

EXAMPLE EXERCISE 3.1 Metric Basic Units and Prefixes

Give the symbol for each of the following metric units and state the quantity measured by each unit:

- (a) gigameter (b) kilogram
 (c) centiliter (d) microsecond

Solution

We compose the symbol for each unit by combining the prefix symbol and the basic unit symbol. If we refer to Tables 3.1 and 3.2, we have the following:

- (a) Gm, length
 (b) kg, mass
 (c) cL, volume
 (d) μs , time

TABLE 3.1 THE METRIC SYSTEM

PHYSICAL QUANTITY	BASIC UNIT	SYMBOL
length	meter*	m
mass	gram	g
volume	liter*	L
time	second	s

*The U.S. Metric Association recommends the spellings "meter" and "liter." All other English-speaking nations use the spellings "metre" and "litre."

TABLE 3.2 METRIC PREFIXES

PREFIX	SYMBOL	MULTIPLE/FRACTION
tera-	T	1,000,000,000,000 = 1×10^{12}
giga-	G	1,000,000,000 = 1×10^9
mega-	M	1,000,000 = 1×10^6
kilo-	k	1000 = 1×10^3
Basic unit: meter, gram, liter, second		
deci-	d	0.1 = 1×10^{-1}
centi-	c	0.01 = 1×10^{-2}
milli-	m	0.001 = 1×10^{-3}
micro-	m*	0.000 001 = 1×10^{-6}
nano-	n	0.000 000 001 = 1×10^{-9}
pico-	p	0.000 000 000 001 = 1×10^{-12}

EXAMPLE EXERCISE 3.1 Metric Basic Units and Prefixes

Continued

Practice Exercise

Give the symbol for each of the following metric units and state the quantity measured by each unit:

- | | |
|----------------|----------------|
| (a) nanosecond | (b) milliliter |
| (c) decigram | (d) megameter |

Answers: (a) ns, time; (b) mL, volume; (c) dg, mass; (d) Mm, length

Concept Exercise

What is the basic unit of length, mass, and volume in the metric system?

Answer: See Appendix G.

EXAMPLE EXERCISE 3.2 Metric Unit Equations

Complete the unit equation for each of the following exact metric equivalents:

- (a) 1 Mm = ? m (b) 1 kg = ? g
 (c) 1 L = ? dL (d) 1 s = ? ns

Solution

We can refer to Table 3.2 as necessary.

- (a) The prefix *mega-* means 1,000,000 basic units; thus, 1 Mm = 1,000,000 m.
 (b) The prefix *kilo-* means 1000 basic units; thus, 1 kg = 1000 g.
 (c) The prefix *deci-* means 0.1 of a basic unit, thus, 1 L = 10 dL.
 (d) The prefix *nano-* means 0.000 000 001 of a basic unit, thus; 1 s = 1,000,000,000 ns.

Alternatively, we can express the unit equation using exponential numbers:

- (a) 1 Mm = 1×10^6 m
 (b) 1 kg = 1×10^3 g
 (c) 1 L = 1×10^1 dL
 (d) 1 s = 1×10^9 ns

TABLE 3.2 METRIC PREFIXES

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giga-	G	1,000,000,000 = 1×10^9
mega-	M	1,000,000 = 1×10^6
kilo-	k	1000 = 1×10^3
Basic unit: meter, gram, liter, second		
deci-	d	0.1 = 1×10^{-1}
centi-	c	0.01 = 1×10^{-2}
milli-	m	0.001 = 1×10^{-3}
micro-	m*	0.000 001 = 1×10^{-6}
nano-	n	0.000 000 001 = 1×10^{-9}
pico-	p	0.000 000 000 001 = 1×10^{-12}



EXAMPLE EXERCISE 3.2 Metric Unit Equations

Continued

Practice Exercise

Complete the unit equation for each of the following exact metric equivalents:

(a) $1 \text{ Gm} = ? \text{ m}$

(b) $1 \text{ g} = ? \text{ cg}$

(c) $1 \text{ L} = ? \mu\text{L}$

(d) $1 \text{ s} = ? \text{ ms}$

Answers:

(a) $1 \text{ Gm} = 1 \times 10^9 \text{ m}$

(b) $1 \text{ g} = 1 \times 10^2 \text{ cg}$

(c) $1 \text{ L} = 1 \times 10^6 \mu\text{L}$

(d) $1 \text{ s} = 1 \times 10^3 \text{ ms}$

Concept Exercise

How many significant digits are in the following unit equation?

$$1 \text{ m} = 1000 \text{ mm}$$

Answer: See Appendix G.

EXAMPLE EXERCISE 3.3 Metric Unit Factors

Write two unit factors for each of the following metric relationships:

- (a) kilometers and meters (b) grams and decigrams

Solution

We start by writing the unit equation to generate the two unit factors.

- (a) The prefix *kilo-* means 1000 basic units; thus, 1 km = 1000 m. The two unit factors are

$$\frac{1 \text{ km}}{1000 \text{ m}} \quad \text{and} \quad \frac{1000 \text{ m}}{1 \text{ km}}$$

- (b) The prefix *deci-* means 0.1 basic unit; thus, 1 g = 10 dg. The two unit factors are

$$\frac{1 \text{ g}}{10 \text{ dg}} \quad \text{and} \quad \frac{10 \text{ dg}}{1 \text{ g}}$$

Practice Exercise

Write two unit factors for each of the following metric relationships:

- (a) liters and milliliters (b) megaseconds and seconds

Answers:

- (a) 1 L/1000 mL and 1000 mL/1 L (b) 1 Ms/1,000,000 s and 1,000,000 s/1 Ms

Concept Exercise

How many significant digits are in the following unit factor?

$$1 \text{ L}/1000 \text{ mL}$$

Answer: See Appendix G.

EXAMPLE EXERCISE 3.4 Metric–Metric Conversion

A hospital has 125 deciliter bags of blood plasma. What is the volume of plasma expressed in milliliters?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Given that 1 L = 10 dL, and 1 L = 1000 mL, the two pairs of unit factors are

Step 1:

mL

Step 2:

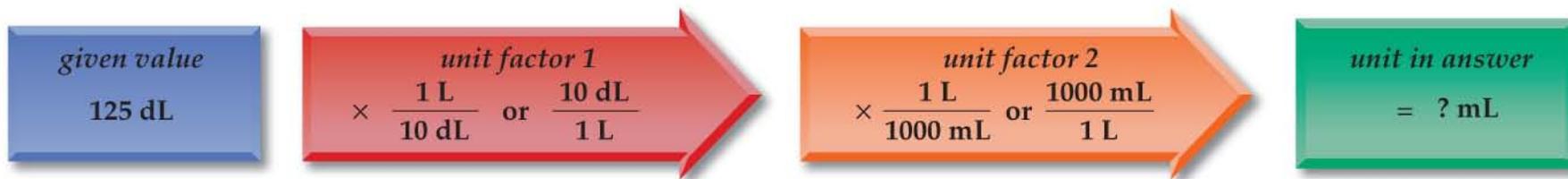
125 dL

Step 3:

$$\frac{1 \text{ L}}{10 \text{ dL}} \quad \text{or} \quad \frac{10 \text{ dL}}{1 \text{ L}}$$

$$\frac{1 \text{ L}}{1000 \text{ mL}} \quad \text{or} \quad \frac{1000 \text{ mL}}{1 \text{ L}}$$

Unit Analysis Map



EXAMPLE EXERCISE 3.4 Metric–Metric Conversion

Continued

Solution

We apply the unit factor 1 L/10 dL to cancel deciliters (dL), and 1000 mL/1 L to cancel liters (L).

$$125 \cancel{\text{dL}} \times \frac{1 \cancel{\text{L}}}{10 \cancel{\text{dL}}} \times \frac{1000 \text{ mL}}{1 \cancel{\text{L}}} = 1.25 \times 10^4 \text{ mL}$$

The given value, 125 dL, limits the answer to three significant digits. Since each unit factor is derived from an exact equivalent, neither affects the number of significant digits in the answer.

Practice Exercise

A dermatology patient is treated with ultraviolet light having a wavelength of 375 nm. What is the wavelength expressed in centimeters?

Answer: 0.0000375 cm (3.75×10^{-5} cm)

Concept Exercise

Express the volume of a cube 1 cm on a side in milliliters.

Answer: See Appendix G.

EXAMPLE EXERCISE 3.5 Metric–Metric Conversion

The mass of Earth is 5.98×10^{24} kg. What is the mass expressed in megagrams?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Given that $1 \text{ kg} = 1000 \text{ g}$, and $1 \text{ Mg} = 1,000,000 \text{ g}$, the two pairs of unit factors are



Earth

Earth The mass of Earth is about 6,000,000,000,000,000,000,000,000 kilograms.

Unit Analysis Map

given value
 $5.98 \times 10^{24} \text{ kg}$

unit factor 1
 $\times \frac{1 \text{ kg}}{1000 \text{ g}} \text{ or } \frac{1000 \text{ g}}{1 \text{ kg}}$

unit factor 2
 $\times \frac{1 \text{ Mg}}{1,000,000 \text{ g}} \text{ or } \frac{1,000,000 \text{ g}}{1 \text{ Mg}}$

unit in answer
 $= ? \text{ Mg}$

Step 1: Mg

Step 2: $5.98 \times 10^{24} \text{ kg}$

Step 3: $\frac{1 \text{ kg}}{1000 \text{ g}}$ or $\frac{1000 \text{ g}}{1 \text{ kg}}$

$\frac{1 \text{ Mg}}{1,000,000 \text{ g}}$ or $\frac{1,000,000 \text{ g}}{1 \text{ Mg}}$

EXAMPLE EXERCISE 3.5 Metric–Metric Conversion

Continued

Solution

We apply the unit factor 1000 g/1 kg to cancel kilograms (~~kg~~), and 1 Mg/1,000,000 g to cancel grams (~~g~~).

$$5.98 \times 10^{24} \cancel{\text{kg}} \times \frac{1000 \cancel{\text{g}}}{1 \cancel{\text{kg}}} \times \frac{1 \text{ Mg}}{1,000,000 \cancel{\text{g}}} = 5.98 \times 10^{21} \text{ Mg}$$

The given value limits the answer to three significant digits. Since each unit factor is derived from an exact equivalent, neither affects the number of significant digits in the answer.

Practice Exercise

Light travels through the universe at a velocity of 3.00×10^{10} cm/s. How many gigameters does light travel in one second?

Answer: 0.300 Gm (3.00×10^{-1} Gm)

Concept Exercise

How many significant digits are in the following unit factor?

$$1 \text{ g}/1000 \text{ mgn}$$

Answer: See Appendix G.

EXAMPLE EXERCISE 3.6 Metric–English Conversion

A half-gallon carton contains 64.0 fl oz of milk. How many milliliters of milk are in a carton (given that 1 qt = 32 fl oz)?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Given that 1 qt = 32 fl oz and that in Table 3.3 we find that 1 qt = 946 mL.

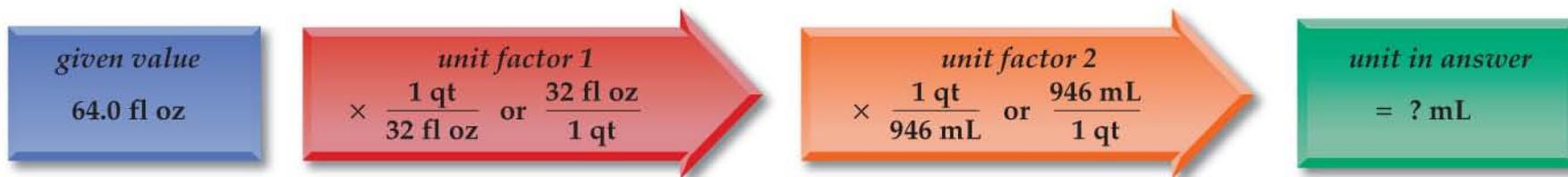
The two pairs of unit factors are

TABLE 3.3 ENGLISH–METRIC EQUIVALENTS

PHYSICAL QUANTITY	ENGLISH UNIT	METRIC EQUIVALENT
length	1 inch (in.)	1 in. = 2.54 cm
mass	1 pound (lb)	1 lb = 454 g
volume	1 quart (qt)	1 qt = 946 mL
time	1 second (sec)	1 sec = 1.00 s

When applying these metric equivalents, assume three significant digits. Since the metric and English systems have different reference standards, these are not exact equivalents; however, the U.S. Bureau of Weights and Measures has redefined 1 in. as exactly equal to 2.54 cm.

Unit Analysis Map



Step 1:

mL

Step 2:

64.0 fl oz

Step 3:

$\frac{1 \text{ qt}}{32 \text{ fl oz}}$ or $\frac{32 \text{ fl oz}}{1 \text{ qt}}$

$\frac{1 \text{ qt}}{946 \text{ mL}}$ or $\frac{946 \text{ mL}}{1 \text{ qt}}$

EXAMPLE EXERCISE 3.6 Metric–English Conversion

Continued

Solution

We apply the unit factor $1 \text{ qt}/32 \text{ fl oz}$ to cancel fluid ounces (~~fl oz~~), and $946 \text{ mL}/1 \text{ qt}$ to cancel quarts (~~qt~~).

$$64.0 \cancel{\text{ fl oz}} \times \frac{1 \cancel{\text{ qt}}}{32 \cancel{\text{ fl oz}}} \times \frac{946 \text{ mL}}{1 \cancel{\text{ qt}}} = 1,890 \text{ mL}$$

The given value, and unit factor 2, each limits the answer to three significant digits. Since unit factor 1 is derived from an exact equivalent, it does not affect the number of significant digits in the answer.

Practice Exercise

A plastic bottle contains 5.00 gallons of distilled water. How many liters of distilled water are in the bottle (given that $1 \text{ gal} = 4 \text{ qt}$)?

Answer: 18.9 L

Concept Exercise

How many significant digits are in the following unit factor?

$$1 \text{ qt}/946 \text{ mL}$$

Answer: See Appendix G.



Milk Carton A half-gallon carton of milk has a volume of 64.0 fluid ounces.

EXAMPLE EXERCISE 3.7 Metric–English Conversion

If a tennis ball weighs 2.0 oz, what is the mass of the tennis ball in grams?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Given that 1 lb = 16 oz and that in Table 3.3 we find that 1 lb = 454 g. The two pairs of unit factors are

Step 1:

g

Step 2:

2.0 oz

Step 3:

$\frac{1 \text{ lb}}{16 \text{ oz}}$ or $\frac{16 \text{ oz}}{1 \text{ lb}}$

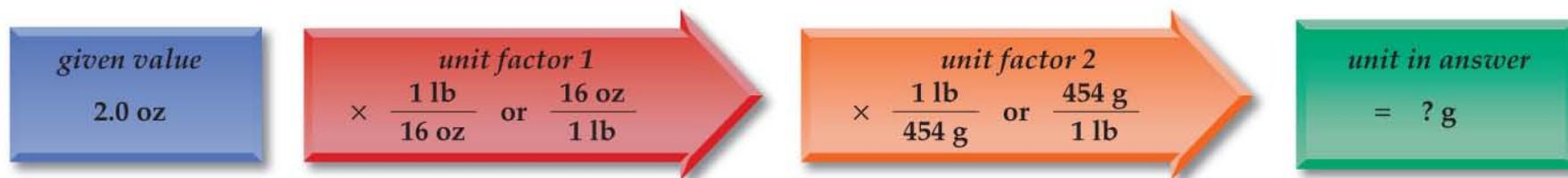
$\frac{1 \text{ lb}}{454 \text{ g}}$ or $\frac{454 \text{ g}}{1 \text{ lb}}$

TABLE 3.3 ENGLISH–METRIC EQUIVALENTS

PHYSICAL QUANTITY	ENGLISH UNIT	METRIC EQUIVALENT
length	1 inch (in.)	1 in. = 2.54 cm
mass	1 pound (lb)	1 lb = 454 g
volume	1 quart (qt)	1 qt = 946 mL
time	1 second (sec)	1 sec = 1.00 s

When applying these metric equivalents, assume three significant digits. Since the metric and English systems have different reference standards, these are not exact equivalents; however, the U.S. Bureau of Weights and Measures has redefined 1 in. as exactly equal to 2.54 cm.

Unit Analysis Map



EXAMPLE EXERCISE 3.7 Metric–English Conversion

Continued

Solution

We apply the unit factor 1 lb/16 oz to cancel ounces (oz), and 454 g/1 lb to cancel pounds (lb).

$$2.0 \text{ oz} \times \frac{1 \text{ lb}}{16 \text{ oz}} \times \frac{454 \text{ g}}{1 \text{ lb}} = 57 \text{ g}$$

The given value, 2.0 oz, limits the answer to two significant digits. Unit factor 1 has no effect as it is derived from an exact equivalent, and unit factor 2 has three significant digits.

Practice Exercise

If a tennis ball has a diameter of 2.5 inches, what is the diameter in millimeters?

Answer: 64 mm

Concept Exercise

How many significant digits are in the following unit factor?

$$1 \text{ kg}/2.20 \text{ lb}$$

Answer: See Appendix G.



Tennis Balls A tennis ball weighs about 2.0 ounces, and has a diameter of 2.5 inches.

EXAMPLE EXERCISE 3.8 Conversion of a Unit Ratio

If a Mazda Miata is traveling at 95 km/h, what is the speed in meters per second (given that 1 km = 1000 m, and 1 h = 3600 s)?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Given that 1 km = 1000 m, and 1 h = 3600 s, the two pairs of unit factors are

Step 1:

$$\frac{\text{m}}{\text{s}}$$

Step 2:

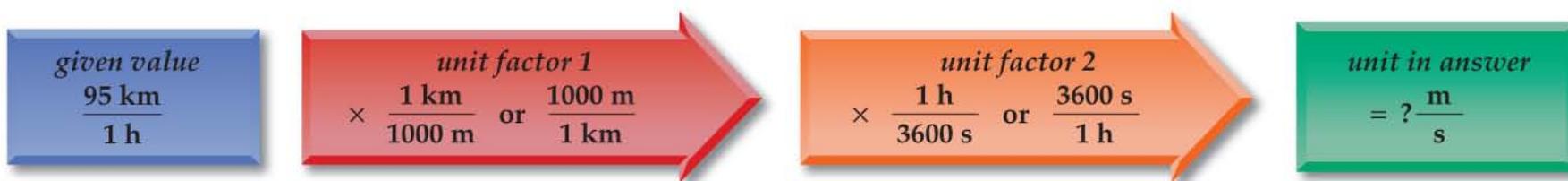
$$\frac{95 \text{ km}}{1 \text{ h}}$$

Step 3:

$$\frac{1 \text{ km}}{1000 \text{ m}} \quad \text{or} \quad \frac{1000 \text{ m}}{1 \text{ km}}$$

$$\frac{1 \text{ h}}{3600 \text{ s}} \quad \text{or} \quad \frac{3600 \text{ s}}{1 \text{ h}}$$

Unit Analysis Map



EXAMPLE EXERCISE 3.8 Conversion of a Unit Ratio

Continued

Solution

We apply the unit factor 1000 m/1 km to cancel kilometers (km), and 1 h/3600 s to cancel hours (h)

$$95 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 26 \text{ m/s}$$

The given value has two significant digits, so the answer is limited to two digits. Since each unit factor is derived from an exact equivalent, neither affects the number of significant digits in the answer.

Practice Exercise

If a runner completes a 10K race in 32.50 minutes (min), what is the 10.0 km pace in miles per hour (given that 1 mi = 1.61 km)?

Answer: 11.5 mi/h

Concept Exercise

Which speed is faster: 65 mi/h or 65 km/h?

Answer: See Appendix G.



Mazda Miata A Mazda Miata.

EXAMPLE EXERCISE 3.9 Volume Calculation for a Rectangular Solid

If a stainless steel rectangular solid measures 5.55 cm long, 3.75 cm wide, and 2.25 cm thick, what is the volume in cubic centimeters?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

No unit factor is required.

Step 1:

cm³

Step 2:

5.55 cm, 3.75 cm, and 2.25 cm

Step 3:

none

Solution

We can calculate the volume of the rectangular solid by multiplying length times width times thickness: $l \times w \times t$.

$$5.55 \text{ cm} \times 3.75 \text{ cm} \times 2.25 \text{ cm} = 46.8 \text{ cm}^3$$

The answer is rounded off to three significant digits because each given value has three significant digits.

EXAMPLE EXERCISE 3.9 Volume Calculation for a Rectangular Solid

Continued

Practice Exercise

If a rectangular brass solid measures 52.0 mm by 25.0 mm by 15.0 mm, what is the volume in cubic millimeters?

Answer: 19.500 mm^3 ($1.95 \times 10^4 \text{ mm}^3$)

Concept Exercise

Express the volume of a cube 10 cm on a side in liters.

Answer: See Appendix G.

EXAMPLE EXERCISE 3.10 Thickness Calculation for a Rectangular Solid

A sheet of aluminum foil measures 25.0 mm by 10.0 mm, and the volume is 3.75 mm³. What is the thickness of the foil in millimeters?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

No unit factor is required.

Step 1:

mm

Step 2:

3.75 mm³, 25.0 mm, and 10.0 mm

Step 3:

none

Solution

We can calculate the thickness of the foil by dividing the volume by length and width. Since the unit of volume is mm³, we obtain the thickness in mm by unit cancellation.

$$3.75 \text{ mm}^3 \times \frac{1}{25.0 \text{ mm}} \times \frac{1}{10.0 \text{ mm}} = \frac{3.75 \text{ mm} \times \cancel{\text{mm}} \times \cancel{\text{mm}}}{25.0 \cancel{\text{mm}} \times 10.0 \cancel{\text{mm}}} = 0.0150 \text{ mm}$$

The answer is rounded off to three significant digits because each given value has three significant digits.

EXAMPLE EXERCISE 3.10 Thickness Calculation for a Rectangular Solid

Continued

Practice Exercise

A sheet of aluminum foil measures 35.0 cm by 25.0 cm, and the volume is 1.36 cm³. What is the thickness of the foil in centimeters?

Answer: 0.00155 cm (1.55×10^{-3} cm)

Concept Exercise

Which of the following is the greatest thickness?

1 mm, 0.1 cm, or 0.001 m

Answer: See Appendix G.



Aluminum foil A thin sheet of aluminum foil.

EXAMPLE EXERCISE 3.11 Metric–English Volume Conversion

Given that an automobile engine has a volume displacement of 498 cm^3 in each cylinder, express the volume in cubic inches.

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Step 1:

in.^3

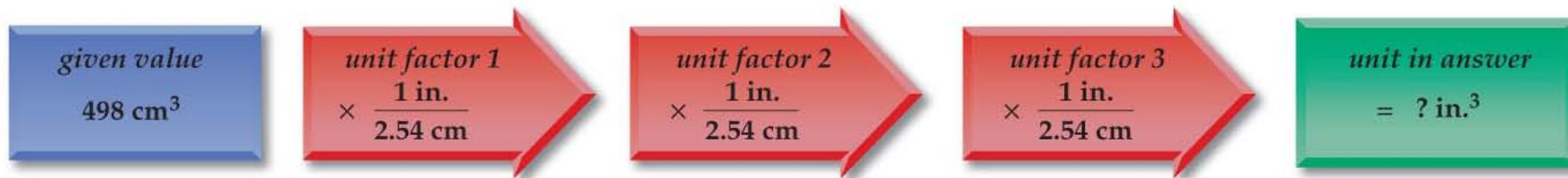
Step 2:

498 cm^3

Step 3:

$\frac{1 \text{ in.}}{2.54 \text{ cm}}$ or $\frac{2.54 \text{ cm}}{1 \text{ in.}}$

Unit Analysis Map



EXAMPLE EXERCISE 3.11 Metric–English Volume Conversion

Continued

Solution

We can calculate the volume in cubic inches by converting the volume given in cubic centimeters. Notice that cm units do not cancel cm^3 . To obtain cubic inches, we must apply the unit factor, 1 in./2.54 cm, three times. Thus,

$$498 \text{ cm}^3 \times \frac{1 \text{ in.}}{2.54 \text{ cm}} \times \frac{1 \text{ in.}}{2.54 \text{ cm}} \times \frac{1 \text{ in.}}{2.54 \text{ cm}} = 30.4 \text{ in.}^3$$

The given value, and unit factors, each limits the answer to three significant digits.

Practice Exercise

Given that an SUV has a 244 in.^3 engine, express the engine volume in liters.

Answer: 4.00 L

Concept Exercise

Which of the following is the greater volume?

500 mL or 500 cm^3

Answer: See Appendix G.

Jonathan Player/The New York Times



Mini Cooper The Mini Cooper is built in England and marketed in the United States by BMW.

EXAMPLE EXERCISE 3.12 Volume by Displacement

A quartz stone weighing 30.475 g is dropped into a graduated cylinder. If the water level increases from 25.0 mL to 36.5 mL, what is the volume of the quartz stone?

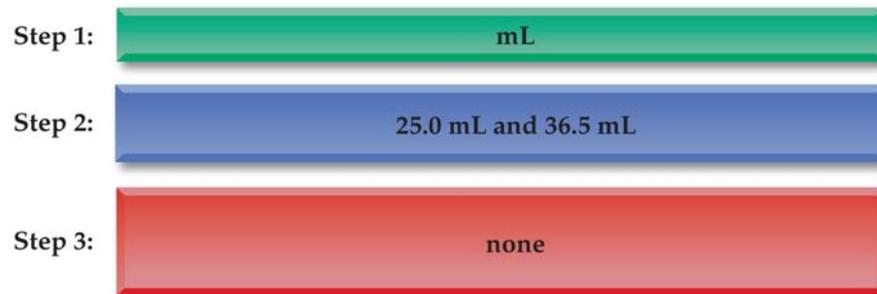
Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

No unit factor is required.



Solution

We can calculate the displaced volume in milliliters by subtracting the initial volume from the final volume.

$$36.5 \text{ mL} - 25.0 \text{ mL} = 11.5 \text{ mL}$$

Practice Exercise

Hydrogen peroxide decomposes to give oxygen gas, which displaces a volume of water into a beaker. If the water level in the beaker increases from 50.0 mL to 105.5 mL, what is the volume of oxygen gas?

Answer: 55.5 mL

EXAMPLE EXERCISE 3.12 Volume by Displacement

Continued

Concept Exercise

Which of the following has the greater volume?

1 mL or 1 cm³

Answer: See Appendix G.

EXAMPLE EXERCISE 3.13 Density Calculation

If a platinum nugget has a mass of 214.50 g and a volume 10.0 cm³, what is the density of the metal?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

No unit factor is required.

Step 1:

g/cm³

Step 2:

214.50 g and 10.0 cm³

Step 3:

none

Solution

We can calculate the density of the platinum nugget by comparing the mass of metal, 214.50 g, to its volume, 10.0 cm³.

$$\frac{214.50 \text{ g}}{10.0 \text{ cm}^3} = 21.5 \text{ g/cm}^3$$

The given volume has three significant digits, so the answer is rounded off to three digits. It is interesting to note that platinum metal is more dense than lead ($d = 11.3 \text{ g/cm}^3$), and more valuable than gold.



Platinum Nugget A small nugget of precious platinum metal.

EXAMPLE EXERCISE 3.13 Density Calculation

Continued

Practice Exercise

Carbon tetrachloride is a solvent used for degreasing electronic parts. If 25.0 mL of carbon tetrachloride has a mass of 39.75 g, what is the density of the liquid?

Answer: 1.59 g/mL

Concept Exercise

Which of the following has the greater density: ice or water?

Answer: See Appendix G.

EXAMPLE EXERCISE 3.14 Density as a Unit Factor

An automobile battery contains 1275 mL of sulfuric acid. If the density of battery acid is 1.84 g/mL, how many grams of acid are in the battery?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

From the definition of density, 1.84 g = 1 mL;
thus, the two unit factors are 1.84 g/1 mL,
and its reciprocal 1 mL /1.84 g.

Step 1:

g

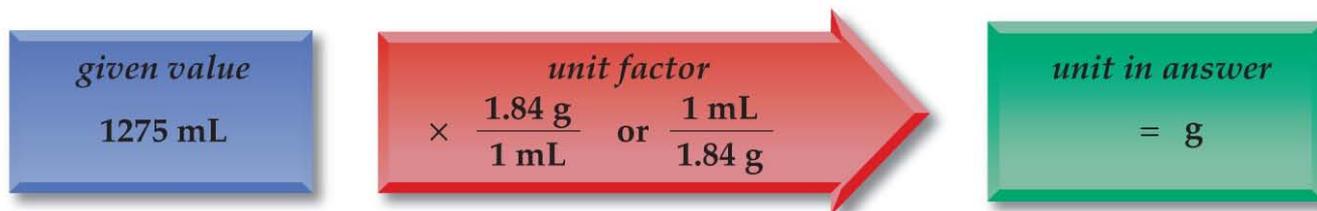
Step 2:

1275 mL

Step 3:

$\frac{1.84 \text{ g}}{1 \text{ mL}}$ or $\frac{1 \text{ mL}}{1.84 \text{ g}}$

Unit Analysis Map



EXAMPLE EXERCISE 3.14 Density as a Unit Factor

Continued

Solution

We apply the unit factor 1.84 g/1 mL to cancel milliliters (mL) which appears in the denominator.

$$1275 \text{ mL} \times \frac{1.84 \text{ g}}{1 \text{ mL}} = 2350 \text{ g}$$

The given value, 1275 mL, has four significant digits, but the unit factor has only three digits. Therefore, the answer is rounded off to three digits. Battery acid is the common name for sulfuric acid, which annually ranks as the most important industrial chemical.

Practice Exercise

The most abundant gases in our atmosphere are nitrogen, oxygen, and argon. What is the volume of 1.00 kg of air? (Assume the density of air is 1.29 g/L.)

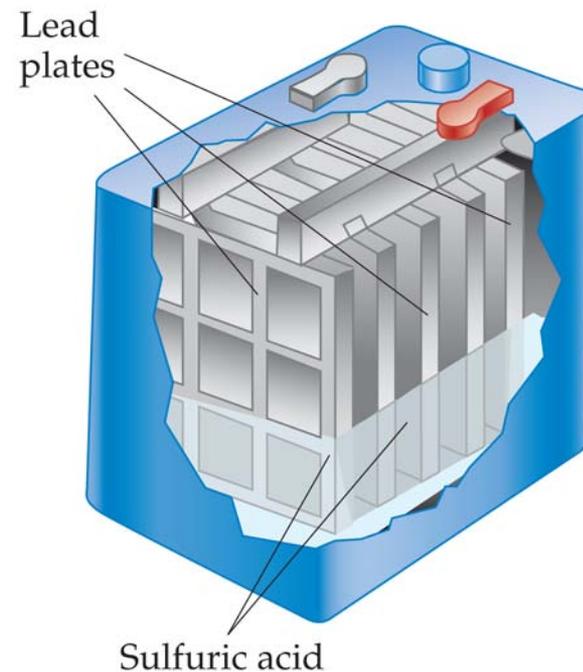
Answer: 775 L

Concept Exercise

Which of the following is the greater density?

1 g/mL or 1 kg/L

Answer: See Appendix G.



Automobile Battery An automobile battery contains lead plates and is filled with sulfuric acid.

EXAMPLE EXERCISE 3.15 Density as a Unit Factor

A 1.00-in. cube of copper measures 2.54 cm on a side. What is the mass of the copper cube (given that d of copper = 8.96 g/cm^3)?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

From the definition of density, $8.96 \text{ g} = 1 \text{ cm}^3$; thus, the two unit factors are $8.96 \text{ g}/1 \text{ cm}^3$, and its reciprocal $1 \text{ cm}^3/8.96 \text{ g}$.

Step 1:

g

Step 2:

2.54 cm cube

Step 3:

$\frac{8.96 \text{ g}}{1 \text{ cm}^3}$ or $\frac{1 \text{ cm}^3}{8.96 \text{ g}}$

Unit Analysis Map

given value
2.54 cm cube

unit factor
 $\times \frac{8.96 \text{ g}}{1 \text{ cm}^3}$ or $\frac{1 \text{ cm}^3}{8.96 \text{ g}}$

unit in answer
= g

EXAMPLE EXERCISE 3.15 Density as a Unit Factor

Continued

Solution

First, we find the volume of the copper cube. We obtain the volume of the cube, 16.4 cm^3 , by multiplying $(2.54 \text{ cm}) (2.54 \text{ cm}) (2.54 \text{ cm})$. We use the given density, $8.96 \text{ g}/1 \text{ cm}^3$, as a unit factor to cancel cubic centimeters (cm^3), which appears in the denominator.

$$16.4 \text{ cm}^3 \times \frac{8.96 \text{ g}}{1 \text{ cm}^3} = 147 \text{ g}$$

The given value and unit factor each has three significant digits, so the answer is rounded off to three significant digits.

Practice Exercise

A cube of silver is 5.00 cm on a side and has a mass of 1312.5 g . What is the density of silver?

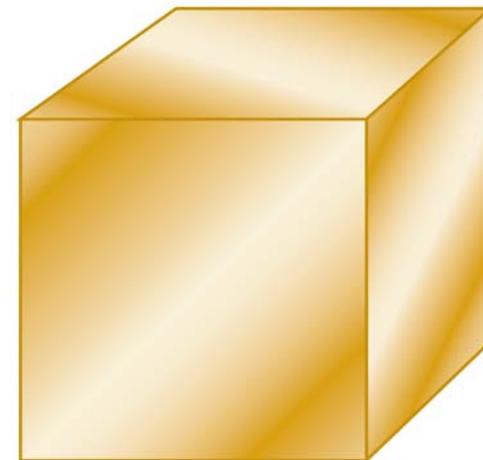
Answer: $10.5 \text{ g}/\text{cm}^3$

Concept Exercise

If some humans float in water and other sink, what is the approximate density of the human body?

Answer: See Appendix G.

Copper



Copper Metal A 1.00-inch cube of copper metal.

EXAMPLE EXERCISE 3.16 °F and °C Temperature Conversions

Normal body temperature is 98.6 °F. What is normal body temperature in degrees Celsius?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

No unit factor is required.

Solution

To calculate °C, we refer to Figure 3.6 and compare the Celsius and Fahrenheit temperature scales. The conversion from °F to °C is as follows.

$$(98.6\text{ }^{\circ}\text{F} - 32\text{ }^{\circ}\text{F}) \times \frac{100\text{ }^{\circ}\text{C}}{180\text{ }^{\circ}\text{F}} = \text{ }^{\circ}\text{C}$$

Simplifying and canceling units gives

$$66.6\text{ }^{\circ}\text{F} \times \frac{100\text{ }^{\circ}\text{C}}{180\text{ }^{\circ}\text{F}} = 37.0\text{ }^{\circ}\text{C}$$

The given value, 98.6 °F, has three significant digits, so the answer is rounded off to three digits. Since 32 °F and 100 °C/180 °F are exact numbers, neither affects the significant digits in the answer.

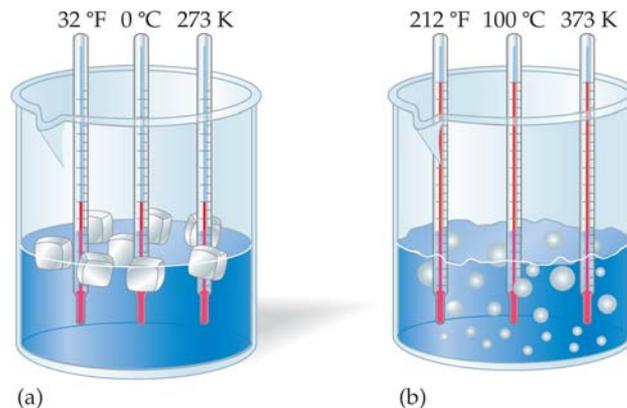
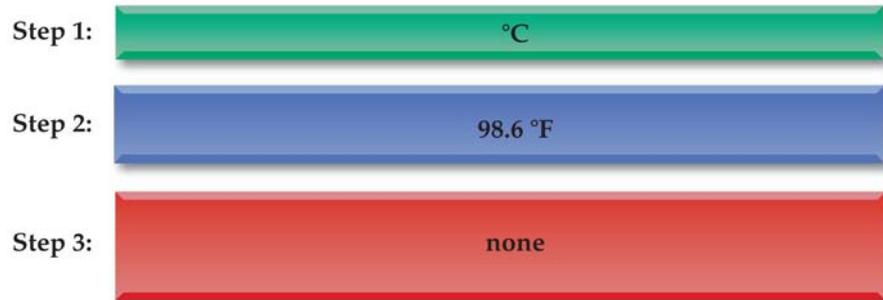


Figure 3.6 Temperature Scales A Fahrenheit, a Celsius, and a Kelvin thermometer are placed in (a) ice water and (b) boiling water. Notice the freezing point and boiling point on each scale. The number of divisions is 180 units on the Fahrenheit scale, 100 units on the Celsius scale, and 100 units on the Kelvin scale.

EXAMPLE EXERCISE 3.16 °F and °C Temperature Conversions

Continued

Practice Exercise

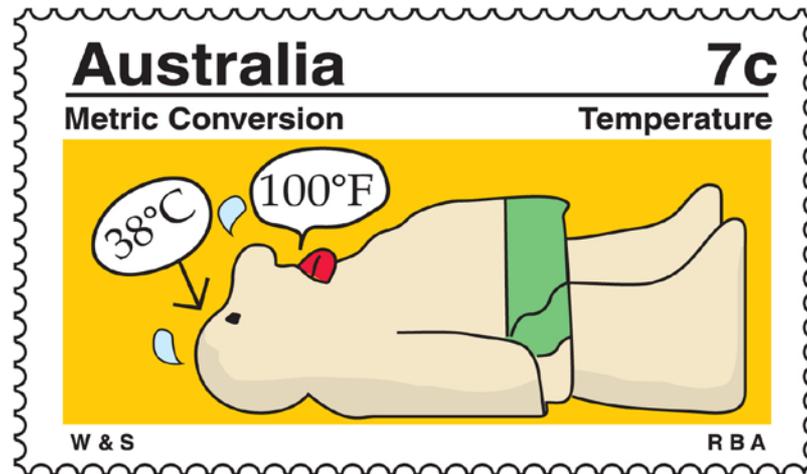
The average surface temperature of Mars is $-55\text{ }^{\circ}\text{C}$. What is the average temperature in degrees Fahrenheit?

Answer: $-67\text{ }^{\circ}\text{F}$

Concept Exercise

What is the relationship between the Celsius and centigrade temperature scales?

Answer: See Appendix G.



Australian Stamp The cartoon illustrates that $38\text{ }^{\circ}\text{C}$ is approximately equal to $100\text{ }^{\circ}\text{F}$

EXAMPLE EXERCISE 3.17 °C and K Temperature Conversions

Dermatologists use liquid nitrogen to freeze skin tissue. If the Celsius temperature of liquid nitrogen is $-196\text{ }^{\circ}\text{C}$, what is the Kelvin temperature?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

No unit factor is required.

Solution

Given the Celsius temperature, we add 273 units to find the corresponding Kelvin temperature.

$$-1.96\text{ }^{\circ}\text{C} + 273 = 77\text{ k}$$

Step 1:

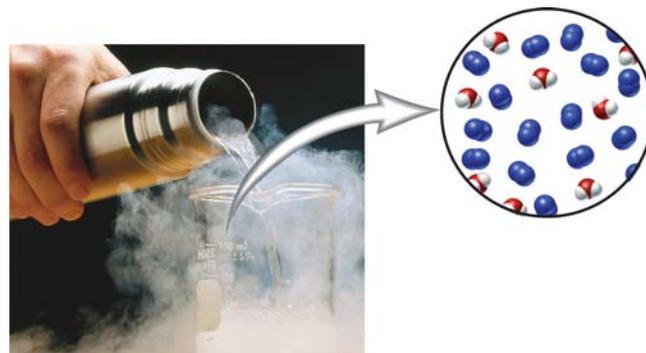
K

Step 2:

$-196\text{ }^{\circ}\text{C}$

Step 3:

none



Liquid Nitrogen Although nitrogen is normally a gas, it liquefies at $-196\text{ }^{\circ}\text{C}$. When liquid nitrogen is poured from a Thermos, it is cold enough to freeze the moisture in air and form a white mist.

EXAMPLE EXERCISE 3.17 °C and K Temperature Conversions

Continued

Practice Exercise

The secret to “fire-walking” is to first walk barefoot through damp grass and then step lively on the red-hot coals. If the bed of coals is 1475 K, what is the Celsius temperature?

Answer: 1202 °C

Concept Exercise

Which of the following temperatures does not exist?

–100 °F, –100 °C, –100 K

Answer: See Appendix G.

EXAMPLE EXERCISE 3.18 Energy Conversion

Burning one liter of natural gas produces 9.46 kcal of heat energy. Express the energy in kilojoules (given that 1 kcal = 4.184 kJ).

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Since the unit equation is 1 kcal = 4.184 kJ, the two unit factors are 1 kcal/4.184 kJ, and its reciprocal 4.184 kJ / 1 kcal.

Step 1:

kJ

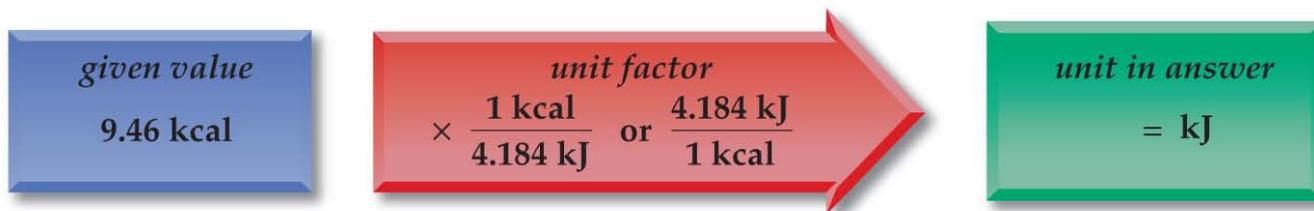
Step 2:

9.46 kcal

Step 3:

$\frac{1 \text{ kcal}}{4.184 \text{ kJ}}$ or $\frac{4.184 \text{ kJ}}{1 \text{ kcal}}$

Unit Analysis Map



EXAMPLE EXERCISE 3.18 Energy Conversion

Continued

Solution

We apply the unit factor 4.184 kJ / 1 kcal to cancel kilocalories (kcal), which appears in the denominator.

$$9.46 \text{ kcal} \times \frac{4.184 \text{ kJ}}{1 \text{ kcal}} = 39.6 \text{ kJ}$$

The given value has three significant digits, and the unit factor has four digits. Thus, we round off the answer to three significant digits.

Practice Exercise

Burning one gram of gasoline produces 47.9 kJ of energy. Express the heat energy in kilocalories (given that 1 kcal = 4.184 kJ).

Answer: 11.4 kcal

Concept Exercise

If an aerosol can feels cold after releasing the spray, is heat flowing from the can or from your hand?

Answer: See Appendix G.



Bunsen Burner A laboratory burner that uses natural gas for fuel.

EXAMPLE EXERCISE 3.19 Specific Heat

An energy-efficient home may have solar panels for heating water. If 350,000 cal heat water from 20.0 °C to 35.0 °C, what is the mass of water (specific heat = 1.00 cal/g × °C)?

Strategy Plan

Step 1: What unit is asked for in the answer?

Step 2: What given value is related to the answer?

Step 3: What unit factor(s) should we apply?

Step 1:

g

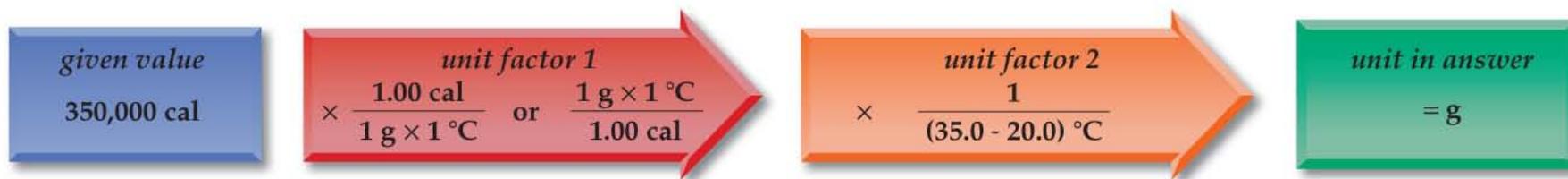
Step 2:

350,000 cal, 20.0 °C to 35.0 °C

Step 3:

$\frac{1.00 \text{ cal}}{1 \text{ g} \times 1 \text{ }^\circ\text{C}}$ or $\frac{1 \text{ g} \times 1 \text{ }^\circ\text{C}}{1.00 \text{ cal}}$

Unit Analysis Map



EXAMPLE EXERCISE 3.19 Specific Heat

Continued

Solution

We apply the unit factor to cancel calories (cal), and (35.0 – 20.0) °C to cancel degrees Celsius (°C).

$$350,000 \text{ cal} \times \frac{1 \text{ g} \times 1 \text{ }^\circ\text{C}}{1.00 \text{ cal}} \times \frac{1}{(35.0 - 20.0) \text{ }^\circ\text{C}} = 23,000 \text{ g (23 kg)}$$

Practice Exercise

A 725 g steel horseshoe is heated to 425 °C and dropped into a bucket of cold water. If the horseshoe cools to 20 °C and the specific heat of steel is 0.11 cal/g × °C, how much heat is released?

Answer: 32,000 cal (32 kcal)

Concept Exercise

If the crust of an apple pie cooks faster than the filling, which has the higher specific heat: the crust or apple filling?

Answer: See Appendix G.



Solar Panels on Rooftop Solar panels collect light energy from the Sun, which is converted to heat energy for the home.