Chapter 6: Quantities in Chemical Reactions

October 10, 2022

Chemistry Department, Cypress College

Class Annoucements

Lecture

- Finally graded homework 3 and go over homework 4 (EC for students who present)
- Finish up Ch 6 and worksheet 7; begin discussion on Ch 7 - Electronic Structure of the Atom
- Quiz and Homework assignment released Fri, Oct 14th at 3pm

Outline

Review: Chemical Equations. Limiting Reagent and Percent Yield

Energy Changes

- Law of Conservation of Energy
- Endothermic and Exothermic Reactions
- Calorimetry

Meaning of a Balanced Equation

Photosysnthesis Chemical Equation

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g) \tag{1}$$

- Balanced chemical equation satisfies the conservation of mass
- Coefficients in front of the molecules represent the relative moles of reactants and products

Approaching Limiting Reactant Problems

$$\mathrm{R1} + \mathrm{R2} \rightarrow \mathrm{P1} \tag{2}$$

- Given a certain amount of each reagents (R1 and R2) to produce P1, determine how much the R2 is needed to completely react with R1
- Based on that calculated value, determine whether there is enough R2 to completely react with R1
- If the amount of R2 is less than what is needed, then R2 is the limiting
- If the amount of R2 is more than what is needed, then R2 is the excess

Percent Yield, Theoretical Yield, and Actual

Percent Yield - describes how much product has been produced

$$\% = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% \tag{3}$$

Actual Yield - the amount produced in the lab (potential errors)

Theoretical Yield - the maximum amount predicted from a given amount of reagents

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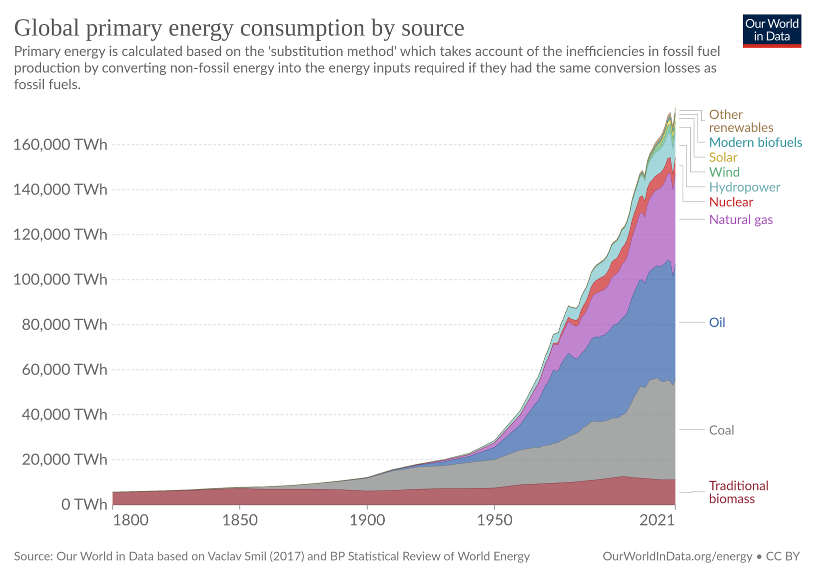
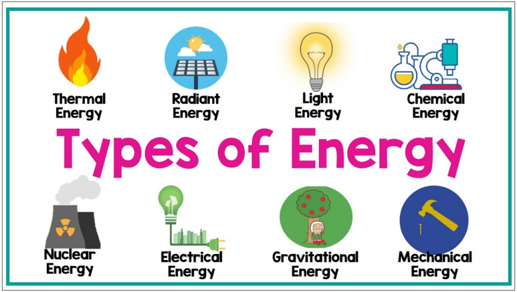
Global Energy Consumption



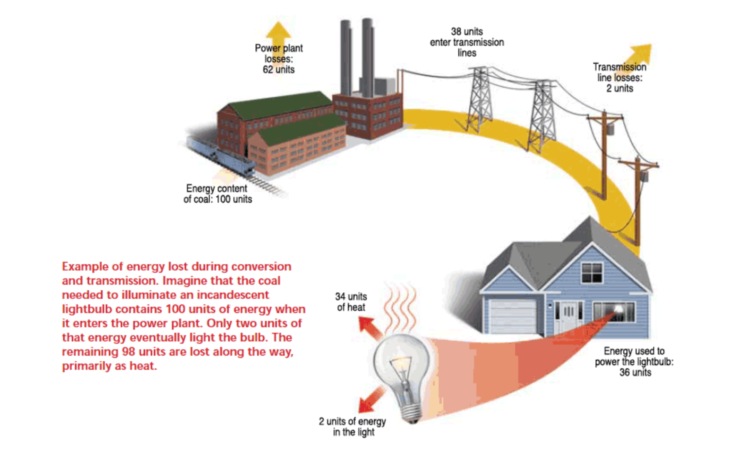
Law of Conservation of Energy



Energy is neither created nor destroyed

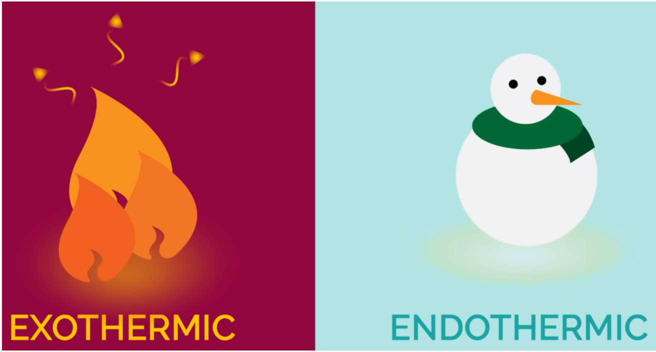
- Energy can be converted from form to another e.g. mechanical, chemical, thermal, nuclear, electrical and vibrational energy
- Converting from one energy form to another is never 100% efficient; there is always a loss of energy

Context: Energy Loss



Approximately only $\sim$ 30% efficiency

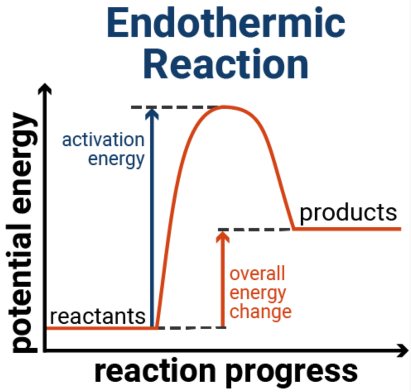
Endothermic and Exothermic Reactions



Exo - external; exothermic reactions give off heat

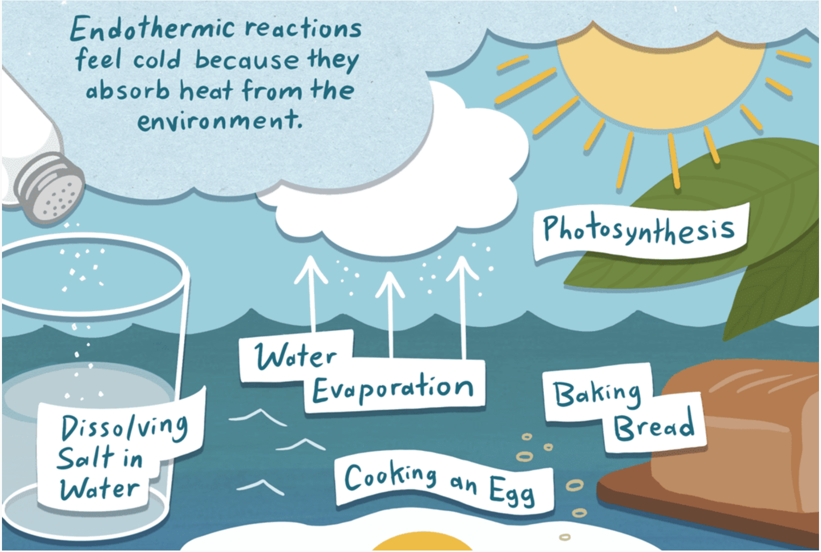
Endo - internal; endothermic reactions absorb heat

Endothermic Reaction Diagram



- **Recall Potential energy** - ability to do work; $\Delta E_{\text{products}} > \Delta E_{\text{reactants}}$
- **Activation energy** - minimum energy to start the reaction; determines the rate at which the reaction undergoes

Examples of Endothermic Reactions



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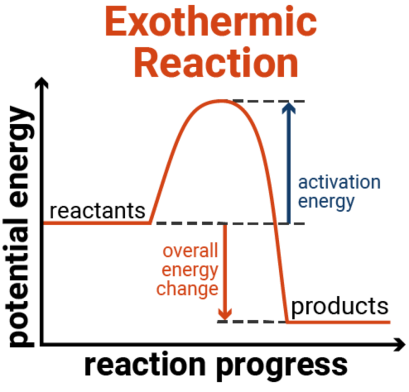
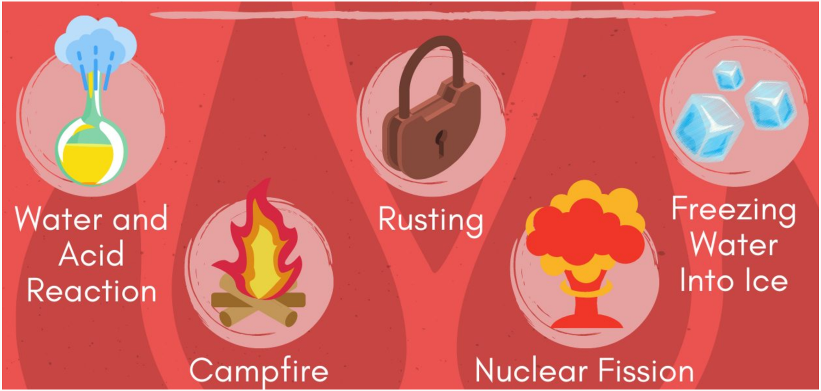
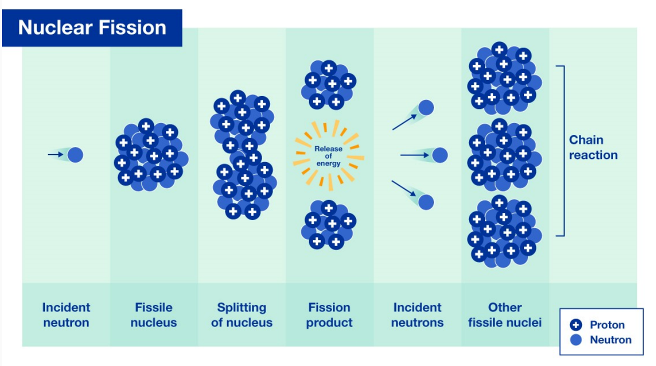


- **Potential energy** - $\Delta E_{\text{products}} < \Delta E_{\text{reactants}}$
- Products are more stable than reactants since preference for lower energy state

Examples of Exothermic Reactions



Nuclear Fission



- **Nuclear fission** - releases energy where the nucleus of an atom splits into two or smaller nuclei
- U-235 atoms breaking down to release up to 200 million eV (4.6×10^9 kcal/mol)
- **Context** - 9.71 kcal/mol to boil water

Practice: Endothermic and Exothermic Reactions

Consider the following reaction:

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

a) Is this reaction endothermic or exothermic?

b) Is the reverse reaction endothermic or exothermic?

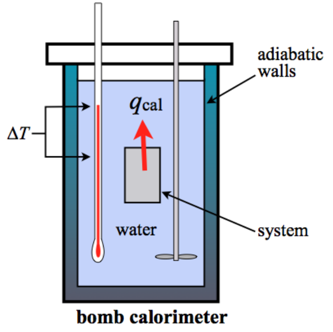
c) For the products or reactants, which ones have the higher potential energy?

Familiarize: Units of Energy

$$4.184 \text{ J} = 1 \text{ Cal}$$

- "Calories" used on food items whould not be confused with the "calorie" used in chemistry
- 1 Cal = 1000 cal

Calorimetry

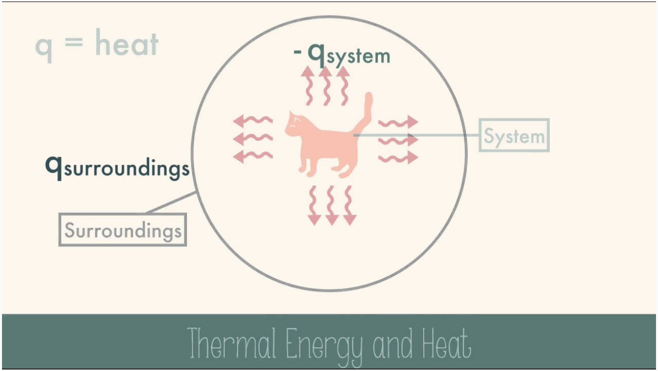


$$q = mC\Delta T \tag{4}$$

where q is heat, m is the mass (g), C is specific heat capacity (°C/g) and T is temperature (°C)

- Performed at constant-pressure (atomospheric pressure)
- Bomb Calorimeter is Insulated where the heat evolved by the reaction is absorbed by the water
- **Specific Heat Capacity** - the amount of heat (q) required to heat an object 1°C/g

Relating Conservation of Energy



$q_{\text{system}} + q_{\text{surrounding}} = 0$ where q is the heat

Negative sign indicate released heat and positive sign indicates absorbed heat

Example: Calorimetry

A brick is placed in an insulated calorimeter containing 5,000 kg of water. The temperature of the water decreases from 25.0°C to 19.4°C when thermal equilibrium is reached

a) Was the initial temperature of the brick greater than or less than the initial temperature of the water? Explain.

b) What is the heat change q of the brick? Specific heat capacity of water is 4.184 J/(g °C).

Practice: Heating Metal Alloy

A sample of metal alloy is heated and then placed in 125.0g of water held in a calorimeter at 22.5°C. The final temperature of the water is 29.0°C. Assume heat exchange only occurs between the water and alloy.

a) Was the initial temperature of the alloy $>$ or $<$ the initial temperature of the water? Explain

b) What is hte heat change of the alloy? Specific heat capacity of water is 4.184 J/(g °C).

Example: Relating to Chemical Reactions

Ethanol (CH_3CH_2OH) burns in excess oxygen. The heat change q for the reaction is -1367 kJ/mol.

a) Is this reaction endothermic or exothermic?

b) What is the heat change when 0.200 mol of CH_3CH_2OH burns?

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b)

$$0.200\text{mol } CH_3CH_2OH \times \frac{-1367\text{kJ}}{1\text{mol } CH_3CH_2OH} = -273\text{kJ}$$

Practice: Combination Reaction

Consider the combination reaction of hydrogen gas and solid iodine. The heat change q for this reaction is $+53.00$ kJ/mol.

a) Is this reaction endothermic or exothermic?

b) What is the heat change when 2.50 mol of I_2 reacts?