Concentrations by %, as well as ppm and ppb

Concentrations by percents, ppm and ppb are most useful when they are done with masses, and we will focus on these in this class. Sometimes % are also done using volumes or grams/volume.

For most college students calculating the concentrations by percents, as well as ppm, and ppb comes easily. If you don’t find them straightforward, don’t get discouraged, just get help right now. Here is a refresher of how concentrations by percents, ppm, and ppb are calculated.

All of them start by calculating the fractional composition

\[
\text{mass fraction} = \frac{\text{mass of the solute}}{\text{mass of the solution}}
\]

For Example: If you make a sugar solution using 101 grams of sugar and 2001 grams of water, the sugar mass fraction would be

\[
\text{sugar mass fraction} = \frac{\text{mass of the sugar}}{\text{total mass of the solution}} = \frac{101 \text{ g}}{2001 \text{ g} + 101 \text{ g}} = 0.0480
\]

People often forget that the bottom part is the sum of the masses. Its pretty easy to do, sometimes it can help just to draw a picture when you are first doing these. This is particularly true if there are many things mixed together. For the solution above the picture would look something like this

| Water 2001 g | Sugar 101 g |

If 3 grams of salt were added the diagram would look like this.

| Salt 3 g | Water 2001 g | Sugar 101 g |

In this second case the sugar mass fraction would be calculated like this
Once you have the mass fraction it can be used to calculate the concentration by percents, ppm or ppb.

For percents you take the mass fraction and multiply it by 100%

\[
\text{concentration by \%} = \text{mass fraction} \times 100\%
\]

Using the first example

\[
\% \text{sugar} = 0.048 \times 100\% = 4.80\%
\]

One of the convenient things about \% is that they can be easily rewritten as a conversion ratio. 4.8\% can be written as

\[
\frac{4.8 \text{ g solute}}{100 \text{ g solution}} \quad \text{or} \quad \frac{100 \text{ g solution}}{4.8 \text{ g solute}}
\]

You use the same mass fraction if you are calculating the concentration in ppm, or ppb of the sugar solution

To obtain ppm you simply multiply the fraction by a million (1 million is the same as 10^6).

\[
\text{ppm sugar} = 0.048 \times 1,000,000 = 48,000 \text{ ppm}
\]

To obtain ppb you simply multiply the fraction by a billion, which is the same as 10^9.

\[
\text{ppb sugar} = 0.048 \times 1,000,000,000 = 48,000,000 \text{ ppb}
\]

Both ppm and ppb can be restated as conversion ratios.

From concentrations given in ppm

\[
\frac{48,000 \text{ g sugar}}{100,000 \text{ g solution}} \quad \text{or} \quad \frac{100,000 \text{ g solution}}{48,000 \text{ g sugar}}
\]

And concentration in ppb
Expressing the sugar water concentrations in ppm and ppb is rather silly because ppm and ppb are used to describe solution with a very low concentration of solute.

Example Problems

% concentrations from known masses

A solution was prepared using 1.00 liter of water, 59 g glucose, and 2.3 g NaCl. One liter of water weighs 1000 grams. The solution needs to be labeled in terms of % glucose and % sucrose. What should the label read?

\[
\% \text{ glucose} = \left( \frac{59 \text{ glucose}}{1000 \text{ g} + 2.3 \text{ g} + 59 \text{ g}} \right) \times 100\% = 55.4\% = 55\%
\]

\[
\% \text{ NaCl} = \left( \frac{2.3 \text{ g NaCl}}{1000 \text{ g} + 2.3 \text{ g} + 59 \text{ g}} \right) \times 100\% = 0.216\% \text{ NaCl} = 0.22\% \text{ NaCl}
\]

ppb from mass data for the solute and the solution

The Environmental Protection Agency limit for lead in drinking water is 15 ppb. A 5090 gram solution is found to contain 0.048 grams of lead. What is the concentration of lead in this solution is ppb, and is this above or below the EPA standard.

\[
\text{ppb lead} = \left( \frac{0.0457 \text{ g lead}}{5090 \text{ g solution}} \right) \times 10^9 = 8978 \text{ ppb}
\]

Should the family with this concentration of lead in their water be concerned about it? Why?

conversion of ppm to ppb

The allowed Arsenic level in drinking water is 10 ppb. A concentration of 0.045 ppm in found in well in New Hampshire. What is this amount in ppb, and is this amount a concern.

1. Find a conversion ratio that relates ppm to ppb. From the definitions of ppb and ppm we know that

\[
0.5 \times 10^6 \text{ ppm} = 0.5 \times 10^9 \text{ ppb}
\]

\[
\left( \frac{0.5 \times 10^9 \text{ ppb}}{0.5 \times 10^6 \text{ ppm}} \right) = \left( \frac{10^9 \text{ ppb}}{10^3 \text{ ppm}} \right) = \left( \frac{10^3 \text{ ppb}}{1 \text{ ppm}} \right)
\]

This relationship gives you the two conversion ratios
To go from ppm to ppb you simply multiply by the conversion ratio that is written with ppb on top.

\[
0.045 \text{ ppm} \left( \frac{10^3 \text{ ppb}}{1 \text{ ppm}} \right) = 0.045 \times 10^3 \text{ ppb} = 45 \text{ ppb}
\]

**Multistep Conversion**

A child’s blood was found to have a lead content of 25.0 µg/L of blood. Unfortunately the amounts in your table are given in ppb. You need to be able to relate the 2 clearly when you speak to the child’s parents. What is the concentration of lead in the child’s blood in ppb? (A liter of blood weighs 1003 grams. 1 µg = 1 \times 10^{-6} grams.)

1. Find the mass of 1 liter of blood in µg so that you have the masses of the solute and the solution in the same type of units.

\[
\left( \frac{1003 \text{ g blood}}{1 \text{ L blood}} \right) \left( \frac{1 \mu g}{10^{-6} \text{ g}} \right) = \frac{1.003 \times 10^9 \mu g \text{ blood}}{1 \text{ L blood}}
\]

2. Calculate the mass fraction

\[
\text{mass fraction} = \frac{25.0 \mu g \text{ lead}}{1.003 \times 10^9 \mu g \text{ blood}} = 2.493 \times 10^{-8}
\]

3. Calculate the concentration in ppb.

\[
2.493 \times 10^{-8} \times 10^9 = 25 \text{ ppb}
\]

**Preparing a solution of a know % concentration**

How many milligrams of KCl are needed to prepare 10 ml of a 1.8% KCl solution? (There is 1 g of the solution in every ml of the solution.)

Known: 

- 74.55 grams KCl/1 mol KCl
- 1000 mg = 1 g
- 1.8 g KCl/100 g KCl solution
- 10 ml KCl solution
- 1 g of solution = 1 ml of solution

Need to Know:

- ? mg KCl
1. Determine how many grams KCl are needed

\[
10\text{mlsolution} \times \left( \frac{1\text{g}\text{solution}}{1\text{mlsolution}} \times \frac{1.8\text{gKCl}}{100\text{g}\text{solution}} \right) = 0.18\text{gKCl}
\]

2. Determine many mg are in 0.18g.

\[
0.18\text{g} \times \left( \frac{1000\text{mg}}{1\text{g}} \right) = 180\text{mg}
\]