# Conversion Factors

Conversion factors are ratios of one object to another object. A ratio is a way of comparing two quantities. The quantities can be compared in three different ways: *a to b*, *a:b,* or *a/b*. At the local grocery store, a case of soda contains 24 cans. We can express the ratio in three forms:

(*a to b*) 24 cans of soda to each case of soda
(*a:b*) 24 cans of soda: 1 case of soda
(*a/b*) 24 cans of soda/1 case of soda

This chapter uses conversion factors frequently to solve problems. Conversion factors are ratios written in the fraction form (*a/b*). In this chapter, there are three major conversion factors we will learn to use:

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|---|
| **A universal conversion factor:**<br>1 mole of chemical contains $6.02 \times 10^{23}$ molecules (or atoms)<br><br>**A molar mass conversion factor:**<br>1 mole of chemical weighs the molar mass of the chemical<br><br>**A chemical formula conversion factor:**<br>1 mole of chemical contains some number of moles of atoms |

If the chemical in the three conversion factors was $CuCl_2$, then the three conversion factors would be:

1 mole of $CuCl_2$ contains $6.02 \times 10^{23}$ molecules of $CuCl_2$

1 mole of $CuCl_2$ weighs 134.6 grams $CuCl_2$ (the molar mass)

1 mole of $CuCl_2$ contains 2 moles of chlorine atoms

The most common way that chemists represent ratios is in a fraction form. The three conversion factors would look like this in the fraction form:

$$\frac{1 \text{ mole } CuCl_2}{6.02 \times 10^{23} \text{ molecule } CuCl_2} \qquad \frac{1 \text{ mole } CuCl_2}{134.6 \text{ g } CuCl_2} \qquad \frac{1 \text{ mole } CuCl_2}{2 \text{ mole Cl atoms}}$$

Each of these conversion factors can be written in the **inverse form**. The first ratio we examined involved cans of soda. We expressed that ratio as 24 cans of soda in 1 case of soda. The inverse form of this ratio is 1 case of soda contains 24 cans of soda. **The key idea here is that either the original ratio or its inverse form is true.** It is true that one case of soda contains 24 cans and it is true that there are 24 cans of soda in one case.

Conversion factors in chemistry can be written as shown above or in the inverse form. Regardless of which form is used, the comparison the conversion factor makes is true. For example, one mole of $CuCl_2$ contains $6.02 \times 10^{23}$ molecules of $CuCl_2$ and there are $6.02 \times 10^{23}$ molecules of $CuCl_2$ in every one mole of $CuCl_2$.

Here are the three major conversion factors from this chapter written in the inverse form:

$$\frac{6.02 \times 10^{23} \text{ molecule } CuCl_2}{1 \text{ mole } CuCl_2} \qquad \frac{134.6 \text{ g } CuCl_2}{1 \text{ mole } CuCl_2} \qquad \frac{2 \text{ mole Cl atoms}}{1 \text{ mole } CuCl_2}$$

The obvious question at this point is: Which form of the conversion factor should you use in a problem? **You use the form that allows the units to cancel.** Units cancel when the unit that appears on the top also appears on the bottom of a fraction somewhere in the solution. This style of problem-solving, where you arrange the conversion factors so that the units cancel, is called unit analysis.

## Conversion Factor Example 1

Which is the correct solution for the question: How many cases of soda can be made from 1200 cans of soda?

$$1200 \text{ cans of soda} \times \frac{24 \text{ cans of soda}}{1 \text{ case of soda}} = 28800 \text{ cans of soda}^2/\text{case of soda}$$

$$1200\ \cancel{\text{cans}} \text{ of soda} \times \frac{1 \text{ case of soda}}{24\ \cancel{\text{cans}} \text{ of soda}} = 50 \text{ cases of soda}$$

*Solution:*

In which solution do the units cancel? In the second solution, the unit “cans of soda” cancels. The correct solution will use conversion factors in a way that units will cancel. Blue lines are drawn through units that cancel.

## Conversion Factor Example 2

2.5 moles of $CuCl_2$ contain how many molecules of $CuCl_2$?

*Solution*

This question uses the universal conversion factor of moles to molecules. Set up the solution so that the units cancel. Blue lines are drawn through units that cancel.

$$2.5\ \cancel{\text{moles}} \text{ of } CuCl_2 \times \frac{6.02 \times 10^{23} \text{ molecules } CuCl_2}{1\ \cancel{\text{mole}}\ CuCl_2} = 1.5 \times 10^{24} \text{ molecules } CuCl_2$$

## Conversion Factor Example 3

The formula for sugar is $C_6H_{12}O_6$. How many moles of sugar are present when 20.0 moles of oxygen are present?

Solution

This question requires the chemical formula conversion factor in the solution. You don't need to concern yourself with whether the conversion factor is inverted or not. Just make sure that the units cancel. Blue lines are drawn through units that cancel.

$$20.0\ \cancel{\text{moles}} \text{ of oxygen} \times \frac{1 \text{ mole } C_6H_{12}O_6}{6\ \cancel{\text{moles}} \text{ oxygen}} = 3.33 \text{ moles } C_6H_{12}O_6$$

## Hints for using conversion factors:

**How do you know what quantity to start with when solving problems?**

Start with the quantity given in the problem and not with the conversion factor. In general, the first quantity in your unit analysis will not have a denominator. In the last example, we started with the number of moles of oxygen:

$$20.0 \text{ moles of oxygen} \times \frac{1 \text{ mole } C_6H_{12}O_6}{6 \text{ moles oxygen}} = 3.33 \text{ moles } C_6H_{12}O_6$$

Notice that the first quantity is a whole number and not a fraction. If you start with the conversion factor, it is much harder to decide whether to use the original or inverse form of the conversion factor.

**Should I enter all of the numerator numbers into the calculator before I enter the denominator numbers, or should I enter each conversion factor into the calculator before I move on to the next conversion factor?**

Either style of entering the numerical quantities will work. You should make a decision to always use one style of entering numbers into a calculator. This helps you avoid skipping a number when you are calculating an answer.

In the example calculation below, you could enter the numbers in either of these orders and obtain the same answer.

$$16 \times \frac{2.54}{3} \times \frac{50}{9} = 75.2$$

Enter the numbers into your calculator as:

$16 \times 2.54 \div 3 \times 50 \div 9 =$

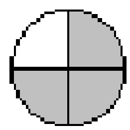
or

$16 \times 2.54 \times 50 \div 3 \div 9 =$

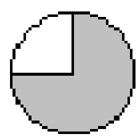
You don’t need to press the ENTER key after each mathematical.

# Fractions, Decimals and Percents

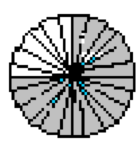
Fractions, decimals, and percentages are all related to each other. Each is used to indicate some part of a whole quantity. For example, ¾, 0.75, and 75% are all used to express a quantity representing three parts out of four. The fraction represents the number of parts of the whole (3 parts of the whole, which is divided into 4 equal sized parts).

$\frac{3}{4}$ = 

The decimal represents the part of one whole (0.75 of the whole).

0.75 = 

The percentage represents the number of parts of a whole that has been divided into 100 parts (75 parts of the whole which has been divided into 100 equal parts).

75% = 

Divide pie up into
100 segments

The fraction, 3/4, is converted to a decimal by dividing the numerator (the number on top of the fraction) by the denominator (the number on bottom of the fraction). Three divided by four is 0.75.

The decimal is converted to the percentage by moving the decimal point two places to the right. This is equivalent to multiplying the decimal by 100% in order to convert it to the percentage. In this conversion, 0.75 becomes 75%

To convert a percent to a decimal, we move the decimal point two places to the left. The decimal point in 75% is understood to be after the five in the percentage. In this conversion, 75% becomes 0.75.

In this chapter, we use percentages more often than decimals or fractions. The term **percent** means “per cent” or “per 100.” When we say that 10% of people prefer Brand A, we mean that 10 people out of 100 people prefer Brand A. When someone has 71% of the votes in an election, it means that 71 people out of 100 people voted for that person. A chemist might say that a substance is 64% nitrogen. The chemist means that 64 atoms out of every 100 atoms are nitrogen.

A percentage is another conversion factor. It can be written as a fraction and used in problem-solving (also called unit analysis). Here are the examples of percentages we used above written as conversion factors.

$$\frac{\text{10 people prefer Brand A}}{\text{100 people expressed an opinion}}$$

$$\frac{\text{71 people voted for candidate}}{\text{100 people voted}}$$

$$\frac{\text{64 atoms of nitrogen}}{\text{100 atoms present}}$$

**The secret to using percentages correctly is to write the units correctly.** It is very important that the units for the “per 100” part indicate what substance is being measured or counted. The numerator or top of the fraction should clearly indicate what small portion of the whole quantity is being measured or counted. In other words, a percentage should be written as:

$$\frac{\text{The Part}}{\text{The Whole}}$$

### Percentage Example 1:

How would you present each percentage as a fraction?

47% of applicants were women
15% of atoms were sulfur

*Solution*

$$\frac{\text{47 female applicants (the Part)}}{\text{100 total applicants (the Whole)}}$$

$$\frac{\text{15 atoms sulfur (the Part)}}{\text{100 atoms total (the Whole)}}$$

Sometimes we are asked to calculate percentages from actual measurements. In this type of problem, a percent is not given in the problem.

### Percentage Example 2:

What percent of people in the class are women if 30 of the 50 students are female?

*Solution:*

Remember to divide the part by the whole. What is the “whole” class number? 50. We divide the “part” (which is 30 female students) by the “whole” (which is 50 male and female students). Then, we multiply by 100 to create the percentage.

$$\frac{\text{30 women}}{\text{50 students}} \times 100 = 60\%$$

Chemists frequently use percentages in calculations. Remember, it is important that you include units in your calculations to avoid mistakes.

### Percentage Example 3:

A total of 476 people were surveyed. When asked to choose the best tasting pizza, 34.2% of them chose Brand B. How many people selected Brand B as the tastiest pizza?

*Solution:*

First, convert the percentage into a conversion factor. Remember that the denominator is always 100 (from the “per cent” part of the question).

The conversion factor we would write would be:

$$\frac{\text{34.2 of people selected Brand B}}{\text{100 people surveyed}}$$

The total number of people we surveyed was MORE than 100. It was 476. How do we include this information in our calculations?

$$\text{476 peo}\cancel{\text{ple surveyed}} \times \frac{\text{34.2 of people selected Brand B}}{\text{100 pe}\cancel{\text{ople surveyed}}}$$

$$= \text{163 people selected Brand B}$$

Notice how the units cancel! We can check the answer to see if it is reasonable. If 476 people were surveyed, is it reasonable that less than 476 chose Brand B? Yes. The percentage of people selecting Brand B was less than 50%. Is 163 less than half of 476? Yes.

## Percentage Example 4:

If 54% of the mass of a mixture of iron and copper is iron, how much iron is there in a sample that has a mass of 25 grams?

*Solution:*

What is the conversion factor we would write for the percentage?

$$\frac{\text{54 grams of iron}}{\text{100 grams mixture}}$$

How did we choose the units "grams?" The unit in which the measurement was done was given in the problem. Now, let's use the conversion factor that we obtained from the percentage in the solution.

$$25\ \cancel{\text{grams mixture}} \times \frac{\text{54 g iron}}{100\ \cancel{\text{gram mixture}}} = \text{14 grams iron}$$

Again, check to see if the answer is reasonable. If about half of the mixture was iron and the mixture weighed 25 grams, we would expect an answer of about 12.5 grams. Our estimate of the answer agrees with the calculated answer.

## Percentage Example 5:

If a mixture of iron and copper was 54% iron, how much of the mixture would you need to use to have 200. grams of iron (plus the copper impurity in the mixture)?

Solution:

This question uses the same conversion factor as the previous example. But how should you arrange the conversion factor so that the units cancel?

$$200.\ \cancel{\text{grams iron}} \times \frac{\text{100 grams mixture}}{54\ \cancel{\text{grams iron}}} = \text{370 g mixture}$$

Notice that we used the inverse form of the percentage. We know to do this so that the units cancel. If you set up the problem so that the units cancel, you will be on the right track to get the correct answer!

## Hints for using percentages:

**What units do you choose when turning the percentage into a conversion factor?**

Look at the question to see what unit of measurement is being used or what substance was being counted. If the question describes centimeters of metal tubing, then both numerator and the denominator will be in centimeters. If the question involved milliliters of solution, then both the numerator and the denominator will be in milliliters. Add other words to the units to help you distinguish “The Part” from “The Whole.”