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Study the Effect of the Sugar Solutions on the Rotation of the Plane of Polarization

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Abstract:

This paper deals with studying the effect of the polarization properties of sucrose solution (sugar which is dissolved in distilled water) as an active material and proves the ability of this solution to rotate the plane of polarized light that passes through it with an angle (θ) which is called the angle of rotation.Angle of rotation depends on the molecular structure, the concentration of the dissolved substance, the path length of the light that passes through the solution,and the light wavelength. The method of measuring the transmitted power and angle of rotation is called “optical activity”. Two types of light source are used. The first one was the xenon lamp and chooses three color from it (red, green, and blue) using the proper filters, and the second source was He-Ne laser of wavelength 632nm. In each case, the rotation angle and transmitted power were measured and the specific angle of rotation was calculated at different concentrations of the solution.

The benefit of this work, as an optical laboratory application to measure optical properties of various materials, including circular birefringence (optical rotation). It has been found that the effect of polarized solution on the rotation angles was very large for blue light when comparing with red, because of these measured angles depends on increasing polarized solution concentrations and due to the short wavelength of blue light with respect to green and red lights.

Introduction

Polarization is a property of waves that describes the orientation of their oscillations. For transvers, it describes the orientation of the oscillations in the plane perpendicular to the wave’s direction of travel. Longitudinal waves such as sound wave in liquids do not exhibit polarization, because for these waves the direction of oscillation is by definition along the direction of travel. Light is an electromagnetic wave, there are always vectors, the electric vector $\bar{E}$and the magnetic vector$\bar{B}$, coexisting in the propagation of the light. The vibrations of a light wave are a varying electric field E and varying magnetic field B which are perpendicular to each other and which have the same frequency. Each of these fields is perpendicular to the direction of travel of the wave. In polarization, we always define the direction of polarization of an E.M wave to be the direction of the electric field vector$\bar{E}$ not the magnetic field [1].

There are several types of the polarization in light such as; Plane-polarized or linear polarize, the wave is linearly polarized when the electric field vectors at any fixed point are oscillates along a line perpendicular to the wave propagation, that means the two components of the electric field E_x and E_y are in phase[2].

Circular polarized, the electric field vector of circularly polarized light sweeps out a circle during each cycle of the wave. The magnitude of the electric field vector remains constant throughout each cycle, but its direction is continuously changing, this mean that the E_x and $E_y$components of the electric field are one quarter wave, or (90^o) out of phase[3].

Elliptical polarization, in this case the electric field vector can be decomposed into component E_x and E_y, where $E_x \neq E_y$and there are a constant phase shift between them, the resultant E-vector describes an ellipse[2].

Most of sources of light emit waves whose planes of polarization vary randomly with time. A wave of this type is said to be unpolarized because over any interval of time its plane of polarization does not favor any one of the possible directions more than any other [3].

There are several methods to polarize the light such as polarization by: absorption, reflection, scattering, and birefringence.

Polarizer:

A polarizer is a device that converts an unpolarized or mixed-polarization beam of electromagnetic waves (e.g. light) into a beam with a single polarization state (usually, a single linear polarization). Polarizer is a thin transparent film made of sheets of plastic (or other materials) containing minute double refracting crystal aligned with their axis parallel. Polarizers can be divided into two general categories:

Beam-splitting polarizer, where the unpolarized beam is split into two beams with opposite polarization states [4].

Absorptive polarizers, where the unwanted polarization states are absorbed by the device. Polarizer will effect on the irradiance and direction of polarization when light passing through the filter, therefore the resulting direction of polarization will be the direction of the polarizer’s transmission axis and the transmitted irradiance will be less than the incident irradiance. The relationship between the irradiance of the incident and transmitted light for a polarizing material is known as Malu’s law [3].

$I = I_o cos^2 \theta$ --------- (1)

where

I is the transmitted irradiance,

I_o is the incident irradiance, and

θ is the polarized angle.

Polarimetry:

Polarimetry is the measurement of the polarization of light. It can be used to measure various optical properties of material, including circular birefringence (optical rotation). A polarimeter to measure this rotation consists of a long tube with flat glass end, into which the sample is placed, at each end of the tube is polarizer are placed, light is pass through the tube, and the polarizer at the other end, attached to an eye piece, is rotated until all light is shut off. The angle of rotation is then read off a scale. The specific rotation of the sample may then be calculated [1].

Optical Activity:

It is the rotation of linearly polarized light as it travels through materials. It appears in solutions of chiral molecules such as sucrose (sugar), solid with rotated crystal planes such as quartz, and spin-polarized gases of atoms or molecules. Chirality is the property of an object of being non-superimposable on its mirror image. Materials with these properties are said to have optical activity and consist of chiral molecules. Chiral centers that have opposite configurations rotate polarized light the same number of degrees, but in opposite directions. Linearly polarized light which enters the solution can be decomposed into a right-circularly and left- circularly polarized partial wave propagate at different phase velocity so that a phase difference arises, which is proportional to the distance covered. After the two partial waves have covered this distance, their superposition results in a linearly polarized wave whose direction of polarization is rotated relative to the original wave. The angle of rotation depends on the molecular structure, the concentration of the dissolved substance, on the path length of the light that pass through the solution and on the wavelength of the light. The observed rotation angle is converted to a specific rotation by using the following formula [5, 6].

$$\varnothing = \Theta / (L \times C) \quad \text{------------} \ (2)$$

where

$\varnothing$ is the specific rotation angle,

Θ is the observed rotation angle in degree,

L is the length of the sample tube, and

C is the concentration of the solution (g/ml).

Experimental Work and Results:

In this work, there are two experimental setups. These are illustrated in figure 1a and b. The first one is constructed from xenon lamp as light source, set of filters(red, blue, and green), polarizer, glass cuvette with dimensions of (15,15,15) cm as the sugar solution container, analyzer, lens, power meter, and observing screen. But the other one consists of He-Ne laser as light source, polarizer, and glass cuvette with sugar solution, analyzer, screen, and power meter.

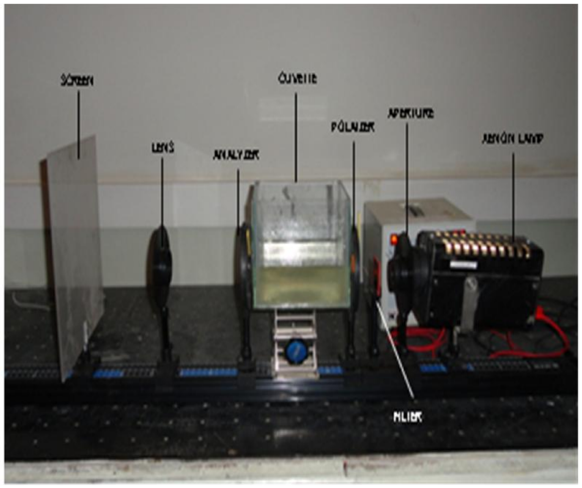

Figure 1(a) First experimental setup with xenon lamp.

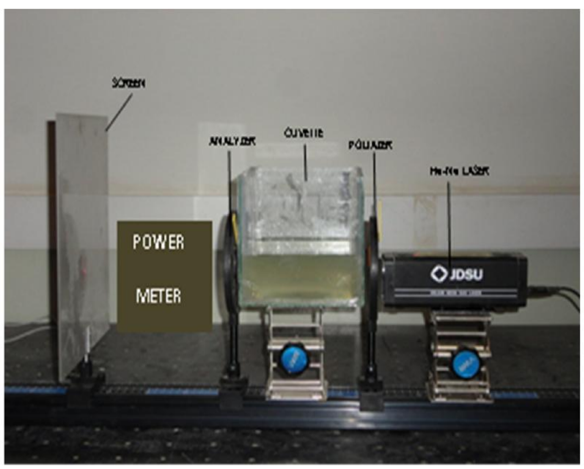

Figure 1(b) Second experimental setup with laser beam.

This experimental setup was built as follows:

1- Rotation of the plane polarization with sugar solution using Xenon lamp, the analyzer is oriented 90^o to the polarizer (analyzer is set to zero) so that no light reaches the observing screen. When an optically active substance (water with sugar) is present, it rotates the polarization of the light and there is no light reach at the screen until rotated the analyzer so that the light is observing in the screen.Three filters are used (red, green, and blue) to show how the rotation angle of the plane polarization of the light change according to the wavelength. Insert the red, green, and blue light filter respectively in the picture slider in front of the aperture of the xenon lamp housing, and adjust maximum darkness in the observing screen with the analyzer, take the position of the analyzer down as the angle of rotation of the solution for all lights.

2- In the setup of laser source, the analyzer was rotated to get equally laser power on the two sides, front view and rear view, and then the cuvette was filled with different concentrations of sugar solution. The analyzer adjusts to get the new laser power (maximum laser power) and measured the analyzer angle.

3- The observed rotation angle (analyzer angle) for different concentration of the sugar solution for (red, green, and blue)light and He-Ne laser were measured as shown in figure 2.

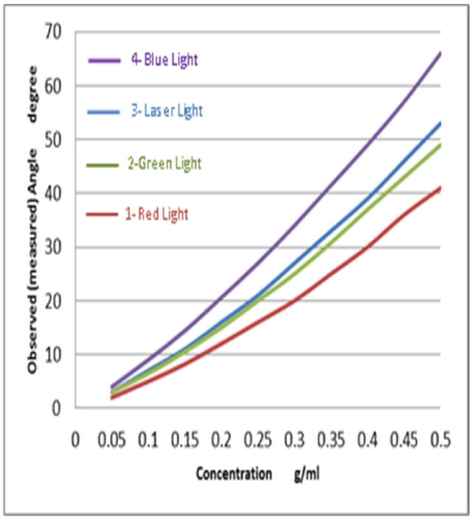

Figure 2: Observed Angle verses concentration at different light sources

4- The specific angle of rotation for different concentrations of sugar solution of xenon lamp and He-Ne laser were calculated using (eq. 2). Results are shown in figure 3.

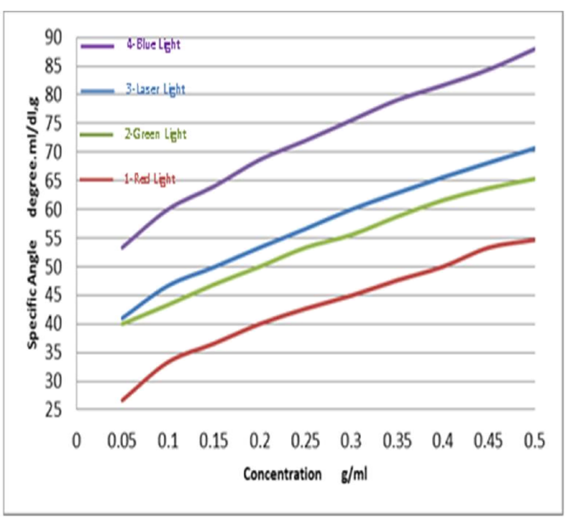

Figure 3: Specific Angle verses concentration at different light sources

5- The transmitted power of the red, green, blue lights and He-Ne laser which was passing through the glass cuvette of sugar solution was measured. Results are shown in figures 4.

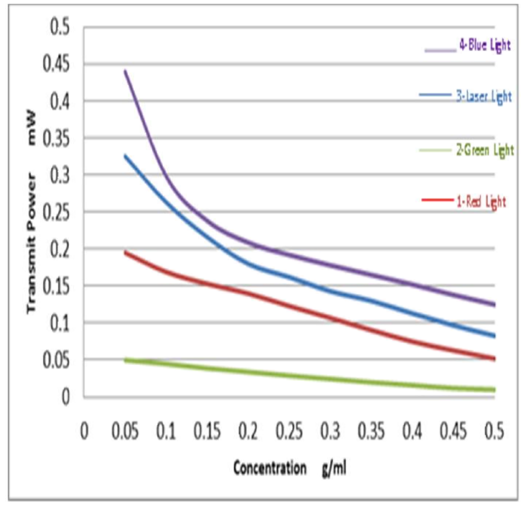

Figure 4: Transmitted power verses concentration at different light sources

Conclusion:

1. In distill water contained sugar; the attenuation in output power would be occurred according to absorption coefficient of sugar particles dissolved in water.
2. The variation of measured rotating angles depends on very important parameter which it's called optical path length. This parameter affected by changing in the polarized solution which it's also affected by the variation of the absorption coefficients for different light wavelengths.
3. The specific angle of He-Ne laser is larger than of red light although that two lights have the same wavelength because of the absorption coefficients of He-Ne laser is smaller than of red light that mean the transmit power of

laser larger than of red light. These behaviors obey to the relation between the specific angles and transmit power according to eq(1).

4. The advantages of method in this work, is easy in design, cheap in price, and taken short time to convert unpolarized light to polarize.

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دراسة تأثير محلول السكر في تدوير مستوى الأستقطاب

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الخلاصة:

يختص هذا البحث بدراسة تأثير الخواص البصرية لمحلول السكروز (السكر المذاب في الماء المقطر) والذي يعتبر كمادة نشطة بصريا وأثبات قابلية هذا المحلول في تدوير مستوى الضوء المستقطب الذي يمر فيه بزاوية (θ) والتي تسمى بزاوية الدوران. تعتمد زاوية الدوران على التركيب الجزيئي والتركيز للمادة المذابة في الماءوطول المسار الذي يسلكه الضوء في المحلول وكذلك على الطول الموجي للضوء المار خلال المحلول. تسمى الطريقة المستخدمة لقياس القدرة النافذة وزاوية الدوران بالنشاط البصري.وتم استخدام مصدرين مختليفين للضوء. الأول هو مصباح الزينون ومعه ثلاثة مرشحات (الأحمر , الأخضر و الأزرق) والمصدر الثاني هو الهيليوم – نيون ليزر ذو الطول الموجي 632 نانومتر.لكلا المصدرين تم قياس الزاوية وقدرة الضوء النافذة,ومنه تم حساب زاويةالدوران خلال مرور الضوء عبر عدة تراكيز مختلفة لمحلول السكر.

أن الفائدة من هذا البحث هو التطبيقات المختبرية البصرية لقياس الخواص البصرية للمواد المختلفة والذي تتضمن الدوران البصري. حيث وجد أن تأثير المادة المستقطبة على زوايا الدوران كان كبيرا جدا في الضوء الأزرق عند مقارنته مع الضوء الأحمر وذلك لأن الزوايا المقاسة تعتمد على زيادة تركيز المادة المستقطبة وقصر الطول الموجي للضوء الأزرق بالنسبة الى الطول الموجي للضوئين الأخضر والأحمر.