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Investigating the Effect of the Yellow Chlorophyll on the Characteristics of Liquid Polyethylene Glycol for Liquid Electrolyte Solar Cells

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Abstract

In this study, polyethylene glycol (PEG) and natural dye were employed to make the liquid electrolyte media for solar cells. To prepare varied amounts of dye, the yellow dye of the flowers was extracted using diluted ethanol via ionized water. To produce a constant concentration of all polymer liquids, 10g of PEG dissolves in 1000 ml of solvents including: (di-water, dilute dye, and concentrated dye) individually. The viscosity of solutions was determined using an Ostwald viscometer at various temperatures. Optical parameters such as transmittance, absorbance, and indirect energy gap were investigated utilizing the ultraviolet spectrum. The results reveal that increasing the temperature causes the viscosity decreases and the solar cell efficiency increases. When the dye concentration is increased, the absorbance and absorption coefficient increase, while the transmittance decreases. After adding the concentrated dye, the energy gap of liquid PEG reduces from 1.4 eV to 0.6 eV. PEG with concentrated dye, on the other hand, is the best sample based on the energy gap value. As a result, four concentrations of PEG liquid were prepared: (0.02, 0.025, and 0.03) w/v concentrations, followed by the addition of the concentration dye in the same quantity for each concentration of PEG liquid. Four prepared liquids were tested for viscosity. The results showed that the viscosity of PEG + concentrated

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dye decreased as the PEG concentration was increased. When the concentration of PEG solution without dye is increased, the viscosity of PEG liquids increases.

Keywords:

Colored solar cell, liquid electrolyte, viscosity, yellow chlorophyll, band gap, absorbance.

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Introduction

The escalating usage of fossil fuels and its associated ecological issues have stimulated extensive research into alternative energy sources that may provide both environmental sustainability and enough energy supply at a reasonable cost (Radhi et al., 2022; Shubbar et al., 2021; Sharaf-Eldin et al., 2023; Lu & Ishida, 2020; Al-Abayechi et al., 2024). Diverse sources of sustainable energy are necessary to meet the rising energy needs of an expanding population. According to (Gielen et al., 2019) energy efficiency and green energy techniques are the fundamental components of this transformation, and their interconnections are also significant. This change is supported by the principles of benefit economics, the availability of widespread and advanced technology, and the advantages of key socio-economic factors (Pye et al., 2019). Renewable energy now provides two-thirds of the world's total energy consumption and plays a crucial role in reducing greenhouse gas emissions. This decrease is necessary to limit the average global surface temperature rise to below 2°C by 2050 (Ortner & Totschnig, 2019). Solarin, (2019) determined that the long-term effect of initiatives aimed at reducing dependency on crude oil resources is restricted. Nevertheless (Sonter et al., 2020) demonstrated that the production of renewable energy is necessary in order to mitigate climate change and the resulting loss of biodiversity. This has led to the development of new technologies and an increase in the production of various metals, which in turn poses threats to biodiversity through mining activities. Renewable energy (RE) sources include geothermal, hydro, solar, tidal, waste, biofuels, and wind. Renewable energy sources represent 26% of the total worldwide power output. The main focus of research is on advancing these sources and accurately predicting their energy generation, as well as improving the associated technologies. The primary focus of research is now on predicting energy output from renewable energy (RE) systems. However, wind and solar power are particularly challenging to anticipate owing to their significant unpredictability compared to other RE sources (Ghosh, 2022). According to (Smith et al., 2022), renewable power production is significantly changing the structure, composition, and behavior of electrical networks. Salvarli & Salvarli, (2020). shown that the use of renewable energy sources would lead to a decrease in environmental expenses, as the energy systems will be run in a secure and cost-effective manner, without causing any environmental issues. Arndt et al., (2019) found that renewable energy sources that vary in their output, such as solar and wind power, would have a significant presence in energy systems, especially in areas with abundant solar and wind resources.

Nanoscience and nanotechnology research covers a wide range of topics (Radhi & Al-Khafaji, 2018; Sattar et al., 2023; Salman et al., 2022; Dawood et al., 2020; Sallal et al., 2024; Radhi et al., 2023; Haleem et al., 2024; Radhi et al., 2024; Humad et al., 2024). It is mostly concerned with nanometer-sized objects. Combining active nanoparticles with polymers is a powerful technique to increase performance and create new jobs in lightweight material solutions. Because of the advantages of the matrix phase and nano-reinforcement phase, the resulting polymer nanocomposites are of interest (Kadhim & Salih, 2020; Jabbar et al., 2018). Natural sources such as plant dyes, DNA, chlorophyll seeds, and many others are among the various options for obtaining nanoscale materials (Alradha et al., 2023; Kadham et al., 2023). Nanotechnology is used in a variety of industries, including food packaging (Kadhim et al., 2021), heavy metal removal from water as a renewable energy source, and surface protection (Talal et al., 2018; Jawad et al., 2019). The sun is a renewable and unimaginable resource that has the power to serve all of the world's people with clean, sustainable energy (Amer Flayeh & Jawad Kadhim, 2022; Tesselaar et al., 2013). One form of photovoltaic converter into electrical energy is dye-sensitized solar cells (DSSCs) (Grätzel, 2001). DSSC has numerous advantages, including being a clean source of energy, cheap cost, and simple to fabricate (Grätzel, 2003; Chiba et al., 2006). The addition of floral dye to the solar cell's foundation is essential for improving the solar cell's efficiency (DSSC) (Aydın et al., 2021). The activation of electrons creates the dye molecule, which acts as a light collector (Aljumaili et al., 2024). Natural dye, which is composed of anthocyanin and other phenolic compounds, has the potential to absorb a wide range of light wavelengths, including those between 490-550 nm (Garcia et al., 2003; Ozuomba et al., 2013). Chlorophyll, which can absorb red, blue, and violet light wavelengths in the 400–450 nm and 650–700 nm ranges, is found in the leaves of all plants (Ozuomba et al., 2013; Srinivasa Rao et al., 2023; Dessy et al., 2023).

The yellow color is primarily caused by the xanthophyll pigment, which is basically a carotenoid. On the other hand, while carotene, which is responsible for the orange color, is a hydrocarbon without an oxygen atom in its structure, xanthophyll, which is responsible for the yellow color, is a hydrocarbon with an oxygen atom in its structure. Both pigments are responsible for giving fruits, yellow paper and vegetables a reddish-orange and yellow color. Due to the presence of the C, H, and O atoms, which constitute the center of light absorption, yellow dye can absorb light throughout the range of 350–600 nm and is essential for both absorption and storage of solar light (Kabir et al., 2019).

The demands of modern living, along with the technical and industrial revolutions, called for the use of numerous highly efficient clean energy sources, such as solar cell networks. The next digital revolution may involve wireless sensor networks and internet devices. A clean energy source can significantly lessen people's suffering when it comes to meeting their needs for electrical, electronic, or other energy (Hussain & Al-Khafaji, 2020). With their enormous global potential, photovoltaics can be used to create semi-permanent smart Internet devices that immediately transform scattered light energy into machine learning and artificial neural network-based computing judgments. Interact and make predictions at the same time. Reducing the energy gap using economically viable materials and attaining high work efficiency at the same time are necessary to boost solar cell efficiency. To accomplish the research objective, natural yellow dyes were used. Several previous studies on the effect of natural extract dyes on solar cell attributes have been undertaken. Suryana et al., (2013) conducted a study in 2013 to see how β-carotene dye obtained from Daucus carota material may be employed as a sanitizer in the fabrication of dye-sensitized solar cells (DSSC). The sandwich configuration of DSSCs included fluorine-doped tin oxide as a transparent conducting oxide, titanium dioxide layer, β-carotene dye, iodide/tri-iodide redox electrolyte, and carbon layer as a counter electrode. When β-carotene dye was present, they determined that the DSSC's photoelectron chemical performance was about 23.910-2 V and the Imax was about 3.310-5 A. The photo-to-electric conversion efficiency of this DSSC, on the other hand, is approximately 12.510-4 (Suryana et al., 2013). Evaluated the adsorption property of natural dye of - carotene on collecting light using a cleaning technique in 2018. Spectroscopy was used to analyze the absorbance values of -carotene utilizing the UV- spectrum. Fourier Transform Infrared was used to investigate dye binding on the surface of TiO_2. UV spectroscopy and the Tauc equation were used to investigate the energy gap and absorbance of the created solar cell. The cells received 100 mW/cm^2 AM 1.5 illumination. The researchers reported a short circuit current density of 0.27 mA/cm^2, photovoltaic of 0.4V, and Fill Factor of 68.89% for the cells. Overall, DSSC is 0.074 percent effective (Halidun et al., 2018). Alesa et al., (2020) examined how natural dye affects PVA Solar cell thin films' optical and thermal performance. PVA, PVA+15ml, PVA+25ml, and PVA + 50ml were used to make three samples of PVA with yellow flower dye. The absorption spectrum, reflectance, energy gap, dielectric constant, and absorption coefficient were measured using a UV-VIS spectrophotometer. Differential scanning calorimeters measured melting point and crystallinity. Materials were tested for structural bonding using FTIR. They found that the concentrated dye solar cell had the lowest energy gap (2.3 eV) and maximum dielectric constant. The solar cell's FTIR absorption ability improves after adding a natural dye (Alesa et al., 2020). However, the current study is considered the first research paper that extracting yellow dye from yellow flowers. The goal of this study is to make a polyethylene glycol (PEG) liquid electrolyte with yellow dye extracted from yellow flowers for use in solar cells.

Materials and Methods

Materials

Polyethylene Glycol (PEG 4000) was utilized as a white powder with the chemical formula [C2nH4n+2O n+1] n, a pH of 5-7, a melting point of 58°C, a solubility of 500 g/L, and a solvent of de-ionized water acquired from Sigma Aldrich. Yellow flowers were utilized to extract the natural dye. Table 1 illustrates the natural extract's constituents.

Table 1. Yellow chlorophyll contents

Property	**Acidity**	**δ ds/m**	**Nitrogen ppm**	**Oxide metal**	**Chlorine Meq/L**	**Ca meq/L**	**So_4 meq/L**	**CO_3 Meq/L**
Dilute specimens	6.5	0.35	21	0.5	3.1	3.5	0.7	0

Methods

Yellow flowers were harvested, rinsed, and pulverized with an electric mixer. After filtering the dye, a concentrated yellowish-brown dye was obtained. Table 2 displays the results of the search.

Table 2. The contents of all specimens

Samples No.	Contents	Ratios of dye
L1	PEG + conc. dye	10g of PEG + 1000 ml con. dye
L2	Low conc. dye	125 ml of conc. dye + 375 ml of water
L3	PEG + low con. dye	5 g of PEG + 500 ml of dilute dye
L4	PEG liquid	5 g of PEG + 500ml of water
L5	Conc. Dye	0.5 of dye : 0.5 of water
L6	0.02 PEG w/v	200g PEG : 1000 ml De-ionized water
L7	0.025 PEG w/v	250g PEG : 1000 ml De-ionized water
L8	0.03	300g PEG : 1000 ml De-ionized water

Results and Discussions

UV- Absorbance

The UV spectra of natural dyes and their solutions are displayed in Figure 1.

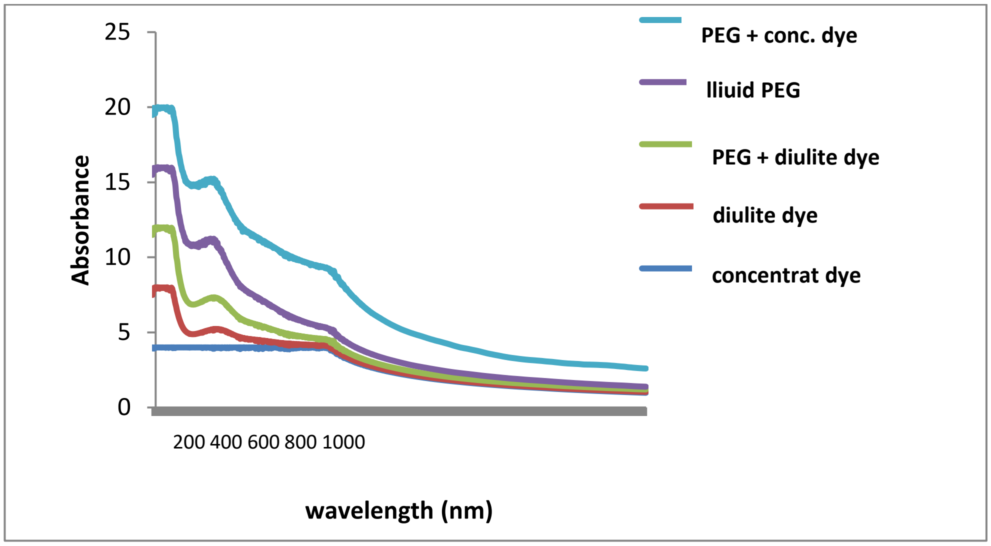

Figure 1. Absorbance curves of specimens

Figure 1 illustrates the ultraviolet region (wavelength 200-225 nm) of the absorption spectra of PEG solution and PEG solution containing diluted dye samples. With concentrated dye, it was brought into the visible range at a wavelength of about 400–550 nm. This is because halogens like N, O, and pb—which have more energy than necessary to stir up electrons—are present in the dye extract. Because halogens have n electrons, they can absorb both visible and ultraviolet light (Oviri & Ekpunobi, 2013).

UV- Transmittance Spectrum

Figure 2 displays the UV-Transmittance Histogram of the specimens.

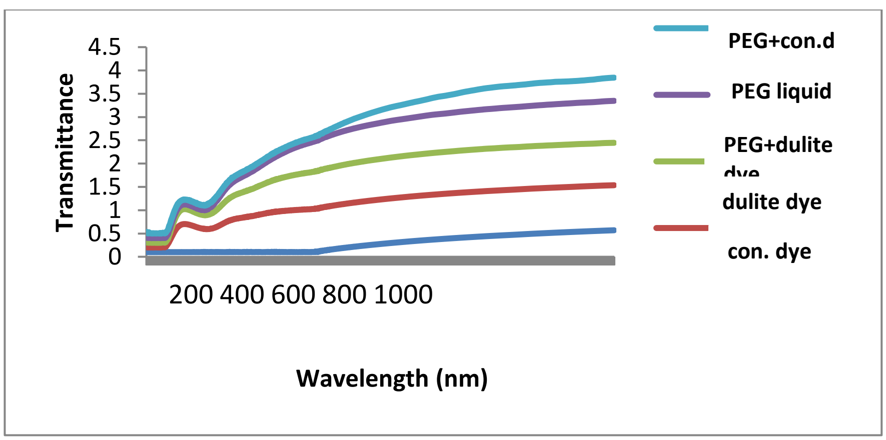

Figure 2. Transmittance of specimens

Take note of Figure 2 Between the short-wave lengths, the transmittance was moved (200-250 nm). The opposite behavior of the logarithmic relationship between transmittance and absorbance is due to impurity atoms and the formation of local levels within the prohibited energy gap between the valence and conduction beams, increasing absorption and decreasing transmittance (Abbas, 2015). These optical properties are very important properties to semiconductors, photo-electric convertors, and detectors.

From eqs. 1 and 2, we can compute absorbance and transmittance as follows:

$$\text{Absorbance} = IA / Io \qquad (1)$$

Transmittance = IT / Io (2)

IA: intensity of absorbance light.

Io is incident light intensity, IT is transmitted intensity of light (Hamid et al., 2018).

Coefficient of Absorption

The absorption coefficient of (liquid PEG, concentrated dye, PEG + concentrated dye, low con. dye, PEG + low con. dye, and PEG+ concentrated dye) samples are depicted in Figure 3. Figure 3 illustrates that the absorption coefficient of absorption increases as photon energy increases. Because the concentrated dye and PEG + concentrated dye contain summation centers of visible and UV-light such as nitrogen, oxygen, sulfur, and halogens, which contain n electrons, these rays have more energy than the energy required to transfer electrons to higher levels (Syafinar et al., 2015).

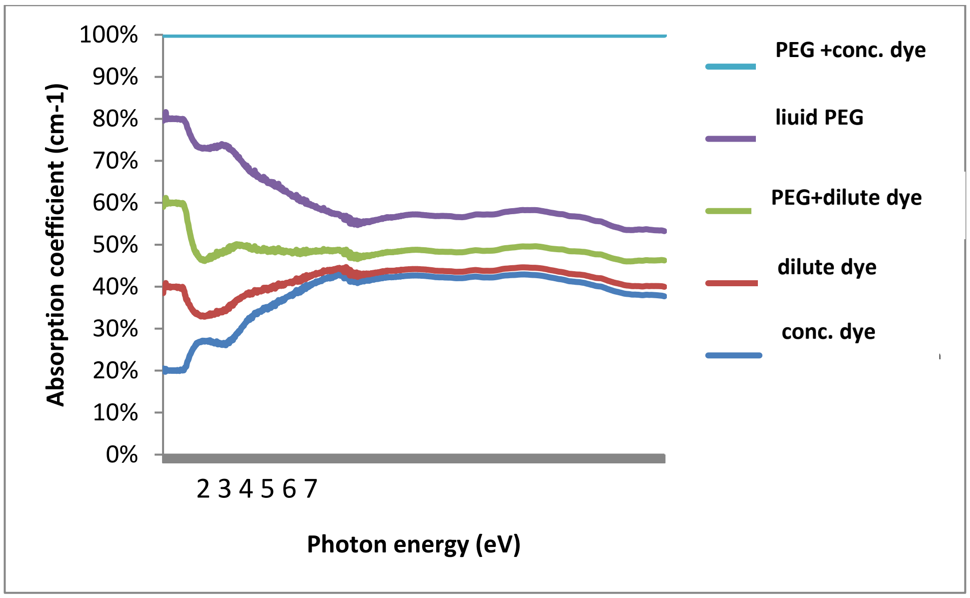

Figure 3. Absorption coefficient against photon energy of all specimens

Indirect Energy Gap

The indirect energy gap against photon energy of all samples is depicted in Figure 4.

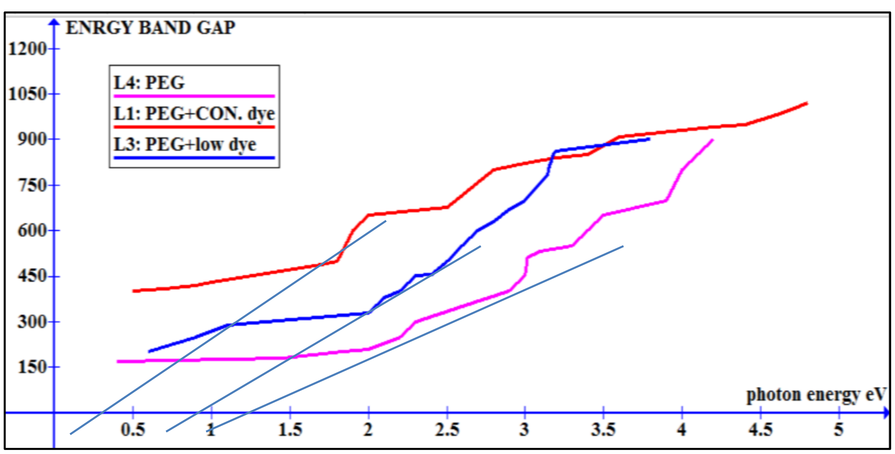

Figure 4. Energy gap against photon energy of all specimens

Table 3. The energy gaps of specimens

Specimens	Components	Band gap (eV)
L1	PEG + conc. dye	0.6
L3	PEG + Dilute dye	1.2
L4	PEG solution	1.4

The energy gaps of specimens shown in Table 3. Observe that the indirect energy band gap reduces with increasing dye concentration because the natural dye with the lowest energy band gap serves as a mid-level for electron transfers from the valence band to the highly excited conduction band. A high efficiency solar cell is produced when the energy band gap is reduced to an extremely tiny amount (Syafinar et al., 2015).

Viscosity of Solutions

This test was carried out at various temperatures (15, 30, 40, and 50 degrees Celsius), as shown in Figure 5. Demonstrate the link between liquid concentration and relative viscosity. As seen in Figure 5, increasing the temperature reduced the viscosity of pure concentrated dye.

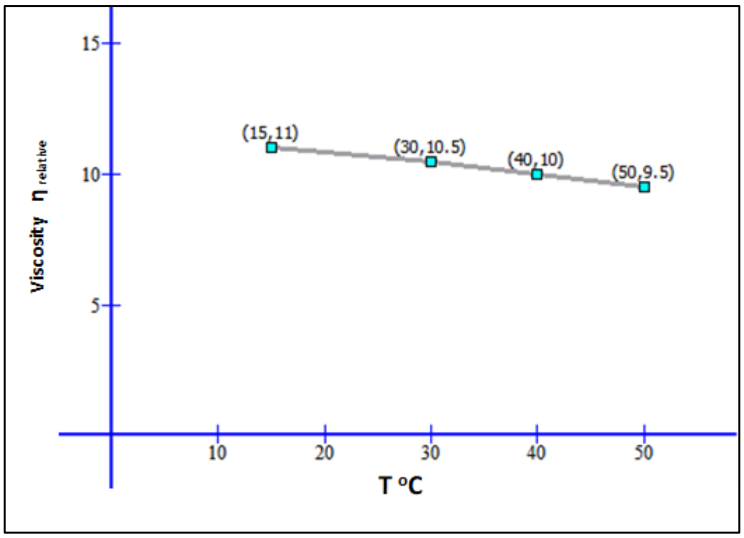

Figure 5. Relationship between the dye concentration and temperature

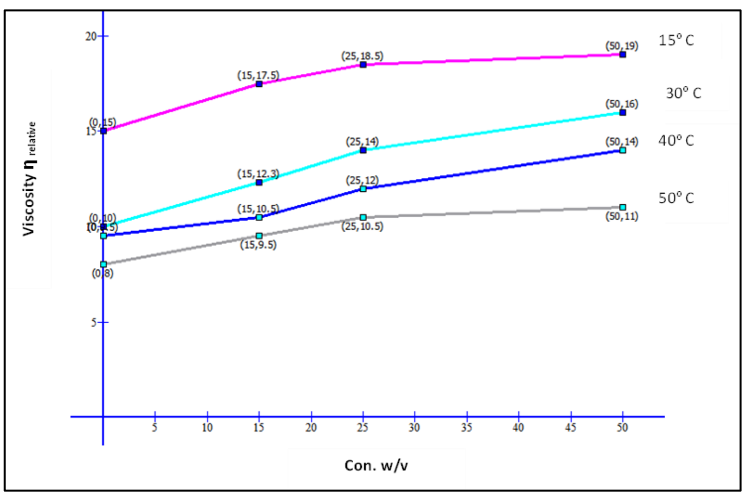

Figure 6. The relationship between non-dyed liquid concentrations and relative viscosity at various temperatures

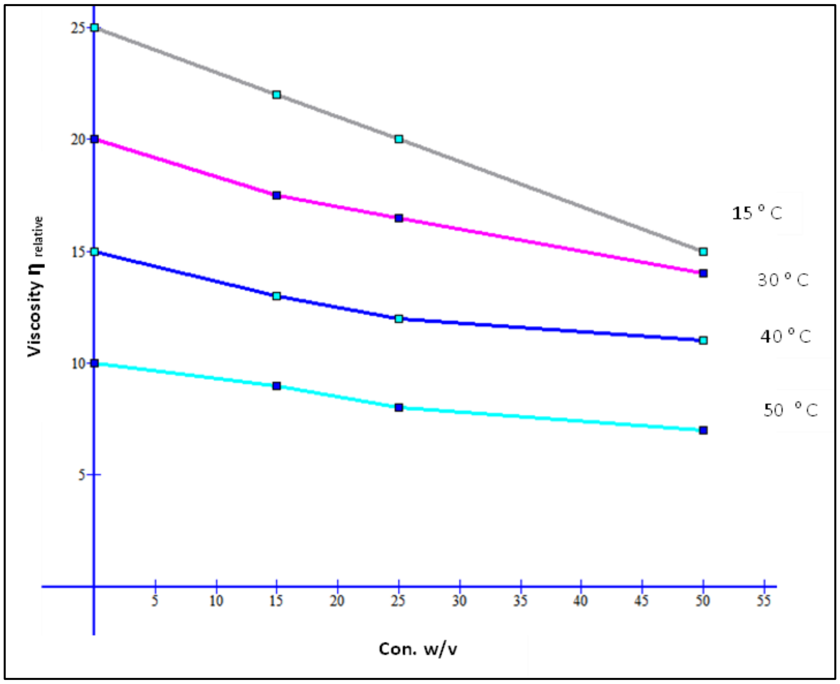

Figure 7. The link between dye concentrations in liquids and relative viscosity at various temperatures

As seen in Figure 6, relative viscosity increases as the concentration of solution without dye increases and decreases as the temperature rises. Figure 7 depicts the behavior of liquid viscosity with dye vs concentration at various temperatures. The viscosity of liquids decreases as the dye concentration in the liquid rises, this is due to the low molecular weight of dye and low viscosity of it (Mohammed et al., 2021), as well as when the temperature rises, the rate of molecular interchange increases as the temperature of the liquid rises, resulting in quicker molecular movement at higher temperatures. Moreover, as the temperature rises, the cohesive force between liquid molecules reduces, resulting in a decrease in viscosity. The efficiency of solar cells was improved by using ionic liquids with a reduced viscosity. This corresponds to (Fang et al., 2019).

Conclusion

- The optical properties of liquid media are enhanced by the addition of natural yellow dye; absorption rises with dye concentration and reaches visible to UV wavelengths about 250-600 nm.
- Adding natural dye leads to decrease the energy gap of medium from (1.4 to 0.6) eV which leads to improve the solar cell's efficiency.
- The viscosity of the liquid medium reduces with temperature, and it leads to an increase in the efficiency of the solar cell. Viscosity decreases from 10 to 7.5, 12 to 11.5, 20 to 17.5, and 25 to 21 under (50, 40, 30, and 15) ^{o}C respectively, with increasing the concentration of dye.

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Conflict of Interest

There is no conflict of interest.

Contributions

All contributors participated in the preparation, writing, and discussion of the results provided in this paper.

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