CHAPTER 10: ENERGY
Active Learning Questions: 1-6; End-of-Chapter Problems: 2-14, 21

10.1 THE NATURE OF ENERGY

Energy: the ability to do work or produce heat

potential energy (PE): energy due to position or its composition (chemical bonds)
- A 10-lb bowling ball has higher PE when it is 10 feet off the ground compared to 10 inches off the ground
  → Greater damage on your foot after falling 10 feet compared to falling only 10 inches
- In terms of chemical bonds, the stronger the bond,
  → more energy is required to break the bond,
  → the higher the potential energy of the bond

kinetic energy (KE): energy associated with an object’s motion
- e.g. a car moving at 55 mph has much greater KE than the same car moving at 15 mph
  → Greater damage if the car crashes at 55 mph than at 15 mph
- Consider these examples of PE and KE: https://www.youtube.com/watch?v=Jnj8mc04r9E

The Law of Conservation of Energy: In a chemical reaction, energy is neither created nor destroyed, so the total energy of the reactants must equal the total energy of the products.
→ Energy is simply converted from one form to another in a chemical reaction.

Six Forms of Energy: heat, light, chemical, electrical, mechanical, and nuclear
- Each can be converted to another.

Example: Identify at least two types of energy involved for each of the following:

a. When you turn on a lamp:

b. When using solar panels:

c. At the Springfield Power Plant in The Simpsons:
Energy changes accompany physical and chemical changes due to changes in potential and kinetic energy. Consider the molecular-level animations on the physical changes of water.

Kinetic Energy and Physical States

**Solids have the lowest KE of the three physical states**
- Highest attraction between particles
  → particles are fixed

**Liquids have slightly higher KE than solids**
- Particles are still attracted to each other but can move past one another
  → particles are less restricted

**Gases have greatest KE compared to solids and liquids**
- Attractive forces completely overcome, so particles fly freely within container
  → particles are completely unrestricted

10.2 TEMPERATURE AND HEAT

**Temperature:** A measure of the average kinetic energies of the particles in a substance
- i.e., a measure of the random motions of the particles in a substance

**Heat:** A measure of the total energy of the particles in a system (also called thermal energy)

**Thermal energy** is the kinetic energy associated with the motion of particles.
- Proportional to a substance’s temperature
- Increases with the size of a sample
- The two beakers at the right both contain boiling water (at 100°C), so the particles have the same average kinetic energy since they have the same temperature.
- However, beaker (b) has greater thermal energy than beaker (a) because it contains twice as much water at the same temperature.
Heat: Energy that is transferred from a body at a higher temperature to one at a lower temperature → **heat always transfers from the hotter to the cooler object!**
- "heat flow" means heat transfer
- View "Nova: Making Stuff Colder": [https://www.youtube.com/watch?v=onWGNtMVbmY&t=0m44s](https://www.youtube.com/watch?v=onWGNtMVbmY&t=0m44s)

**Heat Transfer and Temperature**
- An object becomes hotter by gaining heat.
- An object becomes colder by losing heat—i.e., when you “feel cold”, you are losing heat!

Ex. 1: Fill in the blanks to indicate how heat is transferred:

a. You burn your hand on a hot frying pan.

________________ loses heat, and ______________ gains the heat.

b. Your tongue feels cold when you eat ice cream.

________________ loses heat, and ______________ gains the heat.

Ex. 2: A small chunk of gold is heated in beaker #1, which contains boiling water. The gold chunk is then transferred to beaker #2, which contains room-temperature water.

a. The temperature of the water in beaker #2 _____ ↑ ↓ stays the same

b. Fill in the blanks: ______________ loses heat, and ______________ gains the heat.

Ex. 3: Why do surfaces like a stone countertop or metal flatware (forks, knives, etc.) feel cold? Aren’t they at room temperature like you? Explain.

### 10.3 EXOTHERMIC AND ENDOTHERMIC PROCESSES

**Energy and Chemical and Physical Change**

**endothermic change:** a physical or chemical change that requires energy or heat to occur
- boiling water requires energy: \( \text{H}_2\text{O}(l) + \text{heat energy} \rightarrow \text{H}_2\text{O}(g) \)
- electrolysis of water requires energy: \( 2\text{H}_2\text{O}(l) + \text{electrical energy} \rightarrow 2\text{H}_2(g) + \text{O}_2(g) \)

**exothermic change:** a physical or chemical change that releases energy or heat
- water condensing releases energy: \( \text{H}_2\text{O}(g) \rightarrow \text{H}_2\text{O}(l) + \text{heat energy} \)
- hydrogen burning releases energy: \( 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(g) + \text{heat energy} \)
For \textit{physical changes}, consider whether the reactants or products have more kinetic energy.
- If the reactants have greater kinetic energy than the products $\rightarrow$ \textbf{exothermic} process.
- If the products have greater kinetic energy than the reactants $\rightarrow$ \textbf{endothermic} process.

\begin{itemize}
  \item \textbf{System}: that part of the universe being studied
  \item \textbf{Surroundings}: the rest of the universe outside the system
\end{itemize}

For \textit{chemical changes}, observe if the surroundings (including you) feel hotter or colder after the reaction has occurred.
- If the surroundings are hotter, the reaction released heat $\rightarrow$ \textbf{exothermic reaction}.
- If the surroundings are colder, the reaction absorbed heat $\rightarrow$ \textbf{endothermic reaction}.

\textbf{Ex. 1}: Circle all of the following changes that are \textit{exothermic}:

- freezing
- vaporizing
- sublimation
- melting
- deposition
Ex. 2: A student adds ammonium chloride (NH₄Cl) salt to a test tube containing water and notices that the test tube feels colder as the ammonium chloride dissolves. Is this process exothermic or endothermic? Explain.

Ex. 3: A student mixes two solutions, hydrochloric acid and sodium hydroxide, and notices the beaker with the substances feels hotter as they mix. Is this reaction exothermic or endothermic? Explain.

10.5 MEASURING ENERGY CHANGES

Units of Energy

calorie (cal): unit of energy used most often in the US
– amount of energy required to raise the temperature of 1 g of water by 1˚C
– But a nutritional calorie (abbreviated Cal) is actually 1000 cal: 1 Cal = 1 kcal

joule (J): SI unit of energy
– To recognize the size of a joule, note that 1 watt = 1 \( \text{J} \) \( \text{s}^{-1} \) and 1 kilowatt (kW) = 1000 \( \text{J} \) \( \text{s}^{-1} \)
    → So a 100-watt light bulb uses 100 J every second.
– Heat is also often reported in kilojoules (kJ), where 1 kJ = 1000 J
– To convert between calories and joules, we use the following:

\[
1 \text{ cal} = 4.184 \text{ J} \quad (\text{Note: This is EXACT!})
\]

Electricity usage on our electricity bills is generally reported in kilowatt-hour (kWh).

Example: A 1500W hairdryer running for 5 minutes uses about 125 watt-hours or 0.125 kWh; one type of LCD TV rated at 100W uses about 1 kWh of energy for every 10 hours used; and a 5000W central AC unit uses 5 kWh\(^1\) for every hour run. If the average Seattle home uses about 25 kWh/day, this is equal to how many 100W LCD TVs running nonstop for one day?

\(^1\) https://www.wholesalesolar.com/solar-information/how-to-save-energy/power-table
Energy and Food Values

**food value**: The amount of heat released when food burns completely, in kJ/g or Cal/g food.

- Most of the energy needed by our bodies comes from carbohydrates and fats, and the carbohydrates decompose in the intestines into glucose, \( \text{C}_6\text{H}_{12}\text{O}_6 \).

- The combustion of glucose produces energy that is quickly supplied to the body:

\[
\text{C}_6\text{H}_{12}\text{O}_6(g) + 6 \text{O}_2(g) \rightarrow 6 \text{CO}_2(g) + 6 \text{H}_2\text{O}(g) + \text{heat energy}
\]

- The body also produces energy from proteins and fats, where the latter can be stored and produce more energy than proteins and carbohydrates.

- *ChemMatters: The Science Behind Calories and Nutrition Facts Labels:* [https://www.youtube.com/watch?v=G0O87gWv-Xk](https://www.youtube.com/watch?v=G0O87gWv-Xk)

**specific heat capacity**: amount of heat necessary to raise the temperature of 1 gram of any (or **specific heat**) substance by 1°C; has units of J/g°C

Ex. 1: Water’s specific heat (4.184 J/g·°C) while the specific heats of rocks and other solids (1.3 J/g·°C for dry Earth, 0.88 J/g·°C for concrete, 0.49 J/g·°C for steel). Given the same mass of each and heated with the same amount of energy for water, dry Earth, concrete, and steel at the same initial temperature, indicate which one would have the highest final temperature. Which would have the lowest final temperature? Explain why.

highest final temperature: ____________ lowest final temperature: ____________

Thus, because water covers most of the Earth, water can absorb a lot more energy before its temperature starts to rise.

- Water helps to regulate temperatures on Earth within a comfortable range for humans.
- Why coastal regions have less extreme temperatures compared to desert regions