PROJECT 2: FORMATION AND DISSOLUTION OF KIDNEY STONES

1. INTRODUCTION

Kidney stones, also called renal calculi, are a very common urinary disorder typically characterized by a high incidence and a high recurrence rate. This disorder consists of the formation of insoluble salt deposits in the urinary tract and inside the kidney (**Figure 1**). The incidence of this disorder has increased over the past 30 years for reasons that are not completely known and that have captured the attention of many researchers. The symptoms can vary from almost imperceptible to cramping pain in the back and side in the area of the kidney or in the lower abdomen. Other symptoms are block of the flow of urine, blood in the urine, chills, nausea, and sometimes fever, which explains the thousands of emergency room visits each year that are attributed to kidney stones.

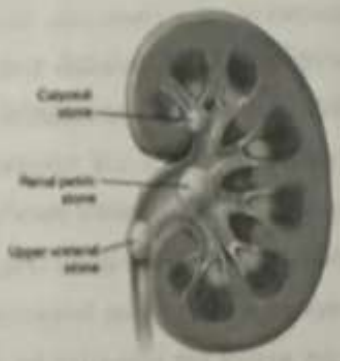

Figure 1. Diagram of kidney stones

This can be an out-of-this-world experience! Literally! Space flights cause an unusual loss of calcium from bone which combined with decreased fluid intake may promote the formation of a kidney stone during and after space flights. Can you imagine the serious consequences that suffering from kidney stone symptoms during a flight may have? There are medical research groups devoted to better understanding such risks to astronauts on long duration spaceflights, and to quantify kidney stone formation potential. By no means is this disorder new: Scientists have found evidence of kidney stones in mummies that are 7000 years old! And in this case, remedies are as old as the malady itself. You most probably have heard someone talk about some home remedy to prevent or cure kidney stones. For instance, some say that drinking a large volume of a certain type of carbonated drink followed by a glass of raw pureed asparagus and abundant water can dissolve kidney stones. We do not endorse any home remedy, but it would certainly be interesting to find out if there are any scientific explanations for this traditional remedy.

Here are two useful links:

http://www.nasa.gov/mission_pages/station/research/experiments/Renal_Stone.html

http://www.kidneyfund.org/kidney-health/kidney-problems/kidney-stones.html

2. PROJECT DESCRIPTION

There are different types of kidney stones and some run in families. The exact cause of a given type depends on the chemical nature of the precipitate or stone and, as you can imagine, their occurrence is related to the solubility of the precipitate, its concentration, and the presence of other chemicals. Factors such as diet and physical activity may be related too. Calcium stones may be the most common. Calcium can combine with other substances, such as oxalate (particularly present in certain foods such as spinach and supplements such as vitamin C), phosphate, or carbonate, to form the stone (**Figure 2**). Individual medical conditions and even medications may have an impact on kidney stone formation. Over 200 different components have been found in analyzed stones, but the stones are classified by their major component. The table below shows the four basic types of stones and what is in them.

Figure 2. Kidney Stone: "Staghorn" Calcium Oxalate. http://dev.stonedisease.org

Table 1. Basic Types of kidney stones and their components

TYPE OF STONE	MAJOR COMPONENT
Calcium Oxalate	CaC_2O_4
Calcium Phosphate	$Ca_3(PO_4)_2$
Uric Acid	Crystallized Uric Acid
Struvite	Mg, PO_4, NH_4
Cystine	Cystine (an amino acid or protein monomer)

In this experiment, your team will contribute some ideas to understand the development of kidney stones and the efficacy of countermeasures. Your team may explore some of the home remedies and cures based on ethnomedicine—traditional medicine—that are popular nowadays and offer a chemical

explanation for their apparent (or not) efficacy. The main objectives of this project are to synthesize several different forms of kidney stones using the chemicals provided in the lab and use home remedies and chemicals to test how well they dissolve the kidney stones and contribute to the quality of life of patients!

PLANNING YOUR PROJECT: During the first week of this project, your team will synthesize at least one type of kidney stone mimic from the chemicals available. **Make sure to keep your stones for next week's experiments**. Your artificial stones should be dry by the second week. You will need to determine the percent yield of the artificial stone(s) reaction and report the appearance of the stone(s) synthesized.

During the second week, your team also will be investigating ways to dissolve the artificial stones and advancing your understanding of solubility. For this, your team will bring at least two home remedies that can potentially dissolve the stone(s) synthesized by each group during the first week. Make sure to calculate the solubility constant of the artificial kidney stone(s) for each home remedy investigated.

Answer the following questions before you start your experiment

1. What is the objective of the project?
2. What are the balanced ionic equilibria for these four potential insoluble salts? You may want to write the complete equation and the net ionic equation. Use proper subscripts to indicate the state of reactants and products).
3. What amounts of reactants would be required to obtain at least 5 grams of each product? Remember to record and organize your calculations and data since they will be indispensable to complete your report, and for others to replicate your experiments.
4. How can an insoluble salt be separated from a solution? Describe the setup on how to separate your kidney stones from the solution. See section 3.
5. You will need to find the percent yield of your reactions. What considerations need to be made to make this measurement accurate?

3. CONCEPTS AND TECHNIQUES

Other topics may need to be reviewed depending on your experimental decisions. It may be the case that some of these topics are new to some members of your team: solubility, chemical equilibrium,

precipitation, acid base reactions, Le Chatelier's Principle, stoichiometric calculations, chelating agents, percent yield. Reviewing these techniques before coming to the lab may make your work easier and more productive: making solutions, different filtration techniques, centrifugation, mass measurement, titrations, dilutions and percentage yield calculations.

4. SUPPLEMENTAL INFORMATION AND ONLINE RESOURCES

These links provide information about concepts, research connection and laboratory techniques. Do not limit your search of information to this resource only.

- USF Laboratory Toolbox: https://www.usf.edu/arts-sciences/departments/chemistry/undergrad/teaching-labs/index.aspx
- Le Chatelier's principle: http://chemwiki.ucdavis.edu/Physical_Chemistry/Equilibria/A._Chemical_Equilibria/2._Le_Chatelier's_Principle
- Precipitation reactions: https://chem.libretexts.org/Textbook_Maps/Inorganic_Chemistry/Supplemental_Modules_(Inorganic_Chemistry)/Descriptive_Chemistry/Main_Group_Reactions/Reactions_in_Aqueous_Solutions/Precipitation_Reactions
- Centrifugation: http://www.jove.com/science-education/5019/an-introduction-to-the-centrifuge
- Kidney stone formation in our body: https://www.youtube.com/watch?v=kd1OgaoHkNk

5. SAFETY NOTES

You may be asked to leave the laboratory if you do not abide by safety norms:

- Laboratory coat, scrub pants, goggles, and gloves MUST be worn during this experiment.
- Use care when handling solutions of strong acids and strong bases. Read the labels! Highly concentrated strong acids and bases should not be handled in this lab. If you are uncertain, ask your TA before handling a chemical.
- Use small amounts of chemicals.
- Do not place your kidney stone samples in the oven while your samples are in the filter paper. Use the appropriate container to heat up and dry the samples.
- If you need to store any chemicals or products made for next week, make sure that you label the container with its content and place it in the proper location. Ask your TA for instructions.

- Wash your hands thoroughly at the end of the experiment.
- If unsure about any chemical or safety precaution, consult with your TA.

Be sure to refer to the **Safety Data Sheet** (SDS), for any chemical you choose to use and discuss their safety with your peers and TA.

6. BASIC AVAILABLE MATERIALS

The following will be available in the laboratory. If you need any equipment or chemicals that are not listed here, your TA may be able to arrange to have them in the lab next week, but you must let them know well ahead of time!

NaCl	Na_2CO_3	KCl	0.1 M HCl
NaH_2PO_4	$Ca(NO_3)_2$	K_2HPO_4	1 M HCl
Na_2HPO_4	$CaCl_2$	$Mg(NO_3)_2$	3 M HCl
Na_3PO_4	$NH_4(NO_3)$	0.1 NaOH	0.05 M EDTA
$Na_2C_2O_4$	$MgCl_2$	1 M NaOH	

7. GUIDING IDEAS AND PLANNING QUESTIONS FOR THE PROJECT

Some of the following items will require writing your ideas in your lab notebook; others are just for group discussion. We encourage you to use the web, textbooks, the USF Laboratory Toolbox, etc. during this planning phase. Your team will need to sort out, analyze and synthesize information. Quite often, researchers use published methods and procedures. As you may guess, they do not use them without verifying the reputation of the source, critiquing and understanding them and making the necessary modifications. Blindly using a procedure is not recommended. Be critical of the information your team gathers.

1. What is the composition of common kidney stones and what are their chemical names and formulas?
2. Can your team figure out a way to use experimental data to estimate the solubility (value) of your artificial stones? Solubility can be expressed in g/mL or as molar solubility.
3. Consider the ionic equilibrium of the four artificial kidney stones: How could you manipulate the chemical environment to increase the solubility of the stones? What would be the effect of adding acids or bases? How else could you manipulate the equilibrium to decrease solubility?

4. How can artificial kidney stones be dissolved under lab conditions? How can they be dissolved under physiological conditions? Find one home remedy and propose a chemical explanation for its use. You may also compare the effectiveness of home remedies if you wish. Keep in mind that this is a chemistry lab and that your chemical interpretation of phenomena is indispensable.
5. Propose two methods for dissolving the artificial kidney stones. How are you going to test these methods experimentally? You may want to use the NASA link given in the introduction for an example of substances that may serve this purpose.
6. EDTA (one of the chemicals available in the lab) is a chelating agent. How do you think this agent can be used in the lab to affect the solubility of the artificial kidney stones? How will your team test this experimentally? Write chemical equations for your proposed use of EDTA.
7. What tests might have been inconclusive? How is your team going to improve them and what procedure are you going to use to repeat them?
8. Was there a dissolving procedure that can be considered better than the others? If so, how would you optimize it? Can you try this optimization in the lab? Describe how.
9. List and plan any other tests you would like to try in the lab. **Check your planning with your TA before you leave the lab.**

If your team requires chemicals not listed above, please check with your TA for their availability. As always, check your work plan with your TA before leaving the laboratory.

Remember you will need to save your artificial kidney stones for your tests next week!

8. PROJECT SUMMARY

1. Did your team encounter any problems synthesizing the stones or during the separation process? Explain. How can you improve your procedure based on your actual experiment?
2. Qualitatively describe the appearance of your kidney stones.
3. Do you have complete equations and calculations that show how to produce the 5.0 grams of each type of kidney stone?
4. What was the experimental yield for each artificial stone? What were the theoretical and percent yields? Arrange your results in a table. Discuss your results.
5. Use the data collected to estimate the solubility of the artificial kidney stones. Are these values in agreement with the reported K_{sp} values for the substances that your team synthesized?

6. Summarize the results of your attempts to modify the solubility of the kidney stones (including the use of the chelating agent). Identify tests that need to be improved and/or repeated next week.
7. In the case of EDTA, what did you conclude from your experiments? Is the chelating effect of the EDTA evident from your data—for example, in comparison to the effect of other chemicals on the kidney stones dissolution?
8. Which of the methods you tried can be applied to humans? What leads your team to these claims? What considerations would be required is this method is to be used by humans?
9. What is the chemical explanation for the effectiveness of the home remedy that your team studied? If you considered more than one, explain each one separately.
10. Are there any suggestions based on your results to prevent formation of kidney stones? Explain.

Remember we want you to use your chemistry knowledge to explain your observations and phenomena. Simply describing things will not be enough when you are preparing your report. Connect your observations with your understanding of reactions at the microscopic (atom/molecule) level.

9. THINGS YOU MAY WANT TO CONSIDER FOR YOUR PROJECT SUMMARY

Make sure you follow the report guidelines provided by your instructor. Organize your experimental data in an easy-to-read format. Use tables to show things such as percentage yield for several syntheses, and observations of the effect of a certain reagent on the solubility of the artificial stones. Likewise, you may want to use a table to compare two or more home remedies in terms of several characteristics. Link to kidney stone pictures http://www.herringlab.com/photos/