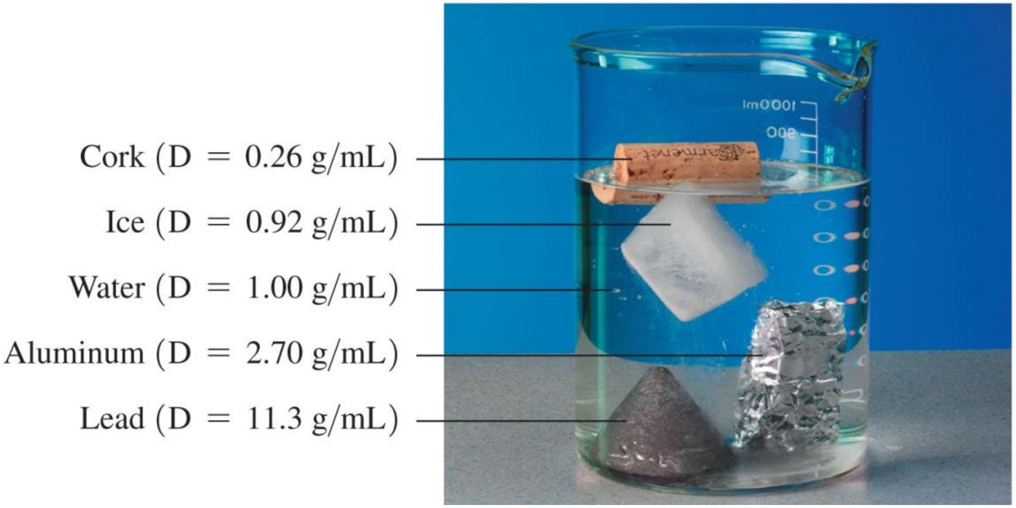
Density

Objects that sink in water are more dense than water; objects that float are less dense.



Learning Goal Calculate the density of a substance; use the density to calculate the mass or volume of a substance.

Density

Density

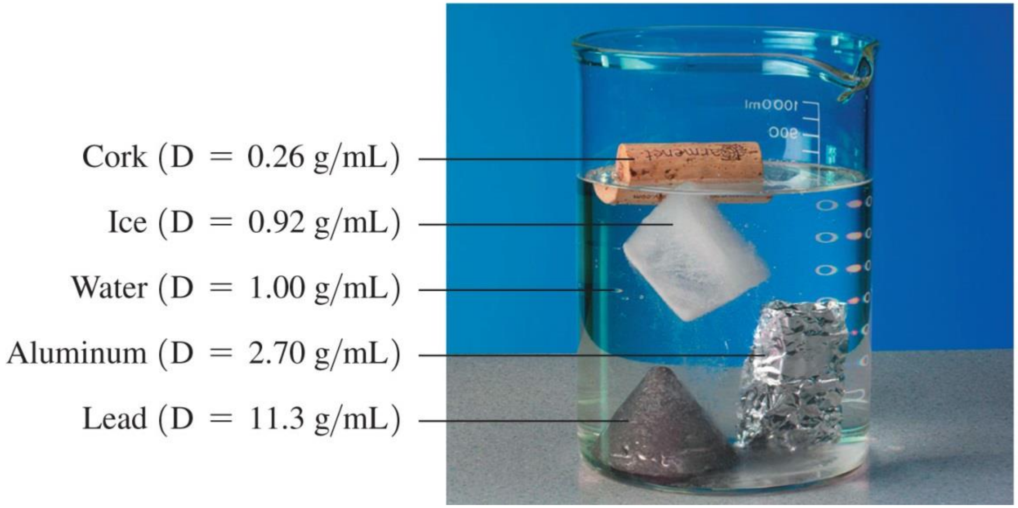
- compares the mass of an object to its volume.
- is the mass of a substance divided by its volume.
- is defined as

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

Density

Substances that have

- higher densities contain particles that are closely packed together.
- lower densities contain particles that are farther apart.
- Metals such as gold and lead have higher densities because their atoms are packed closely together.



Density: Units

In the metric system, densities of solids, liquids, and gases are expressed with different units.

- The density of a solid or liquid is usually given in grams per cubic centimeter (g/cm^3) or grams per milliliter (g/mL).
- The density of a gas is usually given in grams per liter (g/L).

Densities of Common Substances

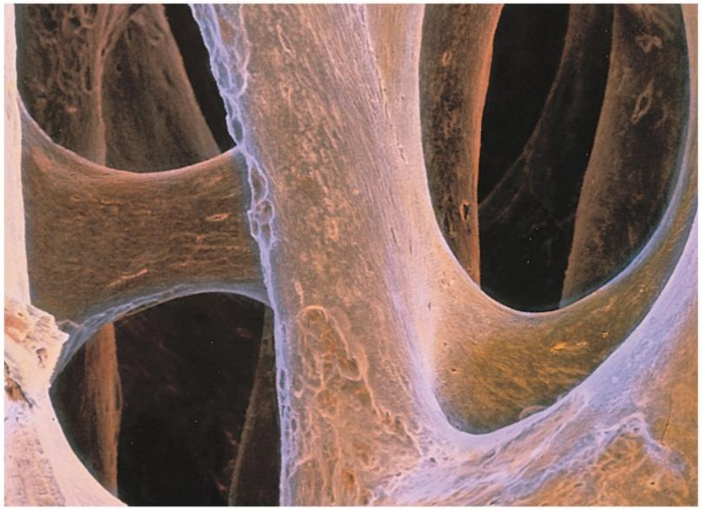
TABLE 2.8 Densities of Some Common Substances

Solids (at 25 °C)	Density (g/mL)	Liquids (at 25 °C)	Density (g/mL)	Gases (at 0 °C)	Density (g/L)
Cork	0.26	Gasoline	0.74	Hydrogen	0.090
Body fat	0.909	Ethanol	0.79	Helium	0.179
Ice (at 0 °C)	0.92	Olive oil	0.92	Methane	0.714
Muscle	1.06	Water (at 4 °C)	1.00	Neon	0.902
Sugar	1.59	Urine	1.003–1.030	Nitrogen	1.25
Bone	1.80	Plasma (blood)	1.03	Air (dry)	1.29
Salt (NaCl)	2.16	Milk	1.04	Oxygen	1.43
Aluminum	2.70	Blood	1.06	Carbon dioxide	1.96
Iron	7.86	Mercury	13.6		
Copper	8.92				
Silver	10.5				
Lead	11.3				
Gold	19.3				

Chemistry Link to Health

Bone Density

A condition of severe thinning of bone known as *osteoporosis* may occur. *Scanning electron micrographs* (SEMs) show **(a)** normal bone and **(b)** bone with osteoporosis due to loss of bone minerals.



(a) Normal bone

(b) Bone with osteoporosis

Chemistry Link to Health

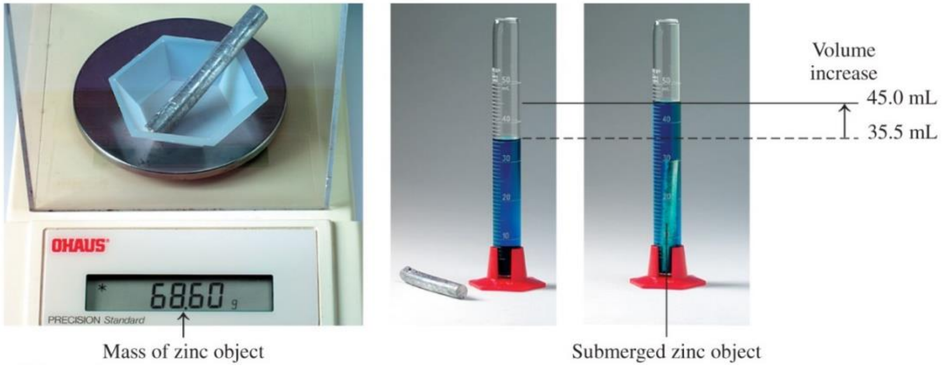
Bone Density

Bone density is often determined by passing low-dose X-rays through the narrow part at the top of the femur (hip) and the spine **(c)**. Bones with high density will block more of the X-rays compared to bones that are less dense.

(c) Viewing a low-dose X-ray of the spine

Density Using Volume Displacement

The density of the zinc object is calculated from its mass and volume.



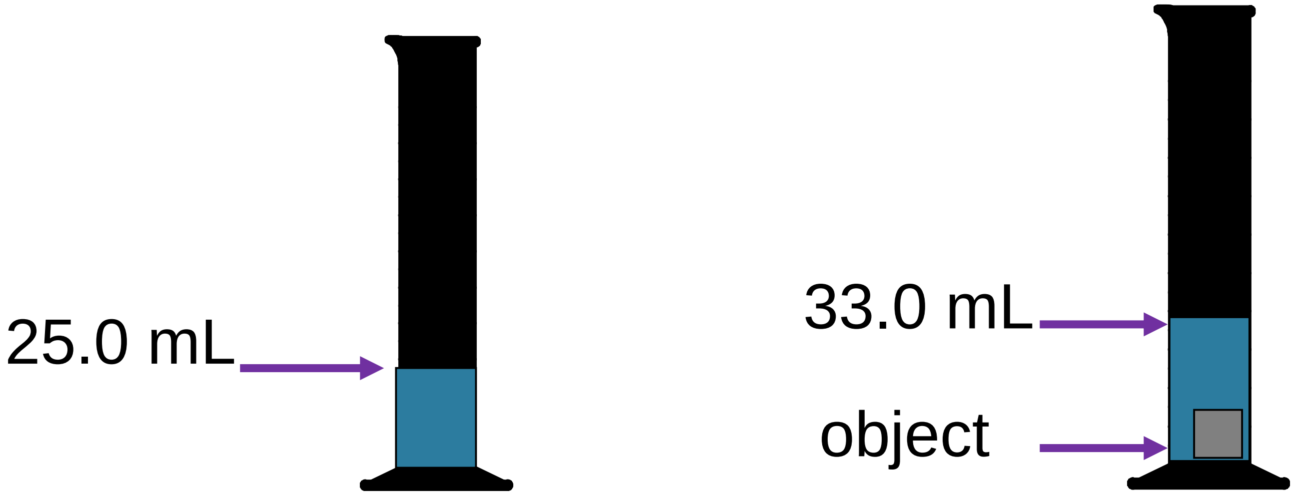
A solid completely submerged in water displaces its own volume of water (its volume is calculated from the volume increase).

$$\text{Density of zinc} = \frac{\text{mass of zinc}}{\text{volume of zinc}} = \frac{68.60\ \text{g}}{45.0\ \text{mL} - 35.5\ \text{mL}} = \frac{68.60\ \text{g}}{9.5\ \text{mL}} = 7.2\ \text{g/mL}$$

4 SFs (68.60 g); 2 SFs (9.5 mL); 2 SFs (7.2 g/mL)

Learning Check

What is the density (g/mL) of a 48.0-g sample of a metal if the level of water in a graduated cylinder rises from 25.0 mL to 33.0 mL after the metal is added?



Solution

What is the density (g/mL) of a 48.0-g sample of a metal if the level of water in a graduated cylinder rises from 25.0 mL to 33.0 mL after the metal is added?

$$\text{Volume by displacement} = 33.0\ \text{mL} - 25.0\ \text{mL} = 8.0\ \text{mL}$$

$$\text{Density} = \frac{\text{mass of sample}}{\text{volume of sample}} = \frac{\overset{\text{3 SFs}}{48.0\ \text{g}}}{\underset{\text{2 SFs}}{8.0\ \text{mL}}} = \underset{\text{2 SFs}}{6.0\ \text{g/mL}}$$

Problem Solving Using Density

CORE CHEMISTRY SKILL
Using Density as a Conversion Factor

If the volume and the density of a sample are known, the mass in grams of the sample can be calculated by using density as a conversion factor.

Problem Solving Using Density

Example: An unknown liquid has a density of 1.32 g/mL. What is the volume (mL) of a 14.7-g sample of the liquid?

Problem Solving Using Density

Example: An unknown liquid has a density of 1.32 g/mL. What is the volume (mL) of a 14.7-g sample of the liquid?

STEP 1 State the given and needed quantities.

ANALYZE THE PROBLEM	Given	Need	Connect
	14.7 g	milliliters	density (g/mL)

STEP 2 Write a plan to calculate the needed quantity.

grams → Density Factor → milliliters

Problem Solving Using Density

Example: An unknown liquid has a density of 1.32 g/mL. What is the volume (mL) of a 14.7-g sample of the liquid?

STEP 3 **Write the equalities and their conversion factors including density.**

$$1.32\text{ g} = 1\text{ mL} \qquad \frac{1.32\text{ g}}{1\text{ mL}} \text{ and } \frac{1\text{ mL}}{1.32\text{ g}}$$

STEP 4 **Set up the problem to calculate the needed quantity.**

Exact

$$14.7\ \cancel{\text{g}} \times \frac{1\text{ mL}}{1.32\ \cancel{\text{g}}} = 11.1\text{ mL of liquid}$$

3 SFs 3 SFs 3 SFs

Learning Check

John took 2.0 teaspoons **(**tsp**)** of cough syrup for a cough. If the syrup had a density of 1.20 g/mL and there is 5.0 mL in 1 tsp, what was the mass, in grams, of the cough syrup?

Solution

John took 2.0 teaspoons (tsp) of cough syrup for a cough. If the syrup had a density of 1.20 g/mL and there is 5.0 mL in 1 tsp, what was the mass, in grams, of the cough syrup?

STEP 1 State the given and needed quantities.

ANALYZE THE PROBLEM	Given	Need	Connect
	2.0 tsp of syrup	grams	conversion factors (mL/tsp, density of syrup)

STEP 2 Write a plan to calculate the needed quantity.

teaspoons → U.S.−Metric factor → milliliters → Density factor → grams

Solution

John took 2.0 teaspoons (tsp) of cough syrup for a cough. If the syrup had a density of 1.20 g/mL and there is 5.0 mL in 1 tsp, what was the mass, in grams, of the cough syrup?

STEP 3 Write the equalities and their conversion factors including density.

$$1\text{ tsp} = 5.0\text{ mL} \qquad 1\text{ mL of syrup} = 1.20\text{ g of syrup}$$

$$\frac{5.0\text{ mL}}{1\text{ tsp}} \text{ and } \frac{1\text{ tsp}}{5.0\text{ mL}} \qquad \frac{1.20\text{ g syrup}}{1\text{ mL syrup}} \text{ and } \frac{1\text{ mL syrup}}{1.20\text{ g syrup}}$$

STEP 4 Set up the problem to calculate the needed quantity.

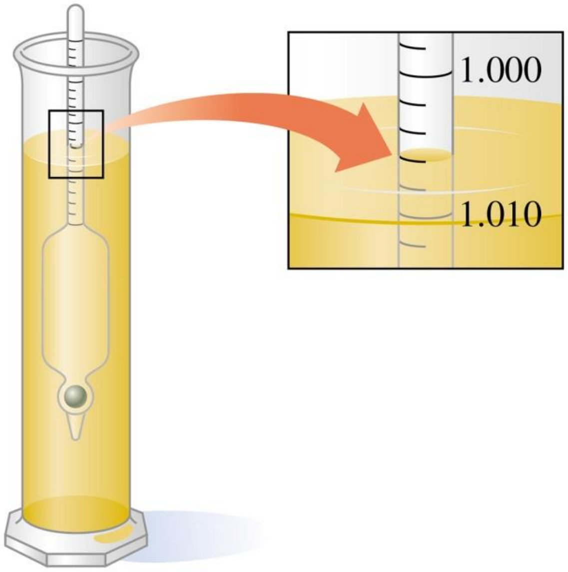
$$\underset{\text{2 SFs}}{2.0\text{ }\cancel{\text{tsp}}} \times \overset{\text{2 SFs}}{\underset{\text{Exact}}{\frac{5.0\text{ }\cancel{\text{mL}}}{1\text{ }\cancel{\text{tsp}}}}} \times \overset{\text{3 SFs}}{\underset{\text{Exact}}{\frac{1.20\text{ g}}{1\text{ }\cancel{\text{mL}}}}} = \underset{\text{2 SFs}}{12\text{ g of syrup}}$$

Specific Gravity

- **Specific gravity (sp gr)** is a relationship between the density of a substance and the density of water.
- Specific gravity is calculated by dividing the density of a sample by the density of water, which is 1.00 g/mL at 4 °C.
- A substance with a specific gravity of 1.00 has the same density as water (1.00 g/mL).

$$\text{Specific gravity} = \frac{\text{density of sample}}{\text{density of water}}$$

Specific Gravity



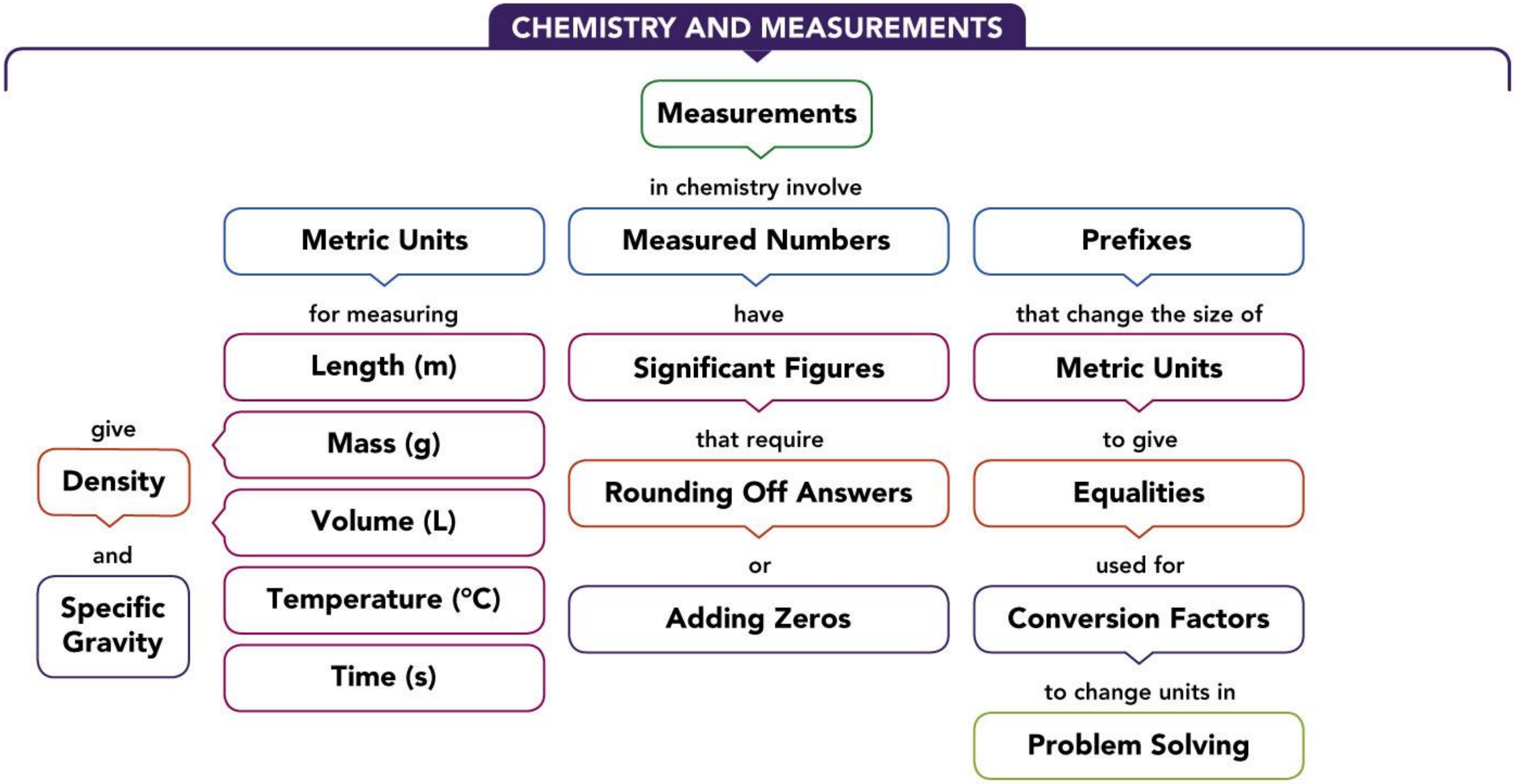
A hydrometer is used to measure the specific gravity of urine. The normal range of specific gravity for urine is 1.003 to 1.030.

The specific gravity can decrease with *type 2 diabetes* and kidney disease. Increased specific gravity may occur with dehydration, kidney infection, and liver disease.

Specific Gravity

In a clinic or hospital, a dipstick containing chemical pads is used to evaluate specific gravity.

Concept Map



CHEMISTRY AND MEASUREMENTS
Measurements
in chemistry involve
Metric Units
for measuring
Length (m)
Mass (g)
Volume (L)
Temperature (°C)
Time (s)
give
Density
and
Specific Gravity
Measured Numbers
have
Significant Figures
that require
Rounding Off Answers
or
Adding Zeros
Prefixes
that change the size of
Metric Units
to give
Equalities
used for
Conversion Factors
to change units in
Problem Solving