Read Sections 1.10, 1.11, and 1.12 in the textbook before viewing the slide show
Unit 5
Measurement – Derived Units

• Area and volume units (1.10)

• Density (1.11)

• Temperature scales and their interconversion (1.12)

• Energy units and their interconversion (1.12)
Area and Volume Measurements (1.10)

• The SI system provides for volume measurement only as it is related to length. Consider the simple conversion below:

Two boxes the same size. The one on the left is measured in yards, the one on the right in feet. The area on the left is 1 yd $\times$ 1 yd = 1 yd$^2$ and that on the right is 3 ft $\times$ 3 ft = 9 ft$^2$. So, 1 yd$^2$ = 9 ft$^2$. Notice this is NOT 1 yd$^2$ = 3 ft$^2$. 
A similar treatment holds for volume with the conversion factor being cubed instead of squared. Consider the cube pictured to the right. If each side were 1 yd, the total volume would be $1 \text{ yd} \times 1 \text{ yd} \times 1 \text{ yd} = 1 \text{ yd}^3$. If each side were measured in feet, the volume would be $3 \text{ ft} \times 3 \text{ ft} \times 3 \text{ ft} = 27 \text{ ft}^3$.

Notice how the unit conversion is squared for area and cubed for volume. The same holds true of measurements in the metric system.
Area and volume conversions in the metric system are very similar. In the metric system, adjusting the decimal point for an area conversion means moving the decimal place two times as far as you would in a length conversion; for a volume move it three times as far.

Example:
0.55 m = 55 cm  (length: base to centi- is two places right)

1.98 m² = 19800 cm²  (area: base to centi- is two x 2 places right)

6.47 m³ = 6470000 cm³ (volume: base to centi- is two x 3 places right)
More on Metric Volume

- The SI-consistent unit of volume is the cubic meter – a box about 1 yd on each side.
- A smaller unit – the liter - is much more convenient for many chemical applications.
- A liter (L) is defined to be the volume of a box that is 1 dm on each side or 1 dm³ (a L is a little larger than one quart in size).
- One thousandth (1/1000) of a dm³ is 1 cm³, also known as one mL.
Conversions Between Volume Units

• Conversion between the liter and other metric volume units is the same as other metric conversions
• The most important relationship in volume conversions is probably:

\[ 1 \text{ L} = 1000 \text{ mL} = 1000 \text{ cm}^3 = 1000 \text{ cc} \]

• Notice the mL, the cm\(^3\), and the cc are the same size
Examples of Volume Conversions

- Consider the following conversions:

  546 mL = 0.546 L

  1.26 L = 1260 mL

  0.0345 cc = 0.0000345 L or $3.45 \times 10^{-5}$

  0.834 L = 834 cm$^3$

Notice they are all three decimal place moves – to the left if going from smaller unit to larger unit, to the right if going from larger unit to smaller unit. Identical to metric moves we looked at previously.
Density

• Measured quantities often use combinations of the seven base units.
• Here we consider density defined as:

\[ \text{density} = \frac{\text{mass}}{\text{volume}} \]

• Density relates the mass of material to its volume and is typically expressed in units such as g/mL, g/cc, or g/cm\(^3\)
The expression for density \( \left( \text{density} = \frac{\text{mass}}{\text{volume}} \right) \) contains three variables. If any two are known, the third may be determined.

As a means of setting up for future types of calculations, we will look at three ways of setting up problems involving density calculations.

- Algebra
- Thinking it through
- Unit conversion
Algebraic Method of Working with Density

- Using standard algebraic approaches, one can consider the following basic possibilities starting from the density expression

\[ \text{density} = \frac{\text{mass}}{\text{volume}} \]

- If mass and volume are known and density is sought, simply substitute the mass and volume into the density expression

- If density and volume are known and mass is sought, rearrange the density expression to:

\[ \text{mass} = \text{density} \times \text{volume} \]

- If density and mass are known and volume is sought, rearrange the density expression to:

\[ \text{volume} = \frac{\text{mass}}{\text{density}} \]
There is a certain logic to these density calculations. A density of 1.85 g/mL may be read as 1.85 g of substance for each and every mL. Consider the following cases:

- **Given a mass and a volume to find density:** apply the definition (mass/volume)
- **Given a density and volume to find mass:** The density is the mass for each and every mL. So, if you have some number of mL and want the mass, multiply the density by the volume.
- **Given a density and mass to find volume:** The density represents the mass for each and every mL. To find the number of mL, you need to find out how many times the density goes into the given mass so divide mass by density.
Unit Conversion

• The density is an example of a unit conversion factor. A density of 2.45 g/mL means that, for this substance, 2.45 g (a mass) is another way of expressing the quantity of material in 1 mL (a volume). Thus ratios of 2.45 g/1 mL or 1 mL/2.45 grams really represent the number “1” since both the numerator and denominator refer to the same quantity of material.

• Any number multiplied by “1” does not change in value.

• The unit conversion concept can be used to multiply a number by “1” to change its units while leaving the measurement intact.

• Examples of use are on the next slides.
Setup of Unit Conversion

• The unit conversion setup takes the following general form:

\[
? \text{desired quantity} = \frac{\text{given quantity}}{1} \times \frac{\text{units desired quantity}}{\text{units given quantity}}
\]

where the last fraction represents the unit conversion factor.

• See the following slide for an example.
Example of Unit Conversion Approach

- Find the volume of 45.0 g of a substance that has a density of 3.45 g/mL.

\[
? \text{desired quantity} = \frac{\text{given quantity}}{1} \times \frac{\text{units desired quantity}}{\text{units given quantity}}
\]

\[
? \text{mL} = \frac{45.0 \text{ g}}{1} \times \frac{1 \text{ mL}}{3.45 \text{ g}} = 13.0 \text{ mL}
\]
There are three primary temperature scales to consider:

<table>
<thead>
<tr>
<th>Fahrenheit (°F)</th>
<th>Celsius (°C)</th>
<th>Kelvin (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>212</td>
<td>100</td>
<td>373.15</td>
</tr>
<tr>
<td>32</td>
<td>0</td>
<td>273.15</td>
</tr>
</tbody>
</table>

Temperature scale comparison based on the freezing point and boiling point of water.
Temperature Conversions

- For Celsius to Fahrenheit:
  \[ \text{°F} = 1.8 \times \text{°C} + 32 \]

- For Fahrenheit to Celsius:
  \[ \text{°C} = \frac{\text{°F} - 32}{1.8} \]

- For Celsius to Kelvin:
  \[ K = \text{°C} + 273.15 \]
• Kelvin is an example of an absolute temperature scale. 0 K is an unattainable temperature though we have been close – about 250 pK (1 pK = 1 x 10^{-12} K).

• Temperatures on the Kelvin scale are written without the degree sign (^\circ). A temperature of 345 K is read as 345 kelvins.
Heat and its Units

• Heat is a term used to refer to energy transferred due to a temperature difference
• Typical units of energy are Joules and calories
• 1 cal = 4.184 J
• A food calorie is actually a kilocalorie.