CHEMISTRY 142 – Chemical Principles II Laboratory – Spring 2022
Lab 2: Testing Materials for CO_2 Capture
Week 1 of 3

Project Goal. In this project-based lab, you will evaluate the effectiveness of different test materials in "capturing" carbon dioxide (CO_2).

Experimental Goals and Introduction. Most people are familiar with or at least aware of current environmental issues, whether it be air pollution, excessive waste, or coastal flooding. One major aspect of these issues is the steadily increasing amount of carbon dioxide (CO_2) gas in the air.[1] CO_2 is a necessary *greenhouse gas*, keeping the earth from freezing, but there is too much of it in the air. This leads to rising global temperatures and an unstable climate. Excess CO_2 also contributes to air pollution and pH imbalance in seawater, which becomes acidic as it absorbs increasing amounts of CO_2.[2] To combat this, researchers are developing methods to remove CO_2 from the air and then convert it to a material that can be used for other purposes. "Carbon Capture Utilization and Storage" (CCUS) refers to the technology and science designed around this challenge (in this context, "Carbon" means "CO_2").[3]

In this project-based lab, you will be using a simple apparatus to generate CO_2 gas and study the efficiency of different test materials in carbon capture using *gravimetric analysis*. This project has two major objectives:

Objective 1: Evaluate the precision of the carbon capture apparatus.
Objective 2: Evaluate the relative ability of test materials to capture CO_2 gas.

You will generate CO_2 gas, expose different test materials to the CO_2 gas, and then use the change in mass of the test material to calculate how much CO_2 was captured. When doing a *quantitative analysis* of the change in mass, it is important to know the precision and reliability of your experimental setup and technique. To do this, you will run the same experiment in triplicate, and then check the precision of your data by calculating the relative standard deviation, (%RSD). Precision refers to the reproducibility of repetitive sets of data and can be expressed as %RSD. %RSD is calculated by taking the standard deviation of the data points, and dividing it by the mean value of the data points:

$$\%RSD = \frac{standard\ deviation}{mean} \times 100$$

This can be quickly determined in Excel using the AVERAGE() function to calculate the mean, and the STDEV.S() function to calculate the standard deviation. The lower the %RSD, the better the precision. A high %RSD means that the measurements varied a lot when the same experiment was repeated..

In the first week of this experiment, you will test a control material, water, to which the other materials will be compared. We expect that the water will not absorb very much CO_2 gas. The CO_2 gas dissolves in water, forming an *aqueous solution*. Aqueous CO_2 then slowly reacts with water to form carbonic acid. This is why pure water in contact with air tends to have a slightly acidic pH rather than a neutral pH of 7. This process is described by the chemical reactions below:

$$\mathbf{CO_2(g) \rightleftarrows CO_2(aq)}$$

$$\mathbf{CO_2(aq) + H_2O(l) \rightleftarrows H_2CO_3(aq)}$$

*Glossary:
Greenhouse gas – a gas that absorbs infrared radiation and prevents too much heat from leaving the atmosphere.
Eutectic point – in a mixture, the lowest possible melting point for all ratios of components.
Precision – in chemical analysis, the reproducibility of a measurement (how close replicate measurements are to each other). This is different from accuracy, which is how close a measurement is to the true value.
Quantitative analysis - a technique to determine how much of a certain component is present in a sample
Gravimetric analysis - a technique that uses the measurement of mass to make a conclusion about the chemicals present in a sample. (This is the same *gravi-* as in *gravity*.)
Project-based learning - in education, a method of teaching/learning that has students engaging in meaningful, longer-term projects that connect to the real world.
Aqueous solution – a solution where water is the solvent.

Learning Outcomes for this Lab:
After completing this project-based lab, you will be able to…
1. Identify a problem, develop a research question, and state a hypothesis.
2. Perform gravimetric analysis and prepare solutions accurately and precisely.
3. Draw conclusions from experimental data and identify potential limitations.
4. Access and comprehend scientific media designed for general audiences.

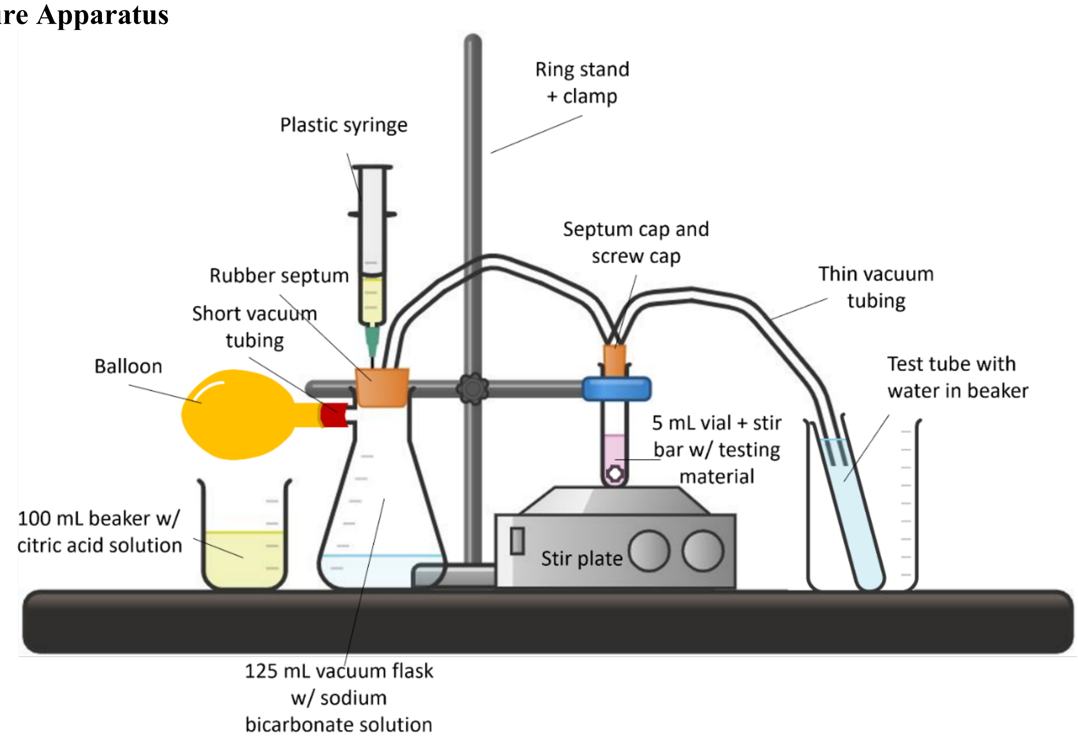
Pre-lab Discussion.
As part of the pre-lab introduction with your instructor, you will have a discussion with the other students at your lab table about the following topics:
1. With your team, come up with 3 examples of global environmental problems that chemists can help solve.
2. What is the problem that you are investigating in this project-based lab?
3. Why is this problem important to study?

Qualitative Observations. As this is a new lab experiment, you will be graded on the quality of your observations. For each step be sure to record not only what you "see", but also any challenges or questions. You will be graded on the accuracy and completeness of these observations, and you will use your observations answer post-lab questions.

Experimental Procedure: This week, you will evaluate the precision of our carbon capture apparatus by using gravimetric analysis to determine the efficiency of a water control to capture CO_2 gas. Because water is a control material that we will compare other materials to later, we do not expect the water to capture very much CO_2 gas.

Materials.
- 2-3 5-mL reaction vials
- Stiff tubing piercing rubber septa and septum cap
- 5 mL plastic syringe with needle (pink 18 gauge)
- P1000 micropipette
- 1 mid-sized spin vane
- 1 Vacuum flask (125 mL, with arm)
- 2 Beakers (100mL)
- Balloon

Carbon Capture Apparatus



Week 1 Protocol

1. Add 10 g citric acid to a beaker. Using a graduated cylinder, measure out 10 mL DI water and add to the citric acid. Make sure to stir the solution with a stirring rod until it is fully dissolved.
2. Add 6.5 g sodium bicarbonate and 20 mL DI water to the 125 mL vacuum flask. Stir the solution with a stirring rod to mix, but note that the sodium bicarbonate will not fully dissolve.
3. Using Figure 1 and the example apparatus as a guide, construct the carbon capture apparatus.
4. Using a P1000 micropipette, add <u>2.00 mL of DI water,</u> 1 mL at a time, to the 5-mL reaction vial. DO NOT try to pick up all 2 mL of water at once with the micropipette. This will damage the micropipette. Add the spin vane to the reaction vial. Record the initial mass of the reaction vial, water, and spin vane (with no cap on the vial) to 3 decimal places.
5. Cap your reaction vial with the septum cap that contains the tubing and check to see that the carbon capture apparatus is fully assembled. Turn the stir plate on and allow the vial to stir at approximately 200 rpm. Do NOT turn up the heat. This is a room-temperature experiment.
6. Using the plastic syringe with needle **(Be careful! Sharps!)**, <u>slowly</u> add the citric acid solution to the sodium bicarbonate over the course of around 20 minutes. **Make sure citric acid does not get in the tube that connects to the 5 mL vial!** Record your observations. After completing the addition of citric acid, allow the reaction vial to stir for an additional 5 minutes.

   **Note: To save time, one member of your team should begin preparing the citric acid, sodium bicarbonate, and water for the next trial of the experiment.*
7. Remove the 5 mL vial from the apparatus, reweigh it, and record your data to 3 decimal places.
8. Repeat the experiment two more times. If you need to reuse the same 5 mL reaction vial, be sure to rinse and dry the vial before beginning the next trial.
9. Wash and put everything away. Your lab instructor will direct you on how to properly dispose of needles in the sharps container.

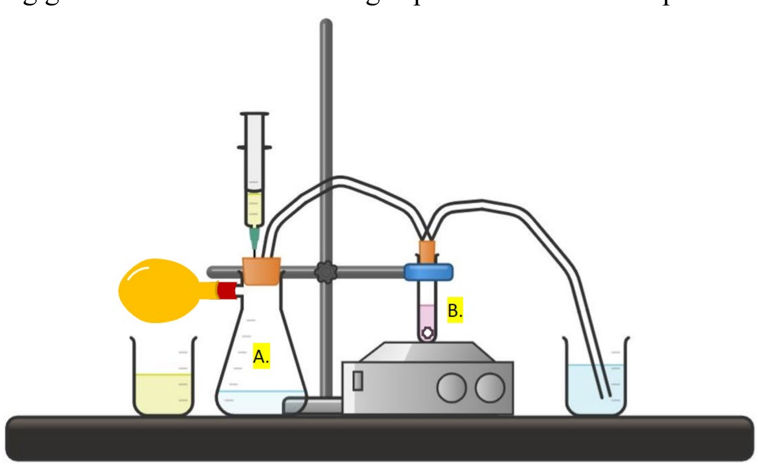
Data Sheet:

Table 1: Mass of CO_2 Captured (report masses to 3 decimal places) and % Relative Standard Deviation

	Trial 1	**Trial 2**	**Trial 3**
Mass of 5 mL reaction vial before CO_2 capture (g)			
Mass of 5 mL reaction vial after CO_2 capture (g)			
Mass of CO_2 captured (after – before) (g)			
Moles of CO_2 captured (mol)			
Average moles CO_2 captured (mol)			
Standard Deviation			
%RSD			

Post-Lab Questions:

1. Based on your %RSD and your observations, how repeatable is your experiment? **%RSD < 20% is ideal.**
2. Where is the CO_2 being generated? Where is it being captured? Label on the picture below or type your answer:



3. Where did you have the most trouble? State one way you will improve your technique next time and suggest one change to the apparatus for the future. Keep in mind that the goal is to increase precision (i.e., decrease %RSD).

Pre-lab assignment.

(1) Watch the YouTube video, linked below. Take notes while you are watching it, and then answer the question below. Causes and Effects of Climate Change | National Geographic | **https://www.youtube.com/watch?v=G4H1N_yXBiA.**

What is the big-picture problem you are trying to help solve in this lab? Why is this important to study?

(2) In your own words, and in complete sentences, define *precision* as related to chemical analysis.

(3) Below is the data from a test of carbon capture using 0.5 M ethylenediamine as the test material. Please read the experimental procedure to better understand where these numbers come from. Go through the calculations you would do to figure out the amount of CO_2 captured, in grams and moles (hint: start with grams and convert to moles). Show your work for one calculation.

Trial Name	**Initial Mass (g)**	**Final Mass (g)**	**CO_2 Captured (g)**	**CO_2 Captured (mol)**
Ethylenediamine 1	31.1752	31.2143		
Ethylenediamine 2	30.5885	30.625		
Ethylenediamine 3	30.5973	30.6295		

Sample calculation:

References:

(1) Keeling, R. F.; Piper, S. C.; Bellenbacher, A. F.; Walker, J. S. Atomspheric Carbon Dioxide Record from Mauna Loa https://data.ess-dive.lbl.gov/view/doi:10.3334/CDIAC/ATG.035 (accessed 2021 -06 -02).

(2) Climate Change: Atmospheric Carbon Dioxide | NOAA Climate.gov https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide (accessed 2021 -06 -04).

(3) Leclaire, J.; Heldebrant, D. J. A Call to (Green) Arms: A Rallying Cry for Greenchemistry and Engineering for CO2 Capture, Utilisation and Storage. *Green Chem.* **2018**, *20* (22), 5058–5081.

(4) Smith, E. L.; Abbott, A. P.; Ryder, K. S. Deep Eutectic Solvents (DESs) and Their Applications. *Chem. Rev.* **2014**, *114* (21), 11060–11082. https://doi.org/10.1021/cr300162p.

Additional resources:

https://www.youtube.com/watch?v=2cWa5ENWxAg "How to make Carbon Dioxide (The Old-Fashioned Way)" by Periodic Videos

Better Carbon Capture Through Chemistry (Fossil Fuels vs Carbon Capture, and other topics): https://cen.acs.org/articles/93/web/2015/12/Better-Carbon-Capture-Through-Chemistry.html

Video about deep eutectic solvents to make the paper industry greener. "Introducing: PROVIDES - Deep Eutectic Solvents": https://www.youtube.com/watch?v=2oDgVDhUXAY