Chapter 3
Matter and Energy

The chapter opening (page 52) showing a room and highlighting the structure of water and the carbon atoms in a graphite tennis racket.

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Chapter 3 Matter and Energy

OUTLINE

3.1 In Your Room
3.2 What is Matter?
3.3 Classifying Matter According to its State: Solid Liquid or Gas
3.4 Classifying Matter According to its Composition: Elements, Compounds, and Mixtures
3.5 How We Tell Different Matter Apart: Physical and Chemical Properties
3.6 How Matter Changes: Physical and Chemical Changes
3.7 Conservation of Mass. There is no New Matter.
Chapter 3 Matter and Energy

OUTLINE (cont.)

3.8 Energy
3.9 Energy and Chemical and Physical Change
3.10 Temperature: Random Molecular and Atomic Motion
3.11 Temperature Changes: Heat Capacity
3.12 Energy and Heat Capacity Calculations
3.1 In Your Room
In Your Room

• Everything you can see, touch, smell or taste in your room is made of matter.

• Chemistry studies matter
  ✓ Properties
  ✓ Changes = Reactions
  ✓ Heat associated with changes

Picture from page 52 again.
3.2 What Is Matter?
What Is Matter?

- **Matter** - occupies space and has mass.
- Atoms
- Molecules = atoms joined together as a unit
- Aluminum can has only aluminum atoms
- Figure 3.2 in the text shows microscopic pictures of Nickel atoms and DNA

Picture of an aluminum can and its atoms from Figure 3.1 (a)
Atoms and Molecules

• Ethyl alcohol is made up of molecules CH$_3$CH$_2$OH
• Similar to Figure 3.1(b)

Figures 3.1 (a) an aluminum can and a bottle of ethanol
Figure 3.1 (b)
Structure Determines Properties

- The properties of matter are determined by the atoms and molecules that compose it.

  **Carbon Monoxide**
  1. Composed of one carbon atom and one oxygen atom.
  2. Colorless, odorless gas.
  3. Burns with a blue flame.
  4. Binds to hemoglobin.

  **Carbon Dioxide**
  1. Composed of one carbon atom and two oxygen atoms.
  2. Colorless, odorless gas.
  3. Incombustible.
  4. Does not bind to hemoglobin.

A CO molecule with one C atom and one O atom

A CO₂ molecule arranged in the order O-C-O
3.3 Classifying Matter According to its State: Solid Liquid or Gas
Classifying Matter by Physical State

- Matter can be classified as solid, liquid, or gas based on the properties it exhibits.

<table>
<thead>
<tr>
<th>State</th>
<th>Shape</th>
<th>Volume</th>
<th>Compress</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>Fixed</td>
<td>Fixed</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Liquid</td>
<td>Indefinite</td>
<td>Fixed</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Gas</td>
<td>Indefinite</td>
<td>Indefinite</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- Fixed = Property doesn’t change when placed in a container.
- Indefinite = Takes the property of the container.
Structure Determines Properties

- Water can exist as a solid or a liquid or a gas.

Figure 3.4 showing the three states of water
Solids

- Particles are packed close together
- Particle vibrate about a fixed position.
- The particles are locked in place so shape and volume are fixed
- Sodium chloride is a solid made up of equal parts sodium (blue) and equal parts chlorine (green)
Solids, Continued

- **crystalline solids** have long range ordered arrangements.
  - Sugar, diamond, salt, quartz

- **amorphous solids** have random arrangement of particles.
  - Glass, plastic,
Liquids

• Closely packed, but mobile atoms and molecules.

• Particles of liquids flow allowing changing of shape, but volume is fixed
  ✓ Water, alcohol, gasoline, vegetable oil
Gases

• Well separated particles in constant random motion
• Particles do not touch except for collisions.
  ✓ Helium, air, carbon dioxide, nitrogen, hydrogen
Gases, Continued

• Because there is space between particles, gases are compressible.

Figure 3.7 an illustration of the non-compressibility of solids and the ability of gasses to be compressed.
3.4 Classifying Matter According to its Composition: Elements, Compounds, and Mixtures
Classification of Matter by Appearance

Illustration on page 57 of the homogeneous mixtures air and sea water showing the structures of the molecules and ions present. Nitrogen and oxygen molecules in air. Water molecules and sodium and chlorine ions in sea water.

- **Homogeneous** = Matter that exists in one phase, either solid, liquid or gas. There are no boundaries between the parts.
  - Solutions (homogeneous mixtures) and pure substances.
  - Sea water (no solids) or air are examples (see above)
- **Heterogeneous** = Matter that exists in more than one phase. There are clear boundaries between the parts.
  - Sand, dirt, or a mixture of oil and water are heterogeneous mixtures.
Practice—Classify the Following as Homogeneous or Heterogeneous

- A bowl of cereal
- Gasoline
- An iron bar
- Cola with ice
- Sugar dissolved in water
Practice—Classify the Following as Homogeneous or Heterogeneous

- A bowl of cereal - heterogeneous
- Gasoline - homogeneous
- An iron bar – homogeneous
- Cola with ice - heterogeneous
- Sugar dissolved in water - homogeneous
Classifying Matter by Composition

- Matter is divided into two types by composition
  - **Pure substances** have uniform fixed compositions.
  - **Mixtures** have variable compositions.

- Pure substances are further divided.
  - **Elements** have only one type of atom
    - Helium, iron, oxygen, (found in the periodic table)
  - **Compounds** have two or more types of atoms combined in a fixed ratio.
    - Water $\text{H}_2\text{O}$, Carbon Dioxide $\text{CO}_2$, salt $\text{NaCl}$

- Because pure substances are uniform in composition any sample will have the same properties.
Water—A Pure Substance

- Colorless, Odorless, Tasteless
- Does not burn
- Breaks down to hydrogen and oxygen if an electric current is passed through it.
- Melting point = 0 °C
- Boiling point = 100 °C
- Density = about 0.998 g/cm³ at 20 °C
Mixtures

• Mixtures may vary in composition.
• All mixtures contain two or more pure substances
• Mixtures are divided into two types
  ✓ **Homogeneous mixtures**  All one phase and uniform in appearance. Also known as solutions
  ✓ **Heterogeneous mixtures**  More than one phase with clear boundaries between parts
Salt Water, a Mixture

• Salt water may have different compositions
  ✓ One grain of salt in a glass of water
  ✓ One teaspoon (about 6 grams) of salt in a glass of water
  ✓ About 88 g of salt (saturated) In a glass of water

• Taste of these mixtures will differ
Brass a Solid Mixture

- Brass is a mixture of copper and zinc, an alloy
- Zinc content ranges from 5% to 40%
- Different compositions have different properties: density, color, melting point
Summary of Pure Substances

**Elements**

1. Made of one type of atom. (Some elements are found as multi-atom molecules in nature. \( \text{O}_2 \))
2. Combine together to make compounds.

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**Compounds**

1. Made of two or more types of atoms that exist as molecules, or array of ions combined in a fixed ratio.

Example: Helium in a blimp has one type of atom: Helium.

Example: Water can be broken down to hydrogen and oxygen.
Summary of Mixtures,

**Heterogeneous**
1. Made of multiple substances, whose presence can be seen.
2. Portions of a sample have different composition and properties.

**Homogeneous**
1. Made of multiple substances, but appears to be one substance.
2. All portions of a sample have the same composition and properties.

Example wet sand has a clear boundary between the liquid water and the solid sand.

Example a cup of tea is one phase: liquid. It contains water, sugar, caffeine, tea compounds, etc.
Classifying Matter

The classification scheme for matter shown in Figure 3.8.
3.5 How We Tell Different Matter Apart: Physical and Chemical Properties
Properties of Matter

• Properties are characteristics of a substance

• Properties are divided into two categories

  ✓ **Physical properties** are properties a substance displays in which there is no change in composition.

  ✓ **Chemical properties** are properties that are displayed when a substance is converted into a new substance (a chemical reaction).
Some Physical Properties

<table>
<thead>
<tr>
<th>Mass</th>
<th>Volume</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>Liquid</td>
<td>Gas</td>
</tr>
<tr>
<td>Melting point</td>
<td>Boiling point</td>
<td>Volatility</td>
</tr>
<tr>
<td>Taste</td>
<td>Odor</td>
<td>Color</td>
</tr>
<tr>
<td>Texture</td>
<td>Shape</td>
<td>Solubility</td>
</tr>
<tr>
<td>Electrical conductance</td>
<td>Thermal conductance</td>
<td>Magnetism</td>
</tr>
<tr>
<td>Malleability</td>
<td>Ductility</td>
<td>Specific heat capacity</td>
</tr>
</tbody>
</table>
Some Physical Properties of Table Sugar (Sucrose)

- White crystalline solid
- Sugar density is 1.587 g/cm³.
- Sugar dissolves in water
- Sugar solutions do not conduct electricity.
- Sugar tastes sweet.
## Some Chemical Properties

<table>
<thead>
<tr>
<th>Acidity</th>
<th>Basicity (aka alkalinity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causticity</td>
<td>Corrosiveness</td>
</tr>
<tr>
<td>Reactivity</td>
<td>Stability</td>
</tr>
<tr>
<td>Inertness</td>
<td>Explosiveness</td>
</tr>
<tr>
<td>(In)Flammability</td>
<td>Combustibility</td>
</tr>
<tr>
<td>Oxidizing ability</td>
<td>Reducing ability</td>
</tr>
</tbody>
</table>
Chemical Properties of Sugar

- Sugar decomposes when heated
- Sugar reacts with strong acids like sulfuric acid to form carbon and water
- Sugar is neither an acid nor a base in water
- Sugar burns to form carbon dioxide and water
- Sugar reacts with potassium nitrate to form potassium carbonate, nitrogen, carbon dioxide and water
Practice—Decide Whether Each of the Observations About Table Salt Is a Physical or Chemical Property

- Salt is a white, granular solid.
- Salt melts at 801 °C.
- Salt is stable at room temperature, it does not decompose.
- 36 g of salt will dissolve in 100 g of water.
- Salt solutions and molten salt conduct electricity.
- When a clear, colorless solution of silver nitrate is added to a salt solution, a white solid forms.
- When electricity is passed through molten salt, a gray metal forms at one terminal and a yellow-green gas at the other.
Practice — Decide Whether Each of the Observations About Table Salt Is a Physical or Chemical Property

• Salt is a white, granular solid = **physical**.
• Salt melts at 801 °C = **physical**.
• Salt is stable at room temperature, it does not decompose = **chemical**.
• 36 g of salt will dissolve in 100 g of water = **physical**.
• Salt solutions and molten salt conduct electricity = **physical**.
• When a clear, colorless solution of silver nitrate is added to a salt solution, a white solid forms = **chemical**.
• When electricity is passed through molten salt, a gray metal forms at one terminal and a yellow-green gas at the other = **chemical**.
3.6 How Matter Changes:
Physical and Chemical Changes
Changes in Matter

• **Physical changes** are changes in matter in which the composition does not change.

• **Chemical changes** are changes in which the composition of matter is changed. Another name for this is chemical reaction.

  ✓ During a chemical reaction, substances are converted into new substances by rearrangement of the atoms
Changes in Matter, Continued

• Physical Changes—.
  ✓ Heating water.
  ✓ Melting ice
  ✓ Boiling alcohol
  ✓ Evaporating butane from a lighter.
  ✓ Dissolving sugar in water.

Figure 3.11
butane molecules evaporating from a lighter
• **Chemical Changes**
  - Sodium metal and chlorine gas combine to form sodium chloride.
  - Burning results in butane from a lighter to be changed into carbon dioxide and water.
  - Silver combines with sulfur in the air to make tarnish.
  - TNT explode to form several gaseous products
  - Silver nitrate solutions react with chlorides to form insoluble silver chloride

Figure 3.12 Butane molecules Burning in a butane Lighter.
Is it a Physical or Chemical Change?

• A physical change does not create a new substance. Only the form of the substance changes.

• A chemical change or chemical reaction results in one or more completely new substances. This is a chemical reaction. Reactants are converted to products.
Phase Changes Are Physical Changes

- Boiling = liquid to gas.
- Melting = solid to liquid.
- Subliming = solid to gas.
- Freezing = liquid to solid.
- Condensing = gas to liquid.
- Deposition = gas to solid.
- State changes require heating or cooling the substance.

Figure on page 62
Water evaporating to Steam.
Practice—Classify Each Change as Physical or Chemical

- Evaporation of rubbing alcohol.
- Sugar turning black when heated.
- An egg splitting open and spilling out.
- Sugar fermenting.
- Bubbles escaping from soda.
- Bubbles that form when hydrogen peroxide is mixed with blood.
Practice—Classify Each Change as Physical or Chemical, Continued

• Evaporation of rubbing alcohol = physical.
• Sugar turning black when heated = chemical.
• An egg splitting open and spilling out = physical.
• Sugar fermenting = chemical.
• Bubbles escaping from soda = physical.
• Bubbles that form when hydrogen peroxide is mixed with blood = chemical.