

Activated Carbon on pH

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Group 3

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Introduction and Objectives

The United States Environmental Protection Agency (EPA) uses activated carbon in water filtration to adsorb natural organic compounds which then affects water quality, taste, as well as smell. Activated carbon is a highly porous material and is available in both granular and particulate form. In the [Adsorption Lab](#), we were able to test the adsorption effects of activated carbon on water filtration. Through that lab, we established that activated carbon does indeed affect the adsorption of an influent. This conclusion then led to our curiosity of whether or not the activated carbon could affect other properties of an incoming influent such as its pH. After some initial research, we found that activated carbon adsorbs chlorides, sulfates, nitrates and bicarbonates (DeSilva, 2001), all which affect the pH of water so with this knowledge we decided to test our theory. If activated carbon does affect pH, this could mean that using activated carbon in the water filtration process is a health hazard to humans since potable drinking water should have a pH between 6 and 8.5. Additionally, not only would water of a pH outside of 6-8.5 be a health hazard, it would also be simply unpleasant to drink. "A high pH causes a bad taste that's often described as metallic. You can sometimes tell by taste when you reach a neutral pH" (DeSilva, 2001). In addition to just testing the effects of activated carbon on pH, we wanted to test if the starting influent pH had any impact. Therefore, we decided to test our hypothesis using a range of influent pH (3.5, 7, 10) to see how and how much the carbon would affect the pH of the resulting filtered effluent.

The objective of this lab is to collect consistent reliable data which can then be analyzed using mathematical and functional models. We aim to produce a conclusive answer to the questions proposed in the introduction. The hypothesis for this lab is that activated carbon does indeed affect the pH of an incoming influent. Based on our research from external sources we predict that activated carbon will increase the pH of the water no matter the starting pH (Does An Activated Carbon Filter Ever Change

pH?, 2011); however, the amount that the starting pH of water is affected will vary depending on the initial pH (DeSilva, 2001).

Equations

$$pH = -\log[H_3O^+] \Rightarrow [H_3O^+] = 10^{-pH}$$

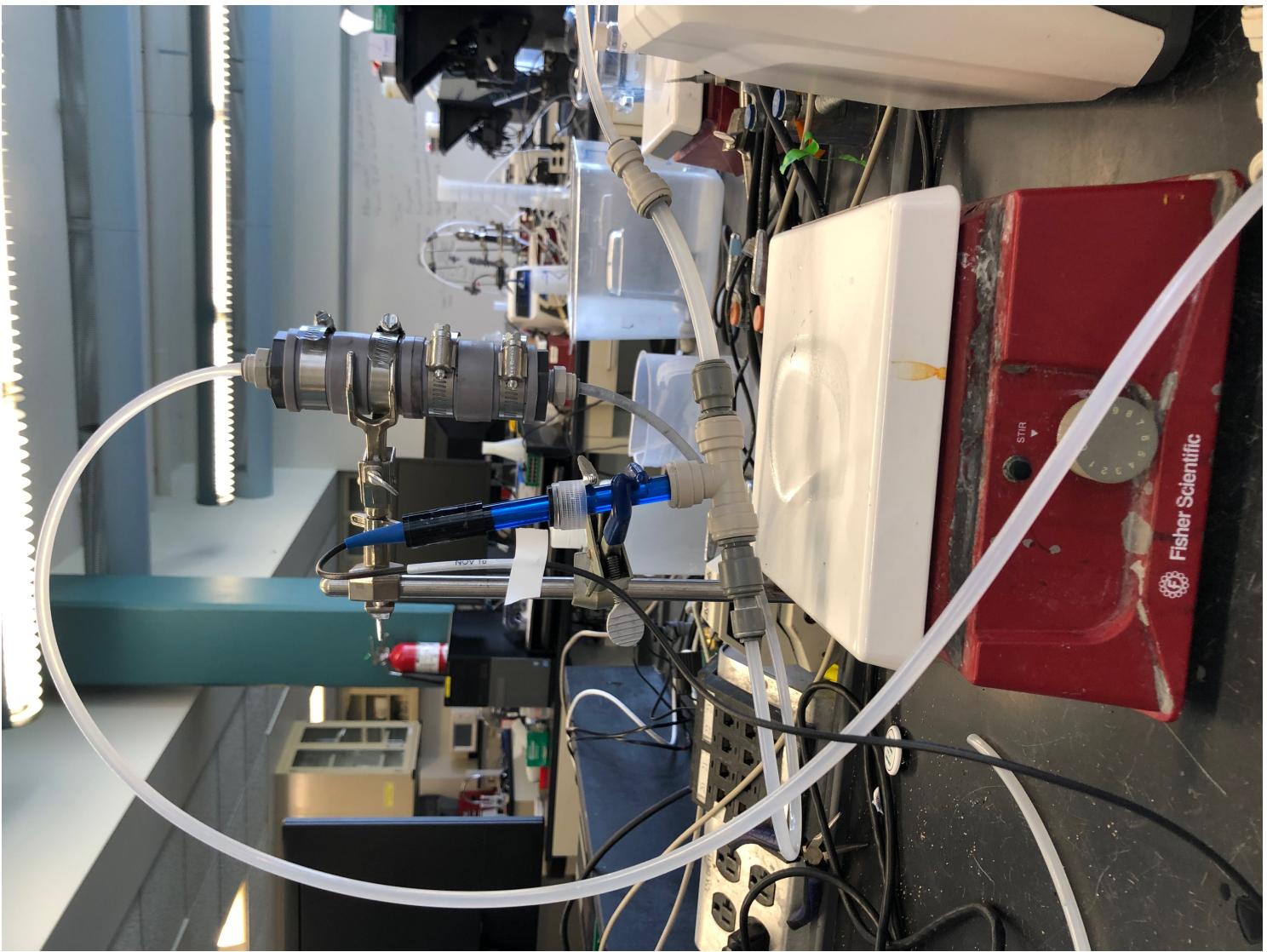
(equation used to calculate titration amount)

Expectations/Anticipated Results:

We expect for all of the trials to produce different results. This means that the activated carbon will affect the influent by varying levels of magnitude for different starting pH values. We anticipated varied results due to the information provided in DeSilva's article. As mentioned before in the Objectives of this lab, we expect the activated carbon to increase the pH of the starting influent for all pH values.

Procedures

The set up of this lab will mimic that of the [Adsorption Lab](#). The four major differences will be that instead of a photometer we will be using a pH probe, we will be reducing the column height from 15cm to 5cm, we will be speeding up the pump speed, and the tubing setup will be greatly simplified in order to reduce the amount tubing necessary. We will measure the pH by using the pH probe after performing its prospective calibration method. The pH probe will be inserted into a T-Connector, and the effluent will pass through the probe in the connector, thus allowing the probe to measure the effluent's pH. The effluent will then drain out of the tubing and into the sink. The entire shortened column will be filled with granular activated carbon to limit the amount of variables that could influence our results. Unlike the Adsorption Lab, we will not be using T-valves because we do not need to reverse the direction of the flow. Between trials, we will reverse the flow of the peristaltic pump to drain the remaining fluid out of the setup and prepare for the next influent. The setup has been pictured below.



Procedural Steps:

1. Set up the tubing and column according to the diagram pictured above: one tube connecting the influent beaker to the peristaltic pump, one tube connecting the peristaltic pump to the input point of the column, one tube connecting the output point of the column to the input of a T-connector, and one tube connecting the output of the T-connector to the drain. The pH probe fitting should be tilted slightly upwards to prevent air bubbles from collecting at the probe. Calibrate the pH probe in ProCoDA.
2. Rinse and dry the column completely. Weigh 9.91 grams of granular activated carbon in a weigh boat. Add to the column and secure the column tightly using the wrench.
3. In a 1000mL beaker, add 600mL of reverse osmosis water. Add a stir bar to the beaker and place on a stir plate, so that the stir bar does not create a vortex in the water. Insert the pH probe into the beaker so that the tip is fully submerged in the water and secure with tape.
4. To create the following pH values, pipette the following amount of corresponding solution into the beaker of water: a. For a pH of 10, 500uL of 0.5M NaOH b. For a pH of 7, 20uL of 0.5M NaOH c. For a pH of 3.5, 300uL of 0.05M HCl Check the resulting pH in ProCoDA in case of an anomaly.

5. Once the influent is ready, remove the beaker from the stir plate and insert the tubing so that the influent can be pumped into the peristaltic pump. Insert the pH probe into the fitting of the T-connector, so that the probe will be fully covered by influent passing through the connector. The pH probe should be tilted slightly upwards and secured with a clamp to the metal rod on the stir plate to prevent air bubbles from collecting at the probe. Set the peristaltic pump to pump 35mL/rev.
6. Begin pumping the influent through to the column. Start recording pH measurements after the influent has passed through the carbon but **before** it reaches the pH probe. Stop the pump as soon as all the influent has entered the tubing, to prevent air from passing through the probe.
7. Repeat steps 3 through 6 for all pH trials using both new unused (virgin) activated carbon and used carbon that has had influent passed through once and twice before, for a total of nine trials (three for pH 3.5, three for pH 7, three for pH 10).
8. To clean up, run reverse osmosis water through the system to flush out any influent. Dismantle tubing, and dispose of and rinse any remaining activated carbon out of the column (**don't dispose of activated carbon in the sink!**).

Key Design Parameters

Flow Rates: 35mL/rev on the Peristaltic Pump

Column Parameters: Length (5cm); Diameter (2.54cm)

Concentrations: 600mL of reverse osmosis water diluted with NaOH (0.5M) and HCl (0.05M) to achieve the desired influent pH values.

Range of Parameters: The property that we will be varying will be the pH of the influent. We will be using neutral reverse osmosis water (pH 7), an acidic solution created with reverse osmosis water and HCl (pH 4), and a basic solution created with reverse osmosis water and NaOH (pH 10).

Resources:

- pH Probe
- #17 Tubing (clear)
- 1 Peristaltic Pump
- 1 T-Connector
- Reverse Osmosis Water
- NaOH Solution (0.5M)
- HCl Solution (0.05M)
- ProCoDA
- Activated Carbon
- Shortened Column of 5cm

Timeline:

- **Week One** (set up lab and create solutions)
 - The 3 influents we will be testing will have a pH of 4, 7, and 10. We plan on creating enough of each test sample to run a couple trials for each.
 - We will create the test samples by starting with neutral reverse osmosis water (pH 7) and a pH probe, and pipetting either HCl or NaOH into the sample until the desired pH is achieved.
- **Week Two** (run all three test samples)
 - We plan on running each pH sample a couple times for the data to be as accurate as possible. We will use a 5cm column of particulate activated carbon.
- **Week Three** (analysis)
 - We will be using ProCoDA to collect and analyze the data, monitoring for changes and trends in pH measurements.

Initial Trial with Reverse Osmosis Water

Carbon Amount: 9.91g Empty Container: 490g Container with Water: 1071g Water = 1071g - 490g = 581g ~ 581mL of water Starting pH: 5.21

From this empty trial we have decided to use 600L of water to prepare the solution.

Table of Influent Solutions Prepared

Target pH	Type of Carbon	Acid/Base Added	Amount Added	Calculated Titrant Amount	Initial pH	Final pH
10	New carbon	NaOH	1 mL	0.599 mL	4.33	10.83
10	Once used	NaOH	0.5 mL	0.599 mL	4.383	9.922
10	Twice used	NaOH	0.5 mL	0.599 mL	4.86	9.994
7	New carbon	NaOH	0.02 mL	0.000596 mL	4.783	7.09
7	Once used	NaOH	0.02 mL	0.000598 mL	4.556	6.908
7	Twice used	NaOH	0.02 mL	0.000595 mL	4.93	7.2
3.5	New carbon	HCl	0.3 mL	3.233 mL	4.330	3.600

Target pH	Type of Carbon	Acid/Base Added	Amount Added	Calculated Titrant Amount	Initial pH	Final pH
3.5	Once used	HCl	0.3 mL	3.234 mL	4.331	3.72

Results and Discussion

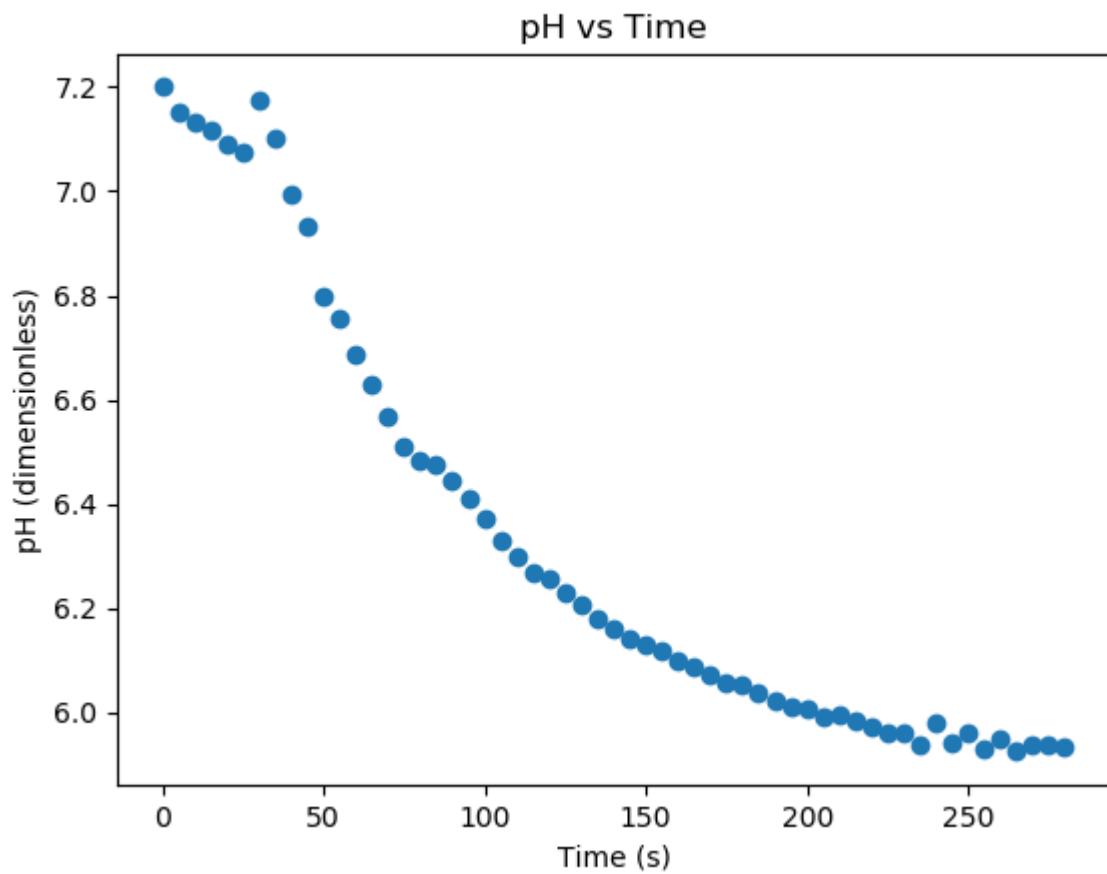


Figure 1: Graph of pH vs Time as time goes on for an initial influent of 10 and unused activated carbon.

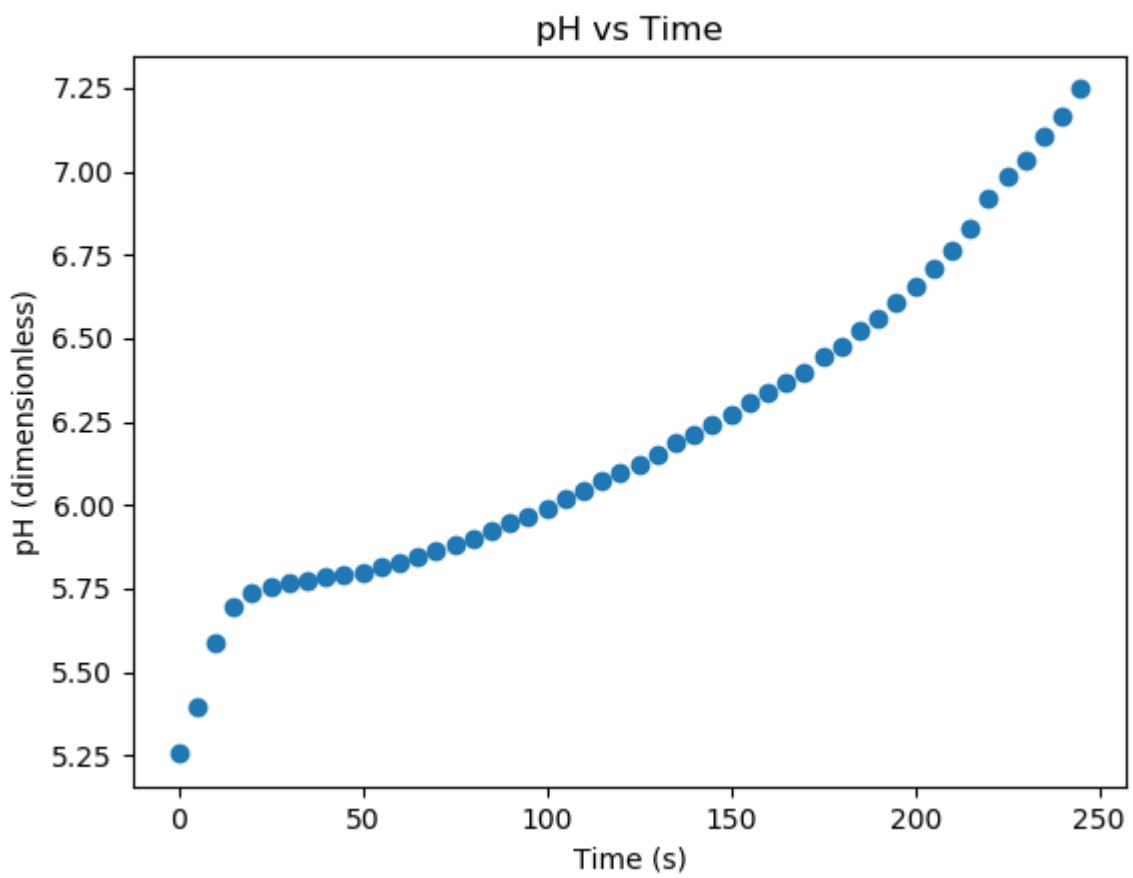


Figure 2: Graph of pH vs Time as time goes on for an initial influent of 10 and the same used activated carbon from the first trial.

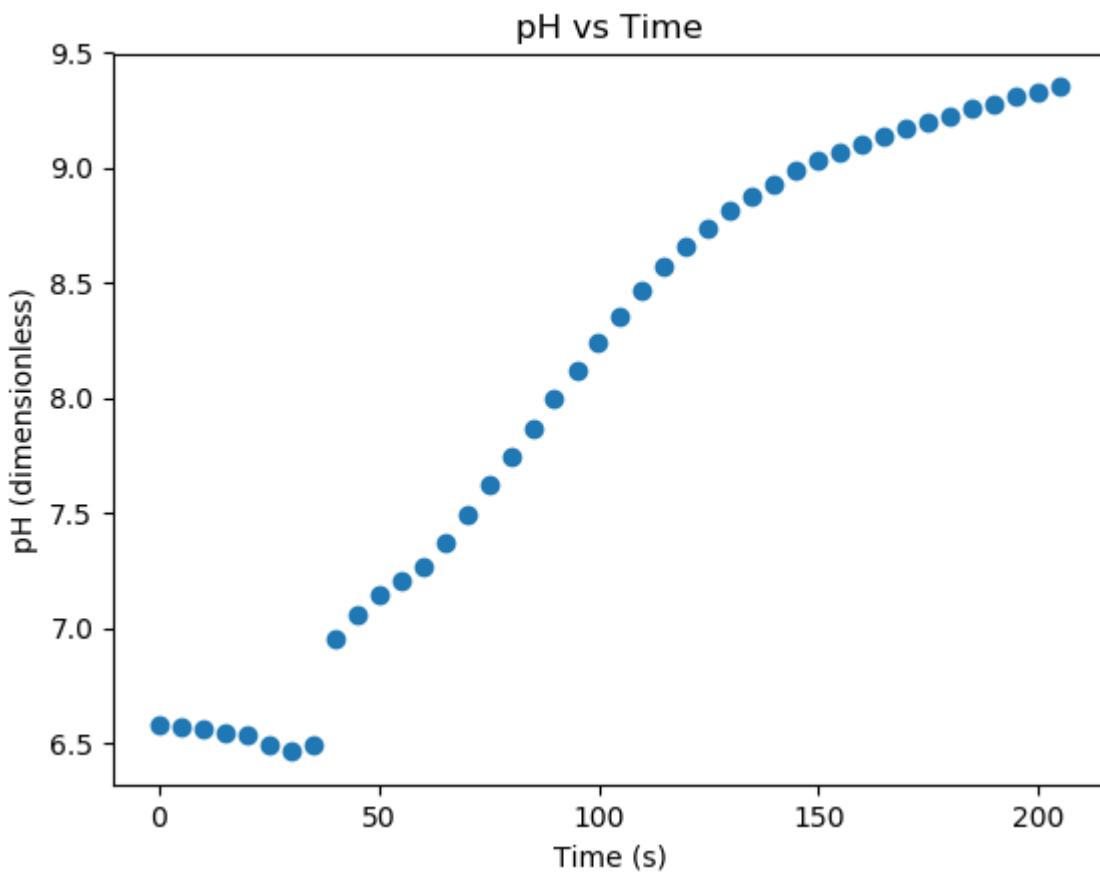


Figure 3: Graph of pH vs Time as time goes on for an initial influent of 10 and the same used activated carbon from the first trial.

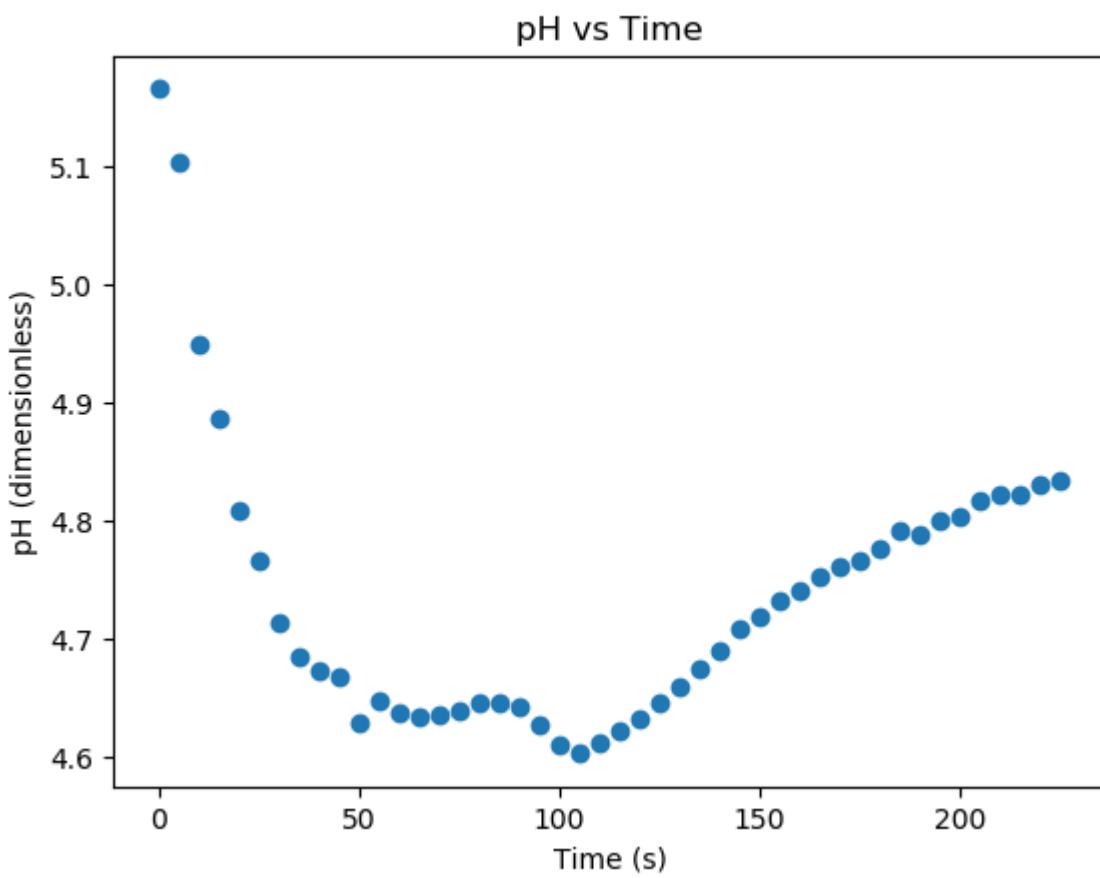


Figure 4: Graph of pH vs Time as time goes on for an initial influent of 7 and unused activated carbon.

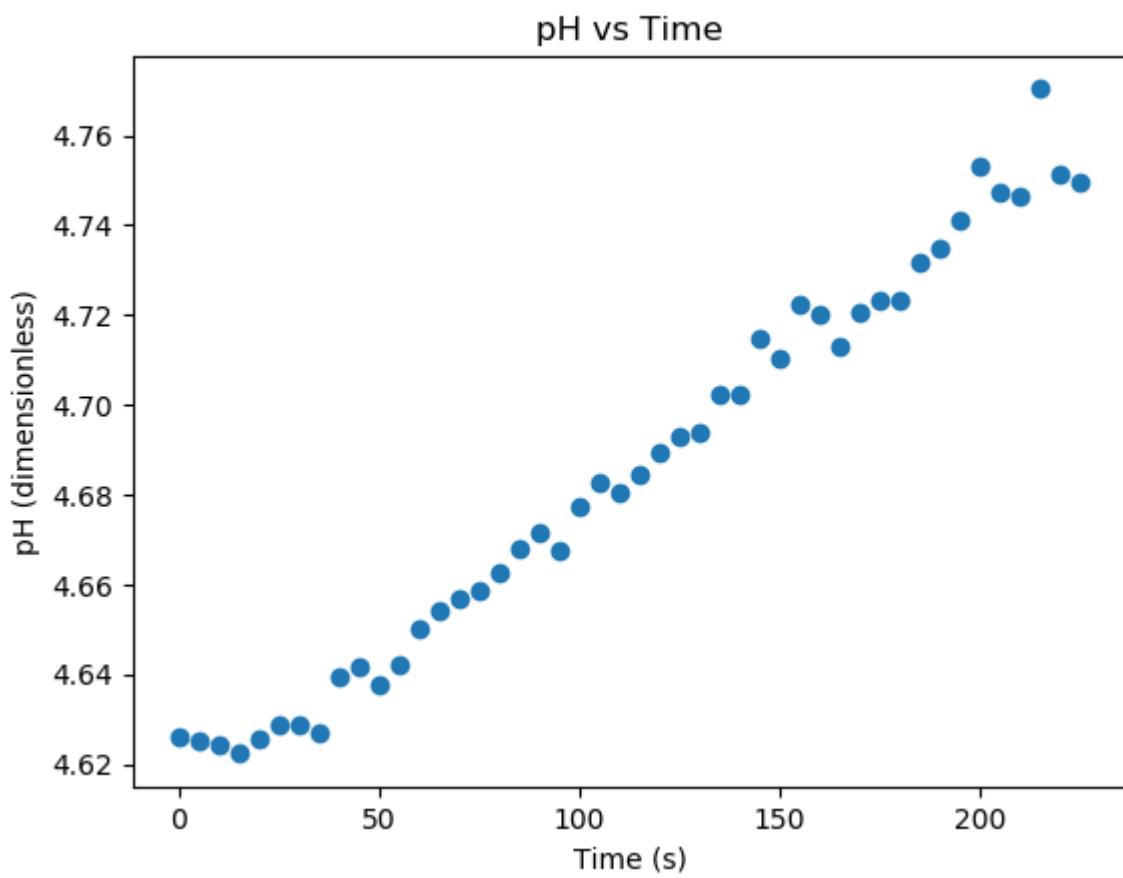


Figure 5: Graph of pH vs Time as time goes on for an initial influent of 7 and the same used activated carbon from the first trial.

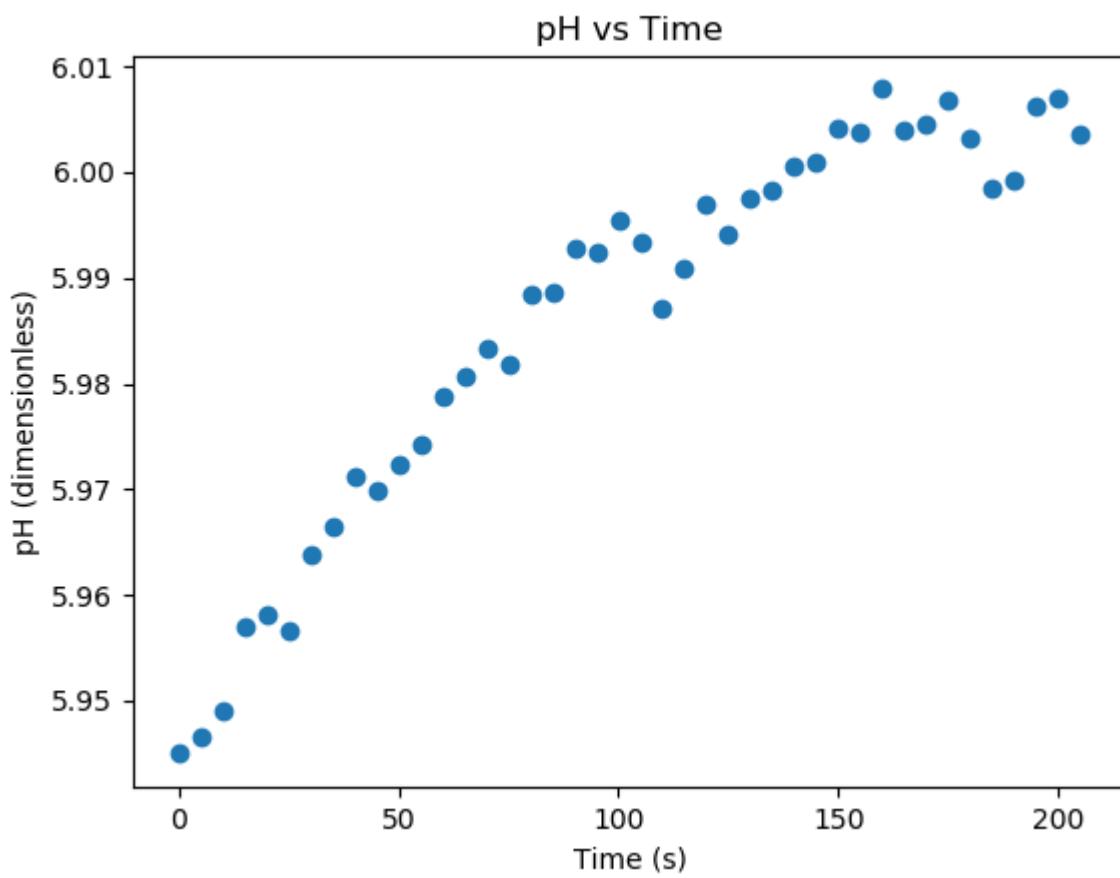


Figure 6: Graph of pH vs Time as time goes on for an initial influent of 7 and the same used activated carbon from the first trial.

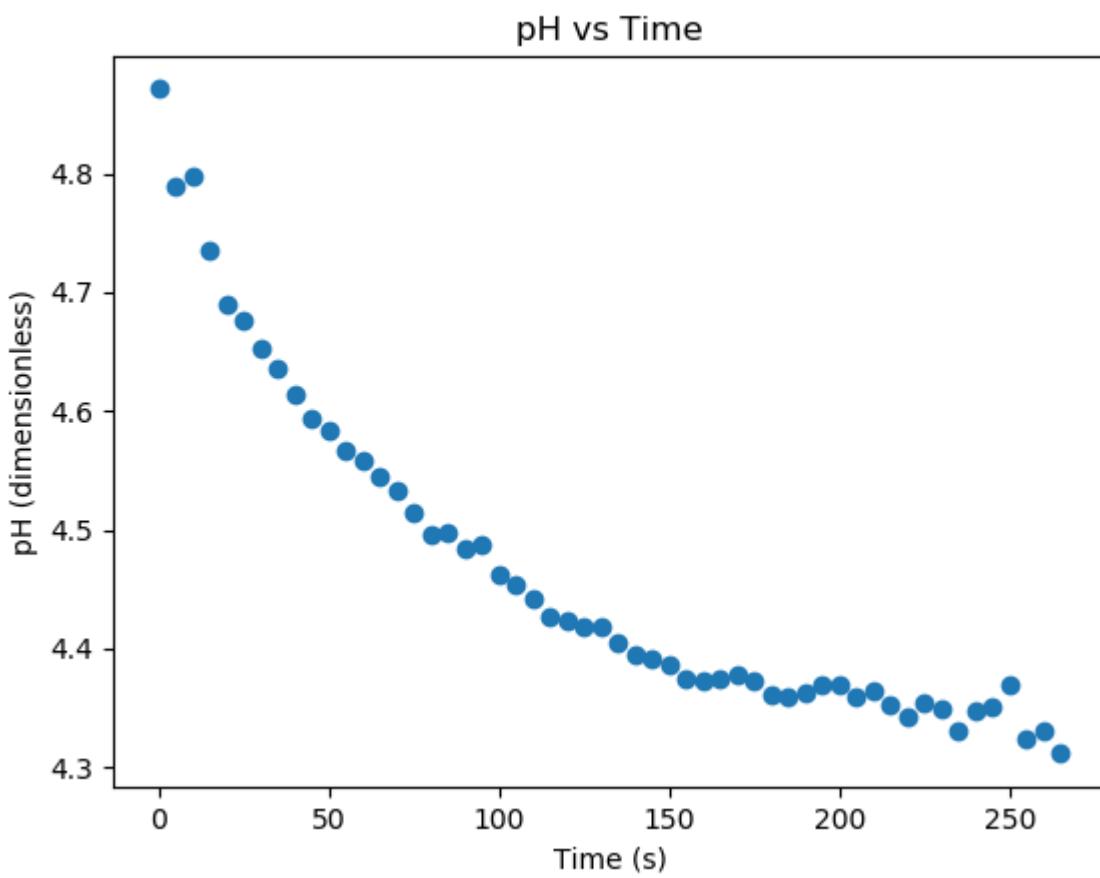


Figure 7: Graph of pH vs Time as time goes on for an initial influent of 3.5 and unused activated carbon.

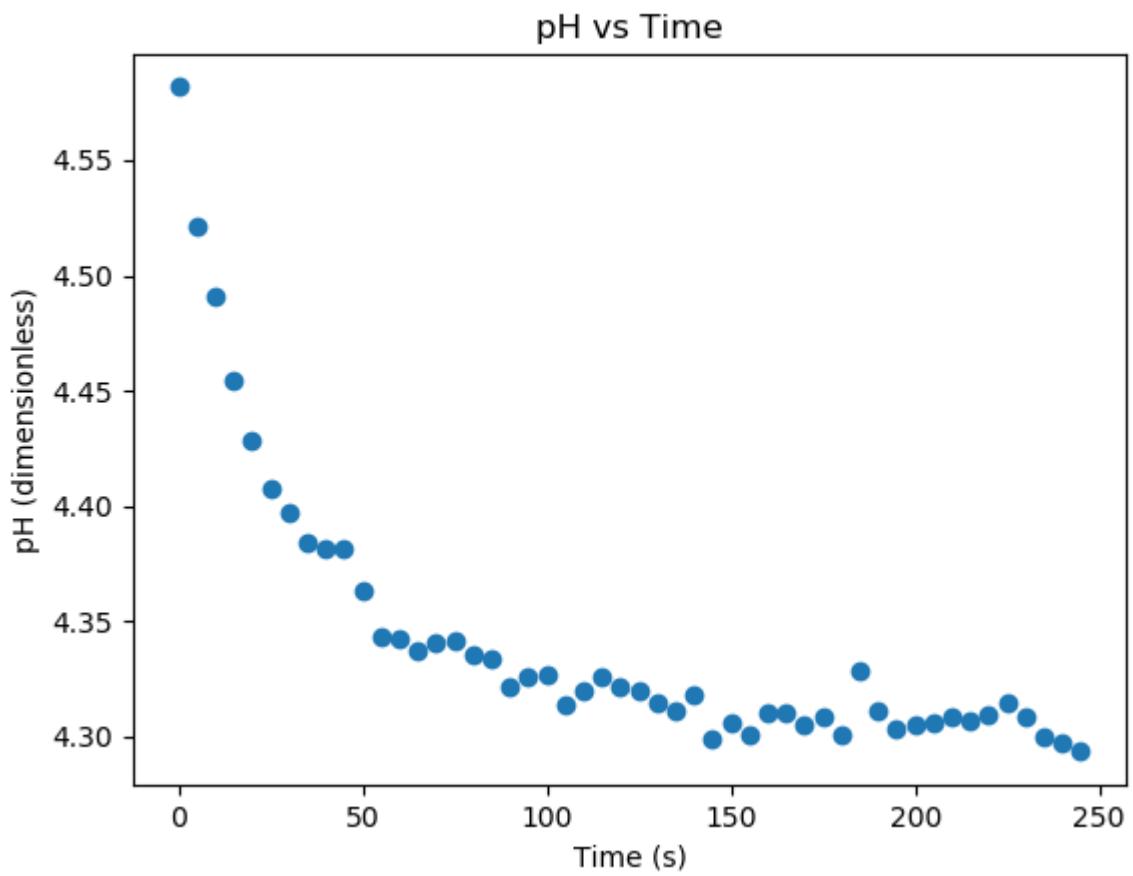


Figure 8: Graph of pH vs Time as time goes on for an initial influent of 3.5 and the same used activated carbon from the first trial.

Table of pH Changes

Initial Influent pH	Type of Carbon	pH Difference Between Influent and First Probe Reading	pH Difference Between First and Last Probe Reading
10	New Carbon	3.678860264	1.216783523000001
10	Once Used	4.525394508	-1.8496041289999994
10	Twice Used	3.424298804999994	-2.7820549010000004
7	New Carbon	1.986285533999994	0.2691020960000001

Initial Influent pH	Type of Carbon	pH Difference Between Influent and First Probe Reading	pH Difference Between First and Last Probe Reading
7	Once Used	2.282951839	-0.1246600149999999
7	Twice Used	1.2534052850000004	-0.0569219590000003
3.5	New Carbon	-1.1892541889999992	0.4775137909999989
3.5	Once Used	-0.8011658479999997	0.22786140499999963

This data was collected after conducting eight total trials with starting influents at a pH of 10, 7, and 3.5. For each pH, one trial was conducted with unused activated carbon, and then at least one more trial (two for pH 7 and 10) was conducted without replacing the carbon from the previous trial.

One data trend observed between trials conducted with unused activated carbon at different influent pH values was that each data set was characterized by a sharp exponential like decrease in pH. However, when the trials were conducted again and each influent was run through carbon that had been previously used, we noticed a trend in both the trials with influent of pH 7 and 10 that the pH of the effluent began to increase whereas the influent of pH 3.5 continued to decrease. The influent of pH 10 increased in an exponential manner (as can be seen in Figure 2) whereas the influent of pH 7 increased in a linear manner (as can be seen in Figure 5 and 6). Additionally, when testing an influent of pH 3.5, we noticed that the pH of the effluent decreased and plateaued at 4.3 regardless of whether the carbon was new or had been used once (as can be seen in Figure 7 and 8). We subsequently ran the influents of pH 7 and 10 through the carbon a third time, and observed that the pH of the effluent in these trials plateaued just short of the original pH of the influent. This data analysis leads us to hypothesize that activated carbon has a threshold to which it adsorbs hydrogen ions, and once that threshold limit has been met, the activated carbon does not affect the pH of the influent anymore. Therefore, the pH of the effluent leaving the column will eventually be the same as the pH of the influent entering the column.

We also observed from our data that the magnitude of the initial pH drop from running through new activated carbon varied depending on the starting pH of the influent. For the most basic influent with a starting pH of 10, the pH of the effluent dropped by a magnitude of 3.68 by the time it passed through the column of carbon and reached the pH probe. For the influent with a less basic starting pH of 7, the magnitude of this initial decrease was 1.99, and for the acidic influent with a starting pH of 3.5, the magnitude of change was actually an increase of 1.19. This further supports our analysis hypothesis

(mentioned in the paragraph above) that there is some sort of threshold for the activated carbon in which the pH of the influent passing through the activated carbon cannot drop below a certain pH--according to our data, this value is about 4.3. For the trials in which we ran acidic influent, the starting pH of the influent was 3.5 which is lower than 4.3 so the activated carbon caused the pH to increase.

A note on the titrant volume, the reverse osmosis water should not have ANC which means that theoretically we should be able to calculate exactly how much titrant is required to obtain our target pH from the starting water pH. This calculation is done in the appendix and added to preparation chart; however, the values which we obtained were not exactly the same as the values used in the lab. To obtain a pH of 10, experimentally we added 0.5mL vs the calculated value of 0.599mL, for a pH of 7 experimentally we added 0.02mL vs the calculated value of 0.0005mL, and lastly for a pH of 3.5 experimentally we added 0.3mL vs the calculated value of 3.233mL. Regarding the last value, we noticed that in the lab the pH of the water plateaued at 3.5 no matter the amount of HCl we added. Initially we wanted to reach a pH of 3, but it was impossible to obtain so we believe that if we had added 3.233mL of HCl the pH would still plateau at 3.5. Due to inconsistencies with the pH probe, we decided to use a trial and error method of titrating so the pH probe was recording the pH values that we wanted.

Conclusions

The data we collected in this lab did not support our original hypothesis. We predicted that the activated carbon would cause the starting pH of an influent to increase no matter the starting pH. However, this was only the case for when the influent pH was 3.5. When the influent was basic, the activated carbon actually caused the pH to decrease. Therefore, we predict that there is a sort of acidity to the activated carbon. Based on our trials, the pH of the activated carbon must be above 3.5 and below 7. However, we know that there is a threshold to the activated carbon's ability to acidify the influent. Once this threshold is reached over time, the pH of the influent starts to go back to its initial pH. We did correctly predict that the effect of the activated would vary based on starting pH. The more basic solution (pH 10) was more affected than the less basic solution (pH 7).

Suggestions/Comments

Originally, we were concerned about time restraints so we drastically shortened the carbon column and quickened the pump rate from that of the Adsorption Lab. However, now we realize that we would have had enough time to run the trials slower. We had to discard some trials which included experimental inaccuracies and larger air bubbles which drastically impacted the data. Perhaps by slowing down the pump rate we could have limited the amount of air bubbles that formed between the pH probe and the drainage tubing. Another suggestion that we have is to recalibrate the pH probe for each lab session. At

first we were reusing a saved calibration of the pH probe that we did on the first day of lab, but we noticed that the readings were slowly becoming more and more inaccurate so we ended up recalibrating our pH probe. It was really interesting to find out that activated carbon does indeed affect the pH of an influent and we hope to keep tabs on this phenomena in hopes that it gets researched further in the future. Some avenues to be explored is a lab that runs acidic influent back through the activated carbon to see if we can re-establish the hypothesized threshold which was mentioned earlier in the Results and Analysis. We hope you enjoyed our lab report!

Appendix

Constant Type	Value
Volume of Influent	600 mL
NaOH Concentration	0.5 M
HCl Concentration	0.05 M
Pump Speed	35 mL/rev
Column Height	5 cm
Column Diameter	2.54 cm

```

# import statements
from aguaclara.core.units import unit_registry as u
import aguaclara.research.environmental_processes_analysis as epa
import aguaclara.core.physchem as pc
import aguaclara.core.utility as ut
import numpy as np
import matplotlib.pyplot as plt
import collections
import os
from pathlib import Path
import pandas as pd
import math

# constants
temp = 22*u.degC
vol = (600*u.mL).to(u.L)
## because HCl is a strong acid and it fully dissolves, the concentration of the HCl equals to the
conc_HCl = 0.05
pH_HCl = -math.log(0.05,10)
pH_HCl
pH_NaOH = 13
Conc_OH_NaOH = 10**-(14-13)*(u.mol/u.L)
Conc_H3O_HCl = 10**(-pH_HCl)*(u.mol/u.L)

# extract data
## pH 10 trial 1
data_pH10_1="https://raw.githubusercontent.com/l1643/Final_Project/master/ph10_trial_one.xls"
# set the start index
start = 0
# get pH array (data is in column 1)
pH10_1 = epa.column_of_data(data_pH10_1, start, 1, -1)
# get time array
time_pH10_1 = epa.column_of_time(data_pH10_1,start,-1).to(u.s)

## pH 10 trial 2
data_pH10_2="https://raw.githubusercontent.com/l1643/Final_Project/master/ph10_trial_two.xls"
start = 0
pH10_2 = epa.column_of_data(data_pH10_2, start, 1, -1)
time_pH10_2 = epa.column_of_time(data_pH10_2,start,-1).to(u.s)

## pH 10 trial 2
data_pH10_2="https://raw.githubusercontent.com/l1643/Final_Project/master/ph10_trial_two.xls"
start = 0
pH10_2 = epa.column_of_data(data_pH10_2, start, 1, -1)
time_pH10_2 = epa.column_of_time(data_pH10_2,start,-1).to(u.s)

## pH 10 trial 3
data_pH10_3="https://raw.githubusercontent.com/l1643/Final_Project/master/ph10_trial_three.xls"
start = 0
pH10_3 = epa.column_of_data(data_pH10_3, start, 1, -1)
time_pH10_3 = epa.column_of_time(data_pH10_3,start,-1).to(u.s)

```

```

## pH 7 trial 1
data_pH7_1="https://raw.githubusercontent.com/l1643/Final_Project/master/ph7_trial_one.xls"
start = 0
pH7_1 = epa.column_of_data(data_pH7_1, start, 1, -1)
time_pH7_1 = epa.column_of_time(data_pH7_1,start,-1).to(u.s)

## pH 7 trial 2
data_pH7_2="https://raw.githubusercontent.com/l1643/Final_Project/master/ph7_trial_two.xls"
start = 0
pH7_2 = epa.column_of_data(data_pH7_2, start, 1, -1)
time_pH7_2 = epa.column_of_time(data_pH7_2,start,-1).to(u.s)

## pH 7 trial 3
data_pH7_3="https://raw.githubusercontent.com/l1643/Final_Project/master/ph7_trial_three.xls"
start = 0
pH7_3 = epa.column_of_data(data_pH7_3, start, 1, -1)
time_pH7_3 = epa.column_of_time(data_pH7_3,start,-1).to(u.s)

## pH 3.5 trial 1
data_pH3_5_1="https://raw.githubusercontent.com/l1643/Final_Project/master/ph3_5_trial_one.xls"
start = 0
pH3_5_1 = epa.column_of_data(data_pH3_5_1, start, 1, -1)
time_pH3_5_1 = epa.column_of_time(data_pH3_5_1,start,-1).to(u.s)

## pH 3.5 trial 2
data_pH3_5_2="https://raw.githubusercontent.com/l1643/Final_Project/master/ph3_5_trial_two.xls"
start = 0
pH3_5_2 = epa.column_of_data(data_pH3_5_2, start, 1, -1)
time_pH3_5_2 = epa.column_of_time(data_pH3_5_2,start,-1).to(u.s)

# graphs
## pH 10 trial 1
plt.plot(time_pH10_1,pH10_1,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')
plt.show()

## pH 10 trial 2
plt.plot(time_pH10_2,pH10_2,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')
plt.show()

## pH 10 trial 3
plt.plot(time_pH10_3,pH10_3,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')

```

```

plt.show()

## pH 7 trial 1
plt.plot(time_pH7_1,pH7_1,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')
plt.show()

## pH 7 trial 2
plt.plot(time_pH7_2,pH7_2,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')
plt.show()

## pH 7 trial 3
plt.plot(time_pH7_3,pH7_3,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')
plt.show()

## pH 3.5 trial 1
plt.plot(time_pH3_5_1,pH3_5_1,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')
plt.show()

## pH 3.5 trial 2
plt.plot(time_pH3_5_2,pH3_5_2,'o')
plt.xlabel('Time (s)')
plt.ylabel('pH (dimensionless)');
plt.title('pH vs Time')
plt.show()

# analysis
initial_pH = [4.33, 4.383, 4.86, 4.783, 4.556, 4.93, 4.330, 4.331]
target_pH = [10, 10, 10, 7, 7, 7, 3.5, 3.5]
initial_influent = [10.83, 9.922, 9.994, 7.09, 6.908, 7.2, 3.6, 3.72]
pH_trial_array = [pH10_1, pH10_2, pH10_3, pH7_1, pH7_2, pH7_3, pH3_5_1, pH3_5_2]
difference_1 = np.zeros(8)*u.dimensionless
difference_2 = np.zeros(8)*u.dimensionless

# calculate the difference between the initial influent pH and the initial pH reading
for i in range(0,8):
    initial_reading = pH_trial_array[i][1]
    difference_1[i] = initial_influent[i] - initial_reading

# 3.678860264 & 4.525394508 & 3.4242988049999994 & 1.9862855339999994 & 2.282951839 & 1.2534052856

```

```

# calculate the difference between the initial pH reading and the last pH reading
for i in range (0,8):
    initial_reading = pH_trial_array[i][1]
    x = len(pH_trial_array[i])
    final_reading = pH_trial_array[i][x-1]
    difference_2[i] = initial_reading - final_reading

# 1.216783523000001 & -1.849604128999994 & -2.7820549010000004 & 0.2691020960000001 & -0.12466001

# function to calculate the H3O+ concentration of an influent given its pH
def H3O_pH(pH):
    H3O = 10**(-pH)
    return H3O

# function to calculate the OH concentration of an influent given its pH
def OH_pH(pH):
    OH = 10**-(14-pH)
    return OH

# calculate the OH and H3O+ concentration of the reverse osmosis water and the desired pH influent
initial_OH_H30 = np.zeros(8)
target_OH_H30 = np.zeros(8)
for i in range(0,8):
    if i < 6:
        initial_OH_H30[i] = OH_pH(initial_pH[i])
        target_OH_H30[i] = OH_pH(target_pH[i])
    else:
        initial_OH_H30[i] = H3O_pH(initial_pH[i])
        target_OH_H30[i] = H3O_pH(target_pH[i])

# calculate the moles of OH and H3O+ in the influent given a fixed influent volume of 600mL
initial_OH_H30 = initial_OH_H30*(u.mol/u.L)
target_OH_H30 = target_OH_H30*(u.mol/u.L)
initial_OH_H30_mol = initial_OH_H30*vol
target_OH_H30_mol = target_OH_H30*vol

# calculate the required mol difference of H3O+ to reach the desired target pH
mol_difference = target_OH_H30_mol - initial_OH_H30_mol
mol_difference

# calculate the required volume of titrant for the amount of H3O
volume_titrant = np.zeros(8)*u.L
for i in range(0,8):
    if i < 6:
        volume_titrant[i] = mol_difference[i]/Conc_OH_NaOH
    else:
        volume_titrant[i] = mol_difference[i]/Conc_H3O_HCl

volume_titrant.to(u.mL)
# 0.5999987172227462 & 0.5999985507234993 & 0.5999956533842394 & 0.0005963595820224688 & 0.0005978

```



References/Bibliography

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