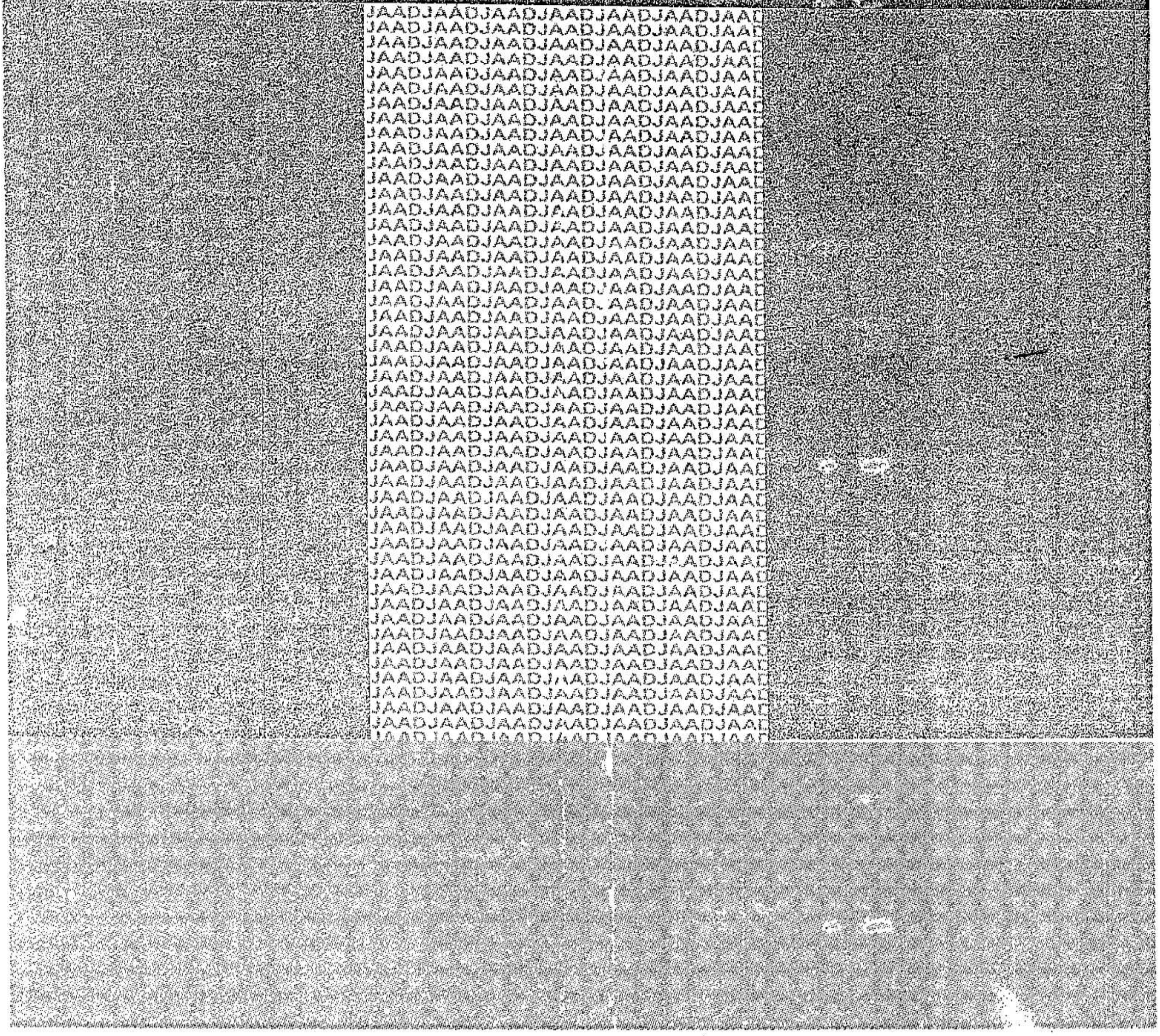
JOURNAL OF ACADEMIC ADVANCEMENT

Vol. 1, No. 1, August., 2009



A Publication of
ACADEMIC RESEARCH ASSOCIATES
Abuja, Nigeria

JAAD

JOURNAL OF ACADEMIC ADVANCEMENT

Vol.1, No. 1. August, 2009.

Published by:

ACADEMIC RESEARCH ASSOCIATES
Abuja, Nigeria

CONTENTS

ARTICLE

PAGE

REFRACTIVE INDICES OF MATERIALS: THE EFFECTS OF VOLUME AND CONCENTRATION

BY

[1]A.S OGUNGBE, [1]R.B ADEGBOLA, [1]A.M ADENUGA AND [2]O.H AKINTOYE

[1]DEPARTMENT OF PHYSICS, LAGOS STATE UNIVERSITY, OJO

[2]DEPARTMENT OF SCIENCE AND TECHNOLOGY EDUCATION, LAGOS STATE UNIVERSITY, OJO

ABSTRACT

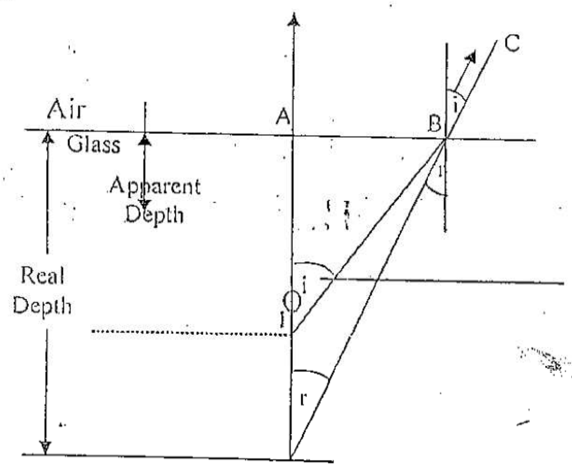
There are standard values of refractive indices of media. But a medium under conditions like change in temperature, concentration and volume will have a refractive index different from its established value. Two of these factors affecting refractive index of materials were considered. They are; concentration and volume. Experiments were performed on some liquids by the real and apparent depths method of refractive index using travelling microscope. The values of their refractive indices were observed to increase with increase in concentration. The refractive index of water was also observed to increase with increase in volume. Keywords: Refractive index, Concentration, Volume, Physical condition

INTRODUCTION

The refractive indices of various substances have been determined and the values are the standards we use for calculation. For example, the refractive indices of water, glass and air are 1.33, 1.52 and 1.0 respectively, [5]. These values are regarded as constants conventionally. However, they vary with physical conditions, such as; pressure, temperature, concentration, volume and wavelength. The examples given above correspond to a wavelength of 589nm, which is the wavelength of yellow light. This implies that if the wavelength of the source of light used in determining the refractive index differs from 589nm, the result would be different from the one obtained. The refractive index also depends on temperature. For example, water at 20°C is 1.33283, at 100°C, it is 1.31766 and at 0°C, it is 1.333346, [3].

Refraction of light causes an object submerged in a liquid of higher refractive index to appear closer to the surface than is actually the case. A thick slab of glass appears to be about two-third of its real thickness when viewed from vertical above. Similarly, water in a pond appears to be only three-quarters of its true depth, [1, 2].

METHODOLOGY: The way refractive index is related to real and apparent depths is illustrated in the figure below:



OBC is a ray very close to the normal which enters the eye from a point O at the bottom of the slab. The emergent ray BC appears to be coming from a virtual image I, so that AI is the apparent depth of the slab.

By using the principle of reversibility of light, the refractive index is given by,

$$n = \frac{\sin i}{\sin r} \quad \text{.......................(1)}$$

But, AIB = i (corresponding angles)

And, AOB = r (alternate angles)

Therefore,

$$n = \frac{\sin AIB}{\sin AOB} \quad \text{.......................(2)}$$

$$= \frac{AB}{BI} \Big/ \frac{AB}{BO}$$

$$= \frac{BO}{BI} = \frac{AO}{AI} \quad \text{where B is very close to A}$$

or,

$$n = \frac{\text{real depth}}{\text{apparent depth}} \quad \text{.......................(3)}$$

The purpose of this experiment is to determine the refractive indices of sodium chloride (NaCl) solution, Copper II Sulphate solution ($CUSO_4$), Ammonium Chloride Solution (NH_4Cl) and Sucrose ($C_{12}H_{22}O_{11}$) with varying concentrations at constant volume.

Three empty beakers were set and labeled A, B and C to prepare three salt solutions using water as solvent. The concentration was expressed as number of moles in 1 dm^3 or 1 litre of solution. One (1) mole per litre of the solution has 58.5g of NaCl (i.e. its molar mass). Thus, 58.5g of NaCl in 1 litre of water corresponds to 100% concentration of the salt solution.

Since preparing 1 litre of solution would be too large, 50ml (0.05mlitre) was prepared and the equivalent mass of NaCl was found. This still gave the same 100% concentration. If 58.5g corresponds to 1 litre of solution, then, 2.93g also corresponds to 0.05 litre of solution. Therefore, 2.93g of NaCl was weighed on the weighing balance, poured in 50ml of water and kept in a vessel. For a lower level of concentration, which is 75% concentration, since 75% of 2.93g of NaCl equals 2.2g, and then 2.2g of NaCl weighed and poured in a vessel already containing 50ml of water to dissolve. Similarly, this was done for the 50% concentration, since 50% of 2.93 of NaCl give 1.47g. The 1.47g was then weighed and poured into another vessel containing 50ml of water to dissolve. The three vessels contained 50ml solution, but with varying concentration. After preparing the three solutions, the vessels were taken one after the other to find the refractive index of the liquid in them. Some grains of fine sand were sprinkled on the bottom of beaker A. The microscope was then focused on the sand to read the vernier scale (d_1). The 100% concentration was then poured into beaker A. The microscope was raised until it was in focus with the sand in the liquid. The reading from the vernier (d_2) was recorded. A finely ground chalk was sprinkled on the surface of the solution, raised the microscope further still until the chalk on the surface was focused and the vernier (d_3) was read. The readings d_1, d_2 and d_3 were taken five times each. The same was done for beakers B and C by pouring 75% and 50% concentrations respectively.

The same procedure was used to find the refractive indices of copper II sulphate solution ($CUSO_4$), Ammonium Chloride Solution (NH_4Cl) and sucrose ($C_{12}H_{22}O_{11}$). Their molar masses are 159.6g, 53.5g and 342.0g respectively.

For the refractive indices of distilled water and drinkable water; some grains of fine sand were sprinkled in a vessel and the microscope was focused on them to read the vernier (d_1). Some water to a depth of 50ml was poured into the vessel. The microscope was then raised until the grains of sand were focused to read the vernier (d_2).Then lycopodium powder was sprinkled on the water surface, raised the microscope further until the powder was focused on the surface of the water and the vernier (d_3) was read.

The experiment was continued by increasing the volume of water to 75ml and 100ml. The readings were taken five times each.

RESULTS OF THE EXPERIMENTS

(a) RESULT OF THE REFRACTIVE INDEX OF SODIUM CHLORIDE SOLUTION

For 100% concentration (Beaker A)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
65.00	68.30	79.20	14.20	10.90	1.30
65.00	68.10	78.90	13.90	10.80	1.29
65.00	68.10	78.70	13.70	10.60	1.29
64.90	68.20	79.00	14.10	10.80	1.31
65.00	68.30	79.10	14.10	10.80	1.31

Mean Refractive Index (n) = 1.30

75% Concentration (Beaker B)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
65.00	67.60	76.50	11.50	8.90	1.39
65.00	67.50	76.40	11.40	8.90	1.28
65.00	67.50	76.30	11.40	8.80	1.30
64.90	67.60	76.60	11.70	9.00	1.30
65.00	67.80	76.70	11.40	8.90	1.28

Mean Refractive Index (n) = 1.29

50% Concentration (Beaker C)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
65.00	67.90	79.10	13.10	10.20	1.28
65.00	67.80	78.00	13.00	10.20	1.28
65.00	67.70	77.90	12.90	10.20	1.29
64.90	67.80	78.00	13.10	10.20	1.28
65.00	67.70	78.10	13.10	10.40	1.26

Mean Refractive Index (n) = 1.27

(b) RESULT OF REFRACTIVE INDEX OF COPPER SULPHATE SOLUTION

100% Concentration (Beaker A)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
104.50	108.30	116.40	11.90	8.10	1.47
104.40	107.60	116.30	11.90	8.70	1.37
104.50	107.60	116.00	11.50	8.40	1.37
104.20	107.50	116.00	11.80	8.50	1.39
104.40	108.30	116.00	11.60	7.70	1.51

Mean Refractive Index (n) = 1.42

60% Concentration (Beaker B)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
104.50	108.30	116.90	12.40	8.60	1.44
104.40	108.00	117.20	12.80	9.20	1.39
104.50	107.90	116.50	12.00	8.60	1.40
104.20	107.70	116.90	12.70	9.20	1.38
104.40	108.10	117.00	12.70	8.90	1.43

Mean Refractive Index (n) = 1.41

20% Concentration (Beaker C)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
104.50	108.30	118.40	13.90	10.10	1.38
104.40	108.20	118.10	13.70	9.90	1.38
104.50	108.40	118.40	13.90	10.00	1.39
104.20	108.10	118.30	14.10	10.20	1.38
104.40	108.40	118.40	14.00	10.00	1.40

Mean Refractive Index (n) = 1.39

(c) RESULT OF THE REFRACTIVE INDEX OF AMMONIUM CHLORIDE

100% Concentration (Beaker C)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
65.00	68.70	79.30	14.30	10.60	1.35
65.00	68.70	79.40	14.40	10.70	1.35
65.00	68.80	79.50	14.50	10.70	1.36
65.00	68.60	79.20	14.20	10.60	1.34
65.00	68.60	79.20	14.20	10.60	1.34

Mean Refractive Index (n) = 1.35

75% Concentration (Beaker B)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
65.00	68.00	78.20	13.20	10.20	1.29
65.00	68.10	78.30	13.30	10.20	1.30
65.00	68.00	78.20	13.20	10.20	1.29
65.00	67.90	78.40	13.40	10.50	1.28
65.00	68.00	78.20	13.20	10.20	1.29

Mean Refractive Index (n) = 1.29

50% Concentration (Beaker C)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
65.00	67.50	77.80	12.80	10.30	1.24
65.00	67.60	77.90	12.90	10.30	1.25
65.00	67.40	77.70	12.70	10.30	1.23
65.00	67.50	77.70	12.70	10.20	1.25
65.00	67.40	77.90	12.90	10.50	1.23

Mean Refractive Index (n) = 1.24

(d) RESULT OF THE REFRACTIVE INDEX OF SUCROSE SOLUTION

100% Concentration (Beaker A)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
64.10	67.80	77.30	13.30	9.50	1.40
64.10	67.30	77.40	13.30	10.10	1.32
64.60	67.80	76.80	12.20	9.00	1.36
64.30	67.60	77.30	13.00	9.70	1.34
64.30	67.60	77.20	12.90	9.60	1.34

Mean Refractive Index (n) = 1.35

75% Concentration (Beaker B)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
63.80	66.50	76.30	12.50	9.80	1.28
63.80	66.00	76.30	12.50	10.30	1.21
63.90	66.50	76.20	12.40	9.70	1.28
63.70	66.60	76.80	13.10	10.20	1.28
63.80	66.20	77.00	13.20	10.80	1.22

Mean Refractive Index (n) = 1.25

50% Concentration (Beaker C)

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_l$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
64.30	66.00	77.60	13.30	11.60	1.15
64.00	65.90	77.50	13.50	11.60	1.16
64.10	66.00	77.60	13.50	11.60	1.16
64.20	65.90	77.70	13.50	11.80	1.14
64.10	66.00	78.00	13.80	12.00	1.16

Mean Refractive Index (n) = 1.15

(e) RESULT OF THE REFRACTIVE INDEX OF DISTILLED WATER AT DIFFERENT VOLUME

At 50 ml

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_l$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
63.40	67.10	77.90	14.50	10.80	1.34
63.50	67.40	78.60	15.10	11.20	1.35
63.50	67.30	78.50	15.00	11.20	1.34
63.40	67.20	78.50	15 10	11.30	1.34
63.70	67.60	78.40	14.70	10.80	1.33

Mean Refractive Index (n) = 1.34

At 75 ml

Mean Refractive Index (n) = 1.36

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_l$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
63.40	68.80	83.50	20.10	14.70	1.37
63.50	68.40	83.50	20.00	15.10	1.32
63.50	69.00	83.50	20.00	14.50	1.38
63.40	68.80	83.10	19.70	14.30	1.38
63.70	68.70	83.20	19.50	14.50	1.34

At 100 ml

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_l$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
63.40	70.90	90.40	27.00	19.50	1.39
63.50	70.30	90.50	27.00	20.20	1.34
63.50	70.90	90.00	26.50	19.10	1.39
63.40	70.50	90.40	27.00	19.90	1.36
63.70	70.50	90.00	26.30	19.80	1.35

Mean Refractive Index (n) = 1.37

RESULT OF THE REFRACTIVE INDEX OF DRINKABLE WATER AT DIFFERENT VOLUME

At 50 ml

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_l$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth

102.00	107.90	125.20	23.20	17.30	1.34
101.30	107.30	124.60	23.30	17.30	1.35
102.00	107.80	124.50	22.50	16.70	1.35
102.00	108.00	124.70	22.70	-16.70	1.36
102.10	108.10	125.40	23.30	17.30	1.35

Mean Refractive Index (n) = 1.35

At 75 ml

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent Depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
102.00	106.00	116.80	14.80	10.80	1.37
101.30	105.50	115.50	14.20	10.00	1.42
102.00 -	105.70	115.70	13.70	10.00	1.37
102.00	105.50	115.50	13.50	10.00	1.35
102.10	105.80	115.80	13.70	10.00	1.37

Mean Refractive Index (n) = 1.38

At 100 m1

d_1 (mm)	d_2(mm)	d_3 (mm)	Real depth $d_3 - d_1$(mm)	Apparent depth $d_3 - d_2$ (mm)	Real depth / Apparent depth
102.00	109.90	130.50	28.50	20.60	1.38
101.30	110.00	130.20	28.90	20.20	1.43
102.00	110.10	130.50	23.50	20.40	1.40
102.00	110.00	130.60	28.70	20.60	1.39
102.10	110.10	130.60	28.50	20.60	1.38

Mean Refractive Index (n) = 1.40

DISCUSSION OF RESULTS

Sodium chloride (NaCl) is soluble in water and gave a transparent solution for its refractive index to be determined. At 100% concentration of NaCl in water, the refractive index is 1.39; at 75% concentration, it is 1.29 and 1.27 at 50% concentration. This shows that the greater the amount of solute in solvent, the denser it becomes, thus giving a higher value of refractive index.

Copper II Sulphate exists in different forms; annydrous form which is a pale green or gray white powder, while the hydrated form is a bright b'ue crystal. Copper sulphate is a desiccant i.e. it absorbs water from air. The hydrated form was used and it dissolved readily in water giving a transparent blue solution. Its refractive indices are 1.42, 1.41 and 1.39 at 100%, 60% and 20% concentrations respectively. As the concentration increases refractive index increases.

Ammonium chloride is a white powder with formula NH_4Cl. It is soluble in water and its refractive indices are 1.35, 1.29 and 1.24 for 100%, 75% and 50% concentrations respectively. Different levels of visibility were observed at different concentrations. The most visible is that of 50% concentration and is due to smaller mass of NH_4Cl in solution. Consequently, apart from concentration of the solute affecting its refractive index the visibility factor also amounts to why refractive index varied with different concentration. The 100% concentration gave the largest value because light will travel at a lower velocity in this cloudy solution before the traveling microscope can be able to focus the sand in it.

Sucrose is a sugar. It is a disaccharide with formula $C_{12}H_{22}O_{11}$ and is also soluble in water resulting in a sugar solution. The higher the sugar contents in solution, the higher its refractive index. The values of its refractive indices are 1.35, 1.25 and 1.15 at 100%, 75% and 50% concentrations respectively. Since sucrose is a sweetener, the solution with the greatest mass of sucrose will be the sweetest making the solution denser.

The refractive indices of distilled water are 1.34, 1.36 and 1.37 at 50ml, 75ml and 100ml respectively while that of drinkable water gave 1.35, 1.38 and 1.40 at 50ml, 75ml and 100ml respectively. Distillation is the process by which water is boiled, evaporated and condensed. Hence, distilled water is free of dissolved minerals like calcium, magnesium, potassium etc. The presence of these minerals in ideal water for the human body makes it denser than distilled water i.e. more concentrated. Distilled water is extremely soft; therefore, light travels faster in it. The refractive index of water at different volumes also changes. The result gives us a relationship between refractive index and volume. It is obvious that the refractive index increases as the volume increases. As the depth continues to increase, the refractive index increases until light can no longer travel through liquid. This explains why beneath oceans of great depth is very dark.

Some errors were encounter in the process of carrying out these experiments; error due to focusing, parallax, and random error. Hence readings were taken five times each and the mean taken to give more accurate results. The traveling microscope was placed in position to minimize the error due to focusing and inadequate illumination.

CONCLUSION

The refractive index of a medium is a very important property of any optical system. It has been discovered that standard value of refractive index of a substance is subject to change due to variability of concentration and volume.

Consequently, a particular substance can be identified; its purity can be confirmed, its concentration can be known e.t.c because refractive index was found to vary directly with concentration and volume. Though refractive index is expressed as a unit-less number, it provides a lot of information about the physical and chemical properties of a material.

REFERENCES

[1] Abbott, A.F (1987) *Ordinary Level Physics*, 4th Edition pp 252-258

[2] Armitage, E (1981) *Practical Physics in S.i Units* pp 82-86

[3] Frank, K. B (1986) *Principles of Physics, 2nd Edition* pp 152-166

[4] Graham, C.H and John, S.H (1982) *Chemistry in context, 2nd Edition* pp 110-125

[5] Nelkon and Parker (1982) *Advanced Level Physics, 5th Edition* pp 326-338

[6] Tonej (1994) "*Your drinking water: How good is it?*" National Testing Laboratories Inc., Ohio.