Chemistry, The Central Science, 11th edition
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Chapter 1
Introduction: Matter and Measurement

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What is Chemistry?

Chemistry is the study of the **properties** and behavior of **matter**.

Why Study Chemistry?

Realms

Macroscopic
Ordinary sized objects

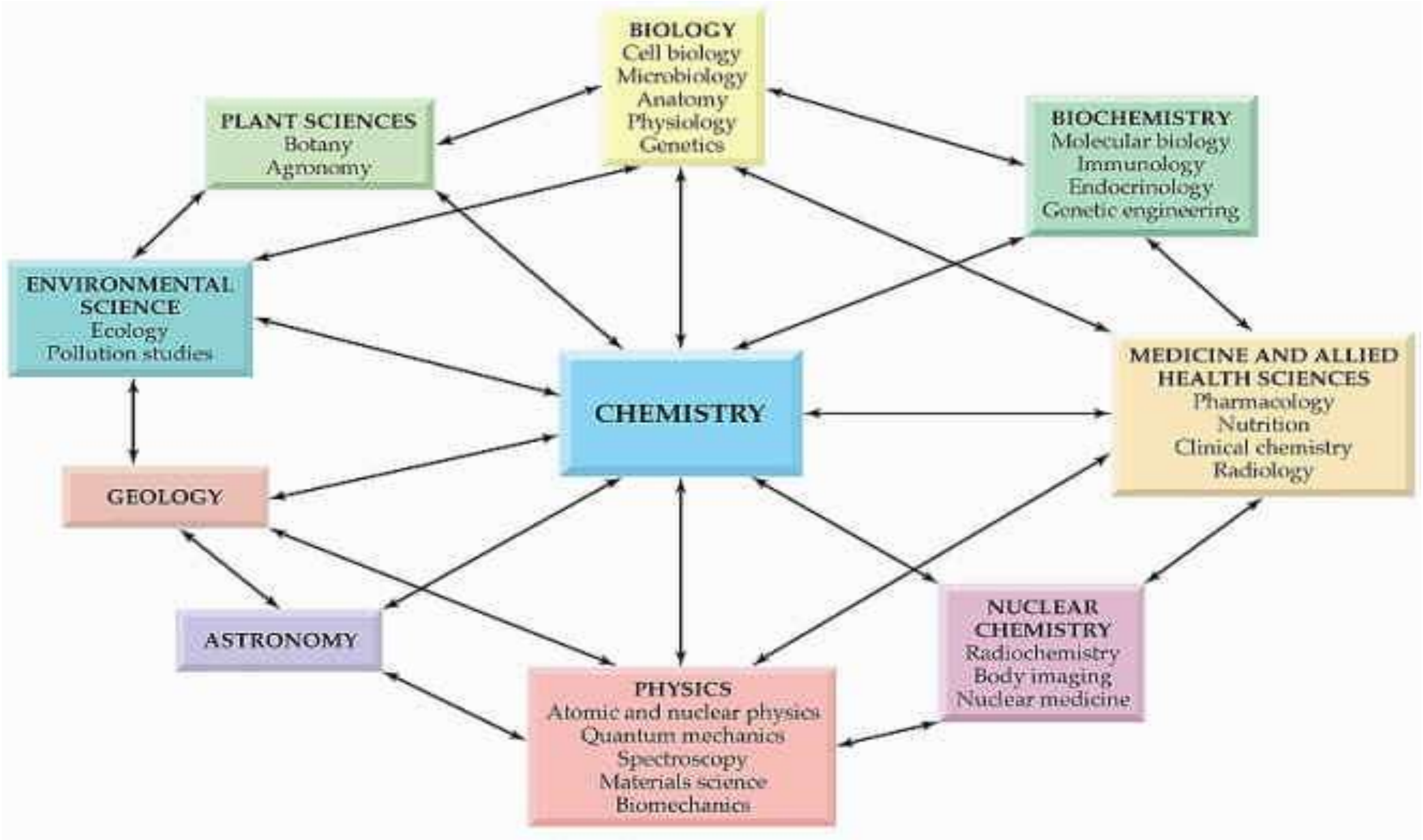
Sub-microscopic
Atoms and molecules

Chemistry is the science that seeks to understand the properties and behavior of matter by studying the properties of atoms and molecules.

Chemistry provides important understanding of our world and how it works.

Chemistry = the central science

Chemistry is often called **the central science** because of its role in connecting the other sciences, with the life and applied sciences.

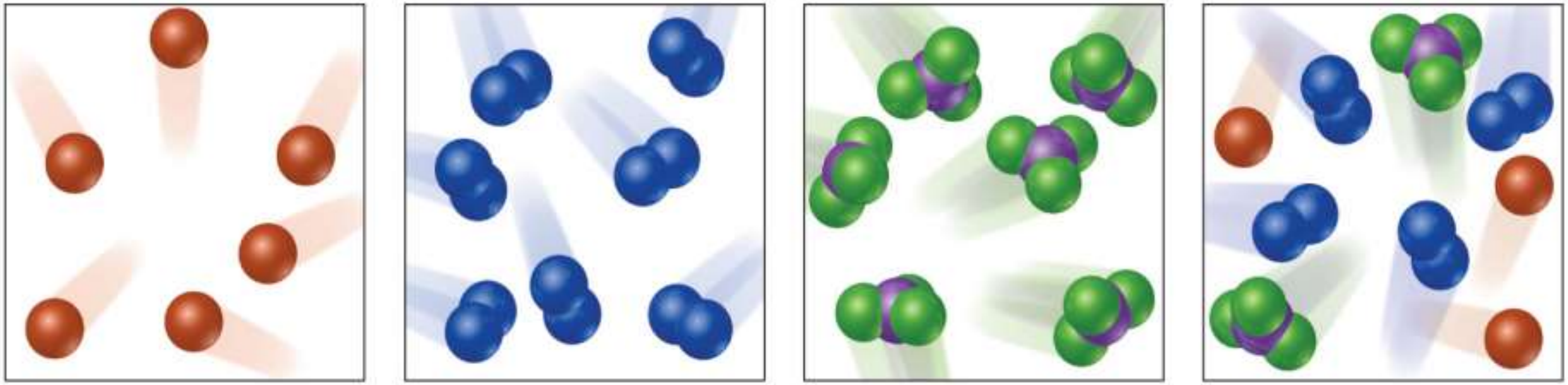


Matter

Is the physical material of the universe

We define matter as anything that has mass and takes up space.

Classification of matter according to its composition



(a) Atoms of an element

(b) Molecules of an element

(c) Molecules of a compound

(d) Mixture of elements and a compound

(b) Water

(c) Carbon dioxide

(d) Ethanol

(e) Ethylene glycol

(f) Aspirin

Atoms are the building blocks of matter.

Each **element** is made of the same kind of atom.

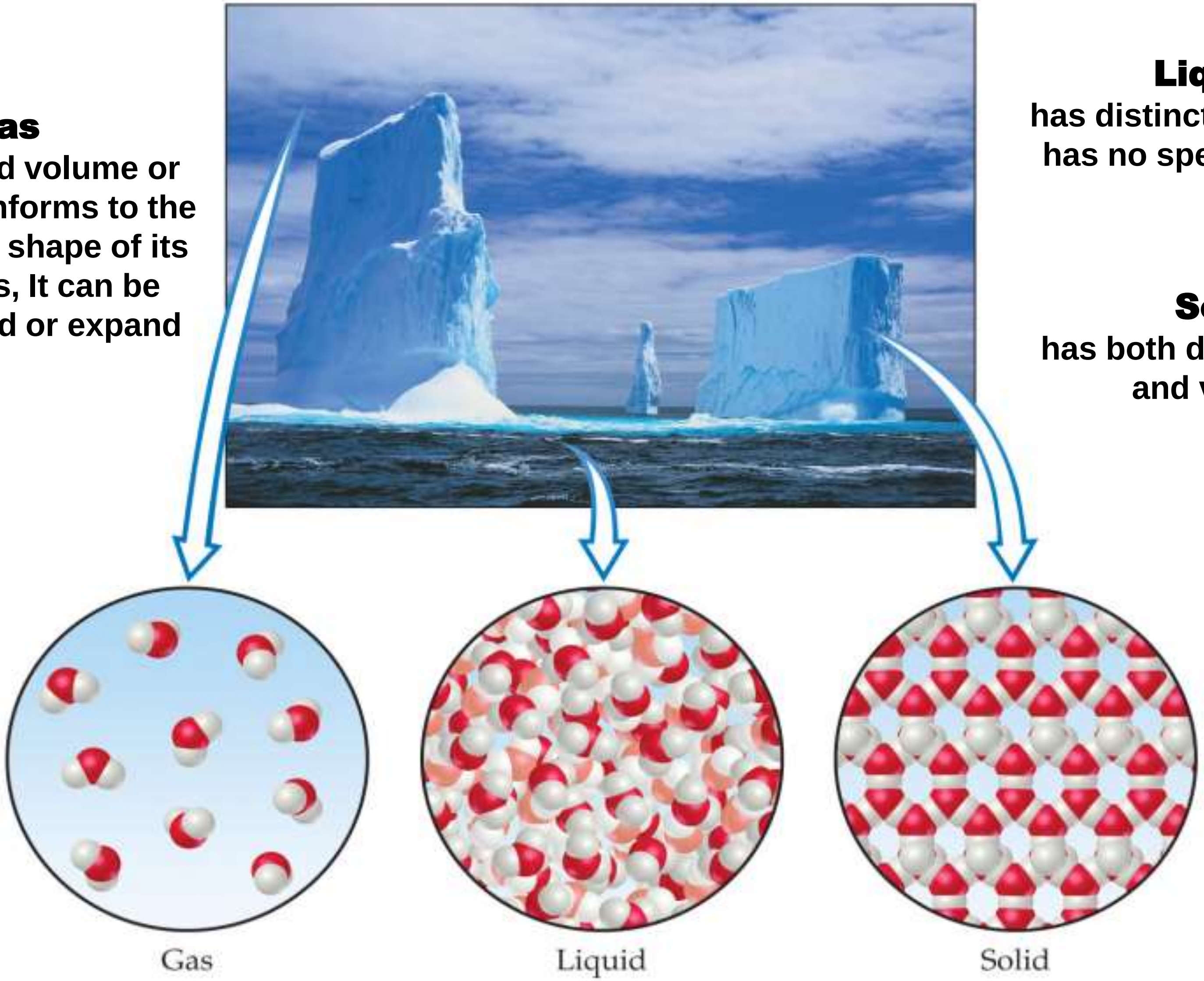
A **compound** is made of two or more different kinds of elements.

Classification of matter according to its physical state

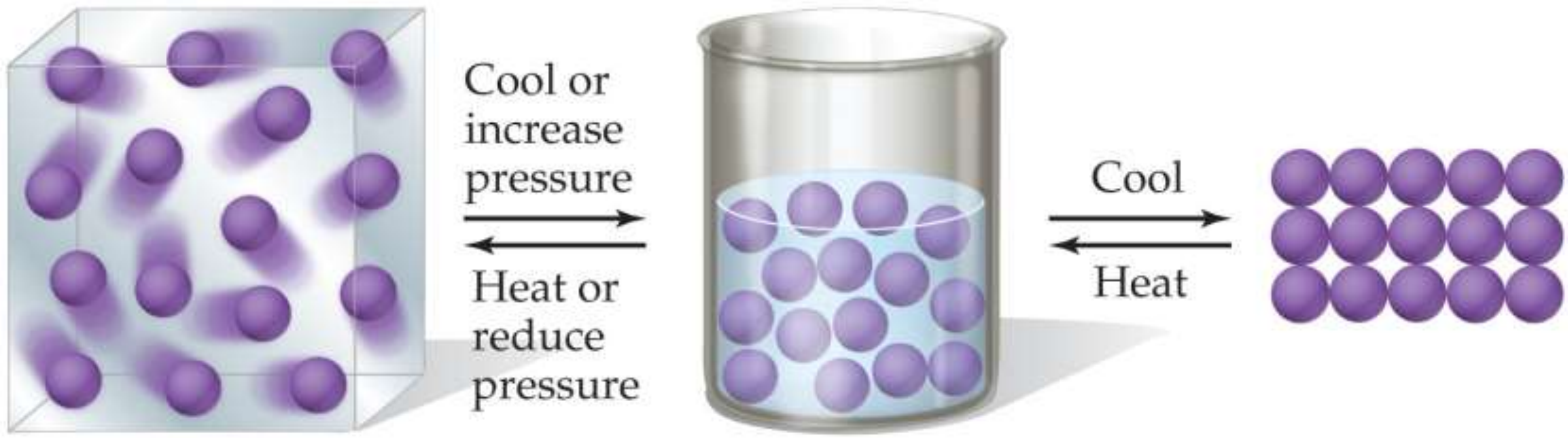
Gas
has no fixed volume or shape, it conforms to the volume and shape of its containers, It can be compressed or expand

Liquid
has distinct volume but has no specific shape

Solid
has both definite shape and volume



States of Matter



Gas

Total disorder; much empty space; particles have complete freedom of motion; particles far apart

Liquid

Disorder; particles or clusters of particles are free to move relative to each other; particles close together

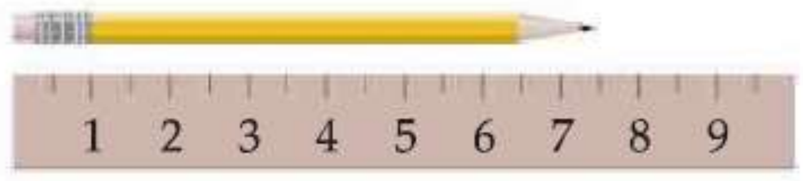
Crystalline solid

Ordered arrangement; particles are essentially in fixed positions; particles close together

1.4
Units of Measurement

Units of Measurement

7.5 meaningless
7.5 cm specifies length



The units used for scientific measurements are those of the **metric units**.

The metric system is an internationally agreed decimal system of measurement that was originally based on the mètre des Archives and the kilogramme des Archives introduced by France in 1799.

SI Units

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s[a]
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A
Luminous intensity	Candela	cd

[a]The abbreviation sec is frequently used.

- Système International d'Unités.
- A different base unit is used for each quantity.
- Seven base units from which all other units are derived.

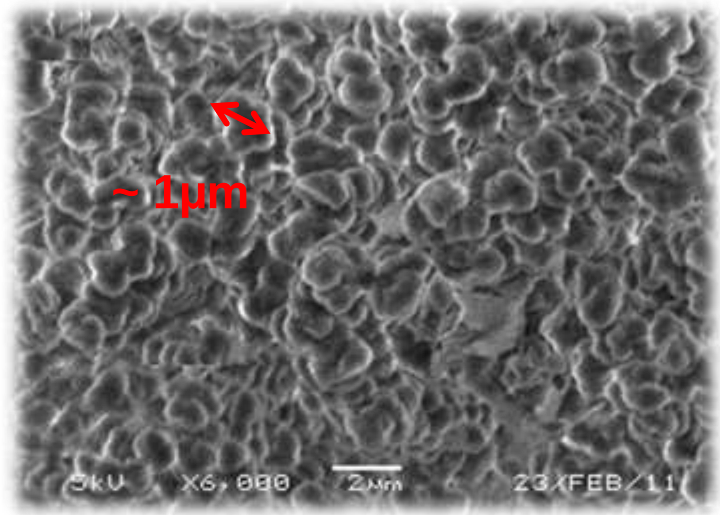
150 000 000 000 m

1.5×10^{11} m

1 µm

0.000001 m

1.0×10^{-6} m



Prefixes are used to indicate decimal **fractions** or **multiples** of various units. Prefixes convert the base units into units that are appropriate for the item being measured.

Prefix	Abbreviation	Meaning	Example
Giga	G	10^9	1 gigameter (Gm) = 1×10^9 m
Mega	M	10^6	1 megameter (Mm) = 1×10^6 m
Kilo	k	10^3	1 kilometer (km) = 1×10^3 m
Deci	d	10^{-1}	1 decimeter (dm) = 0.1 m
Centi	c	10^{-2}	1 centimeter (cm) = 0.01 m
Milli	m	10^{-3}	1 millimeter (mm) = 0.001 m
Micro	μ[a]	10^{-6}	1 micrometer (μm) = 1×10^{-6} m
Nano	n	10^{-9}	1 nanometer (nm) = 1×10^{-9} m
Pico	p	10^{-12}	1 picometer (pm) = 1×10^{-12} m
Femto	f	10^{-15}	1 femtometer (fm) = 1×10^{-15} m

[a]This is the Greek letter mu (pronounced "mew").

Exercise: Which of the following quantities is the smallest?
1 mg, 1 µg, or 1 pg

Length, Mass and Temperature

Length: is the distance between two objects (SI unit m).

Mass: is a measure of the amount of material in an object (SI unit kg).

Sample Exercise 1.2 Using Metric Prefixes

What is the name given to the unit that equals **(a)** 10^{-9} gram, **(b)** 10^{-6} second, **(c)** 10^{-3} meter?

Solution

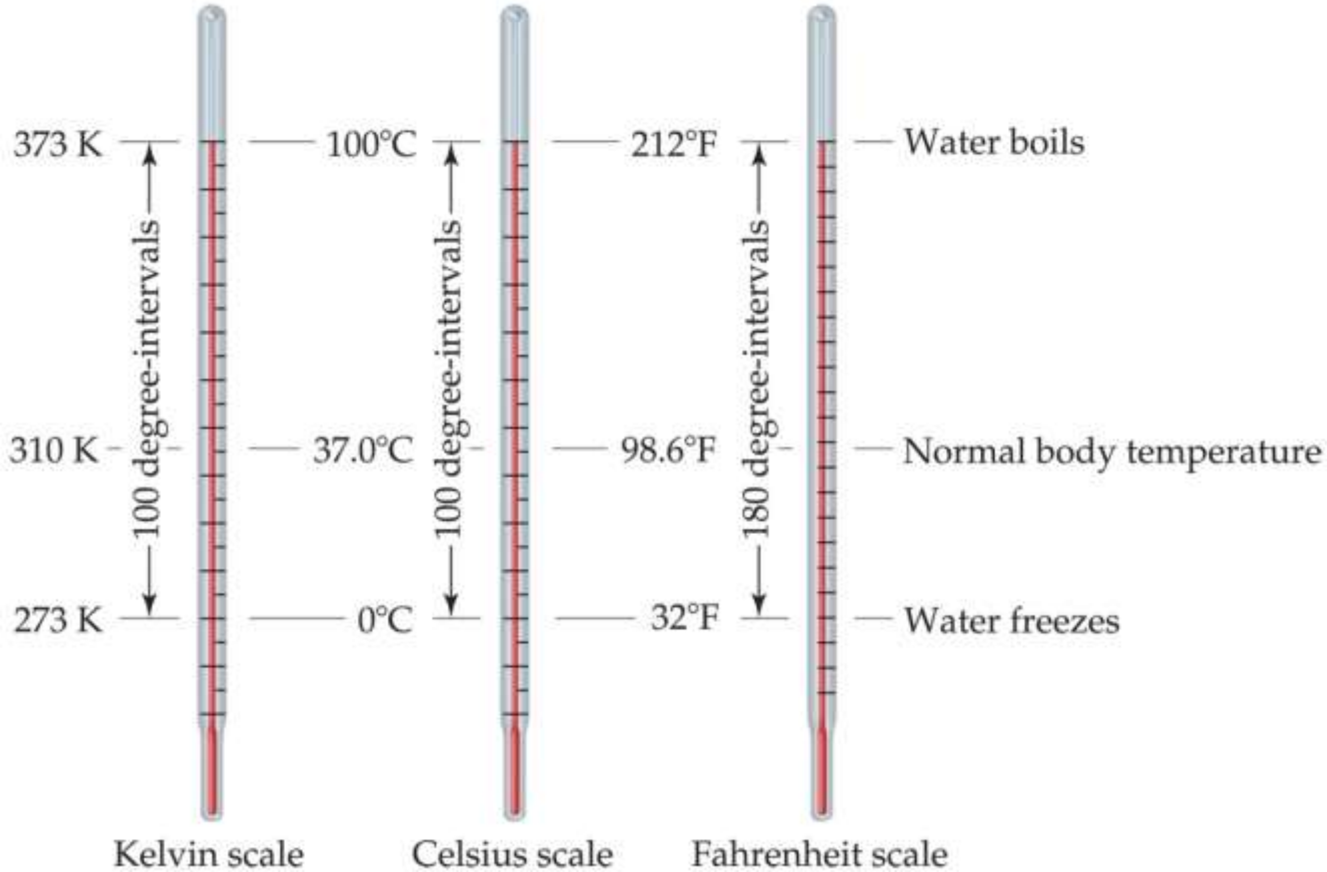
(a) nanogram, ng, **(b)** microsecond, μs, **(c)** millimeter, mm.

Practice Exercise

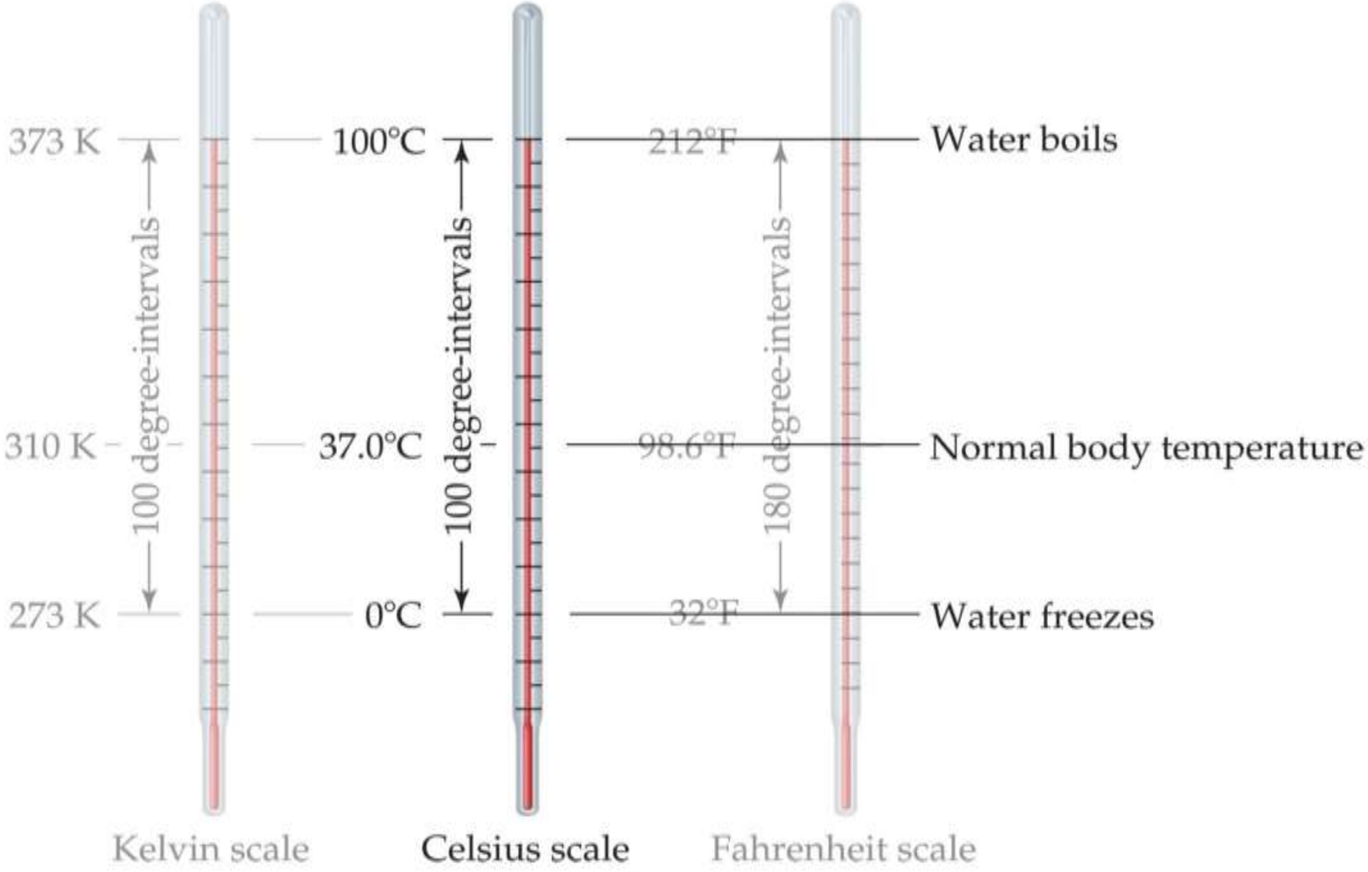
(a) What decimal fraction of a second is a picosecond, ps? **(b)** Express the measurement 6.0×10^3m using a prefix to replace the power of ten. **(c)** Use exponential notation to express 3.76 mg in grams.
Answer: **(a)** 10^{-12} second, **(b)** 6.0 km, (c) 3.76×10^{-3} g

Temperature

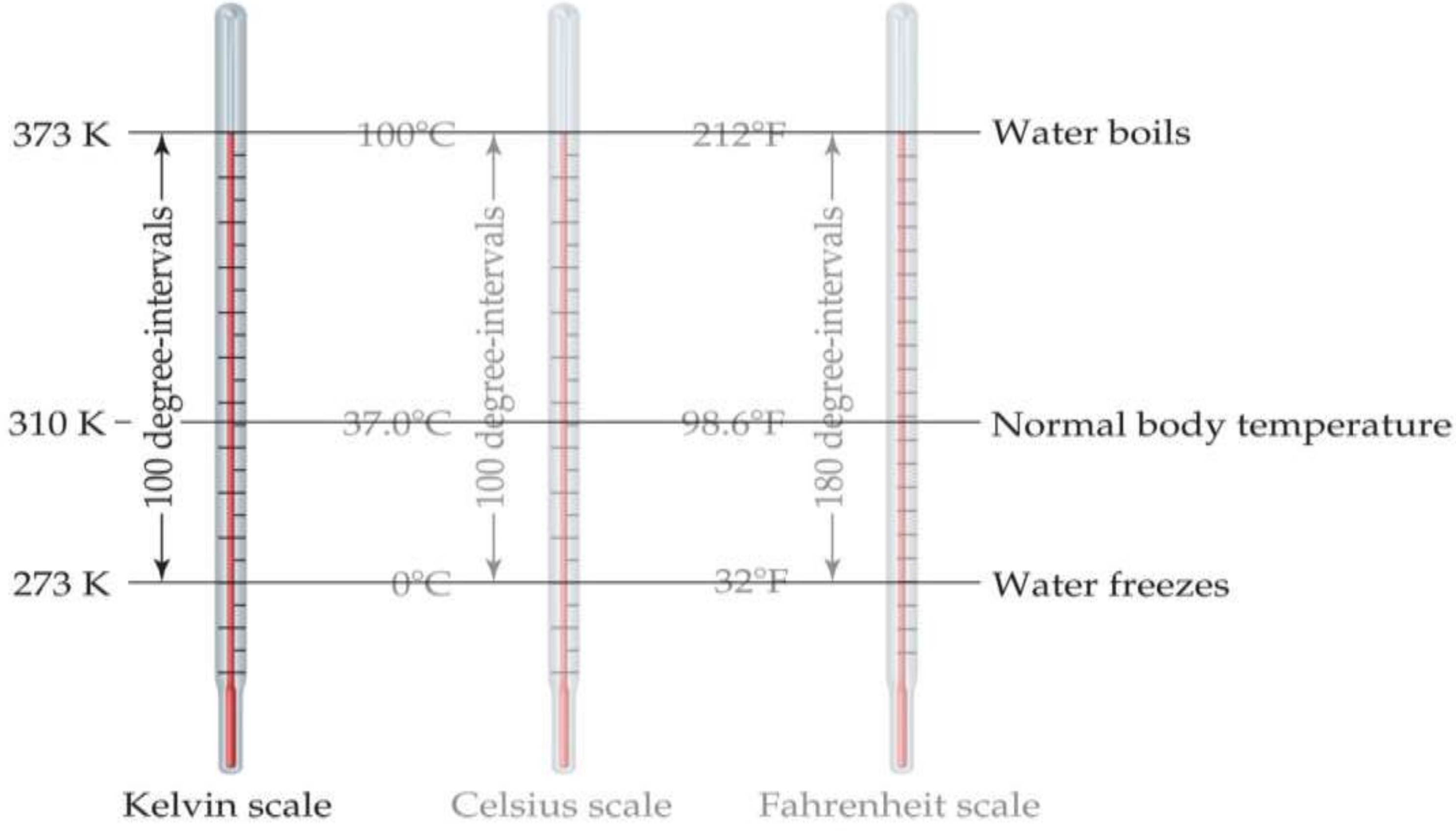
Temperature: is a measure of the hotness or coldness of an object (SI unit K).



- In scientific measurements, the **Celsius** and **Kelvin** scales are most often used.
- The Celsius scale is based on the properties of water.
  - 0°C is the freezing point of water.
  - 100°C is the boiling point of water.

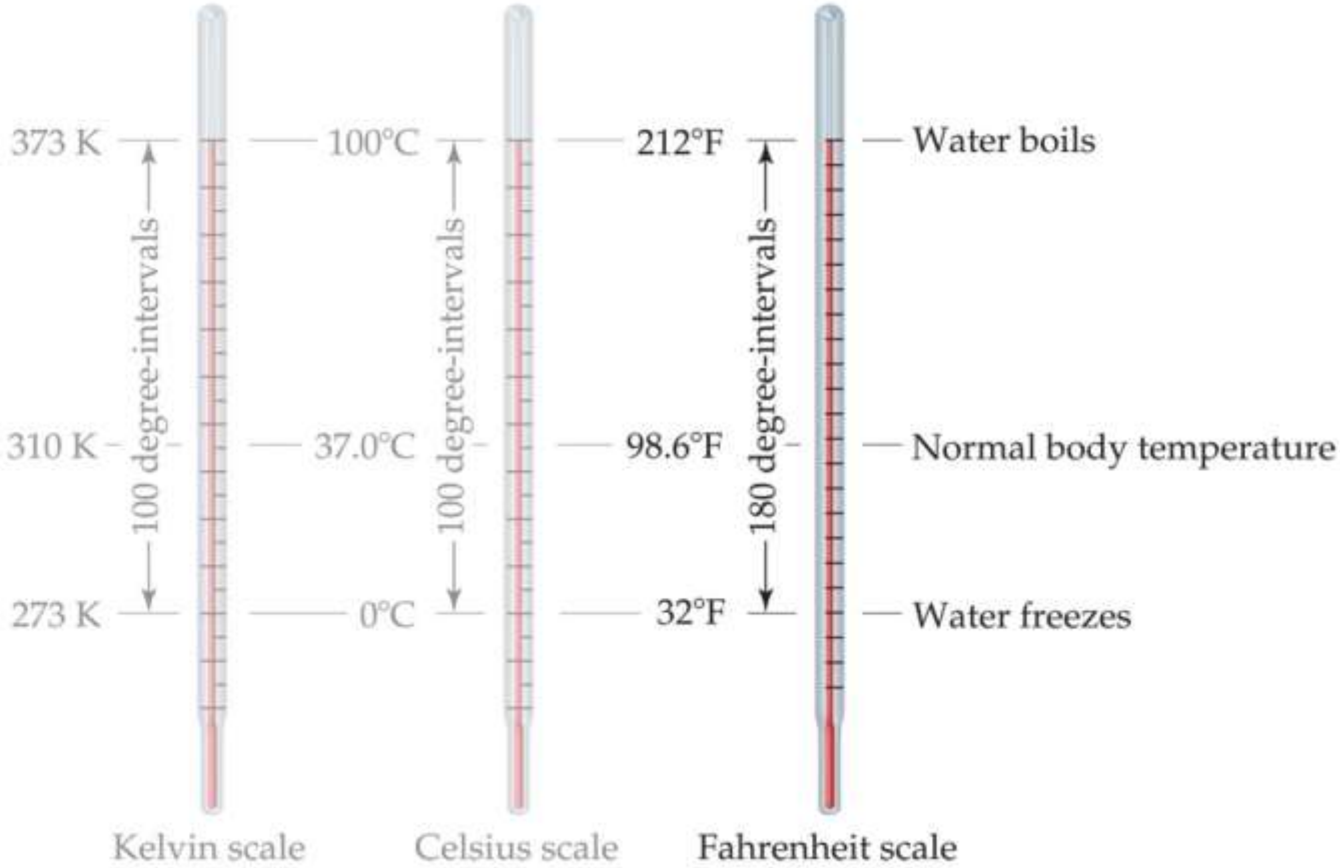


- The Kelvin is the SI unit of temperature.
- It is based on the properties of gases.
- There are no negative Kelvin temperatures.
- **K = °C + 273.15**
- At -273.15 °C (0 K) called absolute zero



- The Fahrenheit scale is not used in scientific measurements.
- On the Fahrenheit scale, water freezes at 32 ^oF and boils at 212 ^oF.

$$°C = \frac{5}{9}(°F - 32)$$



Sample Exercise 1.3 Converting Units of Temperature

If a weather forecaster predicts that the temperature for the day will reach 31 °C, what is the predicted temperature **(a)** in K, **(b)** in °F?

Solution

$$\text{(a)}\quad K = 31 + 273 = 304\ K$$

$$\text{(b)}\quad {}^{\circ}F = \frac{9}{5}(31) + 32 = 56 + 32 = 88\ {}^{\circ}F$$

Practice Exercise

Ethylene glycol, the major ingredient in antifreeze, freezes at –11.5 °C. What is the freezing point in **(a)** K, **(b)** °F?

Answer: **(a)** 261.7 K, **(b)** 11.3 °F

Derived SI Units

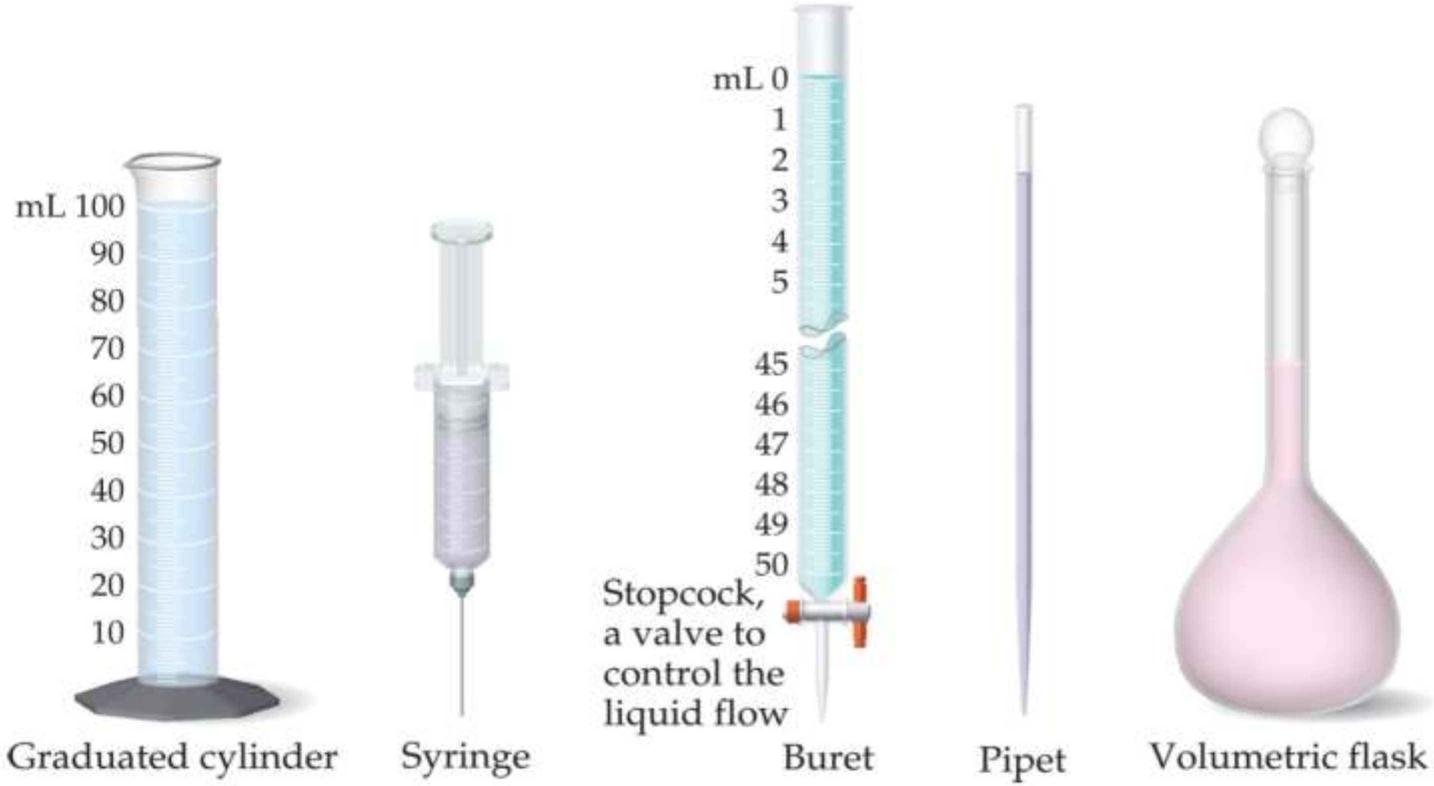
The SI are used to derive the units of other quantities.

For example:

Speed is defined as the ratio of distance traveled to elapsed time. Thus, the SI unit for speed is meters per second (m/s).

Volume

The devices used most frequently in chemistry to measure volume are Syringes, burets, pipets, graduated cylinders and volumetric flasks. Different measuring devices have different uses and different degrees of accuracy



The SI unit of volume is m^3

The most commonly used metric units for volume are the liter (L) and the milliliter (mL) (not SI unites).

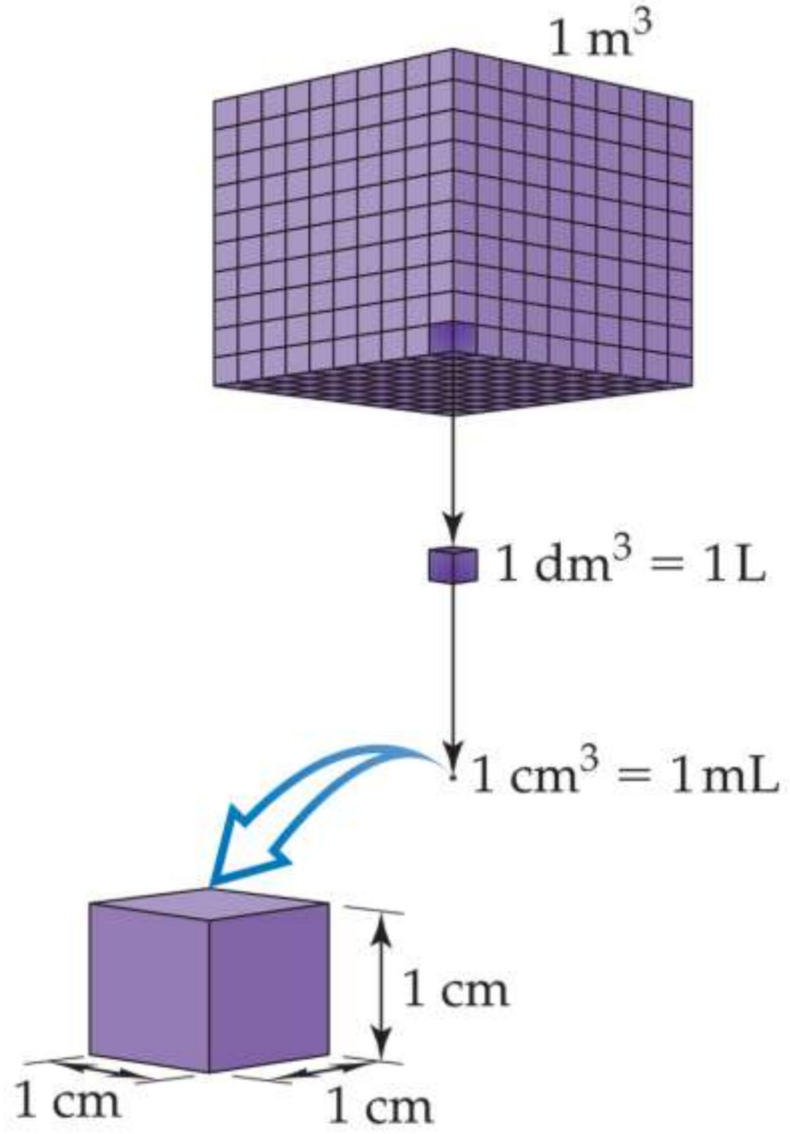
The volume occupied by a cube that is 1 m on each edge is a cubic meter, 1 m^3

$1\ m^3 = 1000\ dm^3$

$1\ L = 1\ dm^3$

$1\ dm^3 = 1000\ cm^3$

$1\ cm^3 = 1\ mL$



Sample Exercise 1.11 Converting Volume Units

Earth's oceans contain approximately 1.36×10^9 km^3 of water. Calculate the volume in liters.

Solution

$1\ \text{L} = 10^{-3}\ \text{m}^3$, $1\ \text{km} = 10^3\ \text{m}$:

$$\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)^3 = \frac{10^9\ \text{m}^3}{1\ \text{km}^3}$$

Thus, converting from km^3 to m^3 to L, we have

$$\text{Volume in liters} = (1.36 \times 10^9\ \cancel{\text{km}^3})\left(\frac{10^9\ \cancel{\text{m}^3}}{1\ \cancel{\text{km}^3}}\right)\left(\frac{1\ \text{L}}{10^{-3}\ \cancel{\text{m}^3}}\right) = 1.36 \times 10^{21}\ \text{L}$$

Density

Density is the amount of mass in a unit volume of the substance.

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

The densities of solids and liquids are commonly expressed in units of (g/mL) (not SI unit).

SI unit of density is kg/m^3

Because most substances change volume when they are heated or cooled, densities are temperature dependent.

- The density of water is 1.00 g/mL (mass equal volume).

- Densities are temperature dependent (because most substances change volume when they are heated or cooled. So, the temperature should be specified).

- The density and weight are sometimes confused.
For example; iron has density more than air, but 1kg of air has the same mass as 1kg of iron, but iron occupies a smaller volume, which giving it a higher density.

TABLE 1.6 ■ Densities of Some Selected Substances at 25 °C

Substance	Density (g/cm^3)
Air	0.001
Balsa wood	0.16
Ethanol	0.79
Water	1.00
Ethylene glycol	1.09
Table sugar	1.59
Table salt	2.16
Iron	7.9
Gold	19.32

Sample Exercise 1.4 Determining Density and Using Density to Determine Volume or Mass

(a) Calculate the density of mercury if 1.00×10^2 g occupies a volume of 7.36 cm^3. **(b)** Calculate the volume of 65.0 g of the liquid methanol (wood alcohol) if its density is 0.791 g/mL. **(c)** What is the mass in grams of a cube of gold (density = 19.32 g/cm^3) if the length of the cube is 2.00 cm?

Solution

(a)

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{1.00 \times 10^2 \text{ g}}{7.36 \text{ cm}^3} = 13.6 \text{ g/cm}^3$$

(b)

$$\text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{65.0 \text{ g}}{0.791 \text{ g/mL}} = 82.2 \text{ mL}$$

(c)

$$\text{Volume} = (2.00 \text{ cm})^3 = (2.00)^3 \text{ cm}^3 = 8.00 \text{ cm}^3$$

$$\text{Mass} = \text{volume} \times \text{density} = (8.00 \text{ cm}^3)(19.32 \text{ g/cm}^3) = 155 \text{ g}$$

Other Derived SI Units

Distance = L = m
Area = L x L = m^2
Volume = L x L x L = m^3

Force = m a = kg (m/s^2) = kg m s^{-2}

Energy = ½ m v^2 = kg $(m/s)^2$ = kg m^2 s^{-2} = J

Pressure = F / A = kg m s^{-2} / m^2 = kg m^{-1} s^{-2} = Pa

Q & A

At what temperature ^{o}F and ^{o}C are the same?

Answer: -40

If you have equal masses of the following metals, which will occupy the largest volume?

- Au, density = 19.3 g/cm^3
- Pb, density = 11.3 g/cm^3
- Ag, density = 10.5 g/cm^3
- Cu, density = 8.92 g/cm^3
- Al, density = 2.70 g/cm^3

Estimate room temperature (~72°F) in °C.

- ~ 15°C
- ~ 22°C
- ~ 27°C
- ~ 32°C
- ~ 37°C

Which represents the largest volume?

- 0.25 L
- 2.5×10^{2} mL
- 2.5×10^{6} μL
- 2.5×10^{8} nL
- 2.5×10^{10} pL

(a) Calculate the density of a 374.5-g sample of copper if it has a volume of 41.8 cm^3. **(b)** A student needs 15.0 g of ethanol for an experiment. If the density of ethanol is 0.789 g/mL, how many milliliters of ethanol are needed? **(c)** What is the mass, in grams, of 25.0 mL of mercury (density = 13.6 g/mL)?

Answers: **(a)** 8.96 g/cm^3, **(b)** 19.0 mL, **(c)** 340 g


Thank You!