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 (what defines **the state of the solution**)
- All other substances are **solutes**.

- But what happens when something dissolves?

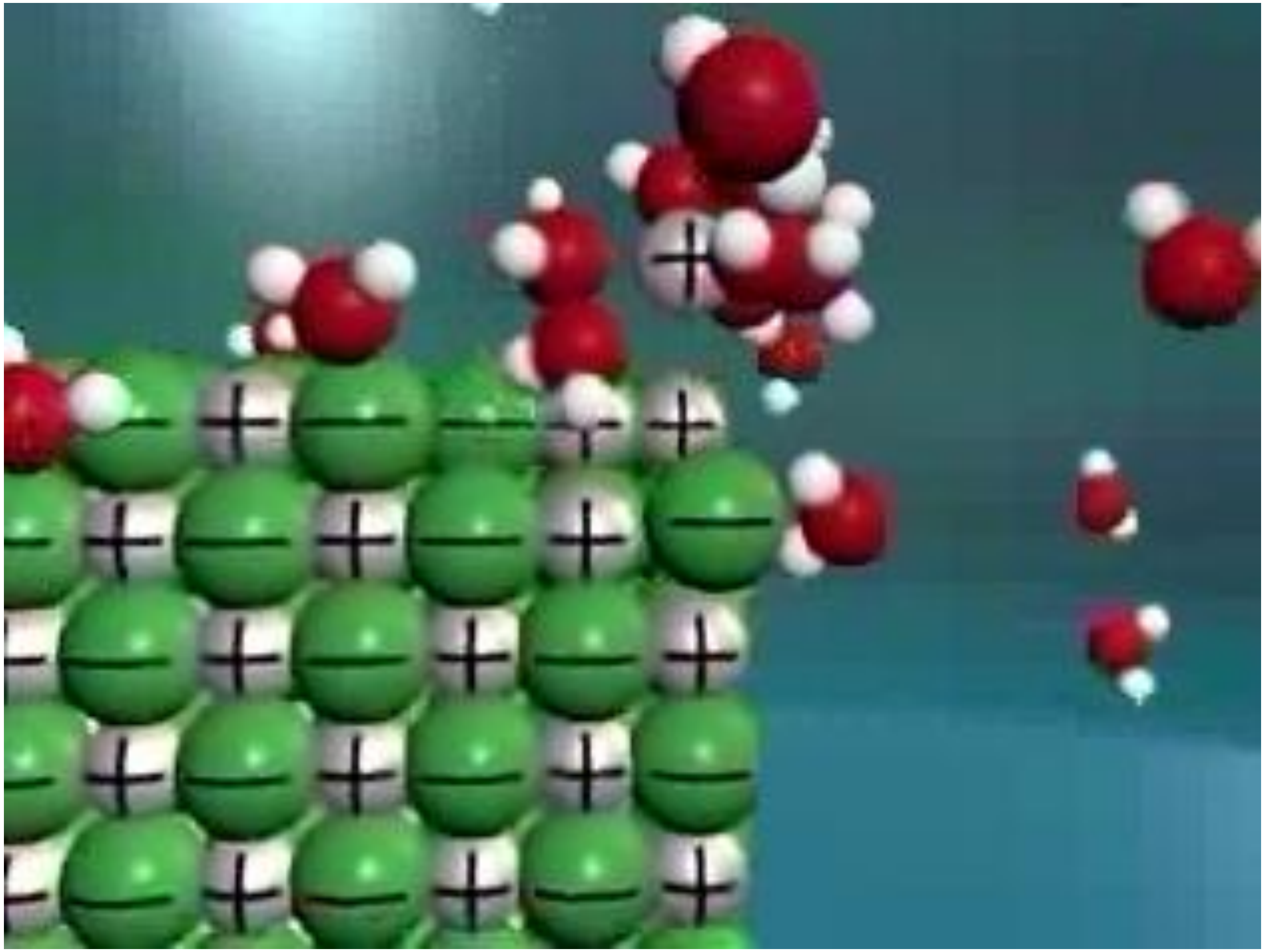
Solutions:

But what happens when something dissolves?

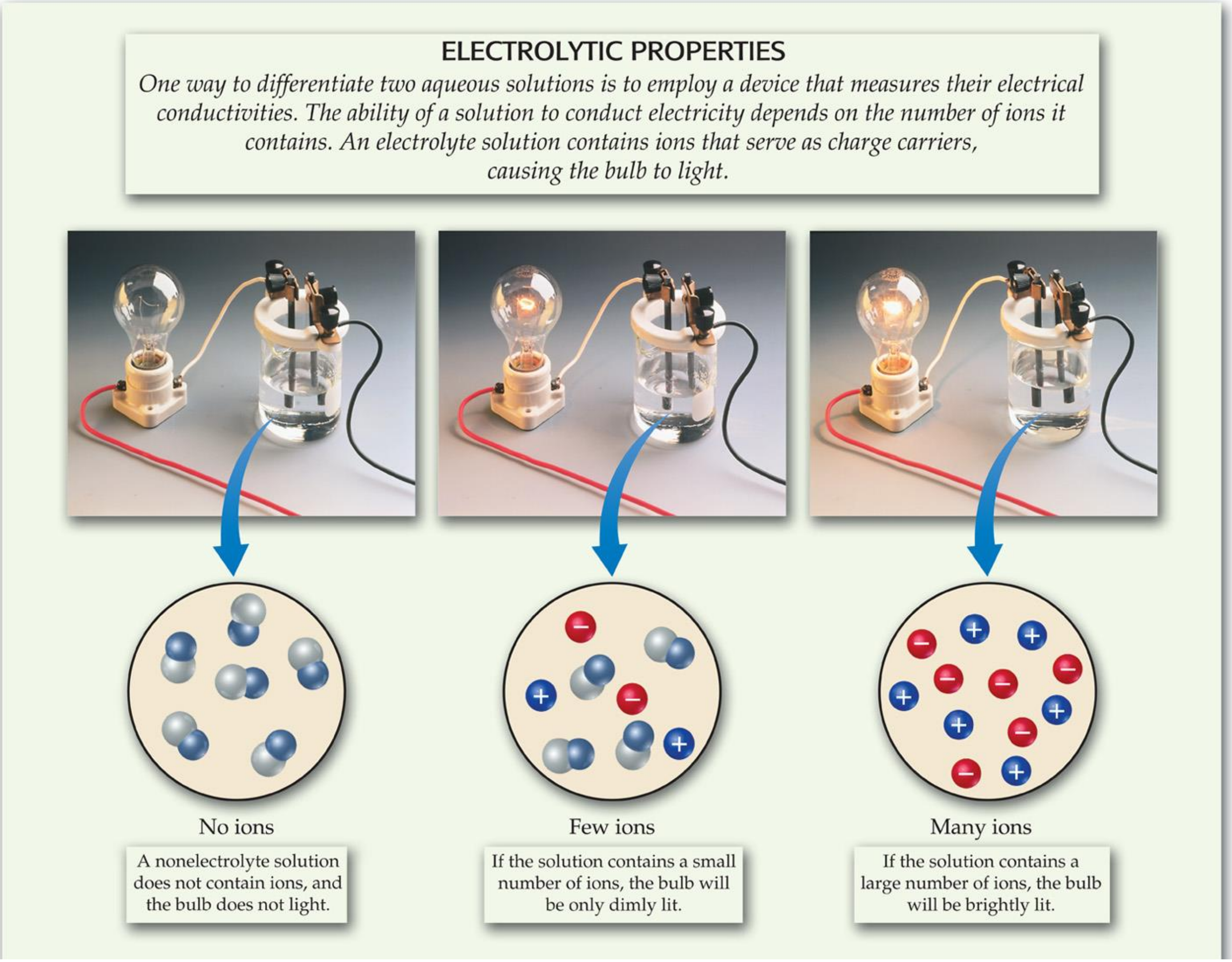
The individual particles that make up the solid separate….

They stop sticking to each other.

Dissociation

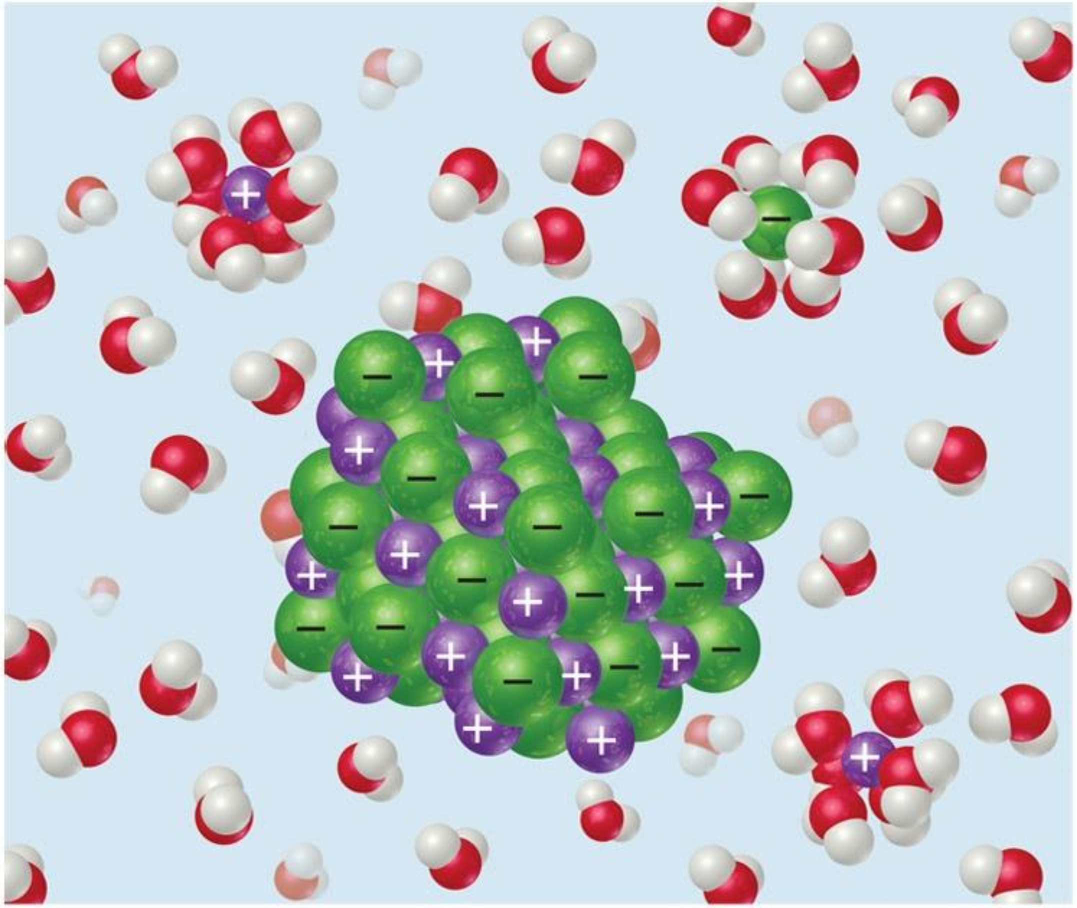


- **ionic compound** dissolves in water
- individual **ions** are **separated.**
- **dissociation.**



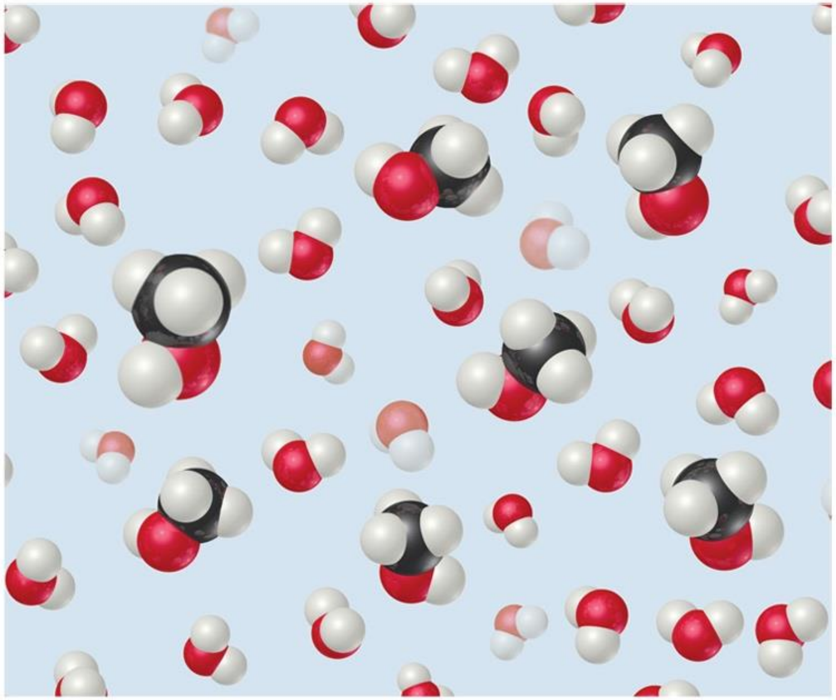
- Substances that dissociate into ions when dissolved in water are **electrolytes.**
- A nonelectrolyte may dissolve in water,
  - but it does not dissociate into ions when it does so.

Electrolytes and Nonelectrolytes



Soluble ionic compounds tend to be electrolytes.

Electrolytes and Nonelectrolytes



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

Acids and bases ARE electrolytes.

All other molecular compounds are nonelectrolytes.

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, $RbOH$, $CsOH$)
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Hydroiodic, HI	
Chloric, $HClO_3$	
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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.

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

Solubility trends

The Flint water crisis: An exercise in ignoring solubility rules.

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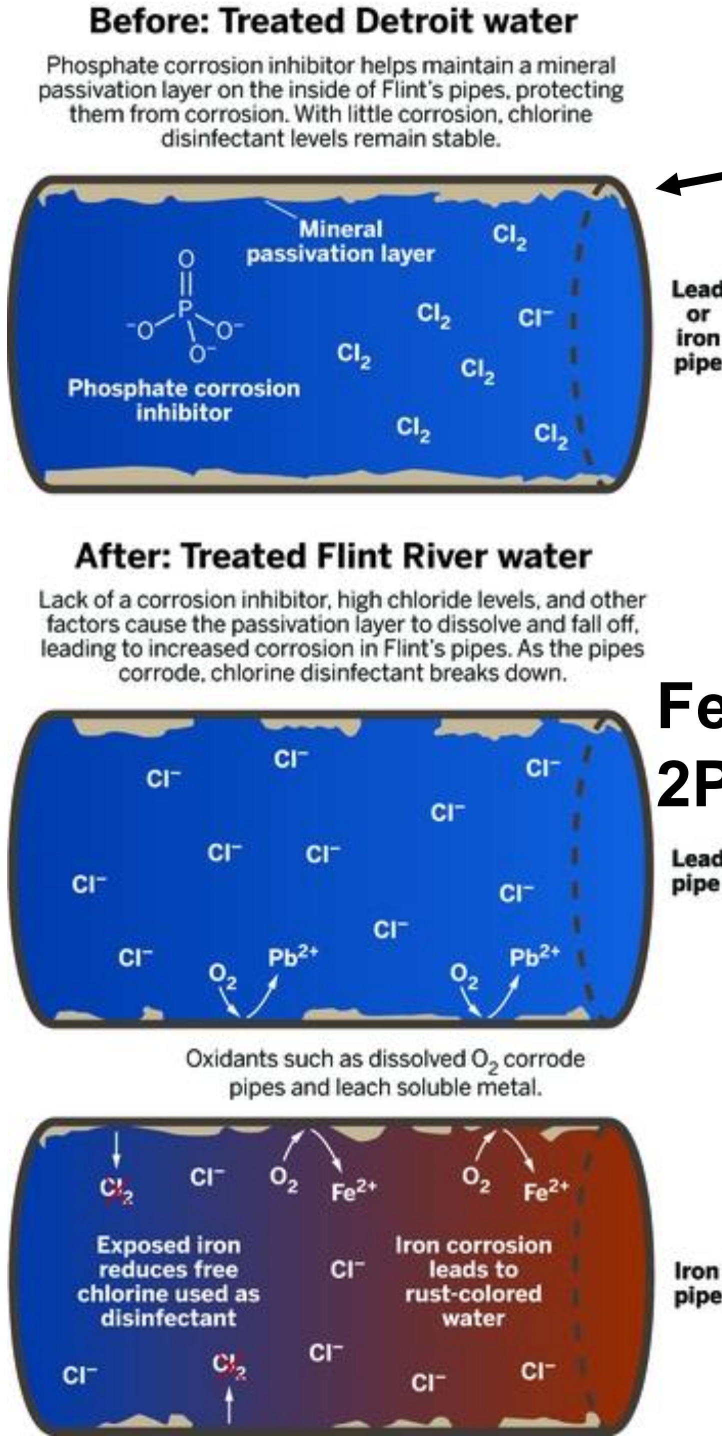
Alkali metal salts are always soluble



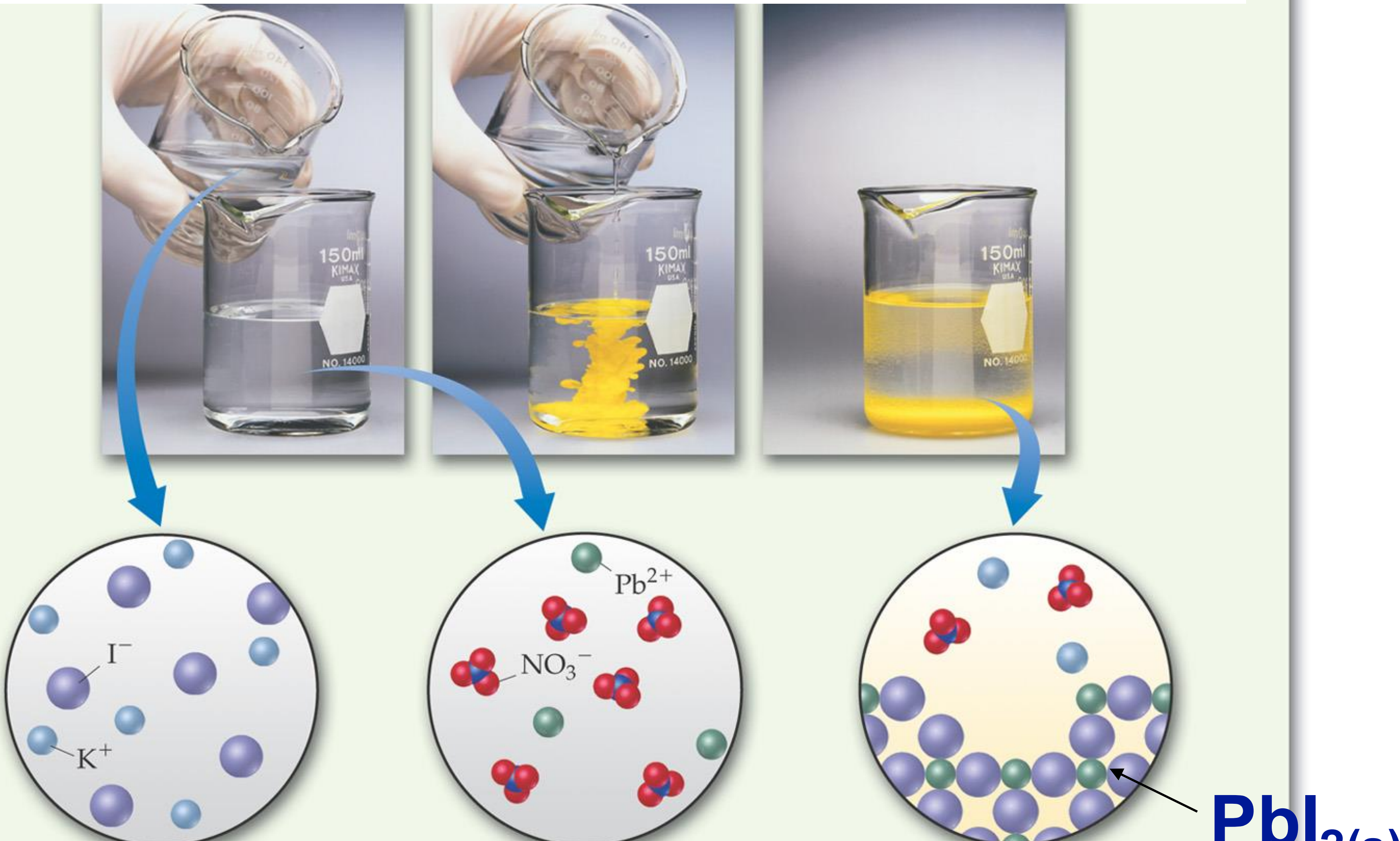
Phosphate Precipitants (Fe^{3+}, Ca^{2+} etc.

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

$2Pb + O_2 \rightarrow 2Pb^{2+} + 2O^{2-}$

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

Precipitation Reactions



$2\,KI(aq)$ + $Pb(NO_3)_2(aq)$ $\longrightarrow$ $PbI_2(s) + 2\,KNO_3(aq)$

The addition of a colorless solution of potassium iodide (KI)

to a colorless solution of lead nitrate

produces a yellow precipitate of lead iodide (PbI_2) that slowly settles to the bottom of the beaker.

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

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.

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

How many different ions will be left in solution?

A. 1
B. 2
C. 3
D. 4

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 (solid)" stuff and "g (gas)" 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's on both the left and right side of the arrow.

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

Net Ionic Equation

- To form the net ionic equation, cross out anything that's on both the left and right side of the arrow.
- The only things left in the equation are those things that **change** (i.e., react) during the course of the reaction.

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

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

Net Ionic Equation

- To form the net ionic equation, cross out anything that's on both the left and right side of the arrow.
- 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. $NaCl_{(aq)} + AgNO_{3(aq)}$ ---------> $AgCl_{(s)} + NaNO_{3(aq)}$

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

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

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

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

3. $3MgCl_{2(aq)} + 2Na_3PO_{4(aq)} \longrightarrow Mg_3(PO_4)_{2(s)} + 6NaCl_{(aq)}$

Choose the net ionic equation:

A. $3MgCl_{2(aq)} + 2Na_3PO_{4(aq)} \longrightarrow Mg_3(PO_4)_{2(s)} + 6NaCl_{(aq)}$

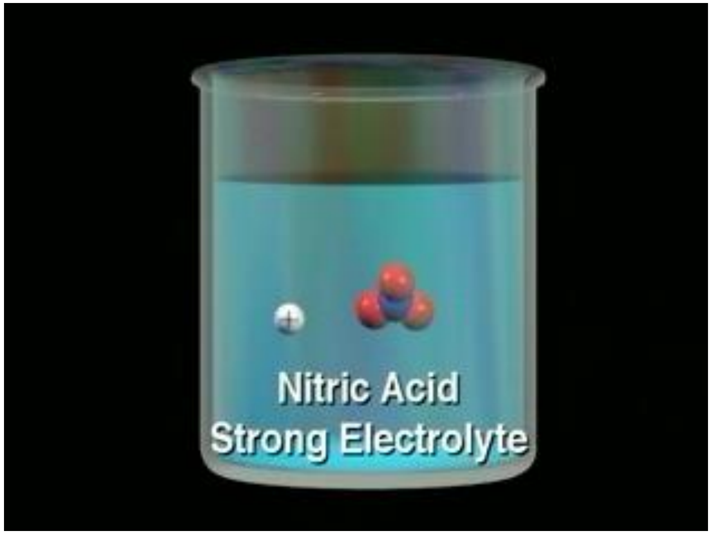
B. $3Mg^{2+} + 6Cl^{-} + 6Na^{+} + 2PO_4^{3-} \longrightarrow Mg_3(PO_4)_{2(s)} + 6Cl^{-} + 6Na^{+}$

C. $3Mg^{2+} + 2PO_4^{3-} \longrightarrow Mg_3(PO_4)_{2(s)}$

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.

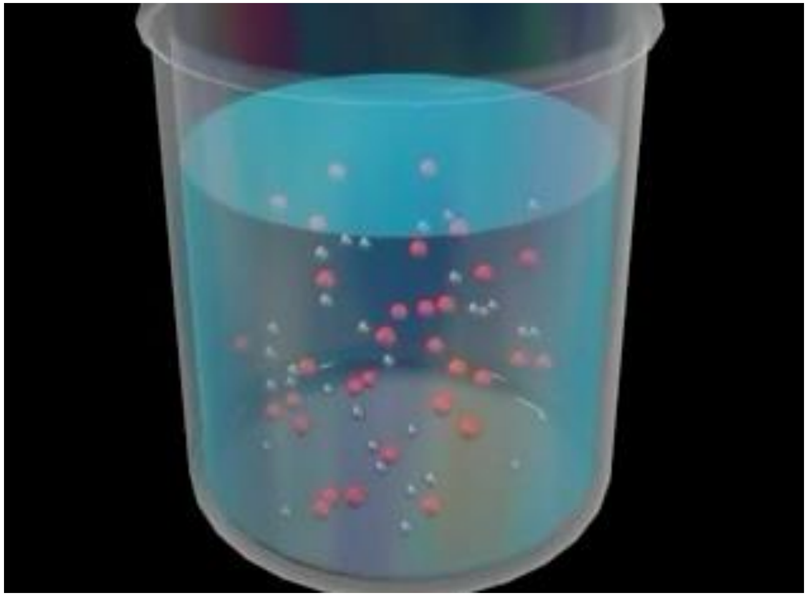
Bases:

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

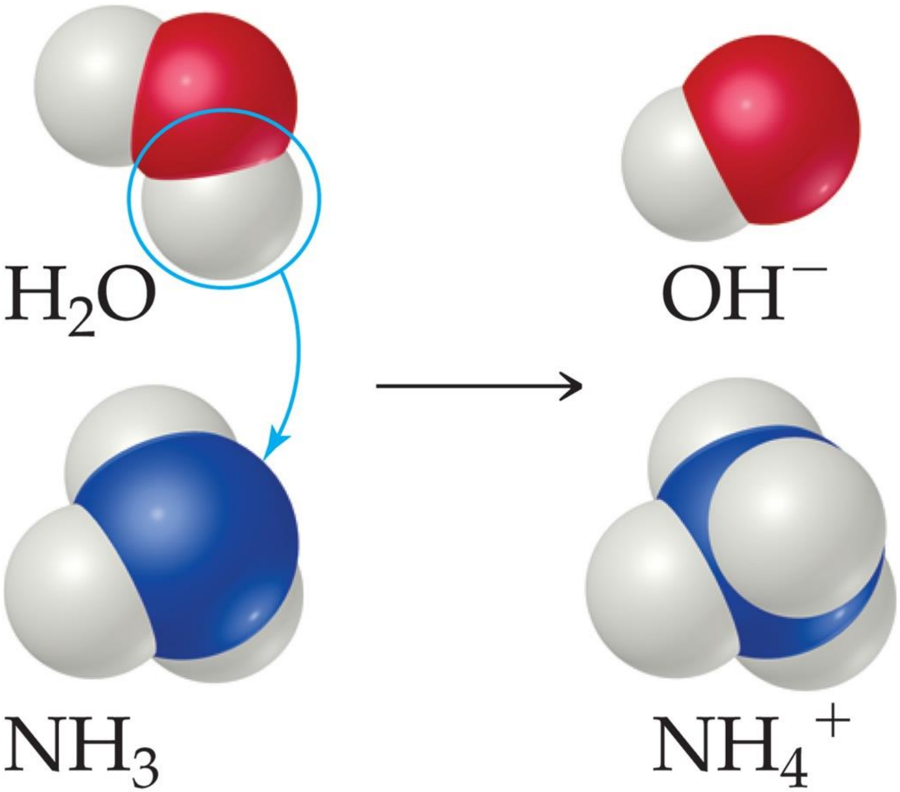
Bases

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

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

Neutralization Reactions

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

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

How many different ions are left in solution?

A. 1
B. 2
C. 3
D. 4
E. 5

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

- reactions that give an unexpected product (acid base).
- Because expected product decomposes to give a gas (CO_2 or SO_2).
- $H_2CO_3 \longrightarrow H_2O + CO_{2(g)}$
- $H_2SO_3 \longrightarrow H_2O + SO_{2(g)}$

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

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

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

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.

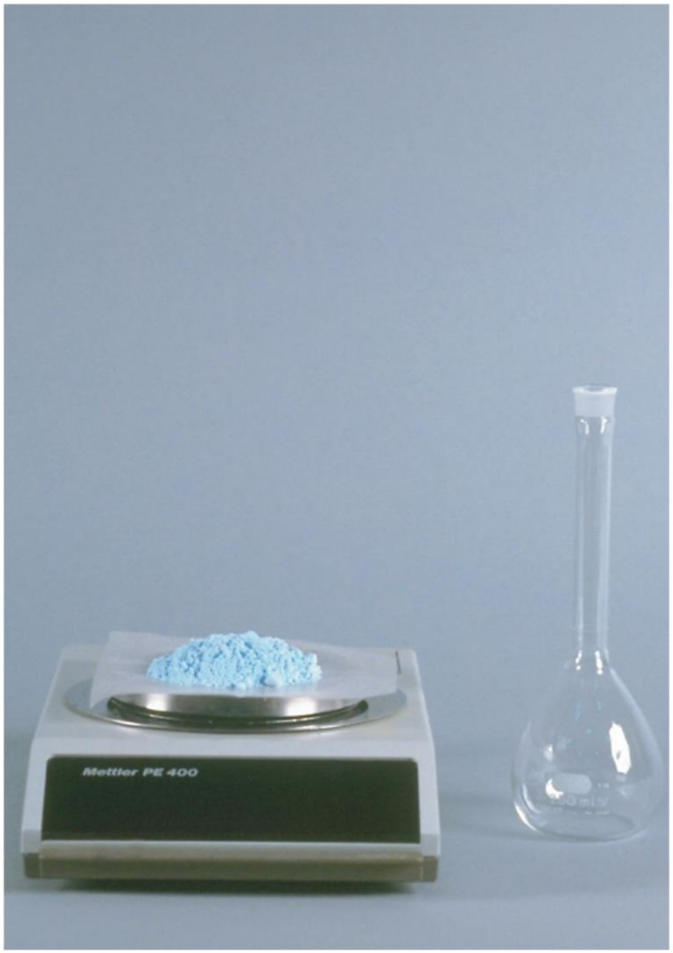
Must find: moles NaCl (M = mol/L)

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



1. **Add some liquid to flask**
2. **Add solid to the liquid**
    1. **The volume must be below your desired volume**
3. **Dissolve all the solid**
4. **Add liquid to correct volume.**

Example

What is the molarity of a solution that contains 10 g of sodium acetate in 0.25 L

MW $NaC_2H_3O_2$: 82 g/mol

A. 0.25 M
B. 0.49 M
C. 0.72 M

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**

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

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?

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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?

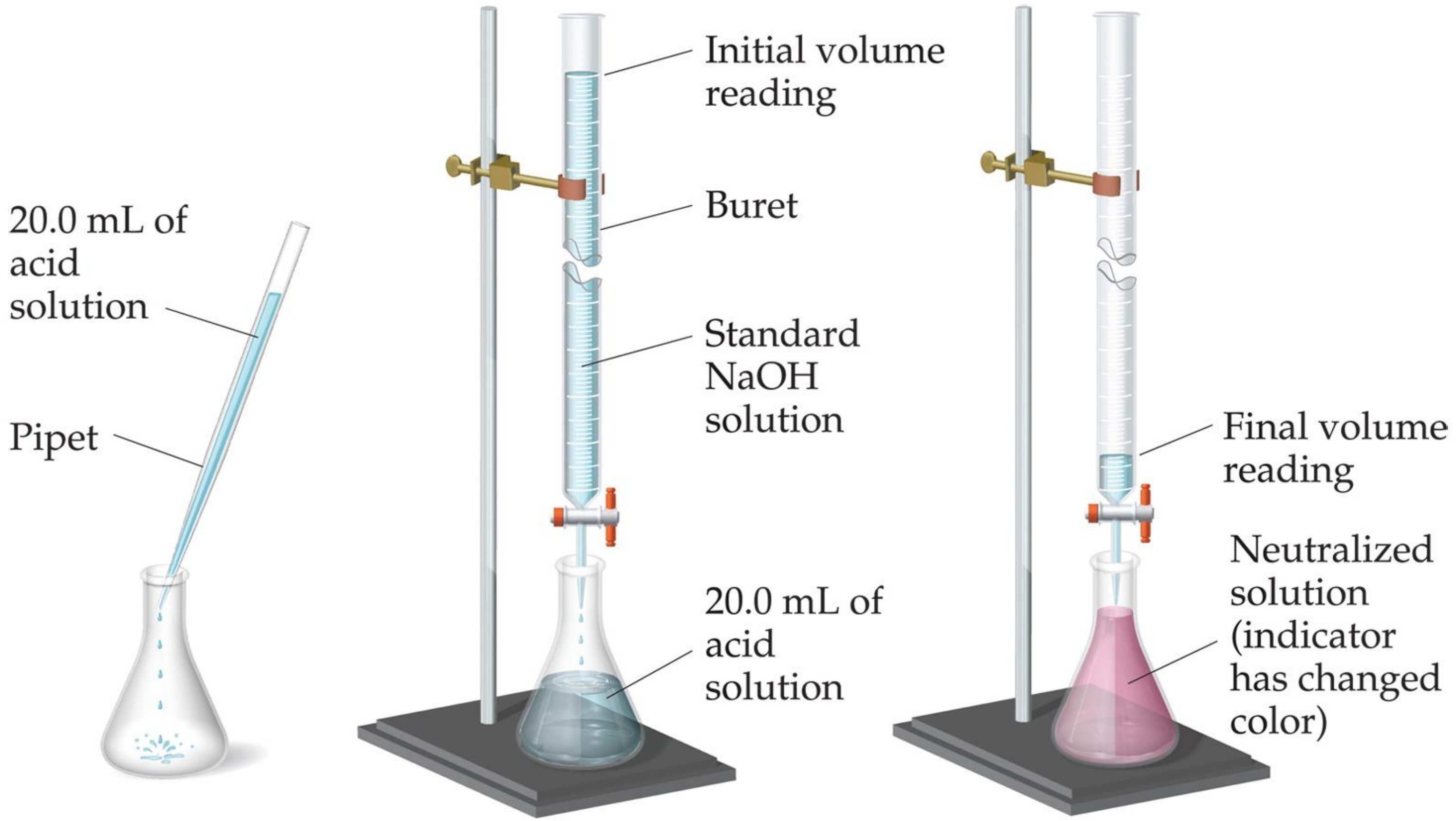
1. Find out how many moles you need in the solution you're making.

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.

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

Titration



Goal: Find the concentration of an unknown solution

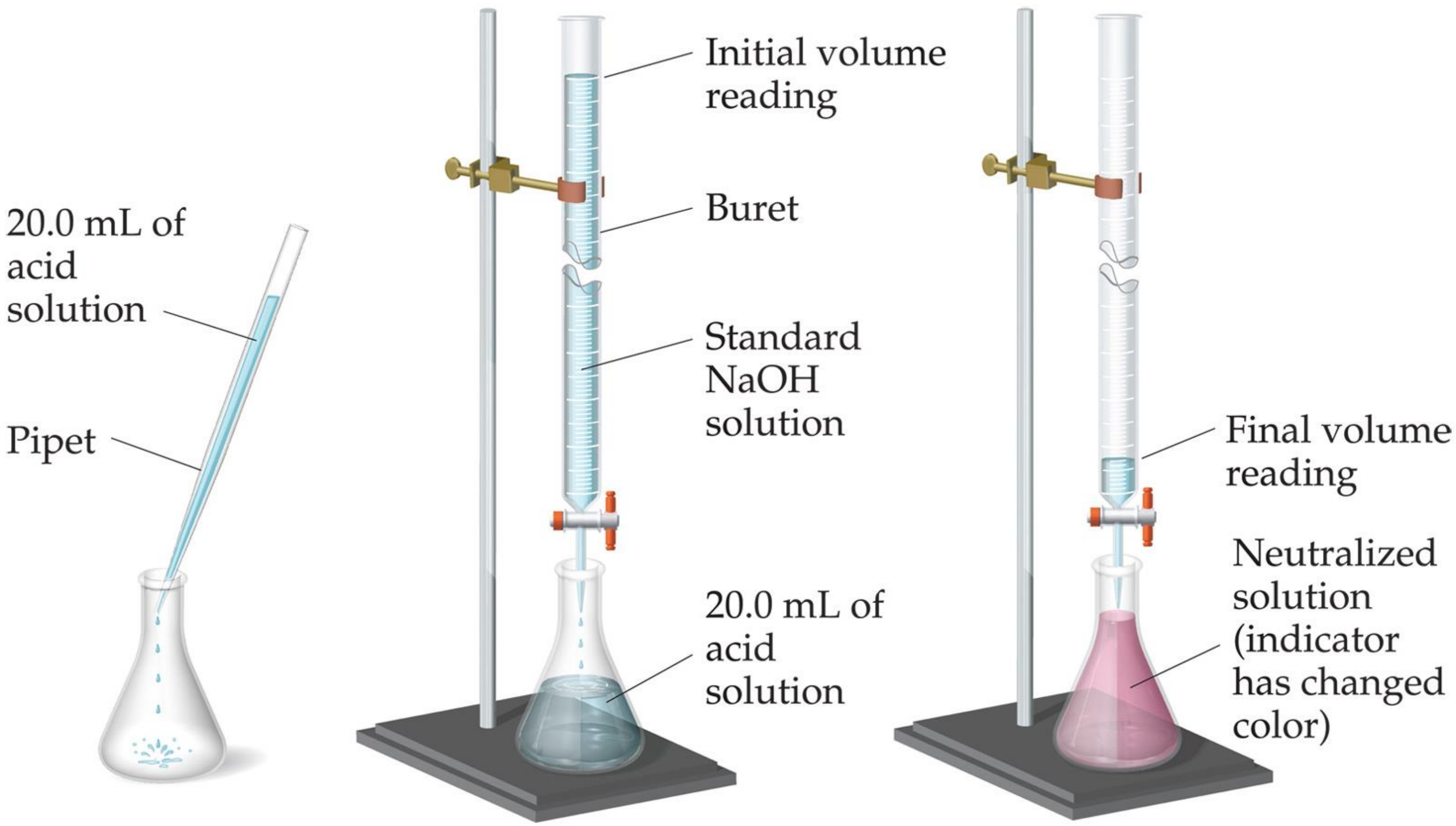
Use:

I. A solution of **Known** concentration (a standard)

II. chemical **reaction**.

III. An **indicator**.

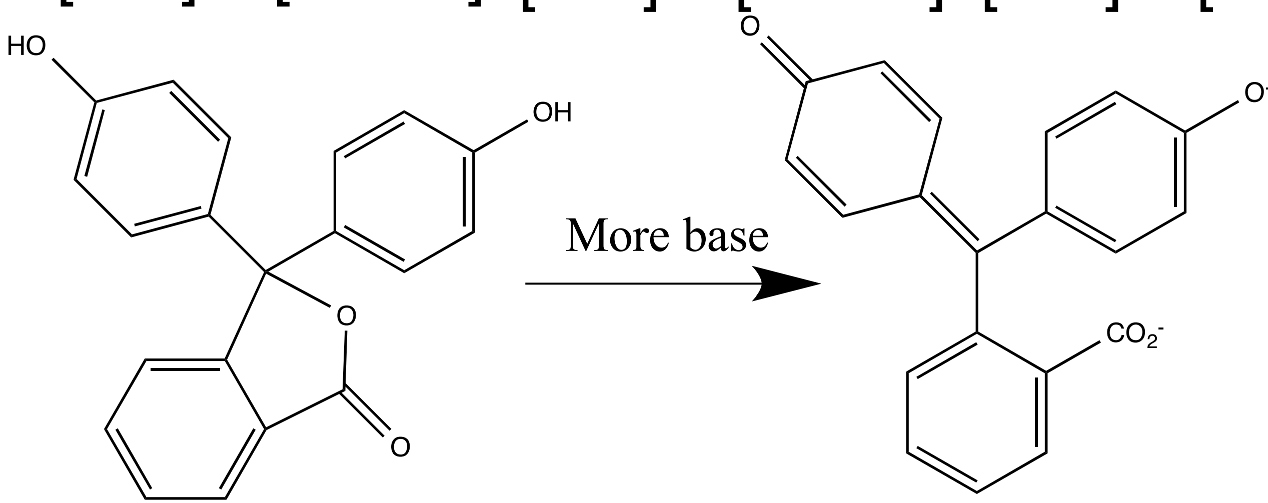
Titration



Example: acid/base titration.

Titration

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



Colorless (acidic) **PINK (basic solution)**

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 ------> 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

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	???	???	

At end point of titration: 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)

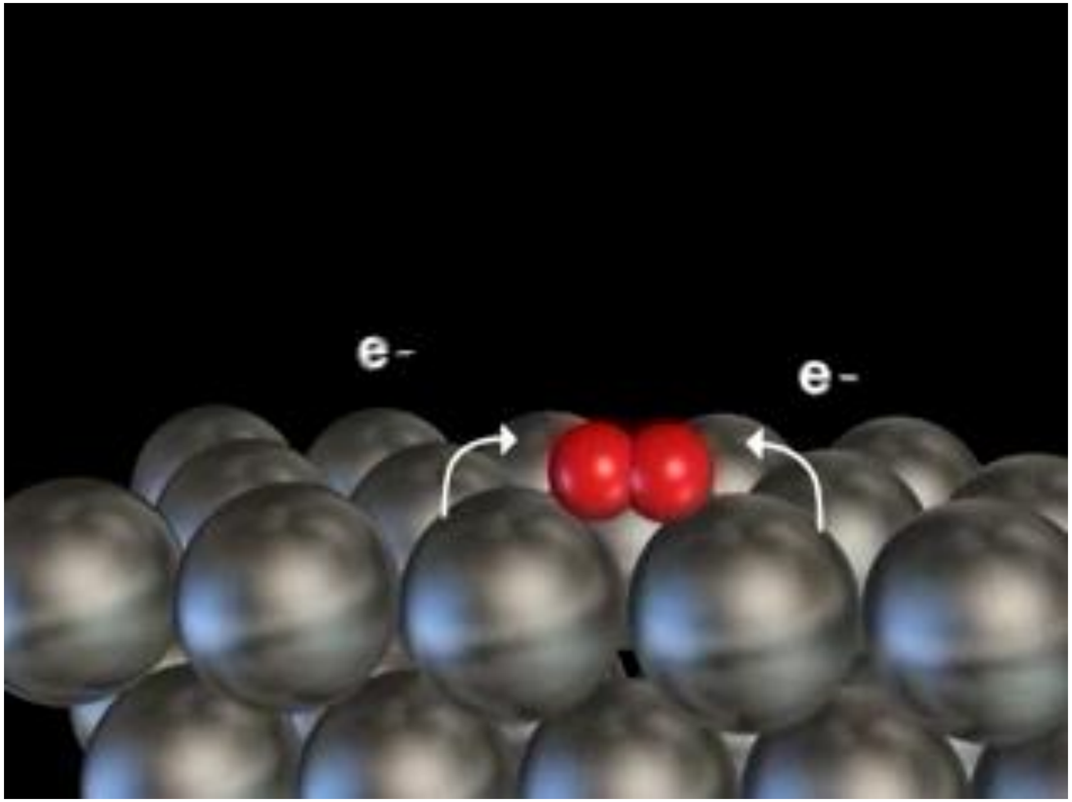
= 0.00339 mole HCl = moles NaOH

[NaOH]=

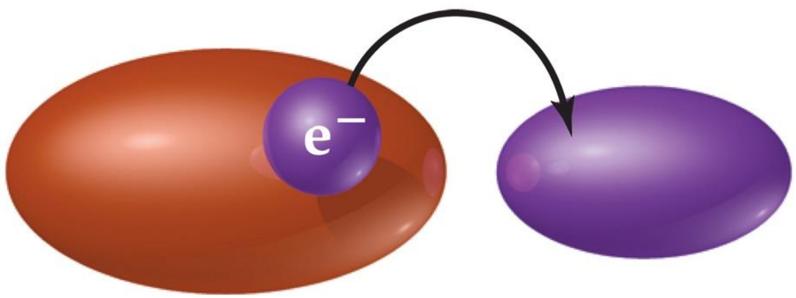
0.00339 mol/0.172L = **0.0197 mol/L (M)**.

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



Substance **oxidized** (loses electron)

Substance **reduced** (gains electron)

One cannot occur without the other.

Electrons must come from somewhere…

And end up somewhere.

- $2Na + Cl_2 \dashrightarrow 2Na^+ + 2Cl^-$

Which species is oxidized?

A. Na

B. Cl_2

C. Na^+

D. Cl^-

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 a molecule is the **charge** on the molecule.

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-}) (−1 no choice) or O_2 (0).
  - 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;
- But halogens can have positive oxidation numbers when they are with F or O,
- Example: 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	+5 -2	+3 -1	+6 -1	+1 -2
CO_3^{2-}	NO_3^-	$FeCl_3$	SF_6	H_2S
	+2 -1	+3 -1	+5 -2	+1 -2
	CaH_2	BBr_3	SO_3^-	ClO^-

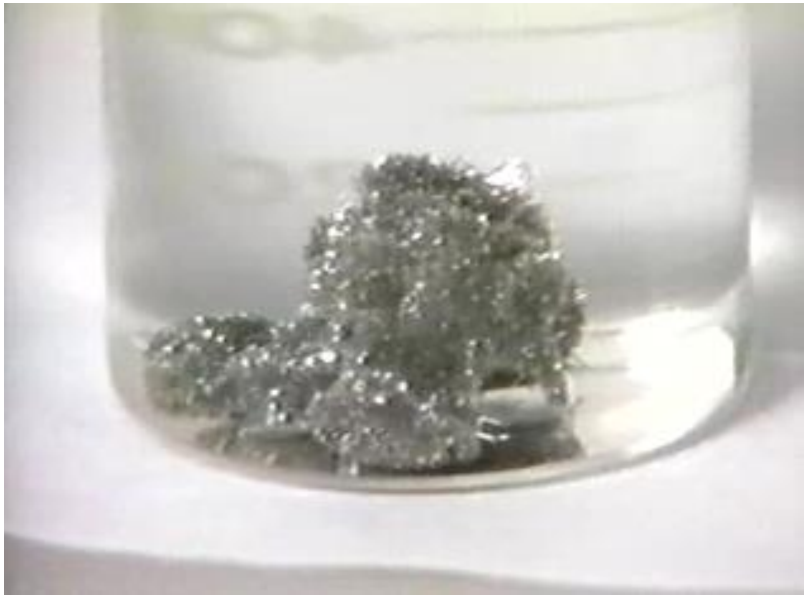
What's the oxidation number for Sulfur in sulfuric acid?

A. 0
B. +2
C. +4
D. +6
E. -6

What's the S oxidation number in the sulfate ion?

A. 0
B. +2
C. +4
D. +6
E. -6

Displacement Reactions



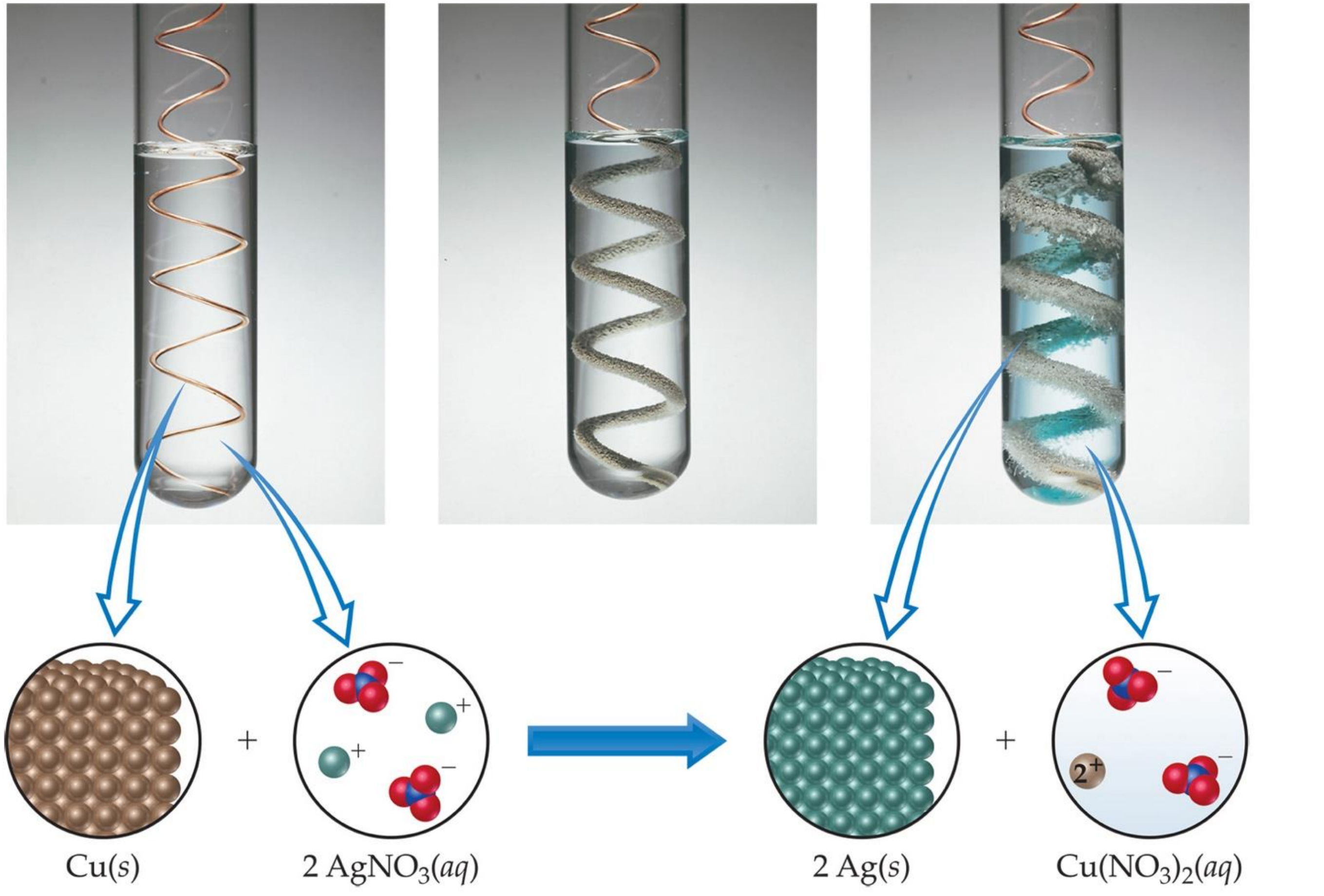
- In displacement reactions, **cations** oxidize an element.
- The **cations** then, are reduced.

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

$2Li(s) + 2HBr \text{ ------> } 2LiBr + H_2$

$Na(s) + AgNO_3 \text{ ------> } NaNO_3 + Ag(s)$

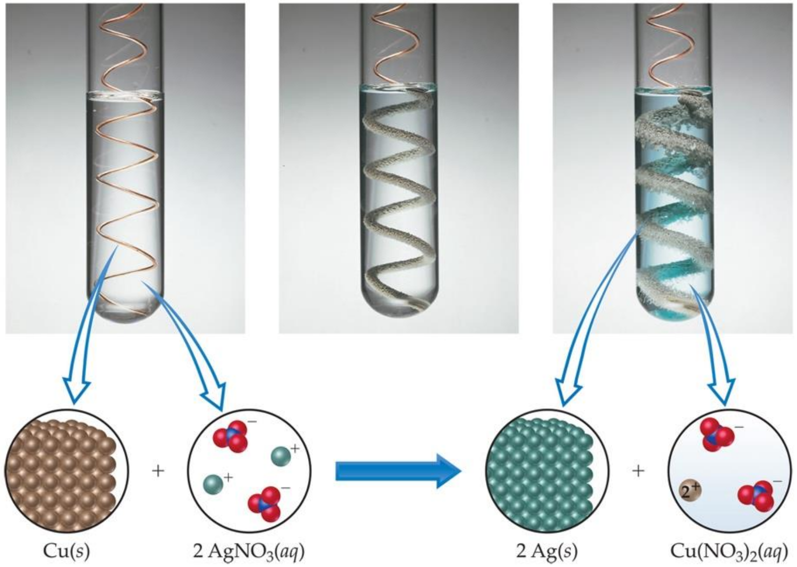
Displacement Reactions



silver ions oxidize copper metal.

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

Displacement Reactions

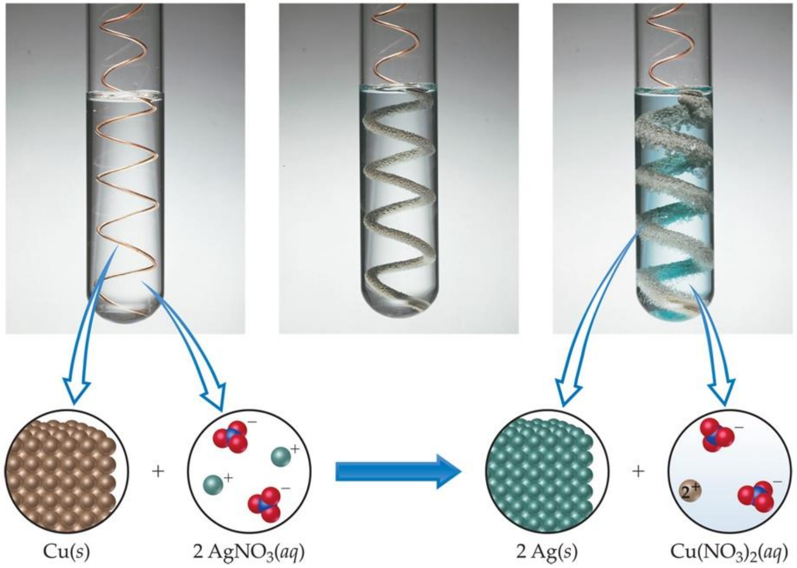


But copper ions will *not* Oxidize silver metal.

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

Why not??

Displacement Reactions



But copper ions will *not*
Oxidize silver metal.

Cu^{2+} (*aq*) + 2 Ag (*s*) ⟶✗ 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	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
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?

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

$Li + H_2$ ----> ?

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

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

A. 1st species oxidized
2nd reduced

B. 1st species reduced
2nd oxidized

C. Nothing.

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	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
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

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

A. $Ca(s) \rightarrow Ca^{2+}$
B. $Zn \rightarrow Zn^{2+}$
C. All of the above
D. None of the above.

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	$H_2(g)$	$\longrightarrow$	$2H^{+}(aq)$	+	$2e^{-}$
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 + $5O_2$ ---------> 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

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

+1 +5 -2   0   0   +1 +4 -2   +1 +6 -2   +4 -2   0

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

What element is oxidized?

A. N
B. O
C. S
D. C

What element is reduced?

What's the reducing agent?

What's the oxidizing agent?

Oxidation reduction reactions
Example: gunpowder

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

$$10\overset{+1\ +5\ -2}{KNO_3}(s) + 3\overset{0}{S}(s) + 8\overset{0}{C}(s) \rightarrow 2\overset{+1\ \ +4\ -2}{K_2CO_3}(s) + 3\overset{+1\ \ +6\ -2}{K_2SO_4}(s) + 6\overset{+4\ -2}{CO_2}(g) + 5\overset{0}{N_2}(g)$$

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?

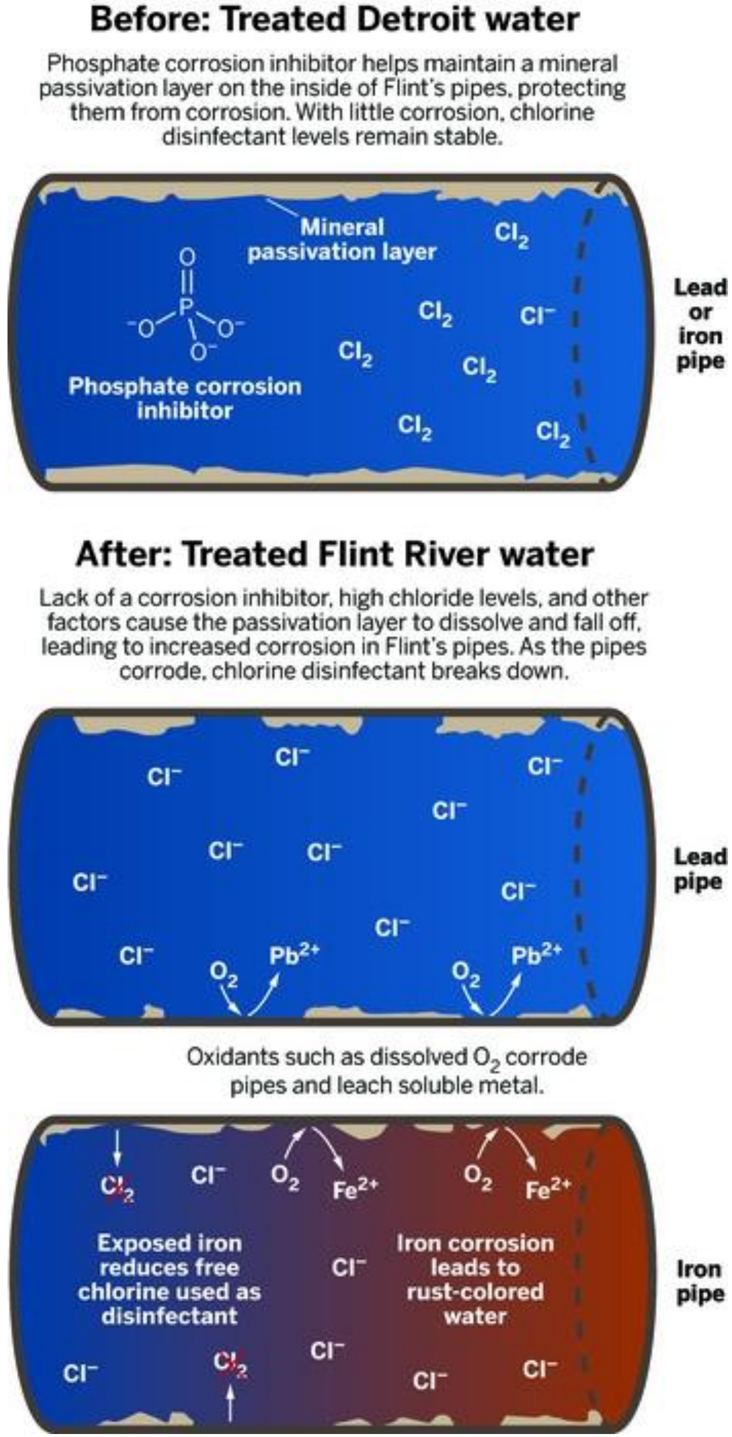
Solubility trends

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



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

Exam 1

- Covers chap 1 - 4.
- Chap 1:Matter and measurement
  - Molecules, compounds etc.
  - Separations
  - Mixtures, Solutions, pure substances etc.
  - Units, dimensional analysis, sig figs.
- Chap 2, atoms, molecules, ions.
  - History experiments
    - Gold foil
    - Cathode ray tube
    - Mulliken oil drops
    - radioactivity

Exam 1

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

Exam 1

- Chemical formulas
- Monoatomic ions
- Ionic compounds
- Polyatomic ions
- Acids
- Naming binary compounds

Exam 1

- Chap 3, Stoichiometry, chemical reactions.
  - Empirical Formulas
  - The mole
  - Stoichimetry and chemical reactions
  - Balancing reactions
  - Limiting reagent.

Chapter 4.

Solution stoichiometery

- Strong vs. weak electrolytes
- Know strong electrolytes
  - strong acids
  - soluble salts

- precipitation reactions
- Ionic equation
- net ionic equation
- Neutralization reactions
- gas forming reactions
  - H_2CO_3 ---- CO_2 H2O

Chapter 4.

- Solution stoichiometery
  - Molarity
  - Dilution
  - Titration
  - Oxidation reduction
    - assigning oxidation numbers
    - who is oxidizing and reducing?
    - activity series

Exam 1 2025

- Homogeneous, heterogeneous mixtures/solutions (1)
- Significant figures (1)
- Subatomic particles (in atoms or not) (1)
- History (1)
- Dimensional analysis/conversions (2)
- Stoichiometry/Limiting reagent/percent cmp (2)
- Isotopes (1)
- Naming compounds/ions/acids polyatomic ions (2)
- Empirical formula (1)
- Strong/weak electrolytes (1)
- Net Ionic Equation (1)
- Acid/base neutralization (1)
- Oxidation numbers (1)
- Oxidation/reduction activity table (1)
- Precipitation reactions (1)

Exam 1 2023

- Homogeneous, heterogeneous mixtures/solutions (1)

  20 g of potassium sulfate is dissolved in water. The resulting is:

  A. mixture

  B. pure substance

  C. homogeneous solution

- Significant figures (1)
  - How many significant figures in 256,004.0042
    - A. 3
    - B. 6
    - C. 8
    - D. 10
- Chemical/physical/intensive/extensive properties (1)
  - Choose the extensive property.
    - A. Density
    - B. Color
    - C. Corrosiveness
    - D. Flamability
    - E. Volume

– History

- Which of the following experiments gave us the charge/mass ratio of the electron?
  - A. Gold foil
  - B. Oil drop
  - C. Cathode ray tube experiments.

– Isotopes

– Neon has an atomic mass of 20.1707 amu. How many neutrons does the most common isotope of neon have?

- A. 8 C. 10 E. 12
- B. 9 D.11 F. 13

-Emprical formula

What is the empirical formula for the compound $C_6H_8O_4$?

A. $C_6H_8O_4$

B. C_1H_2O

C. $C_{1.5}H_2O$

D. $C_3H_4O_2$

– Strong/weak electrolytes

- Which of the following is a strong electrolyte
  - A. H_2SO_3
  - B. HCl
  - C. HF

–Net Ionic equation.

- Which is the proper net ionic equation for the neutralization of hydrochloric acid with Calcium hydroxide (a solid)?
- A. $2HCl(aq) + CaOH_2(aq) \text{ ---}\rightarrow 2H_2O(l) + CaCl_2(aq)$
- B. $2H^+(aq) + 2OH^-(aq) \text{ ---}\rightarrow 2H_2O(l)$
- C. $2H^+(aq) + CaOH_2(s)$. $\text{---}\rightarrow 2H_2O(l) + Ca^{2+}(aq)$

-Acid/base neutralization

How many moles of HCl are requri

A. $C_6H_8O_4$

B. C_1H_2O

C. $C_{1.5}H_2O$

D. $C_3H_4O_2$

– Strong/weak electrolytes

- Which of the following is a strong electrolyte
  - A. H_2SO_3
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- Which is the proper net ionic equation for the neutralization of hydrochloric acid with Calcium hydroxide (a solid)?
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- B. $2H^+$(aq) + $2OH^-$(aq) ---→ $2H_2O$(l)
- C. $2H^+$(aq) +$CaOH_2$(s). ---→ $2H_2O$(l) + Ca^{2+}(aq)

-Acid/base neutralization

How many moles of HCl are requri

A. $C_6H_8O_4$

B. C_1H_2O

C. $C_{1.5}H_2O$

D. $C_3H_4O_2$

– Oxidation numbers

What is the oxidation number for phosphorous in H_3PO_4?

- A. +1
- B. +3
- C. +5
- D. +6
- E. +8

Oxidation/reduction activity table

Which of the following will react as written?

A. $3BaCl_2(s) + 2Al(s) \dashrightarrow 2AlCl_3 + 3Ba(s)$

B. $2AlCl_3 + 3Ba(s) \dashrightarrow 3BaCl_2(s) + 2Al(s)$

C. $LiCl + Na(s) \dashrightarrow$. $Li(s) + NaCl$

Precipitation Reaction.

Given that acetates are very soluble and phosphates are not. Which of the following is most likely a correct reaction?

A. $Ba_3(PO_4)_{2\ (aq)} + 6Na(C_2H_3O_2)(aq) \dashrightarrow$. $3Ba(C_2H_3O_2)_2\ (s) + Na_3(PO_4)(aq)$

B. $Ba_3(PO_4)_{2(s)} + 6Na(C_2H_3O_2)(aq) \dashrightarrow$. $3Ba(C_2H_3O_2)_2\ (aq) + 2Na_3(PO_4)(aq)$

- $NaClO + H_2O$ ---→ $2H_2O + O_2$
- $NaClO + HCl$ → $Cl_2 + OH^-$
- Cl_2 + stuff -→ Cl^- + oxidized stuff.

Demonstration:

$$2Mg + CO_2 \text{ ------> } 2MgO + C \text{ (charcoal)}$$