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# Measurements of Dielectric Constant of Distilled Water under a Static Magnetic Field

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**Abstract**
Optical constants such as refractive index, absorption coefficient, extinction coefficient and the real ($\varepsilon r$) and imaginary ($\varepsilon i$) components of the dielectric constant for distilled water under a static magnetic field (75mT) were determined from the Infrared, Visible and UV optical transmission data. Results have shown the effect of magnetic field on the physical and chemical properties of liquid water. These effects were attributing to the proton of the hydrogen.

**Keywords:** Optical Transmission Method, Refractive Index (n), Extinction Coefficient (k), Magnetic Field, Dielectric Constant, Distilled Water

## 1. Introduction

Visible light is a part of the electromagnetic spectrum with wavelengths (~ 700-400nm) and lies just to the left of the red end of the visible light spectrum and the x-ray portion. The wavelengths of Infrared waves range from (1000 – 0.7 µm) [1]. The wavelengths of ultraviolet waves range from (400~100 nm) [2]. Infrared, Visible and Ultraviolet light are important tools for the characterization of optical constants (reflectivity, absorption, and transmission, extinction coefficient, index of refraction) of materials. Absorption technique is based on measuring the amount of light absorbed by a liquid, a solid, or a gas sample at a given wavelength [3].

The effect of magnetic field on the physical and chemical properties of liquid water was reported in numerous papers. Some studies findings suggested that such an approach should improve cooling and power generation efficiency in industry [4]. Others have suggested that the surface tension of water should be considered as a reliable indicator for studying the effects of magnetic field on water [5]. Other works have showed that applying a static magnetic field on liquid water increases the evaporation rate of water [6]. Other studies have suggested that magnetic fields change the distribution of molecules, causes displacements and polarization of molecules, influences the hydrogen bond, structure of water, and should attribute to symmetric and antisymmetric stretching vibration of HO [7-9]. It can be stated that the effect of static field on the optical properties of liquid water remains under debate topic.

This study is an attempt to understand the effect of static magnetic field on distilled water. The measurements were carried out for the optical constants of distilled water under static magnetic field, such as the dielectric constant (the real ($\varepsilon r$) and imaginary ($\varepsilon i$)) components, absorption coefficients, and the extinction coefficients. The absorption coefficient is defined as the rate of decrease in the intensity of electromagnetic radiation (as light) as it passes through a given substance; the fraction of incident radiant energy absorbed per unit mass or thickness of an absorber [10-11]. The extinction coefficient is a measure of the damping of the electromagnetic wave (as light) as it passes into a medium or the net loss, or attenuation, of light through a material [12-14].

### 1.1 Theory of Optical Properties

The most important description of the amount of radiation penetration into the material is the Linear Attenuation Coefficient, which is a quantity that depends on the energy of the incident photon and the atomic number of the material. This quantity represents a fraction of the energy lost from the incident photon for every 1cm penetrated through the material. The unit of linear absorption coefficient µ is $cm^{-1}$. However, the fundamental mechanism of quantitative analysis in optical (absorption or transmission) methods is the Lambert Beer's law. According to Lambert –Beer's law [15-20], when a narrow photon beam of single energy $h\upsilon_0$ and a flux density $I_0$ (the number of photons per unit area and t time) falls on a homogeneous medium and penetrates it a distance (x), the flux density of the transmitted photon beam from this medium is I and is given as:

$$I(x) = I_0 e^{-\mu X} \quad (1)$$

Applying to liquids or solutions, Lambert-Beer's law states that the amount of radiation of infrared, visible, and ultraviolet light, transmitted or absorbed by a solution is an exponent function of substance concentration and solution thickness [21]. Therefore, measurement of the amount absorption and transmission by a solution allows for the determination of electric constants, such as the absorption coefficient (α), the extinction coefficient (k), and the real and imaginary part of the dielectric constant (ε′ and ε′′) of the solution. In this paper, we report the optical and electrical properties of salt water (%) from the UV Optical transmission data.

The optical property of a transmitting medium is presented as the complex dielectric constant and is given as:

$$\varepsilon = \varepsilon' + \varepsilon'' \quad (2)$$

Where ε′ is the real part and ε′′ is the imaginary part of the dielectric constant of the medium. Both parameters are calculated by the flowing formulas [22]:

$$\varepsilon' = n^2 - k^2 \quad (3)$$

$$\varepsilon'' = 2nk \quad (4)$$

Where n is the refractive index, *n* is related to the velocity of propagation of an electromagnetic wave through the medium. K is the extinction coefficient which is related to the loss of wave energy of the incident electric field to the medium. Therefore, the optical properties of the medium are governed by the interaction of the electric field of the electromagnetic wave and the medium.

The refractive index (n) is related to the transmittance (T) in the medium through the relation [23]:

$$n = \frac{1}{T} + \sqrt{\frac{1}{T^2} - 1} \quad (5)$$

Transmittance is defined as $(\frac{I}{I_0})$, where $I_0$ is intensity of light entering the sample and I is intensity of light emerging from the medium. The absorption coefficient (α) is defined as the ratio of the incident intensity of electromagnetic waves per unit length in the direction of wave propagation in the medium and is related to the absorbance (A) and the thickness of the medium (d) as [24]:

$$\alpha = \frac{2.303A}{d} \quad (6)$$

The absorbance (A) is proportional to concentration of absorbing medium compound and is given as [25]:

$$A = -\log T \quad (7)$$

It can be seen from the relation (6) that the amount of radiation of visible light that is absorbed by a medium (solution), is proportional to the concentration and inversely to the thickness of the medium. On the other hand, the absorption coefficient (α) is related to the extinction coefficient (K) and the wavelength (λ) of the incident photons through the relation [26]:

$$\alpha = \frac{4\pi K}{\lambda} \quad (8)$$

The relation (8) states that the absorption coefficient (α) also depends on solvent, the molecular structure, temperature and the incident wavelength

## 2. Materials and methods

In considering optical methods for measurement of light absorption and transmission in distilled water under the action of static magnetic field (75mT), one is faced with improving existing equipment. In this spectroscopy method, the spectrometer consists of light source, visible light, light filter, yellow with maximum transparency wavelength (580 nm), UV filter with maximum transparency wavelength (366 nm), infrared filter for wavelengths between approx. 930nm and 3200nm, quartz cuvette, ammeter, power supply, photocell, and a permanent magnet. Distilled water was heated to boiling temperature in order to release dissolved gases. Figure1 shows the main units of the optical system.

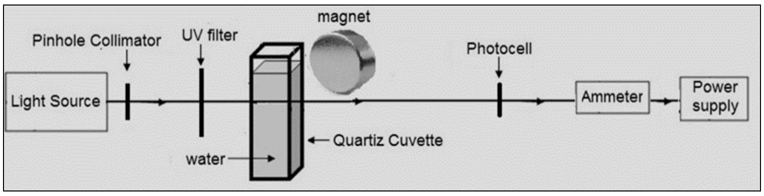


**Fig.1:** The experimental set-up

## 3. Results and discussion

Table1 presents the optical data obtained for distilled water after heating at $100^0$C under the action of a static magnetic field (75mT) as a function of exposure time using visible light (550 nm). It can be seen from table1 that the relative refractive index increases with exposure time to static magnetic field. The same applies for the real and imaginary parts of the dielectric constant. Figure2 shows the linear relation between the real and imaginary parts of the dielectric constant

**Table1**: Optical data for distilled water under a static magnetic field (75mT), Using visible light with an average wavelength (550nm)

| Exposure Time(min) | Refractive index | Absorption coefficient $\alpha$ ($10^{-4}$) | Extinction coefficient k ($10^{-9}$) | Dielectric constant (ε') real part | Dielectric constant imaginary part (ε'') ($10^{-9}$) |
|---|---|---|---|---|---|
| 5 | 1.877686 | 184.24 | 0.806783 | 3.525705 | 3.029772 |
| 10 | 1.877686 | 184.24 | 0.806783 | 3.525705 | 3.029772 |
| 15 | 2.053588 | 230.3 | 1.008479 | 4.217223 | 4.142002 |
| 20 | 2.053588 | 230.3 | 1.008479 | 4.217223 | 4.142002 |
| 25 | 2.191667 | 264.845 | 1.159751 | 4.803109 | 5.08342 |
| 30 | 2.144886 | 253.33 | 1.109327 | 4.600535 | 4.758761 |

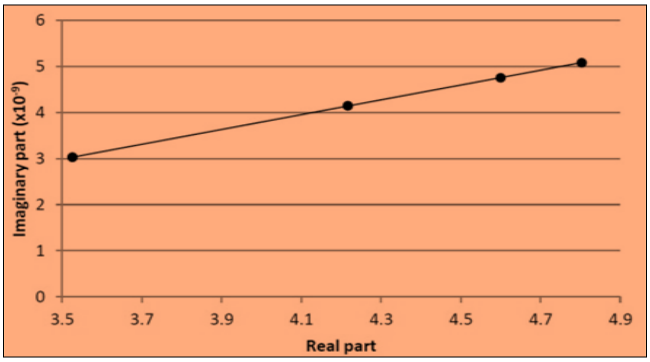


**Fig 2**: The real and imaginary parts of the dielectric constant as a function of magnetic field exposure time

It can be seen from figure2; that the dielectric constant real (ε') and imaginary (ε'') are linear. The effect of static magnetic field on water results in a drop in dielectric constant of water (~80) to lower values (3-5).

**Table 2**: Optical data for distilled water under a static magnetic field (75mT), Using light filter, yellow with maximum transparency wavelength (580 nm)

| Exposure Time(min) | Refractive index | Absorption coefficient $\alpha$ ($10^{-4}$) | Extinction coefficient k ($10^{-9}$) | Dielectric constant (ε') real part | Dielectric constant imaginary part (ε'') ($10^{-9}$) |
|---|---|---|---|---|---|
| 5 | 1.989051 | 172.725 | 0.797615 | 3.956324 | 3.172996 |
| 10 | 1.989051 | 172.725 | 0.797615 | 3.956324 | 3.172996 |
| 15 | 2.157105 | 207.274 | 0.957139 | 4.653104 | 4.129298 |
| 20 | 2.215 25 | 218.785 | 1.010313 | 4.907334 | 4.476192 |
| 25 | 2.335454 | 241.815 | 1.116662 | 5.454346 | 5.215824 |
| 30 | 2.335454 | 241.815 | 1.116662 | 5.454346 | 5.215824 |

Figure 3 shows the linear relation between the absorption coefficient and extinction coefficient of water as a function of magnetic field exposure time.

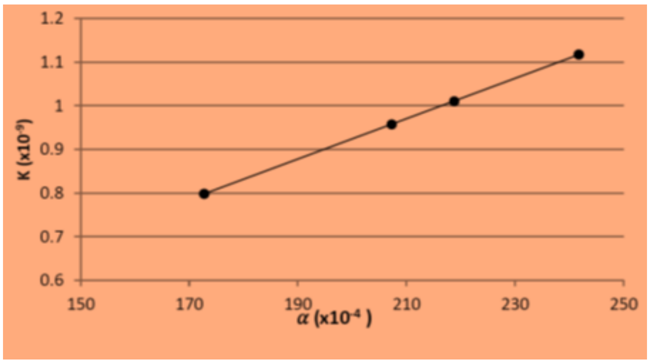


**Fig 3:** The absorption coefficient and extinction coefficient of distilled water as a function of magnetic field exposure time

Table 3 presents the optical data obtained for distilled water under the action of a static magnetic field (75mT) as a function of exposure time using ultraviolet filter, with maximum transparency wavelength (366 nm).

**Table 3**: Optical data for distilled water under a static magnetic field (75mT), using ultraviolet filter, with maximum transparency wavelength (366 nm)

| Exposure Time(min) | Refractive index | Absorption coefficient $\alpha$ ($10^{-4}$) | Extinction coefficient k ($10^{-9}$) | Dielectric constant (ε') real part | Dielectric constant imaginary part (ε'') ($10^{-9}$) |
|---|---|---|---|---|---|
| 5 | 2.195734 | 161.21 | 0.469768 | 4.821249 | 2.062971 |
| 10 | 2.195734 | 161.21 | 0.469768 | 4.821249 | 2.062971 |
| 15 | 2.356048 | 184.24 | 0.536878 | 5.550964 | 2.529824 |
| 20 | 2.527416 | 207.27 | 0.603987 | 6.387831 | 3.053055 |
| 25 | 2.618034 | 218.79 | 0.637542 | 6.854102 | 3.338215 |
| 30 | 2.527416 | 207.27 | 0.603987 | 6.387831 | 3.053055 |

Figure 4 shows the linear relation between the real and imaginary parts of the dielectric constant for distilled water under the action of a static magnetic field (75mT) as a function of exposure time using ultraviolet filter, with maximum transparency wavelength (366 nm).

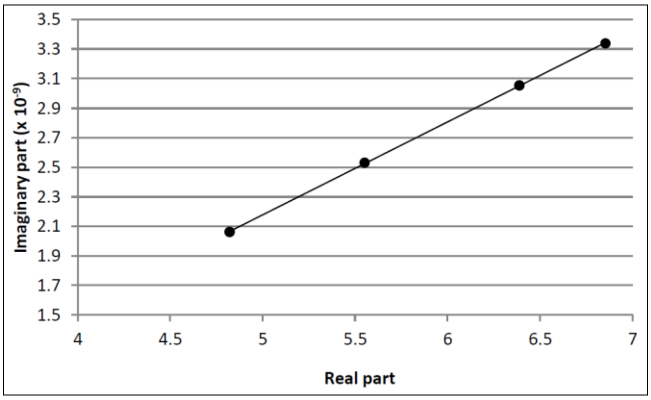


**Fig 4:** The real and imaginary parts of the dielectric constant of water as a function of magnetic field exposure time, using ultraviolet light

**Table 4:** Optical data for distilled water under a static magnetic field (75mT), using infrared filter for wavelengths between approx. (930nm and 3200nm)

| Exposure Time(min) | Refractive index | Absorption coefficient $\alpha$ ($10^{-4}$) | Extinction coefficient k ($10^{-9}$) | Dielectric constant (ε') real part | Dielectric constant imaginary part (ε'') ($10^{-9}$) |
|---|---|---|---|---|---|
| 5 | 2.064684 | 161.21 | 2.650467 | 2.064684 | 10.94475 |
| 10 | 2.130662 | 172.73 | 2.839786 | 2.130662 | 12.10125 |
| 15 | 2.267275 | 195.76 | 3.218424 | 2.267275 | 14.59411 |
| 20 | 2.338296 | 207.27 | 3.407743 | 2.338296 | 15.93662 |
| 25 | 2.411388 | 218.79 | 3.597062 | 2.411388 | 17.34783 |
| 30 | 2.338296 | 207.27 | 3.407743 | 2.338296 | 15.93662 |

Figure5 shows the linear relation between the absorption coefficient and extinction coefficient of distilled water as a function of magnetic field (75mT) exposure time, using infrared filter for wavelengths between approx. (930nm and 3200nm)

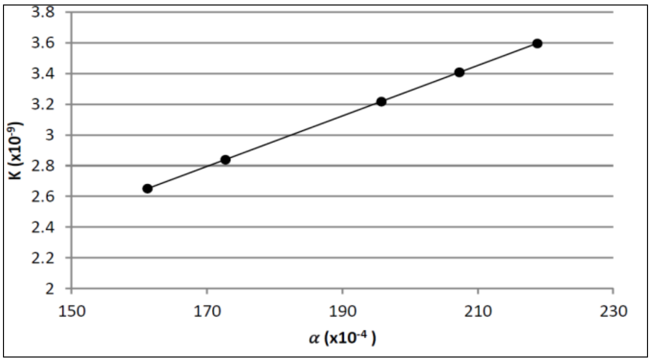


**Fig 5**: The absorption coefficient and extinction coefficient of distilled water as a function of magnetic field exposure time, using infrared filter

It can be seen from the above results that the effect of the applied static magnetic field result in an increase in the refractive index of distilled water and rapid decrease in the dielectric constant (from ~ 80 to 3-5). In addition, the dielectric constant real (**ε'**) and imaginary (**ε''**) are linear. The strength of the dielectric constant is an indicator of how easily an insulating material can be polarized as a result of an external electric field applied to it. However, the effect of static magnetic field on distilled water is to reduce the rotational movement, effects the vibrational modes of water molecules (hydrogen bond mechanism). At present time, this study suggests two interpretations: (i) The proton of the hydrogen atom has a magnetic moment which may oppose (diamagnetic) the applied magnetic field. This will result to hydrogen bond bending or magnetic energy is stored in the bond. (ii) The interaction between the proton of the hydrogen atom and the applied magnetic field is attractive (stretching). This will result to breaking the hydrogen bond. In both cases the physical and chemical properties of liquid water will be different.

## 4. Conclusion

Optical constants such as refractive index, absorption coefficient, extinction coefficient and the real ($\varepsilon r$) and imaginary ($\varepsilon i$) components of the dielectric constant for distilled water under a static magnetic field (75mT) were determined from the Infrared, Visible and UV optical transmission data. Results have shown the effect of magnetic field on the physical and chemical properties of liquid water.

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