

How to make solutions and calculate molarity

A. Why make solutions and calculate molarity?

If you have taken labs courses, you probably had solutions handed to you. In real life, you make your solutions yourself. To function in a lab, you therefore need to be able to figure out what to weigh out on your own.

B. Typical example #1: Fixed volume, adjustable weight

The usual situation is that you're following a recipe that specifies, for example, a 0.5 molar solution of NaOH. You know that "0.5 M" literally means 0.5 moles per liter. Unfortunately:

- You can't weigh out moles.
- You don't need a liter. 200 ml is more than enough.

Let's pause and assess what you have before you. You know that you will make 200 ml of a NaOH solution that is 0.5 M. You know that to do this, you will weigh out so many grams of NaOH and add water to dissolve it, ending up with 200 ml. Do you have enough information to figure out how many grams to weigh?

Units are our friends. Let's ask them for help:

You know the end molarity (0.5 M NaOH), which has units of moles / volume

You know the end volume (200 ml)

You should be able to calculate the number of moles of NaOH in the solution:

$$(\text{moles / volume}) * (\text{end volume}) = \text{moles}$$

So getting the number of moles is straightforward, but what you want is the weight.

You could go from moles to weight if you had some quantity with units of weight/mole:

$$(\text{moles}) * (\text{weight/mole}) = \text{weight}$$

At this point, you should recognize that weight/mole is the definition of molecular weight. You can find the molecular weight of a compound most readily by taking a look at the manufacturer's bottle from which you will be taking the compound. You will almost always see "MW=..." or "FW=..." ("FW" means "free weight" and corresponds to the molecular weight of the compound plus any molecules of water that may precipitate with it). If you don't find it in the bottle, there's many other places to look (a manufacturers catalog, a chemical index,...). Suppose you get the molecular weight of NaOH from one of these sources: it's 40.0 g/mole. Now, plugging in:

$$(0.5 \text{ moles/liter NaOH}) * (200 \text{ ml end volume}) * (40.0 \text{ g/mole}) = \text{amount to weigh out}$$

Problem: the units you get from this equation (after canceling) is: (ml/liter) * g. In order to get grams, you'll have to convert one of the volume units. I'll do it this way:

$$(0.5 \text{ moles/liter NaOH}) * (0.2 \text{ liter end volume}) * (40.0 \text{ g/mole}) = \text{amount to weigh out}$$

Now the units cancel, except for grams, giving 4.00 g.

SQ1. How much $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$ do you need to weigh out to get 150 ml of a 10 mM solution? The free weight is 246.5 g/mol.

B. Typical example #2: Adjustable volume, fixed weight

When you weight out tiny amounts of potent and often very expensive chemicals, it is often impossible to get exactly the weight you were hoping for. For example, suppose you want to make a 2 mg/ml stock solution of an enzyme and you only need about 1 ml. That's easy: $(2 \text{ mg/ml}) \cdot (1 \text{ ml})$... you need 2 mg. Unfortunately, it is not easy to weigh out exactly 2 mg, and you weigh out 2.4 mg instead. Don't bother trying to take away the extra 0.4 mg... you'll be there for hours. Instead, change the volume so that the concentration ends up as you wanted, using all of the 2.4 mg.

SQ2. What volume water should you add to 2.4 mg of the enzyme to get a concentration of 2 mg/ml?

C. Percent solutions

Sometimes you need to make up a solution not by concentration or molarity but by percent, e.g. 20% sucrose or 15% glycerol solutions. Recipes are supposed to add the definition of percent, e.g. 20% sucrose *w/v* (weight per volume) or 15% glycerol *v/v* (volume per volume). The first case means that you should end up with 20 g sucrose in 100 ml of end solution. The second case means that you should end up with 15 ml glycerol in 100 ml of end solution. Of course you wouldn't dream of **adding** 100 ml of water to the sucrose or glycerol, since that would give you an end solution greater than 100 ml (since the solute has volume too).