1.6 SI Units

International System of units (*metric system*)

French *le Système International d'Unités*

TABLE 1.1 SI Base Units

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

TABLE 1.2 Selected SI Prefixes

Prefix	Multiple	Symbol
mega	10^6	M
kilo	10^3	k
deci	10^{-1}	d
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	μ*
nano	10^{-9}	n
pico	10^{-12}	p

*Greek letter mu, pronounced "mew."

In this chapter, we will discuss four base quantities: length, mass, time, and temperature.

(Q) The SI unit of length is:

A. millimeter

B. meter

C. yard

D. centimeter

E. foot

Examples:

$2.54\ cm = 2.54\times10^{-2}\ m$

$1\ mL = 10^{-3}\ L$

$1\ km = 1000\ m$

$1\ ng = 10^{-9}\ g$

$1{,}130{,}000\ m = 1.13 \times 10^{6}\ m =$ **1.13 Mm**

TABLE 1.5 SI Prefixes—Their Meanings and Values[a]

Prefix	Meaning	Symbol	Prefix Value[b] (numerical)	Prefix Value[b] (power of ten)
exa		E		10^{18}
peta		P		10^{15}
tera		T		10^{12}
giga	billions of	G	1000000000	10^{9}
mega	millions of	M	1000000	10^{6}
kilo	thousands of	k	1000	10^{3}
hecto		h		10^{2}
deka		da		10^{1}
deci	tenths of	d	0.1	10^{-1}
centi	hundredths of	c	0.01	10^{-2}
milli	thousandths of	m	0.001	10^{-3}
micro	millionths of	μ	0.000001	10^{-6}
nano	billionths of	n	0.000000001	10^{-9}
pico	trillionths of	p	0.000000000001	10^{-12}
femto		f		10^{-15}
atto		a		10^{-18}

[a]Prefixes in red type are used most often.

[b]Numbers in these columns can be interchanged with the corresponding prefix.

TABLE 1.3 Some Non-SI Metric Units Commonly Used in Chemistry

Measurement	Unit	Abbreviation	Value in SI Units
Length	angstrom	Å	$1\ \text{Å} = 0.1\ \text{nm} = 10^{-10}\ \text{m}$
Mass	atomic mass unit	u (amu)	$1\ \text{u} = 1.66054 \times 10^{-27}\ \text{kg}$ (rounded to six digits)
	metric ton	t	$1\ \text{t} = 10^3\ \text{kg}$
Time	minute	min.	1 min. = 60 s
	hour	h	1 h = 60 min. = 3600 s
Temperature	degree Celsius	°C	$T_K = t_{°C} + 273.15$
Volume	liter	L	$1\ \text{L} = 1000\ \text{cm}^3$

TABLE 1.4 Some Useful Conversions

Measurement	English Unit	English/SI Equality[a]
Length	inch	1 in. = 2.54 cm
	yard	1 yd = 0.9144 m
	mile	1 mi = 1.609 km
Mass	pound	1 lb = 453.6 g
	ounce (mass)	1 oz = 28.35 g
Volume	gallon	1 gal = 3.785 L
	quart	1 qt = 946.4 mL

Laboratory Measurements

- **Four common**
  1. Length
  2. Volume
  3. Mass
  4. Temperature

Laboratory Measurements

1. Length

- SI Unit is meter (m)
- Meter too large for most laboratory measurements
- Commonly use
  - Centimeter (cm)

    $1\text{ cm} = 10^{-2}\text{ m} = 0.01\text{ m}$
  - Millimeter (mm)

    $1\text{ mm} = 10^{-3}\text{ m} = 0.001\text{ m}$

2. Volume

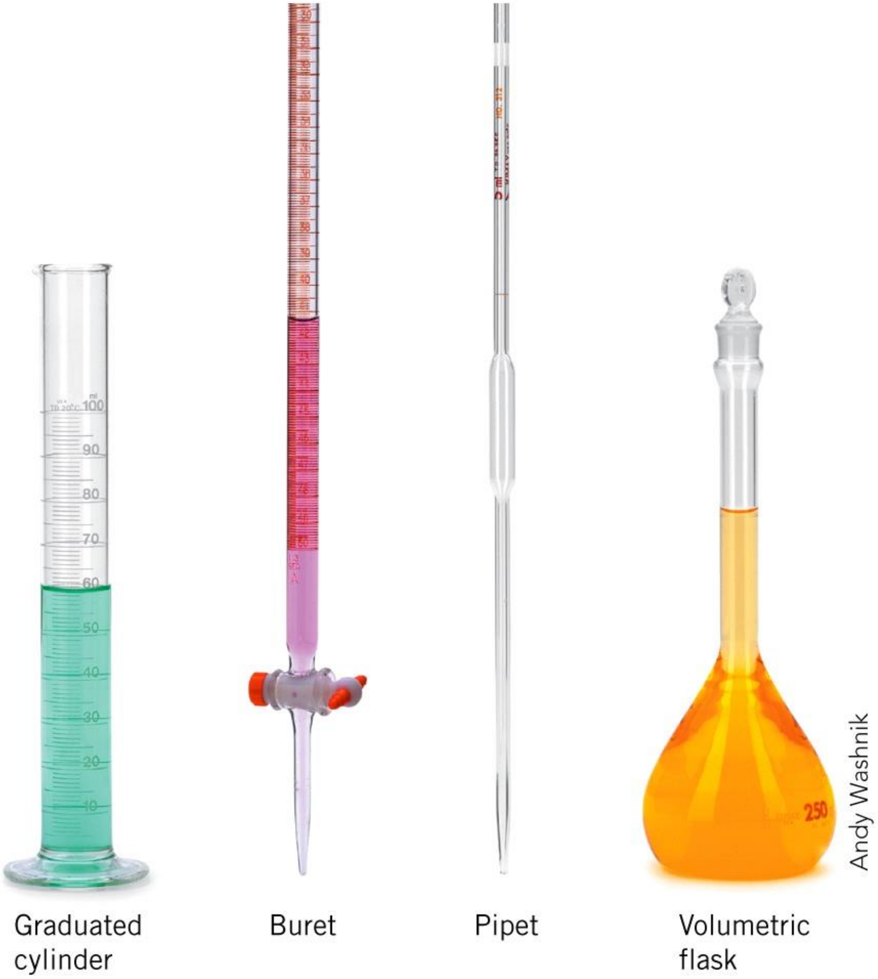
- Dimensions of (length)^3
- SI unit for Volume = m^3
- Most laboratory measurements use *V* in liters (L)

  1 L = 1 dm^3

  Chemistry glassware marked in L or mL

  1 L = 1000 mL
- What is a mL?

  1 mL = 1 cm^3



3. Mass

- SI unit is kilogram (kg)
  - Frequently use grams (g) in laboratory as more realistic size
- 1 kg = 1000 g   1 g = 0.001 kg = $\frac{1}{1000}$ g
- Mass is measured by comparing weight of sample with weights of known standard masses
- Instrument used = balance

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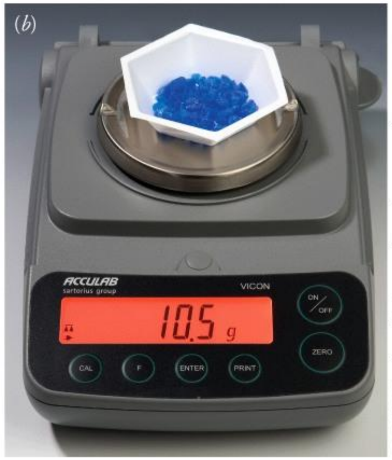

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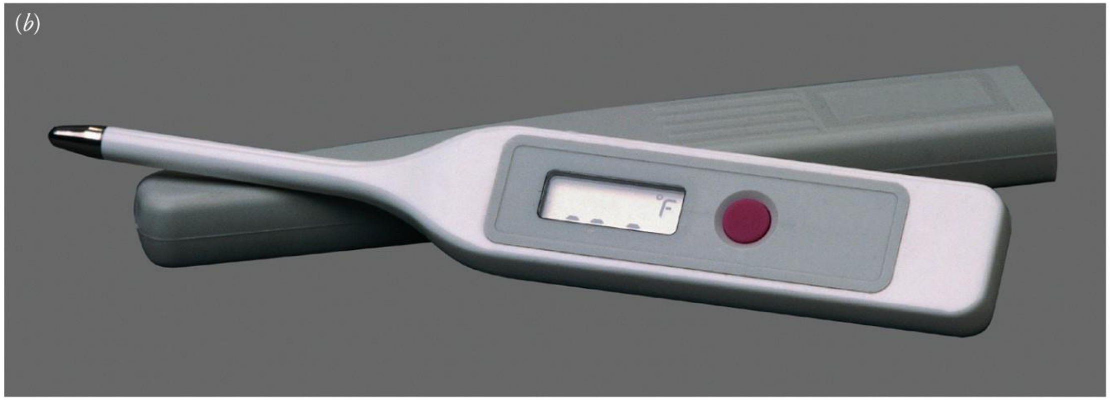
4. Temperature

- Measured with thermometer
- Three common scales

A. Fahrenheit scale

- Common in US
- Water freezes at 32 °F and boils at 212 °F
- 180 degree units between melting and boiling points of water



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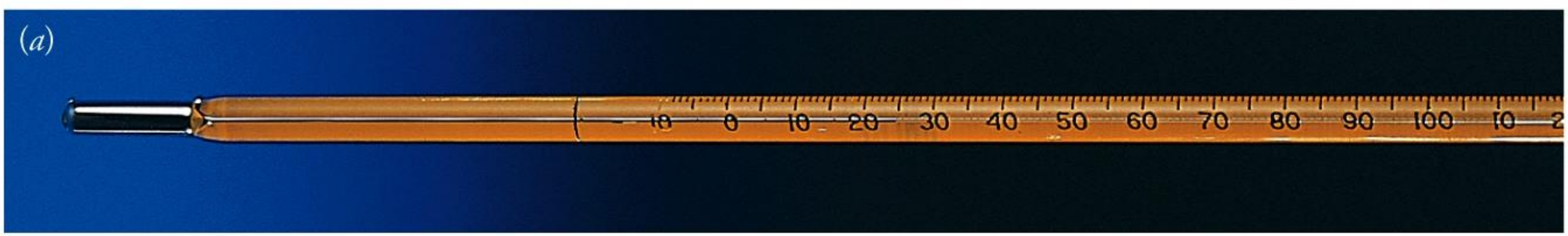
4. Temperature

B. Celsius scale

– Most common for use in science
– Water freezes at 0 °C
– Water boils at 100 °C
– 100 degree units between melting and boiling points of water



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4. Temperature

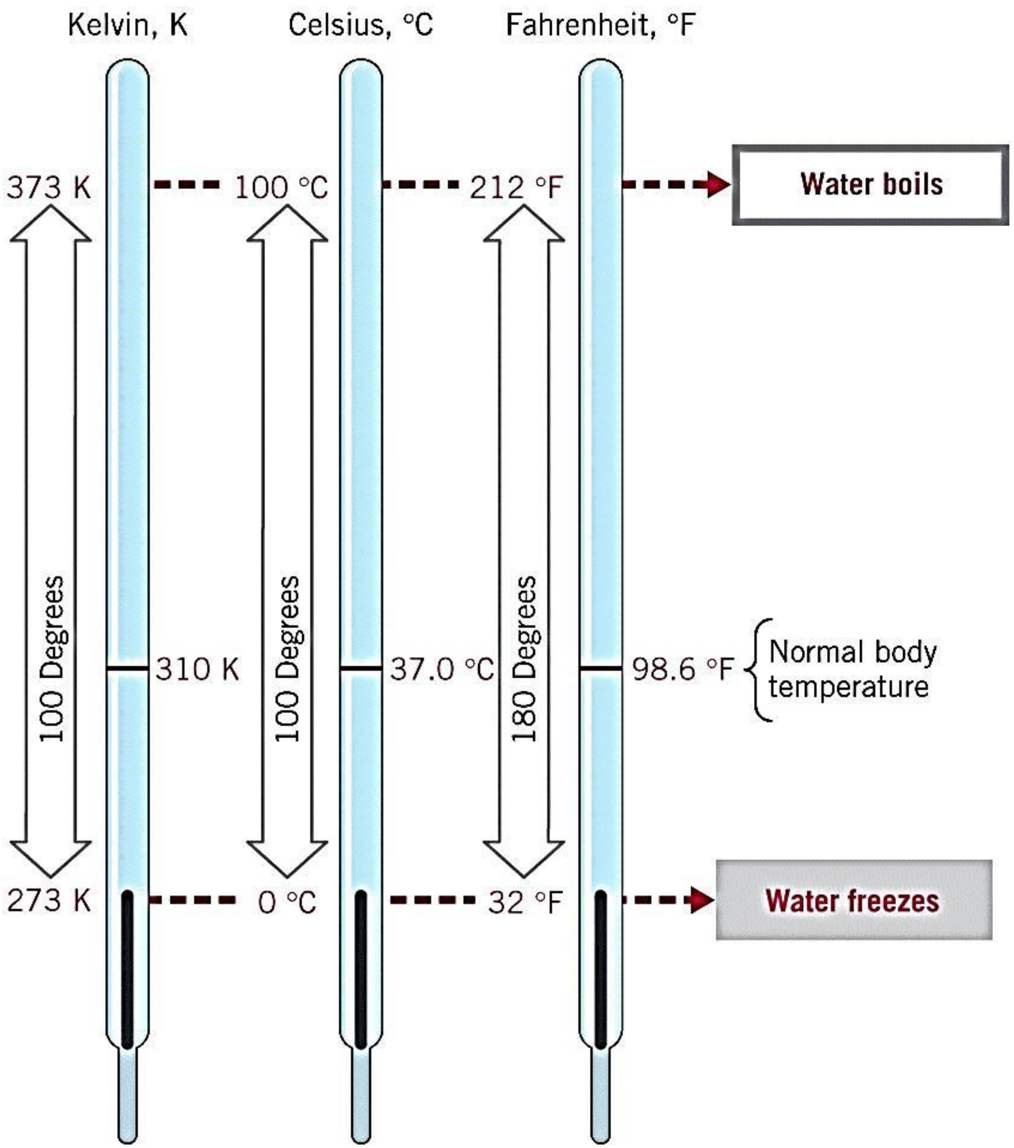
C. Kelvin scale

- SI unit of temperature is **kelvin (K)**
  - **Note:** No degree symbol in front of K
- Water freezes at 273.15 K and boils at 373.15 K
  - 100 degree units between melting and boiling points
- Only difference between Kelvin and Celsius scale is zero point

Absolute Zero

- Zero point on Kelvin scale
- Corresponds to nature’s lowest possible temperature

Temperature Conversions



How to convert between ˚F and ˚C?

$$^{0}F = \frac{9}{5} \times {}^{0}C + 32$$

$32\ ^{0}F = 0\ ^{0}C$

$212\ ^{0}F = 100\ ^{0}C$

Temperature Conversions

- Common laboratory thermometers are marked in Celsius scale
- How to convert to Kelvin scale

$$K = {}^{0}C + 273.15$$

$$273.15\ K = 0\ {}^{0}C$$
$$373.15\ K = 100\ {}^{0}C$$

- Amounts to adding 273.15 to Celsius temperature

Example: What is the Kelvin temperature of a solution at 25 °C?

$$T_K = (25\ {}^{\circ}C + 273.15\ {}^{\circ}C)\frac{1\ K}{1\ {}^{\circ}C}$$ **= 298 K**

1. Convert 121 °F to the Celsius scale.

$$ {}^{0}F = \frac{9}{5} \times {}^{0}C + 32 $$

$$ t_C = \left(t_F - 32\ {}^{\circ}F\right) \left(\frac{5\ {}^{\circ}C}{9\ {}^{\circ}F}\right) $$

$$ t_C = \left(121\ {}^{o}F - 32\ {}^{\circ}F\right)\left(\frac{5\,{}^{\circ}C}{9\,{}^{\circ}F}\right) $$ **= 49 °C**

2. Convert 121 °F to the Kelvin scale.

– We already have in °C so…

$$ T_K = (t_C + 273.15\,{}^{\circ}C)\frac{1\,K}{1\,{}^{\circ}C} = (49 + 273.15\,{}^{\circ}C)\frac{1\,K}{1\,{}^{\circ}C} $$

T_K = 332 K

3. Convert 77 K to the Celsius scale.

$$T_K = (t_C + 273.15\ °C)\frac{1\ K}{1\ °C} \qquad t_C = (T_K - 273.15\ K)\frac{1\ °C}{1\ K}$$

$$t_C = (77\ K - 273.15\ K)\frac{1\ °C}{1\ K}$$ **= –196 °C**

4. Convert 77 K to the Fahrenheit scale.

– We already have in °C so

$$t_F = \left(\frac{9\ °F}{5\ °C}\right)(-196\ °C) + 32\ °F$$ **= –321 °F**

The melting point of UF_6 is 64.53 °C. What is the melting point of uranium UF_6 on the Fahrenheit scale?

A. 67.85 °F

B. 96.53 °F

C. 116.2 °F

D. 337.5 °F

E. 148.2 °F

$$t_F = \left(\frac{9\ °F}{5\ °C}\right) t_C + 32\ °F$$

$$t_F = \left(\frac{9\ °F}{5\ °C}\right) 64.53\ °C + 32\ °F$$

SI Units

- All physical quantities will have units **derived** from these seven SI base units

  e.g., Area

  - Derived from SI units based on definition of area
  - length × width = area
  - meter × meter = area

    $m \times m = m^2$

  - SI unit for area = square meters = m^2

Note: Units undergo same kinds of mathematical operations that numbers do

TABLE 1.3 **Derived Units**

Quantity	Definition of Quantity	SI Unit
Area	Length squared	m^2
Volume	Length cubed	m^3
Density	Mass per unit volume	kg/m^3
Speed	Distance traveled per unit time	m/s
Acceleration	Speed changed per unit time	m/s^2
Force	Mass times acceleration of object	$kg \cdot m/s^2$ (= newton, N)
Pressure	Force per unit area	$kg/(m \cdot s^2)$ (= pascal, Pa)
Energy	Force times distance traveled	$kg \cdot m^2/s^2$ (= joule, J)

- What is the SI derived unit for velocity?

$$\text{Velocity } (v) = \frac{\text{distance}}{\text{time}}$$

$$\text{Velocity units} = \frac{\text{meters}}{\text{seconds}} = \frac{\text{m}}{\text{s}}$$

- What is the SI derived unit for volume of a cube?

$$\text{Volume } (V) = \text{length} \times \text{width} \times \text{height}$$

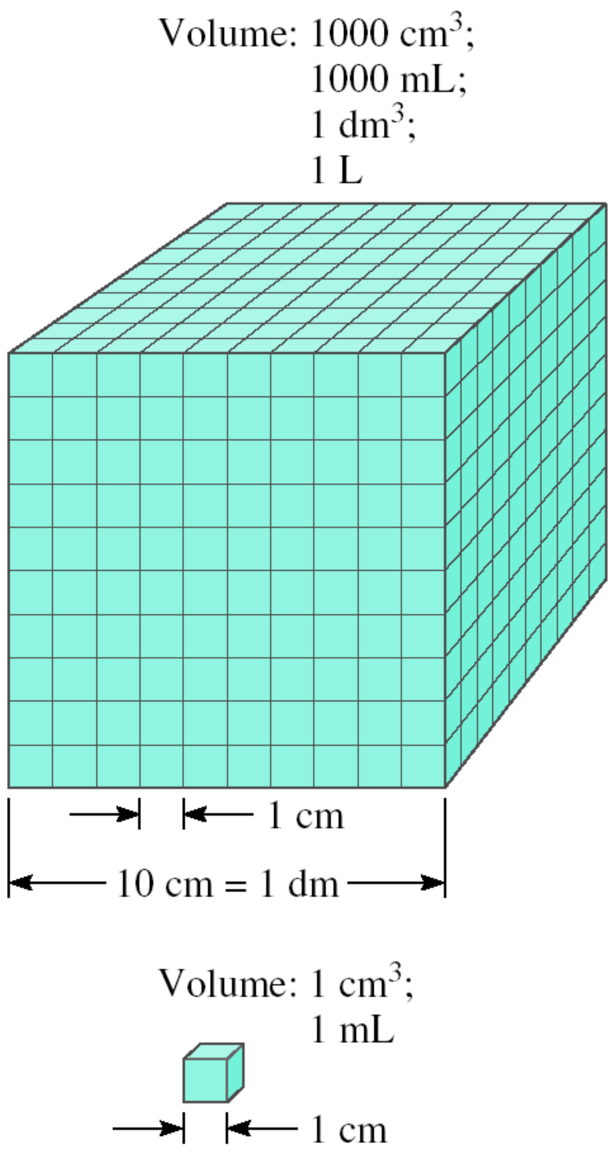
$$V = \text{meter} \times \text{meter} \times \text{meter}$$

$$\boldsymbol{V = \text{m}^3}$$

What is the SI derived unit for acceleration (hint: acceleration = distance/time^2)?

A. mm/min
B. yd/hr^2
C. m/s^2
D. m/s
E. ft^3

Volume – SI derived unit for volume is cubic meter (m^3)



$$1\ cm^3 = (1 \times 10^{-2}\ m)^3 = 1 \times 10^{-6}\ m^3$$

$$1\ dm^3 = (1 \times 10^{-1}\ m)^3 = 1 \times 10^{-3}\ m^3$$

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

$$1\ mL = 1\ cm^3$$

Dimensional Analysis Method of Solving Problems

1. Determine which unit conversion factor(s) are needed
2. Carry units through calculation
3. If all units cancel except for the ***desired unit(s)***, then the problem was solved correctly.

given quantity x conversion factor = desired quantity

$$\cancel{\text{given unit}} \times \frac{\text{desired unit}}{\cancel{\text{given unit}}} = \text{desired unit}$$

A person's average daily intake of glucose (a form of sugar) is 0.0833 pound (lb). What is this mass in milligrams (mg)?

(1 lb = 453.6 g.)

$$\text{pounds} \longrightarrow \text{grams} \longrightarrow \text{milligrams}$$

$$\frac{453.6\ \text{g}}{1\ \text{lb}} \quad \text{and} \quad \frac{1\ \text{mg}}{1 \times 10^{-3}\ \text{g}}$$

$$?\ \text{mg} = 0.0833\ \cancel{\text{lb}} \times \frac{453.6\ \cancel{\text{g}}}{1\ \cancel{\text{lb}}} \times \frac{1\ \text{mg}}{1 \times 10^{-3}\ \cancel{\text{g}}} = 3.78 \times 10^{4}\ \text{mg}$$

Q) A liquid helium storage tank has a volume of 275 L. What is the volume in m^3?

Q) The density of liquid nitrogen at its boiling point (−196°C or 77 K) is 0.808 g/cm^3. Convert the density to units of kg/m^3.

$$\frac{1\ \text{kg}}{1000\ \text{g}} \quad \text{and} \quad \frac{1\ \text{cm}^3}{1\times10^{-6}\ \text{m}^3}$$

$$?\ \text{kg/m}^3 = \frac{0.808\ \cancel{\text{g}}}{1\ \cancel{\text{cm}^3}} \times \frac{1\ \text{kg}}{1000\ \cancel{\text{g}}} \times \frac{1\ \cancel{\text{cm}^3}}{1\times10^{-6}\ \text{m}^3} = 808\ \text{kg/m}^3$$

Example: How to convert a person's height from 68.0 in to cm? if 2.54 cm = 1 in.

Example: Convert 0.097 m to mm.

Example: Convert 3.5 m^3 to cm^3.

Q) Convert speed of light from 3.00×10^8 m/s to mi/hr

(1 mi = 1.609 km)

The Toyota Camry hybrid electric car has a gas mileage rating of 56 miles per gallon. What is this rating expressed in units of kilometers per liter?

1 gal = 3.784 L   1 mile = 1.609 km

A. 1.3×10^2 km L^{-1}

B. 24 km L^{-1}

C. 15 km L^{-1}

D. 3.4×10^2 km L^{-1}

E. 9.2 km L^{-1}

$$56\frac{\text{mi}}{\text{gal}} \times \frac{1\,\text{gal}}{3.784\,\text{L}} \times \frac{1.609\,\text{km}}{1\,\text{mi}}$$

The volume of a basketball is 433.5 in^3. Convert this to mm^3. (1 in. = 2.54 cm)

A. 1.101×10^{-2} mm^3

B. 7.104×10^{6} mm^3

C. 7.104×10^{4} mm^3

D. 1.101×10^{4} mm^3

E. 1.101×10^{6} mm^3

Density

- Ratio of object's mass to its volume

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad d = \frac{m}{V}$$

- Units (depends on what units we use for mass and volume.
  - **g/mL** or **g/cm³**
  - **Or g/L** or **kg/L**

- A student weighs a piece of gold that has a volume of 11.02 cm^3 of gold. She finds the mass to be 212 g. What is the density of gold?

$$d = \frac{m}{V}$$

$$d = \frac{212\text{ g}}{11.02\text{ cm}^3} = \mathbf{19.3\ g/cm^3}$$

Another student has a piece of gold with a volume of 1.00 cm^3. What does it weigh? **19.3 g**

What if it were 2.00 cm^3 in volume? **38.6 g**

(Q) If the density of an object is 2.87×10^{-4} lbs/cubic inch, what is its density in g/mL? (1 lb = 454 g, 1 inch = 2.54 cm)