Chapter 3 – Scientific Measurement

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Section 3.1 – Measurements and Their Uncertainty

- A measurement is a quantity that has both a number and a unit.
- The unit typically used in the sciences are those of the International System of Measurements (SI).
- In scientific notation, a given number is written as the product of two numbers: a coefficient and 10 raised to a power.
- In scientific notation, the coefficient is always a number equal to or greater than one and less than ten.

6.5×10^7

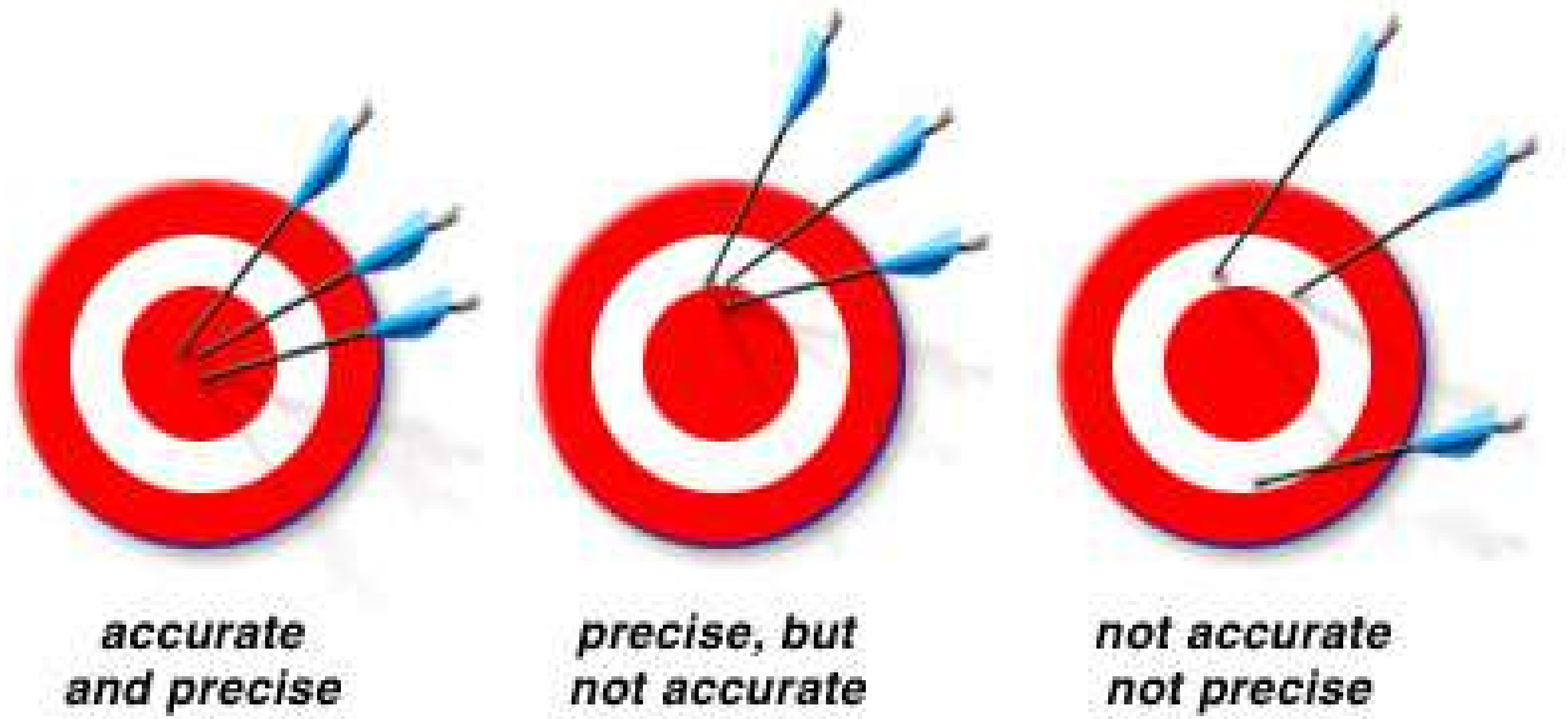
Sample Problems

- Write the following numbers in scientific notation:
  - 39400000 3.94×10^7
  - 2800 2.8×10^3
  - 0.000567 5.67×10^{-4}
  - 0.0000002 2×10^{-7}

- Write the following numbers in regular notation:
  - 3.22×10^4 32200
  - 2.1×10^{-5} 0.000021
  - 8×10^2 800
  - 7.90×10^{-6} 0.00000790

Accuracy vs. Precision

- Accuracy is a measure of how close a measurement comes to the actual or true value.
- Precision is a measure of how close a series of measurements are to one another.



Error

Error = experimental value – actual value

- The accepted value is the correct value.
- The experimental value is the value measured in the lab.
- The percent error is the absolute value of the error divided by the accepted value.

$$\text{Percent Error} = \frac{|\text{Error}|}{\text{Accepted value}} \times 100$$

So in other words,

$$\%E = \frac{|e - a|}{a} \times 100$$

Sample Problem

- A block of aluminum has a mass of 147.3g. A student measures the mass of the block as 138.9g. What is the student's error?

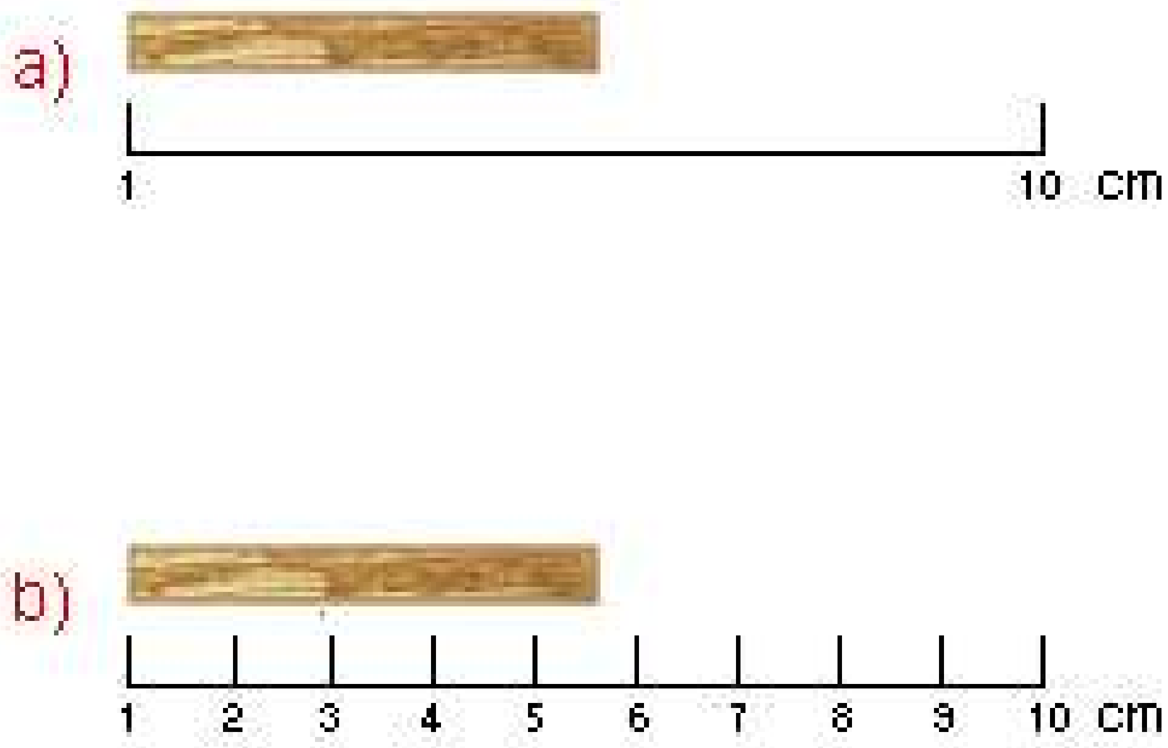
-8.4g

- What is the percent error?

5.70%

Significant Figures

- The significant figures in a measurement include all the digits that are known, plus a last digit that is estimated.



Rules for Significant Figures

- Every nonzero digit is significant. Ex: 254 or 65.43
- Zeros between significant figures are significant. Ex: 3005 or 1.083
- Zeros before (to the left) the significant figures are not significant. Ex: 0.07902 or 0.6932
- Zeros after (to the right) the significant figures AND after the decimal place are significant. Ex: 20.3200 or 63000
- Numbers that can be counted and conversion factors have an infinite number of significant figures. 370 crayons or 1km = 1000m (both have an infinite number of sig. figs.)

Sample Exercise

- How many significant figures are in each measurement?

a. 123 m	3
b. 40506 mm	5
c. 9.8000×10^7 m	5
d. 22 meter sticks	Infinity
e. 0.07080 m	4
f. 98000 m	2

Practice Exercise

- How many significant figures are in each measurement?

a. 0.05730 m **4**

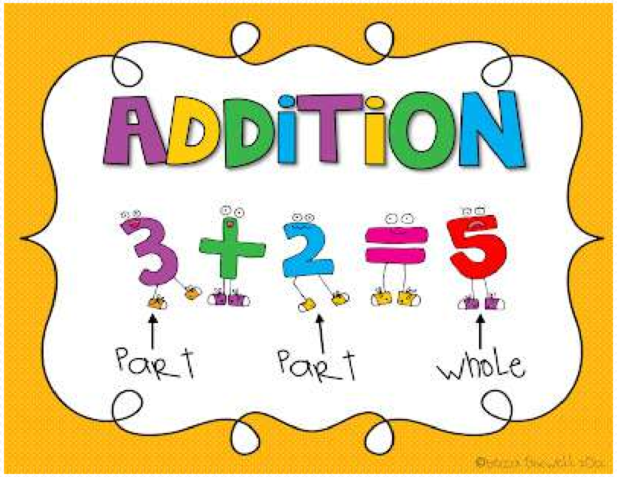
b. 8765 m **4**

c. 0.00073 m **2**

d. 8.750×10^{-2} g **4**

Significant Figures in Calculations

- In general, a calculated answer cannot be more precise than the least precise measurement from which it was calculated.
- Addition and Subtraction
- When adding or subtracting, your answer can only have the same amount of decimal places as the number with the least amount of decimal places.



Sample Exercise

- Calculate the sum of the three measurements. Give the answer to the correct number of significant figures.

12.52 m **2**

349.0 m **1**

+ 8.24 m **2**

369.76 m

Rounding to 1 decimal place

369.8m

Practice Exercise

- Perform each operation. Express your answers to the correct number of significant figures.

a. 61.2 m + 9.35 m + 8.6 m =

79.15 m, round to 1 decimal place = 79.2 m

b. 34.61 m – 17.3 m =

17.31 m, round to 1 decimal place = 17.3 m

Multiply and Divide

- When multiplying or dividing, your answer can only have the same amount of significant figures as the number with the lowest amount of significant figures.

Sample Exercise

- Perform the following operations. Give the answers to the correct number of significant figures.

7.55 m x 0.34 m = **2.567 m^2**

3 **2**

Rounding to 2 sig. figs. = 2.6 m^2

Practice Exercise

- Solve each problem and report your answer with the correct amount of significant figures.

- 2.10 m x 0.70 m =

1.47 m^2, rounded to 2 sig. figs. = 1.5 m^2

- 8432 m / 12.5 =

674.56 m, rounded to 3 sig. figs. = 675m

Section 3.1 Assessment

1. How are accuracy and precision evaluated?
2. A technician experimentally determined the boiling point of octane to be 124.1°C. The actual boiling point of octane is 125.7°C. Calculate the error and the percent error.
3. Determine the number of significant figures in each of the following:
   a. 11 soccer players
   b. 0.070020 m
   c. 10800 m
   d. 5.00 m^3

Section 3.1 Assessment

4. Solve each of the following and express your answer with the correct number of significant figures.

a. 0.00072 x 1800 =

1.296, rounded to 2 sig. figs. = 1.3

b. 0.912 – 0.047 =

0.865, rounded to 3 decimal places = 0.865

c. 54000 x 3500000000 =

189000000000000, rounded to 2 sig. figs. = 190000000000000 or 1.9×10^{14}

Section 3.2 – The International System of Units

- The International system of Units (SI) is a revised version of the metric system that scientists use around the world.

Quantity	SI Base Unit	Symbol
length	meter	m
mass	kilogram	kg
temperature	kelvin	K
time	second	s
amount of substance	mole	mol
luminous intensity	candela	cd
electric current	ampere	A

Prefixes

- Prefixes are used to show a very large or small quantity.
- For your prefixes sheet it is important to remember the following:

$$1 \text{ prefix unit} = 10^{x} \text{ base unit}$$

Example of Base Units	Example of Prefix Units
m	cm
L	mL
g	kg

Writing Conversion Factors

- Remember: 1 prefix unit = 10^x base unit
- Write the conversion factors for the following:

a. cm → m

1 cm = 10^{-2} m

b. g → kg

1 kg = 10^{3} g

c. s → ns

1 ns = 10^{-9} s

d. dL → L

1 dL = 10^{-1} L

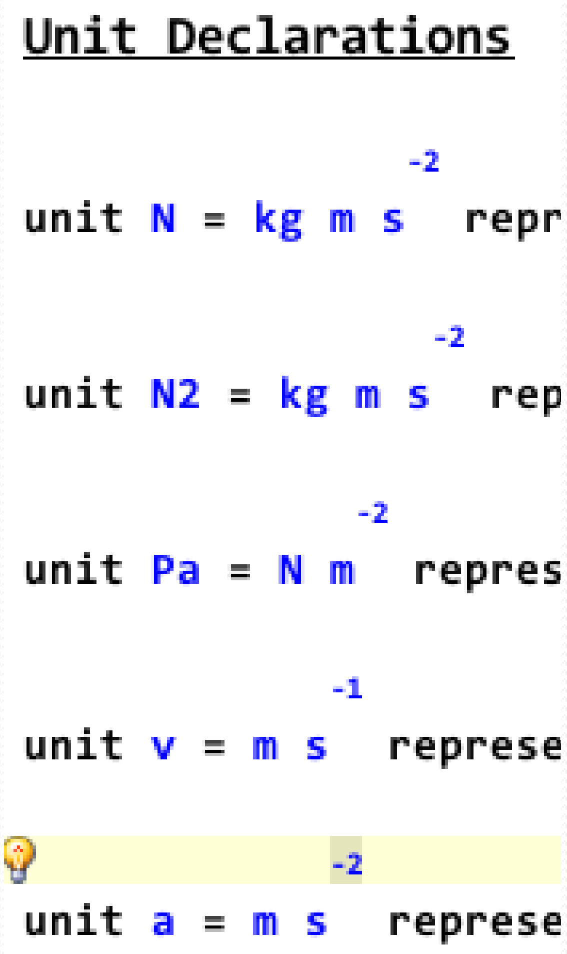
Derived Units

- Some units are a combination of SI base units. These are called derived units.

- Volume = length x width x height

  (m) (m) (m) = m^3

- Density = $\frac{\text{mass}}{\text{volume}}$ $\frac{(\text{kg})}{(m^3)}$ = kg/m^3

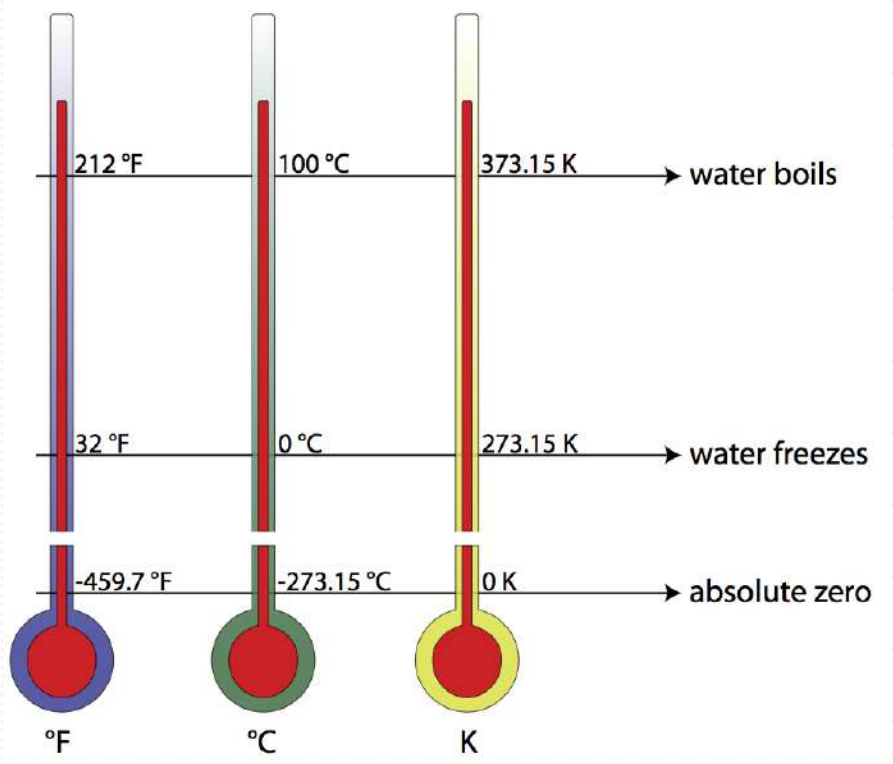


Mass vs. Weight

- Mass is the amount of matter that an object contains. The SI unit is kilograms.
- Weight is the force that measures the pull of gravity on a given mass. The SI unit is Newtons.
- Since weight is based on gravity, it changes with location.
- Mass stays constant regardless of location.

Temperature

- Temperature is a measure of how hot or cold an object is. (It is the measure of the average kinetic energy of an object's particles)
- There are 3 temperature scales that are used: Celsius, Fahrenheit, and Kelvin.



Absolute Zero

- Absolute zero is zero on the Kelvin scale.
- Kelvin temperature is directly proportional to the kinetic energy (speed) of the particles.
- If the particles are not moving, then the Kelvin temperature is zero.
- Since the particles cannot go slower than stopped, then the Kelvin scale does not have any negative values.



Converting Temperatures

- The following formulas are used to convert between temperatures:

- $K = {}^\circ C + 273$

$^\circ C = 5/9({}^\circ F - 32)$

- $^\circ C = K - 273$

$^\circ F = 9/5({}^\circ C) + 32$

Sample Exercise

- Normal human body temperature is 37°C. What is that temperature in kelvin?

310 K

Practice Exercise

- Make the following temperature conversions.

a. 77.2K → ^oC

-195.8^{o}C

b. 120^{o}C → ^oF

248^{o}F

c. 56^{o}F → K

286.3K

Energy

- Energy is the ability to do work or supply heat.
- The SI unit of energy is the Joule (J).
- In America, we use calories instead of Joules.

1 cal = 4.184J

Section 3.2 Assessment

1. What are the SI units for the 5 common base units used in Chemistry?

2. What is the symbol and meaning for each prefix?

    a. milli-

    b. nano-

    c. deci-

    d. centi-

3. List the following units in order from largest to smallest: mL, cL, μL, L, dL.

4. What is the volume of a paperback book 21 cm tall, 12 cm wide, and 3.5 cm thick?

882 cm^3

Section 3.2 Assessment

5. State the difference between weight and mass.
6. Convert 170°C to kelvin.
7. State the relationship between joules and calories.

Section 3.3 – Conversion Problems

- A conversion factor is a ratio of two equivalent measurements.
- Whenever two measurements are equivalent, then the ratio equals 1.

12 in = 1 ft   or   1 ft = 12 in

- Ratio form:

$$\frac{12\text{ in}}{1\text{ ft}} \quad \text{or} \quad \frac{1\text{ ft}}{12\text{ in}}$$

Dimensional Analysis

- Dimensional analysis is a way to analyze and solve problems using the units of the measurements.
- Some conversion factors that you should be familiar with involve time:

1 min = 60 s

60 min = 1 hr

24 hr = 1 day

365 days = 1 yr

3600s = 1 hr

Sample Problem

- How many seconds are in a workday that lasts exactly eight hours?

28800 s

Practice Problems

- How many minutes are there in exactly 1 week?

10080 min

- How many seconds are in exactly 40 hours?

144000 s

- How many years is 895600000 s?

28.4 years

Sample Problem

- Convert 750 dg to grams.

75g

Practice Problems

- Convert 0.044 km to meters.

  44 m

- Convert 6.7 s to milliseconds.

  6700ms

- Convert 4.6 mg to grams.

  0.0046g

Sample Problem

- What is 0.073 cm in micrometers?

730 μm

Practice Problems

- Convert 0.227 nm to centimeters.

2.27×10^{-8} cm

- Convert 1.3×10^4 km to decimeters.

1.3×10^8 dm

- Convert 1325 dag to megagrams.

0.01325 Mg

Sample Problem (Honors)

- Convert 60 g/mL to kg/dL.

6 kg/dL

Practice Problems (Honors)

- Convert 90 km/hr to m/s.

25 m/s

- Convert 78 hg/μL to g/L.

7.8×10^9 g/L

Sample Problem (Honors)

- Convert 20 km^2 to cm^2.

2×10^{11} cm^2

Practice Problems (Honors)

- Convert 140 dm^3 to hm^3.

1.4×10^{-7} hm^3

- Convert 50 m/s^2 to km/hr^2.

648000 km/hr^2

Other Conversion Factors

- Here is a list of other conversion factors that you need to memorize:

1 in. = 2.54 cm

1 kg = 2.2 lbs.

1 cm^3 = 1 mL

1 cal = 4.184 J

Sample Problem

- Convert 120 lbs. into kg.

54.5 kg

Practice Problems

- Convert 250 cal into joules.

1046 J

- Convert 50 cm^3 into liters.

0.05 L

- Convert 25 m into feet.

82.02 ft

Section 3.3 Assessment

1. What conversion factor would you use to convert between these pairs of units?

    a. minutes to hours

    b. grams to milligrams

    c. cubic decimeters to milliliters

2. Make the following conversions:

    a. 14.8 g to micrograms **1.48×10^7 μg**

    b. 3.72×10^{-3} kg to grams **3.72 g**

    c. 66.3 L to cubic centimeters **66300 cm^3**

Section 3.3 Assessment

3. An atom of gold has a mass of 3.271×10^{-23} g. How many atoms of gold are in 5.00 g of gold? **1.53×10^{23} atoms**

4. Convert the following:

a. 7.5×10^{4} J to kilojoules **75 kJ**

b. 3.9×10^{5} mg to decigrams **3900 dg**

c. 2.21×10^{-4} dL to microliters **22.1 μL**

Section 3.3 Assessment

5. (Honors) Light travels at a speed of 3.00×10^{10} cm/s. What is the speed of light in kilometers per hour?

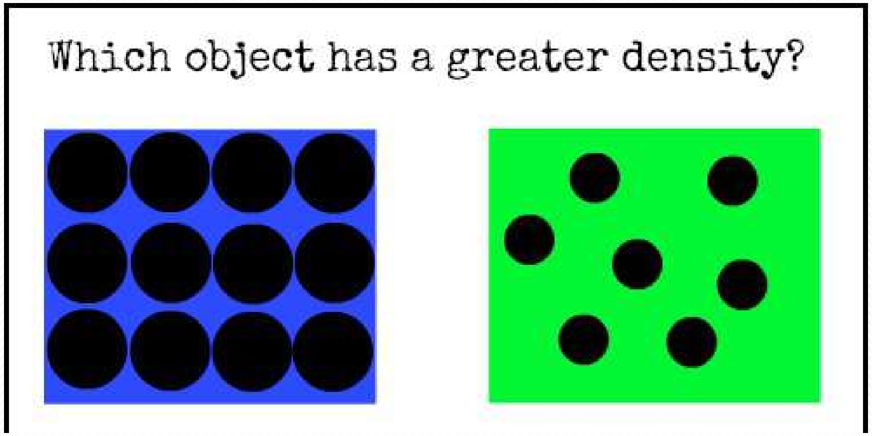
1.08×10^{9} km/hr

Section 3.4 - Density

- Density is the ratio of the mass of an object to its volume.

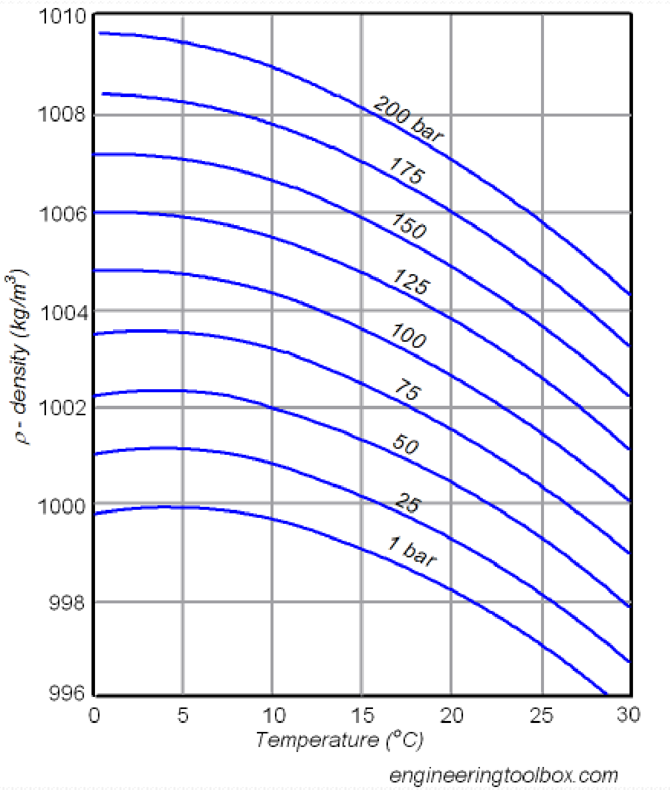
$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

- Density is an intensive property that depends only on the composition of a substance, not on the size of the sample.



Density and Temperature

- The density of a substance generally decreases as its temperature increases.
- Water is an exception to this rule.



Sample Problem

- A copper penny has a mass of 3.1 g and a volume of 0.35 cm^3. What is the density of copper?

8.9 g/cm^3

Practice Problems

- A bar of silver has a mass of 68.0 g and a volume of 6.48 cm^3. What is the density of silver?

10.5 g/cm^3

- A substance has a density of 0.38 g/mL and a volume of 20 mL. What is the mass of the object?

7.6 g

- A metal block has a density of 0.66 g/cm^3 and has a mass of 2 kg. What is the volume of the block?

3030.3 cm^3

Section 3.4 Assessment

1. What determines the density of an object?
2. How does density vary with temperature?
3. A weather balloon is inflated to a volume of 2.2×10^3 L with 37.4 g of helium. What is the density of helium in grams per liter?

0.017 g/L

4. A 68 g bar of gold is cut into 3 equal pieces. How does the density of each piece compare to the density of the original gold bar?
5. A plastic ball with a volume of 19.7 cm^3 has a mass of 15.8 g. Would this ball sink or float in a container of gasoline? (Density of gasoline = 0.675 g/cm^3)

Density 0.802 g/cm^3 so it would sink.

Section 3.4 Assessment

6. What is the volume, in cubic centimeters, of a sample of cough syrup that has a mass of 50.0 g? The density of cough syrup is 0.950 g/cm^3.

52.6 cm^3

7. What is the mass, in kilograms, of 14.0 L of gasoline? (Assume that the density of gasoline is 0.680 g/cm^3.)

9.52 kg

THE END