Chapter 3: Matter and Energy

Check for the MasteringChemistry homework

**Matter:** Anything that has mass and occupies space.
- Matter is composed of atoms
- Atoms may bond together to form molecules or compounds
- Advances in microscopy such as a scanning tunneling microscope (STM) allow scientists to image individual atoms

**Classification of Matter:**

**States of Matter**
- Gas: compress/expand-particles do not interact significantly, far apart
- Liquid-closely spaced particles, free to move around and pass each other
- Solid-vibrate about a fixed point;
- Crystalline: Solids have long range repeating order. Particles occupy specific positions and angles, like table salt or diamond
- Amorphous: no long range order, like plastic, glass or obsidian

**Properties:**
- shape, volume,
- energy content, movement

**Phase Changes:**
- freeze/melt, evaporate/condense, sublime/deposit
- endothermic, exothermic
Water exists as ice, liquid water and steam— all are a bonded collection of H₂O

**Composition of Matter** (see page 59 figure 3.8)

*Pure Substances-* definite proportions, independent of how it is produced

- Elements
  - Molecules
  - Compounds

*Mixtures-* variable proportions

- Heterogeneous
- Homogeneous (solutions)

**Separating Mixtures**

- **Decanting:** immiscible, density differences

  *Filtration:* soluble/insoluble, liquid/solid (pg 71, figure 3.14)

  *Evaporation:* volatile/nonvolatile, dissolved solids

  *Distillation:* volatile, miscible, liquids (pg 71, figure 3.13)

  *Chromatography:* paper, column, gas
Properties of Matter:

Properties: physical, chemical, intensive, extensive
1. Physical: A property or change that does not change the chemical composition such as… temperature, boiling point, odor, solubility, change of state, or separation of mixtures,
2. Chemical: A property or change that does involve a change in the chemical makeup such as… Elements to compounds, reactants forming a different compound, change in chemical structure and composition, rusting (oxidation of metals), copper forming a green patina, combustion/burning or flammability, and decomposition. Chemical reaction… Reactants \( \rightarrow \) Products
3. Intensive: Property is independent of the amount… density, melting point, color
4. Extensive: Property is dependent of the amount… mass, volume, and length

Law of Conservation of Mass:
Law of Conservation of Mass: Matter is neither created or destroyed in a chemical reaction. \((\text{nuclear reactions have significant changes in mass/energy})\)
Mass is conserved.
The total sum of the mass before and after a reaction must be constant.

The behavior of Matter is driven by Energy:
Energy is the capacity to do work or transfer heat. Scientists generally use the unit of joules. Work is energy used to move an object with mass. Heat causes the temperature of an object to increase or change to a higher energy state such as solid to liquid to gas.

Law of Conservation of Energy: The first law of thermodynamics… \(\text{Energy cannot be created or destroyed}\). The energy of the universe is constant. Energy can be transferred from one object/form to another, but never lost.
This law works for ordinary chemical and physical processes.

Law of Conservation of Matter and Energy:
This law combines the two laws relating conservation of matter and energy. The combined laws work for nuclear reactions applying Einstein’s equation, \(E = mc^2\).

Generally processes spontaneously react to lower the overall energy. Specific conditions may change the general result such as melting ice/freezing water: depends on the surrounding temperature. Objects with high energy tend to be unstable
Units of energy:

1 Joule = 1 kg m²/s²

*James Joule (1818-1889) an English scientist who demonstrated Law of conservation of energy*

1 calorie = Energy required to raise 1 gram of water by 1°C or 1K.

1 *food Calorie* = 1 kcal.

1 calorie = 4.184 joules

1 Watt = 1 J/s

1 kWh = 3.60 x 10⁶ J

*Forms of Energy:*

**Potential Energy** (Eᵣ) is the energy by virtue of its position of composition.

**a)** For an object that has height, potential energy is the mass x gravity (9.8 m/s²) x height;  Eᵣ = mgh.

**b)** Another form is electrostatic potential energy from interactions with charged particles; Eₑᵣ = kQ₁Q₂/d, where k is a constant, Q is charge, and d is distance. Like charges repel and opposites attract.

**c)** Potential energy also comes from the arrangement of chemical compositions. When bonds break and new ones form in a chemical reaction, the energy change generally is due to the changes in potential energy/composition.

**Kinetic Energy** (Eₖ) is the energy of motion. For a moving object kinetic energy is half the mass x velocity squared;  Eₖ = ½ mv²

*Electrical Energy* is the energy associated with the flow of electrical charge.

*Chemical Energy* is associated with potential energy changes

*Other forms:*

- Thermal energy in transit is called heat
- Radiant energy, the energy of electromagnetic radiation
- Nuclear energy (E=mc²)
- Magnetic energy
- Elastic energy
- Sound energy
- Mechanical energy
- Luminous energy
Exchanges of Energy:

**Endothermic:** a process that absorbs heat (+)

**Exothermic:** a process that releases heat (-)

**Temperature:** Measures hotness or coldness associated with the constant random motion of particles

Fahrenheit: The English unit we are most familiar with regarding temperature/weather

Celsius: A scale based on water freezing at 0°C and boiling water at 1 atmosphere being 100°C. One unit of Celsius is equivalent to 1.8 units of Fahrenheit.

Kelvin: The SI unit with the same difference between degrees as Celsius. Kelvin is based on an absolute scale and has no negative values.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>°C = (K) -273.15</th>
<th>°F = 1.8(°C) + 32 = 9/5(°C) + 32</th>
</tr>
</thead>
<tbody>
<tr>
<td>K = (°C) + 273.15</td>
<td>°C = [(°F ) – 32]/1.8 = 5/9[(°F) – 32]</td>
<td></td>
</tr>
</tbody>
</table>

Calorimetry:

A calorimeter is an instrument to measure the transfer of heat energy. Coffee-cup calorimeters measure under constant pressure conditions and we call this enthalpy.

**Heat Capacity:** the energy required to raise an object by 1°C (or 1 Kelvin)

**Specific Heat Capacity** (C): the energy required to raise 1 gram by 1°C

The specific heat capacity symbol C is sometimes shown as s

\[ q = m \times C \times \Delta T \]

where

- q is heat
- m is mass
- C the specific heat capacity and
- \( \Delta T \) the final temperature minus the initial temperature
Practice Problems:
1. The average surface temperature of the South Pole is -56°C.
   a) What is this temperature in Kelvin?
   b) What is this temperature in Fahrenheit?

2. What is the potential energy of a 400 g ball on top of a building that is 30.6 m tall?
   Potential energy is the mass x gravity (9.8 m/s²) x height; \( E_p = mgh \)

3. What is the kinetic energy of a 400 g ball moving at 30.0 m/s?
   Kinetic energy is half the mass x velocity squared; \( E_k = \frac{1}{2} mv^2 \)

4. Is there a difference between Temperature and Heat?

5. Place a P before a physical property or change and a C before a chemical property or change:
   _____ The reaction with zinc and hydrochloric acid to produce a gas
   _____ Crystallization of CuSO₄ by evaporation of its aqueous solution
   _____ Metals are shiny, malleable, ductile, good conductors of heat and electricity
   _____ Alkali metals combine with halogens in a 1:1 ratio to form a compound

6. For the following identify each in as many ways as possible using the following:
   a) matter, b) pure substance, c) compound, d) molecule, e) element
   f) homogeneous mix g) heterogeneous mix h) metal i) nonmetal
   j) ionic compound k) alloy l) none
   a) Nitrogen dioxide, NO₂ ________________
   b) Sodium bromide, NaBr ________________
   c) Cu-Zn alloy called brass ________________
   d) Burrito ________________
   e) potassium ________________
   f) hypothesis ________________
Practice Problems: (ANSWERS)

1. a) 217 Kelvin  
b) -69 °F

2. 120 J

3. 180 J

4. Is there a difference between Temperature and Heat?

5. **C** The reaction with zinc and hydrochloric acid to produce a gas  
   **P** Crystallization of CuSO₄ by evaporation of its aqueous solution  
   **P** Metals are shiny, malleable, ductile, good conductors of heat and electricity  
   **C** Alkali metals combine with halogens in a 1:1 ratio to form a compound

6. a) Nitrogen dioxide, NO₂  
   a, b, c, d, (i)

   b) Sodium bromide, NaBr  
   a, b, c, j,

   c) Cu-Zn alloy called brass  
   a, f, k

   d) Burrito  
   a, g

   e) potassium  
   a, b, e, h

   f) hypothesis  
   l