**2. Student Guide – Solutions**

 Knowing how to make a solution is like knowing how to turn the key when starting a car, if you don’t know how to do it properly, you will not get anywhere. Practically every sub-discipline within the biological sciences requires the use of specific solutions. If you don’t know how to make solutions, then you will be faced with many detours along the way.

 Laboratory calculations and making proper solutions are some of the most important procedures in a research or industry laboratory. If solutions are not prepared accurately, experiments may fail, and this is a waste of time and money. Biological experiments are particularly sensitive to alterations in chemical composition of solutions. For example, incorrectly prepared media may inhibit bacterial growth. Solution components are almost always expressed as concentrations – the amount of solute per volume of solution. There are many ways to describe solution concentration, but all of them must express the quantity of solute present in a given quantity of solvent. Concentration can be expressed in several different format solutions in the lab, however the two most common are concentrations based on molarity and concentration based on % (weight/volume) and % (volume/volume).

**Concentrations based on Molarity**

A molar solution contains one mole of solute in one liter of solution. One mole of a solute is equivalent to the molecular weight of the solute. The molecular weight of a solute is often printed on the side of the chemical bottle and may be abbreviated MW.

Note: sometimes you will see the shorthand ‘qs’ meaning quality sufficient. It is a term indicating the total volume of the solution (solute + solvent).

**Mole = 6.02 X 1023 atoms (written as mol or moles)**

A mole of substance is the amount of that substance that contains 6.02 X 1023 atoms.

**Molecular weight (MW) = g/mole**

The molecular weight of a particular molecule is the sum of the atomic weights of all of its constituent atoms. For nearly any laboratory reagent, the molecular weight does not need to be calculated, but is provided on the chemical bottle or jar that the reagent comes in or can be found in reference material. The weight of a molecule is the sum of the weights of the atoms of which it is made. So, for example, sodium chloride is NaCl, or one atom of sodium (Na) and one atom of chlorine (Cl). To calculate the molecular weight of NaCl, you would add the atomic weights of Na and Cl: 22.99 + 35.45 = **58.44 grams/mole**.

**Molarity (M) = moles of solute/liters of solution = moles/L**

Molarity is a measure of concentration of a solution and can be calculated if the molecular weight (MW) of a substance is known.



**Example: Prepare a 1 M NaCl solution.**

Solution:

1. Determine the MW of NaCl by looking on the side of the chemical container (MW = 58.5 g/mol). Alternatively, you can calculate the MW of a solute by adding together the MW of each individual element (MW Na = 23 g/mol; MW Cl=35.5 g/mol; MW NaCl = 58.5 g/mol.
2. Weigh out 58.5 g of NaCl and use ddH20 to bring the total volume of solution to 1 liter.



**Example: Prepare 1 L of 4 M CaCl2.**

Solution:

1. Determine the MW of CaCl2 (MW = 111 g/mol).
2. Calculate the grams of CaCl2 needed for a 1 M solution. Then multiple by 4.

$1 M= \left(\frac{111 g CaCl\_{2}}{1 L}\right)$

$4 M=4\left(\frac{111 g CaCl\_{2} }{1 L}\right)$

 4 M = 444 g CaCl2/L



**Example: Prepare 300 mL of 2 M NaCl.**

 Solution:

1. Determine the MW of NaCl (MW = 58.5 g/mol).
2. Calculate the grams of NaCl needed for a 1 M solution. (58.5 g as determined previously)
3. Calculate grams of NaCl needed for a 2 M solution (58.5 x 2 = 117 g NaCl)
4. Determine grams needed to make 300 mL of solution

$\left(\frac{117g NaCl}{1000 mL}\right)= \left(\frac{x}{300 mL}\right)$

 X = 35.1 g of NaCl qs to 300 mL with ddH20

**When making a complex solution of more than one solute, you just treat each solute individually by determining the appropriate mass for each, then combine in a flask and add the appropriate volume of solvent.**



**Example: Prepare 5 L of 50 mM NaCl and 10 mM Tris-HCL solution. [MW of NaCl 58.44 g/mol, and MW of Tris-HCL is 157.56 g/mol]**

Solution:

1. Moles of solute = M (mol/L) x volume (L)

2. Moles of NaCl = 50 mM = 50 mmol/L, so (0.05 moles/1 L) x 5 L = 0.25 mol NaCl

 (Don’t forget 50 mmol = 10^-3 mol or 0.05 mol)

3. X g of NaCl needed = 0.25 mol NaCl x 58.44 g/mol

 = 14.61 grams NaCl needed

4. Moles of Tris-HCL= 10 mM = 10 mmol/L, so (0.01 moles/1 L) x 5 L = 0.05 mol Tris-HCl

5. X g of Tris-HCl needed = 0.05 mol Tris-HCL x 157.56 g/mol = 7.88 g Tris-HCL needed

6. Make the solution! = Add 14.61 grams of NaCl and 7.88 grams of Tris-HCL to a container and add ddH2O up to 5 L total

***Now you try! The following are examples of molar solution problems using the given molecular weights. (Remember, if you ever need to make a solution with two or more solutes, just calculate them individually, add that mass of powder to a flask for each solute, the add solvent up to the desired final volume.)***

| **Compound** | **Molecular Weight (g/mol)** |
| --- | --- |
| Ammonium sulfate (NH4)2SO4 | 132.14  |
| Hydrochloric acid (HCl) | 36.47 |
| Sodium Hydroxide (NaOH) | 39.99 |
| Sulfuric acid (H2SO4) | 98.08 |

1. How many grams of ammonium sulfate are needed to prepare 500 mL of a 4 M (NH4)2SO4 solution?

2. You weigh out 79.98 g of sodium hydroxide and qs to 500 mL with ddH20. What is the molarity of the solution?

3. I prepared 250 mL of a 0.5 M HCl solution. How many grams of HCl were needed to prepare this initial stock?

4. Is it possible to prepare 300 mL of a 2 M sulfuric acid solution with only 50 g of sulfuric acid remaining? Explain your answer.

**PERCENT SOLUTIONS**

Many reagents in the laboratory are prepared in solution form (percent solutions, molar solutions). Normal solutions are more commonly used in the chemistry lab and will not be covered in this laboratory math module. All of these terms indicate the concentration of the solution; therefore, accurate calculations are important in reagent preparation.

**PERCENT SOLUTIONS**

There are three types of percent solutions (% weight/weight, % weight/volume, % volume/volume). The two most common percent solutions used in the lab are (% weight/volume) and (% volume/volume).

 **weight/volume: %** $\frac{weight}{volume}$ **= Percent weight of solute in the total volume of solution**

*For instance:* A 1 % agarose solution is 1 gram of agarose powder in 100 mL of TAE buffer.

*For instance:* A 5 % milk buffer solution is 5 grams of powdered milk in 100 mL of PBS-T buffer.

 **volume/volume: %** $\frac{volume}{volume}$ **= Percent volume of solute in total volume of solution**

*For instance:* A 70 % isopropanol solution is 70 mL of isopropanol added to 30 mL ddH20 (100 mL total vol.)

*For instance:* A 10 % methanol solution is 10 mL of methanol added to 90 mL ddH20 (100 mL total vol.)



**Example: What is the percent concentration of a solution prepared with 5.85 g of NaCl and diluting to 100 mL with ddH20?**

$\left(\frac{5.85 g}{100 mL}\right)=5.85 \% solution of NaCl$



**Example: What is the percent concentration of a solution prepared with 40 g of CaCl2 and diluting to 500 mL with ddH20?**

$\left(\frac{40 g}{500 mL}\right)= \left(\frac{?g}{100 mL}\right)$

$\left(40 g×100 mL\right)= \left(500 mL× ?g\right)$

$?=8 g$

$\left(\frac{8 g}{100mL}\right)=8 \% CaCl\_{2} solution $

***Now you try! Here are some practice problems for percent solutions.***

1. How many grams of dry milk would you need to prepare 300 mL of 5 % milk buffer for an ELISA assay?

2. What is the percent concentration of an ammonium sulfate solution made using 985 mg of (NH4)2SO4 and diluting to 750 mL with ddH20?

3. The lab is running short of chemicals and there is only 1.5 g of glucose remaining. Is there enough chemical to prepare 30 mL of 2.5 % glucose solution?

**PREPARING SOLUTIONS FROM SOLUTIONS**

**(C1V1 = C2V2)is the same as (V1C1 = V2C2)**

In the lab, you will often need to prepare working solutions from more concentrated stock solutions. It is easiest to solve these problems using the following formula:

$V\_{1}C\_{1}=V\_{2}C\_{2}$

In this formula V = volume and C = concentration. You will use this formula frequently in your laboratory career and it is a simple one, so save yourself time and commit it to memory.



Example: How much 4 M HCl is needed to prepare 500 mL of a 2 M solution.

Solution: $V\_{1}C\_{1}=V\_{2}C\_{2}$

$\left(x\right)\left(4 M HCl\right)=\left(500 mL\right)(2 M HCl)$

$x=\frac{\left(500×2\right) mL}{4}$

$x=250 mL$

***Now you try! Here are some practice problems using C1V1=C2V2***

1. How many mL of 1 M NaOH are needed to prepare 50 mL of 0.5 M NaOH.

2. Sam used 250 mL of stock solution to prepare 1 L of 0.25 M HCl solution. In the meantime, someone in the lab used all of the original stock and Chelsea could not remember the concentration to prepare more reagent. What was the original stock solution of HCl in Chelsea’s lab? (This is a good lesson in the importance of proper labeling!)

3. Tyia used 100 mL of a 4 M NaOH stock to prepare 500 mL of working NaOH solution. What is the molarity of Tyia’s working solution?

**Instructor Key**

***Molar Solutions Answers***

| **Compound** | **Molecular Weight (g/mol)** |
| --- | --- |
| Ammonium sulfate (NH4)2SO4 | 132.14 |
| Hydrochloric acid (HCl) | 36.47 |
| Sodium Hydroxide (NaOH) | 39.99 |
| Sulfuric acid (H2SO4) | 98.08 |

1. How many grams of ammonium sulfate are needed to prepare 500 mL of a 4 M (NH4)2SO4 solution?

(1) 1 M = 132.14 g/1000 mL

(2) 4 M = 4 x 132.14 g/1000 mL = 528.56 g/1000 mL

(3) 528.56 g/1000 mL = X/500 mL

(4) Solving for X = 264.28 g of ammonium sulfate needed

2. You weigh out 79.98 g of sodium hydroxide and qs to 500 mL with ddH20. What is the molarity of the solution?

(1) First determine the # of grams of NaOH in a 1 L solution

 79.98 g/500 mL = X/1000 mL (solve for X) X = 159.96 g

(2) Divide the # of grams in a 1 L solution by the MW to determine the molarity of the prepared solution

 159.96 g/39.99 g per mole (note the grams cancel out) = 4 M

3. I prepared 250 mL of a 0.5 M HCl solution. How many grams of HCl were needed to prepare this initial stock?

(1) First determine the # of grams of HCL to prepare a 1 M solution

 1 M = 36.47 g HCL/1000 mL

(2) Then determine the # of grams of HCL to prepare a 0.5 M solution

 0.5 M = 18.24 g/1000 mL

(3) Finally determine the # of grams for 250 mL of solution

 18.24 g/1000 mL = X/250 mL (solve for X) X = 4.56 g

4. Is it possible to prepare 300 mL of a 2 M sulfuric acid solution with only 50 g of sulfuric acid remaining? Explain your answer.

(1) 1 M H2SO4 = 98.08 g/1000 mL

(2) 2 M H2SO4 = 196.16 g/1000 mL

(3) 196.16 g/1000 mL = X/300 mL (solve for X) X = 58.85 g

(4) No, not enough remaining, need 58.85 g and only have 50 g left

***Percent Solutions Answers***

1. How many grams of dry milk would you need to prepare 300 mL of 5% milk buffer for an ELISA assay?

(1) 5/100 mL = X/300 mL (solve for X) X = 15 g of dry milk buffer is needed to prepare 300 mL of 5 % milk buffer

2. What is the percent concentration of an ammonium sulfate solution made using 985 mg of (NH4)2SO4 and diluting to 750 mL with ddH20?

(1) 985 mg = 0.985 g (remember: 985 mg/1 x 1 g/1000 mg converts mg to g)

(2) 0.985 g/750 mL = X/1000 mL (solve for X) X = 13.13 % (NH4)2SO4 solution

3. The lab is running short of chemicals and there is only 1.5 g of glucose remaining. Is there enough chemical to prepare 30 mL of 2.5 % glucose solution?

(1) 2.5 g/100 mL = 2.5 % glucose solution

(2) 2.5 g/100 mL = X/30 mL (solve for X) X = 0.75 g of glucose needed so yes there is enough

***C1V1=C2V2 Answers***

1. How many mL of 1 M NaOH are needed to prepare 50 mL of 0.5 M NaOH.

(1) X x 1 M = 50 mL x 0.5 M (note that “X” is what we are solving for and “x” means a times symbol)

(2) X = 25 mL qs to 50 mL using ddH2O

2. Sam used 250 mL of stock solution to prepare 1 L of 0.25 M HCl solution. In the meantime, someone in the lab used all of the original stock and Chelsea could not remember the concentration to prepare more reagent. What was the original stock solution of HCl in Chelsea’s lab? (This is a good lesson in the importance of proper labeling!)

(1) 1000 mL x 0.25 M = 250 mL x (X) M (solve for X) X = 1 M HCL

3. Tyia used 100 mL of a 4 M NaOH stock to prepare 500 mL of working NaOH solution. What is the molarity of Tyia’s working solution?

(1) 100 mL x 4 M = 500 mL x (X) M (solve for X) X = 0.8 M