Survey of General, Organic and Biochemistry
Laboratory No 3
CHM 108L-01
Spring 2021

Do Chemists have all solutions?

A teaching experiment produced by

Zulma Jiménez Ph.D.
Department of Chemistry
Notre Dame of Maryland University

Concepts to explore in this lab:

- Solubility
- Solvent vs Solute
- Concentration units (M, %w/v, %w/w)
- Types of solutions: unsaturated and saturated.

Survey of General, Organic and Biochemistry
Laboratory No 3
CHM 108L-01
Spring 2021

Do Chemists have all solutions?

A solution is a homogeneous mixture of two or more substances. A solution may exist as a solid a liquid or a gas. A solution consists of a solute and a solvent. The **solvent** is the substance that is in **greater quantity**. The **maximum amount** of solute that **can be** dissolved in a solvent is called its solubility. For example, at room temperature, you can dissolve up to 203.9 grams of sugar in 100 mL of water. If you change the temperature this ratio 203.9 g/100 mL will change!

When we talk about solutions in chemistry, we have to specify the nature of the solute and the solvent, and their amounts. The ratio of the solute amount and the amount of solution or solvent is called the concentration of the solution. The concentration can have different units:

Name (symbol)	Units
Percentage weight per volume (% w/v)	$\frac{grams\ of\ solute}{milliLiters\ of\ solution} \times 100$
Percentage weight per weight (% w/w)	$\frac{grams\ of\ solute}{grams\ of\ solute + grams\ of\ solvent} \times 100$
Percentage volume per volume (% v/v)	$\frac{milliLiters\ of\ solute}{milliLiters\ solution} \times 100$
Molarity (M)	$\frac{moles\ of\ solute}{Liters\ of\ solution}$
Molality (m)	$\frac{moles\ solute}{kilograms\ of\ solvent}$
Mass per volume (mg/L or g/mL or kg/L)	$\frac{mass\ of\ solute}{volume\ of\ solution}$
Molar fraction ($\bar{\chi}$)	$\frac{moles\ solute}{moles\ of\ solute + moles\ of\ solvent}$

Depending on the amount of solute in the solution, the solution can be concentrated or diluted. For example, we can say that regular Coca-Cola is more concentrated in sugar than Coca-Cola Life (green label); or which is the same, Coca-Cola Life is a dilute solution (less concentrated). We can also say that Coca-Cola Zero has 0% w/v sugar because it is zero grams of sugar. (see Figure 1)

Figure 1. Amount of sugar in different Coca-Cola drinks.

Adding a solute to a pure solvent (typically liquid) produces a solution that have properties that are different from the solvent properties. One of these properties is the freezing point depression, where the freezing point of the solution is lower than the freezing point of the pure solvent. For example, the freezing point of Vodka is -17 ^{o}F compared to the water freezing point which is 32 ^{o}F. Overall, Vodka is a solution of ~40%v/v of ethanol (solute) in water (solvent).

Survey of General, Organic and Biochemistry
Laboratory No 3
CHM 108L-01
Spring 2021

PART ONE

Pre-experiment Questions (write answers on your notebook)

1. Find on the web and draw the Lewis structure on your notebook the chemical structure of the following compounds:

Table N₀1.

Organic Compounds		Inorganic Compounds	
c1	Ethanol	c7	Magnesium sulfate
c2	Citric acid	c8	Sodium sulfate
c3	Ascorbic acid	c9	Calcium sulfate
c4	Oleic acid	c10	Calcium carbonate
c5	Eucalyptol	c11	Sodium carbonate
c6	Geraniol	c12	Magnesium carbonate
		c13	Sodium chloride
		c14	Magnesium chloride
		c15	Calcium chloride

General Protocol (Read entire protocol before starting the experiment)

Testing solubility:

- Label a test tube with the compound number (c#) and solvent name, then add to it 5.0 mL of the solvent (either water or oleic acid).
- Add to the test tube 0.250 grams or 0.500 mL (about 10 drops) of the compound, shake gently for a **couple of minutes** to try to dissolve the compound. Write your observations.

Preparing solutions: (note: all solutions will be prepared with deionized water)

from a solid:

- Using the balance to measure the mass of the solute you need to prepare the solution. (Use a weighting boat to hold the solid)
- Place a funnel on the mouth of a volumetric flask and VERY CAREFULLY transfer the solid to the flask. You can use a spatula to help transferring the solid. After all the solid is transferred, add a very small amount of water (with the water bottle) to the weighting boat and rinse it over the funnel; then rinse the funnel so any solid left on it will fall inside the flask.
- Remove the funnel and slowly start filling the flask with water until you get close to the mark on the neck of the flask; then use a disposable pipet to add drop by drop the water until you reach the mark.
- Place the top of the flask on it to seal the flask. Then ask your professor how to properly mix the solution.
- Label the flask with the name of the substance and the concentration in molarity. Also write your name and the date.

from a concentrated solution:

- Find the volumetric pipet that is labeled with the volume value, of the concentrated solution, that you need to use to prepare the dilute solution. Using the pipetting bulb, pipet the solution up until you reach the mark on the upper neck of the volumetric pipet.

- Carefully transfer the solution from the pipet to a clean volumetric flask. The latter should be marked with the volume of the diluted solution that you want to prepare.
- Using a water bottle, add water to the volumetric flask until you get close to the mark on the neck of the flask; then, use a disposable pipet to add drop by drop the water until you reach the mark.
- Place the top of the flask on it to seal the flask. Then ask your professor how to properly mix the solution.
- Label the flask with the name of the substance and the concentration in molarity. Also write your name and the date.

Experiment

2. Classify the compounds in Table No1 as ionic or covalent compounds.
3. Analyze the structures of the organic compounds (c1-c6) in Table No1 and classify them as polar or non-polar.
4. After looking at the Lewis structures of all the compounds (c1-c15), make a list of the compounds that you **predict** will dissolve in water and those that will not. **Give a reason for your answer**.

Solubility:

5. Individually test the solubility of each of the compound (c1 - c15) **in water** and write detailed observations of each mixture.
6. Individually test the solubility of eucalyptol, geraniol, citric acid, and ascorbic acid **in oleic acid**; and write your detailed observations.

Thinking About the Data

Solubility:

7. For compounds c1-c6, review your observations from numeral 5 and your predictions from numeral 4. How do they compare? Which ones are different? If any of your predictions differ from your observations, look again at the structure of those compounds, and explain why those are or are not soluble in water.
8. Based on your observations in numeral 6 and answers from numeral 3, explain the solubility of eucalyptol, geraniol, citric acid, and ascorbic acid in oleic acid.
9. According to your observations in numeral 5 for compounds (c7-c15), which are the most soluble salts in water, carbonates, sulfates or chlorides anions?
10. According to your observations in numeral 5 for compounds (c7-c15), which are the most soluble salts in water, salts with Na^+ or Mg^{2+} or Ca^{2+} cations?
11. Based on your previous observations and analysis, arrange compounds c7-c15 from the most soluble to the least soluble in water.
12. Find on the web the values of the solubility in water at 20°C, in units of **g/100 ml of H_2O**, for compounds c7-c14; and arrange them from the most soluble to the least soluble in water.
13. How accurately does your list in numeral 11 compares to your list in numeral 12? Why do you think there are discrepancies (if any)?
14. Discuss your answers for numerals 7-13 with the class.

Survey of General, Organic and Biochemistry
Laboratory No 3
CHM 108L-01
Spring 2021

PART TWO

Pre-experiment Questions

15. Watch this video to start learning how to properly prepare a solution. Take notes.
    Watch this video to learn how to use a volumetric pipet. Take notes.
16. Find on the web the solubility in water at 20°C, in units of **g/100 ml of H_2O,** of the following compounds: silver nitrate, calcium chloride, sodium carbonate and hydrogen chloride.
17. Find on the web the definition of dissolve and dissolution in the chemistry context.

Experiment

Solutions:

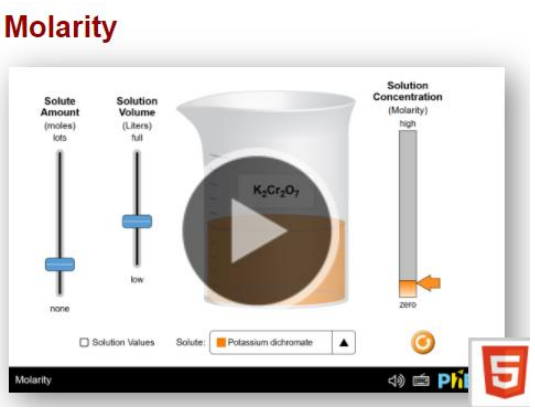
18. Calculate the molar mass or molecular weight of compounds #1-3 listed in Table No2.
19. Calculate the amount of solute needed to prepare 0.100L of solutions with compounds #1-3 with the given concentration. Show your calculation and complete the table below.

Table No2.

#	Compound (solute)	Formula	Molecular weight (g/mol)	Concentration (M)	Volume (L)	Mass (g)	Volume stock solution
1	Silver nitrate	$AgNO_3$		0.100	0.100		----
2	Calcium chloride	$CaCl_2$		0.100	0.100		----
3	Sodium Carbonate	Na_2CO_3		0.100	0.100		----
4	Hydrochloric acid	HCl		0.300	0.100		

20. Calculate the volume of the **stock solution** of HCl you will use to prepare 100 mL of a HCl 0.300 M (solution #4) which is a **dilute solution** (less concentrated). After calculating the volume, prepare the solution.
21. Based on the solubilities you found in numeral 16, is it possible to prepare the solutions listed above?
22. Prepare solutions with compounds #1-3 in the laboratory. Write your observations of the initial solid compounds and the final solutions. (Note: these solutions will be used in LabNo4 where you will explore a few chemical reactions)
23. Write the chemical equation that represents the **dissolution** of each of these three compounds #1-3 in water.
24. Go to this website, and follow these steps:

    a) When the window opens, you will see the image on the right, click on the play button and the simulation will open.
    b) In the simulation page, select the box "Solution Values" on the left bottom part of the page. When the box is selected, you will be able to see values for Solute Amount, Solution Volume, and Solution Concentration in units of molarity.
    c) Pick three different solutes to work with, write their name, molecular formula, and molar mass in Table No3.



d) Pick the Solution Volume, in Liters, that you will use to prepare all solutions, and write it in Table No3. In the simulation page, moving the "Solution Volume (Liters)" bar up and down, select the volume you picked.
e) You will prepare two solutions, **one saturated and one unsaturated**. So, pick your first solute in the simulation page. Then, move the bar for "Solute Amount (moles)" all the way down to zero, and note the color of the solvent. Now, slowly move up the bar for "Solute Amount (moles)" until you find the amount in which **the first crystal** (small square) appears at the bottom of the beaker and write down that number in the Table below for the saturated solution. Add more solute and write your observations of this solution type.
f) Now, pick a "Solute Amount (moles)" which is below the saturation amount, write down the new amount in table No3 and write the observations for this solution type.
g) Repeat d) and e) for the other two solutes.

TableNo3.

Solution Type	**Solute Name, Molecular Formula, and Molar Mass**	**Solvent**	**Solvent Volume (L)**	**Solute Amount (moles)**	**Solution Concentration (M)**	***Solute Amount (grams)**	***Solubility (g/100 mL H_2O)**	**Solution Properties/ Characteristics**
Saturated		H_2O						
Unsaturated								
Saturated		H_2O						
Unsaturated								
Saturated		H_2O						
Unsaturated								

* to complete in numeral 28.

Survey of General, Organic and Biochemistry
Laboratory No 3
CHM 108L-01
Spring 2021

Thinking About the Data

Solutions:

25. The first three solutions #1-3 have the same concentration (0.100 M) and volume (0.100L). Why are the masses of the compounds that you needed to prepare the solutions different? Explain.
26. Write the chemical equation that represents the **dissolution** in water of the salts you picked in numeral 24c).
27. For each solution, calculate the number of moles of each ion present in solution and complete the table below; in the table **M** represents the atomic symbol for the cation and **a+** its charge, and **x** represents the atomic symbol for the anion and **b-** its charge.

Table No4

Solution type – Solute molecular formula	Cation ($\mathbf{M}^{a+}$)	Moles of cation	Anion ($\mathbf{x}^{b-}$)	Moles of anion
Saturated -				
Unsaturated -				
Saturated -				
Unsaturated -				
Saturated -				
Unsaturated -				

28. Based on the number of moles of solute required to obtain a saturated solution, reported in Table No3, calculate the grams of each solute in the saturated solutions, and the solubility of each solute per 100 mL of water. Show your calculations and write your answers in Table No3.
29. Arrange the solutes in order of higher to lower solubility.
30. Watch this video and write a sentence on why the solutions you prepared in the simulation have different colors.
31. Write three conclusions of what you learnt in this laboratory.