INTERNATIONAL BACCALAUREATE

Chemistry Extended Essay

Calculation of Alumina Hydrosol Concentrations by Using Tyndall Light Dispersion Effect in Colloids

Levent ASLANBAŞ

D1129006

Session: May 2011

Supervisor: Ayşe ŞENAY

Word Count: 3328

TED Ankara College Foundation High School, 2011

CONTENTS

Abstract 2

Introduction **3**

Background Information 3

Building up the Research Question 5

Method **7**

Experiment 1 7

Variables 7

Disposal of the Chemicals 8

Materials 9

Procedure 9

Experiment 2 12

Variables 12

Materials 13

Procedure 13

Data Collection and Processing **15**

Conclusion **22**

The Formula 22

Limitations 23

Acknowledgements 23

Bibliography **24**

ABSTRACT

This study is about colloidal mixtures and a method to measure their concentrations. A light beam scatters as it passes through a colloidal mixture. This is called Tyndall Effect. By comparing the effectiveness of Tyndall Effect at different concentration colloids, a formula may be built which can be used to find out the concentration.

Research question of this study is this: "Can concentration of an alumina hydrosol be calculated by using scattering ratios of laser beams in hydrosols and does the wavelength of the laser beam affect the accuracy of the concentration calculation?"

The reason that this subject is studied for a Chemistry extended essay is that this subject is directly related with environmental chemistry. In lakes, seas, rivers and oceans, colloidal systems can be found. If there is too much alumina particle in a water ecosystem, life in that water may be harmed. The formula that is found in this investigation can be used to easily determine the concentration of particles in water.

Different concentrations of Alumina colloids, varying between 20 and 100 μM are tried in this experiment. A strong green light beam is pointed through colloids and their photographs are taken from above the mixtures. The width of light is found in pixels from analysis of photographs and these data are used to determine the relationship between colloid concentration and scattering ratio of the mixture on green laser beam. The same procedure is executed for blue laser to find out if the scattering ratio is constant for all wavelengths or different for varying wavelengths of light. As a result of analysis of the data, a formula which can be used to calculate the concentration of the colloid from the scattering ratio of the light is generated.

(Word Count: 289)

INTRODUCTION

Background Information:

"Colloid and interface science is concerned with particles, droplets and bubbles dispersed in bulk phases, and the properties of the interfacial regions around and within them." [1] Colloidal mixtures are almost homogeneous in macroscopic means, however in microscopic scale, unlike solutions; colloids contain usually spherical much larger particles than molecules of a material and these particles are not distributed completely homogenously. These particles move spontaneously in the material that they are put into. Numerous molecules of a material stick together, forming those (usually) spherical structures. These structures, when put in a medium that they can disperse macroscopically homogeneous, form a colloidal system.*"Colloids are usually classified according to the original states of their constituent parts:"* [2]

In a colloidal structure there are two main constituent parts: Dispersing medium which means the medium in which microscopic particles are dispersed, and dispersed phase which is the particles that mix within the dispersing medium.

Dispersing medium	**Dispersed phase**	**Name**
Solid	Solid	Solid sol
Solid	Liquid	Gel
Solid	Gas	Solid foam
Liquid	Solid	Sol
Liquid	Liquid	Emulsion
Liquid	Gas	Foam
Gas	Solid	Solid aerosol
Gas	Liquid	Aerosol

Table 1: Naming for types of colloids according to physical states of their constituent parts.

[1] <http://www.chm.bris.ac.uk/pt/colloid.htm> (date: 11.27.2010)

[2] <http://www.chm.bris.ac.uk/webprojects2002/pdavies/> (date: 11.27.2010)

Sol type of colloid is one in which dispersed phase is a solid and dispersing medium is fluid (liquid or gas) . The sol type of colloid consisting of liquid water as the dispersing medium and a solid dispersed phase is called hydrosol.[3]

Colloids are everywhere in daily life. Milk is an example of emulsion. Clay is a gel type colloid. The spray deodorants are aerosol type of colloids and even our blood is a colloidal structure.[4][5]

Tyndall effect is the scattering effect of colloidal systems on the light passing through the colloid. When a light beam passes through a colloidal structure, the light rays in the beam that hit the dispersed phase are reflected at a random direction which makes the particles which are in the colloidal structure act like very small light sources reflecting light at random directions. This causes a significant scattering in the light beam as light jumps from one particle to another continuously. When the light beam scatters in the colloidal mixture, diameter of the light beam becomes larger and loses its linearity. This state of scattering based shape loss of light beam in colloids is called Tyndall effect. [6][7]

---

[3] <http://www.britannica.com/EBchecked/topic/552808/sol?anchor=ref27536> (date: 11.29.2010)

[4] Green J. & Damji S., IBID Chemistry, 3rd Edition; International Baccalaureate. Series Title: International Baccalaureate in Detail; January 2008; page 487. (ISBN: 978-1-876659-08-0)

[5] Silberberg, Martin Stuart. Chemistry: the molecular nature of matter and change (International edition). New York; McGraw Hill Education. 2003. Page 517 (ISBN:0-07-111023

[6] <http://www.britannica.com/EBchecked/topic/611583/Tyndall-effect> (date: 11.29.2010)

[7] Srivastava, A. K. & Jain, P. C. Chemistry Vol (1 and 2). New Delhi; VK Publications. 2008. ISBN: 818859783X

Building up the Research Question

As Tyndall Effect takes place in sol type colloids, especially the hydrosol which is studied in this investigation, the light scatters in the colloidal mixture. The method which I use in this investigation is to find ratio at which the laser light beam is dispersed. This method is executed by dividing the diameter of light beam in the center of the mixture to the original diameter of the laser light beam. This gives the ratio of scattering of the laser light beam. By comparing ratios of scattering of different independent variabled colloids, one can determine if there is a meaningful difference between two samples or not.

In my opinion, the scattering ratio may increase according to an increase in size of the dispersed phase particles. Because, as the particles get larger, the chance that light beam may hit the particles shall become much more.

Another factor that may affect the scattering ratio may be the concentration of the dispersed phase particles. This may be true because the more particles in a unit volume is dispersed, the more chance that a laser light beam may hit more particles. To give an analogy to this issue, the concentration effect is similar to a bullet that passes through low dust concentration air. The bullet may collide with less dust particles than it would do in heavily dusty air. Therefore, before constructing a formula to determine the concentration of a hydrosol when the scattering ratio is known, it should be determined if there is a significant relationship between concentration of the hydrosol and the scattering ratio of the light. This is the purpose of the experiment one in this investigation.

By collecting data on the scattering ratios of light beam in different concentrations of colloidal systems and different particle sizes of dispersed phase systems, one may build up a formula of colloid concentration vs. light scattering ratio for hydrosols. By using this formula, the concentration of a certain hydrosol colloidal system can be determined by measuring the light scattering ratio of a colloid.

One of the most abundant and thus easily examined colloidal systems is hydrosol structure as hydrosol can easily be produced by adding solid particles in pure water (water is easily found, which makes hydrosol the most abundant colloidal mixture in the earth). So in this experiment a hydrosol type colloid (solid particles dispersed in water) is examined.

The examined compound which forms hydrosol colloidal structure with water is Aluminum Oxide, Al_2O_3, or in other words Alumina. The reason for choosing alumina is that one of the most abundant compounds in earth is Alumina so there is Alumina in seas, rivers and lakes. The balance of life in water is so easily affected by a single components concentration change; so change in Alumina concentration may affect aquatic life in lakes, seas or rivers as it decreases the plant growth.[8] This issue is directly related with water pollution which is an environmental chemistry subject.

By thinking and researching about these issues, I have decided to study this subject and came up with two research questions which must be answered before finding the formula which I work on:

1- Does the concentration (20, 40, 60, 80 and 100 μM) of a hydrosol type Alumina 20-50 nm particle sized colloidal mixture affect the scattering ratio of straight green laser light (λ: 532 nm) that travels in the colloid?

2- Does the wavelength of the laser beam affect the accuracy of the measurements of the concentration based scattering ratio difference of hydrosol type Alumina colloidal mixture?

---

[8] Andersson, Maud (1988). "Toxicity and tolerance of aluminium in vascular plants". *Water, Air, & Soil Pollution* 39 (3–4): 439–462. <http://www.springerlink.com/content/pxp793217612t333/>

METHOD

Experiment 1

Purpose: To find the relationship between the concentration of a hydrosol type Alumina 20-50 nm particle sized colloidal mixture and the scattering ratio of straight green laser that travels in the colloid.

By finding the relationship mentioned above, there will be enough data for constructing a formula which can be used to determine the concentration of an Alumina colloid by using my method.

Variables:

- **Independent Variable:**
  - The concentration of the colloidal mixture through which the green laser beam passes. (20, 40, 60, 80 and 100μM)

- **Dependent Variable:**
  - The ratio of the radius of the scattered straight laser beam which passes through the Alumina colloid to the radius of the laser light before scattering. (the scattering ratio)

- **Controlled Variables:**
  - The Volume of the colloidal mixture is kept constant at 250 mL.
  - Room temperature will be kept constant in order to avoid any difference in the structure of colloids; because at higher temperatures the dispersed solid spherical particles may stick together and form bigger particles than the estimated size interval. So, any major temperature change in the colloidal mixtures should not be allowed
  - The distance between the colloid and the lens of the camera is kept constant at 20 cm.
  - The resolution of the photographs taken by the camera are kept constant at 15 Megapixels. The same camera is used in all trials.
  - The time the hydrosols were mixed is kept constant at 30 minutes.

- The laser pointer was put 3 cm away from the beaker which contains hydrosol in each and every trial. This is stabilized at 3 cm for controlling the light intensity of the laser pointer.

Disposal of the Chemicals

In this experiment, no harmful materials are used and the alumina in small concentrations have no known harmful effects on the environment.[9] so the disposal of alumina hydrosols can be done by disposing the mixtures down the sink and running lots of water with it to lower its concentration even more.

[9] <http://www.jtbaker.com/msds/englishhtml/a2844.htm> (date: 12.8.2010)

Materials

- Distilled water (2000 mL)
- 500 mL glass beaker. (as container) (x5)
- 1000 mL glass beaker (as container) (x5)
- 250 mL graduated cylinder (± 0.5 mL)
- An automatic magnetic stirrer with its magnet capsule (x1)
- 20-50 nm Al_2O_3 powder (0.01875 g)
- A muller and a mallet
- A digital camera (15 Megapixels)
- A green laser pointer (50 mW) (λ: 532 nm)
- Highly sensitive electronic scale (± 0.1 μg)

Procedure

By keeping the doors and windows of the laboratory closed, the room temperature is tried to be kept constant.

Before adding the Al_2O_3 powder into the distilled water, use muller and mallet to reduce the clumping that might have occurred due to the moisture in the air.

1. Put 750 mL distilled water in the 1000 mL beaker by measuring it with 250 mL graduated cylinder.
2. Put 0.010196 grams of mulled 20-50 nm Al_2O_3 powder into the water put in the beaker.
3. Label the beaker as 100 µM Alumina Colloid (This will be used to prepare mixtures with lower concentrations).
4. Put 100 µM Alumina Colloid containing beaker on the magnetic stirrer, put the magnet capsule into the mixture and start the magnetic stirrer. Do not start step 5 before mixing the colloid for 30 minutes.

5. Put 250 mL 100 µM Alumina colloid into a 500 mL beaker

6. Place the green laser pointer pointing directly at the glass beaker 3 cm away from the container and 4 cm above the ground. (see Diagram 1)

7. Place the digital camera pointing from the top at the laser beam passing through the mixture. The sight axis of the camera must make a right angle with the laser rays. Place the camera 20 cm away from the surface of the colloid. (see Diagram 1 and 2) Take 5 photos without moving the camera when the laser pointer is turned on.

8. Use 100 µM mixture to prepare mixtures with volume of 250 mL and concentrations of 80 µM, 60 µM, 40 µM and 20 µM alumina colloids. Label the mixtures with their concentrations. Below is the method for diluting the mixtures:

- 80 µM: put 200 mL 100 µM mixture in the 500 mL beaker and add 50 mL distilled water into the mixture.
- 60 µM: put 150 mL 100 µM mixture in the 500 mL beaker and add 100 mL distilled water into the mixture.
- 40 µM: put 100mL 100 µM mixture in the 500 mL beaker and add 150 mL distilled water into the mixture.
- 20 µM: put 50mL 100 µM mixture in the 500 mL beaker and add 200 mL distilled water into the mixture.

9. Repeat steps 5 to 7 with mixtures with concentrations written in step 9.

10. Have 4 more trials done by repeating the steps 1-9.

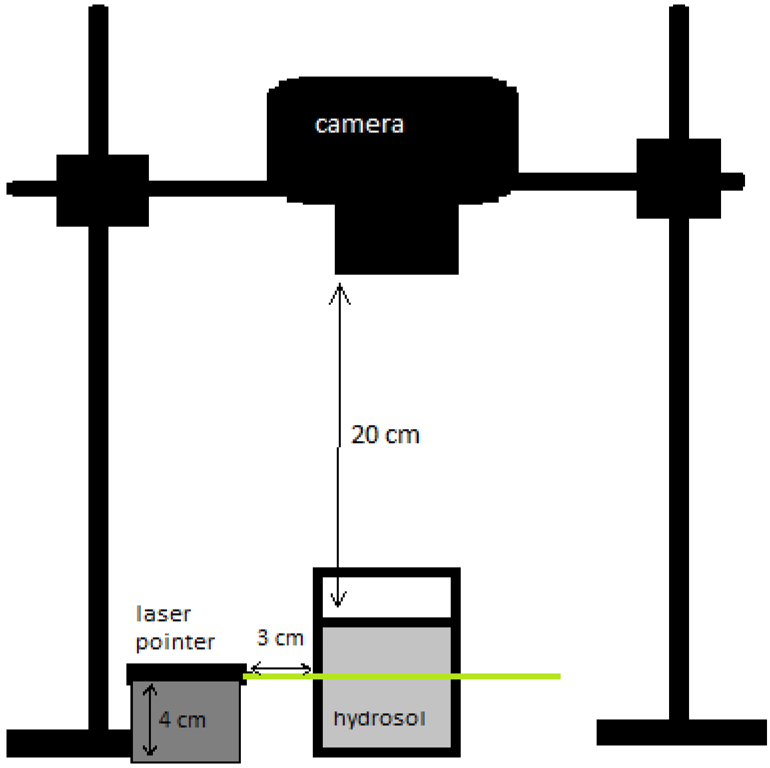


Diagram 1: The diagram shows the experiment setting.

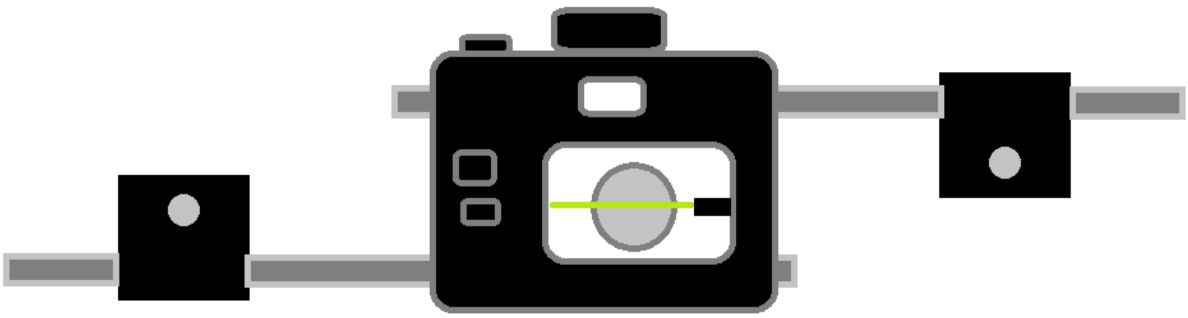


Diagram 2: The diagram shows how the camera is placed, from above.

Experiment 2

(Data and setting of Experiment 1 is needed for processing the data for this experiment.)

Purpose: To determine which color of laser light should be used to construct a formula to calculate the concentration of Alumina hydrosol by using the light scattering ratio in the colloid.

Variables:

- **Independent Variables:**
  - The wavelength of the laser beam which passes through the Alumina 20-50 nm particle sized colloid.
- **Dependent Variables:**
  - The ratio of the radius of the scattered straight laser light and the radius of the laser light before scattering for two independent variables (scattering ratio).
- **Controlled Variables:**
  - The Volume of the colloidal mixture is kept constant at 250 mL.
  - Room temperature will be kept constant in order to avoid any difference in the structure of colloids; because at higher temperatures the dispersed solid spherical particles may stick together and form bigger particles than the estimated size interval.

Materials

- Distilled water (2000 mL.)
- 500 mL glass beaker. (as container) (x5)
- 1000 mL glass beaker (as container) (x5)
- 250 mL graduated cylinder (± 0.5 mL)
- An automatic magnetic stirrer with its magnet capsule. (x1)
- 20-50 nm Al_2O_3 powder (0.01875 g)
- A muller and a mallet.
- A digital camera (15 Megapixels)
- Highly sensitive electronic weight scale (± 0.5 µg)
- A blue laser pointer (50 mW) (λ: 447 nm)

Procedure

By keeping the doors and windows of the laboratory closed, the room temperature is tried to be kept constant.

Before adding the Al_2O_3 powder into the distilled water, use muller and mallet to reduce the clumping might have occurred due to moisture in the air.

1. Put 750 mL distilled water in the 1000 mL beaker by measuring it with 250 mL graduated cylinder.
2. Put 0.010196 grams of 20-50 nm Al_2O_3 powder into the water put in the beaker.
3. Label the beaker as 100 µM Alumina Colloid (This will be used to prepare mixtures with lower concentrations)
4. Put 100 µM Alumina Colloid containing beaker on the magnetic stirrer, put the magnet capsule into the mixture and start the magnetic stirrer. Do not start step 5 before mixing the colloid at least for 30 minutes.

5. Put 250 mL 100 µM Alumina colloid into a 500 mL beaker

6. Place the blue laser pointer pointing directly at the glass cylinder 3 cm away from the container to make sure that the laser pointer is close to the container (Diagram 1).

7. Place the digital camera pointing from the top at the laser beam passing through the mixture. The sight axis of the camera must make a right angle with the laser rays. Place the camera 3 cm away from the glass container (Diagram 1). Take 5 photos without moving the camera when the laser pointer is turned on.

8. Use 100 µM (main) mixture to prepare mixtures with volume of 250 mL and concentrations of 80 µM, 60 µM, 40 µM and 20 µM alumina colloids. Label the mixtures with their concentrations. Below is the method for diluting the mixtures:

- 80 µM: put 200 mL main mixture in the 500 mL beaker and add 50 mL distilled water.
- 60 µM: put 150 mL main mixture in the 500 mL beaker and add 100 mL distilled water
- 40 µM: put 100mL main mixture in the 500 mL beaker and add 150 mL distilled water.
- 20 µM: put 50mL main mixture in the 500 mL beaker and add 200 mL distilled water.

9. Repeat steps 5 to 9 with mixtures with concentrations written in step 9.

10. Have 4 more trials done of the by repeating the steps 1-10

DATA COLLECTION AND PROCESSING

Concentration of the Alumina Colloid (μM)	Trials	Green Laser Width at the center of the colloid according to the photographs taken (pixels)					Blue laser width at the center of the colloid according to the photographs taken (pixels)				
20	Trial 1	33	34	35	35	33	43	40	41	40	42
	Trial 2	32	35	37	35	32	42	41	39	40	43
	Trial 3	35	34	33	34	33	41	42	42	41	40
	Trial 4	34	34	32	35	35	42	40	41	42	40
	Trial 5	32	36	35	34	33	41	40	41	43	41
40	Trial 1	39	37	36	38	37	44	43	43	44	45
	Trial 2	39	38	37	37	36	44	43	42	44	45
	Trial 3	39	37	37	37	38	43	43	45	45	44
	Trial 4	37	38	37	37	39	44	45	42	43	45
	Trial 5	36	39	38	38	37	43	44	44	41	45
60	Trial 1	41	40	41	41	40	47	45	46	48	47
	Trial 2	40	39	41	43	41	46	45	47	46	48
	Trial 3	42	40	42	41	40	46	46	47	45	47
	Trial 4	43	40	42	40	39	47	45	46	46	47
	Trial 5	43	40	42	39	41	48	45	46	47	46
80	Trial 1	43	44	44	45	46	50	52	51	51	49
	Trial 2	45	43	43	46	44	50	51	51	52	50
	Trial 3	44	45	45	46	43	51	52	50	51	50
	Trial 4	45	46	45	44	43	50	52	51	49	51
	Trial 5	43	45	46	45	43	51	52	48	49	51
100	Trial 1	49	47	51	50	48	54	55	54	56	53
	Trial 2	49	48	49	50	50	55	54	56	53	52
	Trial 3	50	49	49	48	49	54	53	57	54	53
	Trial 4	47	51	51	50	48	56	55	53	54	54
	Trial 5	48	48	49	52	51	55	53	54	54	57

Table 2: Raw data table which shows concentrations of Alumina colloids, the color of the laser beam which passes through the Alumina colloids and the widths of laser beams in the centers of the alumina colloids in pixels.

The following applications are done in Paint program, Microsoft Corporation. Version: 6.1.7600.16385.

First, draw a rectangular on the image of the beaker, at the photograph with its corners on the circle which makes the bottom of the beaker. Draw diagonals of the rectangular (see diagram 3). The interception point of two diagonals is the center of the beaker in the image.

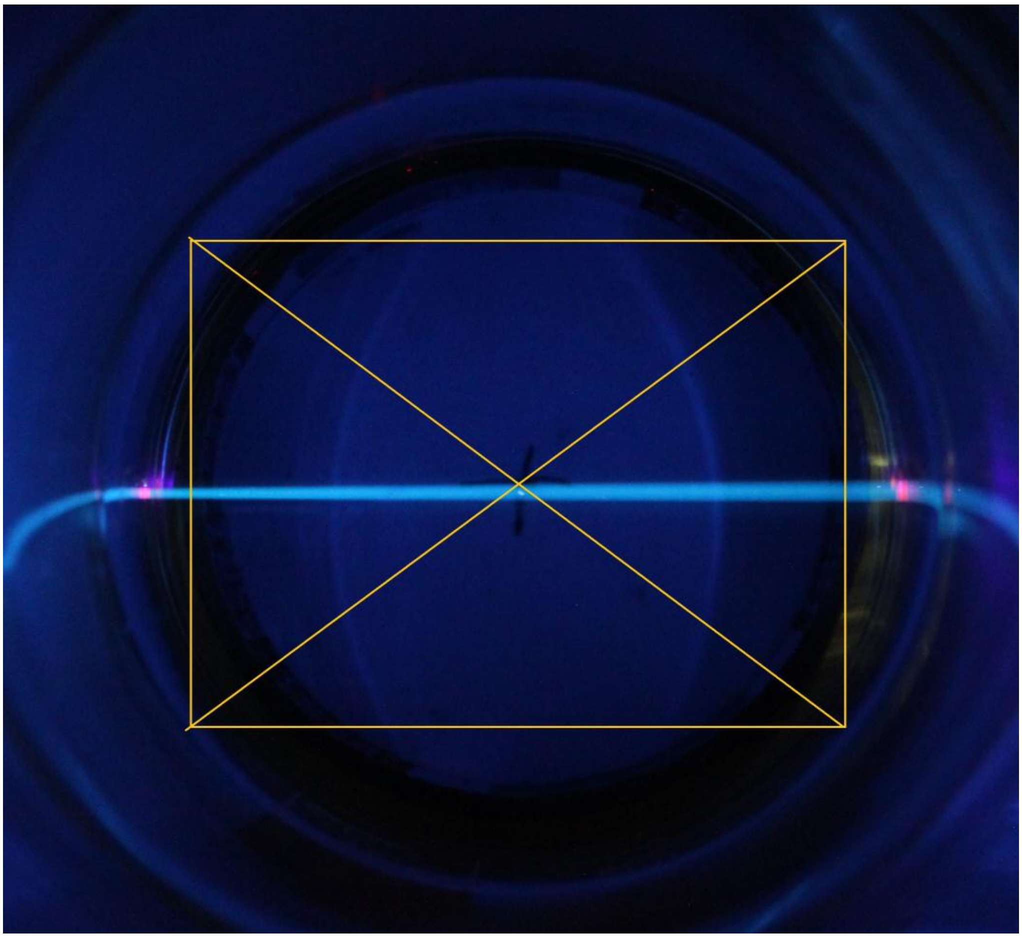


Diagram 3: this diagram shows how the rectangular is drawn in the photograph and how center of the beaker is found.

The width of the laser beam at the center is measured in pixels. First of all, the photo is zoomed in until all the pixels at the center of the image, which is found by the method explained above, can clearly be seen as boxes on the screen. A line is drawn from the uppermost pixel to the one on the very bottom of the light beam at the center. The length of the line is read as pixels by the Paint program. This measurement in pixels formed the width of the laser beam and this data is recorded in table 2.

When every single photograph which was taken in the experiment was analyzed one by one, I came up with those data above. In my measurements, I have discovered that the width of initial laser beam (before refraction) was 29 pixels for green laser and 32 pixels for blue laser by counting the pixels at the point that laser beam enters the beaker, before scattering. When the width of light beams in the center of the colloids are divided by initial widths of the laser beams we come up with scattering ratios of different concentrations of alumina colloids (table3 and 4).

$$\frac{\text{Width of the laser beam at the center (pixels)}}{\text{Width of the initial laser beam (pixels)}} = \text{Scattering Ratio (formula 1)}$$

For trial 1 measurement 1: 33/29 =1.137931

For trial 1 measurement 2: 34/29=1.172414

Scattering ratios given in tables 3 and 4 are calculated by using formula 1.

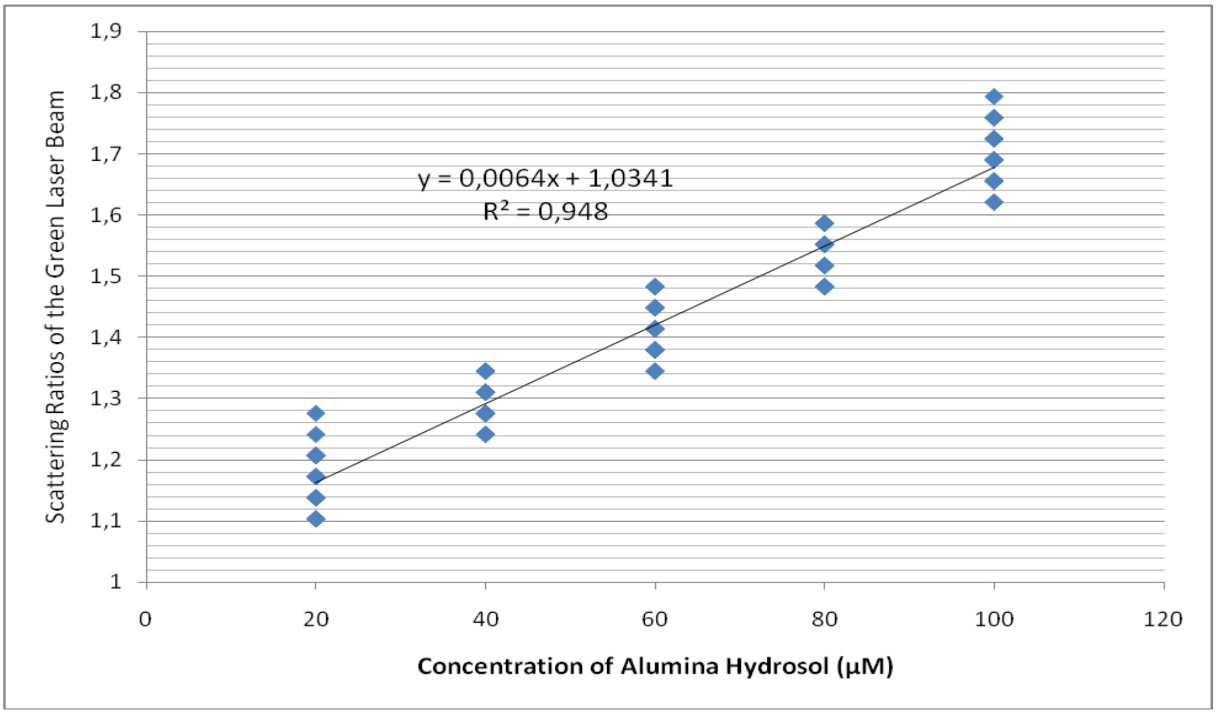
Concentration (μM)	Trials	Scattering ratios for green laser (50mW) (λ: 532 nm)				
20	1	1.137931	1.172414	1.206897	1.206897	1.137931
	2	1.103448	1.206897	1.275862	1.206897	1.103448
	3	1.206897	1.172414	1.137931	1.172414	1.137931
	4	1.172414	1.172414	1.103448	1.206897	1.206897
	5	1.103448	1.241379	1.206897	1.172414	1.137931
40	1	1.344828	1.275862	1.241379	1.310345	1.275862
	2	1.344828	1.310345	1.275862	1.275862	1.241379
	3	1.344828	1.275862	1.275862	1.275862	1.310345
	4	1.275862	1.310345	1.275862	1.275862	1.344828
	5	1.241379	1.344828	1.310345	1.310345	1.275862
60	1	1.413793	1.379310	1.413793	1.413793	1.379310
	2	1.379310	1.344828	1.413793	1.482759	1.413793
	3	1.448276	1.379310	1.448276	1.413793	1.379310
	4	1.482759	1.379310	1.448276	1.379310	1.344828
	5	1.482759	1.379310	1.448276	1.344828	1.413793
80	1	1.482759	1.517241	1.517241	1.551724	1.586207
	2	1.551724	1.482759	1.482759	1.586207	1.517241
	3	1.517241	1.551724	1.551724	1.586207	1.482759
	4	1.551724	1.586207	1.551724	1.517241	1.482759
	5	1.482759	1.551724	1.586207	1.551724	1.482759
100	1	1.689655	1.620690	1.758621	1.724138	1.655172
	2	1.689655	1.655172	1.689655	1.724138	1.724138
	3	1.724138	1.689655	1.689655	1.655172	1.689655
	4	1.620690	1.758621	1.758621	1.724138	1.655172
	5	1.655172	1.655172	1.689655	1.793103	1.758621

Table 3: The table above shows the scattering ratios of the Alumina hydrosol mixtures for the green laser beam according to their concentrations and in five photographs per trial of a concentration.

Concentration (μM)	Trials	Scattering ratios for blue laser (50 mW) (λ: 447 nm)				
20	1	1.34375	1.25000	1.28125	1.25000	1.31250
	2	1.31250	1.28125	1.21875	1.25000	1.34375
	3	1.28125	1.31250	1.31250	1.28125	1.25000
	4	1.31250	1.25000	1.28125	1.31250	1.25000
	5	1.28125	1.25000	1.28125	1.34375	1.28125
40	1	1.37500	1.34375	1.34375	1.37500	1.40625
	2	1.37500	1.34375	1.31250	1.37500	1.40625
	3	1.34375	1.34375	1.40625	1.40625	1.37500
	4	1.37500	1.40625	1.31250	1.34375	1.40625
	5	1.34375	1.37500	1.37500	1.28125	1.40625
60	1	1.46875	1.40625	1.43750	1.50000	1.46875
	2	1.43750	1.40625	1.46875	1.43750	1.50000
	3	1.43750	1.43750	1.46875	1.40625	1.46875
	4	1.46875	1.40625	1.43750	1.43750	1.46875
	5	1.50000	1.40625	1.43750	1.46875	1.43750
80	1	1.56250	1.62500	1.59375	1.59375	1.53125
	2	1.56250	1.59375	1.59375	1.62500	1.56250
	3	1.59375	1.62500	1.56250	1.59375	1.56250
	4	1.56250	1.62500	1.59375	1.53125	1.59375
	5	1.59375	1.62500	1.50000	1.53125	1.59375
100	1	1.68750	1.71875	1.68750	1.75000	1.65625
	2	1.71875	1.68750	1.75000	1.65625	1.62500
	3	1.68750	1.65625	1.78125	1.68750	1.65625
	4	1.75000	1.71875	1.65625	1.68750	1.68750
	5	1.71875	1.65625	1.68750	1.68750	1.78125

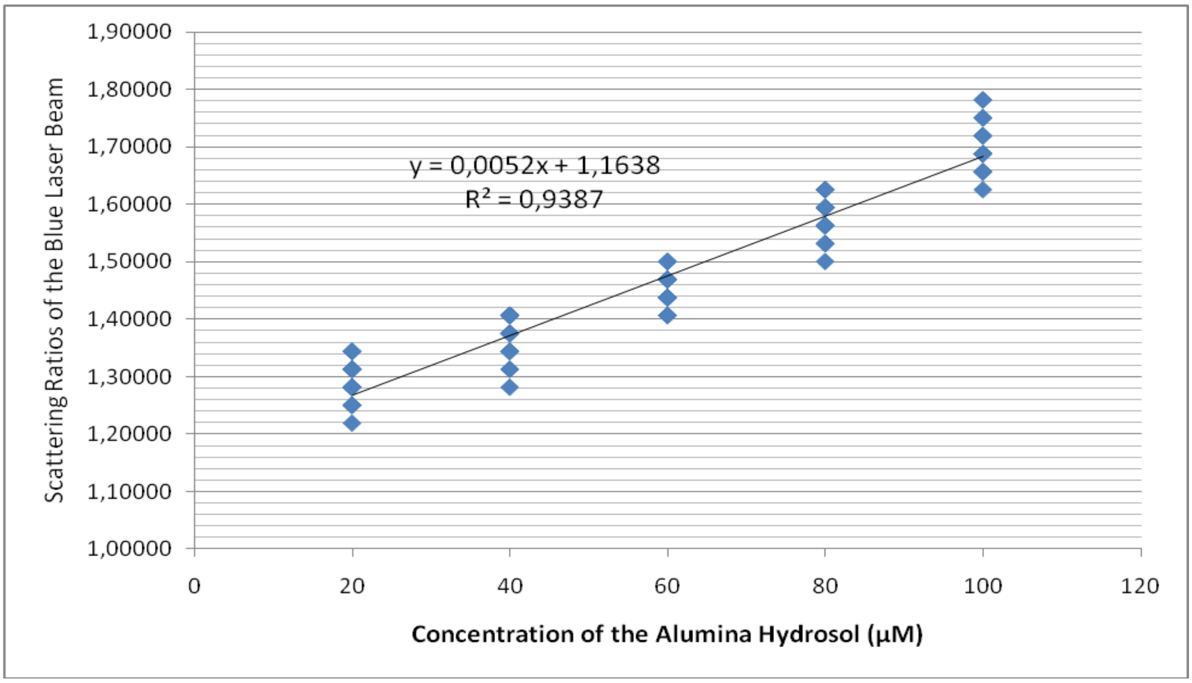
Table 4: The table above shows the scattering ratios of the Alumina hydrosol mixtures for the blue laser beam according to their concentrations and in five photographs per trial of a concentration.

The data in the table 3 are plotted on a regression chart and the R^2 value of the best fit line of the plotting is found in graph 1.



Graph 1: Graph showing the Concentration of the Alumina Hydrosol vs. Scattering ratio of the green laser beam as it passes through the colloid. The data of this graph is at Table 3.

If the same plotting is done for scattering ratios of blue laser beam vs. concentration of the Alumina colloid, and R^2 value for the best fit line is found, Graph 2 is found.



Graph 2: Graph showing the Concentration of the Alumina Hydrosol vs. Scattering ratio of the blue laser beam as it passes through the colloid. The data of this graph is at Table 4.

CONCLUSION

It is found that there is a meaningful relationship between concentration of the Alumina Hydrosol and the scattering ratio of a laser beam as the R^2 values of data taken for both of the lasers are very close to 1. Therefore, it can be stated that there is a strong relation between concentration of the Alumina hydrosol type 20-50 nm particle sized hydrosol and the light scattering ratio of the hydrosol.

As R^2 values for graph 1 and graph 2 are compared, the R^2 value of graph 1 is found greater than for graph 2. This shows that any formula which is to be based on the data taken in this experiment is slightly more accurate for measurements of green laser beam.

This shows that wavelength of the laser beam affects the accuracy of concentration calculation which is to be done by using the formula that is to be found below.

The Formula

There can be found a formula which gives the concentration value of the Alumina Hydrosol if the scattering ratio of the hydrosol on green laser beam is known. I use scattering ratio for green laser beam because green laser beam has a higher accuracy potency than blue laser as it has a higher R^2 value than the blue laser (See graph1and graph2).

The equation for best fit line of the plotting of concentration of alumina hydrosol versus scattering ratio of the green laser beam in the hydrosol is this:

$f(x) = 0.0064x + 1.0341$

f(x) is the scattering ratio of the Alumina hydrosol on the green laser beam. Thus, if this function is inversed, it can be used to find the concentration of the hydrosol by using the scattering ratio of green laser beam passing through it.

$f^{-1}(x) = 147.02x – 148.91$

$C = (147.02\ R_s - 148.91)\mu M$

If the scattering ratio of Alumina hydrosol is known, then the concentration of that Alumina hydrosol can be found by using the formula above. C stands for concentration of the Alumina Hydrosol and R_s is the scattering ratio of the green laser beam.

Limitations

First of all there are not enough independent variables for the second experiment. I managed to find lasers of same power (50mW) with only two different wavelengths: green and blue (532nm and 447nm). There is only two different wavelengths of laser beams: blue and green. This causes an uncertainty about the decision to be given for the wavelength affecting the accuracy of the calculations. This brings a question: What if the relationship between R^2 values of linear regression charts for different wavelengths of laser beams is not linear? This question could not be answered by having only two different wavelengths tried.

Another major limitation is about the aim of the whole project. The aim was to come up with a formula which could be used to determine the particle concentration of any hydrosol type of colloid by using Tyndall effect. However, I did not manage to finance another Alumina like hydrosol ingredient such as Silica (SiO_2) or Titania (TiO_2). This limited the result of the project to the results taken from Alumina hydrosol. I would like to go further with this project as I become a Chemistry student in my university education with university funding me for my research.

Acknowledgements

I would like to thank Ms. Ayşe ŞENAY for her support throughout my project.

Word Count = 3328

Bibliography

1. <http://www.chm.bris.ac.uk/pt/colloid.htm> (date: 11.27.2010)

2. <http://www.chm.bris.ac.uk/webprojects2002/pdavies/> (date: 11.27.2010)

3. <http://www.britannica.com/EBchecked/topic/552808/sol?anchor=ref27536> (date: 11.29.2010)

4. Green J. & Damji S., IBID Chemistry, 3rd Edition; International Baccalaureate. Series Title: International Baccalaureate in Detail; 2008; page 487. (ISBN: 978-1-876659-08-0)

5. Silberberg, Martin Stuart. Chemistry: the molecular nature of matter and change (International edition). New York; McGraw Hill Education. 2003. ISBN:0-07-111023

6. <http://www.britannica.com/EBchecked/topic/611583/Tyndall-effect> (date: 11.29.2010)

7. Andersson, Maud (1988). "Toxicity and tolerance of aluminium in vascular plants". *Water, Air, & Soil Pollution* 39 (3–4): 439–462. <http://www.springerlink.com/content/pxp793217612t333/> (date: 12.3.2010)

8. Srivastava, A. K. & Jain, P. C. Chemistry Vol (1 and 2). New Delhi; VK Publications. 2008. ISBN: 818859783X

9. <http://www.jtbaker.com/msds/englishhtml/a2844.htm> (date: 12.8.2010)