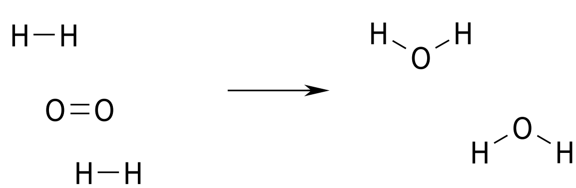
Reactions
Chapter 11

Chemical Equations
Chemical change involves a reorganization of the atoms in one or more substances.

Indications of a Chemical Change
- Temperature change
- Color change (hue) (dilution does not constitute a color change)
- Formation of a solid
- Formation of a gas. (boiling is not a chemical change)

The **Hindenburg** Reaction
- Reactants are on left, products to the right.
- Arrow indicates the change



A chemical equation

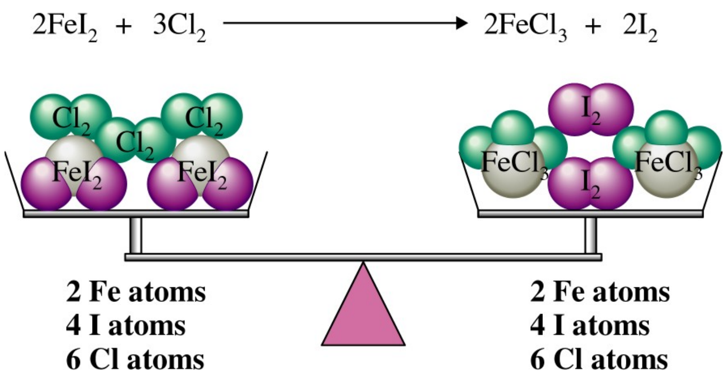
2 H_2 + O_2 → 2 H_2O
- Notice that the formula for the molecules is unchanged.
- To indicate that more than one molecule is required, use coefficients (shown in green).
- The equation is balanced.

The Rules
- Change only the coefficients to balance the chemical equation.

- Balance one element at a time.
- Continue to balance the other elements in the same manner.
- Adjust coefficients to the lowest whole number common multiple.
- Check your answers.

Example

FeI_2 + Cl_2 → $FeCl_3$ + I_2



Balancing Combustion Reactions

(fuel + oxygen gives carbon dioxide and water)

- Balance carbon first
- Hydrogen second
- Oxygen last
- Multiply by 2 if you need to.

___ C_3H_8 + ___ O_2 → ___ CO_2 + ___ H_2O

More Balancing and Things to Avoid

___ C_4H_{10} + ___ O_2 → ___ CO_2 + ___ H_2O

1 C_4H_{10} + 13/2 O_2 → 4 CO_2 + 5 H_2O

2 C_4H_{10} + 13 O_2 → 8 CO_2 + 10 H_2O

- Coefficients should always have the lowest whole number ratio.
- Never Change the subscripts. 8 CO_2 is not the same as C_8O_{16}.

Quantifying Chemical Reactions

Microscopic world	Macroscopic world
amu	grams
atoms or molecules	moles
1 carbon atom = 12 amu	1 mole of carbon = 12 grams
1 water molecule = 18 amu	1 mole of water = 18 grams

The mole (6.02 x 10^{23})

- A macroscopic version of the molecule defined so we can use the periodic table for the macroscopic and microscopic world.
- Defined as the number of atoms in exactly 12.0 g of carbon-12 isotope.
- This is number is called Avogadro's number after the Italian physicist Amedeo Avogadro (1776-1856).

Formula Weight

- The sum of the atomic weights of all the atoms in the molecular formula, whether ionic or molecular.
- Expressed in amu/molecule or grams/mole.
- Also called molecular weight, molar mass

Formula Weight

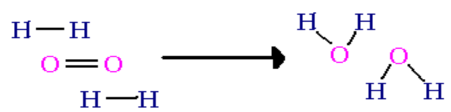
H_2O (2 x 1.0) + (1 x 16.0) = 18.0 g/mole

$Ca(OH)_2$ (1 x 40.1) + (2 x 1.0) + (2 x 16.0) = 74.1 g/mole

C_3H_8 (3 x 12.0) + (8 x 1.0) = 44.0 g/mole

A Chemical Reaction

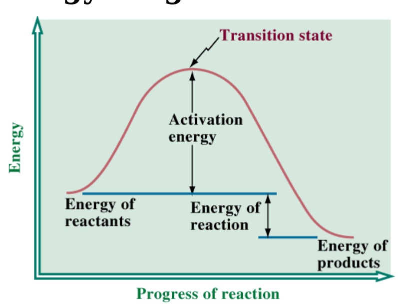
What is happening in a reaction?



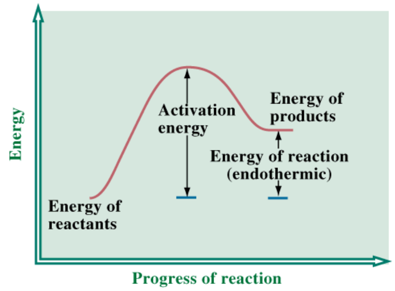
Three things are required for a reaction to occur:

- Molecules must collide.
- They must collide with enough energy to break old bonds so new ones can form.
- They must collide in the correct orientation.

Energy Diagram for exothermic reaction



Energy Diagram for endothermic reaction



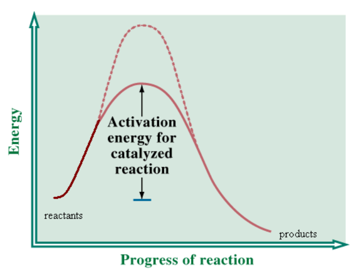
Kinetics (rate of reaction)

Three ways to increase the rate of a reaction

- Increase Concentration
  - Increases number of collisions
- Increase Temperature
  - Increases collisions & collisions that have enough energy to break old bonds
- Use a catalyst.
  - Lowers energy barrier (Activation energy)

A Catalyst

- A compound that increases the rate of a reaction without itself undergoing a permanent change at the end of the process.



Chemical Equilibrium

- Most reactions are reversible, some are not.
- Reversible reactions are shown with a double arrow.
- An equilibrium condition exists when the rate of the forward reaction equals the rate of the reverse reaction.
- Equilibrium: The exact balancing of two processes that are opposite each other.
- Chemical equilibrium: A dynamic state where the concentrations of all reactants remain constant.

Acids and Bases

Arrhenius

•Acid: A substance that make H^+ (H_3O^+) when dissolved in water.

•Base: A substance that makes OH^- when dissolved in water.

•An acid/base reaction occurs when and H^+ from an acid reacts with an OH^- from a base.

Acids

•Strong acids: Dissociate completely when dissolved in water.

– HCl, HNO_3

•Weak acids only dissociate a little bit.

– CH_3CO_2H, H_2CO_3

Base

•Strong base: dissociates completely when dissolved in water.

– NaOH, KOH

•Weak base: Makes only a little bit of OH^-

– NH_3, HCO_3^-

ACIDS AND BASES

Acids	Bases
HCl (hydrochloric acid or muriatic acid)	Cl^- (chloride ion)
H_2SO_4 (sulfuric acid)	SO_4^{2-} (sulfate ion)
H_3O^+ (hydronium ion)	H_2O (water)
CH_3CO_2H (acetic acid)	$CH_3CO_2^-$ (acetate ion)
H_2CO_3 (carbonic acid)	HCO_3^- (bicarbonate)
NH_4^+ (ammonium ion)	NH_3 (ammonia)
H_2O (water)	OH^- (hydroxide ion)

Water

- Water auto-ionizes

$$H_2O + H_2O \rightleftarrows H_3O^+ + OH^-$$

acid base [10^{-7}M] [10^{-7}M]

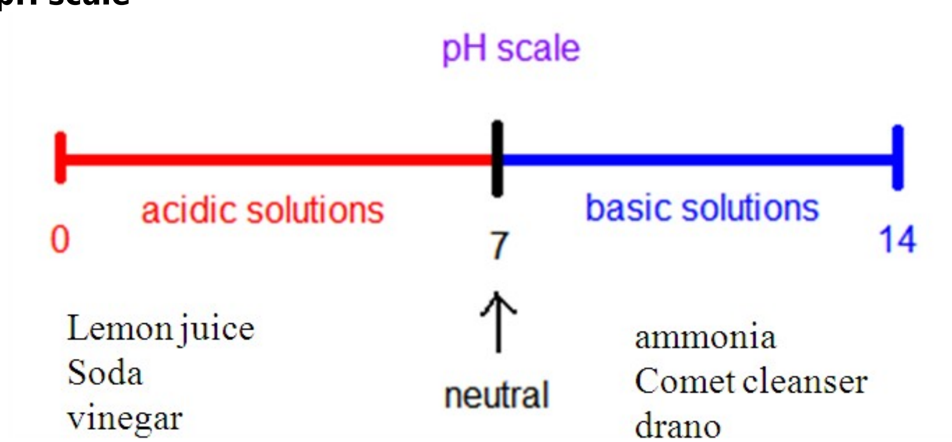
$$K = \frac{[H_3O^+][OH^-]}{[H_2O]^2} = [H_3O^+][OH^-] = 1 \times 10^{-14}$$

There is very little H+ and OH – in pure water.

pH = -log [H^+]

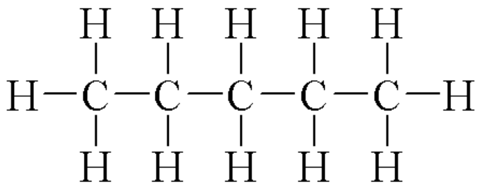
pH less than 7: excess H^+
pH more than 7: excess OH^-
pH = 7: H+ = OH^-

pH scale



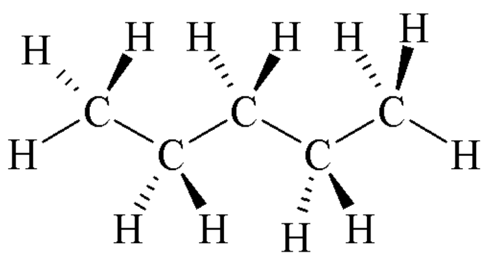
Organic Molecules

Lewis Structure



Carbon always has 4 bonds, hydrogen always has one bond.

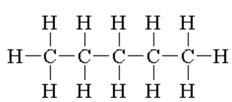
VSEPR



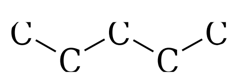
These carbons are tetrahedral and have bond angles of 109.5 degrees

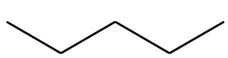
Condensed Formula

$$CH_3CH_2CH_2CH_2CH_3$$



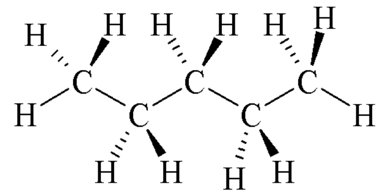
Stick figures



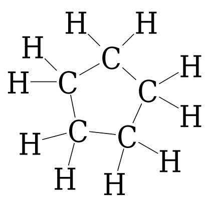


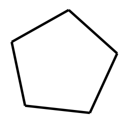
Stick Figures (Rules)

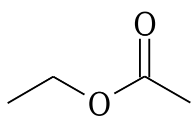
- Hydrogens attached to carbons are not shown. (Hydrogens attached to hetero-atoms are shown)
- Each vertex and terminus is a carbon.
- All hetero-atoms are shown explicitly.

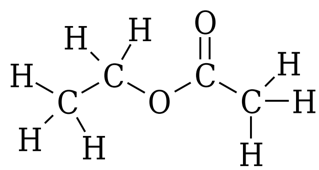


Example









How many carbon atoms? 4
How many hydrogen atoms? 8
How many oxygen atoms? 2
Names of straight chain alkanes

Homework

1. Balance the following equation:__ C_5H_{12} + __ O_2 -> __ CO_2 + __ H_2O
2. Balance the following equation:__ C_6H_{14} + __ O_2 -> __ CO_2 + __ H_2O
3. __ $FeCl_3$ + ___ NaOH -> __ NaCl + __$Fe(OH)_3$
4. The combustion of a hydrocarbon fuel does not produce
   (A) H_2
   (B) H_2O
   (C) CO_2
5. Would you expect a solution of H_2CO_3 to be acidic or basic?
6. Would you expect a solution of HCO_3^- to be acidic or basic?
7. A solution has a pH of 11.0. Is the solution acidic or basic?
8. A solution has a pH of 4.30. Is the solution acidic or basic?

9. How many carbons in the above structure?
10. How many hydrogens in the above structure?

Answers 1) 1,8,5,6 2) 2, 19, 12, 14 3) 1, 3, 3, 1 4) A
5) acidic 6) Basic, it is on the base side of the chart. 7) Basic, it is above seven. 8) Acidic, it is below seven. 9) Seven 10) Sixteen