1.6 SI Units

International System of units (*metric system*)

French *le Système International d'Unités*

V.I

TABLE 1.1 SI Base Units

	Quantity	Unit	Symbol
1.	Length	meter	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Temperature	kelvin	K
5.	Amount of substance	mole	mol
6.	Electric current	ampere	A
7.	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.

اللهم صلّ وسلّم على نبينا محمد وعلى آله وصحبه أجمعين

(Q) The SI unit of length is:

A. millimeter

B. meter

C. yard

D. centimeter

E. foot

Examples:

$2.54\ cm = 2.54 \times 10^{-2}\ m$

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

$1\ km = 1000\ m$

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

Scientific Notation

Mega

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

Exercise 1.4 Express the following quantities using an SI prefix and a base unit. For instance, 1.6×10^{-6} m = 1.6 μm. A quantity such as 0.000168 g could be written 0.168 mg or 168 μg.

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a. 1.84×10^{-9} m
b. 5.67×10^{-12} s
c. 7.85×10^{-3} g
d. 9.7×10^{3} m
e. 0.000732 s
f. 0.000000000154 m

See Problems 1.65 and 1.66.

a. 1.84×10^{-9} (m) → 1.84 (nm)

b. 5.67×10^{-12} (s) → 5.67 (ps)

c. 7.85×10^{-3} (g) → 7.85 (mg)

d. 9.7×10^{3} (m) → 9.7 (Km)

e. 0.000732 (s)
→ $.732 \times 10^{-3}$ s → .732 (ms)
→ 732×10^{-6} s → 732 (μs)

f. .000000000154 (m)
→ $.154 \times 10^{-9}$ → .154 (nm)
→ 154×10^{-12} → 154 (pm)

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 cm = 10^{-2} m = 0.01 m
  - Millimeter (mm)

    1 mm = 10^{-3} m = 0.001 m

2. Volume

Derived Quantity

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

$1\ L = 1\ dm^3$

Chemistry glassware marked in L or mL

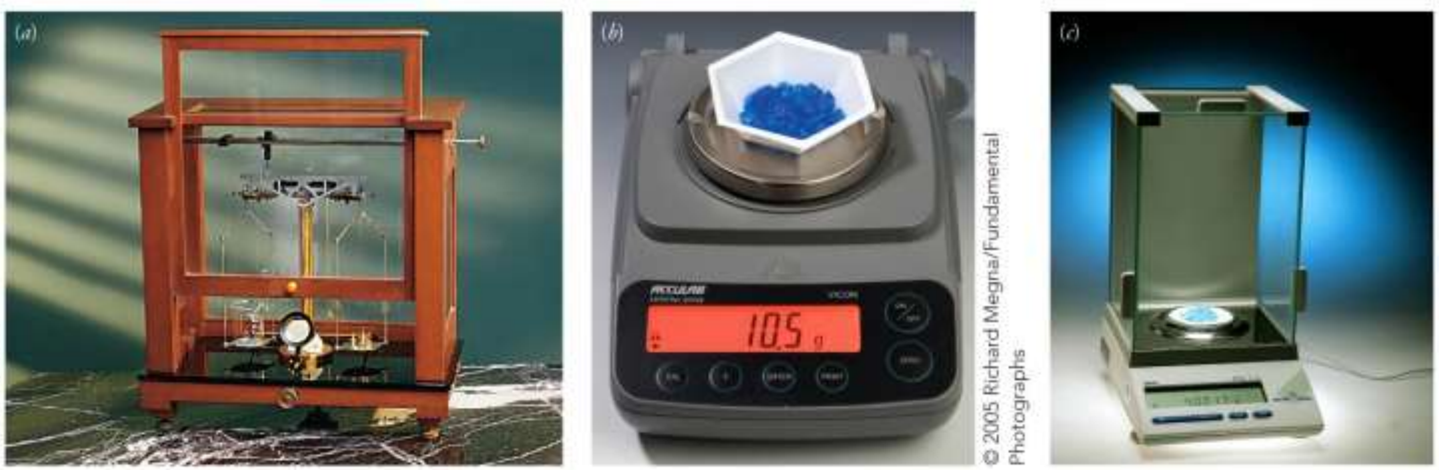
$1\ L = 1000\ mL$

- 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
- Mass is measured by comparing weight of sample with weights of known standard masses
- Instrument used = balance



Michael Watson
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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

212 - 32 = 180

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

4. Temperature

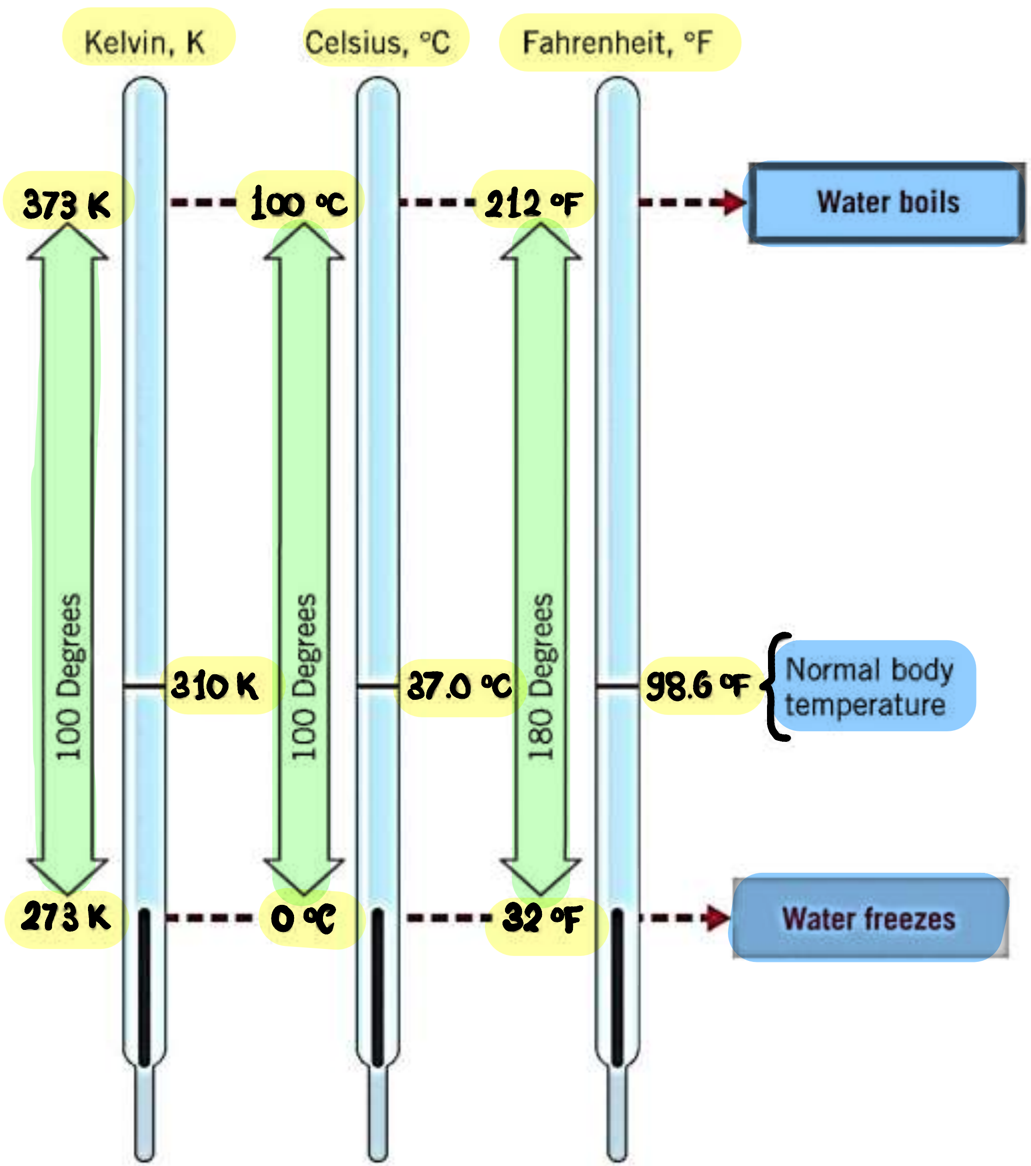
C. Kelvin scale

- 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 → 0 K° = 273.15 °C

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

Temperature Conversions



How to convert between °F and °C?

#

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

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

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

#

$$(^{0}F - 32) \times \frac{5}{9} = {}^{0}C$$

Temperature Conversions

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

$$K = {}^{0}C + 273.15$$
$${}^{\circ}C = K - 273.15$$

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?

exact

$$T_{\mathrm{K}} = (25\ {}^{\circ}\mathrm{C} + 273.15\ {}^{\circ}\mathrm{C})\frac{1\,\mathrm{K}}{1\ {}^{\circ}\mathrm{C}} \quad \mathbf{= 298\ K}$$

2-SF

1. Convert 121 °F to the Celsius scale.

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

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

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

2-SF × (5/9) → exact

2. Convert 121 °F to the Kelvin scale.

– We already have in °C so...

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

2SF   exact

T_K = 322 K

3. Convert 77 K to the Celsius scale.

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

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

↳ zero decimal places

4. Convert 77 K to the Fahrenheit scale.

– We already have in °C so

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

Question

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

64.53 C° ⟶ F°

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

$F = \frac{9}{5} \times 64.53C^\circ + 32 = 148.154$

exact

exact

$\infty \times 4 = ④$

$2 + \infty$

148.2

Example 1.3 Converting from One Temperature Scale to Another

Gaining Mastery Toolbox

Critical Concept 1.3
There are several commonly used temperature scales: Celsius, Fahrenheit, and Kelvin. The Celsius temperature scale is used most frequently in the laboratory. Using mathematical relationships, temperature values can be converted between the Celsius, Kelvin, and Fahrenheit scales.

Solution Essentials:
- Relationship (conversion formula) between Kelvin and Celsius temperatures
- Relationship (conversion formula) between Celsius and Fahrenheit temperatures

The hottest place on record in North America is Death Valley in California. It reached a temperature of 134°F in 1913. What is this temperature reading in degrees Celsius? in kelvins?

Problem Strategy This calculation involves conversion of a temperature in degrees Fahrenheit (°F) to degrees Celsius (°C) and kelvins (K). This is a case where using formulas is the most reliable method for arriving at the answer.

Solution Substituting, we find that

$$t_C = \frac{5°C}{9°F} \times (t_F - 32°F) = \frac{5°C}{9°F} \times (134°F - 32°F) = \mathbf{56.7°C}$$

In kelvins,

$$T_K = \left(t_C \times \frac{1\ K}{1°C}\right) + 273.15\ K = \left(56.7°C \times \frac{1\ K}{1°C}\right) + 273.15\ K = \mathbf{329.9\ K}$$

$\Rightarrow$ 134 F° $\longrightarrow$ C° $\longrightarrow$ K° 8

C° = F° = $\frac{9}{5}$ × C° + 32

$\frac{5}{9}$ × (134 − 32) =

$\frac{5}{9}$ × 102 = 56.7 C°

exact ∞ 3-SF 3-SF

K° = K° = C° + 273.15

1 + ∞ = 1

K° = 56.7 + 273.15 =

exact

1-dp → 329.85 = 329.9 K°

Exercise 1.5

a. A person with a fever has a temperature of 102.5°F. What is this temperature in degrees Celsius? b. A cooling mixture of dry ice and isopropyl alcohol has a temperature of −78°C. What is this temperature in kelvins?

See Problems 1.69, 1.70, 1.71, and 1.72.

A. → 102.5 F° —?→ C°

B. → -78 °C —?→ °K

A.) $F = \frac{9}{5} \times C° + 32 =$

Exact. exact

$102.5 = \frac{9}{5} \times C° + 32 =$

$\frac{5}{9} \times 70.5 = °C$

$\infty \times$ 3-sf $=$ 39.166 = 39.2 C° (2-sf)

B.) $°K = C° + 273.15$

$K° = -78 + 273.15$

zero dp + ∞ = zero

$K° = 195.15$

$K° = 195\ K°$

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

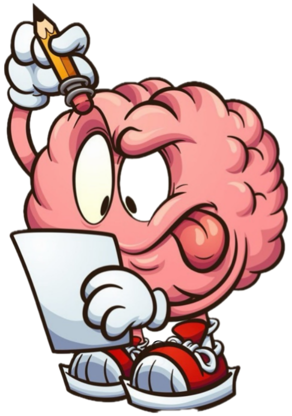
  $m \times m = m^2$

  – 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?

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

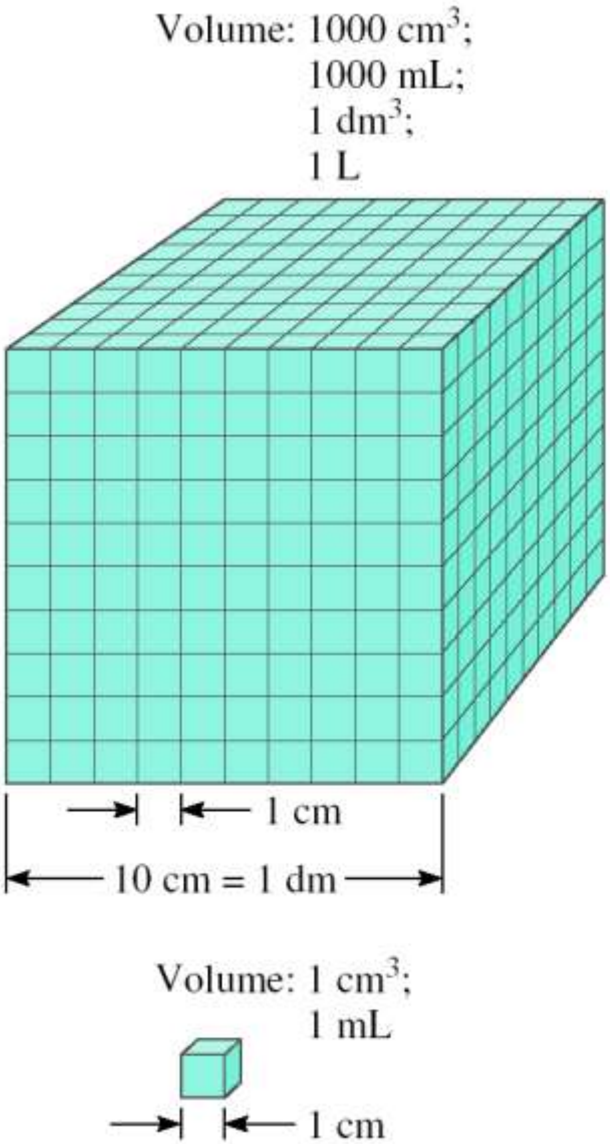
$$V = \text{meter} \times \text{meter} \times \text{meter}$$

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

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)



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

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

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

$1\ mL = 1\ cm^3$

$1\ m^3 = 1000\ L$

Volumetric flask

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

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

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.)

pounds ⟶ grams ⟶ milligrams

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

given quantity × Conversion Factor = Desired Unit

4-SF

3-SF

$$?\ \text{mg} = 0.0833\ \text{lb} \times \frac{453.6\ \text{g}}{1\ \text{lb}} \times \frac{1\ \text{mg}}{1\times10^{-3}\ \text{g}} = 3.78\times10^{4}\ \text{mg}$$

Q. → 0.0833 pound (Lb) $\xrightarrow{??}$ mg

Conversion factor

given quantity

1 lb = 453.6 g

exact number

3-SF

\# $0.0833 \, (\cancel{Lb}) \times \frac{453.6 \, (\cancel{g})}{1 \, (\cancel{Lb})} \times \frac{10^3 \, (mg)}{1 \, (\cancel{g})} =$

3-SF → 37.78488×10^3 → $37.8 \times 10^3 = 3.78 \times 10^4$ mg

Rounding

ما تحسبه

Desire Unit

Q. → Volume = 275 (L) $\xrightarrow{??}$ $(m)^3$

$1 m^3 = 1000 (L)$

$275 \, (\cancel{L}) \times \frac{10^{-3} \, m^3}{1 \cancel{L}} = 275 \times 10^{-3} \, (m)^3 \xrightarrow{=} .275 \, m^3$

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.

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

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

Q) The density of liquid nitrogen at its boiling point (−196°C or 77 K) is 0.808 g/cm³. Convert the density to units of kg/m³.

Explanation:

→ Density = .808 g / cm³ $\xrightarrow{??}$ Kg / m³

| 1 Kg = 1000 g |

| 1 m = 100 cm |

$$\frac{0.808\ (g)}{(cm)^3} \times \frac{10^{-3}\ (Kg)}{1\ (g)} \times \frac{(1\ cm)^3}{(10^{-2}\ m)^3} = 10^{-6}$$

$$0.808 \times 10^{3}\ Kg/m^3 \rightarrow 808\ Kg/m^3$$

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

\# 68.0 in → cm

$$\frac{68.0\ \text{in}}{} \times \frac{2.54\ \text{cm}}{\text{in}} = 172.72 = 173\ \text{cm}$$

3-SF 3-SF 3-SF

Example: Convert 0.097 m to mm.

1 m = 10^3 mm

\# 0.097 m → mm

$$.097\ \text{m} \times \frac{10^3\ \text{mm}}{1\ \text{m}} = .097 \times 10^3\ \text{mm}$$

97 mm

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

1m = 100 cm

$$3.5\ m^3 \times \frac{(10^2\ cm)^3}{1\ m^3} = 3.5 \times 10^6 cm$$

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

(1 mi = 1.609 km)

Km → m

mile

$$Speed = 3.00 \times 10^8\ m/s \rightarrow mi/hr$$

105

$$\frac{3.00 \times 10^8\ m}{s} \times \frac{3600\ s}{1\ hr} \times \frac{1\ mil}{1.609\ Km} \times \frac{1\ Km}{10^3\ m}$$

$$6712.24363 \times 10^5 \frac{mil}{hr} \rightarrow 6.712 \times 10^8 \rightarrow 6.71 \times 10^8 \frac{mil}{hr}$$

$1 mi = 1609$

$$\frac{3.00 \times 10^8 \ m}{s} = \frac{mi}{hr}$$

(k)

$$\frac{3.00 \times 10^8 \ m}{s} \times \frac{3600 s}{1 hr} \times \frac{1 km}{10^3 m} \times \frac{1 mi}{1,609 km}$$

$1 km = 1 \times 10^3 m$

$= 6712.24363 \times 10^5$

$= 6.71224363 \times 10^8$

$6.71 \times 10^8 \ mi/hr$

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}

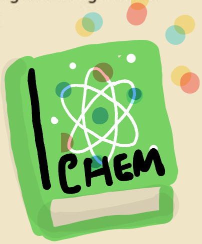
$$56\,\frac{\text{mi}}{\text{gal}} \times \frac{1\ \text{gal}}{3.784\ \text{L}} \times \frac{1.609\ \text{km}}{1\ \text{mi}}$$

Example 1.6 Converting Units: Metric Unit to Metric Unit

Gaining Mastery Toolbox

Critical Concept 1.6
Dimensional analysis can be used to convert metric units. Unit conversion factors are the key to applying dimensional analysis to solve problems.

Solution Essentials:
- Metric conversion factors
- The metric system
- Rules for significant figures and rounding



Nitrogen gas is the major component of air. A sample of nitrogen gas in a glass bulb weighs 243 mg. What is this mass in SI base units of mass (kilograms)?

Problem Strategy This problem requires converting a mass in milligrams to kilograms. Finding the correct relationship for performing such a conversion directly in one step might be more difficult than doing the conversion in multiple steps. In this case, conversion factors for converting milligrams to grams and from grams to kilograms are relatively easy to derive, so it makes sense to do this conversion in two steps. First convert milligrams to grams; then convert grams to kilograms. To convert from milligrams to grams, note that the prefix *milli-* means 10^{-3}. To convert from grams to kilograms, note that the prefix *kilo-* means 10^3.

Diagramming the solution clearly shows how two conversion factors (2 ➡) are used to solve the problem.

Solution Since 1 mg = 10^{-3} g, you can write

$$243\ \text{mg} \times \frac{10^{-3}\ \text{g}}{1\ \text{mg}} = 2.43 \times 10^{-1}\ \text{g}$$

Then, because the prefix *kilo-* means 10^3, you write

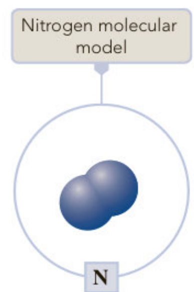
$$1\ \text{kg} = 10^3\ \text{g}$$

and

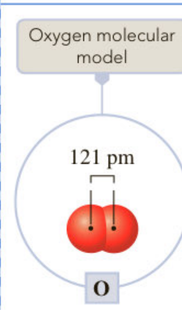
$$2.43 \times 10^{-1}\ \text{g} \times \frac{1\ \text{kg}}{10^3\ \text{g}} = \mathbf{2.43 \times 10^{-4}\ kg}$$

Note, however, that you can combine the two conversion steps as follows:

$$243\ \text{mg} \times \underbrace{\frac{10^{-3}\ \text{g}}{1\ \text{mg}}}_{\text{converts mg to g}} \times \underbrace{\frac{1\ \text{kg}}{10^3\ \text{g}}}_{\text{converts g to kg}} = 2.43 \times 10^{-4}\ \text{kg}$$



Answer Check Often, mistakes lead to answers that are easily detected by giving them a *reasonableness check*. For example, if while solving this problem you mistakenly write the conversion factors in inverted order (although this should not happen if you use units in your calculation), the final answer will be very large. Or perhaps you inadvertently copy the exponent from your calculator with the wrong sign, giving the answer as 2.43×10^4 kg. A large answer is not reasonable, given that you are converting from small mass units (mg) to relatively large mass units (kg). Both of these errors can be caught simply by taking the time to make sure that your answer is reasonable. After completing any calculations, be sure to check for reasonableness in your answers.



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

$$433.5\ in^3 \times \frac{(25.4\ mm)^3}{1\ in^3} =$$

4-SF; exact

2.54 cm → x10¹ = 25.4 mm

$$7103792.244\ mm^3 = 7.104 \times 10^6\ mm^3$$

B.

Example 1.7: The world's oceans contain approximately 1.35×10^9 km^3 of water. What is this volume in liters?

1km = 1×10^3 m = $1 \times 10^3 \times 10^2$ cm = 1×10^5 cm (km^3 → cm^3)

(cm^3 → L) (1 cm^3 = 1mL) (1mL= 1×10^{-3}L)

The world's oceans contain approximately $1.35 \times 10^9\ km^3$ of water. What is this volume in liters?

example 1.7 :

→ $1.35 \times 10^9\ Km^3$ ⟶?? Volume (L)

$1\ m^3 = 1 \times 10^3\ L$

$(\times 10^3)^3 = 10^9$

$1.35 \times 10^9\ Km^3 \longrightarrow m^3 = 1.35 \times 10^{18}\ m^3$

$$1.35 \times 10^{18}\ m^3 \times \frac{1 \times 10^3\ L}{1\ m^3} = 1.35 \times 10^{21}\ (L)$$

Exercise 1.8 The oxygen molecule (the smallest particle of oxygen gas) consists of two oxygen atoms a distance of 121 pm apart. How many millimeters is this distance?	See Problems 1.81, 1.82, 1.83, and 1.84.

ICHEM

121 pm $\xrightarrow{??}$ mm

$1\ pm \rightarrow 10^{-9}\ mm$

$$121\ pm \times \frac{10^{-9}\ mm}{1\ pm} = 121 \times 10^{-9}\ mm$$

$$\Rightarrow 1.21 \times 10^{-7}\ mm$$

Exercise 1.10 Using the definitions 1 in. = 2.54 cm and 1 yd = 36 in. (both exact), obtain the conversion factor for yards to meters. How many meters are there in 3.54 yd?	See Problems 1.87, 1.88, 1.89, and 1.90.

ICHEM

3.54 yd $\xrightarrow{?}$ m

$1\ yd = 0.9144\ m$

$$3.54\ yd \times \frac{.9144\ m}{1\ yd} = 3.236976 = 3.24\ m$$

3-SF

exact

Exercise 1.9 A large crystal is constructed by stacking small, identical pieces of crystal, much as you construct a brick wall by stacking bricks. A unit cell is the smallest such piece from which a crystal can be made. The unit cell of a crystal of gold metal has a volume of 67.6 Å^3. What is this volume in cubic decimeters?

See Problems 1.85 and 1.86.

\# Volume 67.6 Å^3 $\xrightarrow{??}$ dm^3

$1\ \text{Å} = 1\times10^{-10}\ \text{m}$	$1\ \text{m} = 10^{1}\ \text{dm}$

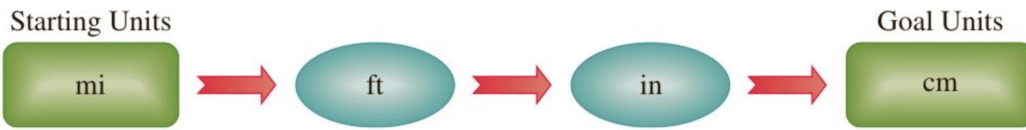
$$67.6\ \text{Å}^3 \times \frac{(1\times10^{-10}\ \text{m})^3}{1\ \text{Å}^3} \times \frac{(10^{1}\ \text{dm})^3}{(1\ \text{m})^3} =$$

$$67.6 \times 10^{-30} \times 10^{3}\ \text{dm}^3 \rightarrow 67.6 \times 10^{-27}\ \text{dm}^3$$

$$6.76 \times 10^{-26}\ \text{dm}^3$$

How many centimeters are there in 6.51 miles? ✓Example - 1.10:

Problem Strategy This problem involves converting from U.S. to metric units: specifically, from miles to centimeters. One path to a solution is using three conversions: miles to feet, feet to inches, and inches to centimeters. Table 1.4 has the information you need to develop the conversion factors for U.S. to metric units.



Solution From the definitions, you obtain the following conversion factors:

V.I →

$$1 = \frac{5280\ \text{ft}}{1\ \text{mi}} \qquad 1 = \frac{12\ \text{in.}}{1\ \text{ft}} \qquad 1 = \frac{2.54\ \text{cm}}{1\ \text{in.}}$$

Then,

$$6.51\ \text{mi} \times \underbrace{\frac{5280\ \text{ft}}{1\ \text{mi}}}_{\text{converts mi to ft}} \times \underbrace{\frac{12\ \text{in.}}{1\ \text{ft}}}_{\text{converts fi to in.}} \times \underbrace{\frac{2.54\ \text{cm}}{1\ \text{in.}}}_{\text{converts in. to cm}} = \mathbf{1.05 \times 10^6\ cm}$$

All of the conversion factors used in this example are exact, so the number of significant figures in the result is determined by the number of significant figures in 6.51 mi.

Thomas Jablonski/Fotolia LLC

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/cm^3**
  - **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?

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

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

Q.

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.

(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)

$1 mL = 1 cm^3$

pound

$$\text{density} = \frac{2.87 \times 10^{-4}\ lb}{(in)^3} \times \frac{1\ (in)^3}{(2.54\ cm)^3} \times \frac{454\ g}{1\ lb} = 79.51271808\ g/cm^3$$

$$7.9512 \times 10^{-3}\ g/cm \longrightarrow 7.95 \times 10^{-7}\ g/mL$$

(Q) Which one of the following has the largest length?

A) 1.5×10^{-2} mm → 1.5×10^{-5} m

B) 15 km → 15×10^{3} m

C) 1.5×10^{14} nm → 1.5×10^{5} m

D) 1.5×10^{15} pm → 1.5×10^{3} m

$$A < D < B < C$$

$$1\ \text{Kg} = 10^{6}\ \text{mm}$$
$$1\ \text{Kg} = 10^{12}\ \text{nm}$$
$$1\ \text{Kg} = 10^{15}\ \text{pm}$$

A. $$1.5 \times 10^{-2}\ \text{mm} \times \frac{1\ \text{Kg}}{10^{6}\ \text{mm}} = 15 \times 10^{-9}\ \text{Kg}$$

C. $$1.5 \times 10^{14}\ \text{nm} \times \frac{1\ \text{Kg}}{10^{12}\ \text{nm}} = 15 \times 10^{1}\ \text{Kg}$$

D. $$1.5 \times 10^{15}\ \text{pm} \times \frac{1\ \text{Kg}}{10^{15}\ \text{pm}} = 15 \times 10^{-1}\ \text{Kg}$$

Example 1.4 Calculating the Density of a Substance

Gaining Mastery Toolbox

Critical Concept 1.4
Density is the relationship of the mass to volume (m/V) of a substance. Unlike mass, density is a characteristic (physical property) that can be used to identify and distinguish pure substances from each other.

Solution Essentials:
- Density of a substance is calculated by dividing the mass of substance (m) by the volume (V) that the mass of substance occupies
- Rules for significant figures and

A colorless liquid, used as a solvent (a liquid that dissolves other substances), is believed to be one of the following:

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Substance	*Density (in g/mL)*
n-butyl alcohol	0.810
ethylene glycol	1.114
isopropyl alcohol	0.785
toluene	0.866

To identify the substance, a chemist determined its density. By pouring a sample of the liquid into a graduated cylinder, she found that the volume was 35.1 mL. She also found that the sample weighed 30.5 g. What was the density of the liquid? What was the substance?

Toluene

$$\rightarrow \text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{30.5\ (\text{g})}{35.1\ (\text{mL})} = 0.868\ \text{g/mL}$$

Exercise 1.6 A piece of metal wire has a volume of 20.2 cm^3 and a mass of 159 g. What is the density of the metal? We know that the metal is manganese, iron, or nickel, and these have densities of 7.21 g/cm^3, 7.87 g/cm^3, and 8.90 g/cm^3, respectively. From which metal is the wire made?

See Problems 1.73, 1.74, 1.75, and 1.76.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{159\ \text{g}}{20.2\ \text{cm}^3} = 7.87\ \text{g/cm}^3$$

IRON

Example : 1.5

An experiment requires 43.7 g of isopropyl alcohol. Instead of measuring out the sample on a balance, a chemist dispenses the liquid into a graduated cylinder. The density of isopropyl alcohol is 0.785 g/mL. What volume of isopropyl alcohol should he use?

Mass = 43.7 (g)

Density = 0.785 g/mL

$D = \frac{M}{V} \Rightarrow 0.785 = \frac{43.7}{V}$

$V = 55.668$ ml

Exercise 1.7 Ethanol (grain alcohol) has a density of 0.789 g/cm³. What volume of ethanol must be poured into a graduated cylinder to equal 30.3 g?

See Problems 1.77, 1.78, 1.79, and 1.80.

Density = 0.789 cm³

Mass = 30.3g

$D = \frac{M}{V} \Rightarrow 0.789 = \frac{30.3}{V}$

$V = 38.4\ cm^3$

Learning Objectives / Important Terms

1.1 Modern Chemistry: A Brief Glimpse

Learning Objectives

- Provide examples of the contributions of chemistry to humanity.

1.2 Experiment and Explanation

Learning Objectives

- Describe how chemistry is an experimental science.
- Understand how the scientific method is an approach to performing science.

Important Terms

experiment
law
hypothesis
theory

1.3 Law of Conservation of Mass

Learning Objectives

- Explain the law of conservation of mass.
- Apply the law of the conservation of mass. Example 1.1

Important Terms

mass
matter
law of conservation of mass

1.4 Matter: Physical State and Chemical Composition

Learning Objectives

- Compare and contrast the three common states of matter: solid, liquid, and gas.
- Describe the classifications of matter: elements, compounds, and mixtures (heterogeneous and homogeneous).
- Understand the difference between chemical changes (chemical reactions) and physical changes.
- Distinguish between chemical properties and physical properties.

Important Terms

solid
liquid
gas
states of matter
physical change
chemical change (chemical reaction)
physical property
chemical property
substance
element
compound
law of definite proportions (law of constant composition)
mixture
heterogeneous mixture
homogeneous mixture (solution)
phase

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1.5 Measurement and Significant Figures

Learning Objectives

- Define and use the terms *precision* and *accuracy* when describing measured quantities.
- Learn the rules for determining significant figures in reported measurements.
- Know how to represent numbers using scientific notation.
- Apply the rules of significant figures to reporting calculated values.
- Be able to recognize exact numbers.
- Know when and how to apply the rules for rounding.
- Use significant figures in calculations. Example 1.2

Important Terms

unit
precision
accuracy
significant figures
number of significant figures
scientific notation
exact number
rounding

1.6 SI Units

- Become familiar with the SI (metric) system of units, including the SI prefixes.
- Convert from one temperature scale to another. Example 1.3

International System of units (SI)
SI base units
SI prefix
meter (m)
angstrom (Å)
kilogram (kg)
second (s)
Celsius scale
kelvin (K)

1.7 Derived Units

- Define and provide examples of derived units.
- Calculate the density of a substance. Example 1.4
- Use density to relate mass and volume. Example 1.5

SI derived unit
liter (L)
density

1.8 Units and Dimensional Analysis (Factor-Label Method)

- Apply dimensional analysis to solving numerical problems.
- Convert from one metric unit to another metric unit. Example 1.6
- Convert from one metric volume to another metric volume. Example 1.7
- Convert from any unit to another unit. Example 1.8

dimensional analysis (factor-label method)
conversion factor

Key Equations

$$T_K = \left(t_C \times \frac{1\ K}{1°C}\right) + 273.15\ K$$

$$t_C = \frac{5°C}{9°F} \times (t_F - 32°F)$$

$$d = m/V$$

Done by: Joud Jaber

Thank You