JOURNAL OF KUFA–PHYSICS
journal.uokufa.edu.iq/index.php/jkp/index | ISSN: 2077–5830

Synthesis, characterization, and study of the optical properties of new Schiff bases

Ghufran Arkan Mohammed Hussain[1], Shaymaa Jabbar Abdulrazzaq[2], and Atheraa Abdul Kadhim Wasaf[3]

1,2 Department of Physics –College of Education for Girls- University of Kufa

3 Department of Chemistry, College of Education for girls, University of Kufa.

Corresponding Author E-mail: ghufran.alnajm@student.uokufa.edu.iq

ARTICLE INF.

Article history:
Received: 24 FEP., 2026
Revised: 17 MAR., 2026
Accepted: 25 MAR., 2026
Available Online: 28 JUN. 2026

Keywords:

Schiff bases

optical band gap,
photovoltaic material,
Antioxidant Activity.

ABSTRACT

Schiff bases have attracted considerable interest in recent years owing to their uses in optoelectronics and their easy synthesis. This study involved the preparation of Schiff bases via a condensation reaction between Folic acid (FA) and two separate aldehyde derivatives, 3,4-dimethoxy benzaldehyde and 4-pyridinecarboxaldehyde, yielding two unique Schiff base compounds ((E)-(4-(((2-((3,4-dimethoxybenzylidene)amino)-4-oxo-3,4-dihydropteridin-6-yl)methyl)amino)benzoyl)-L-glutamic acid (F1) and (E)-(4-(((4-oxo-2-((pyridin-4-ylmethylene)amino)-3,4-dihydropteridin-6- yl)methyl) amino) benzoyl) -L-glutamic acid (F2), respectively. The synthesized Schiff base compounds have been characterized using FT-IR, UV-Vis, ^{1}H-NMR, ^{13}C-NMR, antibacterial, and antioxidant studies, confirming the effective synthesis of the targeted molecular structures. The UV-Vis spectra revealed that the absorption range of compounds largely falls in the ultraviolet region, which is a result of electronic excitation of $\pi\rightarrow\pi^*$ and $n\rightarrow\pi^*\pi$ in the conjugated system. The optical studies revealed a refractive index of (n=1.2) for both compounds, and a wide optical energy band gap that ranged between (3.86-3.78ev), indicating that such materials are not conductive to electricity and therefore, act as optically transparent insulators. The result also showed significant effectiveness of the two compounds, as compound F1 showed the highest antibacterial activity with an inhibition diameter of (24mm) at a concentration of (1mg/ml) compared to F2. The compounds also recorded antioxidant activity of (86.678%) for F1 and (85.492%) for F2. Moreover, the properties of the synthetic compounds make them exceptionally suitable for optoelectronic and photonic applications such as UV-blocking finishes, anti-reflective coats, optical filters and insulating coats in electrical and optical equipment.

DOI: https://doi.org/10.31257/2018/JKP/2026/v18.i1.23332

تخليق, تشخيص و دراسة الخواص البصرية لقواعد شيف الجديدة

غفران اركان محمد حسين[1], شيماء جبار عبد الرزاق[2], عذراء عبد الكاظم وساف[3]

2,1 قسم الفيزياء- كلية التربية للبنات- جامعة الكوفة, 3 قسم الكيمياء -كلية التربية للبنات- جامعة الكوفة

الـــخُـــلاصــــة

حظيت قواعد شيف في السنوات الأخيرة باهتمام كبير نظرا لاستخداماتها في الالكترونيات الضوئية وسهولة تصنيعها. تضمن هذا العمل تحضير قواعد شيف عبر تفاعل التكثيف بين حمض الفوليك (FA) و مركبين منفصلين من الالدهيد. وهما -3,4ثنائي ميثوكسي نزيالدهيد و -4بيريدين كاربوسالدهيد, مما اسفر عن تكوين مركبين فريدين من قواعد شيف هما :((E)-(4-(((2-((3,4-ثنائي ميثوكسي بنزيليدين)امينو)-4-اوكسو-3,4-ثنائي هيدروبتريدين-6-يل)ميثيل)امينو)بنزويل-حمض الجلوتاميك (F1), و (E)-(4-(((4-أوكسو-2-((بيريدين-4-يل ميثيلين)أمينو)-4،3-ثنائي هيدروبتريدين-6-يل)ميثيل)أمينو)بنزويل)-حمض الجلوتاميك (F2). وتم توصيف مركبات قواعد شيف المصنعة باستخدام تقنية C^{13}NMR,^{1}H-NMR ,UV-VIS, FT-IR, الدراسات المضادة للبكتريا و مضادات الاكسدة, مما يؤكد فعالية تركيب البنى الجزيئية المستهدفة, وأشارت أطياف الاشعة فوق البنفسجية و المرئية الى ان نطاق امتصاص المركبات يقع بشكل رئيسي في منطقة الاشعة فوق البنفسجية, بسبب الانتقالات الالكترونية $\pi\rightarrow\pi^*$ و $n\rightarrow\pi^*$ داخل النظام المترافق. اظهرت الدراسات البصرية معامل انكسار بلغ (n=1.2) لكل من المركبين, كما اظهرت فجوة طاقة بصرية واسعة تتراوح بين (3.86-3.78 ev), مما يشير الى ان هذه المواد تتميز بموصلية كهربائية محدودة وتعمل كعوازل وشفافة بصريا. كما بينت النتائج فعالية بالوجيه للمركبين, حيث اظهر المركب F1 اعلى نشاط مضاد للبكتريا بقطر تثبيط (24mm) عند تركيز (1mg/ml) مقارنة F2, كما سجلت المركبات نشاط مضاد للأكسدة بنسبة (86.678%) لـF1 و (85.492%) لـF2. وبناء على ذلك فأن خصائص المركبات المصنعة تجعلها مناسبة بشكل استثنائي للتطبيقات الضوئية, بما في ذلك الطلاءات الحاجبة للأشعة فوق البنفسجية, و الطبقات المضادة للانعكاس, و المرشحات البصرية, و الطبقات العازلة في الأجهزة الكهربائية و البصرية.

الكلمات المفتاحية:

قواعد شيف

فجوة الطاقة

خلايا شمسية

مضادات بكتيرية

1. INTRODUCTION

Schiff bases are deemed to be important organic compounds in applied chemistry because they can be easily synthesized and are easy in their physical and biological characteristics. Most of these compounds were formed by condensation of aldehyde or ketone with primary amines to produce an azomethine (-C=N-) type bonds and most of their behaviour is due to this bond. One of the biomolecules that can be converted into Schiff base derivatives is folic acid because it has an active functional group of ($-NH_2$) that can react with different aldehyde compounds. Schiff bases have gained more scientific attention in recent years as a result of their unique optical characteristics, including the absorption of light and the transport of electrons, making it possible to use in a number of applications. These compounds have a high bioactivity especially as antioxidants and antibacterial agents, and thus, they are an attractive choice when it comes to a wide range of medical uses. The current study will help to prepare a set of Schiff bases based on products of folic acid and aldehydes, investigate their optical characteristics, test their antibacterial behavior with certain bacteria specimens, and test their free radical scavenging potential [1-5]. The potential outcome of this study will be anticipated to give clear optical image properties and significant biological reaction that will suggest their potential application in future medical and analysis procedures.

2. The theoretical part

Optical properties of materials are a result of the interaction between the nature and distribution of charge in the material (ionic, electronic, or molecular) and the electromagnetic radiation. When an electromagnetic beam hits the material, some of the radiations are absorbed thereby transforming the radiations to heat energy inside the material. The remaining portion is referred to as transmitted radiation and does not dissipate its energy. The rest of the light radiation is reflected on the surface of the material [6]. It is possible to assess several optical parameters to describe the electronic structure of the material and its behaviour to the electromagnetic radiation.

2.1 Absorbance

According to the Beer-Lambert law, the intensity of light absorbed by a material increases proportionally with the quantity of the absorbing entity. This absorption (A) is calculated by comparing the intensity of the light before entering the studied sample (I_0) and the intensity that leaves after entering it (I). Equation (1) shows the described relation [7,8]:

$$A = \log \frac{I_o}{I} \quad \text{-----} \quad (1)$$

2.2 Absorption coefficient

Absorption coefficient (α) denotes the photon absorption coefficient, representing the characteristic distance that a photon of a specific wavelength can travel into the material before being absorbed. The optical absorption coefficient measures the size of the light that a material absorbs with each unit distance [9,10]. The relation described can be seen in equation (2) [11] as follows:

$$\alpha = 2.303\frac{A}{d} \quad \text{-----} \quad (2)$$

Absorption coefficient (α), absorption (A), and the sample's thickness (d).

2.3 Energy gap

Studying a material using the optical absorption is a very simplistic way of elucidating some of the characteristics associated with the band structure of the material. The technique that is used to calculate the optical band gap energy [12] uses the following relation (3) [13]:

$$\alpha h\upsilon = C(h\upsilon - E_g)^n \quad \text{-----}(3)$$

Energy of incident photon (hυ), is a constant which is determined by the properties of band structure (C), energy gap (E_g) and constant which is determined by the type of electronic transition (n=$\frac{1}{2}$ for direct allowed transition, n= $\frac{3}{2}$ for direct forbidden transition, n=2 for indirect allowed transition, n=3 for indirect forbidden transition).

2.4 Refractive index

Optical refractive index (n) is one of the basic parameters that determine the dispersion of light and is necessary to evaluate its linear optical properties in the material [14]. The linear refractive index (n) can be calculated using the following equation (4) [15]:

$$n=\frac{(1+R^{0.5})}{(1-R^{0.5})} \quad ---- \quad (4)$$

Refractive index (n), the reflectance (R) of the material.

2.5 Extinction coefficient

An extinction coefficient measures how much light or radiation of a given wavelength a certain species absorbs or reflects [16]. The extinction coefficient can be calculated using the following equation(5) [17].

$$k=\frac{\alpha\,\lambda}{4\,\pi} \quad ----- \quad (5)$$

The extinction coefficient (k), the wavelength of the incident photon (λ).

2.6 Dielectric constant

The dielectric constant, or relative permittivity, represents how a material responds to an applied electric field. It is a physical parameter that governs polarization behavior and influences the electrical and optical properties of matter [18]. This can be described by the following equation (6,7,8) [19].

$$\varepsilon = \varepsilon_{real}\text{-}i\varepsilon_{im} \quad ----- \quad (6)$$

$$\varepsilon_{real} = n^2\text{-}k^2 \quad ----- \quad (7)$$

$$\varepsilon_{im} = 2nk \quad ----- \quad (8)$$

Real part (ε_{real}), and imaginary part (ε_{im})of the dielectric constant **3.**

Experimental details

Ethanol (CAS NO. **64-17-5**) was purchased from **Alpha**. Folic acid was obtained from **HiMedia Laboratories Pvt. Ltd**.. **3,4-dimethoxy benzaldehyde** and **4-pyridinecarboxaldehyde** were supplied by **Sigma-Aldrich (Merck)**. All chemicals were of analytical grade and used without further purification.

3.1. Preparation of the Schiff base

Schiff base compounds were synthesized under laboratory conditions through a condensation reaction between folic acid (FA) and various aldehyde compounds (3,4-dimethoxy benzaldehyde (comp.1), 4-pyridinecarboxaldehyde (comp.2)), using an equal number of molar ratio (1:1) of folic acid and the corresponding aldehyde. The reactants were dissolved in (50ml) of absolute ethanol with a few drops of glacial acetic acid as a catalyst. The reaction mixture was heated at a temperature ranging from(150-200)^{0}C time is (4-5) h. The progress of the reaction was monitored by TLC. The resulting product was placed in a glass watch dish and left to dry at room temperature[20], as shown in the Fig.1. The obtained compounds were ((E)-(4-(((2-((3,4-dimethoxybenzylidene) amino) - 4 -oxo-3,4-dihydropteridin-6-yl) methyl) amino)benzoyl)-L-glutamic acid (F1), (E)- (4-(((4-oxo-2-((pyridin-4-ylmethylene)amino) -3,4-dihydropteridin-6-yl) methyl) amino)benzoyl)-L-glutamicacid (F2), look to the Table 1.

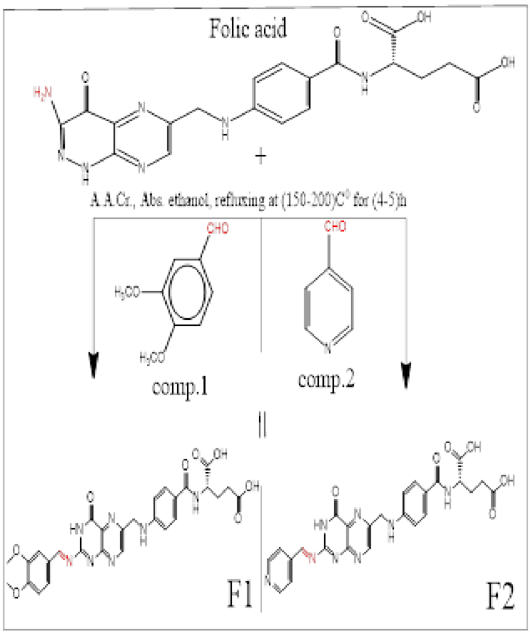


Figure 1. Interaction diagram.

Table 1. The Molecular Formula, the colour, yield, and melting point of Schiff base compounds.

Comp.	Molecular Formula	Melting point ^oC	colour	Yield %
F1	$C_{28}H_{27}O_{8}$	161-162	Light yellow	100
F2	$C_{25}H_{22}O_{6}$	157-159	Light yellow	93

The Schiff base compositions were prepared by dissolving a known weight of each substance in the (DMSO) solvent based on the calculation of the number of moles. The number of moles was calculated using the below formula[21]:

$$n=\frac{m}{M.wt} \quad ----- \quad (9)$$

The number of moles is (n), the measured mass of the compound (m), and the molecular weight is (M.Wt).

After complete dissolution and stirring, dilution was carried out using the relationship[21]:

$$C_1V_1=C_2V_2 \quad ----- \quad (10)$$

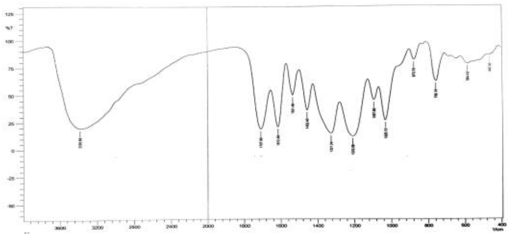
Where C_1 and V_1 are the initial molarity concentration and volume, and C_2 and V_2 are the final molar concentration and volume.

4. Results and discussion

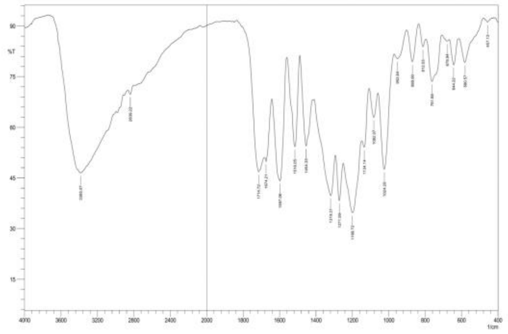
The Schiff base was characterized by FT-IR, UV-Vis, ^{1}H NMR, and ^{13}C NMR spectroscopy. The obtained spectra confirm the successful formation of the structure. Furthermore, the compounds were examined for their antibacterial and antioxidant activities. The synthesized compounds exhibited antibacterial and antioxidant activities.

4.1 FTIR

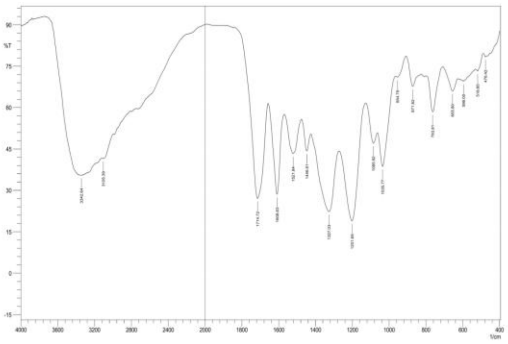
The infrared (FTIR) spectra of (FA) and the synthesized Schiff bases are presented in Table 2. This Table summarizes the characteristic absorption bands and their corresponding functional group assignment, while Fig. 2 shows the overall FTIR spectrum, confirming the presence of the expected functional groups[22].



(a)



(b)



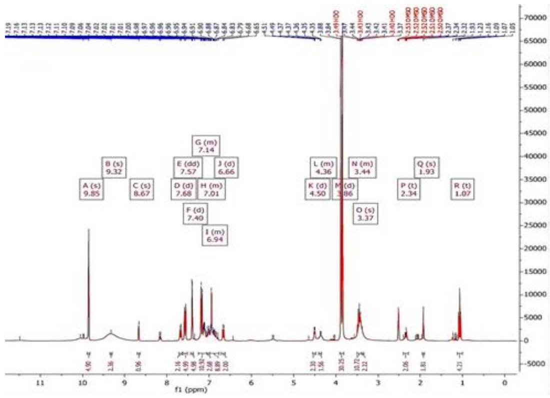
(c)

Figure 2. The FTIR spectra of the two Schiff bases, (a) IR of the FA, (b) IR of the F1, (c) IR of the F2.

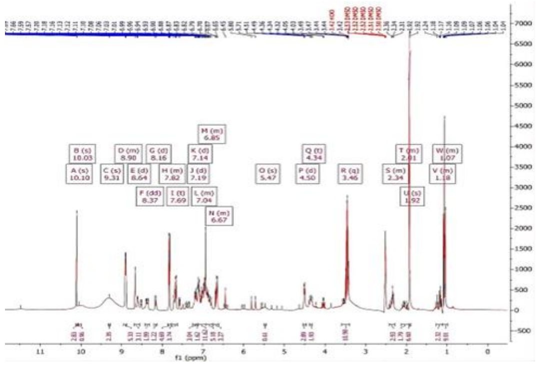
It confirmed the formation of the Schiff base through the disappearance of the primary amine (-NH_2) bands of FA and the appearance of the characteristic azomethine (-C=N-) band in both F1 and F2, confirming the expected chemical composition of the Schiff base.

4.2 ^{1}HNMR, and ^{13}CNMR

Bothe ^{1}HNMR, and ^{13}CNMR spectra of the compounds were recorded, providing detailed information about the hydrogen and carbon environment, as shown in Table 3. The obtained spectra verified the molecular structure and the success the Schiff base[23,24], as shown in Fig.3 and 4.



(a)



(b)

Figure 3. ^{1}HNMR of Schiff bases (a) F1, (b) F2.

Intensities are in agreement with the anticipated chemical structure. It records the presence of special signals relative to the protons of various groups in the (F1) and (F2), and the chemical shift positions and signal, which proved the successful preparation of the Schiff base.

Table 2. The key functional groups of FT-IR spectral data of the (FA) and Schiff base ligand.

Assign.	FA (cm^{-1})	F1 (cm^{-1})	F2 (cm^{-1})
υ (OH) stretching	3390	3385.07	3342.64
υ (N-H) stretching	3390	-	-
υ (C=N) stretching	-	1597	1608.63

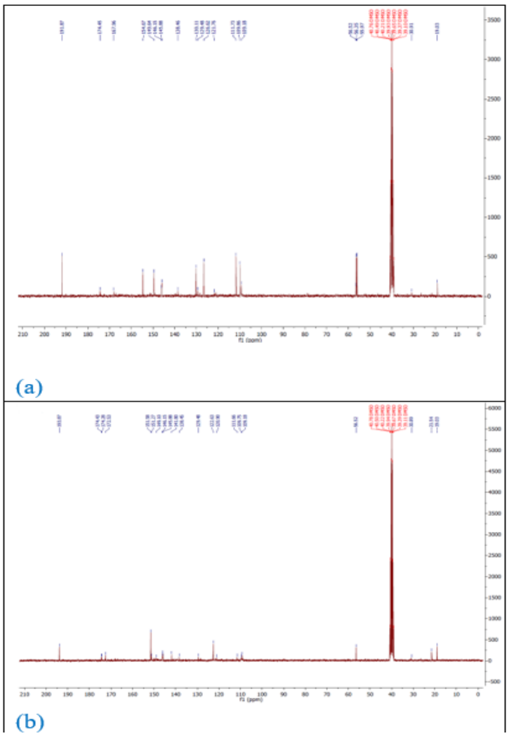


Figure 4. $^{13}CNMR$ *spectra* of Schiff bases, (a) F1, (b) F2.

^{13}CNMR spectrum is a structural map that is specific and indicative of the various chemical environments of the carbon atoms in the compound. The signals are represented coherently as per their anticipated structural association. This match is a good indication of how right the chemical structure is and how successful the process of preparation has been.

Table 3. ^{1}HNMR, and ^{13}CNMR spectra data of the Schiff base, identification of the most important functional groups in the compounds.

Comp.	Assign.	^{1}H δ(ppm)	Assign.	^{13}C δ(ppm)
F1	NH	6.94 8.67	Ar-C	109.18 129.48
	Ph-H	6.66 7.59	Ar-C-OCH_3	149.10 151.27
	-C=N	7.68	-C=N	172.53
	COOH	11.5 12.3	COOH	174.28 174.43
	CH_2	2.09 2.33	OCH_3	56.52
			-C=C-	193.87
	CH_3	3.86	CH_2	19.03 30.89
F2	NH	6.85 8.90 12.3	Ar-C	109.18 1294 8
	Ph-H	6.67 8.64	Ar-C-N	149.10
	-C=N-	7.95	-C=N	172.53
	COOH	11.5 12.3	COOH	56.52
	CH	4.39	-C=C-	193.87
	CH_2	2.09 2.33	CH_2	19.03 30.89

4.3 UV-VIS spectra

A strong absorption region was observed between (200-400) nm, as shown in Fig. 5. This is attributed to the appearance of absorption peaks (π→π*), which is a highly sensitive transition to hydrogen bonds. An absorption band was apparent at (300nm) that may attributable to (n→π*) resulting from the occurrence of (C=C) and (C=O). A sharp decrease in transmittance was noted, with complete transmittance absence in the visible spectrum. The refractive index was calculated using Eq. (4), and the result are shown in Table 4.The high refractive index of examined compounds is attributed to the presence of aromatic rings [25]. The observed increment in the refractive index is related to the significant rise in the refractive index in the ultraviolet range due to intense electronic transitions occurring when the photon's energy approaches the optical bandgap of the material, as shown in Fig. 6.

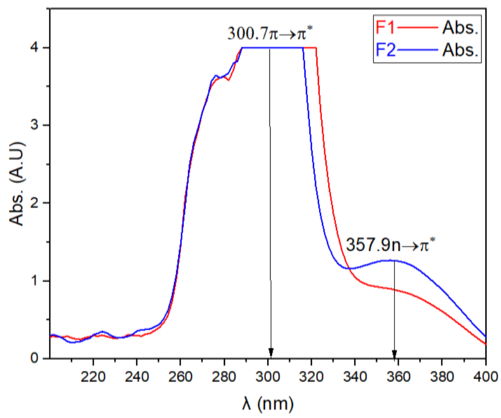
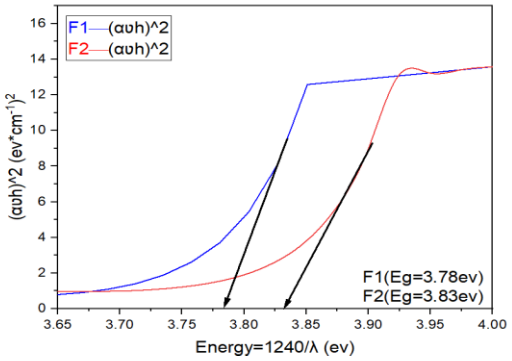


Figure 5. Absorbance spectra for synthesized Schiff base.

The magnitude of these peaks shows that there is a great interaction between the light and the electronic structure of the compounds which reveals their effectiveness in absorbing electromagnetic radiation.



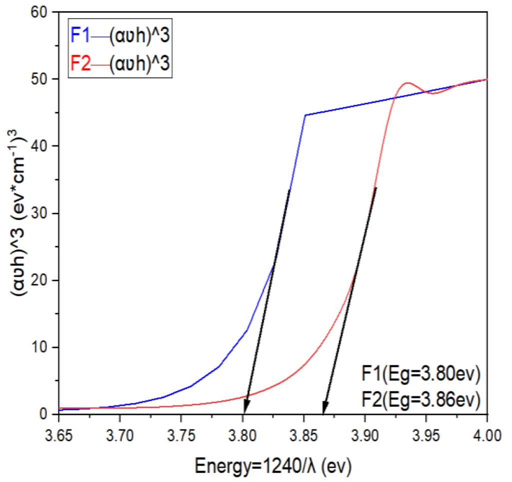


Figure 6. This value demonstrates the (Eg) of the material that has been studied.

The absorption coefficient is lower than 10^4 in the absorption edge region, thus, the electronic transition is indirect. The energy band gap is calculated from Eq. (3). Fig. 6 shows the energy band gap difference of the F1 and F2. The energy gap has the greatest value of Eg=3.86ev, which means that the indirect transition is of the type of forbidden (indirect forbidden transition). In this view of the energy gap being of great value, the material is considered to be an insulating material. This finding was established by El-Gammal et al. (2018). It was also observed that the presence of an N atom in the para position leads to a decrease in the energy gap of (0.06ev), which is consistent with the results obtained by Sidir et al. (2019) [26,27].

Table 4. The optical properties of the Schiff bases.

Optical properties	F1	F2
n	1.2	1.2
α(cm^{-1})	0.921	0.921
K*10^{-6}	2.36	2.31
Eg (ev) (Indirect allowed)	3.78	3.83
Eg (ev) (Indirect forbidden)	3.80	3.86
ε_{real}	1.5	1.5
ε_{im}*10^{-6}	5.78	5.67

4.5 Antibacterial Activity

The synthesized compounds were tested with regards to their microbiological activity against Gram-positive (Staphylococcus aureus) and Gram-negative (Acinetobacter baumannil) bacterial strains. F1 showed much better antibacterial activity (higher concentration (1mg/ml)) with a great inhibitory activity to Gram-positive bacteria, and its inhibition zone reached about (24mm) as compared to (F2). It was also found that both compounds (F1 and F2) were showing some activity against Gram-negative bacteria. The identified antibacterial effect can be explained by the electron-withdrawing acidic carboxyl groups, which facilitate the contact of the compounds with bacterial cell components and the effectiveness of its inhibitor capacity [28] as is demonstrated in Table 5. Fig. 7. Biological activity of Schiff base.

Table 5. Antibacterial Activity data of the Schiff base ligand.

NO.	Comp.	Conc. (mg/ml)	Staph.	A.B
1	F1	1	24	20
2		0.5	17	16
3		0.25	13	12
1	F2	1	22	20
2		0.5	15	16
3		0.25	12	11

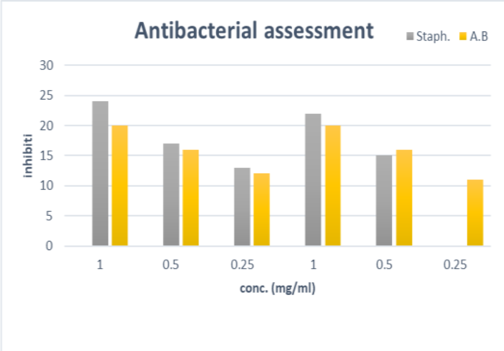


Figure 7. Synthesized compounds: biological activity.

4.6 Antioxidant Activity

DPPH is an unstable form of free radical, which is purple in color and has intense absorption at 517nm. Because there is a presence of an antioxidant, the free radical in DPPH will dissociate, and the absorption of the free radical will be reduced, and the color will lose its intensity.

The antioxidant properties of the produced compounds (F1 and F2) were explored with the evaluation of reducing power and free radical scavenging activity of these compounds in the context of DPPH assay at various concentrations. The outcome revealed that the two compounds had a high antioxidant activity in a concentration-dependent mode. F1 and F2 exhibited a better reducing power than the ascorbic acid, which was used as standard antioxidant. The highest absorbance value of (0.5153) was at a concentration of (0.12mg/ml), then it steadily declined to (mag/ml) at (1mg/ml). The results denote that the prepared compounds have a strong electron-donating capacity [29]. Table 6 presents the corresponding data. Fig. 8. Antioxidant percentage activity.

Table 6. This is in the form of the declining power of ascorbic acid and its capacity to eliminate free radicals.

sample name	Conc. (mg/ml)	Abs.	scavenging %
F1	0.12	0.3741	62.835
	0.25	0.2241	77.737
	0.5	0.149	85.198
	1	0.1341	86.678
F2	Control	1.0066	-
	0.12	0.4316	56.965
	0.25	0.2472	75.351
	0.5	0.1485	85.193
	1	0.1455	85.492
	Control	1.0257	-

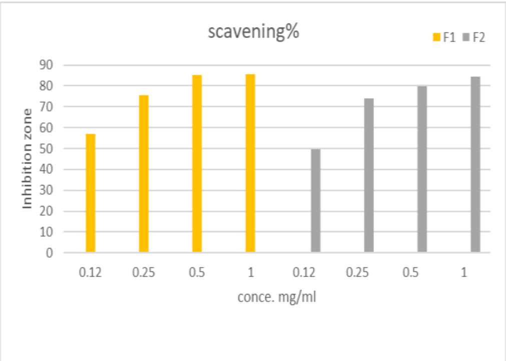


Figure 8. Activity of certain prepared Schiff base compounds (as antioxidants) expressed in percentages.

The antioxidant activity of the compound (F1) in the free radical scavenging system is the highest of the synthesized Schiff base compounds, with 85.492% and 86.678% as the rate of free radical scavenging by the DPPH technique[5].

5. Conclusion

1- It was found that the refractive index and the gap between the energy levels are high due to the increase in the electron density of the compounds.

2-A high bacterial activity was observed against (staph.) at a concentration (1mg/ml) of the F1 compared to F2. In addition to their broad-spectrum antibacterial activity, the synthesized compounds also exhibited significant antioxidant capacity, indicating their potential to protect biological systems from oxidative stress.

3-Folic acid compounds are extensively absorbed in the ultraviolet space, thus they can be used in photovoltaic applications.

6. Future work

Future research may focus on synthesizing a wider range of Folic Acid-based Schiff base derivatives using different aldehyde substituents to better understand the relationship between molecular structure and optical properties. Furthermore, subsequent studies could investigate the electrical and thermal properties of these compounds to gain a deeper understanding of their physical behaviour and stability. Moreover, extensive biological studies, such as cytotoxicity and pharmacokinetic studies, are recommended to more broadly evaluate the potential biomedical applications of these compounds.

Acknowledgment

I'd like to thank my supervisors (Dr. Shaymaa) and (Dr. Atheraa) for their direction, support, and scientific advice during this study. This study was completed thanks to their skills and encouragement.

References:

[1] H. Bouznif, L. L. Justino, M. I. Soares, T. Costa, M. L. Ramos, T. Nikitin, *et al.*, "Novel tetradentate N2O2 water-soluble Schiff Base and its Al (III) complex: Synthesis, structural characterization, and correlations between structure and stability against hydrolysis," *J. Mol. Struct,* vol. 1331, p. 141581, 2025.

[2] N. A. M. Salih, "Synthesis, Characterization, and Bioactivity Studies of the Schiff Base Ligand and its Zinc (II) Complex," *ARO-THE SCIENTIFIC JOURNAL OF KOYA UNIVERSITY,* vol. 12, pp. 108-114, 2024.

[3] A. T. Numan, K. F. Ali, and E. I. Al-salihi, "Synthesis and Characterization of Schiff Base Folic Acid Based Ligand and Its Complexes," *Ibn AL-Haitham Journal For Pure and Applied Science,* vol. 28, pp. 69-85, 2017.

[4] K. Garg, A. Chakraborty, A. Bhattacharjee, S. P. Choudhury, S. Kumari, and D. Bhattacharjee, "Computational Investigation of Reactivity Parameters, UV-Vis and IR Spectra, NLO Properties, and Temperature-Dependent Thermodynamic Characteristics of Schiff-Based Interdigitated 5O. m (m= 14, 16) Liquid Crystalline Compounds: A DFT Analysis," *arXiv preprint arXiv:2405.16632,* 2024.

[5] P. Mahadevi and S. Sumathi, "Schiff base metal complexes: Synthesis, optoelectronic, biological studies, fabrication of zinc oxide nanoparticles and its photocatalytic activity," *Results in Chemistry,* vol. 6, p. 101026, 2023.

[6] S. H. I. a. T. M. A. Afrah M. AL-Hussainey, "Study the Absorption and Fluorescence Spectra of Some Organic Dyes," *Journal of Engineering and Applied Science,* vol. 4, pp. 7276-7270, 2019.

[7] D. N. Barreto, V. G. Leal, J. A. M. Conrado, G. M. Fernandes, C. C. S. Machado, A. D. Batista, *et al.*, "Performing reliable absorbance and fluorescence measurements with low budget-A tutorial for beginners," *Química Nova,* vol. 44, pp. 1184-1191, 2021.

[8] T. G. Mayerhöfer, S. Pahlow, and J. Popp, "The Bouguer-Beer-Lambert law: Shining light on the obscure," *ChemPhysChem,* vol. 21, pp. 2029-2046, 2020.

[9] H. J. Lee, M. M. A. Gamel, P. J. Ker, M. Z. Jamaludin, Y. H. Wong, and J. P. David, "Absorption coefficient of bulk III-V semiconductor materials: a review on methods, properties and future prospects," *J. Electron. Mate,* vol. 51, pp. 6082-6107, 2022.

[10] M. B. Pramanik, M. A. Al Rakib, M. A. Siddik, and S. Bhuiyan, "Doping Effects and Relationship between Energy Band Gaps, Impact of Ionization Coefficient and Light Absorption Coefficient in Semiconductors," *European Journal of Engineering and Technology Research,* 2024.

[11] M. Rasheed, S. Shihab, and O. W. Sabah, "An investigation of the structural, electrical and optical properties of graphene-oxide thin films using different solvents," in *Journal of Physics: Conference Series*, 2021, p. 012052.

[12] K. Fabrizio, K. N. Le, A. B. Andreeva, C. H. Hendon, and C. K. Brozek, "Determining optical band gaps of MOFs," *ACS Materials Letters,* vol. 4, pp. 457-463, 2022.

[13] A. Kumar, R. Kumar, N. Verma, A. Anupama, H. K. Choudhary, R. Philip*, et al.*, "Effect of the band gap and the defect states present within band gap on the non-linear optical absorption behaviour of yttrium aluminium iron garnets," *Optical Materials,* vol. 108, p. 110163, 2020.

[14] A. S. Hassanien and I. Sharma, "Optical properties of quaternary a-Ge15-x Sbx Se50 Te35 thermally evaporated thin-films: refractive index dispersion and single oscillator parameters," *Optik,* vol. 200, p. 163415, 2020.

[15] L. H. Aboud, Z. F. Mahdi, and W. J. A. Al-Zahra, "Linear and nonlinear optical properties of the dye laser (acridine dye)," *Academic Research International,* vol. 5, p. 135, 2014.

[16] T. George, V. Sivam, M. Vaiyapuri, R. Anandan, G. K. Sivaraman, and T. C. Joseph, "Standardizing biofilm quantification: harmonizing crystal violet absorbance measurements through extinction coefficient ratio adjustment," *Archives of microbiology,* vol. 207, pp. 1-7, 2025.

[17] M. A. Saleh, A. O. Mousa, and M. H. Shinen, "Study the Optical Properties of Polyaniline-PEDOT Nano Composite," *International Journal of Multidisciplinary and Current Research,* vol. 6, pp. 1038-1043, 2018.

[18] N. Yao, X. Chen, X. Shen, R. Zhang, Z. H. Fu, X. X. Ma*, et al.*, "An atomic insight into the chemical origin and variation of the dielectric constant in liquid electrolytes," *Angewandte Chemie,* vol. 133, pp. 21643-21648, 2021.

[19] P. O. Amin, K. A. Ketuly, S. R. Saeed, F. F. Muhammadsharif, M. D. Symes, A. Paul*, et al.*, "Synthesis, spectroscopic, electrochemical and photophysical properties of high band gap polymers for potential applications in semi-transparent solar cells," *BMC chemistry,* vol. 15, p. 25, 2021.

[20] A. A. K. Wasafa, N. D. Jaffera, and E. A. W. Alkuwaityb, "Synthesis, characterization, and studying of (thermal, spectral and physical) properties of new Schiff base monomers and liquid Crystal compounds from Ampicillin," *Synthesis,* vol. 10, p. 11, 2023.

[21] V. U. Nwagbara, W. A. Iyama, C. Kayini, and H. M. Kwaambwa, "Efficiency of Moringa Oleifera Seed Biomass in the Removal of Lead (II) Ion in Aqueous Solution," *European Journal of Applied Sciences–Vol,* vol. 10, 2022.

[22] O. S. Oladeji, M. I. Ikhile, O. Ojo, C. M. Fotsing, M. Mamo, P. G. Ndungu*, et al.*, "Synthesis, FTIR, NMR, UV–vis and electrochemistry analysis of ferrocenyl Schiff bases," *Inorganica Chimica Acta,* vol. 546, p. 121319, 2023.

[23] D. Nartop and H. Öğütcü, "Synthesis of new unsymmetrical Schiff bases as potential antimicrobial agents," *Sinop Üniversitesi Fen Bilimleri Dergisi,* vol. 5, pp. 13-25, 2020.

[24] F. Oktay and S. Yıldırım, "Synthesis, Characterization and Docking Studies of a Schiff Base Ligand and Some Metal Complexes," *Pharmata,* vol. 5, pp. 16-21, 03/16 2025.

[25] Z. Lin, R. Kabe, K. Wang, and C. Adachi, "Influence of energy gap between charge-transfer and locally excited states on organic long persistence luminescence," *Nat. Commun,* vol. 11, p. 191, 2020.

[26] O. A. El-Gammal, A. F. Al-Hossainy, and S. A. El-Brashy, "Spectroscopic, DFT, optical band gap, powder X-ray diffraction and bleomycin-dependant DNA studies of Co (II), Ni (II) and Cu (II) complexes derived from macrocyclic Schiff base," *Journal of Molecular Structure,* vol. 1165, pp. 177-195, 2018.

[27] İ. Sıdır, Y. G. Sıdır, H. Berber, and F. Demiray, "Electronic structure and optical properties of Schiff base hydrazone derivatives by solution technique for optoelectronic devices: Synthesis, experiment and quantum chemical investigation," *Journal of Molecular Structure,* vol. 1176, pp. 31-46, 2019.

[28] J. N. Saleh and A. Khalid, "Synthesis, characterization and biological activity evaluation of some new pyrimidine derivatives by solid base catalyst AL2O3-OBa," *Central Asian Journal of Medical and Natural Science,* vol. 4, pp. 231-239, 2023.

[29] E. Sreelekha, B. George, A. Shyam, N. Sajina, and B. Mathew, "A comparative study on the synthesis, characterization, and antioxidant activity of green and chemically synthesized silver nanoparticles," *BioNanoScience,* vol. 11, pp. 489-496, 2021.