Optical Activity of Sugar

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I. INTRODUCTION

Understanding how the concentration of sugar in solution has practical applications in medicine. Currently, testing blood-sugar levels requires drawing a small blood sample for chemical testing. An application of research into the effect of solution sugar concentration on light polarization would be for testing blood sugar levels in diabetics non-invasively.

In order to understand how sugar concentration in water affects the polarization of light, we measured the intensity of light exiting a second, constant angle polarizer as a function of the angle of the first polarizer. We used a bright white light source, a photometer, and a series of beakers varying in size with different concentrations of sugar in water. By using two polarizers, one at a constant angle and the other at varying angles, we were able to determine the relative polarization change by the sugar water. For each trial, the first (varying) polarizer began at 90 degrees to the second (constant) polarizer, and was then rotated in 10 degree increments to 0 degrees relative to the second polarizer. We first began by measuring the intensity of light exiting the second polarizer for no beaker, then small, medium, and large beakers with no water. This initial dataset provided us with a baseline for the intensity of light exiting the second polarizer.

The method used to polarize a white-light source consisted of two Polaroid polarizers: an individual polarizer produces linearly polarized light by selective absorption. More specifically, our method used two polarizers to determine both the polarization of light entering the solution beaker and the light exiting the solution beaker. Knowing both these polarizations allowed us to determine the change in polarization through the solution beaker.

II. METHODS

There were several possible sources of uncertainty unrelated to error in measurement. The first was the use of external light sources. A phone flashlight was used to see the angle of the polarizer and the intensity meter. The computer light was also on during the trials in order to input data directly into code. Although the phone flashlight was necessary to make measurements, its effect on the intensity meter could have been minimized by shielding the fiber optic cable from the flashlight's light. The computer light was also necessary to input data, but it was not in the direct line of sight of the intensity meter.

A secondary source of uncertainty could be the swirling of the solution in the beaker. The swirling of the solution could have caused light to scatter unevenly, leading to either higher or lower intensity readings. The possible source of uncertainty stemming from the swirling of the solution could have been minimized by allowing the solution to settle longer prior to taking measurements.

A tertiary source of uncertainty could be the amount of light traveling through each differently sized beakers directly into the fiberglass optical cable. We are unsure if there would be any direct way to minimize the possible uncertainty stemming from the amount of light traveling through each differently sized beaker. However, this uncertainty can be discarded when comparing intensity measurements between trials with the same beaker size.

A final possible source of uncertainty stemmed from the medium beaker being broken and needing to be replaced prior to the solution 2 experiment. Although unlikely, the replacement beaker could have had slightly different optical properties than the original medium beaker.

III. DATA AND RESULTS

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
No Beaker		
90	0.00	0.10
80	0.14	0.10
70	0.47	0.10
60	1.00	0.30
50	1.65	0.30
40	2.40	0.30
30	3.00	1.00
20	3.40	1.00
10	3.60	1.00
0	3.80	1.00
Small Beaker		
90	0.00	0.10
80	0.05	0.10
70	0.40	0.10
60	0.78	0.10
50	1.25	0.30
40	1.75	0.30
30	2.20	0.30
20	2.55	0.30
10	2.70	0.30
0	2.85	0.30
Medium Beaker		
90	0.00	0.10
80	0.12	0.10
70	0.47	0.10
60	0.94	0.10
50	1.50	0.30
40	2.10	0.30
30	2.65	0.30
20	3.00	1.00
10	3.20	1.00
0	3.30	1.00
Large Beaker		
90	0.00	0.10
80	0.10	0.10
70	0.37	0.10
60	0.80	0.10
50	1.30	0.30
40	1.80	0.30
30	2.25	0.30
20	2.50	0.30
10	2.80	0.30
0	2.90	0.30

TABLE 1. No water:

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
Small Beaker		
90	0.880	0.010
80	2.650	0.010
70	6.200	0.030
60	12.000	0.030
50	18.000	0.100
40	25.500	0.100
30	31.000	0.100
20	35.000	0.100
10	38.000	0.100
Medium Beaker		
0	39.000	0.100
90	0.270	0.010
80	0.880	0.010
70	2.500	0.030
60	4.600	0.100
50	7.400	0.100
40	10.000	0.300
30	12.500	0.300
20	14.500	0.300
10	15.500	0.300
0	16.000	0.300
Large Beaker		
90	0.090	0.010
80	0.430	0.010
70	1.300	0.030
60	2.400	0.030
50	3.900	0.100
40	5.200	0.100
30	6.600	0.100
20	7.600	0.100
10	8.200	0.100
0	8.600	0.100

TABLE 2. Water

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
Small Beaker		
100	0.80	0.03
90	2.25	0.03
80	5.00	0.10
70	8.90	0.10
60	13.00	0.30
50	16.50	0.30
40	21.50	0.30
30	24.00	0.30
20	26.00	0.30
10	25.50	0.30
0	24.00	0.30
Medium Beaker		
90	1.90	0.03
80	3.90	0.10
70	6.20	0.10
60	9.20	0.10
50	11.50	0.30
40	13.50	0.30
30	15.00	0.30
20	15.00	0.30
10	14.50	0.30
0	13.50	0.30
Small Beaker		
90	1.30	0.03
80	2.50	0.03
70	4.00	0.10
60	5.40	0.10
50	6.70	0.10
40	7.60	0.10
30	8.30	0.10
20	8.50	0.10
10	8.10	0.10
0	7.20	0.10

TABLE 3. Solution 1

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
Small Beaker		
90	5.00	0.10
80	7.70	0.10
70	11.00	0.30
60	14.00	0.30
50	17.00	0.30
40	18.50	0.30
30	19.00	0.30
20	19.50	0.30
10	17.50	0.30
0	13.50	0.30
Medium Beaker		
90	9.40	0.10
80	13.50	0.30
70	17.50	0.30
60	21.00	0.30
50	23.00	0.30
40	23.50	0.30
30	24.50	0.30
20	22.00	0.30
10	19.50	0.30
0	15.50	0.30
Small Beaker		
90	2.20	0.03
80	3.10	0.10
70	4.30	0.10
60	5.20	0.10
50	5.80	0.10
40	5.90	0.10
30	6.40	0.10
20	5.80	0.10
10	5.10	0.10
0	3.70	0.10

TABLE 4. Solution 2

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
Small Beaker		
90	1.70	0.03
80	5.30	0.10
70	11.00	0.30
60	17.50	0.30
50	26.00	0.30
40	34.00	1.00
30	40.00	1.00
20	44.00	1.00
10	46.00	1.00
0	46.00	1.00
Medium Beaker		
90	0.58	0.01
80	1.75	0.03
70	3.40	0.10
60	5.80	0.10
50	8.40	0.10
40	11.00	0.30
30	12.00	0.30
20	13.00	0.30
10	13.50	0.30
0	13.50	0.30
Small Beaker		
90	0.41	0.01
80	1.10	0.03
70	2.25	0.03
60	3.60	0.10
50	5.10	0.10
40	6.40	0.10
30	7.30	0.10
20	8.00	0.10
10	8.20	0.10
0	8.00	0.10

TABLE 5. Solution 3

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
Small Beaker		
90	1.20	0.03
80	3.80	0.10
70	9.20	0.10
60	16.00	0.30
50	24.50	0.30
40	32.00	1.00
30	38.00	1.00
20	43.00	1.00
10	46.00	1.00
0	46.00	1.00
Medium		
90	0.29	0.01
80	1.05	0.03
70	2.55	0.10
60	4.50	0.10
50	6.60	0.10
40	9.20	0.30
30	11.00	0.30
20	12.00	0.30
10	13.00	0.30
0	13.00	0.30
Large Beaker		
90	0.15	0.01
80	0.61	0.01
70	1.55	0.03
60	2.80	0.03
50	4.20	0.10
40	5.50	0.10
30	6.60	0.10
20	7.60	0.10
10	8.00	0.10
0	8.20	0.10

TABLE 6. Solution 4

IV. DISCUSSION

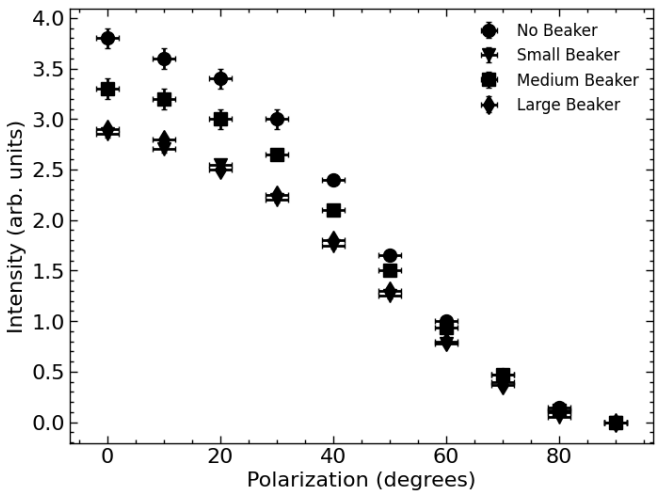

FIG. 1. Intensity vs. Polarization for varying beaker sizes with no water.

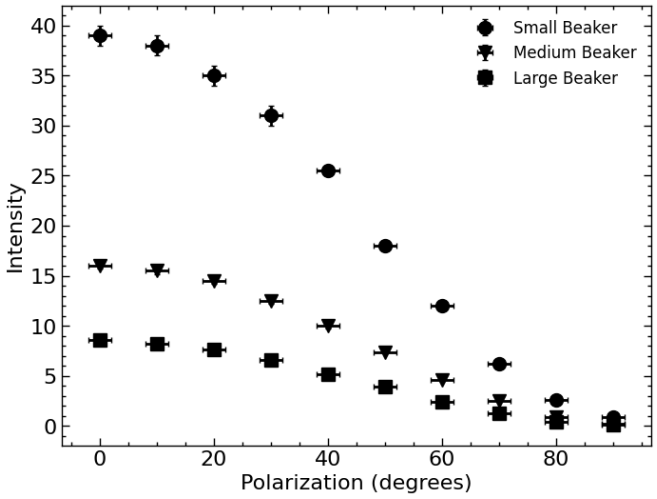

FIG. 2. Intensity vs. Polarization for varying beaker sizes with water.

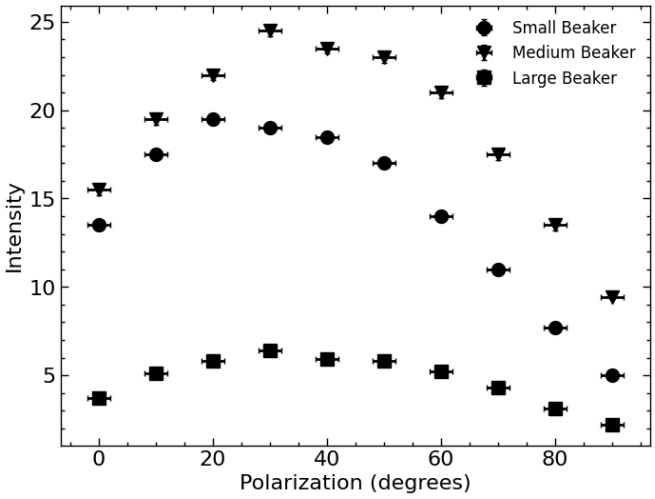

FIG. 4. Intensity vs. Polarization for varying beaker sizes with solution 2.

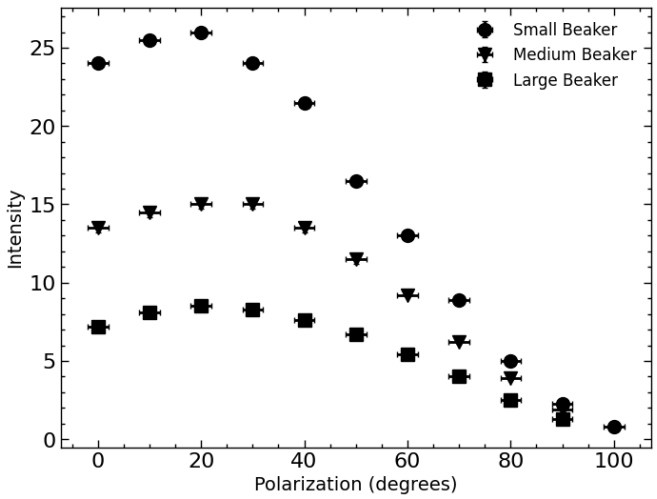

FIG. 3. Intensity vs. Polarization for varying beaker sizes with solution 1.

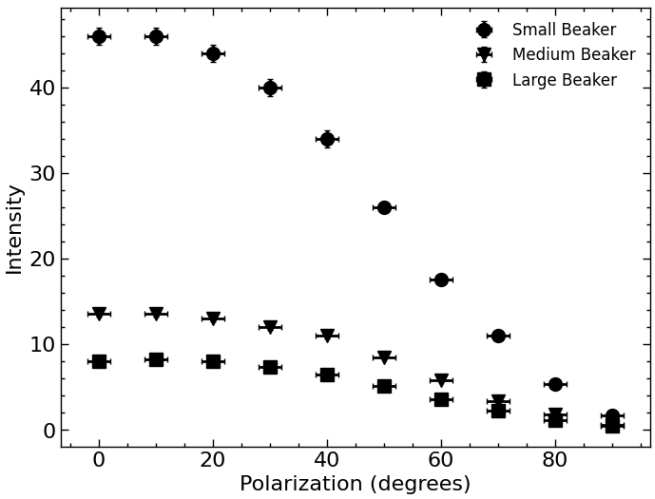

FIG. 5. Intensity vs. Polarization for varying beaker sizes with solution 3.

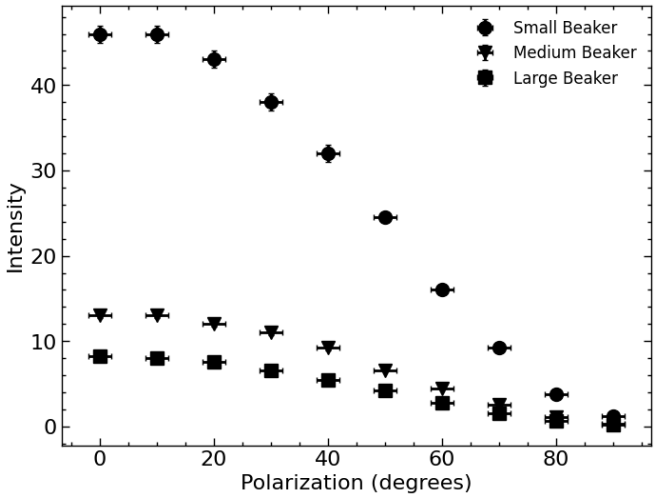

FIG. 6. Intensity vs. Polarization for varying beaker sizes with solution 4.

Each of the following graphs show the phase shift as a function of sugar concentration in water, with each separate graph containing data from one beaker size. The phase shifts were found by fitting the intensity vs. polarization data to a cosine function. By representing phase shift versus sugar concentration, we can quantify how the polarization of light changes as a function of sugar concentration in water.

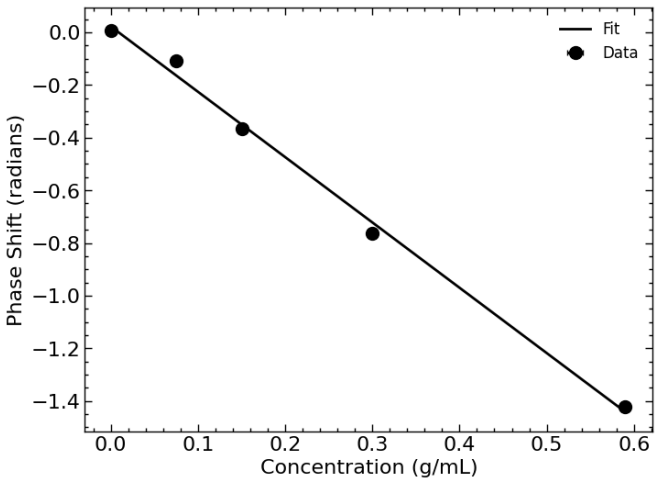

FIG. 7. This graph shows the phase shifts for large beaker.

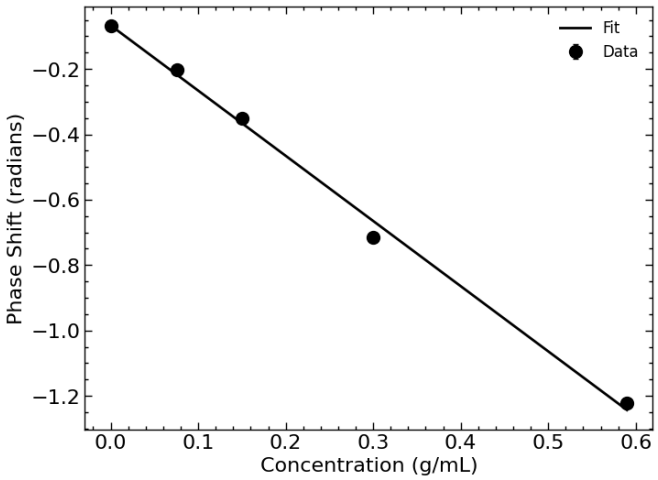

FIG. 8. Phase shifts for medium beaker.

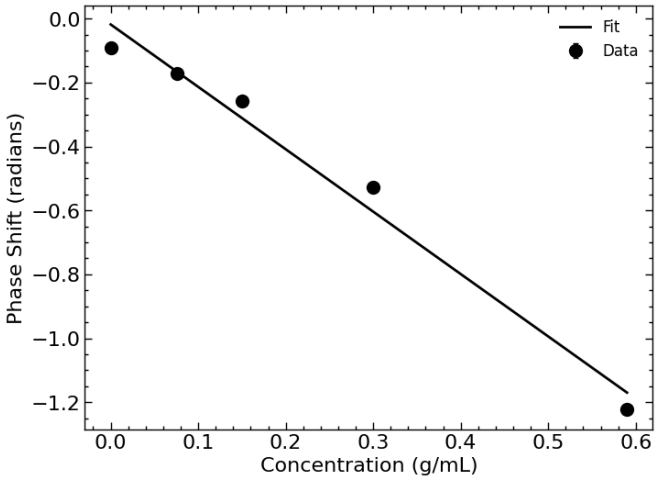

FIG. 9. Phase shifts for small beaker.

V. CONCLUSION