Some of the most important lab math to know (in my opinion):

- **Metric conversions**
  - Get really comfortable moving decimal places to convert between μ, m, etc. (esp. μL, mL & L)
- **Converting between molecular weight (MW) or formula weight (FW)*, molarity, and weight/volume**
  - MW (or FW) = g/mol
  - Molarity (M) = mol/L
  - g/L =(MW)(molarity)
  - M = (g/L) / (MW or FW)

  * although the terms molecular weight and formula weight are often used interchangeably, molecular weight is technically only for covalent compounds, whereas formula weight can refer to ionic compounds as well as hydrates & other complexes. Both are g/mol
- **For protein biochemists, converting between kDa (what the MW for proteins is often given as), mg/mL, & molarity**
  - 1 kDa = 1000 Da (Daltons)
  - 1 Da = 1 g/mol
  - 1 kDa = 1000 g/mol
  - 1 mg/mL = 1 g/L
  - Going from MW ***in kDa*** and molarity (M) to mg/mL:
    - (MW in kDa)(M x 1000) = mg/mL
  - Going from MW in kDa and mg/mL to molarity:
    - Molarity = (mg/mL) / ((MW in kDa)(1000))
- **Understanding & using when necessary % w/v**
  - % w/v = g/L x 100%
    - 1 % w/v = 1 g / 100 mL
- **Making solutions from solids**
  - If you have a desired volume & concentration:

    (Desired volume)(**needed mass**) = desired concentration

    Needed mass = (desired concentration)/(desired volume)

- Calculating the volume of solvent needed to get to a final desired concentration based on a measured amount (e.g. for when you're measuring small volumes and it's impractical to weigh out precisely the target mass)

  (measured mass)/(**needed volume**) = desired concentration

  Needed volume = (measured mass)/(desired concentration)

- Salvaging solutions by adding extra solvent and/or mass to match what you actually have present in your current solution
  - Too much mass? Calculate volume

    (Measured mass) / (**total volume needed**) = desired concentration

    Total volume needed = (measured mass) / (desired concentration)

    Needed additional volume = **total volume needed** – current volume

  - Too much volume? Calculate mass

    (**total mass needed**) / (current volume) = desired concentration

    Total mass needed = (desired concentration)(current volume)

    Extra mass needed = **total mass needed** – current mass

    Alternatively, calculate the mass you need to add directly (rather than first finding total then subtracting). To do that…

    Extra volume = current volume – intended volume

    Extra mass needed = (extra volume)(desired concentration)

    If adding that mass will not appreciably change the final volume, just add it. If adding that mass would change the final volume, calculate mass for a higher volume with enough wiggle room. Add the mass for that, then adjust the volume to that higher volume.

- **Diluting solutions**
  - From any form of concentration (as long as same units on both sides)
    - $C_1V_1 = C_2V_2$
      - Initial concentration (C_1) x initial volume (V_1) = final concentration (C_2) x final volume (V_2)
  - From relative concentrations (X factors)
    - (Desired total volume) / (X factor) = needed volume of the stock solution
    - (Volume of the stock solution you want to use)(X factor) = total volume to dilute to

- **Making master mixes**
    - Pre-mix the parts of reaction mixtures that are the same between all reactions. Then add that to the unique parts
        - Make more than you need to account for volume loss during transfers
- **Serial dilutions**
    - Dilution factor (DF): how much you are diluting by each time
        - e.g. if you're halving it each time, DF would be 2
    - Multiply the initial concentration by (1/DF) raised to the number of dilutions to get the concentration of that dilution

Links to more information

more on metric conversions: blog: https://bit.ly/metric_calcs ; YouTube: https://youtu.be/A-J7kdLNb8c

more on sig figs here: http://bit.ly/significantfiguress & https://youtu.be/q29Cv5i5PuI

more on dimensional analysis: http://bit.ly/dimensionalanalysising & https://youtu.be/KQMA0aAGfP4

more about concentrations: http://bit.ly/sciencestocksolutions ; YouTube: https://youtu.be/RjXYvOiLh2w & https://youtu.be/wC623-AGBOs

and a couple cheat sheets for molecular weights: https://drive.google.com/file/d/1TqCRh23TO8s5T23DjBcJeCUWI23ps9sI/view?usp=sharing

and concentrations: https://drive.google.com/file/d/1v7pff7cEpJTvr-IADLwdwwFOIEDdz8Ny/view?usp=sharing

more lab-mathy things: https://thebumblingbiochemist.com/lets-talk-science/math-y-stuff/ & https://www.youtube.com/playlist?list=PLUWsCDtjESrGfML5aO-J8vgzm2OYGPwhL

More on making solutions: blog form: http://bit.ly/sciencestocksolutions ; YouTube: https://youtu.be/4R_5qxmMzas & https://youtu.be/9OtxOHLYaOQ

More on serial dilutions: http://bit.ly/serialdilutions

more about all sorts of things: All (with topics listed) http://bit.ly/2OllAB0 or search blog: http://thebumblingbiochemist.com

common SI prefixes

peta	P	10^{15}	quadrillion
tera	T	10^{12}	trillion
giga	G	10^{9}	billion
mega	M	10^{6}	million
kilo	k	10^{3}	thousand
hecto	h	10^{2}	hundred
deka	da	10^{1}	ten
		10^{0}	**one**
deci	d	10^{-1}	tenth
centi	c	10^{-2}	hundredth
milli	m	10^{-3}	thousandth
micro	µ	10^{-6}	millionth
nano	n	10^{-9}	billionth
pico	p	10^{-12}	trillionth
femto	f	10^{-15}	quadrillionth

metric prefixes let us work with large & tiny numbers

you can stick these prefixes in front of any base unit (g, mol, M, etc.)

milli	m	10^{-3}	1/1,000	thousandth of a...
micro	µ	10^{-6}	1/1,000,000	millionth of a...
nano	n	10^{-9}	1/1,000,000,000	billionth of a...
pico	p	10^{-12}	1/1,000,000,000,000	trillionth of a...

you can multiply by factors of 10 to easily convert between units with different metric prefixes

there are 1000 mg in 1 g; 1000 µg in 1 mg; 1000 ng in 1 µg, etc.

base unit
divide by 10^3 / multiply by 10^3
milli m
micro µ
nano n
pico p

you can also draw this out using dimensional analysis

e.g. $\frac{10^3\,\mu g}{1\,mg} = 1 \quad \frac{10^3\,mg}{1\,g} = 1$

$50\,\mu g \times \frac{1\,mg}{10^3\,\mu g} = 0.05\,mg$

there are 1,000,000 µg in 1 g; 1,000,000 ng in 1 mg, etc.

base unit
divide by 10^6 / multiply by 10^6
milli m
micro µ
nano n
pico p

e.g.: 50 ng = 50/10^6 = 0.00005 mg (can also be written as 5×10^{-5} mg)

5×10^{-9} g = 5 ng

0.00005 g = 0.00005 x 10^6 = 50 µg

you can similarly convert between other prefixes

base unit
divide by 10^9 / multiply by 10^9
milli m
micro µ
nano n
pico p

base unit
divide by 10^{12} / multiply by 10^{12}
milli m
micro µ
nano n
pico p

when unsure whether to multiply or divide, write it out & make sure your units cancel

think small! - some mental shortcuts

often we're dealing with solutions at the µL scale, so lots of conversions

When converting to thinking in terms of **less stuff** (e.g. a smaller volume or mass), the **number should get smaller** (e.g. there are fewer molecules in a µL or a µg than there are in a L or a g).

But when you're converting to thinking of **same amount of stuff, just in terms of smaller units**, the **number should be bigger** (e.g. there are more µg in a g than there are mg in a g and more µL in a L than mL in a L).

Often concentrations are given in mg/mL. This is the same as µg/µL.

Recognize that **when prefixes are the same, you will be dividing them by the same factor of 10, so they'll still be the same.** In fact, it's also the same as ng/nL, or g/L!

divide by 10^3 / multiply by 10^3
milli m
micro µ
nano n
pico p

Using similar reasoning to remember, M (mol/L) is the same as µmol/µL, and mmol/mL.

& nmol/µL is the same as mM since nano is one thousandth of µ, we need to use the one thousandth prefix, with M, hence "mM"

base unit
divide by 10^3 / multiply by 10^3

milli	m	10^{-3}	thousandth of a...
micro	µ	10^{-6}	millionth of a...
nano	n	10^{-9}	billionth of a...
pico	p	10^{-12}	trillionth of a...

When unsure what to do, write it out & make sure units cancel out

If your concentration is in mM (mmol/L), how many mol per µL?

$\frac{Y\,\cancel{mmol}}{\cancel{L}} \times \frac{1\,mol}{10^3\,\cancel{mmol}} \times \frac{1\,\cancel{L}}{10^6\,\mu L} = Y \times 10^{-9}\,mol/\mu L$

10^{-9} - that's the nano prefix! So this is the same as Y nmol/µL!
e.g. a 50 mM NaCl solution would have 50 nmol NaCl per µL

relative concentrations

often concentrated solutions will be described in terms of relative concentrations (relative to the final, "working" concentration)

1X is the working concentration - the concentration you want it to be at in your final solution

1X

in $C_1V_1=C_2V_2$ terms, 1X is your C2
the concentration of the stock is your C1

$C_1V_1=C_2V_2$
initial concentration X initial volume = final concentration X final volume

the relative concentration (x-factor) = $\frac{C_1}{C_2}$

the number before the X is the dilution factor of the working concentration

10 X	50 X	1000 X
10X more concentrated than you want	50X more concentrated than you want	1000X more concentrated than you want

divide final desired volume by x-factor to figure out how much concentrate you need

$V_1 = \frac{V_2}{\text{x-factor}}$

e.g. if you want a final volume of 100mL, add 100/10 =10mL of 10X; 100/50=2mL of 50X or 100/100=1mL of 100X stock

multiply starting volume of concentrate by x-factor to figure out final volume to dilute it to*

$V_2 = \text{x-factor} * V_1$

e.g. if you start with 10mL concentrate, dilute 10X to 10*10=100mL, 50X to 10*50= 500mL; and 100X to 10*100=1000mL (1L)

*before you dilute it directly to that final volume, keep in mind that there might be other components contributing to that final total volume

calculations with relative concentrations

you can treat relative concentrations just like other concentrations in terms of $C_1V_1=C_2V_2$

$C_1V_1=C_2V_2$

initial concentration X initial volume = final concentration X final volume

the working concentration, 1X, is your C_2

the stock concentration, something X, is your C_1

the X's cancel out (just like units would) so we can ignore them and focus on the number before the X

the relative concentration (x-factor) = $\frac{C_1}{C_2}$

How much concentrate do I need to make a certain final volume?

$V_1=\frac{C_2V_2}{C_1}=\frac{V_2}{\frac{C_1}{C_2}}$ $\quad V_1=\frac{V_2}{\text{x-factor}}$

if you know the final volume you want, divide by the # before the x to figure out how much of the concentrated stock you need

e.g. if you want a final volume of 100mL, add 100/10 =10mL of 10X stock

What should my final volume be given starting amount of stock?

$V_2=\frac{C_1V_1}{C_2}$ $\quad V_2=\text{x-factor}*V_1$

if you know the initial volume you want to use, multiply by the # before the x to figure out how much final volume you want (what should you dilute it to?)

e.g. if you start with 10mL concentrate, dilute 10X to 10*10=100mL

tip: if you're making stock solutions, where possible make them with dilution factors of multiples of 10 for easy mental math

for example, if your stock is 1000X, you can quickly calculate that you need 1mL per L

similarly, when possible, choose a final volume that's divisible by the x-factor

for example, if you have a 6X gel loading buffer, prepare 6, 12, 24, 36... µL

working with protein concentrations

proteins vary greatly in size, so mass/volume can be misleading

The molecular weight (MW) of proteins is typically given in **Daltons (Da)** or **kiloDaltons (kDa)**

1 Da = 1 g/mol 1 kDa = 1000 Da = 1000 g/mol = 1 kg/mol

To go from Da to kDa, divide by 1000. To go from kDa to Da, multiply by 1000

you can think of the Da as shorthand so you don't have to write "g/mol"

quick estimates: the average amino acid is ~0.1 kDa (100 Da) so a 1000 amino-acid-long protein would have a MW of ~100 kDa

estimated protein length from MW (in kDa) = kDa x 10

estimated MW (in kDa) from protein length = # amino acids / 10

to go from mass/volume* to molarity:

molarity = (mass / volume) / MW

$\text{molarity} = \frac{\cancel{g}}{L} \times \frac{mol}{\cancel{g}}$

make sure this is in Da (convert from kDa if needed)

*shortcut: protein concentration is generally measured/reported in mg/mL, but mg/mL = g/L = µg/µL because in each case you're dividing both of these by the same factor of 10

molarity = (mg / mL) / MW (in Da) molarity = (mg/mL) / (MW (in kDa) x 1000) — in terms of kDa

mass/volume from molarity and MW

mg/mL = molarity X MW (in Da) mg/mL = molarity X (MW (in kDa) x 1000)

mass from molarity and volume

mg = molarity X MW (in Da) X mL or µg = molarity X MW (in Da) X µL

% weight/volume (%w/v) is a relative concentration

it is sometimes used for dilute aqueous solutions, especially in medicine

1% w/v = 1g/100mL

Why?

it comes from the fact that water has a density of 1g/mL (at room temp) and adding a little solute won't change that

So the density of most biological solutions is close to the density of pure water, so ~1g/mL.

So if you say that there's 1g of something else in there, and the solution still had a density of 1g/mL it'd have to mean that the solution was 100% your thing. So 1g/mL is 100% w/v.

warning: for this to hold true, the thing you're adding has to be similar to the density of water and/or there's just so little of it compared to water that it doesn't make too much of a dent

$C_1V_1=C_2V_2$

initial concentration X initial volume = final concentration X final volume

rearrange

isolate the unknown

$C_1=\frac{C_2V_2}{V_1}$ or $V_1=\frac{C_2V_2}{C_1}$ or $C_2=\frac{C_1V_1}{V_2}$ or $V_2=\frac{C_1V_1}{C_2}$

then exchange

stick in the known

replace those placeholders with numbers

and math it out

solve for the unknown

solution-making calculating example - Part 1

$C_1V_1=C_2V_2$

initial concentration X initial volume = final concentration X final volume

what stock solutions do you have?

initial concentrations

C_1 1M Tris pH 8
5M NaCl

initial volumes

V_1 this is what you need to find

what final solution do you want?

desired concentrations

C_2 10mM Tris pH 8
100mM NaCl

desired volumes

V_2 250 mL

$C_1V_1=C_2V_2$ it for each component, then add water to get to the final desired volume

try it out (at least the calculating part!) and I'll meet you with the answer in the next figure!

solution-making calculating example

Use 1M Tris & 5M NaCl stock solutions to make 250mL of a solution that is 10mM Tris, 100mM NaCl

convert units so they're consistent

1000 mM = 1 M

so...

10 mM = 0.01 M

100 mM = 0.1 M

Calculate amount of Tris needed

$$C_{1(Tris)}V_{1(Tris)} = C_{2(Tris)}\,250\text{ mL}$$

$$1M_{(Tris)}V_{1(Tris)} = 0.01M_{(Tris)}\,250\text{ mL}$$

$$V_{1(Tris)} = \frac{0.01M_{(Tris)}\,250\text{ mL}}{1M_{(Tris)}}$$

$$V_{1(Tris)} = 2.5\text{ mL}$$

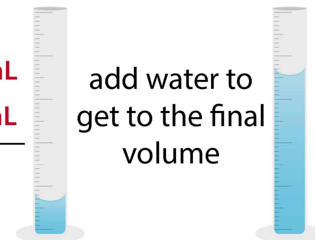
Calculate amount of NaCl needed

$$C_{1(NaCl)}V_{1(NaCl)} = C_{2(NaCl)}\,250\text{ mL}$$

$$5M_{(NaCl)}V_{1(NaCl)} = 0.1M_{(NaCl)}\,250\text{ mL}$$

$$V_{1(NaCl)} = \frac{0.1M_{(NaCl)}\,250\text{ mL}}{5M_{(NaCl)}}$$

$$V_{1(NaCl)} = 5\text{ mL}$$



add water to get to the final volume

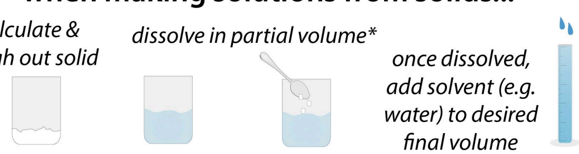
stuff takes up space!

molarity (M) is mol solute / L *solution*

this is ***total*** solution volume

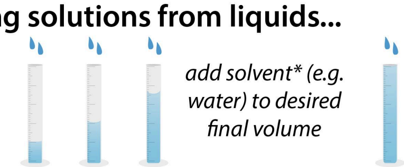
so when you prepare a solution of a specific molarity, you need to take into account the volume of the solute

when making solutions from solids...



*the more solid you need to stuff in there, the more space you need to leave

when making solutions from liquids...



*if the liquids interact or otherwise affect one another (e.g. EtOH & water), the solvent volume might be different than what you'd calculate

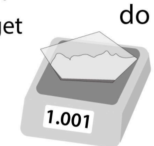
Solution-making from solids

calculate

Use the formula weight or molecular weight (g/mol) to figure out how much you need to weigh out to get the desired molarity (mol/L)

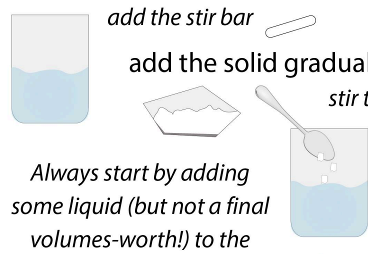
weigh

do it



dissolve

Start with a lower volume than your final volume because the solid will take up space



Always start by adding some liquid (but not a final volumes-worth!) to the vessel before solid, or you'll get a hard lump, perhaps with a stir bar stuck in it.

adjust volume

Transfer to a graduated cyclinder

Adjust volume in a graduated cylinder - NOT the beaker - & beware of the stir bar!

salty stock solution example

NaCl has a formula weight of ~58.44 g/mol

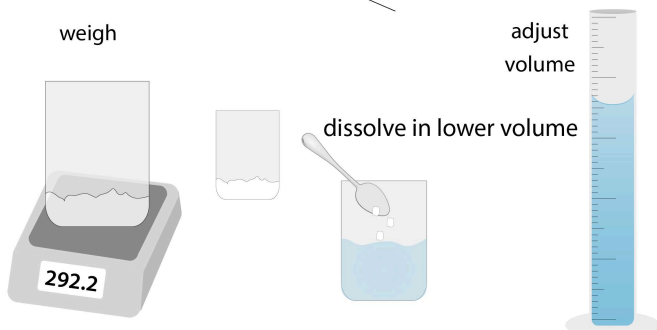
If I want a 5 molar (5M) solution

in molarity:

$$\textbf{MOLARITY} = \frac{\text{moles of something}}{\text{liter}}$$

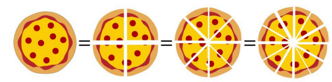
a mole is just 6×10^{23} of something (Avogadro's Number)

$$\frac{5\ \cancel{\text{mol NaCl}}}{1\text{L solution}} \times \frac{58.44\text{ g NaCl}}{1\ \cancel{\text{mol NaCl}}} = \frac{292.2\text{ g NaCl}}{1\text{L solution}}$$

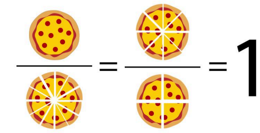


dimensional analysis!

There's many a way to same-thing-say! And this lets us convert units!



when you divide something by itself, even if that something is described in different ways, you get 1



so you can harmlessly change units by multiplying or dividing anything by 1

for examples...

starting info: I have 2 pizzas. Each has 12 slices. There are 24 people

How many slices do I have?

start point: $\frac{\text{2 pizzas}}{}$ = destination: ? slices

$$\frac{2\ \cancel{\text{pizzas}}}{} \times \frac{12\text{ slices}}{1\ \cancel{\text{pizza}}} = 24\text{ slices}$$

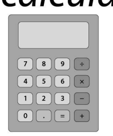
How many slices does each person get?

start point: $\frac{\text{2 pizzas}}{\text{24 people}}$ = destination: $\frac{\text{? slices}}{\text{person}}$

$$\frac{2\ \cancel{\text{pizzas}}}{24\text{ people}} \times \frac{12\text{ slices}}{1\ \cancel{\text{pizza}}} = \frac{1\text{ slice}}{\text{person}}$$

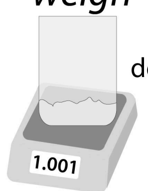
pH buffer stock making

calculate



use the formula weight to figure out how much you need to weigh out to get the desired molarity

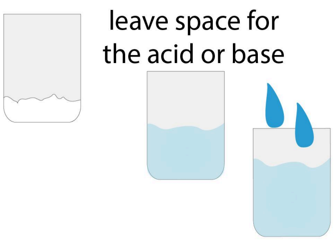
weigh



do it

dissolve/dilute partway

leave space for the acid or base



adjust pH

add concentrated acid/base dropwise while monitoring pH change

once it (stably) gets to the desired pH (at the desired temp)

adjust volume

do this in a graduated cylinder - NOT the beaker - and beware of the stir bar!

Tris base has a formula weight of ~121.14 g/mol

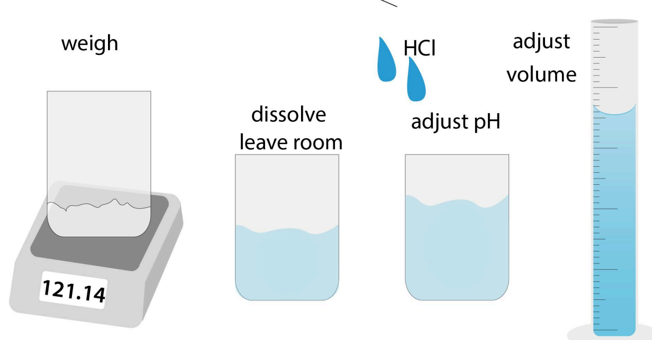
We want a 1 molar (1M) solution

in molarity:

$$\textbf{MOLARITY} = \frac{\text{moles of something}}{\text{liter}}$$

a mole is just 6×10^{23} of something (Avogadro's Number)

$$\frac{1\ \cancel{\text{mol Tris}}}{1\text{L solution}} \times \frac{121.14\text{ g Tris}}{1\ \cancel{\text{mol Tris}}} = \frac{121.14\text{ g Tris}}{1\text{L solution}}$$



salty stock solution example

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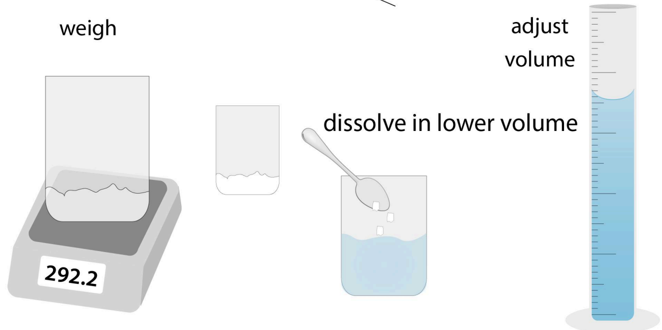


solution-making calculating example

Use 1M Tris & 5M NaCl stock solutions to make 250mL of a solution that is 10mM Tris, 100mM NaCl

convert units so they're consistent

1000 mM = 1 M

so...

10 mM = 0.01 M

100 mM = 0.1 M

Calculate amount of Tris needed

$$C_{1(\text{Tris})} V_{1(\text{Tris})} = C_{2(\text{Tris})} 250\ \text{mL}$$

$$1\text{M}_{(\text{Tris})} V_{1(\text{Tris})} = 0.01\text{M}_{(\text{Tris})} 250\ \text{mL}$$

$$V_{1(\text{Tris})} = \frac{0.01\text{M}_{(\text{Tris})} 250\ \text{mL}}{1\text{M}_{(\text{Tris})}}$$

$$V_{1(\text{Tris})} = 2.5\ \text{mL}$$

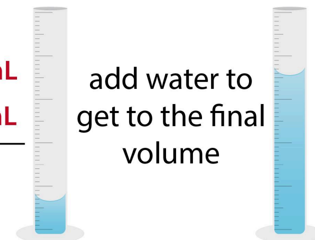
Calculate amount of NaCl needed

$$C_{1(\text{NaCl})} V_{1(\text{NaCl})} = C_{2(\text{NaCl})} 250\ \text{mL}$$

$$5\text{M}_{(\text{NaCl})} V_{1(\text{NaCl})} = 0.1\text{M}_{(\text{NaCl})} 250\ \text{mL}$$

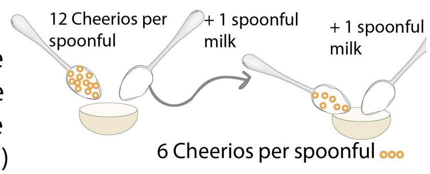
$$V_{1(\text{NaCl})} = \frac{0.1\text{M}_{(\text{NaCl})} 250\ \text{mL}}{5\text{M}_{(\text{NaCl})}}$$

$$V_{1(\text{NaCl})} = 5\ \text{mL}$$



serial dilutions

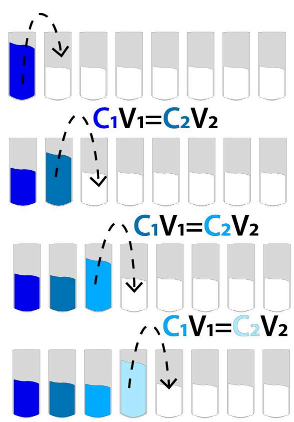
a series of stepwise dilutions where you're diluting a thing by the same factor each time (the dilution factor, DF)



$$C_1 V_1 = C_2 V_2$$

initial concentration X **initial volume** = **final concentration** X **final volume**

in a serial dilution, the final concentration of 1 thing (C_2) becomes initial concentration (C_1) for the next



You can easily figure out the concentration of each dilution in a standard curve without having to math out the whole series.

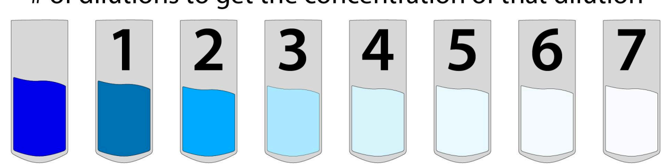
you just need to know the initial concentration, the # of dilutions since then and the **Dilution Factor**: how much are you diluting by each time?

for example, if you halve it each time (i.e. each dilution has 1/2 the concentration of the prior one), you'd have a dilution factor of 2.

if each dilution has 1/3 the concentration of the prior one), you'd have a dilution factor of 3.

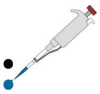
if each dilution has 1/4 the concentration of the prior one), you'd have a dilution factor of 4. etc. etc. etc.

multiply the initial concentration by (1/DF) raised to the # of dilutions to get the concentration of that dilution



C_1 $\quad C_1\left(\frac{1}{DF}\right)^1$ $\quad C_1\left(\frac{1}{DF}\right)^2$ $\quad C_1\left(\frac{1}{DF}\right)^3$ $\quad C_1\left(\frac{1}{DF}\right)^4$ $\quad C_1\left(\frac{1}{DF}\right)^5$ $\quad C_1\left(\frac{1}{DF}\right)^6$ $\quad C_1\left(\frac{1}{DF}\right)^7$

The bumbling biochemist 06/29/2024 https://bit.ly/importantlabmath

Lab tip:  Make Master Mixes

Determine which reagents are the same in each reaction mixture and mix those together (making enough for all reactions + a little extra to account for volume loss in transfers, etc.), then add that to the part(s) that are different.

Master Mixes

make sure you make enough happiness to share!
make enough as you need for # of people and a little to spare!

# of people	10		
prepare as if there were	11		
per person		total to make	
reagent	quantity	reagent	quantity
puppies	5	puppies	=S9*T3
kittens	1	kittens	
rainbows	2	rainbows	
Parafilm	1	Parafilm	
just add person!			

# of people	10		
prepare as if there were	11		
per person		total to make	
reagent	quantity	reagent	quantity
puppies	5	puppies	55
kittens	1	kittens	11
rainbows	2	rainbows	22
Parafilm	1	Parafilm	11
just add person!			

Master Mixes

MORE SERIOUSLY...

# of reactions		8		
prepare as if there were		8.5		
per reaction			total to make of mastermix	
reagent	quantity (uL)		reagent	quantity
RNA (at 50uM)	2			
10X PNK buffer	5		10X PNK buffei	42.5
water	37		water	314.5
hot ATP	5		hot ATP	42.5
PNK	1		PNK	8.5
final volume	50		volume mastermix to make	
				408
amount of master mix per sample				
	48		amount of wiggle room	
			amount you "need": 8*48= 384	
			408-384 = 24uL extra	

Always prepare more than you think that you need...

You have to account for volume loss due to liquid sticking on the pipets, tubes, etc. &/or evaporating out.

and, if possible, prepare enough to redo if at first you don't succeed!

2 + extra rule of thumb

Ideally, make/save enough sample to redo an experiment if it doesn't work without having to go all the way back to actually getting &/or preparing that sample.