# Synthesis and Liquid Crystalline Properties of Triazole-Based Azo-Schiff Base Derivatives for Optoelectronic Applications

Haneen J. Atiws, Wassan Baqir Ali and Noor Sabah Al-Obaidi
*Department of Chemistry, College of Science, University of Diyala, 32001 Baqubah, Iraq*
*scichemms232405@uodiyala.edu.iq, dr.wassan976@uodiyala.edu.iq, noorsabah@uodiyala.edu.iq*

Keywords: 1,2,4-Triazole, Schiff Base, Azo Compounds, Liquid Crystals, POM.

Abstract: A new series of 1,2,4-triazole-based heterocyclic Schiff base derivatives were prepared via a multi-stage synthetic pathway. This pathway begins with the base compound 2-((4-hydroxybenzylidene)amino)acetic acid, which reacts with thiocarbhydrazide to produce the required intermediates. These compounds were subsequently subjected to condensation, isomerization, and structural modification to yield the final derivatives. The chemical structure of the prepared compounds was confirmed using a range of advanced spectroscopic techniques. Fourier transform infrared (FT-IR) spectra revealed the characteristic extensions and vibrations of the imine (–C=N–) and azo (–N=N–) groups. In addition to the signals of the hydroxyl (–OH) and thiol (–SH) groups, both the $^1$H-NMR and $^{13}$C-NMR spectra supported the validity of the proposed structure by showing chemical shifts consistent with the heterocyclic structure and the triazole nucleus. The structural study showed that the molecular shape of 3-phenylthiazolidine-2-one compounds replaced by pentyloxy and octyloxy chains has a spatial distribution and morphological regularity that gives it remarkable mesogenic behavior, indicating the possibility of its use in crystalline liquid material applications or thermally responsive functional materials. According to POM, the birefringent textures and typical upon heating textures patterns of the samples confirm the presence of thermotropic liquid crystalline phases nematic (N) and smectic (SC). The synthesized triazole-based azo-Schiff base derivatives have been found to possess conjugated π-systems and anisotropic molecular order, thus suggesting their potential application in LCD and optoelectronic materials.

## 1 INTRODUCTION

Aromatic heterocycles are planar rings of atoms containing at least one non-carbon atom (N, S, O) [1]-[4]. A large portion of natural products are heterocyclic compounds, and some are being utilised as pharmaceuticals, agrochemicals, etc [5]-[6]. One of its most important interactions is that Azo-Schiff base compounds represent a novel category of. These organic compounds are notable for possessing two functional groups in their structures: (CH=N) and (N=N) [7]-[9]. Schiff bases are Compounds that are formed as a result of the nucleophilic addition reaction of aldehydes and ketones with primary amines, and which have carbon-nitrogen double bonds (–C=N–) in their structure [10]-[11]. Azo dyes, being the largest class of synthetic dyes carrying the (-N=N-) group, which are categorised based on their elemental composition and use, are the main focus of colour chemistry [12]. Azo-Schiff base ligands and their metal complexes have been extensively studied over the past few decades. It has been found that azo Schiff base compounds have a wide range of applications in liquid crystals [13]. Liquid crystals (LCs) are imperative middle phases that exhibit properties of both the fluid and solid states [14]-[18]. The liquid crystal technological revolution is intriguing because it exhibits characteristics of both liquids and solid crystals. They exhibit fluidic behavior, although their molecular arrangement remains fixed, similar to that of a crystal [19].

## 2 EXPERIMENTAL

### 2.1 Synthesis of 2-((4-hydroxybenzylidene)amino)acetic acid[A]

Initially, (0.5g) of glycine was dissolved in (10 mL) of absolute ethanol in a round-bottom flask.

Similarly, p-hydroxybenzaldehyde (0.8g) was dissolved in (10 mL) of absolute ethanol in a separate container. Then, three drops of concentrated sulfuric acid were added to the mixture of glycine and p-hydroxybenzaldehyde as a catalyst for the reaction to form a Schiff base. Then, the reaction mixture was heated in a water bath at 55-60°C for 8 hours. (TLC) was used to monitor the reaction's progress. The mixture was allowed to cool to room temperature. The solid product was then separated from the liquid phase by filtration. After filtration, the precipitate was washed with distilled water [20].

## 2.2 Synthesis of Thiocarbonohydrazid [B]

The mixture hydrazine hydrate (24.5ml) was placed, which was equipped with a thermometer, an efficient agitator, and a reflux condenser. The temperature was lowered to 10 °C, and (6.2ml) of carbon disulfide was added dropwise into the flask while maintaining the temperature below 15 °C. The temperature was raised gradually to 85 °C for two hours. TLC checked the reaction completion and the compound's purity. The Reaction mixture was cooled to 10 °C, and the precipitate was filtered and washed with distilled water [21].

## 2.3 Synthesis of 4-(4-amino-5-mercapto-4H-1,2,4-triazol-3 yl)methyl)imino)methyl)phenol [C]

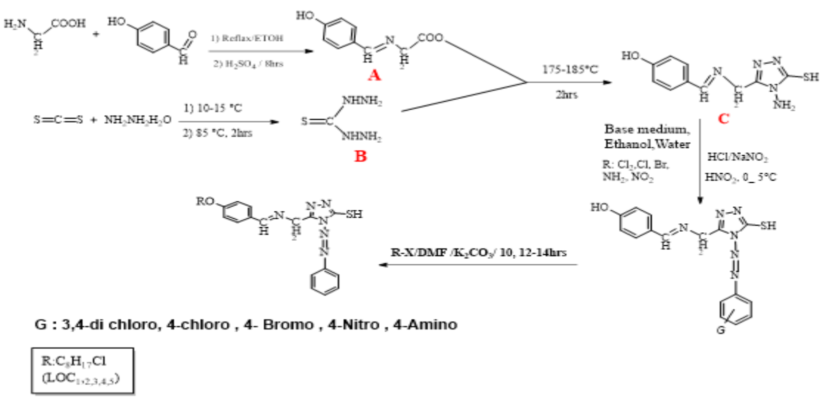
The 2-((4-hydroxybenzylidene)amino)acetic acid (1.79 g) and thiocarbonohydrazide (1.59 g) was ground thoroughly with a mortar to create a homogenous mixture. After being put in a Pyrex fusion tube, the mixture was heated for two hours at 175–185°C in an oil bath. The product was then rinsed with a cold solution of sodium bicarbonate and distilled water (5 g, 25 ml) to remove any last traces of acidic impurities. The washing process produced effervescence, which indicates that the acidic byproducts were neutralised. After that, the substance was filtered and thoroughly cleaned with cold distilled water.

## 2.4 Synthesis of 4-(5-mercapto-4-(4-substituted-phenyl)diazenyl)-4H-1,2,4-triazol-3-yl)methyl)imino)methyl)phenol [C1-C5]

The mixture (1g) of the substance was dissolved in a solution composed of (2 g in 10 ml) of HCl in distilled water and stirred until completely dissolved. The solution was chilled in an ice bath, maintaining a temperature range of 0–5°C. A preposition solution was obtained by dissolving 2g of sodium nitrite ($NaNO_2$) in 5 mL of distilled water, which was also cooled in the same ice bath. The sodium nitrite solution was added dropwise to the produced starting material solution, while continuously stirring and cooling. Subsequently, (0.89g) of chlorobenzene, bromobenzene, aniline, nitrobenzene, and dichlorobenzene were solubilised in appropriate solvents. This was checked using pH papers until the solution reached a neutral level, forming a diazonium dye precipitate [22].

## 2.5 Synthesis of 4-(4-Subsitutied)diazenyl)-5-(E)-(4(octyloxy)benzylidene) amino)methyl)-4H-1,2,4-triazole-3-thiol of L[OC1-OC5]

A round-bottom 50 mL flask with a reflux condenser was used. (0.3 g) of a mixed diazonium salt [C1-C5], synthesised earlier, was dissolved in 5 mL of DMF. The media was adjusted for reaction conditions by adding 0.1 g of $K_2CO_3$. 5 mL of DMF was used to dissolve 0.11 mL of 1-chloro-octanone in another container. After that, this solution was gradually added to the initial mixture while being constantly stirred. The resultant mixture was heated in an oil bath for 12-14 hrs at a temperature between 120 and 130 °C. The progress of the reaction was monitored using TLC. The reaction mixture was then allowed to cool gradually to room temperature, thoroughly washed with distilled water to remove any inorganic salts and impurities, and subsequently dried in an oven at a low temperature between 40 and 50°C [23].



Scheme 1: Synthesis of the compounds ($C_1$-$C_5$)($LOC_1$-$LOC_5$)($LPC_1$ $LPC_5$).

# 3 RESULTS AND DISCUSSION

## 3.1 Characterization by FTIR

### 3.1.1 FTIR Spectrum of 2-((4-hydroxybenzylidene)amino)acetic acid[A]

FT-IR spectrum exhibits a broad band at 3167 (O–H), 2879 $cm^{-1}$ (C–H) stretching, 1667 $cm^{-1}$ (C=O) (carboxylic group), 1598 $cm^{-1}$ (C=N) stretching (hydrazone), 1519,1546 $cm^{-1}$ (C=C) Aromatic, 1386–1315 $cm^{-1}$ (C–N) stretching (hydrazine) and (C–O) stretching (C–O) bending (phenol and carboxyl), 1160 $cm^{-1}$.

### 3.1.2 FTIR Spectrum Thiocarbonohydrazid[B]

The band at 3271 and 3209 $cm^{-1}$, symmetric and asymmetric group ($NH_2$).2858 $cm^{-1}$ (C–H) Aromatic, 1609.8 $cm^{-1}$ to (C=N) imine, 1511.9, 1445.3 $cm^{-1}$ (C=C), while those at 1261.3 and 1171.2 $cm^{-1}$ represent (C–N) bending.

### 3.1.3 FTIR Spectrum of 4-(5-mercapto-4-(4-substituted-phenyl)diazenyl)-4H-1,2,4-triazol-3-yl)methyl)imino)methyl)phenol [C1-C5]

The main bands were shown in Table 1.

### 3.1.4 FTIR Spectrum of 4-(4-Subsitutied)diazenyl)-5-(E)-(4(octyloxy)benzylidene) amino)methyl)-4H-1,2,4-triazole-3-thiol of L[OC1-OC5]

FTIR LOC1 2929.8, 2860.4 cm-$^{1}$ (C–H) Stretching (aliphatic & aromatic), 1604.7 $cm^{-1}$ (C=N) Stretching (imine / azomethine group), 1506 $cm^{-1}$ (N=N), 1456 $cm^{-1}$ (C=C) stretching (aromatic ring), 1252 cm-$^{1}$ (C–O) Stretching (phenolic / alkoxy group), 1170 $cm^{-1}$ (C–N) Stretching (triazole ring) [24], (Fig. 1). The main bands were shown in Table 2, Figures 2 - 5.

Table 1: FT-IR Vibrational bands of synthesized compounds [$C_1$-$C_5$].

| Comp.Symb. | υ $(cm)^{-1}$, IR | | | | | | |
|---|---|---|---|---|---|---|---|
| | (O–H) | (C–H) Ar. | (C–H) Aliph. | (C=N) | (C=C) | (N=N) | (C–N) |
| C | 3310<br>3197 | 3083 | 2854 | 1607 | 1512 | 1443 | 1169<br>1242 |
| C1 | 3196 | 3090 | 2810<br>2936 | 1609 | 1511 | 1440 | 1172<br>1235 |
| C2 | 3334<br>3154 | 3010 | 2809 | 1605 | 1511 | 1445 | 1167<br>1261 |
| C3 | 3164 | 3048 | 2801 | 1605 | 1511 | 1441 | 1171<br>1237 |
| C4 | 3329<br>3166 | 3096 | 2817 | 1609 | 1511 | 1441 | 1171<br>1241 |
| C5 | 3188 | 3075 | 2895 | 1609 | 1515 | 1440 | 1168<br>1237 |

Table 2: FT-IR Vibrational bands of synthesized compounds L[$OC_1$-$OC_5$].

| Com. Symb. | υ (cm)$^{-1}$, IR | | | | | |
|---|---|---|---|---|---|---|
| | C–H Arom. | C–H Aliph. | C=N | C=C | N=N | C–N |
| LOC1 | 2929 | 2860 | 1604 | 1506 | 1456 | 1170<br>1252 |
| LOC2 | 2928 | 2858 | 1606 | 1508 | 1458 | 1170<br>1251 |
| LOC3 | 2926 | 2856 | 1606 | 1508 | 1458 | 1171<br>1249 |
| LOC4 | 2926 | 2828 | 1602 | 1510 | 1448 | 1251 |
| LOC5 | 2928 | 2929 | 1602 | 1509 | 1454 | 1168 |

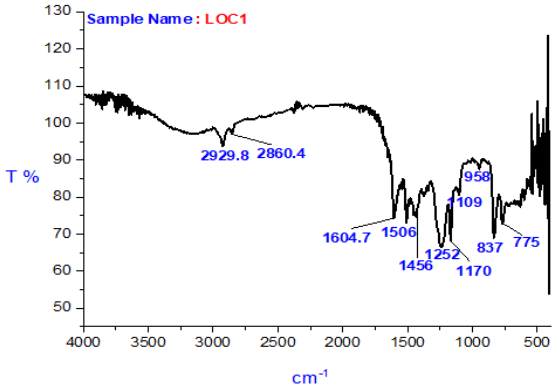


Figure 1: FTIR spectrum of LOC1.

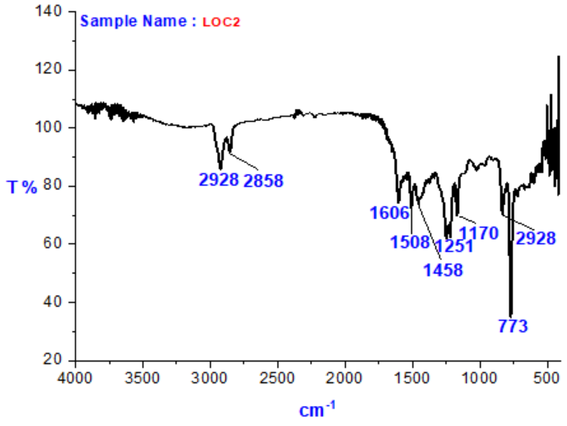


Figure 2: FTIR spectrum of LOC2.

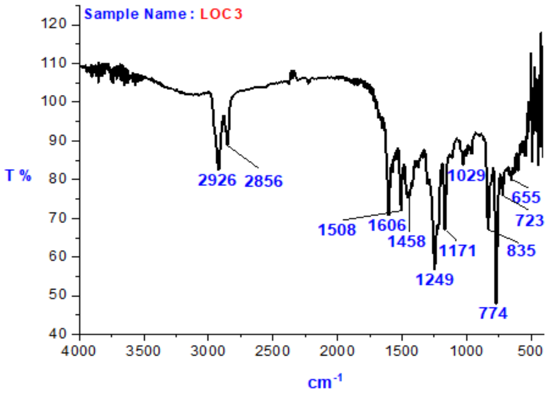


Figure 3: FTIR spectrum of LOC3.

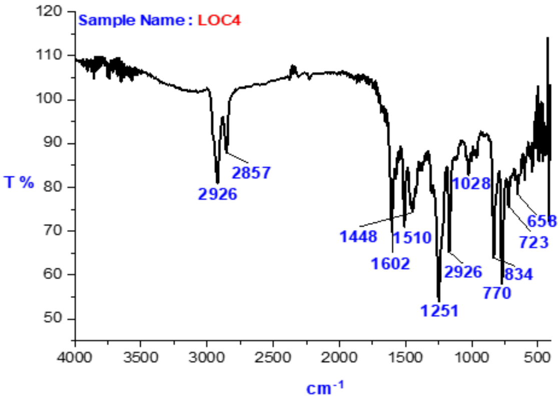


Figure 4: FTIR spectrum of LOC4.

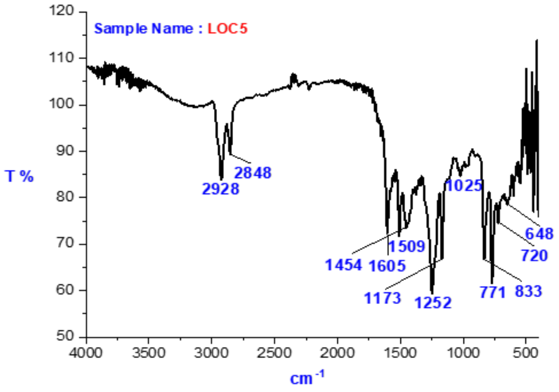


Figure 5: FTIR Spectrum of LOC5.

## 3.2 Characterization by NMR

### 3.2.1 Analysis NMR Spectrum. NMRSpectrumof 2-((4-hydroxybenzylidene)amino)acetic acid[A]

$^{1}$H-NMR Spectrum (400 MHZ, DMSO-d6) 10.58 (s, 1H, OH. H), 9.00 (s, 1H, imine. H), 7.73–7.78 (m, 2H, arom. H). 6.93–6.97 (m, 2H, arom. H). 3.43 (s, 2H,.2methylene. H), (Fig. 6). $^{13}$C-NMR 191.36 (C=O). 163.00 (C–O /C=N) imine carbon. 132.86, 128.95, 116.34 (arom. Carbons). 40.43, 40.21, 39.81, 39.60 (aliphatic carbons), (Fig. 7).

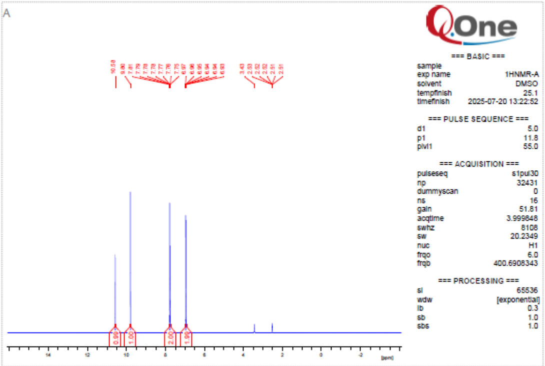


Figure 6: $^{1}$H-NMR Spectrum of A.

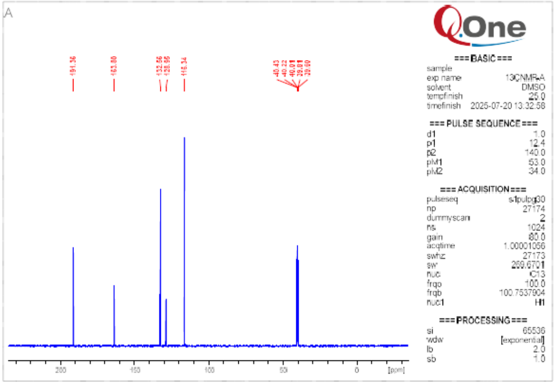


Figure 7: $^{13}$C-NMR Spectrum of A.

### 3.2.2 NMR Spectrum of 4-(4-amino-5-mercapto-4H-1,2,4-triazol-3 yl)methyl)imino)methyl)phenol [C]

$^{1}$H-NMR 8.52 (s, 1H, Azomethine. H). δ 6.70–6.94 ppm (m, 2H, para/meta, H), δ 7–8 ppm (m, 4H, arom. H). δ 5.42 ppm phenolic (s, 1H, O–H. H), δ 3–3.10 ppm (br s, –NH2. H), (Fig. 8). $^{13}$C-NMR 167.06 (C=O), 160.8–160.7 Aromatic C–O / C–N, 130.8–125.6 Aromatic carbons (C–H or quaternary) 116.9–115.3 Multiple aromatic carbons, 114.7 Aromatic carbon near a substituent. 108.4–105.9 Aromatic/alkoxy carbon (C–O–Ar), (Fig. 9).

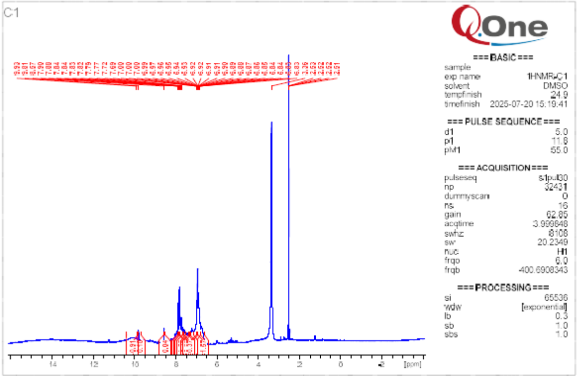


Figure 8: $^{1}$H-NMR Spectrum of C.

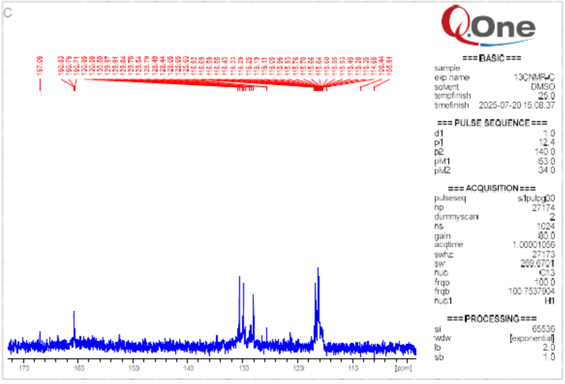


Figure 9: $^{13}$C-NMR Spectrum of C.

### 3.2.3 NMR Spectrum of 4-(5-mercapto-4-(4-substituted-phenyl)diazenyl)-4H-1,2,4-triazol-3-yl)methyl)imino)methyl)phenol [C1-C5]

$^1$H-MNR δ 9.93,9.81 ppm (s, (N–H), δ 8.57ppm (s, 1H, Imine. H) (=CH–N), δ 7.80–7.00ppm (m (6–7H) arom. H) (phenolic + di chloropyridine rings), δ 6.80–6.60ppm (m, phenolic ring), δ 5.40–5.50ppm (s, phenolic), 13.0–14.0ppm (s,(S–H) (triazole-thione, Hexchangeable), (Fig. 10). The $^{13}$C-NMR 108–133 ppm Aromatic carbons. Of both the phenolic and dichloro-pyridine rings, as well as the carbon attached to the azomethine (–CH=N) group (Fig. 11).

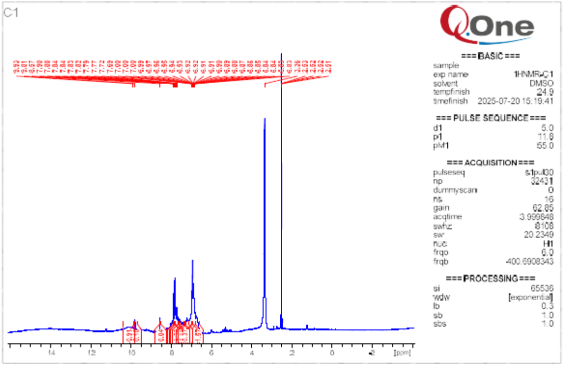


Figure 10: $^1$H-NMR Spectrum of C1

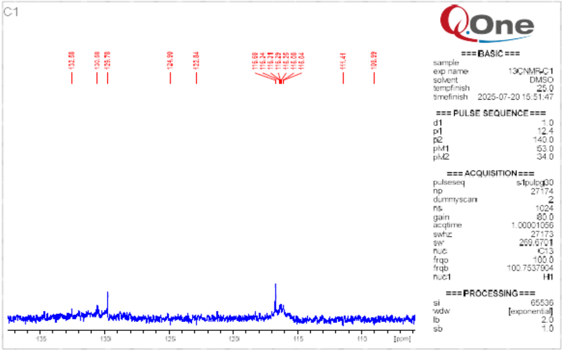


Figure 11: $^{13}$C-NMR Spectrum of C1

### 3.2.4 NMR of 4-(4-Subsitutied)diazenyl)-5-(E)-(4(octyloxy)benzylidene) amino)methyl)-4H-1,2,4-triazole-3-thiol of L [OC1-OC5]

$^1$H-NMR spectrum of LOC1. δ 9.89 ppm (s, ~1H, imine. H) (–CH=N–), δ 8.6 – 6.8 ppm (m, ~4–6H, arom. H), δ 4.66 ppm (s/weak t, ~2H, (–O–CH–). H), δ 3.37 ppm (m, ~2–4H, CH. H) Near hetero aromatic (N or S), δ 1.29 (br m / triplet, 3H, methyl. H) Long alkyl chain (Fig. 12).

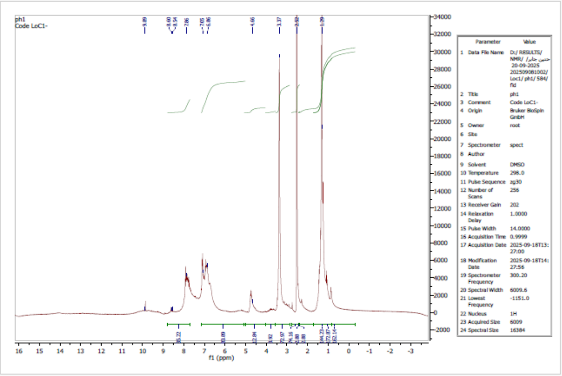
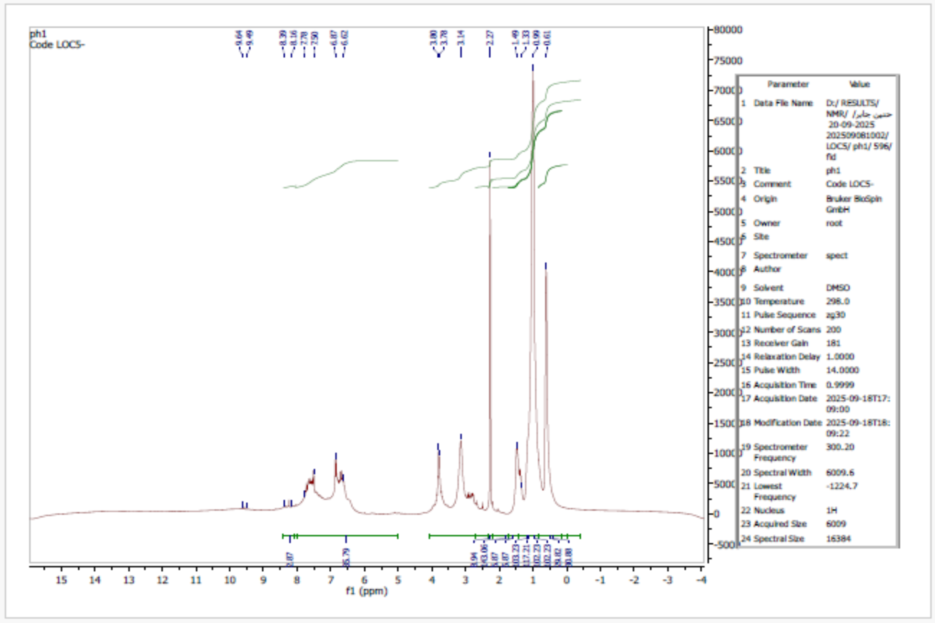


Figure 12: 1H-NMR spectrum of [LOC1].

$^1$H-NMR spectrum of LPC5.δ10.23 – 9.80 ppm (br s, ~1H amide. H), δ8.24 – 6.86 ppm (m, ~4–6H, arom. H), δ 4.76 ppm (s or weak d, ~1H, C–H. H) near O/N (–CH–O– or –CH–N–), δ 3.73 – 3.11ppm (m ~4H, methylene. H) Near O/N (–CH–O– / –CH–N–), δ 2.29, 2.24 ppm (s to weak m, ~2–3H Aliph. H), , Ar (–CH–C=O–, Ar–CH), δ 1.37, 1.24ppm (t/m, ~3–6H, Aliph. H) CH / CH (Fig. 13).



| | Parameter | Value |
|---|---|---|
| 1 | Data File Name | D:/ RESULTS/ NMR/ حسين جابر/ 20-09-2025 202509081002/ LOC5/ ph1/ 596/ fid |
| 2 | Title | ph1 |
| 3 | Comment | Code LOC5- |
| 4 | Origin | Bruker BioSpin GmbH |
| 5 | Owner | root |
| 6 | Site | |
| 7 | Spectrometer | spect |
| 8 | Author | |
| 9 | Solvent | DMSO |
| 10 | Temperature | 298.0 |
| 11 | Pulse Sequence | zg30 |
| 12 | Number of Scans | 200 |
| 13 | Receiver Gain | 181 |
| 14 | Relaxation Delay | 1.0000 |
| 15 | Pulse Width | 14.0000 |
| 16 | Acquisition Time | 0.9999 |
| 17 | Acquisition Date | 2025-09-18T17:09:00 |
| 18 | Modification Date | 2025-09-18T18:09:22 |
| 19 | Spectrometer Frequency | 300.20 |
| 20 | Spectral Width | 6009.6 |
| 21 | Lowest Frequency | -1224.7 |
| 22 | Nucleus | 1H |
| 23 | Acquired Size | 6009 |
| 24 | Spectral Size | 16384 |

Figure 13: $^{1}$H-NMR spectrum of [LPC5].

## 3.3 Characterization by (POM)

POM analysis confirmed that the synthesized triazole azo-Schiff base derivatives were thermotropic liquid crystalline. Rephrase More Undo Alkoxy substituent-containing compounds exhibited nematic (N) and smectic (SC) textures upon heating the thermal transitions of the prepared compounds were shown in Table 3, presumably because a rod-like aromatic structure with polar terminal groups could stabilize monotropic mesophases which were thermally more stable due to anisotropic molecules [25], (Fig. 14 - 16).

Figure 14: The nematic phase of (L-OC1).

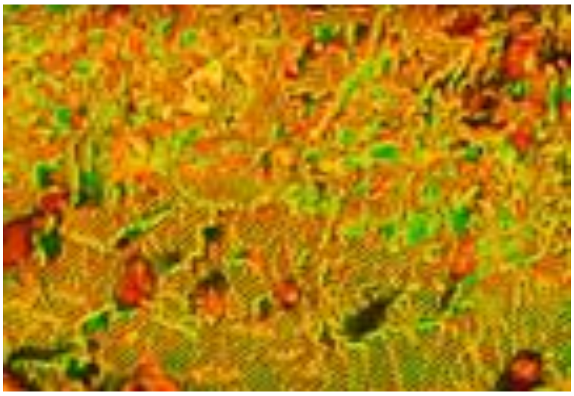


Figure 15: The Smectic phase of (LOC2).

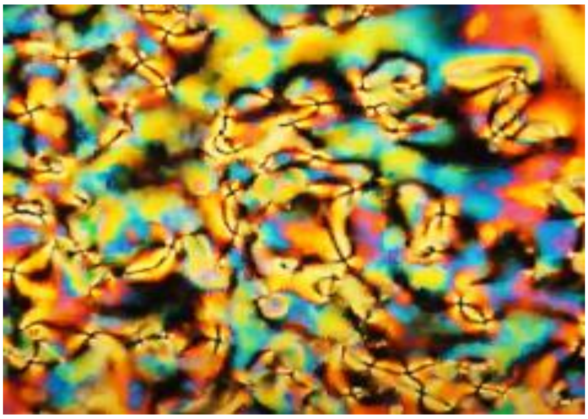


Figure 16: The Nematic phase of (LOC2).

Table 3: Thermal transitions and liquid crystalline phases of the prepared compounds.

| Comp | Heat | Cr | SA | SC | N | ΔSC | ΔN |
|---|---|---|---|---|---|---|---|
| L-OC1 | Heat | 158 |  | 172 |  | 12 |  |
|  | Cool |  |  |  |  |  |  |
| Comp. | Heat | Cr | SA | SC | N | ΔSC | ΔN |
| L-OC2 | Heat | 166 |  | 179 | 193 | 13 | 14 |

## 4 CONCLUSIONS

The current study demonstrated the successful preparation of a new series of heterocyclic Schiff base derivatives based on the 1,2,4-triazole nucleus via a multi-stage synthetic pathway starting from the base compound 2-((4-hydroxybenzylidene) amino)acetic acid. This gradual approach has allowed control over the chemical structure of the final compounds through condensation, isomerization, and structural modification processes, resulting in the production of derivatives bearing long alkoxyl chains of the pentyloxy and octyloxy types. The structural identity of these derivatives was verified using a comprehensive suite of advanced spectroscopic techniques FT-IR spectra confirmed the presence of key functional groups such as imine (–C=N–) and azo (–N=N–) in addition to signals from hydroxyl (–OH) and thiol (–SH) groups. The 1H-NMR and 13C-NMR spectra also showed that the chemical shifts matched the expected arrangement of the heterocyclic structure and triazole nucleus, thus supporting the proposed structure of the prepared compounds. Through polarized light microscopy (POM) analysis, it was found that octyloxy and pentyloxy derivatives possess clear birefringence and exhibit a characteristic nematic or thickened texture, which is direct evidence of their stable mesogenic behavior. These compounds also exhibit a level of long-range organization resulting from the morphological symmetry and spatial distribution of the 3-phenylthiazolidine-2-one chain, reflecting the influence of the alkoxyl chains on the phase response and optical properties. These results confirm that combining a triazole nucleus with azo-Schiff units and long alkoxyl chains generates materials that combine thermal stability with a distinctive phase response, making this class of compounds promising candidates for the development of mesogeneous materials for optoelectronic applications and display technologies. In addition, they can be used in the design of advanced functional materials based on thermal or optical responses. Therefore, this study represents an important step towards expanding the base of mesogenic compounds based on multifunctional heterocyclic systems.

## ACKNOWLEDGMENTS

The authors would like to thank Department of Chemistry-College of Science-University of Diyala for continuous support and facilities.

## REFERENCES

[1] K. C. Dze and F. Samad, “Heterocycles, their synthesis and industrial applications: a review,” Int. J. Appl. Sci. Eng. Technol., vol. 8, pp. 36-56, 2020.

[2] A. Frühauf, M. Behringer, and F. J. Meyer-Almes, “Significance of five-membered heterocycles in human histone deacetylase inhibitors,” Molecules, vol. 28, no. 15, p. 5686, 2023.

[3] S. D. Perera, Introduction to Heterocyclic Chemistry, 2022.

[4] M. Aatif, M. A. Raza, K. Javed, S. M. Nashre-ul-Islam, M. Farhan, and M. W. Alam, “Potential nitrogen-based heterocyclic compounds for treating infectious diseases: a literature review,” Antibiotics, vol. 11, no. 12, p. 1750, 2022.

[5] E. Kabir and M. Uzzaman, “A review on biological and medicinal impact of heterocyclic compounds,” Results in Chemistry, vol. 4, p. 100606, 2022.

[6] A. Amin, T. Qadir, P. K. Sharma, I. Jeelani, and H. Abe, “A review on the medicinal and industrial applications of N-containing heterocycles,” The Open Medicinal Chemistry Journal, vol. 16, no. 1, 2022.

[7] S. K. Abbas, Z. M. Hassan, F. H. Fakhri, D. H. Attol, B. H. Taresh, J. J. Jahil, and et al., “Synthesis, characterization of new azo-Schiff base chelating complex with new azo-base ligand by template method and study the photo-decolorization of their complex with Pd(II) using $NiCo_2O_4$/UV-A system,” 2025.

[8] K. J. Al-Adilee, S. H. Jawad, H. A. K. Kyhoiesh, and H. M. Hassan, “Synthesis, characterization, biological applications, and molecular docking studies of some transition metal complexes with azo dye ligand derived from 5-methyl imidazole,” Journal of Molecular Structure, vol. 1295, p. 136695, 2024.

[9] N. A. R. Al-Qasii, A. T. Bader, and Z. Mosaa, “Synthesis and characterization of a novel azo-dye Schiff base and its metal ion complexes based on 1,2,4-triazole derivatives,” Indonesian Journal of Chemistry, vol. 23, no. 6, pp. 1555-1566, 2023.

[10] E. Raczuk, B. Dmochowska, J. Samaszko-Fiertek, and J. Madaj, “Different Schiff bases-structure, importance and classification,” Molecules, vol. 27, no. 3, p. 787, 2022.

[11] N. T. Subasi, “Overview of Schiff bases,” in Schiff Base in Organic, Inorganic and Physical Chemistry, 2022.

[12] R. Khanum, R. S. Ali, H. R. Rangaswamy, S. S. Kumar, A. G. Prashantha, and A. S. Jagadisha, "Recent review on synthesis, spectral studies, versatile applications of azo dyes and its metal complexes," Results in Chemistry, vol. 5, p. 100890, 2023.

[13] K. D. Katariya, K. J. Nakum, and M. Hagar, "New fluorinated azo/Schiff base liquid crystals: synthesis, characterisation, mesomorphic study and DFT calculations," Liquid Crystals, vol. 49, no. 3, pp. 312-326, 2022.

[14] A. Shete, S. Nadaf, R. Doijad, and S. Killedar, "Liquid crystals: characteristics, types of phases and applications in drug delivery," Pharm. Chem. J., vol. 55, no. 2, pp. 106-118, 2021.

[15] A. R. Rabbi and J. Al Faysal, "Preparation, characterization and applications of liquid crystals: a review," IOSR Journal of Applied Chemistry, vol. 13, no. 12, pp. 43-54, 2020.

[16] Z. Jamain, M. Khairuddean, M. L. Loh, N. A. Manaff, and M. Z. H. Makmud, "Synthesis and characterization of hexasubstituted cyclotriphosphazene derivatives with azo linking units," Malaysian Journal of Chemistry, vol. 22, pp. 125-140, 2020.

[17] J. Guardia, J. A. Reina, M. Giamberini, and X. Montane, "An up-to-date overview of liquid crystals and liquid crystal polymers for different applications: a review," Polymers, vol. 16, no. 16, p. 2293, 2024.

[18] A. Shete, S. Nadaf, R. Doijad, and S. Killedar, "Liquid crystals: characteristics, types of phases and applications in drug delivery," Pharmaceutical Chemistry Journal, vol. 55, no. 2, pp. 106-118, 2021.

[19] Z. M. Abdulhameed and N. R. Jber, "Chemistry of triazene–liquid crystals: a review," Al-Nahrain J. Sci., vol. 28, no. 1, pp. 56-71, 2025.

[20] A. S. Al-Mahdawi, and et al., "Synthesis, characterization and evaluation biological activity of some 2-mercaptobinzemidazol complexes," Results in Chemistry, vol. 13, p. 101893, 2025.

[21] A. K. Gupta, S. Prachand, A. Patel, and S. Jain, "Synthesis of some 4-amino-5-(substituted-phenyl)-4H-[1,2,4]triazole-3-thiol derivatives and antifungal activity," Int. J. Pharm. Life Sci., vol. 3, no. 7, pp. 1848-1857, 2012.

[22] H. K. Dakheel and A. A. Habeeb, "Synthesis and characterization studies of new heterocyclic azo compound 2-[2′-(4,5-dimethylthiazolyl azo]-5-amino aniline with some complexes metal ions," Al-Muthanna J. Pure Sci., vol. 10, no. 1, 2023.

[23] Z. Jamain, M. Khairuddean, M. L. Loh, N. A. Manaff, and M. Z. H. Makmud, "Synthesis and characterization of hexasubstituted cyclotriphosphazene derivatives with azo linking units," Malays. J. Chem., vol. 22, pp. 125-140, 2020.

[24] S. H. Kadhum, W. B. Ali, and A. A. Jarullah, "Synthesis, Characterization and Antibacterial Activity for 2-(1, 1-dimethyl-1, 3-dihydro-2H-benzo [e] indol-2-ylidene) malonaldehyde Indole," Academic Science Journal, vol. 1, no. 4, pp. 109-124, 2023.

[25] J. E. Houston, E. A. Kelly, M. Kruteva, K. Chrissopoulou, N. Cowieson, and R. C. Evans, "Multimodal control of liquid crystalline mesophases from surfactants with photoswitchable tails," Journal of Materials Chemistry C, vol. 7, no. 35, pp. 10945-10952, 2019.