2.7: Multi-Step Conversions

Learning Objectives

- To convert a value reported in one unit to a corresponding value in a different unit using multiple conversion factors.

Multiple Conversions

In some cases, multiple conversions are required to obtain the desired unit. For example, suppose we want to convert 54.7 km to millimeters. We will set up a series of conversion factors so that each conversion factor produces the next unit in the sequence.

We may first convert the given amount in km to meters, knowing that 1 km = 1000 m, then from meters to millimeters, knowing that 1 mm = 10^{-3} m.

Concept Map

$$\text{km} \xrightarrow[1\ \text{km}]{1000\ \text{m}} \text{m} \xrightarrow[10^{-3}\ \text{m}]{1\ \text{mm}} \text{mm}$$

Calculation

$$54.7\ \cancel{\text{km}} \times \frac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}} \times \frac{1\ \text{mm}}{10^{-3}\ \cancel{\text{m}}} = \boxed{54{,}700{,}000\ \text{mm}}$$

$$= \boxed{5.47 \times 10^{7}\ \text{mm}}$$

Multi-Step Conversions

In each step, the previous unit is canceled and the next unit in the sequence is produced, with each successive unit canceling out until only the desired unit in the answer remains.

Example 2.7.1

Convert 58.2 milligrams to megagrams in one multi-step calculation.

Solution

Steps for Problem Solving	
Identify the "given" information and what the problem is asking you to "find."	Given: 58.2 mg Find: Mg
List other known quantities. Metric prefixes are found in 2.5: The Metric System. Other conversions may be found in Appendix 2: Conversions.	1 mg = 10^{-3} g 1 Mg = 10^{6} g
Prepare a concept map and use the proper conversion factor(s).	$\text{mg} \xrightarrow[1\ \text{mg}]{10^{-3}\ \text{g}} \text{g} \xrightarrow[10^{6}\ \text{g}]{1\ \text{Mg}} \text{Mg}$
Calculate the answer.	$58.2\ \cancel{\text{mg}} \times \frac{10^{-3}\ \cancel{\text{g}}}{1\ \cancel{\text{mg}}} \times \frac{1\ \text{Mg}}{1{,}000{,}000\ \cancel{\text{g}}} = \boxed{0.0000000582\ \text{Mg}}$ $= \boxed{5.82 \times 10^{-8}\ \text{Mg}}$ Neither conversion factor affects the number of significant figures in the final answer.
Think about your result.	Milligrams are a tiny unit. Megagrams are a huge unit. It makes sense that the larger number is associated with the smaller unit (mg) and that the smaller number is associated with the larger unit (Mg).

✅ Example 2.7.2

Express a speed of 65 mi/h in SI units (m/s).

Solution 1

Steps for Problem Solving	
Identify the "given" information and what the problem is asking you to "find."	Given: 65 mi/h Find: m/s
List other known quantities. Metric prefixes are found in 2.5: The Metric System. Other conversions may be found in Appendix 2: Conversions. Pay close attention to the distinction between m, mi, and min.	1 mi = 1.609 km 1 km = 1000 m 1 h = 60 min 1 min = 60 s
Prepare a concept map and use the proper conversion factor(s).	$\frac{\text{mi}}{\text{h}} \xrightarrow[1\ \text{mi}]{1.609\ \text{km}} \frac{\text{km}}{\text{h}} \xrightarrow[1\ \text{km}]{1000\ \text{m}} \frac{\text{m}}{\text{h}} \xrightarrow[60\ \text{min}]{1\ \text{h}} \frac{\text{m}}{\text{min}} \xrightarrow[60\ \text{s}]{1\ \text{m}}$
Calculate the answer.	$\frac{65\ \cancel{\text{mi}}}{\cancel{\text{h}}} \times \frac{1.609\ \cancel{\text{km}}}{1\ \cancel{\text{mi}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}} \times \frac{1\ \cancel{\text{min}}}{60\ \text{s}} = \boxed{29\ \frac{\text{m}}{\text{s}}}$
Think about your result.	It matches the answer calculated using a different set of conversion factors. (see Solution 2)

Solution 2

Steps for Problem Solving	
Identify the "given" information and what the problem is asking you to "find."	Given: 65 mi/h Find: m/s
List other known quantities. Metric prefixes are found in 2.5: The Metric System. Other conversions may be found in Appendix 2: Conversions. Pay close attention to the distinction between m, mi, and min.	1 mi = 5280 ft 1 m = 3.281 ft 1 h = 3600 s
Prepare a concept map and use the proper conversion factor(s).	$\frac{\text{mi}}{\text{h}} \xrightarrow[3600\ \text{s}]{1\ \text{h}} \frac{\text{mi}}{\text{s}} \xrightarrow[1\ \text{mi}]{5280\ \text{ft}} \frac{\text{ft}}{\text{s}} \xrightarrow[3.281\ \text{ft}]{1\ \text{m}} \frac{\text{m}}{\text{s}}$
Calculate the answer.	$\frac{65\ \cancel{\text{mi}}}{\cancel{\text{h}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} \times \frac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}} \times \frac{1\ \text{m}}{3.281\ \cancel{\text{ft}}} = \boxed{29\ \frac{\text{m}}{\text{s}}}$
Think about your result.	It matches the answer calculated using a different set of conversion factors. (see Solution 1)

Example 2.7.2 above shows two different solutions. However, the end result is the same, 65 mi/h is the same as 29 m/s. This demonstrates one of the major advantages of using dimensional analysis as a problem-solving tool. There are no formulas to learn or memorize. One must simply pay attention to the conversion factors to ensure that the proper units cancel out and leave the desired units for the answer.

Example 2.7.2 also shows the importance of placing the correct units in the numerator and denominator. When using units that show one type of unit "per" another type of unit, the unit that precedes the / symbol belongs in the numerator, while the unit that follows the / symbol belongs in the denominator. Just like we think of 65 mi/h as $65\frac{\text{mi}}{\text{h}}$, we should also think of 2.70 g/mL as $2.70\frac{\text{g}}{\text{mL}}$. By doing so, you will ensure that units cancel properly when setting up a

dimensional analysis calculation.

✏️ Exercise 2.7.1

Perform each conversion in one multi-step calculation.

A. Convert 43.007 nL to kL.
B. One lap around a modern running track is 400 m. Track events used to be measured in yards. Convert 400 m to yd. Round your answer to three significant figures.
C. How many seconds are in one day?

Answer A

4.3007×10^{-11} kL

Answer B

437 yd

Answer C

8.64×10^{4} s

⚖️ Career Focus: Pharmacist

A pharmacist dispenses drugs that have been prescribed by a doctor. Although that may sound straightforward, pharmacists in the United States must hold a doctorate in pharmacy and be licensed by the state in which they work. Most pharmacy programs require four years of education in a specialty pharmacy school. Pharmacists must know a lot of chemistry and biology in order to understand the effects that drugs (which are chemicals, after all) have on the body. Pharmacists can advise physicians on the selection, dosage, interactions, and side effects of drugs. They can also advise patients on the proper use of their medications, including when and how to take specific drugs properly. Pharmacists can be found in drugstores, hospitals, and other medical facilities. Curiously, an outdated name for pharmacist is *chemist*, which was used when pharmacists formerly did a lot of drug preparation, or *compounding*. In modern times, pharmacists rarely compound their own drugs, but their knowledge of the sciences, including chemistry, helps them provide valuable services in support of everyone's health.

Figure 2.7.1: A woman consulting with a pharmacist. (Public Domain; Rhoda Baer via National Cancer Institute, an agency that is part of the National Institutes of Health.)

Summary

- In multi-step conversion problems, the previous unit is canceled for each step and the next unit in the sequence is produced, each successive unit canceling out until only the unit needed in the answer is left.