NJIT SUMMER RET PROGRAM 2012
INSTRUCTIONAL MODULE
BY MINA ARMANI
NANO TECHNOLOGY IN PHARMACEUTICAL INDUSTRY
Solubility and Intermolecular Forces

Lesson 1: "Like Dissolves Like"

Subject: Chemistry

NJCCC Standards and Indicators:

5.1.12.D.2: Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams.
5.1.12.C.1: Reflect on and revise understandings as new evidence emerges.
5.1.12.C.2: Use data representations and new models to revise predictions and explanations.
5.2.12.A.5: Describe the process by which solutes dissolve in solvents.

Learning Objectives: Students will be able to

- **Analyze** the effect of temperature and particle size on the solubility of a series of solutes; vitamin C, and vitamin B, Vitamin E and Caffeine in two different solvents; water vs. acetone.
- **Plot** graphs using collected data.
- **Interpret** the relationship between the dependent and the independent variables based on the generated graphs to infer a valid conclusion explaining the effect of intermolecular and inramolecular forces in solubility.
- **Infer** a valid conclusion explaining the effect of intermolecular and inramolecular forces on solubility.
- **Propose** the best method of dissolving different solutes in a hydrogel solution.

Introduction:

Intramolecular forces are the attraction forces between atoms within one molecule. Intramolecular forces are:

1. Ionic bond
2. Covalent bond
3. Metallic bond

Covalent bonds are formed between non-metals sharing electrons while ionic bonds are attraction forces between two oppositely charged ions, a cation formed from a metal losing electron(s) and an anion formed from a non-metal gaining electron(s). Metallic bonds are an attraction force between the free or delocalized electrons and the positively charged metals. Metallic bonds are responsible for observing properties such as ductility, malleability, thermal and electrical conductivity, opacity and luster in metals. They are integral in explaining the physical properties of compounds.

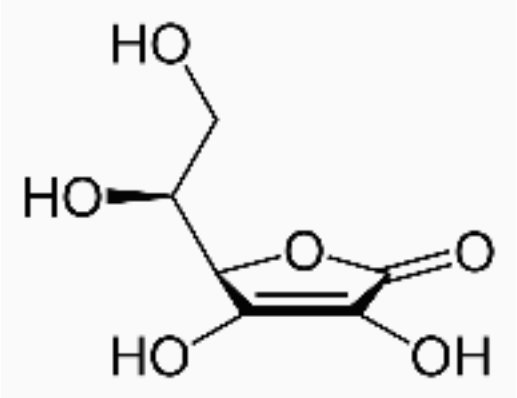
Intermolecular forces are the attraction or repulsion forces between atoms, molecules or ions. Intermolecular forces are:

1. London dispersion force
2. Debye (induced dipole) force

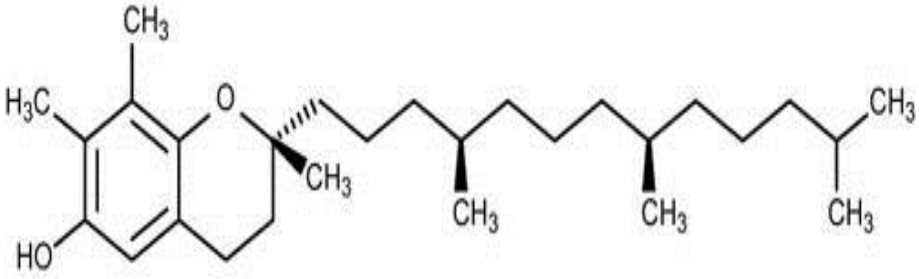
3. Dipole-dipole interaction
4. Ion-dipole and ion-induced dipole forces
5. Hydrogen bonding

They are important in determining the physical and chemical properties of compounds. In this module students will learn about the solubility of a series of compounds or solutes in two different solvents, water and acetone.
The selected solutes are Vitamin C (ascorbic acid), Vitamin B12 (Cobalamin), Vitamin E (Gamma Tocopherol) and Caffeine.

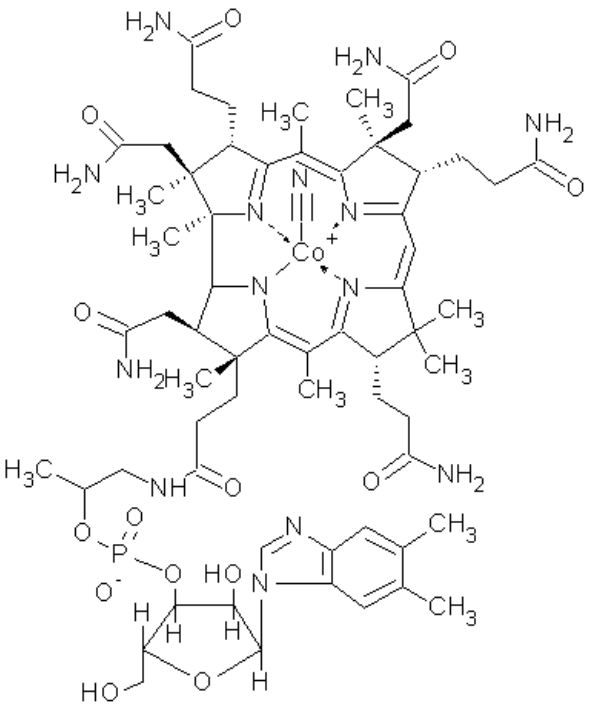
Intermolecular and intramolecular forces are the determining factor in solubility of a solute in a particular solvent. Non-polar solutes tend to dissolve in non-polar solvents while polar solutes tend to dissolve in polar solvents. This is known as the “LIKE DISSOLVE LIKE” rule.



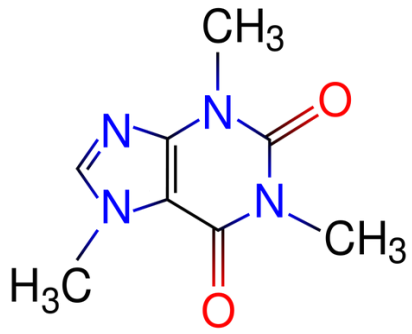
Vitamin C or Ascorbic Acid



Vitamin E or Gamma-Tocopherol



Vitamin B12 or Cobalamin

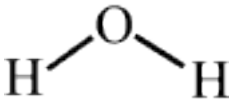
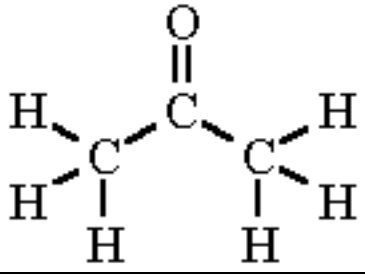


Caffeine

Activity:
Students will:
Weigh out (grams) specified amount of solutes using electrical balances.
Grind samples of solutes (Vitamin C and B) using pistol and mortar into a powder.
Measure specified volume of water and acetone using a graduated cylinder.
Measure dissolution time of the samples of different particle in water vs. acetone at room temperature.
Measure dissolution time of the samples of different particle in water vs. acetone at 37 °C water bath.
Tabulate the results and plot graphs to explain the relationships between the solubility, temperature and particle size.

Research:
Prior to the actual experimentation investigate polarity and non-polarity of the given solutes and solvents. Based on the gathered information predict if the solubility of each solute in the given solvents. Record your prediction below.

A) Record in table below if the compound is polar or non-polar.

		Polar	Non-Polar
Solute	Vitamin C		
	Vitamin B12		
	Vitamin E		
	Caffeine		
Solvent	Water 		
	Acetone 		

B) Predict the solubility of each solute in water and acetone based on the above information in the table below.

Solute	Solubility in Water	Solubility in Acetone
Vitamin C		
Vitamin B12		
Vitamin E		
Caffeine		

Activity:

Material:

Vitamin C	4 tablets
Vitamin B	4 tablets
Vitamin E	4 tablets
Caffeine	0.2 g
Acetone	160 mL
Water	160 mL
10 mL Test Tube	16
Water Bath	37 °C
Glass stirring rod	
Spatula	
Electrical Balance	
Mortar and Pistol	
Thermometer	

Procedure:

1. Using mortar and pistol grind one tablet of vitamin B, vitamin C, separately into a fine powder, be mindful of cross contamination. Wash and dry the mortar and pistol between different samples.

2. Measure the mass of each sample using an electric balance.

3. Store each sample in a separate vial, label with name of the compound, date, your name.

Day One:

A) Solubility in water vs. temperature

- **Room Temperature (record using a thermometer)**

Part I) Whole tablet or capsule

4. Using an electric balance weigh out a tablet of Vitamin C, record the weight and place it in a test tube. Label the test tube with the name of the compound, your name and date. Mark it with a “U” for ungrounded.

5. Using an electric balance weigh out a tablet of Vitamin B, record the weight and place it in a test tube. Label the test tube with the name of compound, your name and date. Mark it with a “U” for ungrounded.

6. In one test tube drop a capsule of vitamin E; label the test tube with the name of compound, your name, and date. Mark it with a “W” for whole.

7. Add to each test tube 5 ml of Distilled Water. Using a glass stirring rod try to dissolve each tablet or capsule while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Record the Room Temperature _____ °C

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		

Part II) Powdered tablet or content of capsule

8. In one test tube, add the previously powdered Vitamin C, label it with the compound name, your name and date.

9. In one other test tube, add the previously powdered Vitamin B, label it with the compound name, your name and date.

10. In another test tube, empty the content of a vitamin E capsule (cut the capsule with a scissor), label it with the compound name, your name and date.

11. Using an electric balance, weight out 0.2 g of caffeine into a test tube, label it with the compound name, your name and date.

12. Add to each test tube 5 ml of Distilled Water. Using a glass stirring rod try to dissolve the solute while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		
Caffeine		

➢ **37** °C **Temperature water bath (record using a thermometer)**

Part I) Whole tablet or capsule

1. Using an electric balance weigh out a tablet of Vitamin C, record the weight and place it in a test tube. Label the test tube with the name of the compound, your name and date. Mark it with a “U” for ungrounded.

2. Using an electric balance weigh out a tablet of Vitamin B, record the weight and place it in a test tube. Label the test tube with the name of compound, your name and date. Mark it with a “U” for ungrounded.

3. In one test tube drop a capsule of vitamin E; label the test tube with the name of compound, your name, and date. Mark it with a “W” for whole.

4. Add to each test tube 5 ml of 37°C Distilled Water and transfer immediately into the 37°C water bath. Using a glass stirring rod try to dissolve each tablet or capsule while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Temperature: 37 °C

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		

Part II) Powdered tablet or content of capsule

5. In one test tube, add the previously powdered Vitamin C, label it with the compound name, your name and date.

6. In one other test tube, add the previously powdered Vitamin B, label it with the compound name, your name and date.

7. In another test tube, empty the content of a vitamin E capsule (cut the capsule with a scissor), label it with the compound name, your name and date.

8. Using an electric balance, weight out 0.2 g of caffeine into a test tube, label it with the compound name, your name and date.

9. Add to each test tube 5 ml of 37°C Distilled Water and transfer immediately into the 37°C water bath. Using a glass stirring rod try to dissolve the solute while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Temperature: 37 °C

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		
Caffeine		

Answer the following questions:

Compound	Vitamin C	Vitamin B	Vitamin E	Caffeine
Did temperature affect the solubility of the following compounds?				
Did particle size have any effect on the solubility of the following compounds?				

Day Two:

B) Solubility in acetone vs. temperature

- **Room Temperature (record using a thermometer)**

Part I) Whole tablet or capsule

13. Using an electric balance weigh out a tablet of Vitamin C, record the weight and place it in a test tube. Label the test tube with the name of the compound, your name and date. Mark it with a "U" for ungrounded.

14. Using an electric balance weigh out a tablet of Vitamin B, record the weight and place it in a test tube. Label the test tube with the name of compound, your name and date. Mark it with a "U" for ungrounded.

15. In one test tube drop a capsule of vitamin E; label the test tube with the name of compound, your name, and date. Mark it with a "W" for whole.

16. Add to each test tube 5 ml of acetone. Using a glass stirring rod try to dissolve each tablet or capsule while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Record the Room Temperature _____ °C

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		

Part II) Powdered tablet or content of capsule

17. In one test tube, add the previously powdered Vitamin C, label it with the compound name, your name and date.

18. In one other test tube, add the previously powdered Vitamin B, label it with the compound name, your name and date.

19. In another test tube, empty the content of a vitamin E capsule (cut the capsule with a scissor), label it with the compound name, your name and date.

20. Using an electric balance, weight out 0.2 g of caffeine into a test tube, label it with the compound name, your name and date.

21. Add to each test tube 5 ml of acetone. Using a glass stirring rod try to dissolve the solute while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		
Caffeine		

➢ **37** °C **Temperature water bath (record using a thermometer)**

Part I) Whole tablet or capsule

10. Using an electric balance weigh out a tablet of Vitamin C, record the weight and place it in a test tube. Label the test tube with the name of the compound, your name and date. Mark it with a “U” for ungrounded.

11. Using an electric balance weigh out a tablet of Vitamin B, record the weight and place it in a test tube. Label the test tube with the name of compound, your name and date. Mark it with a “U” for ungrounded.

12. In one test tube drop a capsule of vitamin E; label the test tube with the name of compound, your name, and date. Mark it with a “W” for whole.

13. Add to each test tube 5 ml of 37°C equilibrated acetone and transfer immediately into the 37°C water bath. Using a glass stirring rod try to dissolve each tablet or capsule while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Temperature: 37 °C

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		

Part II) Powdered tablet or content of capsule

14. In one test tube, add the previously powdered Vitamin C, label it with the compound name, your name and date.

15. In one other test tube, add the previously powdered Vitamin B, label it with the compound name, your name and date.

16. In another test tube, empty the content of a vitamin E capsule (cut the capsule with a scissor), label it with the compound name, your name and date.

17. Using an electric balance, weight out 0.2 g of caffeine into a test tube, label it with the compound name, your name and date.

18. Add to each test tube 5 ml of 37°C equilibrated acetone and transfer immediately into the 37°C water bath. Using a glass stirring rod try to dissolve the solute while keeping track of the time using a stopwatch. Record your observation and if dissolved record the time.

Temperature: 37 °C

Compound	Was it soluble or not? Record your observation here.	Time of dissolution (min/sec)
Vitamin C		
Vitamin B		
Vitamin E		
Caffeine		

Answer the following questions:

Compound	Vitamin C	Vitamin B	Vitamin E	Caffeine
Did temperature affect the solubility of the following compounds?				
Did particle size have any effect on the solubility of the following compounds?				

Data Analysis and Results:

1) Create a bar graph for the solubility of each solute/solvent combination at room temperature.
2) Create a bar graph for the solubility of each solute/solvent combination at 37 °C temperature.
3) Create a scattered plot of time (min) vs. temperature (°C) for each solute/solvent combination.
4) Write a formal lab report following the provided rubric, and include your graphs and tables in there.
5) Answer the following questions:
   a) What determines for a covalent bond to polar or non-polar?
   b) What determines for a compound to be polar or non-polar?
   c) Is it possible for a compound containing polar bonds to be non-polar? How?

Student Assessment (Demonstration of Acquired Skills & Knowledge):

- Students will plot bar graphs of time (sec) that takes to dissolve same amount of two different particle sizes (fine and coarse) of different compounds at room temperature vs. two different solvents (water and acetone) respectively.
- Students will plot graphs (scatter plot) of time (sec) that takes to dissolve same amount of different compounds of two different particle sizes in the optimum solvent at different temperatures.
- Students will analyze the graphs to infer the relationships between temperature, solvent and particle size on solubility and explain the results using intermolecular and intramolecular forces.
- Students will answer the analysis questions provided.
- Students will write a formal lab report following the provided rubric.

Lesson 2: Caffeine Strip

Subject: Chemistry

NJCCC Standards and Indicators:
5.1.12.C.2: Use data representations and new models to revise predictions and explanations.
5.3.12 A.1: Represent and explain the relationship between the structure and function of each class of complex molecules using a variety of models.

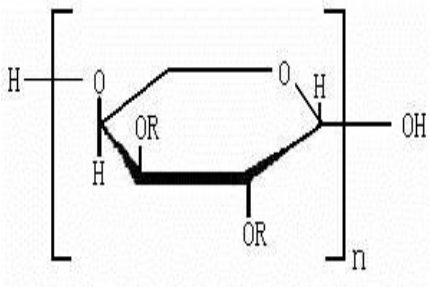
Learning Objectives: Students will be able to
Determine the polarity of Hydroxypropyl Methyl Cellulose (HPMC), Sodium Alginate and Gelatin molecules using scientific resources.
Determine the effect of intermolecular forces on the solubility of Caffeine in HPMC, Sodium Alginate, and Gelatin.
Determine the optimum hydrogel to be used for the uniform distribution of caffeine.

Introduction:
Hydrogels are long polymeric compounds that are water soluble due to their ionic side chains. These polymers can be linked together through their side chains and they can form flexible gels in water. This gel can be used to carry other chemical compounds such as medicines, vitamins or amino acids into human system.

In this study students will investigate the uniform dissolution of caffeine in three different bio gels, HPMC, Gelatin, and sodium alginate. This is to design a new delivery mechanism of high concentration of caffeine in human system.

Biopolymers used in this study are:

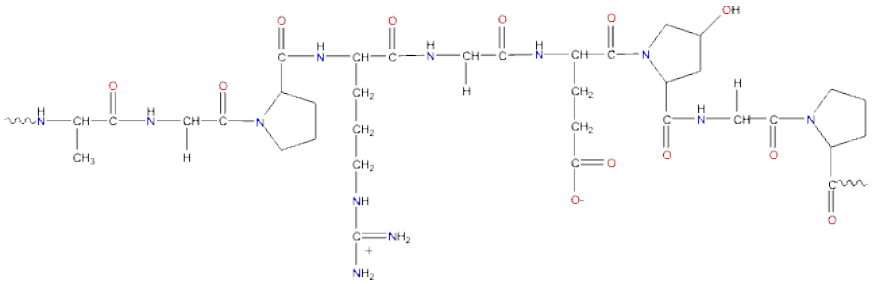
1) HPMC - Hydroxypropyl Methyl Cellulose



Where: n is number of glucose units in cellulose molecule.
R is CH_3 or $CH_2CH(0H)CH_3$.

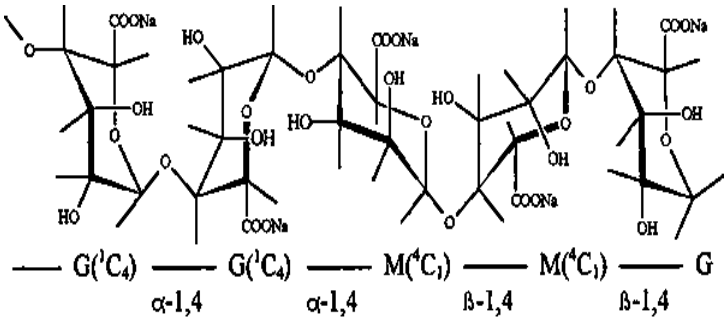
http://www.shhuiguang.com/pages/Hydroxypropyl_Methyl_Cellulose_en.htm

2) Gelatin contains many glycine (almost 1 in 3 residues, arranged every third residue), proline and 4-hydroxyproline residues. A typical structure is -Ala-Gly-Pro-Arg-Gly-Glu-4Hyp-Gly-Pro-.



http://www.lsbu.ac.uk/water/hygel.html

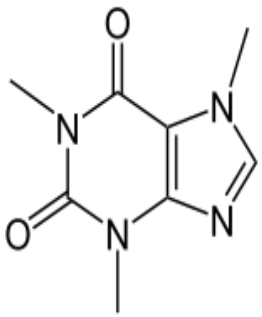
3) Sodium Alginate



http://www.fao.org/docrep/W6355E/w6355e0x.htm

It is an anionic polysaccharide that is abundant in the cell wall of brown algae. It can absorb water about 200-300 times of its weight to from a viscous gum. It has a vast application in medicine, food, medical products and fabric waterproofing and fireproofing among many others.

4) Caffeine (1,3,7-trimethyl-1*H*-purine-2,6(3*H*,7*H*)-dione 3,7-dihydro-1,3,7-trimethyl-1*H*-purine-2,6-dione)



http://en.wikipedia.org/wiki/Caffeine

A 16 Oz cup of coffee contains about 100 mg or 0.1 g caffeine. As a result in this study students will take about 0.1 grams of caffeine to distribute in a biopolymeric gel.

Activity:

Students will
Weigh out (grams) specific amount of HPMC, Sodium Alginate and Gelatin solutions using an electrical balance.
Predict the best bio gel solvent for uniform distribution of caffeine using literature.
Conclude based on the experimental results the best bio gel to uniformly distribute caffeine in.
Weight out (grams) specific amount of solute using an electric balance
Propose and investigate a method to casting and drying a uniform film of the prepared mixture.
Organize and Record the collected data and the photographs of the final products.

Material:
Sodium Alginate solution (2% solution)
HPMC (Hydroxyl Propyl Methyl Cellulose) solution (6% solution)
Freshly made Gelatin solution
Caffeine
Petri Dish
Square Glass Plate
Glass-Stirring Rod
Electrical Balance
Fume Hood
Hair Dryer
Hot Plate

Procedure:
I – Day One: Uniform Distribution and Film Casting of Caffeine in HPMC

1. Take three 50 mL beakers and label them with your name, date and the hydrogel being used, water is used as the control.

2. Using an electrical balance, measure the mass of the empty beaker and record it here. _____ grams

3. Using an electrical balance, add about 10.0 grams of HPMC to each labeled beaker. Record the total mass here. _____ grams

4. Subtract step 2 from step 3 and record it here. This is the mass of HPMC. Record it here. _____ grams

5. Using an electric balance, measure the mass of a weighing paper. Record the mass here. _____ grams

6. Using an electric balance add to the weighing paper about 0.1 gram of caffeine. Record the mass here. _____ grams

7. Subtract step 6 from step 5. This is the actual mass of Caffeine. Record it here. _____ grams

8. Calculate percent mass of caffeine in HPMC using the following formula. Record it here. %_____

$$\%\text{mass} = \frac{\text{Mass of Caffeine}}{\text{Mass of Caffeine + Mass of}}$$

9. Mix the solution thoroughly using a magnetic stirring bar on a magnetic stirrer with hot plate functionality slowly until it is uniformly mixed. Use low heat to speed up the dissolution process. Use a thermometer to monitor the temperature, it should not go above 40°C. Make sure the tip of the thermometer does not touch the magnetic stir bar.

10. When dissolved pour the mixture uniformly and slowly into a labeled Petri dish. If not dissolved completely, still cast the gel for comparison of a non-uniform distribution to a uniform distribution.

11. Use hotplate to dry one sample, label the petri dish accordingly. Use fume hood to dry another sample, label the petri dish accordingly. Use hair dryer to dry the third sample, label the petri dish accordingly. If using fume hood leave the sample uncovered and allow drying overnight.

12. Record your observation the day after and describe the physical characteristics of the casted gel. Take picture for your lab report.

II – Day Two: Uniform Distribution and Film Casting of Caffeine in Sodium Alginate

1. Take three 50 mL beakers and label them with your name, date and the hydrogel being used, water is used as the control.
2. Using an electrical balance, measure the mass of the empty beaker and record it here. _____gra ms
3. Using an electrical balance, add about 10.0 grams of 2% Sodium Alginate solution to the labeled beaker. Record the total mass here. _____gra ms
4. Subtract step 2 from step 3 and record it here. This is the mass of sodium alginate. Record it here. _____gra ms
5. Using an electric balance, measure the mass of a weighing paper. Record the mass here. _____gra ms
6. Using an electric balance add to the weighing paper about 0.1 gram of caffeine. Record the mass here.
7. Subtract step 6 from step 5. This is the actual mass of Caffeine. Record it here. _____gra ms
8. Mix the solution thoroughly using a magnetic stirring bar on a magnetic stirrer with hot plate functionality slowly until it is uniformly mixed. Use low heat to speed up the dissolution process. Use a thermometer to monitor the temperature, it should not go above 40°C. Make sure the tip of the thermometer does not touch the magnetic stir bar.

9. When dissolved, add 1 grams of 2% Calcium Chloride solution and mix with a glass-stirring rod. Then pour the mixture uniformly and slowly into a labeled Petri dish. If not dissolved completely, still cast the gel for comparison of a non-uniform distribution to a uniform distribution.

10. Use hotplate to dry one sample, label the petri dish accordingly. Use fume hood to dry another sample, label the petri dish accordingly. Use hair dryer to dry the third sample, label the petri dish accordingly. If using fume hood leave the sample uncovered and allow drying overnight.

11. Calculate percent mass of caffeine in sodium alginate using the following formula. Record it here

$$\%\text{mass} = \frac{\text{Mass of Caffeine}}{\text{Mass of Caffeine + Mass of Alginate + mass of } CaCl_2}$$

12. Record your observation the day after and describe the physical characteristics of the casted gel. Take picture for your lab report.

III- Day Three: Uniform Distribution and Film Casting of Caffeine in Gelatin.

1. Take three 50 mL beakers and label them with your name, date and the hydrogel being used, water is used as the control.

2. Using an electrical balance, measure the mass of the empty beaker and record it here. _____ grams

3. Using an electrical balance, add about 10.0 grams of Gelatin to the labeled beaker. Record the total mass here. _____ grams

4. Subtract step 2 from step 3 and record it here. This is the mass of HPMC. Record it here. _____ grams

5. Using an electric balance, measure the mass of a weighing paper. Record the mass here.
6. Using an electric balance add to the weighing paper about 0.1 gram of caffeine. Record the mass here. _____ grams

7. Subtract step 6 from step 5. This is the actual mass of Caffeine. Record it here. _____ grams

8. Calculate percent mass of caffeine in Gelatin using the following formula. Record it here. %_____

$$\%\text{mass} = \frac{\text{Mass of Caffeine}}{\text{Mass of Caffeine + Mass of}}$$

9. Mix the solution thoroughly using a magnetic stirring bar on a magnetic stirrer with hot plate functionality slowly until it is uniformly mixed. Use low heat to speed up the dissolution process. Use a thermometer to monitor the temperature, it should not go above 40°C. Make sure the tip of the thermometer does not touch the magnetic stir bar.

10. When dissolved pour the mixture uniformly and slowly into a labeled Petri dish. If not dissolved completely, still cast the gel for comparison of a non-uniform distribution to a uniform distribution.

11. Use hotplate to dry one sample, label the petri dish accordingly. Use fume hood to dry another sample, label the petri dish accordingly. Use hair dryer to dry the third sample, label the petri dish accordingly. If using fume hood leave the sample uncovered and allow drying overnight.

12. Record your observation the day after and describe the physical characteristics of the casted gel. Take picture for your lab report.

IV- Analysis Questions:

1. Describe the solubility of the solute in each hydrogel and explain your observation using intermolecular and inramolecular forces.
2. Did your solubility predications agree with the actual outcome? Why or why not?
3. Explain why one can remove gum from a piece of fabric with “goo-gun” but not water using the concepts of intermolecular and inramolecular forces.

Student Assessment (Demonstration of Acquired Skills & Knowledge):

Formal:

- Students will record data correctly in their lab notebook according to standards provided to them.
- Students will write a formal lab report presenting and explaining their data using the provided rubric.
- Students will answer the analysis questions provided.
- Unit Test will be given out at the end of all the activities.

Alternative:

- Students will create a power point presentation using background information of current research and their collected data.

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