Observation

**observation** - a way of acquiring information about nature.

Some observations are simple descriptions about the characteristics or behavior of nature.

“Pepsi is a liquid with a brown color and a sweet taste. Bubbles are observed floating up through it.”

Some observations compare a characteristic to a standard numerical scale.

“A 240 mL serving of Pepsi contains 27 g of sugar.”

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Hypotheses

A **hypothesis** is a tentative interpretation or explanation of the observations.

“The sweet taste of soda pop is due to the presence of sugar.”

A good hypothesis is **falsifiable** (which means that further testing has the potential to prove it wrong).

One test may invalidate your hypothesis.

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Experiments

An **experiment** is a highly controlled observation designed to validate or invalidate hypotheses (laws or theories).

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Scientific Laws

A **scientific law** is a brief statement that synthesizes past observations into one statement and predicts future ones.

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Theories

A **theory** attempts to provide a broader and deeper explanation for what we observe in terms of the underlying causes.
States of Matter

*states (phases) of matter* – the physical form of a substance.

Matter exists in three forms or states: *solid, liquid,* and *gas.*

**Solid** – a form of matter with a definite volume and definite shape independent of its container.

**Liquid** – a form of matter that has a definite volume but and indefinite shape (it assumes the shape of its container).

**Gas** – a form of matter that has neither a definite volume or shape (gases expand to fill the volume and take the shape of its container).

Classifying Matter by Physical State

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

<table>
<thead>
<tr>
<th>Table 2.2: Properties of Liquids, Solids, and Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
</tr>
<tr>
<td>solid</td>
</tr>
<tr>
<td>liquid</td>
</tr>
<tr>
<td>gas</td>
</tr>
</tbody>
</table>

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Water can exist in all three states (depending on the temperature and pressure).

**Change of State** – the conversion of a substance from one state to another.

**Solids**

- the particles in a solid are packed close together and are fixed in position – although they may vibrate or oscillate
- the close packing of the particles results in solids being *incompressible*
- the inability of the particles to move around results in solids retaining their shape and volume when placed in a new container, and prevents the particles from flowing

**Liquids**

- the particles in a liquid are closely packed (about as close as in a solid), but they have some ability to move around and by each other
- the close packing results in liquids having a fixed volume and being *incompressible*
- but the ability of the particles to move allows liquids to take the shape of their container and to flow – however they don’t have enough freedom to escape and expand to fill the container

**Gases**

- in the gas state, the particles have complete freedom from each other
- the particles are constantly flying around, bumping into each other and the container
- in the gas state, there is a lot of empty space between the particles (i.e., the atoms or molecules are separated by large distances) – on average
• because there is a lot of empty space, the particles in gases can be squeezed closer together – therefore gases are compressible
• because the particles are not held in close contact and are moving freely, gases expand to fill and take the shape of their container, and will flow

Changes in Matter

**Physical Changes** - changes in the properties of matter that do not affect the chemical makeup (composition) of a substance or object.

- Heating water
  - raises its temperature, but it is still water
- Evaporating butane from a lighter
- Dissolving sugar in water
  - even though the sugar seems to disappear, it can easily be separated back into sugar and water by evaporation
- Melting ice
  - both ice and liquid water are composed of water molecules
- Shattering glass
  - the pieces are still glass

Phase Changes (changes of state) are Physical Changes

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

Properties of Matter

**Property** – any characteristic that can be used to describe or identify one substance or object from another.

**Physical properties** – characteristics of matter that can be seen or measured without changing the chemical identity of the substance.

**Chemical properties** – characteristics that determine how the composition of matter changes as a result of contact with other matter or the influence of energy
  - characteristics that describe the behavior of matter
  - chemical properties can only be seen or measured when the substance undergoes a chemical change (chemical reaction)

Some Chemical Properties

- Rusting (of iron)
- Combustion (of gasoline)
- Tarnishing (of silver)
- Hardening (of cement)
- Flammability
- Acidity
- Toxicity
- Corrosiveness

Some Chemical Properties of Iron

- iron is easily oxidized in moist air to form rust
- when iron is added to hydrochloric acid, it produces a solution of ferric chloride and hydrogen gas
- iron is more reactive than silver, but less reactive than magnesium
Changes in Matter

**physical changes** - changes in the properties of matter that do not affect the chemical makeup (composition) of a substance or object.

**chemical changes** (chemical reactions) involve a change in the properties of matter as a result of a change in its composition.

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**Is it a Physical or Chemical Change?**

- A **physical change** results in a different form of the same substance
  - The kinds of molecules don’t change
  - You will observe different physical properties because different forms of the same substance have their own physical properties

- A **chemical change** results in one or more completely new substances
  - The new substances have different molecules than the original substances
  - You will observe different physical properties because the new substances have their own physical properties

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**TABLE 1.1  Some Properties of Water, Sugar, and Baking Soda**

<table>
<thead>
<tr>
<th>Water</th>
<th>Sugar (Sucrose)</th>
<th>Baking Soda (Sodium Bicarbonate)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorless liquid</td>
<td>White crystals</td>
<td>White powder</td>
</tr>
<tr>
<td>Odorless</td>
<td>Odorless</td>
<td>Odorless</td>
</tr>
<tr>
<td>Melting point, °C</td>
<td>100°C</td>
<td>Begins to decompose at 100°C and giving off water.</td>
</tr>
<tr>
<td>Boiling point, °C</td>
<td>100°C</td>
<td>Decomposes at 270°C, giving off water and carbon dioxide.</td>
</tr>
<tr>
<td><strong>Chemical properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composition:</td>
<td>Composition:</td>
<td></td>
</tr>
<tr>
<td>31.2% hydrogen</td>
<td>6.4% hydrogen</td>
<td>27.4% sodium</td>
</tr>
<tr>
<td>89.8% oxygen</td>
<td>42.1% carbon</td>
<td>1.2% hydrogen</td>
</tr>
<tr>
<td>51.5% oxygen</td>
<td>14.3% carbon</td>
<td>97.1% oxygen</td>
</tr>
</tbody>
</table>

*Compositions are given by mass percent.  
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**Classification of Matter**

- **Pure Substance**
  - **Constant Composition**
  - **Homogeneous**

- **Mixture**
  - **Variable Composition**

**pure substance** - matter that is composed of only one type of atom or molecule (of uniform chemical composition throughout)

- sugar

**mixture** - matter that is composed of different kinds of two or more different types of atoms or molecules

- **sugar water**
Copper – a Pure Substance

- color – brownish red
- shiny, malleable and ductile
- excellent conductor of heat and electricity
- melting point = 1,084.62°C
- density = 8.96 g/cm³ at 20°C

Brass – a Mixture

<table>
<thead>
<tr>
<th>Type</th>
<th>Color</th>
<th>% Cu</th>
<th>% Zn</th>
<th>Density g/cm³</th>
<th>MP °C</th>
<th>Tensile Strength psi</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilding</td>
<td>reddish</td>
<td>95</td>
<td>5</td>
<td>8.86</td>
<td>1066</td>
<td>50K</td>
<td>pre-82 pennies, munitions, plaques</td>
</tr>
<tr>
<td>Commercial</td>
<td>bronze</td>
<td>90</td>
<td>10</td>
<td>8.80</td>
<td>1043</td>
<td>61K</td>
<td>door knobs, grillwork</td>
</tr>
<tr>
<td>Jewelry</td>
<td>bronze</td>
<td>87.5</td>
<td>12.5</td>
<td>8.78</td>
<td>1035</td>
<td>66K</td>
<td>costume jewelry</td>
</tr>
<tr>
<td>Red</td>
<td>golden</td>
<td>85</td>
<td>15</td>
<td>8.75</td>
<td>1027</td>
<td>70K</td>
<td>electrical sockets, fasteners &amp; eyelets</td>
</tr>
<tr>
<td>Low</td>
<td>deep yellow</td>
<td>80</td>
<td>20</td>
<td>8.67</td>
<td>999</td>
<td>74K</td>
<td>musical instruments, clock dials</td>
</tr>
<tr>
<td>Cartridge</td>
<td>yellow</td>
<td>70</td>
<td>30</td>
<td>8.47</td>
<td>954</td>
<td>76K</td>
<td>car radiator cores</td>
</tr>
<tr>
<td>Common</td>
<td>yellow</td>
<td>67</td>
<td>33</td>
<td>8.42</td>
<td>940</td>
<td>70K</td>
<td>lamp fixtures, bead chain</td>
</tr>
<tr>
<td>Muntz metal</td>
<td>yellow</td>
<td>60</td>
<td>40</td>
<td>8.39</td>
<td>904</td>
<td>70K</td>
<td>nuts &amp; bolts</td>
</tr>
</tbody>
</table>

Classification of Mixtures

**homogeneous** - matter that is uniform throughout
- appears to be one thing
- every piece of a sample has identical properties, though another sample with the same components may have different properties
- solutions (homogeneous mixtures)

**heterogeneous** - matter that is non-uniform throughout
- contains regions with different properties than other regions

Pure Substances vs. Mixtures

**Pure Substances**
1) all samples have the same physical and chemical properties
2) constant composition = all samples have the same components in the same percentages
3) homogeneous
4) separate into components based on chemical properties
5) temperature usually stays constant while melting or boiling

**Mixtures**
1) different samples may show different properties
2) variable composition = samples made with the same pure substances may have different percentages
3) homogeneous or heterogeneous
4) separate into components based on physical properties
5) temperature changes while melting or boiling because composition changes