

## Calculating %, ppm, ppb, and ppt

Percent, ppm, ppb, and ppt, (parts per hundred, per million, per billion, and per trillion) are all fractions. They all refer to the part of something of interest divided by the whole sample.

$$\text{fraction} = \frac{\text{part}}{\text{whole}}$$

### **Percent (%)**

When you talk of percent, you're scaling the fraction up to 100 (per "cent" is per "hundred"), so:

$$\text{percent} = \frac{\text{part}}{\text{whole}} \times 100$$

If you have a room full of 25 people and 16 of them are women, the percent of women in the room is

$$\frac{16}{25} \times 100 = 64\%$$

You're basically scaling the fraction up to 100. So, the 64 represents the number of women you'd have if you had 100 people and the same fraction or ratio of women/people.

### **Parts per Million (ppm) and more**

Now, ppm is just the same except that you're scaling up to a million instead of a hundred. The "ppm" value is the number of women you'd have if you have a million people and the same ratio of women/people.

$$\frac{16}{25} \times 1,000,000 = 640,000 \text{ ppm}$$

For a ppb, it's scaling up to a billion, or:

$$\frac{16}{25} \times 1,000,000,000 = 640,000,000 \text{ ppb}$$

This example isn't very useful for ppm or ppb, because we usually only use these quantities for very small ratios, like if you had 6 women in a crowd of a 150,000 people. Then the "part" is 6 and the "whole" is 150,000. The parts per million is then:

$$\frac{6}{150000} \times 1,000,000 = 40 \text{ ppm}$$

In chemistry, it's more like this: you have a 150 gram sample and you figure out that it contains 0.00006 grams of gold. To express this in %, ppm, and ppb, you do the same sort of calculation as above and it always involves the part/whole ratio:

$$\frac{0.00006 \text{ g}}{150 \text{ g}} \times 100 = 0.000040\%$$

$$\frac{0.00006 \text{ g}}{150 \text{ g}} \times 1,000,000 = 0.40 \text{ ppm}$$

$$\frac{0.00006 \text{ g}}{150 \text{ g}} \times 1,000,000,000 = 400 \text{ ppb}$$

The "units" for the "part" and the "whole" always need to be the same, so you might need to do a conversion first, so that the units cancel out on top and bottom.

## Using Percent, Parts per Million, and Parts per Billion

Now, if you know the percent and want to use it in a calculation, it's worth rearranging things a little, because "percent" means parts per hundred. It is the fraction that you need to use in these calculations, not the percent itself (or ppm, or ppb).

So, if you have a room full of people and you know that it's 64% women, and you want to know how many women are present if you also know there are just 25 people in the room (and you don't feel like counting), then the calculation is

$$25 \text{ people} \times \frac{64 \text{ women}}{100 \text{ total people}} = 16 \text{ women.}$$

What you've done here is use the fact that 64% means 64 per hundred, or 64 parts per hundred of the whole.

In the chemistry example, you might know that a certain bottle of water contains 400 ppb gold by mass. If you know that the water in the bottle weighs a total of 150 grams, you can use the 400 ppb as (400 grams of gold per 1 billion grams of water), or

$$150 \text{ grams water} \times \frac{400 \text{ grams Au}}{10^9 \text{ grams water}} = 0.00006 \text{ grams of gold.}$$

If you have 17,000 gallons of water (the volume of water in an average backyard swimming pool) that is 400 ppb gold by mass, you can use some conversion factors and the density of water (1 g/mL) to get its mass, then use the ppb calculation to get the mass of gold in the pool:

$$17,000 \text{ gallons of water} \times \frac{3.785 \text{ L}}{1 \text{ gallon}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ g}}{1 \text{ mL}} \times \frac{400 \text{ grams Au}}{10^9 \text{ grams water}} = 26 \text{ grams Au}$$

*At \$28/gram, that's about \$720 worth of gold in the pool, IF the concentration is correct.*