Chemical Reactions

"The leading priests and teachers of religious law were plotting how to kill Jesus, but they were afraid of the people's reaction." Luke 22:2

- chemical reaction: chemical change resulting from a collision between atoms or molecules, forming new molecules with different physical and chemical properties
- reactants: original substances before chemical reaction
  products: new substances produced by the reaction
  ex: Na + Cl --> NaCl
  reactant reactant product
- chemical equation: expression that uses chemical symbols to represent a chemical reaction

  $2H_2 + O_2 \rightarrow 2H_2O$

  Coefficient (big numbers) subscripts (small numbers)

  where 2 is the coefficient: indicates number of molecules; no coefficient means 1 molecule
  small 2 are subscripts, indicating number of atoms (NOT molecules!)
  --> in the above example, two molecules of H_2 combine with one molecule of O_2 to produce two molecules of H_2O

- TOTAL number of atoms on the reactant side is calculated using coefficients and subscripts:
  2 molecules H_2 x 2 hydrogen atoms per molecule = 4 hydrogen atoms
  1 molecule O_2 x 2 oxygen atoms per molecule = 2 oxygen atoms
- TOTAL number of atoms on the product side:
  2 molecules of H_2O x 2 hydrogen atoms per molecule = 4 hydrogen atoms
  2 molecules of H_2O x 1 oxygen atom per molecule = 2 oxygen atoms
- law of conservation of mass: total mass of reactants must equal total mass of products
  both sides of a chemical equation must have the same number and types of atoms, requiring the need to balance equations
- [Application p. 156]
- chemical formulas cannot be changed to balance an equation because changing a chemical formula would change the substances involved in the reaction

1. When balancing an equation, ONLY THE COEFFICIENTS CAN BE CHANGED
2. Balance the element with the largest subscript first
3. In an equation involving a pure element and one or more compounds, balance the pure element last.

Fe	+	O_2	-->	Fe_2O_3	not balanced
Fe	+	$3O_2$	-->	$2Fe_2O_3$	O balanced, Fe is not
$4Fe$	+	$3O_2$	-->	$2Fe_2O_3$	Fe balanced, O balanced

- [Application p. 157]

<u>Chemical Thermodynamics</u>

- chemical thermodynamics: study of the relationship between chemical reactions and the laws of thermodynamics
- every chemical bond contains chemical energy (a form of potential energy) that may be released as thermal energy when molecules combine or break apart
- first law of thermodynamics: energy gained or lost by a system = energy lost or gained by the surroundings
- exothermic: chemical reaction that releases thermal energy
  reactants --> products + energy
  temperature of products higher than temperature of reactants
  gasoline burning, explosion of dynamite, breaking down of sugars in body
- endothermic: energy absorbed and stored in chemical bonds of the products
  reactants + energy --> products
  instant cold packs
- second law of thermodynamics: every chemical reaction must cause a decrease in usable energy and an increase in entropy (disorder)
- spontaneous reaction: reaction that is able to occur by itself without continuing outside help; in every spontaneous reaction, the usable energy of the products is less than the usable energy of the reactants

Chemical Reactions II

A time to kill, And a time to heal; A time to break down, And a time to build up"
Ecclesiastes 3:3

Chemical Kinetics

- chemical kinetics: area of chemistry that addresses rates of chemical reactions
- five main factors that affect the rate of a chemical reaction:
  1. activation energy: kinetic energy necessary for molecules to break the old bonds and form new bonds
  2. temperature: raising the temp of a substance causes its atoms or molecules to move around more rapidly, increasing kinetic energy --> more frequent and more energetic collisions; increase in temp will usually speed up a chemical reaction
  3. concentration: number of collisions is more likely if more particles are squeezed into a limited space; increasing concentration increases rate of reaction; decreasing concentration of reactants decreases rate of reaction
  -in reactions involving gases, increasing the pressure of the gas may increase the reaction rate
  -combustion: reaction of a fuel with oxygen; burning
  ` 4. surface area: increasing surface area of reactants increases the reaction rate; more area over which molecules can collide and react; surface area can be increased by grinding into smaller pieces
  5. catalysts: substance that alters the rate of a chemical reaction without being permanently changed itself in the reaction; often used to increase the rate of reaction
  ex: breakdown of hydrogen peroxide into water and oxygen with iron catalyst

$$H_2O_2 \xrightarrow{Fe} H_2O + O_2$$

Chemical Equilibrium

- Some chemical reactions are reversible, in which the reaction can be made to go backwards:
  $H_2 + I_2 \rightarrow 2HI$ but can be reversed to $2HI \rightarrow H_2 + I_2$

  Rewritten to show arrows going both directions: $H_2 + I_2 \rightleftarrows 2HI$
- When a reaction is reversible, the forward and reverse reactions occur simultaneously; if both reactions occur at the same rate, the system is in chemical equilibrium

Types of Chemical Reactions

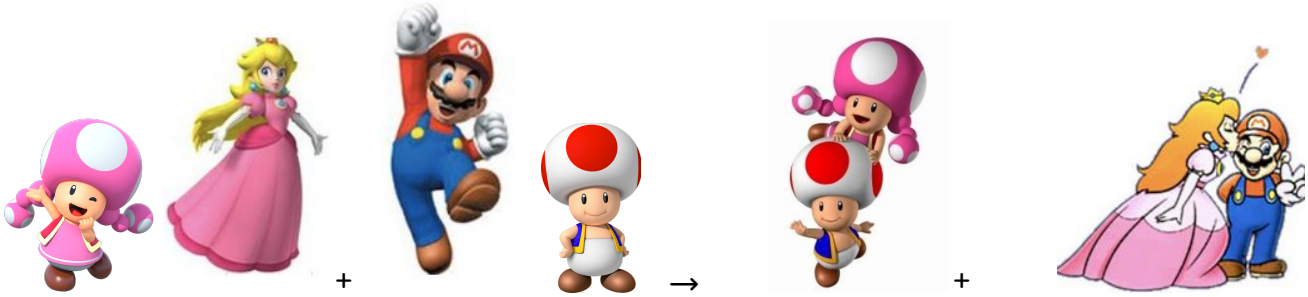
- Chemical reactions classified into four basic categories according to how the reactants break up or combine

1. Combination reactions: two or more substances combine to form a third substance
2. Decomposition reactions: a compound breaks down to form different substances
3.. Single-displacement reactions: an element in a compound is replaced by another element; also called substitution reactions

example:

4. Double-displacement reactions: two compounds exchange atoms or ions

example:



Type of reaction	Basic formula	Examples
combination	$A + B \rightarrow AB$	$2Na + Cl_2 \rightarrow 2NaCl$ $C + O_2 \rightarrow CO_2$ $NH_3 + HNO_3 \rightarrow NH_4(NO_3)$
decomposition	$AB \rightarrow A + B$	$2H_2O \rightarrow H_2 + O_2$ $2H_2O_2 \rightarrow 2H_2O + O_2$ $CaCO_3 \rightarrow CaO + CO_2$
single-displacement	$A + BC \rightarrow B + AC$	$Cl_2 + 2NaBr \rightarrow Br_2 + 2NaCl$ $2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$ $Zn + 2HCl \rightarrow H_2 + ZnCl_2$
double-displacement	$AB + CD \rightarrow AD + CB$	$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$ $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2HOH$

Salts, Acids, and Bases

- Salt: any ionic compound that does not contain a H^+ ion or hydroxide OH^- ion; when a salt dissolves in water, it breaks apart into its component ions
  Ex: when NaCl dissolves in water, it dissociates into Na^+ and Cl^- so "salt water" actually contains Na^+ and Cl^- ions, not molecules of NaCl
- Acids: contain a H covalently bonded to an electronegative atom; substances that produce hydronium ions (H^+) when dissolved in water
  -*Ex*: HCl dissolves in water to form $H^+ + Cl^-$
  -sour taste; turn litmus red
  -vinegar (acetic acid), citric acid, vitamin C (ascorbic acid), HCl acid
- Bases: substances that produce hydroxide (OH^-) ions when dissolved in water
  -*Ex*: NaOH dissociated in water to form $Na^+ + OH^-$
  -slippery to touch with bitter taste; turn litmus blue
  -NaOH, bleach (sodium hyperchlorite), baking soda (sodium bicarbonate), ammonia
- Neutral: neither acids nor bases
  Ex: water, milk
- pH scale: measure of concentration of H_3O^+ ions in a given solution
  Range from 0 (acidic) to 14 (basic):