

# Chem With Com

# Chemical Equations and Chemical Reactions

- Chapter 1.3 (Physical and Chemical Properties)
- Chapter 7.1 (Writing and Balancing Chemical Equations)
- Chapter 7.2 (Classifying Chemical Reactions)

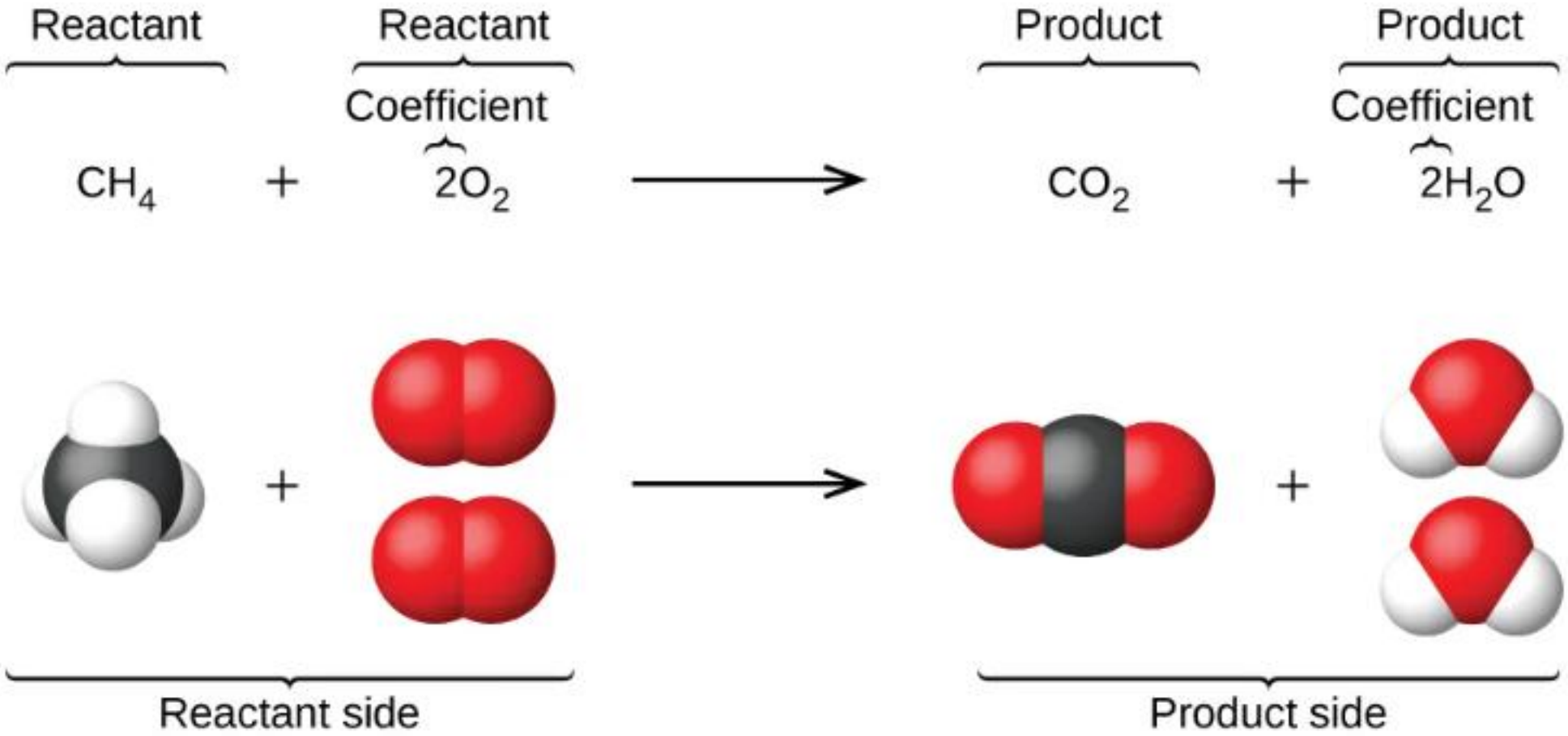
Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

# Chemical Equations and Balancing

- Chapter 7.1 (Writing and Balancing Chemical Equations)

Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

# Chemical Equations



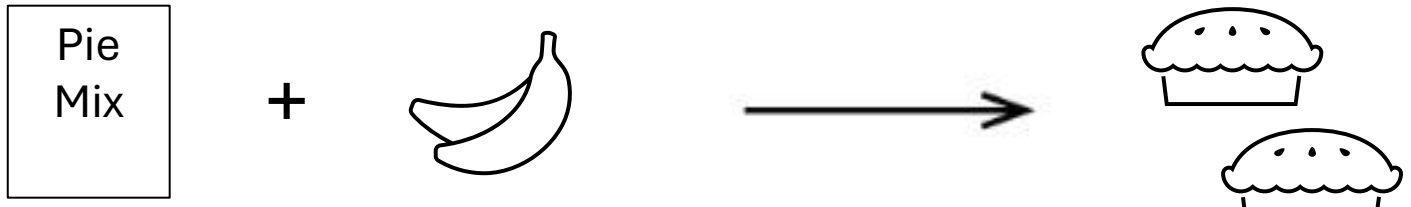

1. The substances undergoing reaction are called **reactants**, and their formulas are placed on the left side of the equation.
2. The substances generated by the reaction are called **products**, and their formulas are placed on the right side of the equation.
3. Plus signs (+) separate individual reactant and product formulas, and an arrow (⟶) separates the reactant and product (left and right) sides of the equation.
4. The relative numbers of reactant and product species are represented by **coefficients** (numbers placed immediately to the left of each formula). A coefficient of 1 is typically omitted.

# Cooking is similar to chemistry

Reactant | Reactant | Product

Coefficient | Coefficient

**1 pie mix + 2 bananas → 2 banana pies**




Reactant side | Product side

1. The substances undergoing reaction are called **reactants**, and their formulas are placed on the left side of the equation.
2. The substances generated by the reaction are called **products**, and their formulas are placed on the right side of the equation.
3. Plus signs (+) separate individual reactant and product formulas, and an arrow (⟶) separates the reactant and product (left and right) sides of the equation.
4. The relative numbers of reactant and product species are represented by **coefficients** (numbers placed immediately to the left of each formula). A coefficient of 1 is typically omitted.

# States of Matter

| Phase | Symbol | Examples | Notes |
|---|---|---|---|
| Solid | (s) | $PbI_2$ (s), $H_2O$ (s) | These can be suspended solids in a liquid or dry solids |
| Liquid | (l) (lowercase "L") | $H_2O$ (l), $C_8H_{18}$ (l) | |
| Gas | (g) | $N_2$ (g), $O_2$ (g), $H_2O$ (g) | |
| Aqueous | (aq) | NaCl (aq), $Ag^{1+}$ (aq) | Dissolved in water. Compounds like NaCl (aq) are actually separate like $Na^{1+}$ (aq) and $Cl^{1-}$ (aq) |

$$2\mathrm{Na}(s) + 2\mathrm{H_2O}(l) \longrightarrow 2\mathrm{NaOH}(aq) + \mathrm{H_2}(g)$$

# Ingredients List vs Recipe

Bread + Cheese → Sandwich



Ingredients list = unbalanced equation

How much do we need of each??

2 Bread + 1 Cheese → 1 Sandwich



Recipe = balanced equation

Ratio

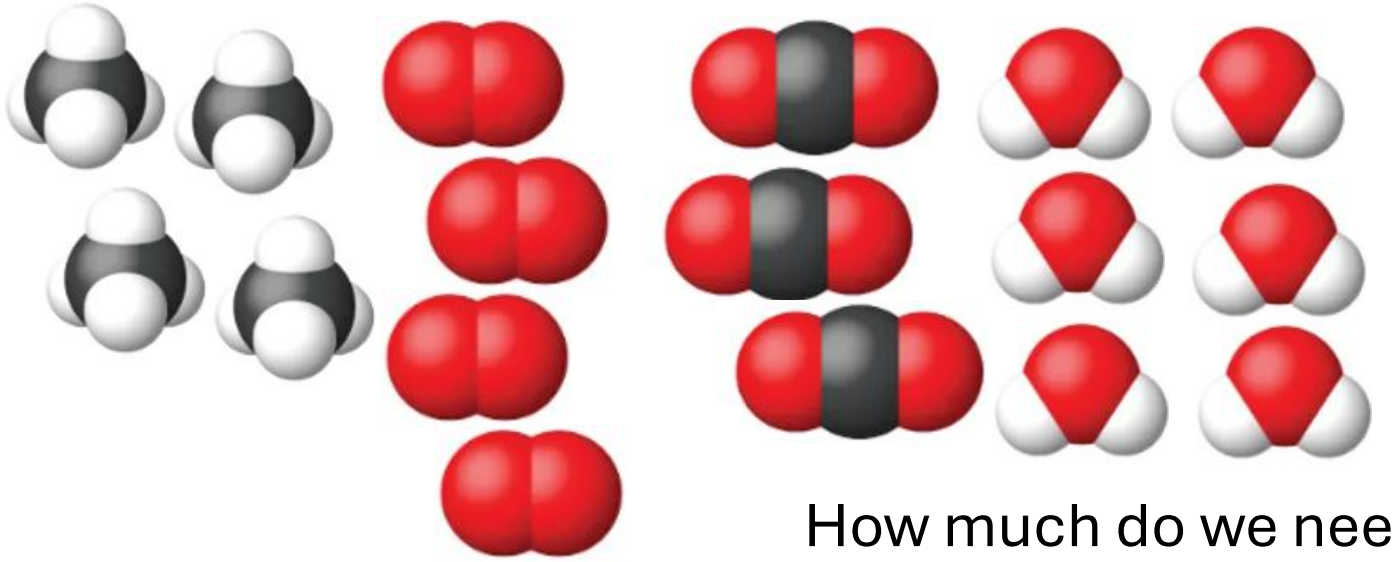
2 bread : 1 cheese

1 cheese : 1 sandwich

2 bread : 1 sandwich

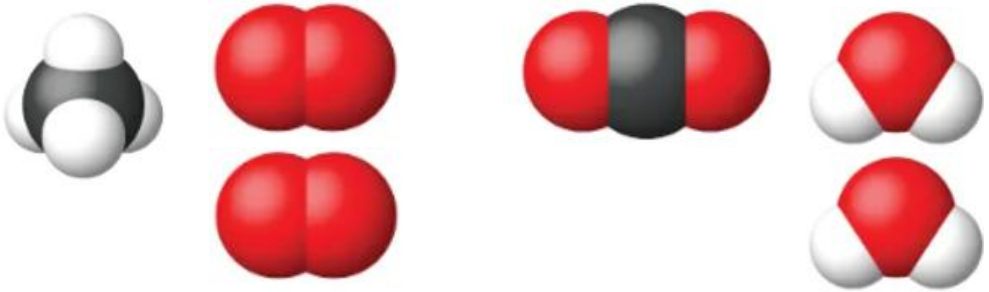
# Ingredients List vs Recipe

$CH_4 + O_2 \rightarrow CO_2 + H_2O$ Ingredients list = unbalanced equation



How much do we need of each??

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ Recipe = balanced equation



Ratio

$1\ CH_4 : 2\ H_2O$

$1\ CH_4 : 2\ O_2$

$2\ O_2 : 1\ CO_2$

$1\ CO_2 : 2\ H_2O$

Many more ratios!

# Chemical reactions are just rearrangement of atoms

Bread + Cheese → Sandwich



At your house you have many ingredients. Most of the time you don't just have 2 pieces of bread and 1 piece of cheese.

Bread + Cheese → Sandwich



We know if there is an ingredient or product, we must have at least one of those.

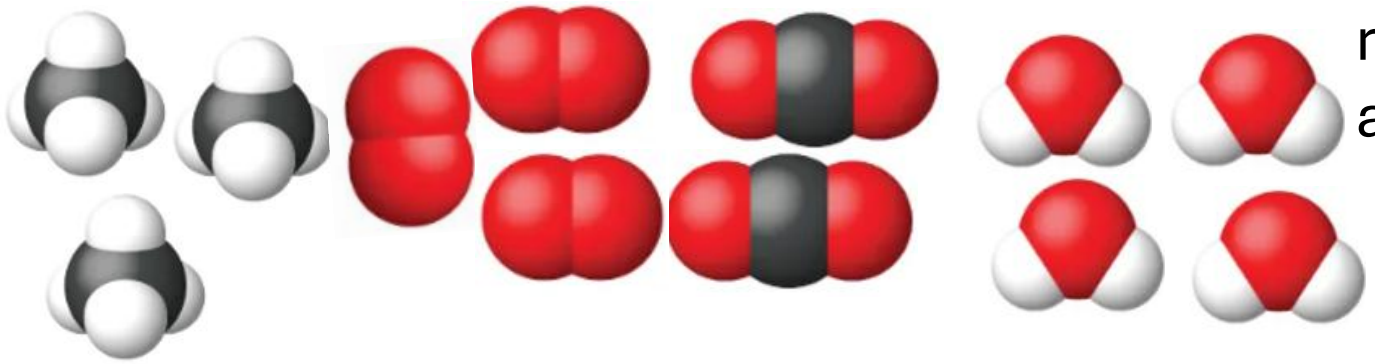
2 Bread + 1 Cheese → 1 Sandwich



Chemical reactions are just rearrangements of atoms so whatever quantity of ingredients we start with, we have to finish with. Since the product is a sandwich, we must have 2 pieces of bread and 1 piece of cheese as ingredients.

# Chemical reactions are just rearrangement of atoms

$CH_4 + O_2 \rightarrow CO_2 + H_2O$



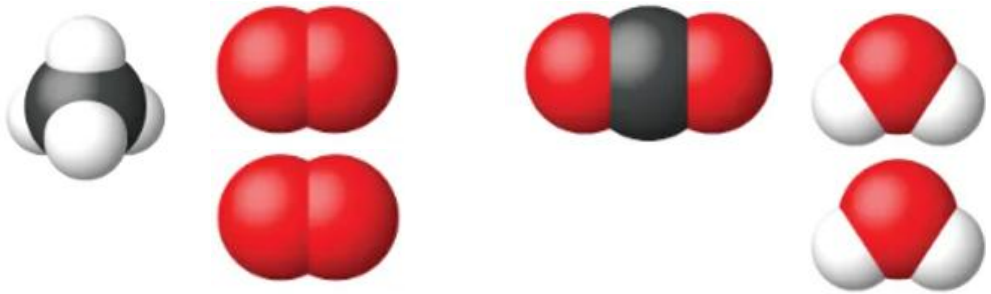
In a chemical reaction you have many reactants. You don't just have the exact amount of reactants.

$CH_4 + O_2 \rightarrow CO_2 + H_2O$



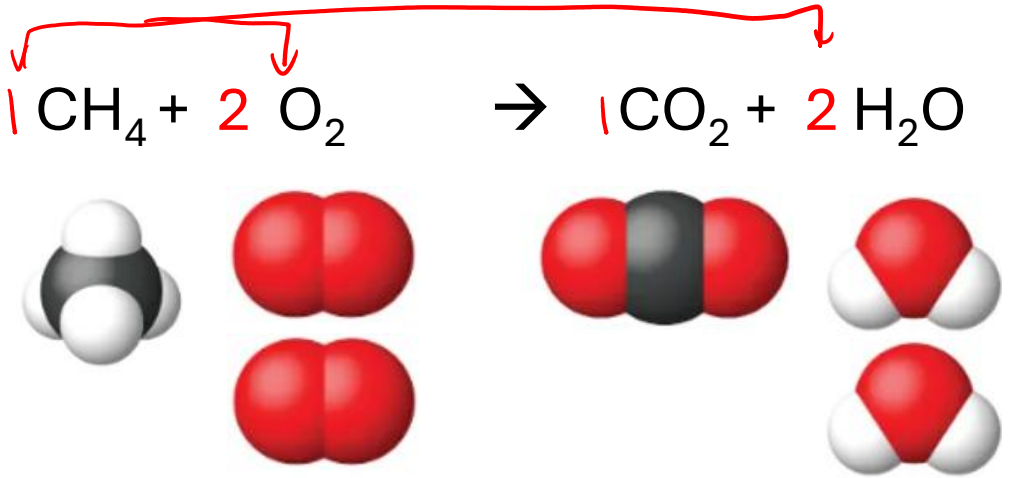
We know if there is a reactant or product, we must have at least one of those.

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



Chemical reactions are just rearrangements of atoms so whatever quantity of reactants we start with, we have to finish with. Since the products have 4 oxygen atoms, 4 hydrogen atoms, and 1 carbon atom, we need the same in the reactants

# Ratios of ingredients and products can be in any quantities but chemists use moles. This is the mole ratio!




Ratio

1 $CH_4$ : 2 $O_2$

1 dozen $CH_4$ : 2 dozen $O_2$

1 hundred $CH_4$ : 2 hundred $O_2$

1 mole $CH_4$ : 2 moles $O_2$

1 x ($6.022 \times 10^{23}$) $CH_4$ : 2 x ($6.022 \times 10^{23}$) $O_2$

# Balancing Equations = creating a recipe and using up all the ingredients

You've been invited to a potluck style party. You were tasked with bringing surf and turf burgers for everyone (1 hamburger patty+1 crispy fish patty+3 buns+1 piece of cheese). You go to the burger shop and they don't have any so you decide the closest thing is to buy a crispy fish sandwich and a cheeseburger and assemble them yourself. You don't want to waste anything so you assemble all the ingredients you don't need into something else as well.

Cheeseburger
$CHB_2$

+

Crispy Fish Sandwich
$CFB_2$

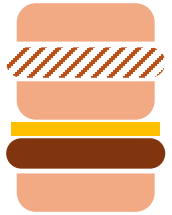


+





Surf and Turf Burger
$CFHB_3$



+

Bun
B



+

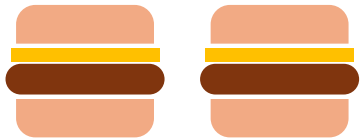
Cheese
C



KEY
C = cheese
H = Hamburger
F = Crispy Fish Patty
B = Bun

Can't really serve a piece of bread and cheese so you need to buy more ingredients to use everything up

2 Cheeseburgers
$2\ CHB_2$



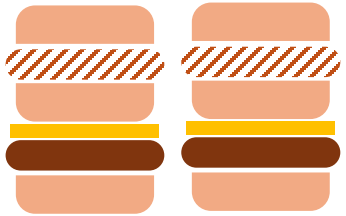
+

2 Crispy Fish Sandwiches
$2\ CFB_2$



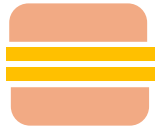


2 Surf and Turf Burgers
$2\ CFHB_3$



+

1 Grilled Cheese
$1\ C_2B_2$



# How to balance chemical equations – Com's Way

1. Take inventory of all the atoms (or polyatomic ions) in the reactants and products.
2. Select a reactant or product with the most atoms.
3. Within your selection, choose an atom (or polyatomic ion) and balance them on both sides of the reaction arrow by increasing the coefficient on the reactant or product.
4. Retake inventory of all the atoms in the reactant and products
5. Repeat steps 3 and 4 with the other atom (or polyatomic ion) that was in your original selection.
6. Choose another atom or reactant or product to balance and repeat steps 3 and 4
7. Repeat step 6 as many times as necessary

Note: If polyatomic ions are together in the reactants and products, keep them together and don't separate into atoms

$$Cu(s) + HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + H_2O(l) + NO(g)$$

$NO_3$ the same on both sides of reaction

$$(NH_4)_2Cr_2O_7(s) \longrightarrow Cr_2O_3(s) + N_2(g) + H_2O(g)$$

$NH_4$ NOT the same on both sides of reaction

# How to balance chemical equations – Com's Way

Step 1: Take inventory of all the atoms or polyatomic ions in the reactants and products

$CH_4 + O_2 \rightarrow CO_2 + H_2O$

C = 1, H = 4, O = 2 | C = 1, H = 2, O = 3

Step 2: Select a reactant or product with the most atoms. ($CH_4$ has the most atoms)

5 atoms

$CH_4 + O_2 \rightarrow CO_2 + 2\,H_2O$

C = 1, H = 4, O = 2 | C = 1, H = ~~2~~ 4, O = ~~3~~ 4

Step 3: Within your selection, choose an atom (or polyatomic ion) and balance them on both sides of the reaction arrow by increasing the coefficient on the reactant or product. (choosing H)

Step 4: Retake inventory of all the atoms in the reactant and products. (Even though we picked H, we also change O because we increased the coefficient that affected the oxygen in the product)

Step 5: Repeat steps 3 and 4 with the other atom (or polyatomic ion) that was in your original selection. (C in $CH_4$ already balanced)

$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$

C = 1, H = 4, O = ~~2~~ 4 | C = 1, H = ~~2~~ 4, O = ~~3~~ 4

Step 4: again

Step 3: again

Step 6: Choose another atom or reactant or product to balance and repeat steps 3 and 4. (oxygen is the last atom needing balancing)

Step 7: Repeat step 6 as many times as necessary

## Balancing Chemical Equations

Write a balanced equation for the reaction of molecular nitrogen ($N_2$) and oxygen ($O_2$) to form dinitrogen pentoxide.

Unbalanced equation $N_2\,(g) + O_2\,(g) \rightarrow N_2O_5\,(s)$

**Check Your Learning**

Write a balanced equation for the decomposition of ammonium nitrate to form molecular nitrogen, molecular oxygen, and water. (Hint: Balance oxygen last, since it is present in more than one molecule on the right side of the equation.)

Unbalanced equation $NH_4NO_3\,(s) \rightarrow N_2\,(g) + O_2\,(g) + H_2O\,(l)$

# Balancing Practice

$$Ca_3(PO_4)_2(aq) + H_3PO_4(aq) \longrightarrow Ca(H_2PO_4)_2(aq)$$

# Building Molecular Equations and Net Ionic Equations

- Chapter 1.3 (Physical and Chemical Properties)
- Chapter 7.1 (Writing and Balancing Chemical Equations)

Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

# Physical changes are the same chemical formula, but just in different states of matter – solid, liquid, gas



(a) (b)

**Figure 1.18** (a) Wax undergoes a physical change when solid wax is heated and forms liquid wax. (b) Steam condensing inside a cooking pot is a physical change, as water vapor is changed into liquid water. (credit a: modification of work by "95jb14"/Wikimedia Commons; credit b: modification of work by "mjneuby"/Flickr)

physical properties include density, color, hardness, melting and boiling points, and electrical conductivity.

# Changing matter into something else and changing the chemical formula is a chemical change



(a) (b)

**Figure 1.19** (a) One of the chemical properties of iron is that it rusts; (b) one of the chemical properties of chromium is that it does not. (credit a: modification of work by Tony Hisgett; credit b: modification of work by "Atoma"/Wikimedia Commons)

Rusting



(a)

Burning



(b)

Cooking



(c)

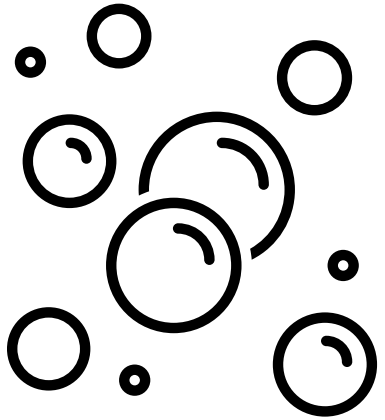
Rotting



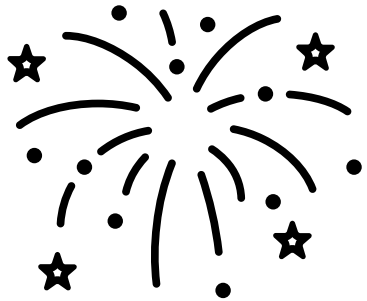
(d)

**Figure 1.20** (a) Copper and nitric acid undergo a chemical change to form copper nitrate and brown, gaseous nitrogen dioxide. (b) During the combustion of a match, cellulose in the match and oxygen from the air undergo a chemical change to form carbon dioxide and water vapor. (c) Cooking red meat causes a number of chemical changes, including the oxidation of iron in myoglobin that results in the familiar red-to-brown color change. (d) A banana turning brown is a chemical change as new, darker (and less tasty) substances form. (credit b: modification of work by Jeff Turner; credit c: modification of work by Gloria Cabada-Leman; credit d: modification of work by Roberto Verzo)

# Did a chemical reaction occur??



Gas Formed – bubbles, vapor, odor



- Energy Transfer – light, heat, cold

Precipitate – solid forming in various solutions (opposite of dissolving)



Color Change



https://www.britannica.com/science/chemical-reaction/Precipitation-reactions
YouTube – DIY bama

# Building a balanced molecular equations from words

- Nomenclature Review (Topic 5)
- Go word by word and write chemical symbols, reaction symbols, phases, and charges. (Topic 5)
- Build chemical reaction by **making neutral compounds**. (Topic 5)

$CO_2$ (aq) (aq) $Na^{1+}$ $OH^{1-}$ →

When carbon dioxide is dissolved in an aqueous solution of sodium hydroxide, the mixture reacts to yield aqueous sodium carbonate and liquid water.

(aq) $Na^{1+}$ $CO_3^{2-}$ + (l) $H_2O$

$$CO_2\,(aq) + NaOH\,(aq) \rightarrow Na_2CO_3\,(aq) + H_2O\,(l)$$

Aqueous because it said dissolved in a aqueous solution

1 $Na^{1+}$ and 1 $OH^{1-}$ because together they make a neutral compound

2 $Na^{1+}$ and 1 $CO_3^{2-}$ because together they make a neutral compound

- Balance

$$CO_2\,(aq) + 2\,NaOH\,(aq) \rightarrow Na_2CO_3\,(aq) + H_2O\,(l)$$

Write a balanced equation describing each of the following chemical reactions.

(c) When solid sodium chloride is added to aqueous sulfuric acid, hydrogen chloride gas and aqueous sodium sulfate are produced.

# Net Ionic Equations – Where the action is!

complete balanced molecular equation

$$CO_2\,(aq) + 2\,NaOH\,(aq) \rightarrow Na_2CO_3\,(aq) + H_2O\,(l)$$

total ionic equation

$$CO_2\,(aq) + 2\,Na^{1+}\,(aq) + 2\,OH^{1-}\,(aq) \rightarrow 2\,Na^{1+}\,(aq) + CO_3^{2-}\,(aq) + H_2O\,(l)$$

net ionic equation

$$CO_2\,(aq) + 2\,OH^{1-}\,(aq) \rightarrow CO_3^{2-}\,(aq) + H_2O\,(l)$$

# Net Ionic Equations – Where the action is!

- Build a complete balanced molecular equation from words

complete balanced molecular equation

$CO_2\,(aq) + 2\,NaOH\,(aq) \rightarrow Na_2CO_3\,(aq) + H_2O\,(l)$

aqueous but not ionic

liquid so not aqueous

total ionic equation

$CO_2\,(aq) + \boxed{2\,Na^{1+}\,(aq)} + 2\,OH^{1-}\,(aq) \rightarrow \boxed{2\,Na^{1+}\,(aq)} + CO_3^{2-}\,(aq) + H_2O\,(l)$

- Total Ionic Equation - separate all ionic aqueous reactants and products
- Polyatomic ions stay together!

net ionic equation

$CO_2\,(aq) + 2\,OH^{1-}\,(aq) \rightarrow CO_3^{2-}\,(aq) + H_2O\,(l)$

- Net Ionic Equation – leave out spectator ions. Spectator ions are ions that are exactly the same on the reactant and product sides. Spectator ions don't really do anything but watch the other ions work!

## Check Your Learning

Diatomic chlorine and sodium hydroxide (lye) are commodity chemicals produced in large quantities, along with diatomic hydrogen, via the electrolysis of brine, (sodium chloride) in water

Write balanced molecular, complete ionic, and net ionic equations for this process.

**Write the complete balanced molecular equation, total ionic equation, and net ionic equation for the following:**

(c) When solid sodium chloride is added to aqueous sulfuric acid, hydrogen chloride gas and aqueous sodium sulfate are produced.

# Precipitation and Acid-Base Reactions

- Chapter 7.2 (Classifying Chemical Reactions)

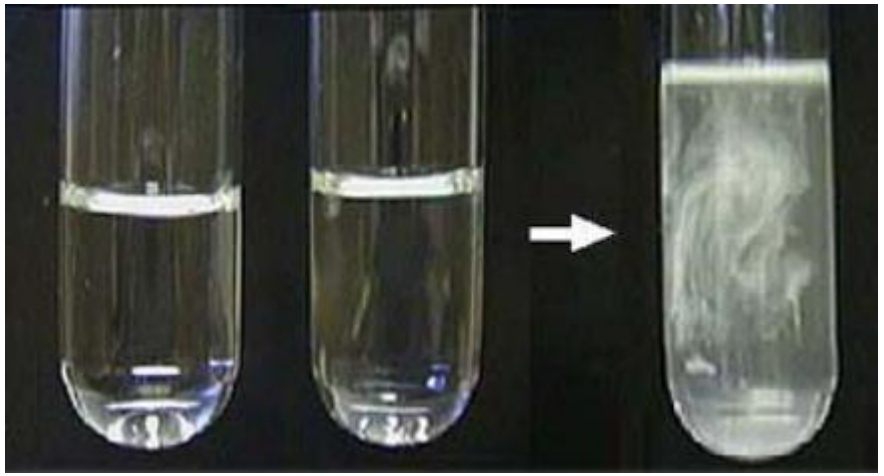
Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

# Types of Reactions

- Precipitation Reactions – two solutions mixed together create a solid
- Acid-Base Reactions – combining and acid and a base to make water and a “salt”
- Oxidation-Reduction (Redox) Reactions – a transfer of electrons

# Precipitation Reactions

- Combining two solutions results in the formation of a solid (precipitate)

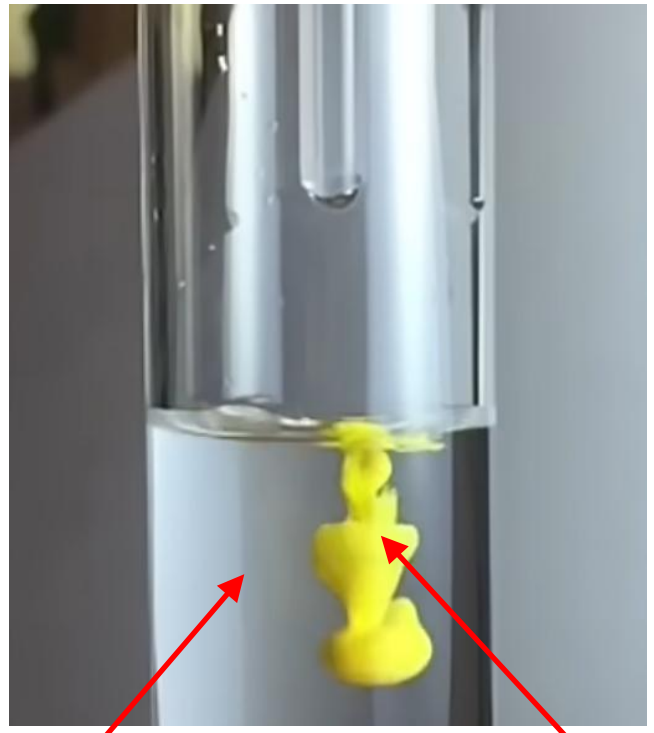


- The opposite of dissolving
- Most are ionic reactions
- Usually from double replacement reactions (A and C are swapping places)

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

# Precipitation Reactions





| Lead(II) Nitrate | + | Potassium Iodide |
|---|---|---|
| $Pb(NO_3)_2$ (aq) | + | 2 KI (aq) |

| Potassium Nitrate | + | Lead(II) Iodide |
|---|---|---|
| 2 $KNO_3$ (aq) | + | $PbI_2$ (s) |

Chapter 7.2, YouTube – “H de G” – Lead Iodide Precipitating

# Precipitation Reactions

$Pb(NO_3)_2$ (aq)
Aqueous means these are separate and dissolved in water.

$NO_3^{1-}$ $Pb^{2+}$ $NO_3^{1-}$ $Pb^{2+}$ $NO_3^{1-}$ $NO_3^{1-}$



KI (aq)
Aqueous means these are separate and dissolved in water.

$I^{1-}$ $K^{1+}$ $I^{1-}$ $K^{1+}$ $I^{1-}$ $K^{1+}$

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

$Pb^{2+}$ (aq) + 2 $NO_3^{1-}$ (aq) + 2 $K^{1+}$ (aq) + 2 $I^{1-}$ (aq) ➡ 2 $KNO_3$ (aq) + $PbI_2$ (s)

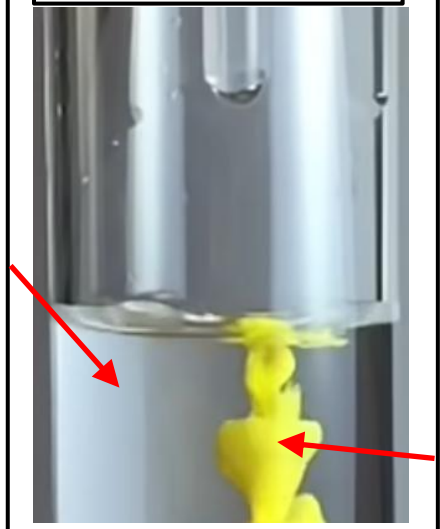
swap cations

$KNO_3$ (aq)
Aqueous means these are still separate and dissolved in water.

$NO_3^{1-}$ $K^{1+}$ $NO_3^{1-}$ $K^{1+}$ $K^{1+}$ $NO_3^{1-}$

EVERYTHING TOGETHER

$NO_3^{1-}$ $I^{1-}$ $Pb^{2+}$ $K^{1+}$



$PbI_2$ (s)
Solid means these are now ionically bonded together and have precipitated out of solution and will eventually settle to the bottom

$PbI_2$ $PbI_2$

Chapter 7.2, YouTube – “H de G” – Lead Iodide Precipitating

# How do we know what becomes solid? Experimentally

## Soluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $NH_4^+$<br>group I cations:<br>$Li^+$<br>$Na^+$<br>$K^+$<br>$Rb^+$<br>$Cs^+$ | none |
| $Cl^-$<br>$Br^-$<br>$I^-$ | compounds with $Ag^+$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| $F^-$ | compounds with group 2 metal cations, $Pb^{2+}$, and $Fe^{3+}$ |
| $C_2H_3O_2^-$<br>$HCO_3^-$<br>$NO_3^-$<br>$ClO_3^-$ | none |
| $SO_4^{2-}$ | compounds with $Ag^+$, $Ba^{2+}$, $Ca^{2+}$, $Hg_2^{2+}$, $Pb^{2+}$ and $Sr^{2+}$ |

## Insoluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $CO_3^{2-}$<br>$CrO_4^{2-}$<br>$PO_4^{3-}$<br>$S^{2-}$ | compounds with group 1 cations and $NH_4^+$ |
| $OH^-$ | compounds with group 1 cations and $Ba^{2+}$ |

# How to figure out precipitation reactions

1. Break apart compounds in the reactants side into cations (+) and anions (-)
2. Swap the cations with each other
3. Make neutral compounds in the products
4. Balance atoms in the reactants and products
5. Check the solubility table and see if precipitates form in the products

potassium sulfate and barium nitrate

$K_2SO_4\,(aq) + Ba(NO_3)_2\,(aq) \rightarrow$

Step 1: break apart compounds

$2\,K^{1+}\,(aq) + SO_4^{2-}\,(aq) + Ba^{2+}\,(aq) + 2\,NO_3^{1-}\,(aq) \rightarrow BaSO_4\,(??) + KNO_3\,(??)$

swap cations

Step 2: Swap cations

Step 3: Make neutral compounds

$K_2SO_4\,(aq) + Ba(NO_3)_2\,(aq) \rightarrow BaSO_4\,(??) + 2\,KNO_3\,(??)$

Step 4: Balance

$K_2SO_4\,(aq) + Ba(NO_3)_2\,(aq) \rightarrow BaSO_4\,(s) + 2\,KNO_3\,(aq)$

Step 5: assign phases based on solubility table

## Check Your Learning

Which solution could be used to precipitate the barium ion, $Ba^{2+}$, in a water sample: sodium chloride, sodium hydroxide, or sodium sulfate? What is the formula for the expected precipitate?

### Soluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $NH_4^+$<br>group I cations:<br>$Li^+$<br>$Na^+$<br>$K^+$<br>$Rb^+$<br>$Cs^+$ | none |
| $Cl^-$<br>$Br^-$<br>$I^-$ | compounds with $Ag^+$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| $F^-$ | compounds with group 2 metal cations, $Pb^{2+}$, and $Fe^{3+}$ |
| $C_2H_3O_2^-$<br>$HCO_3^-$<br>$NO_3^-$<br>$ClO_3^-$ | none |
| $SO_4^{2-}$ | compounds with $Ag^+$, $Ba^{2+}$, $Ca^{2+}$, $Hg_2^{2+}$, $Pb^{2+}$ and $Sr^{2+}$ |

### Insoluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $CO_3^{2-}$<br>$CrO_4^{2-}$<br>$PO_4^{3-}$<br>$S^{2-}$ | compounds with group 1 cations and $NH_4^+$ |
| $OH^-$ | compounds with group 1 cations and $Ba^{2+}$ |

## Predicting Precipitation Reactions

Predict the result of mixing reasonably concentrated solutions of the following ionic compounds. If precipitation is expected, write a balanced net ionic equation for the reaction.

(a) potassium sulfate and barium nitrate

(b) lithium chloride and silver acetate

## Soluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $NH_4^+$<br>group I cations:<br>$Li^+$<br>$Na^+$<br>$K^+$<br>$Rb^+$<br>$Cs^+$ | none |
| $Cl^-$<br>$Br^-$<br>$I^-$ | compounds with $Ag^+$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| $F^-$ | compounds with group 2 metal cations, $Pb^{2+}$, and $Fe^{3+}$ |
| $C_2H_3O_2^-$<br>$HCO_3^-$<br>$NO_3^-$<br>$ClO_3^-$ | none |
| $SO_4^{2-}$ | compounds with $Ag^+$, $Ba^{2+}$, $Ca^{2+}$, $Hg_2^{2+}$, $Pb^{2+}$ and $Sr^{2+}$ |

## Insoluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $CO_3^{2-}$<br>$CrO_4^{2-}$<br>$PO_4^{3-}$<br>$S^{2-}$ | compounds with group 1 cations and $NH_4^+$ |
| $OH^-$ | compounds with group 1 cations and $Ba^{2+}$ |

## Predicting Precipitation Reactions

Predict the result of mixing reasonably concentrated solutions of the following ionic compounds. If precipitation is expected, write a balanced net ionic equation for the reaction.

(c) lead (II) nitrate and ammonium carbonate

## Soluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $NH_4^+$<br>group I cations:<br>$Li^+$<br>$Na^+$<br>$K^+$<br>$Rb^+$<br>$Cs^+$ | none |
| $Cl^-$<br>$Br^-$<br>$I^-$ | compounds with $Ag^+$, $Hg_2^{2+}$, and $Pb^{2+}$ |
| $F^-$ | compounds with group 2 metal cations, $Pb^{2+}$, and $Fe^{3+}$ |
| $C_2H_3O_2^-$<br>$HCO_3^-$<br>$NO_3^-$<br>$ClO_3^-$ | none |
| $SO_4^{2-}$ | compounds with $Ag^+$, $Ba^{2+}$, $Ca^{2+}$, $Hg_2^{2+}$, $Pb^{2+}$ and $Sr^{2+}$ |

## Insoluble Ionic Compounds

| contain these ions | exceptions |
|---|---|
| $CO_3^{2-}$<br>$CrO_4^{2-}$<br>$PO_4^{3-}$<br>$S^{2-}$ | compounds with group 1 cations and $NH_4^+$ |
| $OH^-$ | compounds with group 1 cations and $Ba^{2+}$ |

# Acid-Base Reactions

- Acids – can release a hydrogen into water

$$HCl\ (aq) \rightarrow H^{1+}\ (aq) + Cl^{1-}\ (aq)$$

$$H_2SO_4\ (aq) \rightarrow 2\ H^{1+}\ (aq) + SO4^{2-}\ (aq)$$

- Base – can accept a hydrogen

$$OH^{1-} + H^{1+} \rightarrow H_2O$$

$$CO_3^{2-} + 2\ H^{1+} \rightarrow H_2CO_3$$

- Acids usually start with an H in the formula
- Product is usually water
- Most common base is $OH^{1-}$ or $CO_3^{2-}$ but there are many other bases.

## Check Your Learning

Write the net ionic equation representing the neutralization of any strong acid with an ionic hydroxide. (Hint: Consider the ions produced when a strong acid is dissolved in water.)

| 6 Strong Acids | | 6 Strong Bases | |
|---|---|---|---|
| $HClO_4$ | perchloric acid | LiOH | lithium hydroxide |
| HCl | hydrochloric acid | NaOH | sodium hydroxide |
| HBr | hydrobromic acid | KOH | potassium hydroxide |
| HI | hydroiodic acid | $Ca(OH)_2$ | calcium hydroxide |
| $HNO_3$ | nitric acid | $Sr(OH)_2$ | strontium hydroxide |
| $H_2SO_4$ | sulfuric acid | $Ba(OH)_2$ | barium hydroxide |

**Figure 14.6** Some of the common strong acids and bases are listed here.

# Oxidation-Reduction (redox) Reactions

- Chapter 7.2 (Classifying Chemical Reactions)

Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

# Oxidation-Reduction (Redox) Reactions

- Oxidation = loss of electrons; Reduction = gain of electrons
- Oxidation-Reduction (redox) reactions = transfer of electrons
  - An element has a different oxidation number (see next slide) in the reactants and products
- Types of redox reactions:
  - Combustion -
    - Very common - has some C, H and $O_2$ in the reactants and $CO_2$ and $H_2O$ in products.

      CH + $O_2$ → $CO_2$ + $H_2O$

      $C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l)$
  - Single replacement -
    - usually formation of ionic compounds

      A + BC → B + AC

      $Cu(s) + 2AgNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + 2Ag(s)$
  - Combination -
    - Things coming together

      A + B → AB

      $PCl_3(l) + Cl_2(g) \longrightarrow PCl_5(s)$
  - Decomposition –
    - Things coming apart

      AB → A + B

      $2H_2O \longrightarrow H_2 + O_2$

# Oxidation Numbers = Book way

1. The oxidation number of an atom in an elemental substance is zero.
2. The oxidation number of a monatomic ion is equal to the ion's charge.
3. Oxidation numbers for common nonmetals are usually assigned as follows:
    - Hydrogen: +1 when combined with nonmetals, −1 when combined with metals
    - Oxygen: −2 in most compounds, sometimes −1 (so-called peroxides, $O_2^{2-}$), very rarely — $\frac{1}{2}$ (so-called superoxides, $O_2^{-}$), positive values when combined with F (values vary)
    - Halogens: −1 for F always, −1 for other halogens except when combined with oxygen or other halogens (positive oxidation numbers in these cases, varying values)
4. The sum of oxidation numbers for all atoms in a molecule or polyatomic ion equals the charge on the molecule or ion.

Note: The proper convention for reporting charge is to write the number first, followed by the sign (e.g., 2+), while oxidation number is written with the reversed sequence, sign followed by number (e.g., +2). This convention aims to emphasize the distinction between these two related properties.

# Oxidation Numbers = Com's Way (beginner rules)

1. All of the same elements in a molecule/compound will have the same oxidation number.
2. Oxidation numbers within a compound, element, or ion must add up to the net electric charge.
3. Oxidation numbers are USUALLY the same as their expected charges. Assign them in order from highest to lowest priority. (Highest Priority) Group 1, Group 2, Fluorine, Oxygen, Group 17 (Lowest Priority)

# Oxidation Numbers = Com's Way (beginner rules)

Do these in priority order starting with #1

1. All of the same elements in a molecule/compound will have the same oxidation number. i.e. All H will be the same in $H_2O$
2. Oxidation numbers within a compound, element, or ion must add up to the net electric charge.

- Al = there is no charge listed and there is only 1 atom so the oxidation number is 0
- $Al^{3+}$ = there is a 3+ charge listed and there is only 1 atom so the oxidation number is 3+
- $H_2$ = there is no charge listed so and there are 2 H atoms so the oxidation number for 2 H's have to add up to 0 so H + H = 0 so 0 + 0 = 0 so the oxidation # is 0

- $Cu_2O$ = there is no charge listed and there are 2 Cu and 1 O atom so Cu + Cu + O = 0.
- $SO_4^{2-}$ = there is a 2- charge listed and there is 1 S atom and 4 O atoms so S + O + O + O + O = -2
- $H_2O$ = there is no charge listed and there are 2 H atoms and 1 O atom so H + H + O = 0

3. Oxidation numbers are USUALLY the same as their expected charges. Assign them in order from highest to lowest priority. (Highest Priority) Group 1, Group 2, Fluorine, Oxygen, Group 17 (Lowest Priority)

- $H_2O$ = (no charge listed) H + H + O = 0;
  assign H first (Group 1) and the usual charge is 1+ so:

H + H + O = 0
(+1)+(+1)+ O = 0
O = -2

Oxidation Numbers
H = +1
O = -2

- $SO_4^{2-}$ = (2- charge listed) S + O + O + O + O = -2;
  assign O first (Group 16) and the usual charge is 2- so:

S + O + O + O + O = -2
S +(-2) +(-2) +(-2) +(-2) = -2
S = +6

Oxidation Numbers
S = +6
O = -2



Note: Rules will change and get more detailed in more advanced chemistry classes.

**Check Your Learning**

Assign oxidation states to the elements whose atoms are underlined in each of the following compounds or ions:

(a) $K\underline{N}O_3$

(b) $\underline{Al}H_3$

(c) $\underline{N}H_4^+$

(d) $H_2\underline{P}O_4^-$

1. All of the same elements in a molecule/compound will have the same oxidation number.
2. Oxidation numbers within a compound, element, or ion must add up to the net electric charge.
3. Oxidation numbers are USUALLY the same as their expected charges. Assign them in order from highest to lowest priority. (Highest Priority) Group 1, Group 2, Fluorine, Oxygen, Group 17 (Lowest Priority)

**Check Your Learning**

This equation describes the production of tin(II) chloride:

$$\mathrm{Sn}(s) + 2\mathrm{HCl}(g) \longrightarrow \mathrm{SnCl_2}(s) + \mathrm{H_2}(g)$$

Is this a redox reaction?

1. All of the same elements in a molecule/compound will have the same oxidation number.
2. Oxidation numbers within a compound, element, or ion must add up to the net electric charge.
3. Oxidation numbers are USUALLY the same as their expected charges. Assign them in order from highest to lowest priority. (Highest Priority) Group 1, Group 2, Fluorine, Oxygen, Group 17 (Lowest Priority)

# Reaction Summary

- Precipitation Reactions – two solutions mixed together create a solid
  - AB (aq) + CD (aq) → AD (s) + CB (aq)
- Acid-Base Reactions – combining and acid and a base to make water and a "salt"
  - Acid ($H^{1+}$) + Base ($OH^{1-}$ or $CO_3^{2-}$) → $H_2O$ + Salt
- Oxidation-Reduction (Redox) Reactions – a transfer of electrons
  - Combustion -
    - usually has some C, H and $O_2$ in the reactants and $CO_2$ and $H_2O$ in the products.

      $CH + O_2 \rightarrow CO_2 + H_2O$
  - Single replacement -
    - usually formation of ionic compounds

      $A + BC \rightarrow B + AC$
  - Combination -
    - Things coming together

      $A + B \rightarrow AB$
  - Decomposition –
    - Things coming apart

      $AB \rightarrow A + B$