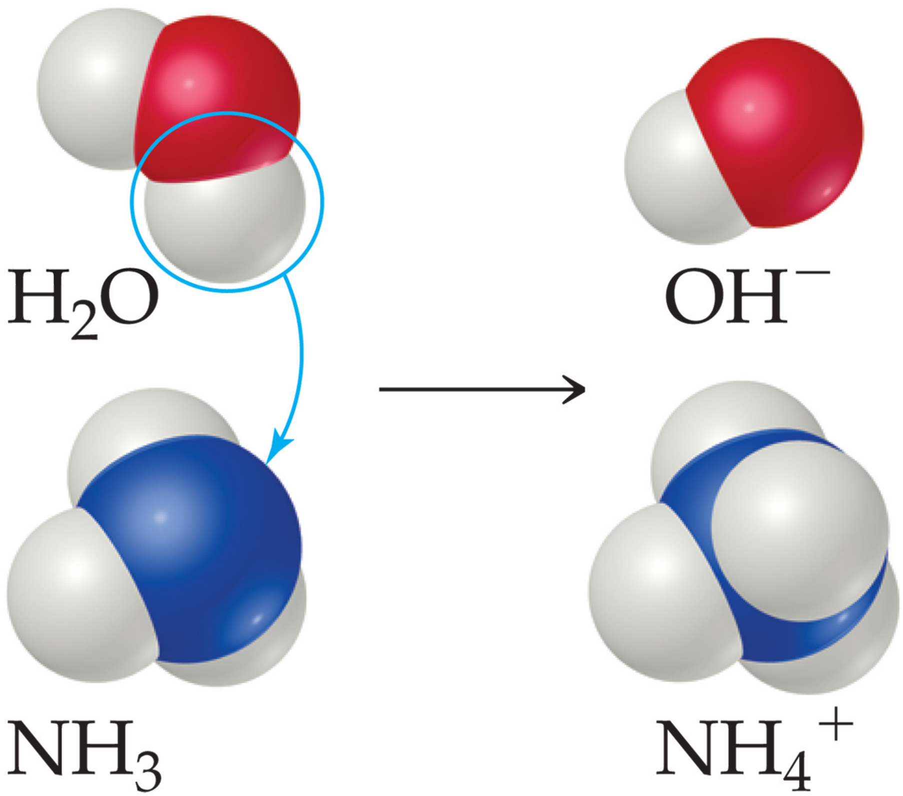
Bases

The strong bases are the soluble salts of hydroxide ion:

- Alkali metals
- Calcium ($Ca(OH)_2$
- Strontium ($Sr(OH)_2$
- Barium ($Ba(OH)_2$



Acid-Base Reactions



In an acid-base reaction, the acid donates a proton (H^+) to the base.

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

Neutralization Reactions

When an acid and a base are combined.

Products are usually a salt and water.

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

Neutralization Reactions

strong acid strong base reaction net ionic equation:

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

$$H^{+}\ (aq) + Cl^{-}\ (aq) + Na^{+}\ (aq) + OH^{-}(aq) \longrightarrow$$
$$Na^{+}\ (aq) + Cl^{-}\ (aq) + H_2O\ (l)$$

Neutralization Reactions

When a strong acid reacts with a strong base, the net ionic equation is…

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

Dissociate

$$H^+\ (aq) + Cl^-\ (aq) + Na^+\ (aq) + OH^-(aq) \longrightarrow Na^+\ (aq) + Cl^-\ (aq) + H_2O\ (l)$$

Cross out

$$H^+\ (aq) + \cancel{Cl^-\ (aq)} + \cancel{Na^+\ (aq)} + OH^-(aq) \longrightarrow \cancel{Na^+\ (aq)} + \cancel{Cl^-\ (aq)} + H_2O\ (l)$$

Net

$$H^+\ (aq) + OH^-(aq) \longrightarrow H_2O\ (l)$$

Neutralization Reactions

Reaction between Milk of Magnesia, $Mg(OH)_2$, and HCl.

A phase change results as $Mg(OH)_{2(s)}$ goes into solution.

$$Mg(OH)_{2(s)} + 2HCl_{(aq)} \text{ ----> } 2H_2O + MgCl_{2(aq)}$$
$$Mg(OH)_{2(s)} + 2H^+ + \cancel{2Cl^-} \text{ ----> } 2H_2O + Mg^{2+} + \cancel{2Cl^-}$$
$$Mg(OH)_{2(s)} + 2H^+ \text{ -----> } 2H_2O + Mg^{2+}$$

Gas-Forming Reactions

- metathesis reactions that give an unexpected product (acid base).
- Because expected product decomposes to give a gas (CO_2 or SO_2).

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

$$NaHCO_3\,(aq) + HBr\,(aq) \longrightarrow NaBr\,(aq) + CO_2\,(g) + H_2O\,(l)$$

$$SrSO_3\,(s) + 2\,HI\,(aq) \longrightarrow SrI_2\,(aq) + SO_2\,(g) + H_2O\,(l)$$

Gas-Forming Reactions

- This reaction gives the predicted product, but you had better carry it out in the hood, or you will be very unpopular!
- Just as in the previous examples, a gas is formed as a product of this reaction:

$$Na_2S\ (aq) + 2HCl\ (aq) \longrightarrow 2NaCl\ (aq) + H_2S\ (g)$$

Stinky

Solution Stoichiometry

- Chemistry arithmetic in solution

Molarity

- Molarity is a measure of concentration of a solution.

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

A unit of concentration.

Example

Make 300. mL of a 0.250 M solution of NaCl.

Needed: grams of NaCl.

Must find: moles NaCl (M = mol/L)

MW NaCl: 23 + 35.4 = 58.4 g/mol

300. mL = 0.300 L

0.250 mol/L(0.300 L)(58.4g/mol) = 4.38 g

Mixing a Solution

Example

What is the molarity of a solution that contains 15 g of sodium acetate in 0.25 L

MW $NaC_2H_3O_2$: 82 g/mol

Needed: moles sodium acetate so you can calculate mol/L

$$\frac{15\cancel{g} \quad 1\text{ mole}}{82\cancel{g}} = 0.18\text{ mol}$$

0.18 mol/0.25L = 0.73 mol/L

Dilution

Example

You have a stock solution of 4.2 M $(NH_4)_2SO_4$.
How much do you need to make 2.5 L of a 0.3 M $(NH_4)_2SO_4$ solution?

Example

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How do we think it through? There's more than one way, here's one:

1. Find out how many moles you need in the solution you're making.
2. Find out what volume of the stock you need for that many moles.

Example

You have a stock solution of 4.2 M $(NH_4)_2SO_4$. How much do you need to make 2.5 L of a 0.3 M $(NH_4)_2SO_4$ solution?

1. Find out how many moles you need in the solution you're making.

moles NH_4SO_4 needed = 2.5 L(0.3 mol/L) = 0.75 moles

Example

You have a stock solution of 4.2 M $(NH_4)_2SO_4$. How much do you need to make 2.5 L of a 0.3 M $(NH_4)_2SO_4$ solution?

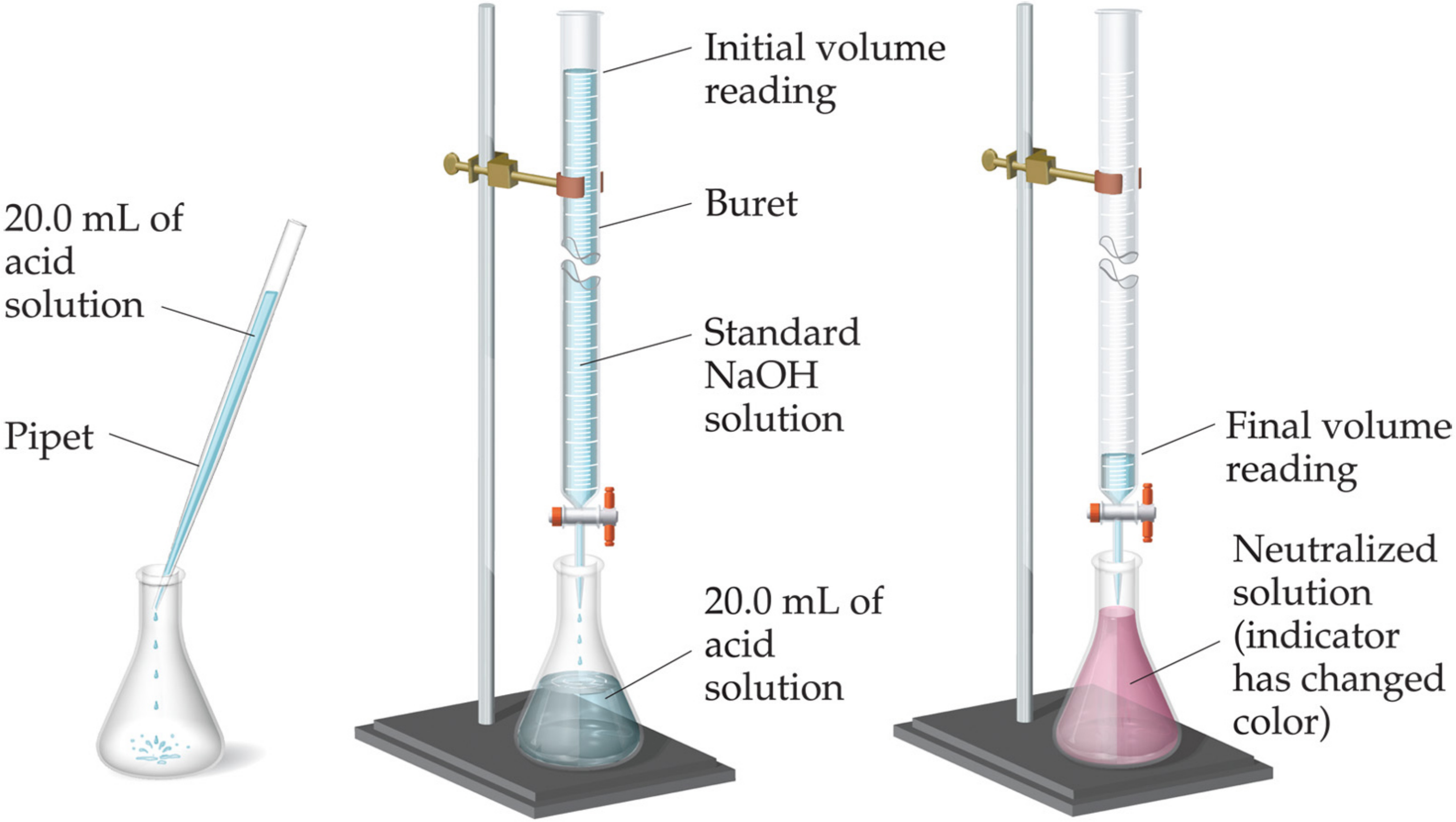
1. Find out how many moles you need in the solution you're making.

moles NH_4SO_4 needed = 2.5 L(0.3 mol/L) = 0.75 moles

2. Find out what volume of the stock you need for that many moles.

Volume of stock = $\dfrac{\text{(moles } (NH_4)_2SO_4 \text{ needed)}}{\text{(4.2 M } (NH_4)_2SO_4\text{)}} = \dfrac{\text{(0.75moles}}{\text{(4.2mol/L stock)}}$ = 0.18L

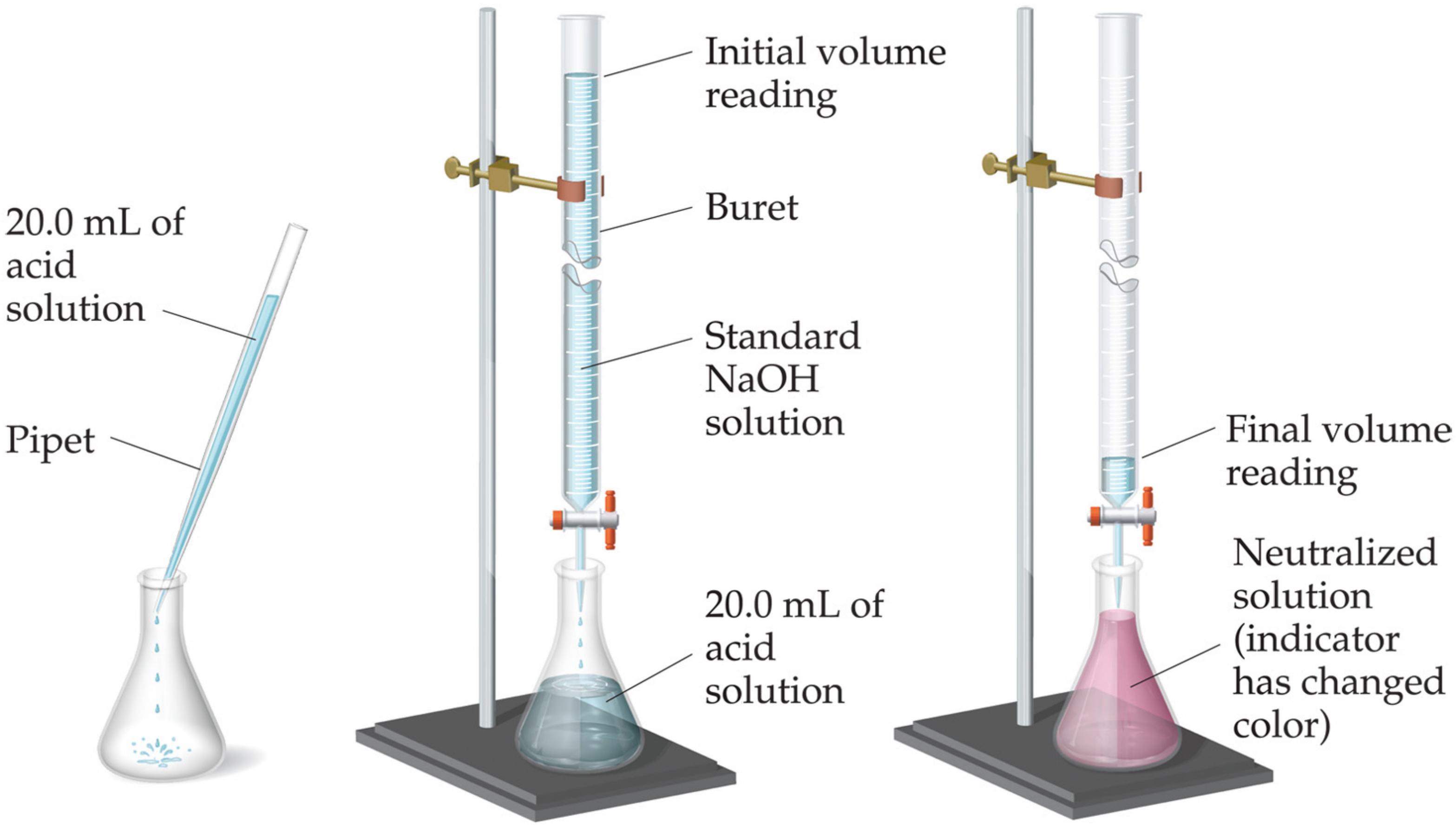
Titration



Use:

Known concentration of a solution and chemical reaction to find amount of an unknown.

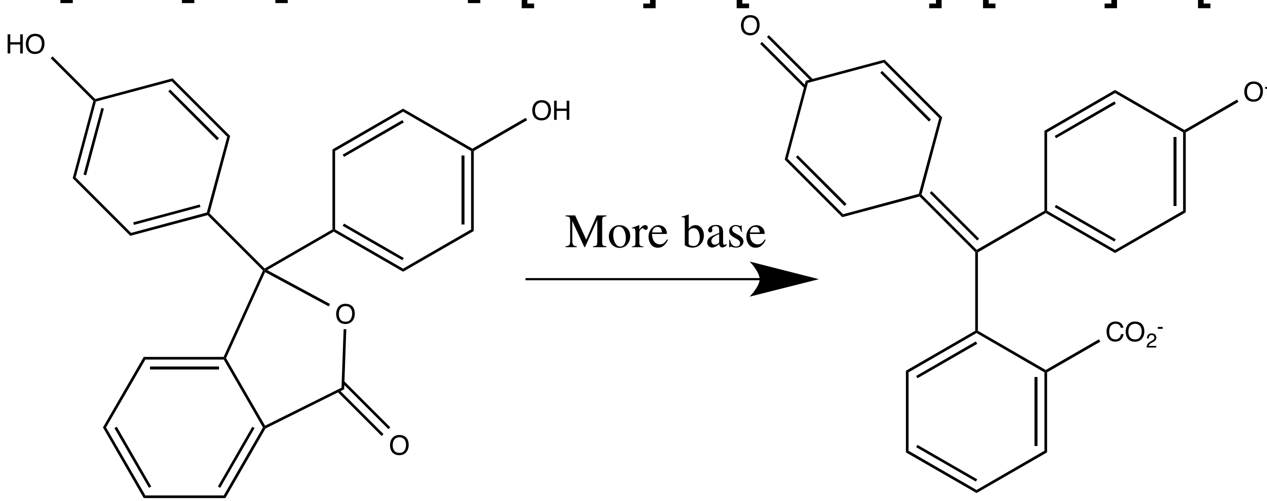
Titration



Example: acid/base titration.

Titration

[HCl] > [NaOH] [HCl] = [NaOH] [HCl] < [NaOH]



Colorless **PINK**

Titration

[HCl] > [NaOH]   [HCl] = [NaOH]   [HCl] < [NaOH]

Add one reactant to the other gradually
An indicator shows when reactant is used up.
Example, Acid/base:

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

Example

0.172 L of an NaOH solution is titrated to its endpoint with 80.32 mL of a 0.0423 M solution of HCl. What was the concentration of the NaOH solution?

1. Write down reaction and what we know:

	HCl +	NaOH ------> $NaCl + H_2O$
[M]	0.0423	?
V	0.08032 L	0.172L
moles	???	???

Example

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1. Write down reaction and what we know:

	HCl +	NaOH ------> NaCl + H_2O
[M]	0.0423	?
V	0.08032 L	0.172L
moles	???	???

moles HCl added = moles NaOH in unknown solution

Example

0.172 L of an NaOH solution is titrated to its endpoint with 80.32 mL of a 0.0423 M solution of HCl. What was the concentration of the NaOH solution?

1. Write down reaction and what we know:

	HCl +	NaOH ------> $NaCl + H_2O$
[M]	0.0423	?
V	0.08032 L	0.172L

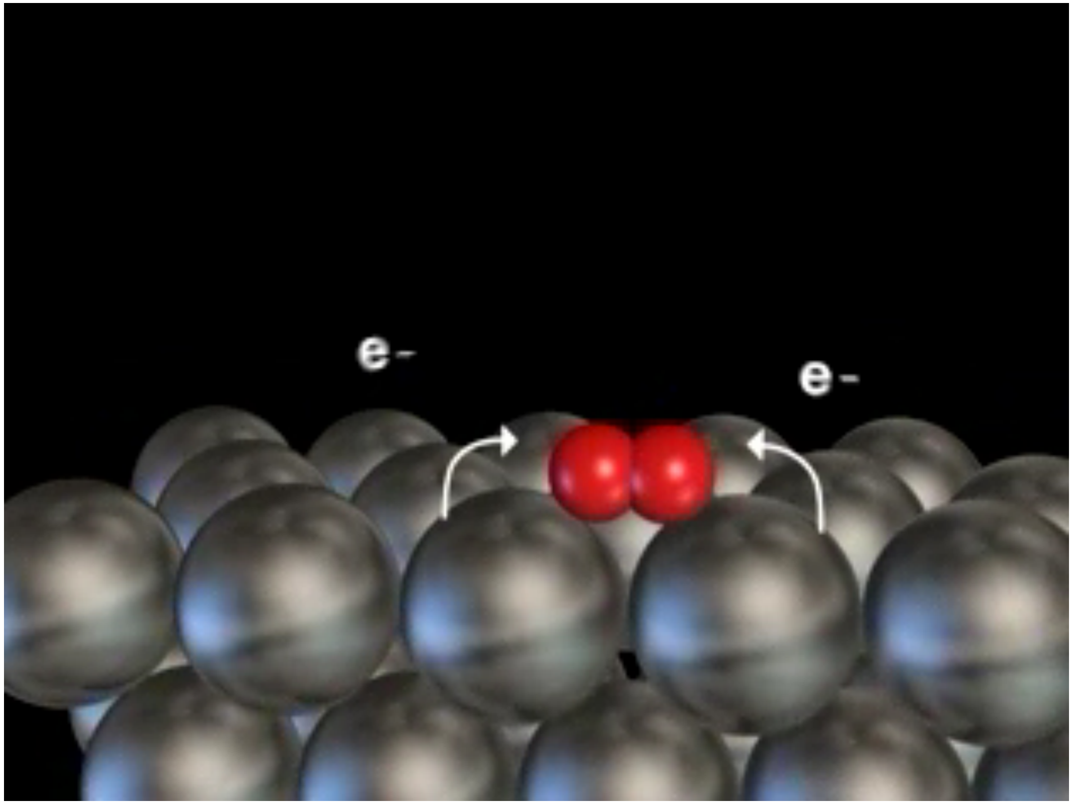
moles = 0.08032 L(0.0423 mol/L)

= 0.00339 mole HCl = moles NaOH

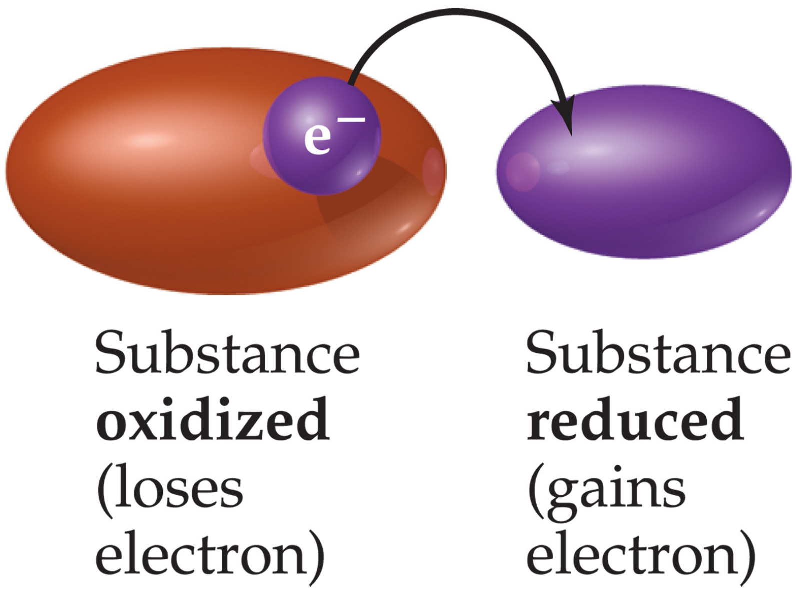
[NaOH]= 0.00339 mol/0.172L=**0.0197 mol/L** (M).

Oxidation-Reduction Reactions

- An oxidation occurs when an atom or ion *loses* electrons.
- A reduction occurs when an atom or ion *gains* electrons.



Oxidation-Reduction Reactions



One cannot occur without the other.

Electrons must come from somewhere…

And end up somewhere.

Oxidation Numbers

But how do you know if oxidation/reduction has happened?

Keep track of the electrons.

Assign a number to each ***element***

See how they change from react. To prod.

Book-keeping for electrons

Assigning Oxidation Numbers

- Elements in their elemental form have an oxidation number of 0.
  - O oxidation number in O_2 = 0
  - F oxidation number in F_2 = 0
- The oxidation number of a monatomic ion is the same as its charge.

  Na oxidation number 0

  Na^+ oxidation number +1

Oxidation Numbers

- The sum of the oxidation numbers in a neutral compound is 0.
- The sum of the oxidation numbers in an ion is the charge on the ion.

CCl_4 Cl o.n. -1 -1(4) = -4. C o.n. +4

ClO_4^- O: -2(4) = -8 Cl: +7 (7-8=-1)

Assigning Oxidation Numbers

- Nonmetals tend to have negative oxidation numbers, but:
  - some are positive in certain compounds or ions (when they are bound to other nonmetals).

  - Oxygen has an oxidation number of −2, except in the peroxide ion (O_2^{2-}) in which it has an oxidation number of −1.
    - CO_2, H_2O, CaO etc. O has -2 oxidation number

  - Hydrogen is −1 when bonded to a metal, +1 when bonded to a nonmetal.
    - NaH H has -1 oxidation number
    - HCl H has +1 oxidation number
    - CH_4 H has +1 oxidation number

Oxidation Numbers

- Fluorine always has an oxidation number of −1.
- The other halogens have an oxidation number of −1 when the oxidation number is negative;
- they can have positive oxidation numbers when they are with F or O, most notably in oxyanions.
  - CCl_4, HCl, Cl o.n. -1
  - ClO_4^- Cl o.n. +7 (must be because O is always -2)
  - HCOCl Cl o.n. -1

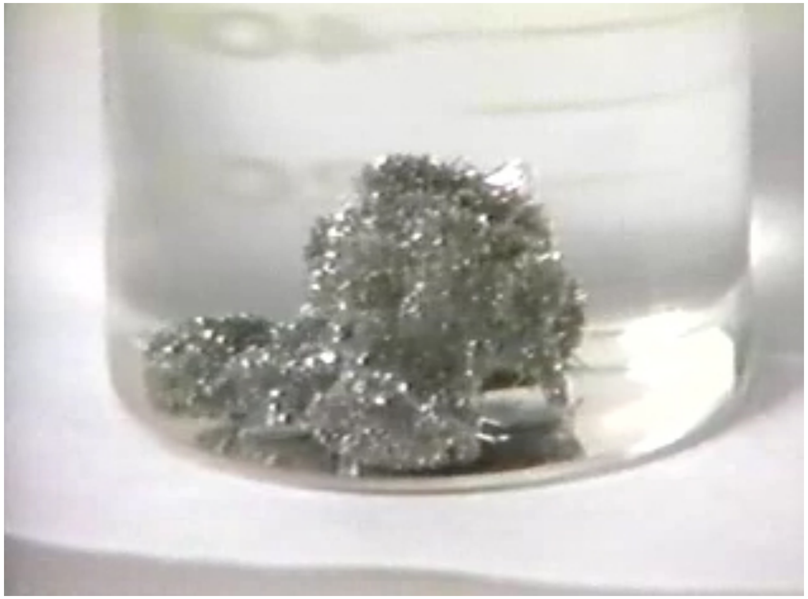
Oxidation Numbers

CO_3^{2-}	NO_3^-	$FeCl_3$	SF_6	H_2S
H_2SO_4	CaH_2	BBr_3	SO_3^-	ClO^-

Oxidation Numbers

+4 -2 CO_3^{2-}	+5 -2 NO_3^{-}	+3 -1 $FeCl_3$	+6 -1 SF_6	+1 -2 H_2S
+1 +6 -2 H_2SO_4	+2 -1 CaH_2	+3 -1 BBr_3	+5 -2 SO_3^{-}	+1 -2 ClO^{-}

Displacement Reactions



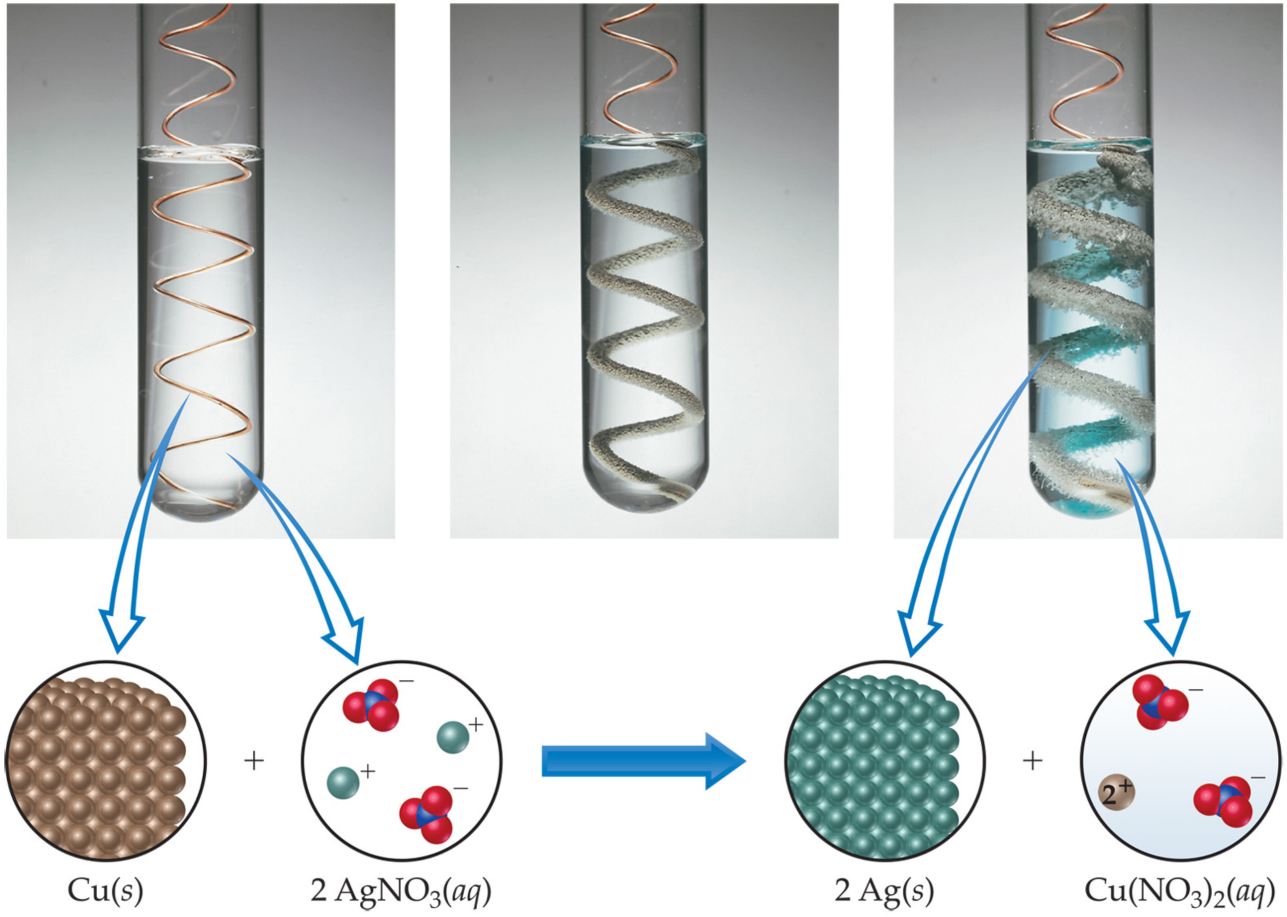
- In displacement reactions, **cations** oxidize an element.
- The **cations** then, are reduced.

A + BX -------> AX + B

2Li(s) + 2HBr ------> 2LiBr + H_2

Na(s) + $AgNO_3$ ------> $NaNO_3$ + Ag(s)

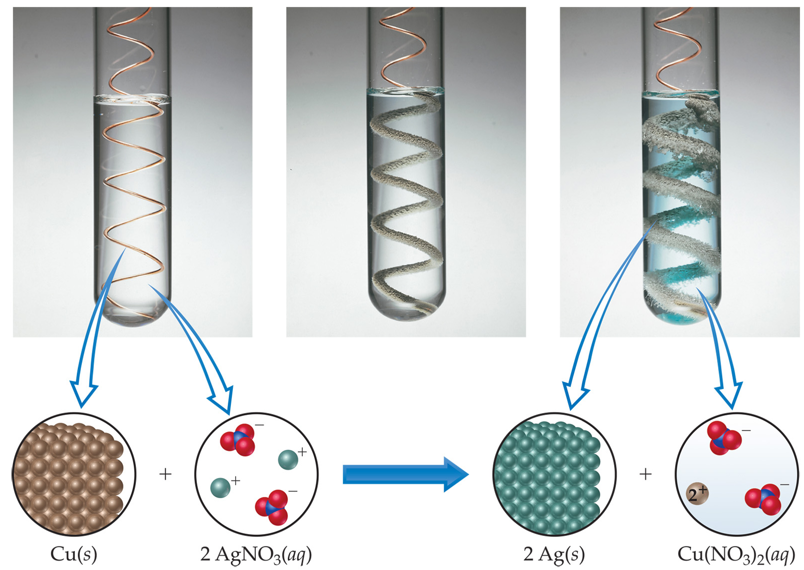
Displacement Reactions



silver ions oxidize copper metal.

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

Displacement Reactions

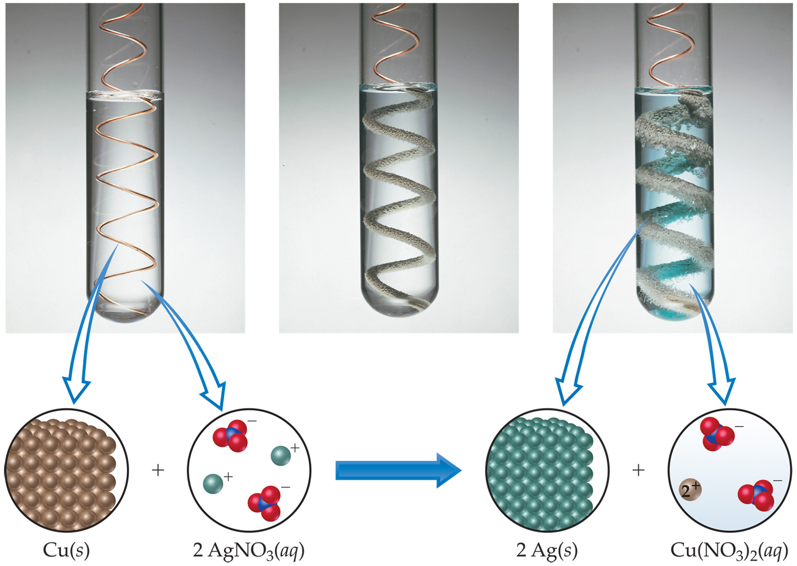


But copper ions will *not* Oxidize silver metal.

$$Cu^{2+}\,(aq) + 2\,Ag\,(s) \not\longrightarrow Cu\,(s) + 2\,Ag^{+}\,(aq)$$

Why not??

Displacement Reactions



But copper ions will *not* Oxidize silver metal.

$$Cu^{2+}(aq) + 2\,Ag(s) \not\longrightarrow Cu(s) + 2\,Ag^{+}(aq)$$

Taking electrons from Ag is Harder than taking them from Cu

Activity Series

Metal	Oxidation Reaction				
Lithium	$Li(s)$	$\longrightarrow$	$Li^{+}(aq)$	+	e^{-}
Potassium	$K(s)$	$\longrightarrow$	$K^{+}(aq)$	+	e^{-}
Barium	$Ba(s)$	$\longrightarrow$	$Ba^{2+}(aq)$	+	$2e^{-}$
Calcium	$Ca(s)$	$\longrightarrow$	$Ca^{2+}(aq)$	+	$2e^{-}$
Sodium	$Na(s)$	$\longrightarrow$	$Na^{+}(aq)$	+	e^{-}
Magnesium	$Mg(s)$	$\longrightarrow$	$Mg^{2+}(aq)$	+	$2e^{-}$
Aluminum	$Al(s)$	$\longrightarrow$	$Al^{3+}(aq)$	+	$3e^{-}$
Manganese	$Mn(s)$	$\longrightarrow$	$Mn^{2+}(aq)$	+	$2e^{-}$
Zinc	$Zn(s)$	$\longrightarrow$	$Zn^{2+}(aq)$	+	$2e^{-}$
Chromium	$Cr(s)$	$\longrightarrow$	$Cr^{3+}(aq)$	+	$3e^{-}$
Iron	$Fe(s)$	$\longrightarrow$	$Fe^{2+}(aq)$	+	$2e^{-}$
Cobalt	$Co(s)$	$\longrightarrow$	$Co^{2+}(aq)$	+	$2e^{-}$
Nickel	$Ni(s)$	$\longrightarrow$	$Ni^{2+}(aq)$	+	$2e^{-}$
Tin	$Sn(s)$	$\longrightarrow$	$Sn^{2+}(aq)$	+	$2e^{-}$
Lead	$Pb(s)$	$\longrightarrow$	$Pb^{2+}(aq)$	+	$2e^{-}$
Hydrogen	$H_2(g)$	$\longrightarrow$	$2\,H^{+}(aq)$	+	$2e^{-}$
Copper	$Cu(s)$	$\longrightarrow$	$Cu^{2+}(aq)$	+	$2e^{-}$
Silver	$Ag(s)$	$\longrightarrow$	$Ag^{+}(aq)$	+	e^{-}
Mercury	$Hg(l)$	$\longrightarrow$	$Hg^{2+}(aq)$	+	$2e^{-}$
Platinum	$Pt(s)$	$\longrightarrow$	$Pt^{2+}(aq)$	+	$2e^{-}$
Gold	$Au(s)$	$\longrightarrow$	$Au^{3+}(aq)$	+	$3e^{-}$

Top: easy To steal an Electron

Bottom, Hard to Steal e^-

Activity Series

Metal	Oxidation Reaction				
Lithium	$Li(s)$	$\longrightarrow$	$Li^{+}(aq)$	+	e^{-}
Potassium	$K(s)$	$\longrightarrow$	$K^{+}(aq)$	+	e^{-}
Barium	$Ba(s)$	$\longrightarrow$	$Ba^{2+}(aq)$	+	$2e^{-}$
Calcium	$Ca(s)$	$\longrightarrow$	$Ca^{2+}(aq)$	+	$2e^{-}$
Sodium	$Na(s)$	$\longrightarrow$	$Na^{+}(aq)$	+	e^{-}
Magnesium	$Mg(s)$	$\longrightarrow$	$Mg^{2+}(aq)$	+	$2e^{-}$
Aluminum	$Al(s)$	$\longrightarrow$	$Al^{3+}(aq)$	+	$3e^{-}$
Manganese	$Mn(s)$	$\longrightarrow$	$Mn^{2+}(aq)$	+	$2e^{-}$
Zinc	$Zn(s)$	$\longrightarrow$	$Zn^{2+}(aq)$	+	$2e^{-}$
Chromium	$Cr(s)$	$\longrightarrow$	$Cr^{3+}(aq)$	+	$3e^{-}$
Iron	$Fe(s)$	$\longrightarrow$	$Fe^{2+}(aq)$	+	$2e^{-}$
Cobalt	$Co(s)$	$\longrightarrow$	$Co^{2+}(aq)$	+	$2e^{-}$
Nickel	$Ni(s)$	$\longrightarrow$	$Ni^{2+}(aq)$	+	$2e^{-}$
Tin	$Sn(s)$	$\longrightarrow$	$Sn^{2+}(aq)$	+	$2e^{-}$
Lead	$Pb(s)$	$\longrightarrow$	$Pb^{2+}(aq)$	+	$2e^{-}$
Hydrogen	$H_2(g)$	$\longrightarrow$	$2\,H^{+}(aq)$	+	$2e^{-}$
Copper	$Cu(s)$	$\longrightarrow$	$Cu^{2+}(aq)$	+	$2e^{-}$
Silver	$Ag(s)$	$\longrightarrow$	$Ag^{+}(aq)$	+	e^{-}
Mercury	$Hg(l)$	$\longrightarrow$	$Hg^{2+}(aq)$	+	$2e^{-}$
Platinum	$Pt(s)$	$\longrightarrow$	$Pt^{2+}(aq)$	+	$2e^{-}$
Gold	$Au(s)$	$\longrightarrow$	$Au^{3+}(aq)$	+	$3e^{-}$

What happens?

$Li + H^{+}$ ------> ?

$Li + H_2$ ----> ?

$Mn(s) + Fe^{2+}$ ---> ?

$Cr(s) + K^{+}$ -----> ?

$Ca(s) + Zn(s) + Mg^{2+}$?

Activity Series

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2\,H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

What happens?

$Li + H^{+}$ ------> $Li^{+} + H_2$

$Li + H_2$ ----> nothing

$Mn(s) + Fe^{2+}$ --->

$Mn^{2+} + Fe$

$Cr(s) + K^{+}$ ----->

nothing

$Ca(s) + Zn(s) + Mg^{2+}$?

-→ $Ca^{2+} + Zn(s) + Mg(s)$

Oxidation reduction reactions

A more complicated redox reaction:

$$P_4 \quad + \quad 5O_2 \quad \text{---------}> \quad P_4O_{10}$$

O.N. 0 0 +5 -2

P **O**

+5(4) = 20 -2(10) = -20

electrons hop from P to O redox reaction

Oxidation reduction reactions Example: gunpowder

$$10\ KNO_3 + 3\ S + 8\ C \rightarrow 2\ K_2CO_3 + 3\ K_2SO_4 + 6\ CO_2 + 5\ N_2.$$

$$10\overset{+1}{K}\overset{+5}{N}\overset{-2}{O_3}(s) + 3\overset{0}{S}(s) + 8\overset{0}{C}(s) \rightarrow 2\overset{+1}{K_2}\overset{+4}{C}\overset{-2}{O_3}(s) + 3\overset{+1}{K_2}\overset{+6}{S}\overset{-2}{O_4}(s) + 6\overset{+4}{C}\overset{-2}{O_2} + 5\overset{0}{N_2}$$

What element is oxidized?
What element is reduced?
What's the reducing agent?
What's the oxidizing agent?

Oxidation reduction reactions Example: gunpowder

$$10\ KNO_3 + 3\ S + 8\ C \rightarrow 2\ K_2CO_3 + 3\ K_2SO_4 + 6\ CO_2 + 5\ N_2.$$

$$10\overset{+1}{K}\overset{+5}{N}\overset{-2}{O}_3(s) + 3\overset{0}{S}(s) + 8\overset{0}{C}(s) \rightarrow 2\overset{+1}{K}_2\overset{+4}{C}\overset{-2}{O}_3(s) + 3\overset{+1}{K}_2\overset{+6}{S}\overset{-2}{O}_4(s) + 6\overset{+4}{C}\overset{-2}{O}_2(g) + 5\overset{0}{N}_2(g)$$

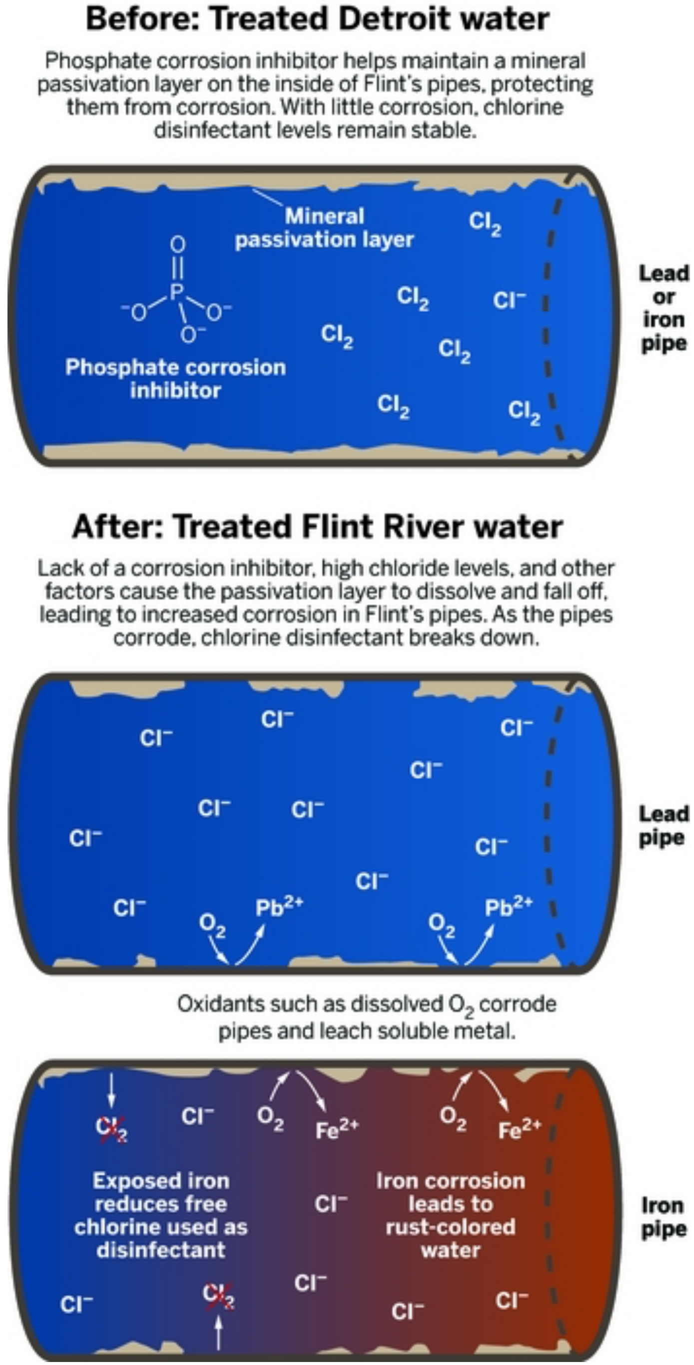
What element is oxidized? C (0 → +4), S (0 → +6)

What element is reduced? N (+5 → 0),

What's the reducing agent? Carbon and sulfur

What's the oxidizing agent? Potassium nitrate (salt peter)

Why do you think this is an explosive?



https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/2016-2017/december-2016/flint-water-crisis.html

Solubility trends

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	$C_2H_3O_2^-$	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}

Insoluble Ionic Compounds		Important Exceptions
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and NH_4^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

NH_4^+ salts are always soluble

Alkali metal salts are always soluble

- $NaClO + H_2O \dashrightarrow 2H_2O + O_2$
- $NaClO + HCl \rightarrow Cl_2 + OH^-$
- Cl_2 + stuff $\rightarrow$ Cl^- + oxidized stuff.

Demonstration:

$2Mg + CO_2$ ------> $2MgO + C$ (charcoal)