DISPERSION OF THE VISIBLE ROTATORY POWER FOR AQUEOUS GLUCOSE SOLUTIONS

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In order to determine the dispersion of the visible rotatory power of glucose aqueous solutions, the method of channeled spectra was applied. The channeled spectra were recorded with a spectrophotometer to which a device consisting from two crossed polarizers having a cell containing active solution between them has been attached in the measure beam.

The visible rotatory birefringence of glucose solution is about [1.3 – 2.75]10^{-6} and the dispersive parameter varies in the range [1.8 – 3.0]10^{-8}. The specific rotation of aqueous glucose solution varies in the visible range with about 100 degrees/ dm, decreasing from blue to red.

Keywords: channeled spectra, rotatory dispersion, glucose solution, optical rotatory birefringence.

1. Introduction

The most common optical materials are isotropic, preserving the light polarization state. However, there are important classes of materials classified as birefringent or optically active, in which the light polarization is modified in the propagation process.

Optical activity is the phenomenon of turning the polarization plane around the direction of motion as the light travels through certain materials such as solutions of chiral molecules (sugars, amino-acids, enzymes, Penicillin, Ibuprofen, DNA, etc.), crystalline solids (quartz), or spin-polarized gases of atoms or molecules [1]. The chiral molecule exhibits optical activity either in solution or in its natural form. The optically active substances can be dextrorotatory or levorotatory as the rotation is to the right or left. The degree of rotation depends on the light wavelength, the path way length and the properties of the material (e.g. specific rotation and concentration).

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Optical activity is linked to the intramolecular chiral conformation of the glucose molecules at the air/liquid interface [2]. Glucose and sugars in general play a central role in many scientific fields including chemistry, biology, medicine (besides, several attempts have been made to use it to diagnose diabetic diseases), pharmaceutics, as well as in the food industry (glucose optical activity is used to evaluate the quality and the concentration of syrup in the food industry) [3].

Like most of the molecules of biological interest, glucose is a chiral molecule and thus its presence or its concentration could be detected via optical activity either in solution or in its natural form [4]. The optical activity can sometimes be modified by the interaction with other molecules or with the environment [5].

Glucose is a monosaccharide with formula $C_6H_{12}O_6$, whose five hydroxyl (OH) groups are arranged in a specific way along six carbon atoms. In nature, glucose is made during photosynthesis from water and carbon dioxide, using energy from sunlight. Glucose is stored as a polymer, in plants as starch and in animals as glycogen. Glucose is the primary source of energy in most organisms, from bacteria to human, through aerobic respiration, anaerobic respiration, or fermentation. Organisms use also glucose as a precursor for the synthesis of several important substances, such as cellulose or chitin, or to be added onto certain protein and lipids on a process called glycosylation [6].

Glucose is easily soluble in water (and in several other solvents). Whether in water or in the solid form, glucose is optically active, due to its molecular chirality: D-glucose is dextrorotatory, while the mirror-image isomer, L-glucose, is levorotatory.

Usually, the optical rotation is measured with a polarimeter, by using monochromatic light with the wavelength of 589 nm (the sodium D line). For example, the value measured in these conditions for D-glucose is + 52.7 deg/dm [7]. Here, we use a method to determine the optical rotatory dispersion of glucose, which allows evaluation the specific rotation for the entire visible spectrum in a fast way. The method consists in the recording of the channeled spectrum of a transparent layer of glucose solution. Channeled spectrum is a succession of maxima and minima of the flux density resulting from the phase difference introduced between light circularly polarized to right and to left components propagating with different velocities [8]. The method devoted to estimation of optical rotatory dispersion was previously validated for anisotropic polymer foils [9] thin layers of liquid crystals or quartz [10,11] to determine the linear birefringence, being later extended to polymer solutions [12,13] for the estimation of optical rotatory dispersion.

2. Theoretical Background

The transparent optically active glucose solution changes the azimuth angle (angle between the initial orientation of the electric field intensity and its orientation at a given moment) with a quantity which is dependent on the specific rotation [θ], the solution concentration C, and the thickness L of the layer measured along the light traveling direction:

$$\theta = [\theta]CL \quad (1)$$

The specific rotation of the glucose solution depends on the radiation wavelength λ_0 and on the rotatory birefringence Δn_c:

$$[\theta] = \frac{\pi}{\lambda_0}\Delta n_c \quad (2)$$

The rotatory birefringence is defined as the difference between the refractive indices of the solution for left-handed (n_l) and right-handed (n_r) circularly polarized radiations:

$$\Delta n_c = n_l - n_r \quad (3)$$

The optical rotatory birefringence is a dispersive parameter. The specific rotation is also a dispersive parameter, depending on the light wavelength both directly, through the factor $1/\lambda_0$, and indirectly through the optical rotatory birefringence.

The method of channeled spectrum permits the determination of circular birefringence and its dispersion in a large spectral range for which the solution is transparent. Thus, when the polarization plane does not change, or it rotates with an integer number of π, the radiation remains with its electric field perpendicular to the transmission direction of the second polarizer cannot pass through it. Consequently, the flux density measured after of the second polarizer is null. On the other hand, when the polarization plane rotates with an odd number of $\pi/2$, the electric field becomes parallel to the transmission direction of the second polarizer and pass with highest intensity, determining the maxima in the channeled spectrum. The transmission factor of the device (defined as the ratio between the light flux measured after of the second polarizer and the light flux at the entrance of the solution cell) can be written as
[14-16]:

$$T = sin^2 \frac{\pi}{\lambda_0}\Delta n_c CL \quad (4)$$

When the visible radiation source illuminates the solution cell, the light emerging from it has component with different degrees of rotation and channeled spectrum like that one illustrated in figure1 is obtained.

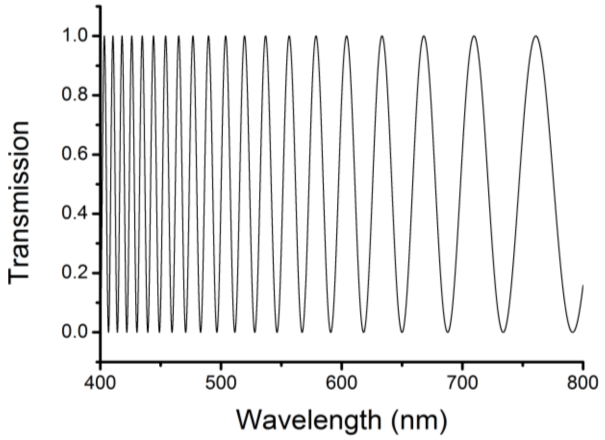

Fig. 1. Channeled spectrum of aqueous glucose solutions (30% concentration).

The values of the wavelengths in the maxima $\lambda_{k+1/2}$ and minima λ_k of the channeled spectrum are used to determine the rotatory birefringence Δn_c at a given wavelength and its dispersion, expressed by the non-dimensional parameter δ (variation of $\Delta n_c$from a channel of order k to the neighbor maximum of order k + *1/2*, situated towards lower wavelengths in the visible range). The formulas were previously established [17]:

$$\Delta n_c = \frac{1}{2L}\frac{\lambda_{k+1/2}(\lambda_k - \lambda_{k+1})}{\lambda_{k+1} - 2\lambda_{k+1/2} + \lambda_k}, \tag{5a}$$

$$\delta = \frac{1}{2L}\frac{2\lambda_{k+1}\lambda_k - \lambda_{k+1/2}(\lambda_{k+1} - \lambda_k)}{\lambda_{k+1} - 2\lambda_{k+1/2} - \lambda_k}. \tag{5b}$$

These formulas are efficient for materials with small values of the dispersive parameter. They allow estimating the rotatory birefringence and its dispersion by using the wavelengths of two consecutive minima and the maximum between them, or two consecutive maxima and the minimum between them, respectively, from the channeled spectrum.

3. Results and Discussion

The channeled spectrum of glucose in water (30% concentration), kept in a cell with fixed thickness (*L=1 dm*) is shown in figure 1. The number of channels in the spectrum depends on the glucose concentration in solution. The values of the rotatory birefringence Δn_c, dispersive parameter $\delta$and specific rotation [θ] are given in table 1 and plotted in figures 2, 3and 4, respectively, as a function of wavelength, for the glucose solution in water (30% concentration).

From figure 2 and figure 4 it results a decrease of both rotatory birefringence and specific rotation with increasing the light wavelength for glucose solution in water. The obtained values for the rotatory birefringence are in good agreement with the previously reported ones. The dispersive parameter is not a characteristic of the glucose solution. A cell of 1dm full with 30% solution of glucose determines the rotation angles resulting from figure 4 for each visible component of light. The dependence of the dispersive parameter on the light wavelength figure 3 demonstrates that the initial supposition about its constant value is not valid in the visible range for the aqueous glucose solution and observed a linear dependence of the dispersive parameter on the wavelength. Anyway because of the values of the dispersive parameter δ are approximately 100 times smaller than the rotatory birefringence Δn_c one can consider that the obtained results have enough precision.

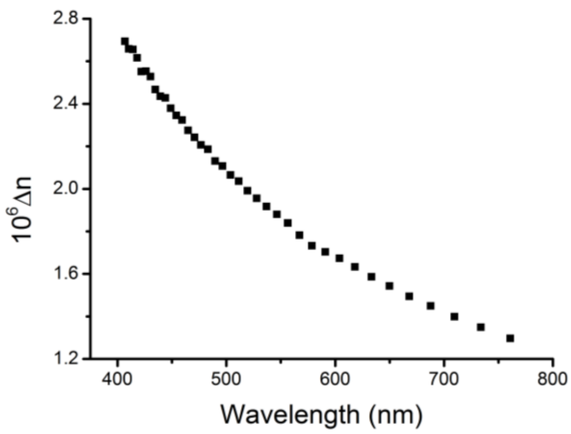

Fig. 2. Rotatory birefringence of aqueous glucose solutions (30% concentration) function of light wavelength.

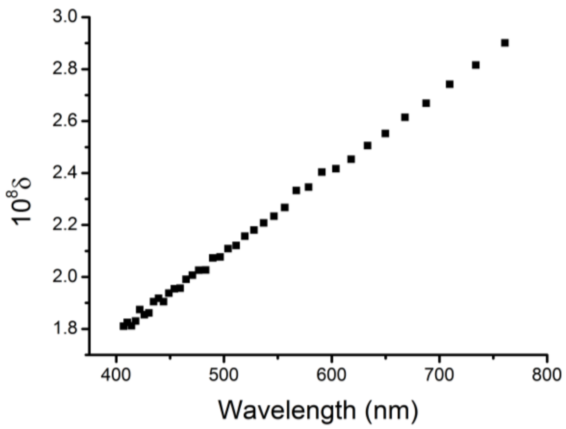

Fig. 3. Dispersive parameter for aqueous glucose solutions (30% concentration) function of light wavelength.

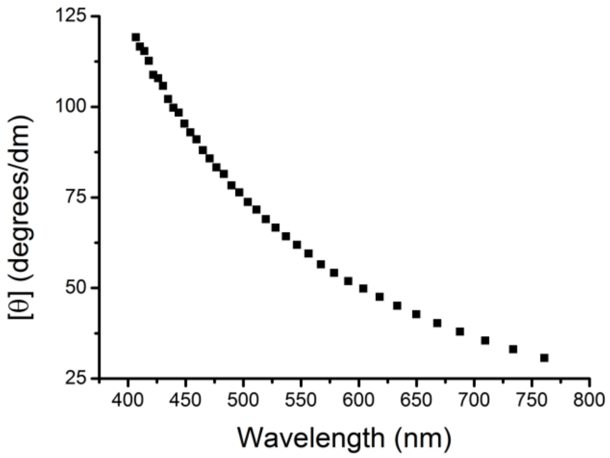

Fig.4.Specific rotation of aqueous glucose solutions (30% concentration) function of light wavelength.

4. Conclusions

The method of channeled spectrum was applied here to estimate the rotatory birefringence and specific rotation of glucose solution in water. This method has the advantage that permits measurements over the entire visible range in a fast way, by performing only one experiment. Both parameters, the rotatory birefringence and specific rotation of the glucose solution in water, decrease with the increasing of the light wavelength.

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