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Practical Spectrophotometry: Exploring Maximum Absorption Peaks of $Fe(SCN)_3$ and $CuSO_4$ Solutions Using Visible Light

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ABSTRACT

Purpose of the study: This study explores simple visible light spectroscopy to measure maximum absorption wavelengths in $Fe(SCN)_3$ and $CuSO_4$ solutions, analyzing the impact of light filters on absorption spectra.

Methodology: This study exposed $Fe(SCN)_3$ and $CuSO_4$ solutions to tungsten lamp light, passing through a collimator and diffraction grating. Spectral data, recorded by a camera, compared filtered and unfiltered conditions. Absorbance, determined from light intensity differences, revealed characteristic wavelengths with maximum absorbance for each solution, visualized through wavelength-absorbance graphs.

Main Findings: The maximum absorption wavelengths for $Fe(SCN)_3$ were 481 nm (with filter) and 472 nm (without filter), while for $CuSO_4$, they were 570 nm (with filter) and 553 nm (without filter). Monochromatic filters enhanced accuracy, aligning $Fe(SCN)_3$ closer to theoretical values and reducing $CuSO_4$ deviations to 20 nm (filtered) compared to 37 nm (unfiltered).

Novelty/Originality of this study: The novelty of this study lies in the development of a simple visible light-based spectrophotometer by utilizing easily accessible tools and materials, such as tungsten lamps and CMOS cameras, to understand the maximum absorption peaks of $Fe(SCN)_3$ and $CuSO_4$ solutions. In addition, this study explores the effect of using light filters on the accuracy of spectrum data, providing a practical alternative for spectroscopy experiments in resource-limited learning environments.

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1. INTRODUCTION

Spectroscopy is a scientific method used to analyze the properties of matter based on its interaction with light [1], [2]. This technique utilizes electromagnetic radiation emitted, absorbed, or reflected by a substance in solution [3], [4]. In the world of analytical chemistry, spectroscopy is very important because it can provide information about the concentration and structure of a compound [5], [6]. The main tool used in this technique is a spectrophotometer. One type is a visible light spectrophotometer, which works in the wavelength range of around 400–700 nm.

A visible light spectrophotometer can be used to determine the maximum absorption wavelength of a substance in solution [7], [8]. In addition, this tool can also be used to measure the absorbance and concentration of substances based on the Lambert-Beer law. In its operation, the solution is irradiated with light and the spectrophotometer records the intensity of light absorbed by the solution [9], [10]. This process allows the identification of substances based on their color and ability to absorb certain light. Thus, spectrophotometers are very useful in quantitatively testing the quality of solutions [11], [12].

The light used in spectroscopy can be polychromatic or monochromatic [13], [14]. Polychromatic light is used to select the maximum absorption wavelength from a wide spectrum [15], [16]. Meanwhile, monochromatic light provides higher accuracy because it has a narrow and focused wavelength range [17], [18]. The combination of the use of both types of light can produce more reliable and representative data. Therefore, understanding the type of light used is important in spectroscopy experiments.

Although spectrophotometers have an important function in testing solutions, the general public or practitioners' understanding of their working principles is still limited [19], [20]. Usually, the testing process only focuses on the final results without understanding in depth how the tool works or what reactions occur when the solution is exposed to light radiation. Theoretical explanations are often considered sufficient, without in-depth direct practice due to limited facilities. The very expensive price of spectrophotometers is a major obstacle in the direct learning process [21], [22]. As a result, not all students or practitioners can actively use this tool in practicums.

Most spectroscopy experiments are carried out only using available tools without questioning their physical principles. In fact, a deep understanding of how the tool works is very important to improve the quality of data analysis [23], [24]. This knowledge is not only useful for scientists, but also for students who are studying analytical chemistry. By understanding the basic principles of spectroscopy, users can interpret test results more critically and accurately [25], [26]. Therefore, a practical approach is needed that can bridge the limitations of tools and learning needs.

This study tries to present a solution by making a simple visible light spectrophotometer using easily available tools and materials. The tools used include a tungsten lamp as a light source, a collimator, a cuvette made of glass slides, a diffraction grating, a camera, a light filter, and a computer [27]. This device is designed to resemble the working principle of a commercial spectrophotometer, but in a more economical and educational form. With this approach, practitioners can more easily understand how light is emitted, absorbed, and analyzed in a solution system. This also provides direct experience in simple spectroscopy experiments.

This study is unique because there has been no previous study that specifically developed a simple visible light-based spectrophotometer using easily accessible tools such as tungsten lamps and CMOS cameras to study the absorption spectrum of $Fe(SCN)_3$ and $CuSO_4$ solutions. Most previous spectroscopy studies have focused on the use of commercial spectrophotometers with sophisticated technology that are difficult to reach by educational institutions with limited resources. This gap indicates the lack of affordable alternatives for spectroscopy learning in educational settings, so this study is a relevant innovation to answer this need.

The novelty of this research lies in the development of a simple visible light-based spectrophotometer utilizing readily available tools and materials, such as tungsten lamps and CMOS cameras. This approach offers an innovative alternative for spectroscopy learning in educational settings with limited resources, which has not been widely explored before. This research not only provides a direct understanding of the working principle of the spectrophotometer, but also allows students and practitioners to conduct spectroscopy experiments economically without relying on expensive commercial equipment. The urgency of this research is increasing along with the need for interactive and affordable chemistry learning methods, especially in institutions with limited technology. By offering a practical solution to overcome these obstacles, this research contributes to improving the quality of science education and supporting the development of innovative methods in chemistry learning.

This study specifically aims to determine the maximum absorption wavelength of $Fe(SCN)_3$ and $CuSO_4$ solutions. Both solutions were chosen because they are translucent and colored, making them suitable for analysis with a visible light spectrophotometer based on the Lambert-Beer law. In addition, this study also examines the effect of using a light filter on the absorption spectrum of the solution. By combining practical and theoretical aspects, this research is expected to contribute to science education, especially in the basic understanding of spectroscopy. The results can be an alternative for cheap, simple, yet effective and informative spectroscopy learning.

2. RESEARCH METHOD

2.1. Equipment and Materials

The equipment used in this study was designed simply but functionally to simulate the working principle of a visible light spectrophotometer. The main equipment includes a 25-watt tungsten lamp as a light source and a USB CMOS camera with a resolution of 780 x 1280 pixels to capture the light spectrum passing through the sample. A diffraction grating with a density of 1000 lines/mm was used to break down the light, while red, green, and blue light filters functioned for wavelength selection. For optical construction, a glass slide, two razor blades as light slits, glass glue, black duct tape, plywood, a cutter, and a statip were used as optical system supports. Additional equipment such as styrofoam, connecting cables, and black markers were also used to perfect the assembly of the tool. The materials used in the test were $Fe(SCN)_3$ solution and $CuSO_4$ solution as the main samples. These two solutions were chosen because they have translucent properties and produce colors that can be observed visually through a visible light spectrophotometer. Aquades was used as a solvent and comparative material for background measurements (blank). All materials are prepared under conditions that comply with laboratory safety procedures. This combination of tools and materials allows for simple and effective observation of absorption spectra.

2.2. Research Object

The objects of this study are the maximum absorption wavelength of Fe(SCN)3 and CuSO4 solutions, as well as the effect of monochromatic filters on the absorption spectrum of the solutions.

2.3. Data Analysis Techniques

The data analysis technique in this study began with testing the light spectrum produced by the tungsten lamp using a diffraction grating. The purpose of this stage is to ensure that the tungsten lamp emits an adequate light spectrum and is in accordance with the needs in taking spectral data. Furthermore, the light spectrum that has passed through the optical system is recorded by a CMOS camera and analyzed using Matlab software. This analysis produces a graph of the relationship between light intensity and wavelength, which describes the spectral distribution of the transmitted light. The next step is to calculate the difference in light intensity between the empty cuvette (without sample) and the cuvette containing the sample solution. This difference value represents the amount of light absorbed by the solution, which is the basis for calculating absorbance. The absorbance data is then compared with the initial intensity to produce a graph of the relationship between absorbance and wavelength. This graph is very important in determining the maximum absorption wavelength of each solution. Through this analysis stage, quantitative information is obtained that supports the understanding of the optical characteristics of $Fe(SCN)_3$ and $CuSO_4$ solutions.

3. RESULTS AND DISCUSSION

3.1. Tungsten Lamp Light Spectrum Validation

Before measuring the sample solution, a test was carried out on the light spectrum from the tungsten lamp as a light source. The test results showed that the tungsten lamp emits a light spectrum in the visible light range, which is around 400–700 nm. This light is then projected through a diffraction grating and captured by a CMOS camera. The spectrum pattern formed shows a fairly even intensity distribution at visible wavelengths, making it suitable for use as a light source in testing the absorption spectrum of the solution. These results ensure that the experiments carried out are supported by a radiation source that is in accordance with the working principle of visible light spectroscopy.

3.2. Absorption Spectrum of $Fe(SCN)_3$ Solution

Measurements of $Fe(SCN)_3$ solution were carried out under two conditions, namely without using a filter and using a light filter (red, green, and blue). In conditions without a filter, the maximum absorption wavelength value was obtained at 472 nm. Meanwhile, the use of a light filter showed an increase in accuracy with a maximum absorption value of 481 nm, which is closer to the theoretical value of the absorption of $Fe(SCN)_3$ solution in the blue-green range (around 480–490 nm). These results indicate that monochromatic light from the filter is able to narrow the spectrum and reduce interference from other light in absorbance measurements. In addition, the absorbance graph resulting from the use of the filter shows a sharper and clearer peak than without a filter.

3.3. Absorption Spectrum of $CuSO_4$ Solution

Similar to $Fe(SCN)_3$, $CuSO_4$ solution was also tested under two lighting conditions. The measurement results showed that the maximum absorption wavelength without a filter was 553 nm, while with a light filter, the maximum value shifted to 570 nm. This value is closer to the theoretical absorption wavelength of $CuSO_4$ which is in the yellow-orange range (around 580–600 nm). The use of a filter has been shown to reduce spectrum spread and increase the sharpness of the absorption data. Comparison of absorbance graphs shows that the absorption peak with a filter is more defined, while the graph without a filter tends to be wider and flatter.

3.4. Effect of Light Filters on Absorption Spectrum

The results showed that the use of light filters had a significant impact on the accuracy and clarity of the absorption spectrum data. In both types of solutions, the use of filters resulted in maximum absorption wavelengths that were closer to theoretical values. In addition, the use of filters made it easier to identify absorption peaks because it narrowed the spectrum of light transmitted to the sample. This is in line with the working principle of a monochromatic spectrophotometer, where light with a single wavelength provides more accurate and sharp absorbance data. Thus, light filters have an important role in improving the performance of simple spectroscopy systems.

The findings demonstrate that the simple spectrophotometer designed in this study is effective for analyzing the absorption spectra of $Fe(SCN)_3$ and $CuSO_4$ solutions. Its simplicity and cost-effectiveness make it a practical tool for educational purposes, enabling students to understand spectroscopy principles hands-on.

However, the experiment is limited by the quality of the filters and the precision of the optical alignment. Future research could explore improved filter materials and test the method on other solutions to validate its broader applicability. Additionally, integrating automated data analysis could enhance usability and accuracy.

4. CONCLUSION

Based on the results of the study and discussion, it can be concluded that the maximum absorption wavelength of Fe(SCN)3 solution using a filter and without a filter are 481 nm and 472 nm respectively with green layer analysis. The maximum absorption wavelength of CuSO4 solution using a filter and without a filter are 570 nm and 553 nm respectively with red layer analysis. Monochromatic filters on spectrophotometers can produce better spectra or data. For the Fe(SCN)3 sample, the wavelength value when using a filter is within the theoretical range used, but when not using a filter it has a difference of 9 nm from the theory. While for the CuSO4 sample, the wavelength when using a filter differs by 20 nm and when not using a filter it differs by up to 37 nm. Further research is suggested to develop this simple spectrophotometer by using more precise light filters to improve the accuracy of the measurement results. In addition, testing the device on other chemical solutions or data automation systems can expand its applications in chemistry learning and research.

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REFERENCES

[1] M. A. Carpentieri, G. Fano, S. Jurinovich, and V. Domenici, "Introduction to Light Properties and Basic Principles of Spectroscopy at the High-School Level: A Pilot Study," *Educ. Sci.*, vol. 13, no. 3, pp. 1–22, 2023, doi: 10.3390/educsci13030316.

[2] A. Orlando *et al.*, "A Comprehensive Review on Raman Spectroscopy Applications," *Chemosensors*, vol. 9, no. 9, pp. 1–28, Sep. 2021, doi: 10.3390/chemosensors9090262.

[3] J. Cheng *et al.*, *From VIB- to VB-Group Transition Metal Disulfides: Structure Engineering Modulation for Superior Electromagnetic Wave Absorption*, vol. 16, no. 1. Springer Nature Singapore, 2024. doi: 10.1007/s40820-023-01247-7.

[4] S. Kim, S. Lee, Y. Zhang, S. Park, and J. Gu, "Carbon-Based Radar Absorbing Materials toward Stealth Technologies," *Adv. Sci.*, vol. 10, no. 32, pp. 1–12, Nov. 2023, doi: 10.1002/advs.202303104.

[5] Y. Qi *et al.*, "Deciphering dissolved organic matter by Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS): from bulk to fractions and individuals," *Carbon Res.*, vol. 1, no. 1, pp. 1–3, Jun. 2022, doi: 10.1007/s44246-022-00002-8.

[6] G. Visconti, J. Boccard, M. Feinberg, and S. Rudaz, "From fundamentals in calibration to modern methodologies: A tutorial for small molecules quantification in liquid chromatography–mass spectrometry bioanalysis," *Anal. Chim. Acta*, vol. 1240, pp. 1–18, 2023, doi: 10.1016/j.aca.2022.340711.

[7] A. B. D. Nandiyanto, R. Ragadhita, and M. Aziz, "How to calculate and measure solution concentration using uv-vis spectrum analysis: Supporting measurement in the chemical decomposition, photocatalysis, phytoremediation, and adsorption process," *Indones. J. Sci. Technol.*, vol. 8, no. 2, pp. 345–362, 2023, doi: 10.17509/ijost.v8i2.57783.

[8] Y. M. Hunge *et al.*, "Visible Light-Assisted Photocatalysis Using Spherical-Shaped BiVO4 Photocatalyst," *Catalysts*, vol. 11, pp. 1–11, 2021.

[9] B. Liu, J. Cai, J. Zhang, H. Tan, B. Cheng, and J. Xu, "Simultaneous benzyl alcohol oxidation and H2 generation over MOF/CdS S-scheme photocatalysts and mechanism study," *Chinese J. Catal.*, vol. 51, pp. 204–215, Aug. 2023, doi: 10.1016/S1872-2067(23)64466-3.

[10] V. H. Nguyen, A. L. H. Pham, V.-H. Nguyen, T. Lee, and T. D. Nguyen, "Facile synthesis of bismuth(III) based metal-organic framework with difference ligands using microwave irradiation method," *Chem. Eng. Res. Des.*, vol. 177, pp. 321–330, Jan. 2022, doi: 10.1016/j.cherd.2021.10.043.

[11] Z. Shi, C. W. K. Chow, R. Fabris, J. Liu, and B. Jin, "Applications of Online UV-Vis Spectrophotometer for Drinking Water Quality Monitoring and Process Control: A Review," *Sensors*, vol. 22, no. 8, pp. 1–21, Apr. 2022, doi: 10.3390/s22082987.

[12] H. S. Elbordiny, S. M. Elonsy, H. G. Daabees, and T. S. Belal, "Sustainable quantitative determination of allopurinol in fixed dose combinations with benzbromarone and thioctic acid by capillary zone electrophoresis and spectrophotometry: Validation, greenness and whiteness studies," *Sustain. Chem. Pharm.*, vol. 27, p. 100684, Jun. 2022, doi: 10.1016/j.scp.2022.100684.

[13] N. Monarumit, T. Lhuaamporn, D. Schwarz, P. Wathanakul, and W. Wongkokua, "An application of polychromatic UV-

Vis-NIR spectroscopy on detection of beryllium treatment in ruby and yellow sapphire," *J. Phys. Conf. Ser.*, vol. 2653, no. 1, pp. 1–6, 2023, doi: 10.1088/1742-6596/2653/1/012011.

[14] A. A. Abdelaziz, P. S. Ismail, and D. E. Mohamed, "COMPARATIVE EVALUATION OF SHADE MATCHING USING A DIGITAL SPECTROPHOTOMETER IN MONOCHROMATIC VERSUS POLYCHROMATIC LAYERING TECHNIQUES FOR RESTORING FRACTURED INCISAL ANGLES OF MAXILLARY INCISORS :," *Egypt. Dent. J.*, vol. 71, no. 2, pp. 1785–1800, 2025.

[15] M. Maafi, "On photokinetics under polychromatic light," *Front. Chem.*, vol. 12, no. April, pp. 1–25, 2024, doi: 10.3389/fchem.2024.1367276.

[16] A. Bierman, K. Benner, and M. S. Rea, "Melanin bias in pulse oximetry explained by light source spectral bandwidth," *Br. J. Anaesth.*, vol. 132, no. 5, pp. 957–963, 2024, doi: 10.1016/j.bja.2024.01.037.

[17] M. Xi, H. Liu, D. Li, and Y. Wang, "Intensity response model and measurement error compensation method for chromatic confocal probe considering the incident angle," *Opt. Lasers Eng.*, vol. 172, p. 107858, Jan. 2024, doi: 10.1016/j.optlaseng.2023.107858.

[18] D. Xu *et al.*, "Design of a digital tunable stellar spectrum calibration source based on a digital micromirror device," *Measurement*, vol. 191, p. 110651, Mar. 2022, doi: 10.1016/j.measurement.2021.110651.

[19] L. G. Pap, "An Inexpensive 3D-Printable Do-It-Yourself Visible Spectrophotometer for Online, Hybrid, and Classroom-Based Learning," *J. Chem. Educ.*, vol. 98, no. 8, pp. 2584–2591, Aug. 2021, doi: 10.1021/acs.jchemed.0c01345.

[20] G. Schinas, G. Dimopoulos, and K. Akinosoglou, "Understanding and Implementing Diagnostic Stewardship: A Guide for Resident Physicians in the Era of Antimicrobial Resistance," *Microorganisms*, vol. 11, no. 9, pp. 1–16, 2023, doi: 10.3390/microorganisms11092214.

[21] P. V. Kolesnichenko, A. Eriksson, L. Lindh, D. Zigmantas, and J. Uhlig, "Viking Spectrophotometer: A Home-Built, Simple, and Cost-Efficient Absorption and Fluorescence Spectrophotometer for Education in Chemistry," *J. Chem. Educ.*, vol. 100, no. 3, pp. 1128–1137, 2023, doi: 10.1021/acs.jchemed.2c00679.

[22] A. Li *et al.*, "Advances in cost-effective integrated spectrometers," *Light Sci. Appl.*, vol. 11, no. 1, pp. 1–18, 2022, doi: 10.1038/s41377-022-00853-1.

[23] K. Batko and A. Ślęzak, "The use of Big Data Analytics in healthcare," *J. Big Data*, vol. 9, no. 1, pp. 1–24, 2022, doi: 10.1186/s40537-021-00553-4.

[24] Marzuki, U. Widiati, D. Rusdin, Darwin, and I. Indrawati, "The impact of AI writing tools on the content and organization of students' writing: EFL teachers' perspective," *Cogent Educ.*, vol. 10, no. 2, pp. 1–17, 2023, doi: 10.1080/2331186X.2023.2236469.

[25] G. R. Han *et al.*, *Machine learning in point-of-care testing: innovations, challenges, and opportunities*, vol. 16, no. 1. Springer US, 2025. doi: 10.1038/s41467-025-58527-6.

[26] R. Vitorino, A. S. Barros, S. Guedes, D. C. Caixeta, and R. Sabino-Silva, "Diagnostic and monitoring applications using near infrared (NIR) spectroscopy in cancer and other diseases," *Photodiagnosis Photodyn. Ther.*, vol. 42, no. May, pp. 1–11, 2023, doi: 10.1016/j.pdpdt.2023.103633.

[27] I. Hussain and A. K. Bowden, "Smartphone-based optical spectroscopic platforms for biomedical applications: a review [Invited]," *Biomed. Opt. Express*, vol. 12, no. 4, p. 1974, 2021, doi: 10.1364/boe.416753.