

**Lecture /6 Calculating the Concentration of a Chemical Solution**

[Concentration](https://www.thoughtco.com/definition-of-concentration-605844) is an expression of how much [solute](https://www.thoughtco.com/definition-of-solute-and-examples-605922) is dissolved in a [solvent](https://www.thoughtco.com/definition-of-solvent-604651) in a chemical [solution](https://www.thoughtco.com/definition-of-solution-604650). There are multiple [units of concentration](https://www.thoughtco.com/molarity-and-normality-differences-606118). Which unit you use depends on how you intend to use the chemical solution. The most common units are molarity, molality, normality, mass percent, volume percent, and mole fraction. Here are step-by-step directions for calculating concentration, with examples showing the math and tips on when to use the units.

How to Calculate Molarity of a Chemical Solution

[Molarity](https://www.thoughtco.com/molarity-definition-in-chemistry-606376) is one of the most common units of concentration. It is used when the temperature of an experiment won't change. It's one of the easiest units to calculate. You get the mass of solute for the solution, mix the solute with a known volume of solvent, and divide mass by volume for concentration.

[**Calculate Molarity**](https://www.thoughtco.com/molar-concentration-of-ions-example-problem-609513): moles solute per liter of solution (*not* volume of solvent added since the solute takes up some space)

**symbol**: M

**M = moles / liter**

**Example**: What is the molarity of a solution of 6 grams of NaCl (~1 teaspoon of table salt) dissolved in 500 milliliters of water?

First, convert grams of NaCl to moles of NaCl.

From the periodic table:

* Na = 23.0 g/mol
* Cl = 35.5 g/mol
* NaCl = 23.0 g/mol + 35.5 g/mol = 58.5 g/mol
* Total number of moles = (1 mole / 58.5 g) \* 6 g = 0.10 moles

Now determine moles per liter of solution:

M = 0.10 moles NaCl / 0.50 liter solution = 0.20 M solution (0.20 molar solution)

Note that I assumed dissolving the 6 grams of salt did not appreciably affect the volume of the solution. When you prepare a molar solution, avoid this problem by adding solvent to your solute to reach a specific volume.

How to Calculate Molality of a Solution

[Molality](https://www.thoughtco.com/differences-between-molality-and-molarity-609192) is used to express the concentration of a solution when you are performing experiments that involve temperature changes or are working with colligative properties. Note that with aqueous solutions at room temperature, the density of water is approximately 1 kg/L, so M and m are nearly the same.

**Calculate Molality**: moles solute per kilogram solvent

**symbol**: m

**m = moles / kilogram**

**Example**: What is the molality of a solution of 3 grams of KCl (potassium chloride) in 250 ml of water?

First, determine how many moles are present in 3 grams of KCl. Start by looking up the number of grams per mole of potassium and chlorine on a [periodic table](https://www.thoughtco.com/clickable-periodic-table-of-the-elements-3891282). Then add them together to get the grams per mole for KCl.

* K = 39.1 g/mol
* Cl = 35.5 g/mol
* KCl = 39.1 + 35.5 = 74.6 g/mol

For 3 grams of KCl, the number of moles is:

(1 mole / 74.6 g) \* 3 grams = 3 / 74.6 = 0.040 moles

Express this as moles per kilogram solution. Now, you have 250 ml of water, which is about 250 g of water (assuming a density of 1 g/ml), but you also have 3 grams of solute, so the total mass of the solution is closer to 253 grams than 250. Using 2 significant figures, it's the same thing. If you have more precise measurements, don't forget to include the mass of solute in your calculation!

* 250 g = 0.25 kg
* m = 0.040 moles / 0.25 kg = 0.16 m KCl (0.16 molal solution)

How to Calculate Normality of a Chemical Solution

[Normality](https://www.thoughtco.com/definition-of-normality-in-chemistry-605419) is similar to molarity, except it expresses the number of active grams of a solute per liter of solution. This is the gram equivalent weight of solute per liter of solution.

[Normality](https://www.thoughtco.com/how-to-calculate-normality-609580) is often used in acid-base reactions or when dealing with acids or bases.

**Calculate Normality**: grams active solute per liter of solution

**symbol**: N

**Example**: For acid-base reactions, what would be the normality of 1 M solution of sulfuric acid (H2SO4) in water?

Sulfuric acid is a strong acid that completely dissociates into its ions, H+ and SO42-, in aqueous solution. You know there are 2 moles of H+ ions (the active chemical species in an acid-base reaction) for every 1 mole of sulfuric acid because of the subscript in the chemical formula. So, a 1 M solution of sulfuric acid would be a 2 N (2 normal) solution.

How to Calculate Mass Percent Concentration of a Solution

[Mass percent](https://www.thoughtco.com/definition-of-mass-percentage-and-examples-605878) composition (also called mass percent or percent composition) is the easiest way to express the concentration of a solution because no unit conversions are required. Simply use a scale to measure the mass of the solute and the final solution and express the ratio as a percentage. Remember, the sum of all percentages of components in a solution must add up to 100%

Mass percent is used for all sorts of solutions but is particularly useful when dealing with mixtures of solids or anytime physical properties of the solution are more important than chemical properties.

**Calculate Mass Percent**: mass solute divided by mass final solution multiplied by 100%

**symbol**: %

**Example**: The alloy Nichrome consists of 75% nickel, 12% iron, 11% chromium, 2% manganese, by mass. If you have 250 grams of nichrome, how much iron do you have?

Because the concentration is a percent, you know a 100-gram sample would contain 12 grams of iron. You can set this up as an equation and solve for the unknown "x":

12 g iron / 100 g sample = x g iron / 250 g sample

Cross-multiply and divide:

x= (12 x 250) / 100 = 30 grams of iron

How to Calculate Volume Percent Concentration of a Solution

[Volume percent](https://www.thoughtco.com/definition-of-volume-volume-percentage-605945) is the volume of solute per volume of solution. This unit is used when mixing together volumes of two solutions to prepare a new solution. When you mix solutions, the volumes *aren't always additive*, so volume percent is a good way to express concentration. The solute is the liquid present in a smaller amount, while the solution is the liquid present in a larger amount.​

**Calculate Volume Percent**: volume of solute per volume of solution (*not* volume of solvent), multiplied by 100%

**symbol**: v/v %

v/v % = liters/liters x 100% or milliliters/milliliters x 100% (doesn't matter what units of volume you use as long as they are the same for solute and solution)

**Example**: What is the volume percent of ethanol if you dilute 5.0 milliliters of ethanol with water to obtain a 75-milliliter solution?

v/v % = 5.0 ml alcohol / 75 ml solution x 100% = 6.7% ethanol solution, by volume.

How to Calculate Mole Fraction of a Solution

[Mole fraction](https://www.thoughtco.com/mole-fraction-definition-chemistry-glossary-606379) or molar fraction is the number of moles of one component of a solution divided by the total number of moles of all chemical species. The sum of all mole fractions adds up to 1. Note that moles cancel out when calculating mole fraction, so it is a unit less value. Note some people express mole fraction as a percent (not common). When this is done, the mole fraction is multiplied by 100%.

**Symbol** : X or the lower-case Greek letter chi, χ, which is often written as a subscript

**Calculate Mole Fraction**: XA = (moles of A) / (moles of A + moles of B + moles of C...)

**Example**: Determine the mole fraction of NaCl in a solution in which 0.10 moles of the salt is dissolved in 100 grams of water.

The moles of NaCl is provided, but you still need the number of moles of [water](https://www.thoughtco.com/weird-and-interesting-water-facts-4093451), H2O. Start by calculating the number of grams in one mole of water, using periodic table data for hydrogen and oxygen:

* H = 1.01 g/mol
* O = 16.00 g/mol
* H2O = 2 + 16 = 18 g/mol (look at the subscript to note there are 2 hydrogen atoms)

Use this value to convert the total number of grams of water into moles:

(1 mol / 18 g ) \* 100 g = 5.56 moles of water

Now you have the information needed to calculate mole fraction.

* Xsalt = moles salt / (moles salt + moles water)
* Xsalt = 0.10 mol / (0.10 + 5.56 mol)
* Xsalt = 0.02

More Ways to Calculate and Express Concentration

There are other easy ways to express the concentration of a chemical solution. Parts per million and parts per billion are used primarily for extremely dilute solutions.

**g/L**  = grams per liter = mass of solute / volume of solution

**F** = formality = formula weight units per liter of solution

**Ppm**  = [parts per million](https://www.thoughtco.com/definition-of-parts-per-million-605482) = ratio of parts of solute per 1 million parts of the solution

**ppb**  = parts per billion = ratio of parts of solute per 1 billion parts of the solution.