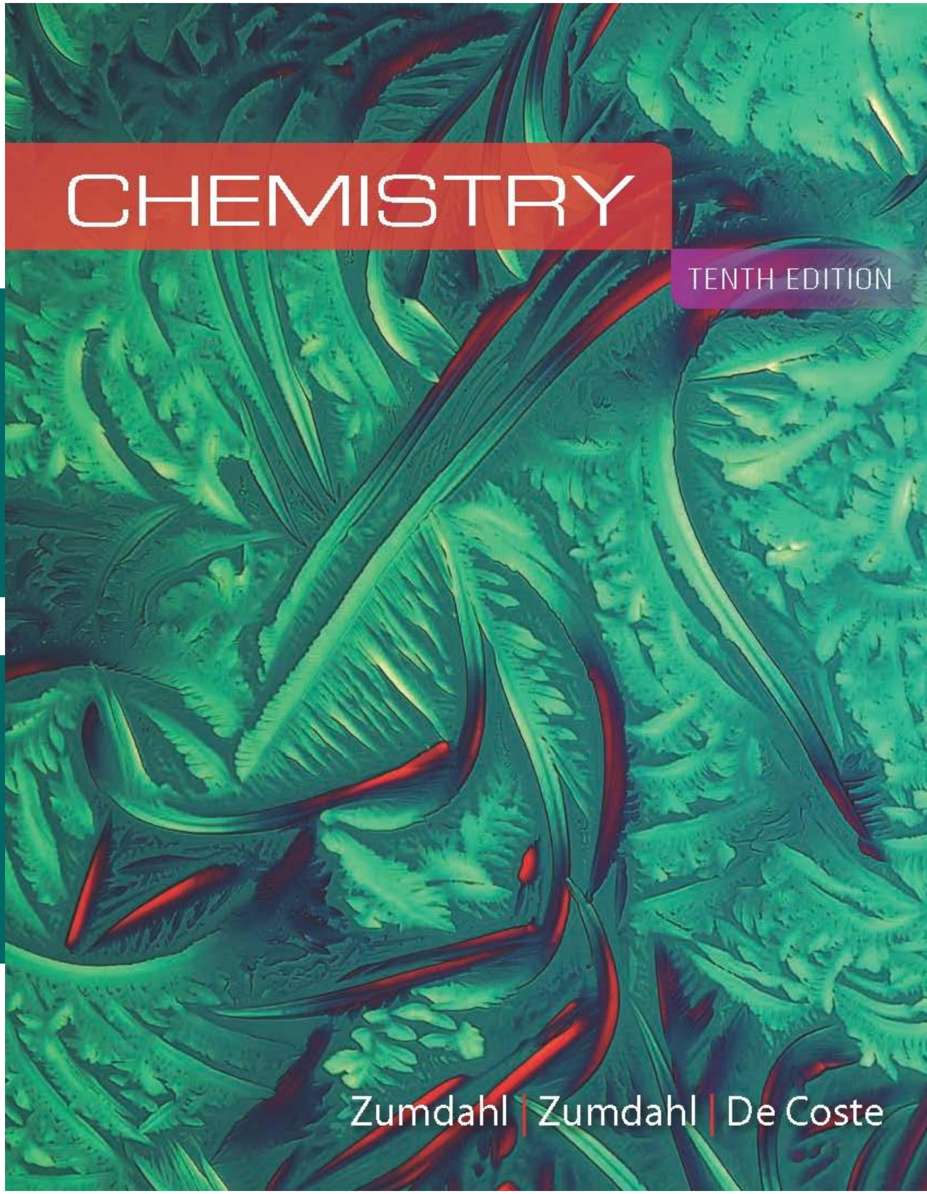


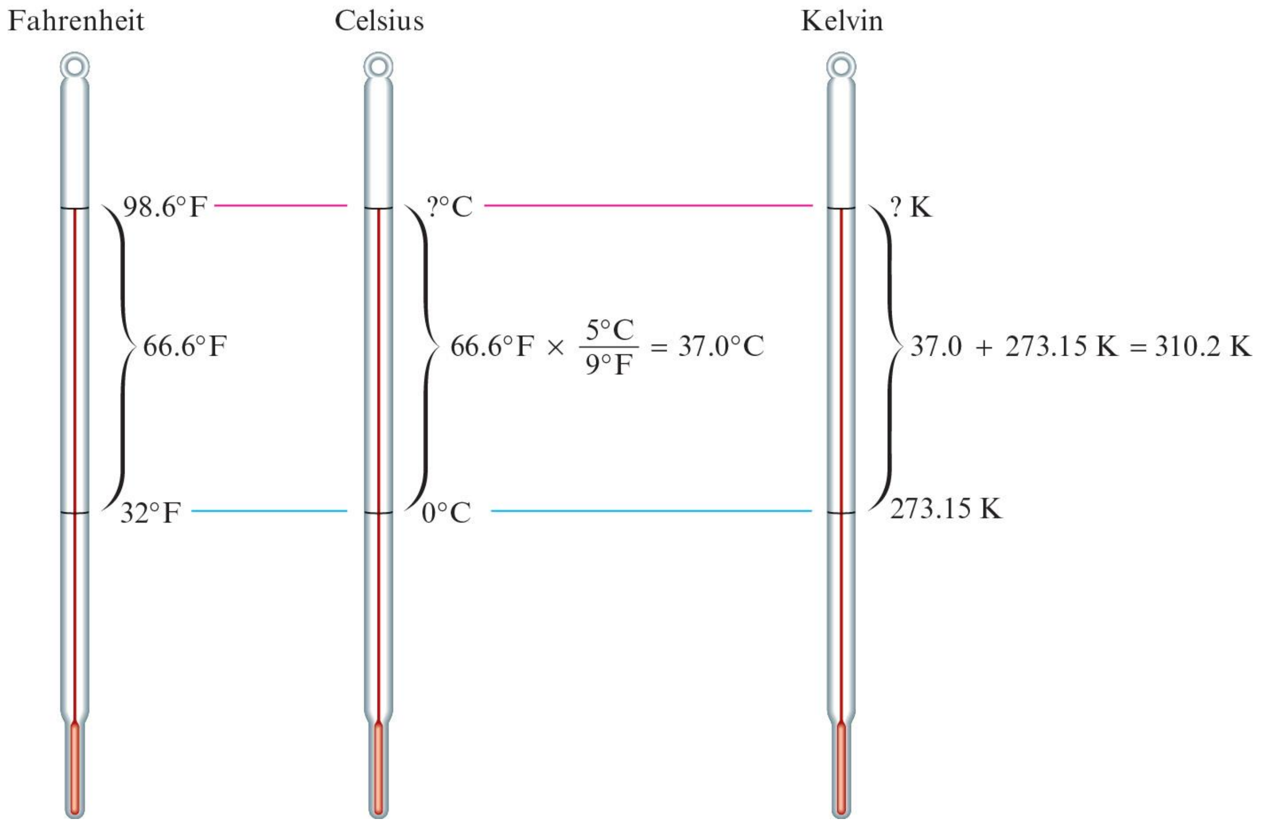
Chapter 1

Chemical Foundations

Systems for Measuring Temperature

- Celsius scale and Kelvin scale are used in the physical sciences
  - Size of the temperature unit (the degree) is the same
  - Temperature in Celsius units is designated ° C, and temperature in Kelvin scale is symbolized by the letter *K*
- Fahrenheit scale is used in the engineering sciences

Figure 1.10 - Normal body temperature on the Fahrenheit, Celsius, and Kelvin scales



Kelvin and Celsius Scales

- Differ in their zero points
- Conversion between the scales requires an adjustment for the different zero points

$$\text{Temperature (Kelvin)} = \text{temperature (Celsius)} + 273.15$$

$$\text{Temperature (Celsius)} = \text{temperature (Kelvin)} - 273.15$$

Fahrenheit and Celsius Scales

- Degree sizes and the zero points are different
- Conversion between these scales considers two adjustments
  - One for degree size
  - One for the zero point

Fahrenheit and Celsius Scales: Difference in Degree Size

- 212° F = 100° C and 32° F = 0° C

$$212 - 32 = 180 \text{ Fahrenheit degrees} = 100 - 0 = 100 \text{ Celsius degrees}$$

- Thus, 180° on the Fahrenheit scale is equivalent to 100° on the Celsius scale, and the unit factor is

$$\frac{180°\text{F}}{100°\text{C}} \quad \text{or} \quad \frac{9°\text{F}}{5°\text{C}}$$

Fahrenheit and Celsius Scales: Different Zero Points

- Converting from Fahrenheit to Celsius

$$(T_F - 32°F)\frac{5°C}{9°F} = T_C$$

  - T_F - Temperature on the Fahrenheit scale
  - T_C - Temperature on the Celsius scale

Fahrenheit and Celsius Scales: Different Zero Points

(continued)

- Converting from Celsius to Fahrenheit

$$T_{\mathrm{F}} = T_{\mathrm{C}} \times \frac{9^{\circ}\mathrm{F}}{5^{\circ}\mathrm{C}} + 32^{\circ}\mathrm{F}$$

  - T_F - Temperature on the Fahrenheit scale
  - T_C - Temperature on the Celsius scale

Example 1.12 - Temperature Conversions II

- One interesting feature of the Celsius and Fahrenheit scales is that $-40°$ C and $-40°$ F represent the same temperature
  - Verify that this is true

Example 1.12 - Solution

- Where are we going?
  - To show that –40° C = –40° F
  - What do we know?
    - The relationship between the Celsius and Fahrenheit scales
- How do we get there?
  - The difference between 32° F and –40° F is 72° F
  - The difference between 0° C and –40° C is 40° C

Example 1.12 - Solution (continued)

- The ratio of these is

$$\frac{72°\text{F}}{40°\text{C}} = \frac{8 \times 9°\text{F}}{8 \times 5°\text{C}} = \frac{9°\text{F}}{5°\text{C}}$$

- Thus –40° C is equivalent to –40° F

Relationship between the Fahrenheit and Celsius Scales

- 40° on both the Fahrenheit and Celsius scales represents the same temperature

$$\frac{\text{Number of Fahrenheit degrees}}{\text{Number of Celsius degrees}} = \frac{T_{\mathrm{F}} - (-40)}{T_{\mathrm{C}} - (-40)} = \frac{9°\mathrm{F}}{5°\mathrm{C}}$$

$$\frac{T_{\mathrm{F}} + 40}{T_{\mathrm{C}} + 40} = \frac{9°\mathrm{F}}{5°\mathrm{C}}$$

  - T_{F} and T_{C} represent the same temperature but not the same number

Interactive Example 1.13 - Temperature Conversions III

- Liquid nitrogen, which is often used as a coolant for low-temperature experiments, has a boiling point of 77 K
  - What is this temperature on the Fahrenheit scale?

Interactive Example 1.13 - Solution

- Where are we going?
  - To convert 77 K to the Fahrenheit scale
  - What do we know?
    - The relationship between the Kelvin and Fahrenheit scales
- How do we get there?
  - We will first convert 77 K to the Celsius scale

$$T_C = T_K - 273.15 = 77 - 273.15 = -196^\circ \text{ C}$$

Interactive Example 1.13 - Solution (continued)

- Now convert to the Fahrenheit scale

$$\frac{T_F + 40}{T_C + 40} = \frac{9°F}{5°C}$$

$$\frac{T_F + 40}{-196°C + 40} = \frac{T_F + 40}{-156°C} = \frac{9°F}{5°C}$$

$$T_F + 40 = \frac{9°F}{5°C}\left(-156°C\right) = -281°F$$

$$T_F = -281°F - 40 = -321°F$$

Exercise

- Convert the following Celsius temperatures to Kelvin and to Fahrenheit degrees
  a. Temperature of someone with a fever, 39.2° C

  312.4 K; 102.6° F

  b. Cold wintery day, –25° C

  248 K; –13° F

Exercise (continued)

- Convert the following Celsius temperatures to Kelvin and to Fahrenheit degrees

c. Lowest possible temperature, –273° C

0 K; –459° F

d. Melting-point temperature of sodium chloride, 801° C

1074 K; 1473.8° F

Density

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

- Property of matter that is used as an identification tag for substances
- Density of a liquid can be determined easily by weighing an accurately known volume of liquid

Interactive Example 1.14 - Determining Density

- A chemist, trying to identify an unknown liquid, finds that 25.00 cm^3 of the substance has a mass of 19.625 g at 20° C

Interactive Example 1.14 - Determining Density (continued)

- The following are the names and densities of the compounds that might be the liquid:

Compound	Density in g/cm^3 at 20°C
Chloroform	1.492
Diethyl ether	0.714
Ethanol	0.789
Isopropyl alcohol	0.785
Toluene	0.867

- Which of these compounds is the most likely to be the unknown liquid?

Interactive Example 1.14 - Solution

- Where are we going?
  - To calculate the density of the unknown liquid
  - What do we know?
    - The mass of a given volume of the liquid
- How do we get there?
  - To identify the unknown substance, we must determine its density

Interactive Example 1.14 - Solution (continued)

- Density can be determined by using its definition

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{19.625\text{ g}}{25.00\text{ cm}^3} = 0.7850\text{ g/cm}^3$$

  - This density corresponds exactly to that of isopropyl alcohol, which therefore most likely is the unknown liquid
  - However, note that the density of ethanol is also very close
  - To be sure that the compound is isopropyl alcohol, we should run several more density experiments

Table 1.5 - Densities of Various Common Substances* at 20° C

Substance	Physical State	Density (g/cm^3)
Oxygen	Gas	0.00133
Hydrogen	Gas	0.000084
Ethanol	Liquid	0.789
Benzene	Liquid	0.880
Water	Liquid	0.9982
Magnesium	Solid	1.74
Salt (sodium chloride)	Solid	2.16
Aluminum	Solid	2.70
Iron	Solid	7.87
Copper	Solid	8.96
Silver	Solid	10.49
Lead	Solid	11.34
Mercury	Liquid	13.56
Gold	Solid	19.32

*At 1 atmosphere pressure.

Join In (10)

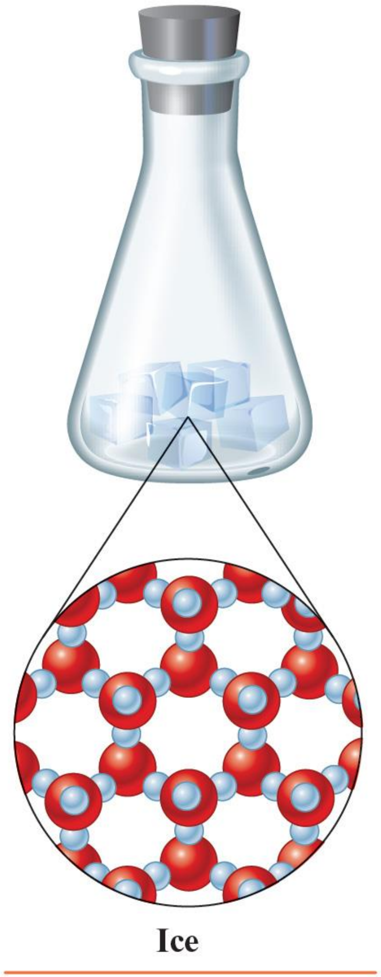
- A 25 g cylinder of iron (d = 7.87g/mL) and a 1.0 gram pellet of copper (d = 8.96 g/mL) are placed in 500 mL of water (d = 0.9982 g/mL)
  - Predict whether each will float or sink in water
    a. Iron will float, and copper will sink
    b. Iron will sink, and copper will float
    c. Iron and copper will sink
    d. Iron and copper will float
    e. More information is needed

Matter

- Anything that occupies space and has mass
- Has many levels of organization and is complex
- Exists in three **states**
  - Solid
  - Liquid
  - Gas

Properties of a Solid

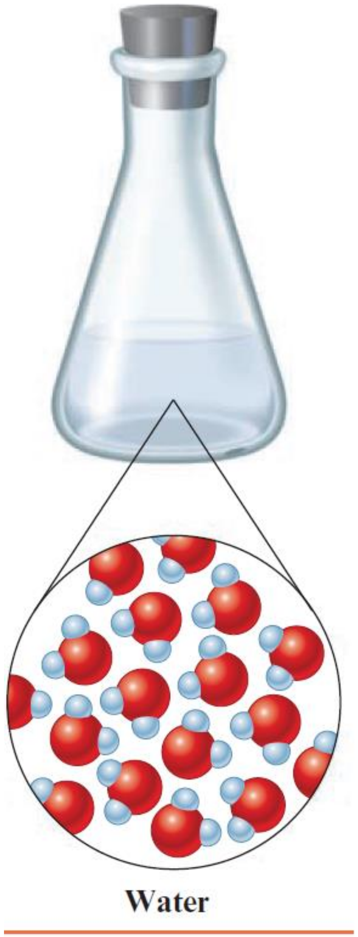
- Rigid
- Fixed volume and shape
- Slightly compressible



Solid: The water molecules are locked into rigid positions and are close together

Properties of a Liquid

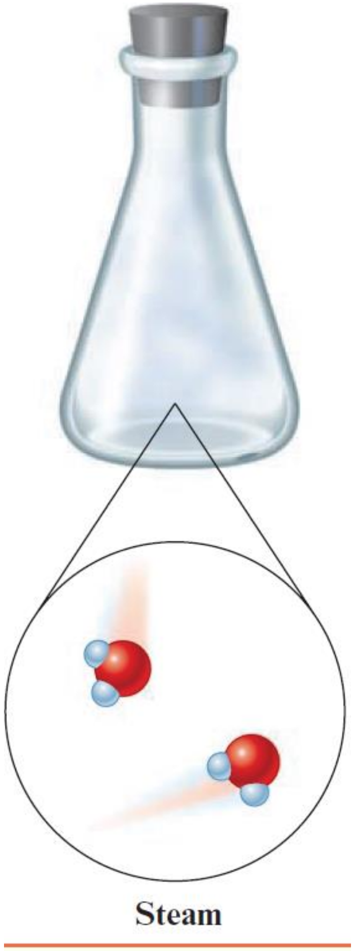
- Definite volume
- No specific shape
  - Assumes the shape of its container
- Slightly compressible



Liquid: The water molecules are still close together but can move around to some extent

Properties of a Gas

- No fixed volume or shape
  - Takes on the shape and volume of its container
- Highly compressible
  - Relatively easy to decrease the volume of a gas



Gas: The water molecules are far apart and move randomly

Mixtures

- Have variable composition
- Classification
  - **Homogeneous mixture**: Has visibly indistinguishable parts and is often called a **solution**
  - **Heterogeneous mixture**: Has visibly distinguishable parts
- Can be separated into **pure substances**, which have constant compositions, by physical methods

Physical Change

- Change in the form of a substance
  - No change in the chemical composition of the substance
- Example
  - Boiling or freezing of water
- Used to separate a mixture into pure compounds
  - Will not break compounds into elements

Methods for Separating Components in a Mixture

- **Distillation**
- **Filtration**
- **Chromatography**

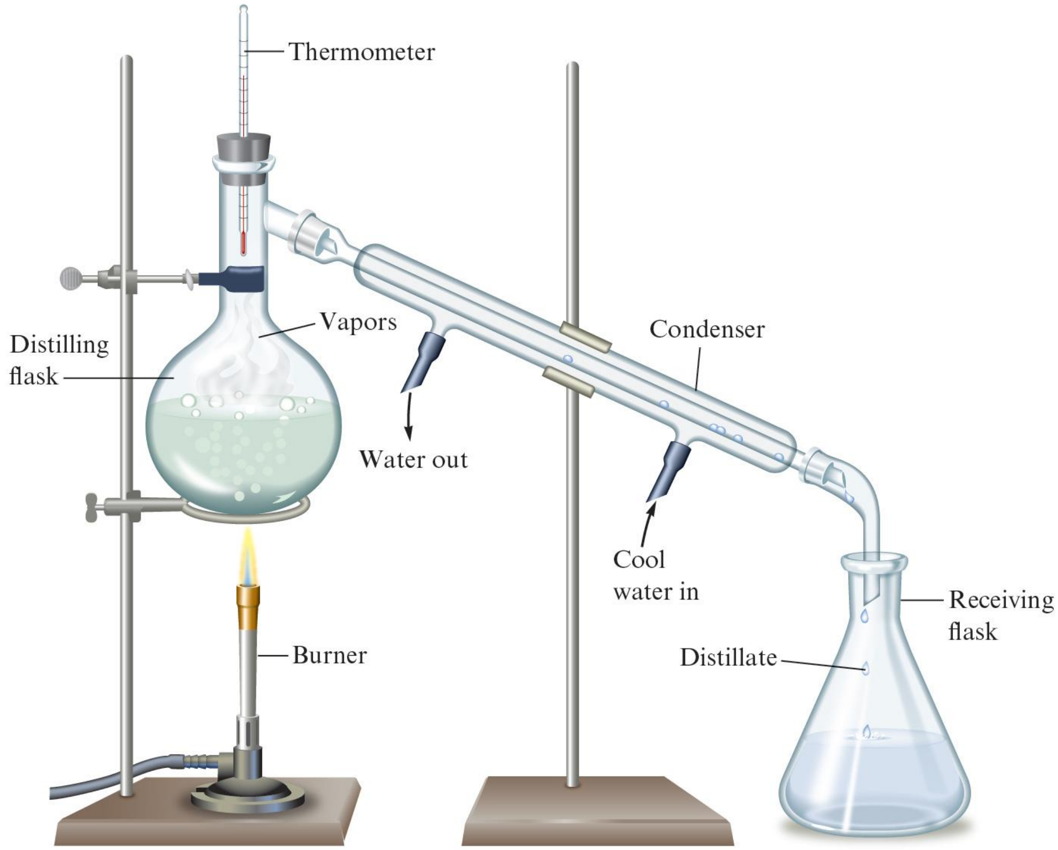
Distillation

- Depends on the differences in the volatility of the components
- One-stage distillation process involves heating the mixture in a distillation device
  - Most volatile component vaporizes at the lowest temperature
  - Vapor is passed through a condenser, where it condenses back into its liquid state

One-Stage Distillation - Drawback

- When a mixture contains several volatile components, the one-step distillation does not give a pure substance in the receiving flask
  - More elaborate methods are required

Figure 1.12 - Simple Laboratory Distillation Apparatus



Filtration

- Used when a mixture consists of a solid and a liquid
- Mixture is poured onto a mesh, such as filter paper, which passes the liquid and leaves the solid behind

Chromatography

- General name applied to a series of methods that use a system with two states (phases) of matter
  - Mobile phase - Liquid or gas
  - Stationary phase - Solid
- Separation occurs because the components of the mixture have different affinities for the two phases
  - They move through the system at different rates

Chromatography (continued)

  - Component with a high affinity for the mobile phase will quickly go through the chromatographic system as compared to one with a high affinity for the solid phase
- **Paper chromatography**: Uses a strip of porous paper for the stationary phase

Figure 1.13 - Paper Chromatography of Ink

a

A dot of the mixture to be separated is placed at one end of a sheet of porous paper

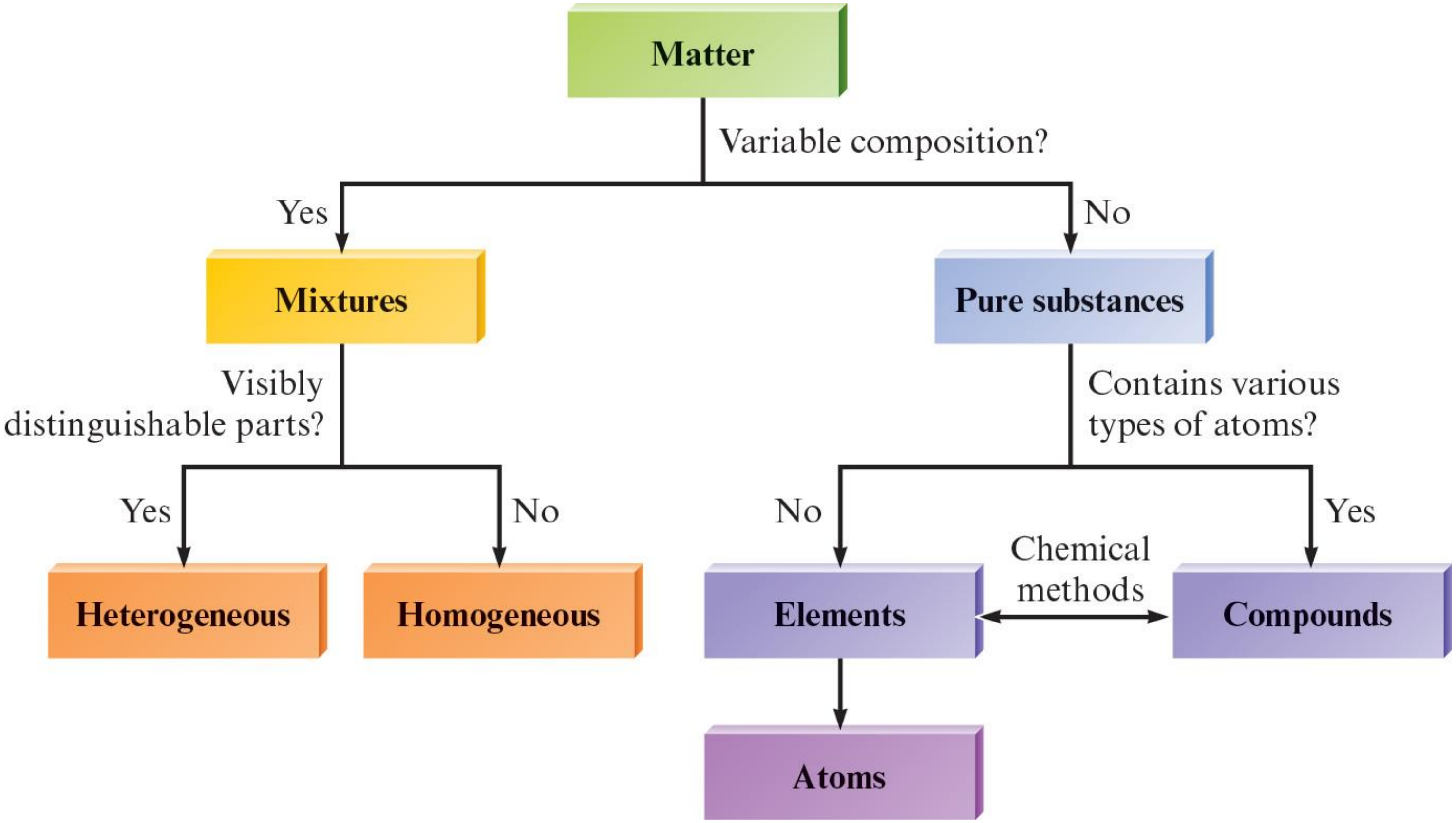
b

The paper acts as a wick to draw up the liquid

Pure Substances

- Either compounds or free elements
  - **Compound**: Substance with a constant composition that can be broken down into its elements via chemical processes
    - Given substance becomes a new substance or substances with different properties and different composition
  - **Element**: Substance that cannot be broken down into simpler substances by physical or chemical means

Figure 1.14 - The Organization of Matter



Join In (12)

- Which of the following statements is false?
  a. Solutions are always homogeneous mixtures
  b. Atoms that make up a solid are mostly open space
  c. Elements can exist as atoms or molecules
  d. Compounds can exist as elements or molecules

Join In (1)

- Which of the following is an example of a quantitative observation?
  a. Solution A is a darker red color than solution B
  b. The grass is green
  c. Substance A has a greater mass than substance B
  d. The temperature of the water is 45° C

Homework

A rectangular block has dimensions 2.9 cm x 3.5 cm x 10.0 cm. The mass of the block is 615.0 g. What are the volume and density of the block??