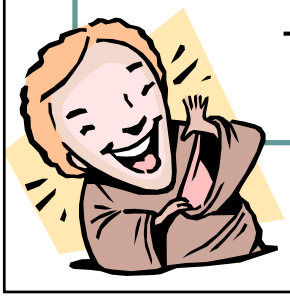
AP Chemistry

Chapter 5

Thermodynamics



The Nature of Energy

Section 5.1

- What is thermodynamics?
  - *It is the study of energy and its transformations*
- Thermochemistry - *Studies the relationships between chemical reactions and energy changes*

Kinds of Energy

Section 5.1

- Kinetic Energy --> *energy of motion*

Expressed by the formula

$E_k = 1/2\ mv^2$

Kinds of Energy

Section 5.1

- **Potential Energy** --> energy in relation to the position to other objects
- is considered at rest or *stored energy*
  - Expressed by the formula
    - $E_p = mgh$
  - Example: An object raised to above the surface of the Earth

Kinds of Energy

Section 5.1

- **Potential energy *cont*…**
  - Forces other than gravity can lead to potential energy.
  - Example: electrostatic forces between charged particles in chemistry
    - an electron has potential energy when its near a proton

What we will do in this chapter

Section 5.1

- We will look at energy change at the atomic or molecular level.
  - Example: examine how foods store energy that is released to be used as energy by our bodies
- We will also examine thermal energy and how it is associated with the kinetic energy of molecules in a substance

Units of Energy

Section 5.1

- Energy is measured in two units
  - Joule --> is the SI unit for energy
  - 1 J = 1 kg•m^2/s^2
  - a joule is not a large amount of energy..so we generally use kJ or kiloJoules
    - 1000 Joules = 1 kiloJoule

Calorie - *another unit of energy*
1 cal = 4.184 J 1000 cal = 1 kcal=1 Cal

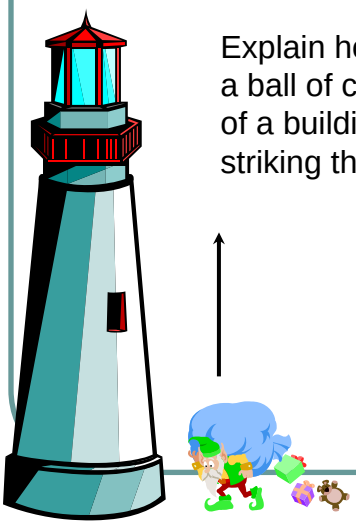
What's a force?

Section 5.1

- A **force** is any push or a pull on an object
  - Forces change the motion of an object
- **Work** results when a force moves an object a distance in the same direction as the force
- It takes energy to do work…*essentially we put energy into something when we do work*

Section 5.1

Energy and Work Practice Problem



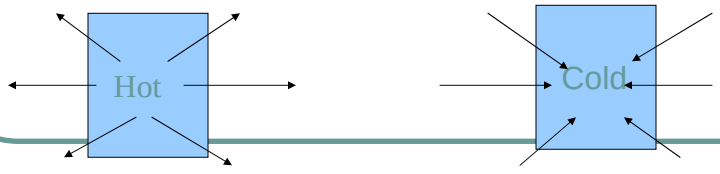
Explain how energy is transferred from a ball of clay that is hiked up to the top of a building and then released striking the ground.

What is the potential energy of the sack (m=50kg) as it is held at the top of a 1000 ft building?

Section 5.1

What is Heat?

- Is another way energy is transferred
- Heat is the energy that is transferred from a hotter object to a colder one
  - ex: a combustion reaction
  - System and surroundings



Additional Practice Problems

Section 5.1

- **What is the kinetic energy, in joules, of**
  - **a mole of Argon atoms moving with a speed of 650 m/s?**

Additional Practice Problems

Section 5.1

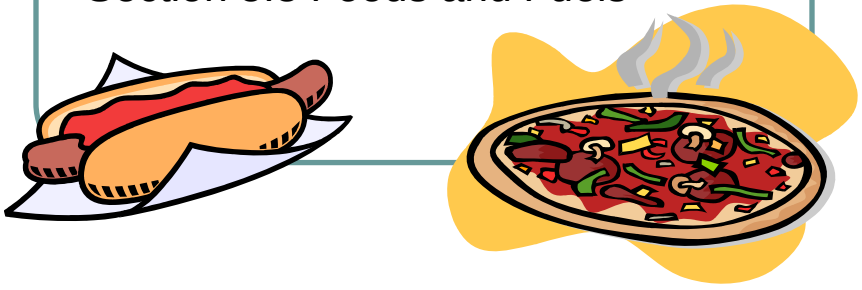
Calculate the kinetic energy of a 7.3-kg steel ball traveling at 18.0 m/s.

Calorimetry

Section 5.5

Thermochemistry

Section 5.8 Foods and Fuels



Foods values

- Nutrition values are listed on packaged items to explain the composition

Reduced Fat
triscuit
• No Cholesterol
• Low Saturated Fat
(CONTAINS 3g FAT PER SERVING)
• Good Source of Dietary Fiber

Nutrition Facts
Serving Size 8 Wafers (32g)
Servings Per Container About 8

Amount Per Serving
Calories 130 Calories from Fat 25
% Daily Value*

Total Fat 3g	**5%**
Saturated Fat 0.5g	**3%**
Polyunsaturated Fat 0g	
Monounsaturated Fat 1g	
Cholesterol 0mg	**0%**
Sodium 170mg	**7%**
Total Carbohydrate 24g	**8%**
Dietary Fiber 4g	**17%**
Sugars 0g	
Protein 3g	

Vitamin A 0% • Vitamin C 0%
Calcium 0% • Iron 10%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

How Much Energy???

TABLE 5.4 Compositions and Fuel Values of Some Common Foods

	Approximate Composition (% by mass)			Fuel Value	
	Carbohydrate	Fat	Protein	kJ/g	kcal/g
Carbohydrate	100	–	–	17	4
Fat	–	100	–	38	9
Protein	–	–	100	17	4
Apples	13	0.5	0.4	2.5	0.59
Beer[a]	1.2	–	0.3	1.8	0.42
Bread	52	3	9	12	2.8
Cheese	4	37	28	20	4.7
Eggs	0.7	10	13	6.0	1.4
Fudge	81	11	2	18	4.4
Green beans	7.0	–	1.9	1.5	0.38
Hamburger	–	30	22	15	3.6
Milk (whole)	5.0	4.0	3.3	3.0	0.74
Peanuts	22	39	26	23	5.5

[a] Beers typically contain 3.5 percent ethanol, which has fuel value

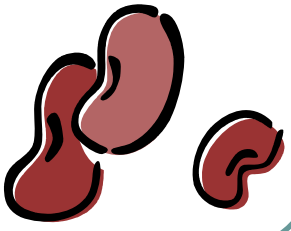
You need To know These values

Examining the Composition

- (a) A 28-g (1oz) serving of a popular breakfast cereal served with 120 mL (1/2 cup) of skim milk provides 8 g of protein, 26 g of carbs, and 2 g of fat. Using the average fuel values of these kinds of substances, estimate the amount of food energy in this serving.
- (b) A person of average weight uses about 100 Cal/mile when running or jogging. How many servings of this cereal provide the fuel value requirements for running 3 miles?

Red beans???? *Yuck!*

- (a) Dry red beans contain 63% carb, 22% protein, and 1.5% fat. Estimate the fuel value of these bean.
- (b) Very light activity like reading or watching TV uses about 7 kJ/min. How many minutes of such activity can be sustained by the energy provided by a can of chicken noodle soup containing 13 g of protein, 15 g of carbs and 5 g of fat?



The First Law of Thermodynamics

Section 5.2

- The first law of thermodynamics states that energy can neither be created nor destroyed
- Energy lost by a system will be gained by its surroundings..and vice versa

Analyzing energy of a system

Section 5.2

- **Internal Energy** – is the sum of all kinetic and potential energy of all components of the system.

$$\Delta E = E_{final} - E_{initial}$$

Analyzing energy of a system

Section 5.2

- A positive value of ΔE results when $E_{final} > E_{initial}$, indicating the system gained energy

  A negative value of ΔE results when $E_{final} < E_{initial}$, indicating the system lost energy

Analyzing energy of a system

Section 5.2

- In a chemical reaction, the initial state of the system refers to the reactants and the final state to the products
- We can analyze the ΔE gained or lost in a system by examining the processes that cause the changes to the system

  …*heat and work*

Relating ΔE to Heat and Work

Section 5.2

- The internal energy of a system can changes in two general ways
  - *As heat or as work*
- When a system undergoes any chemical or physical change, the accompanying change in internal energy is given by:

$$\Delta E = q + w$$

Conventions of *q* and *w*

Section 5.2

q > 0: Heat is transferred from the surrounding to the system

q < 0: Heat is transferred from the system to the surrounding

w > 0: Work is done by the surroundings on the system

w < 0: Work is done by the system on the surroundings

Practice Problem

Section 5.2

- Calculate the change in the internal energy of the system for a process in which the system absorbs 140 J of heat from the surroundings and does 85 J of work on the surroundings

$$E = q + W = 140J - 85J = 55J$$

Endothermic and Exothermic Processes

Section 5.2

- Endothermic – when the system absorbs heat from the surroundings
- Exothermic – when heat flow out of the system to the surroundings

State Function

Section 5.2

- The internal energy of a system is a *state function*
- *A state function is a property of a system that is determined by specifying its condition*
- The value of a state function does not depend on the history of the sample..only its present condition…*what does this mean?*

State Function

Section 5.2

- Change in energy ΔE is a state function..as it could have resulted from changes in work or heat
- Work (w) and Heat (q) individually are not state functions because they are specific in their route of change

AP Chemistry

5.3 Enthalpy

5.4 Enthalpies of Reaction

Enthalpy

Section 5.3

- The majority of physical and chemical changes take place under the essentially constant pressure of the Earth's atmosphere
- *Result → only tiny amounts of work are performed as the system expands and contracts against the force of the atmosphere*
  - *Thus..most of the energy gained or lost is in the form of heat*

Enthalpy

Section 5.3

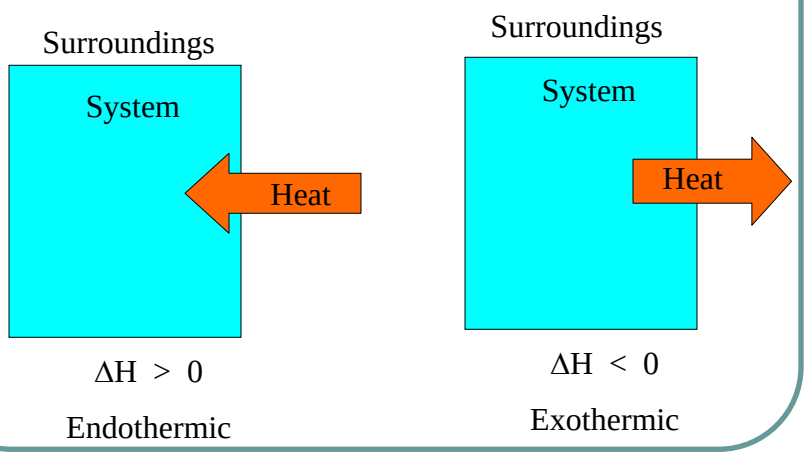
- Most of our discussions will focus on the transfer of heat under these conditions
- Enthalpy (meaning to warm): is the heat that is transferred under constant pressure
  - *Denoted by the symbol ΔH*

$$\Delta H = H_{final} - H_{initial} = q_p$$

Q_p = heat gained or lost by the system when the process occurs under constant pressure

Enthalpy *cont…*

Section 5.3



Enthalpies of Reaction

Section 5.4

- Since $\Delta H = H_{final} - H_{initial}$

$$\Delta H = H(products) - H(reactants)$$

The enthalpy change that accompanies a reaction is called the enthalpy of reaction or the heat of reaction ΔH_{rxn}

Example

Section 5.4

- Combustion of Hydrogen

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)} \quad \Delta H = -483.6\ kJ$$

The reaction occurs under constant pressure and the negative sign tells us its exothermic

Balanced chemical equations of this sort are Called thermo-chemical equations

Guidelines for using Thermo-chemical Reactions

Section 5.4

- **1) Enthalpy is an extensive property** → the magnitude of ΔH is directly proportional to the amount of reactant consumed
- Example

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)} \quad \Delta H = -483.6 \text{ kJ}$$

Twice reactants will result in 2 x ΔH

Guidelines cont…

Section 5.4

- 2) **The enthalpy change for a reaction is equal in magnitude but opposite in sign to ΔH for the reverse reaction**

$$2H_2O_{(g)} \rightarrow 2H_{2(g)} + O_{2(g)} \quad \Delta H = 483.6 \text{ kJ}$$

Guidelines cont…

Section 5.4

- 3) The enthalpy change for a reaction depends on the state of the reactants and products
- Example

$2H_2O_{(l)} \rightarrow 2H_2O_{(g)} \quad \Delta H = +88\ kJ$

Energy has to be put in (endothermic) to change water in liquid form to gas

Example

Section 5.4

- Hydrogen Peroxide can decompose to water and oxygen by the reaction:

$2H_2O_{2(l)} \rightarrow 2H_2O_{(l)} + O_{2(g)} \quad \Delta H = -196\ kJ$

Calculate the value of q when 5.00 g of $H_2O_{2(l)}$ decomposes at constant pressure

Heat = (5.00 g H_2O_2) (1 mol H_2O_2 / 34 g) (-196 kJ / 2 mol H_2O_2)

Q = Heat = -14.4 kJ

Hess's Law

Section 5.6

- The Notes for this section are included in the lecture worksheet

Enthalpies of Formation

Section 5.7

- The Notes for this section are included in the lecture worksheet